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Greenhouse Gas Emissions from Household Waste in Denpasar City

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Abstract

The increasing population growth and changing consumption patterns of the people have resulted in an increase in the volume, type and characteristics of waste. The rate of waste production continues to increase, not only in line with the rate of population growth but also in line with the increasing consumption patterns of society and the level of people's income. The solid waste sector is one of the sources of greenhouse gas emissions that is important to address because the decomposition of waste is a significant source of CH_4 whose addition to the atmosphere contributes to climate change, so regional and national mitigation actions in the waste sector are very important. the increase in greenhouse gases caused by human activities in producing greenhouse gases is greater than the ability of the environment to repair itself. The greenhouse gas produced exceeds the ability of the environment to recycle so that greenhouse gases accumulate in the atmosphere. The increase in emissions of CO_2, CH_4 and N_2O gases in the atmosphere causes various problems, including changes in the nature of the climate which have an impact on climate change. The problem of garbage in Denpasar City cannot be separated from various factors because Denpasar City is the capital of Bali Province, the center of education, the center of the economy and is one of the tourist destinations with a cultural perspective, resulting in a high population growth rate which has an impact on the volume of waste, one of which is household waste. Community behavior in managing household waste plays a role in causing greenhouse gas emissions, such as the act of burning garbage and littering. Efforts to reduce greenhouse gas emissions in the City of Denpasar are carried out through composting, reuse, reduce and recicle activities both at the community level and in landfills. Achievement of reducing greenhouse gas emissions based on mitigation actions in the domestic solid waste sub-sector in Denpasar City for the period 2010 to 2019 was 17.2 Gg CO_2e with weighting of reducing greenhouse gas emissions from composting by 15.1 Gg CO_2e and the rest from 3R activities of 2.1 Gg CO_2e.

Keywords: waste; household; emissions; greenhouse gases; Denpasar.

JelClassification: Q53; Q57; R11.

Introduction

Garbage is a problem that must be faced by the community, because garbage is a form of environmental pollution, where garbage can have an impact on public health, such as; odors, floods, destroy aesthetics, fire, greenhouse effect and so on. The waste problem is often discussed by various groups, both locally, regionally, nationally and internationally, but until now there is no right way to solve it, so it needs to be done comprehensively and integratedly from upstream to downstream so that it can benefit the government and society in general. from an economic, social, cultural point of view, and the products produced are environmentally friendly technologies. Human activities generally produce waste, where the amount or volume of waste is proportional to the level of people's consumption of goods / materials used daily. Likewise with the type of waste, it really depends on the type of material consumed by the community (Nurkomalasari 2014). If waste is not managed, it will have an impact on the environment, especially the City of Denpasar as a tourism destination (Sudipa *et al.* 2020). Healthy behavior is expected to maintain, improve health and protect ourselves from the threat of disease, while a healthy environment is expected to create a conducive environment, pollution-free, healthy settlements and healthy waste management (Azkha 2016). Household waste management by involving community participation can reduce the generation of waste that is disposed of at the final waste processing site (Artiningsih 2008).

The solid waste sector is one of the sources of greenhouse gas emissions that is important to deal with because the decomposition of waste is a significant source of CH_4 whose addition in the atmosphere contributes to climate change, so regional and national mitigation actions in the waste sector are very important (KLHK 2018). The increase in emissions of CO_2, CH_4 and N_2O gases in the atmosphere causes various problems, including changes in the nature of the climate which have an impact on climate change (Herawati 2012). The decomposition of waste from the decomposition process of organic waste under anaerobic conditions can produce CH4 (methane gas) if an increase in methane gas in the atmosphere will cause climate change (Riswan *et al*. 2011). Suprihatin *et al.* (2014) stated that methane is the second most important greenhouse gas after carbon dioxide. One of the most important sources of methane is the anaerobic decomposition of waste. This approach is considered important because people can integrate their knowledge and experience in waste management that they face directly and routinely (Luthfi *et al.* 2013). Household waste management with community participation can more effectively reduce greenhouse gas emissions (Kiswandayani *et al.* 016). In reducing greenhouse gases, the community paradigm continues to be instilled as a first step in building a mindset towards household waste so that it can run well (Hayat *et al.* 2018). Utilizing the potential of local communities in reducing greenhouse gas emissions through environmentally friendly waste management (Riswan *et al.* 2011). Most of the people have tried to process their organic waste into compost. Meanwhile, inorganic waste is managed through a Waste Bank (Sudiro *et al.* 2018).

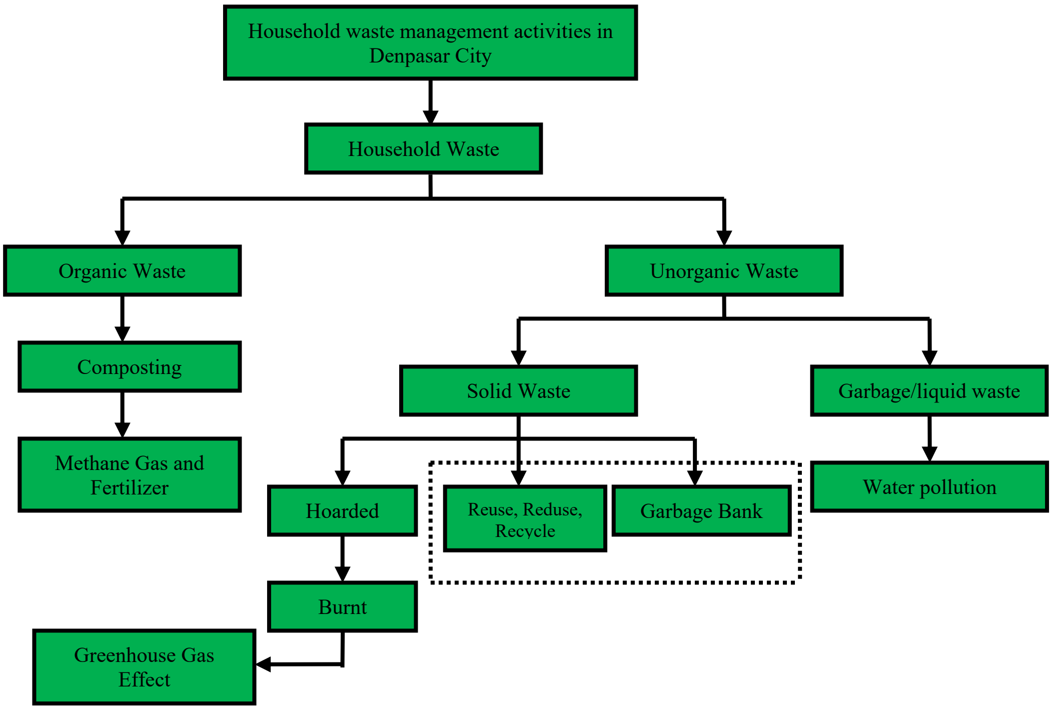
The study used a qualitative approach in data collection. The results show that in 2017 until now, the mitigation actions taken have increased with recycling activities, until 2019 amounting to 17.2 Gg CO_2e.

2. Methodology

In achieving the research results, the research methodology or approach used to determine the greenhouse gas emissions that can be reduced from household waste management is shown in Figure 1.

To calculate the level of greenhouse gas emissions from the household waste sector in Denpasar City, we used the Intergovernmental Panel on Climate Change worksheet (IPCC 2012). The quantitative data obtained from the primary data in the form of calculation data of waste generation and composition are needed to calculate greenhouse gas emissions from the household waste sector. The data is processed and analyzed to calculate greenhouse gas emissions at the BAU level (Bussenes As Usual) and to calculate greenhouse gas emissions with community participation in household waste management, because community knowledge about waste is quite good but it needs behavior change in handling waste (Ramon *et al.* 2015). if garbage does not become a breeding ground for disease germs and does not become an intermediary medium for the widespread spread of a disease (Azwar 2013).

Figure 1.



In this study, data processing uses the THIER 2 method because primary data already exists, and the analysis used is in accordance with Intergovermental Plane Climate Change (IPCC) (2012). To calculate the methane gas emissions generated from the waste generation, the calculation formula is as follows. 1) Analysis of the calculation of waste emissions that are directly disposed of in landfills; Methane emission analysis is carried out by calculating the waste generation that enters the Sarbagita Regional landfill with the following formula:

Emission CH_4 = (MSWT x MSWf x MCF x DOC x DOCF x F x - R) x (1-OX)

MSWT = Total population of Denpasar City x waste generation (Indonesian National Standard)

Information :

MSWT = Waste generation in landfills (tonnes / year)

MSWF = Fraction of waste generated (100%)

MCF = Methane correction factor (0.4 based on IPCC)

DOC = degradation of organic carbon (Kg C / Kg of waste)

DOCF = Fraction of DOC (0.5 based on IPCC)

F = Fraction of CH_4 in landfills (0.5 according to IPCC)

OX = Oxidation factor (0.1 based on IPCC)

R = Recovery CH4 (tonnes / year)

12/16 = Convert from C to CH4

The default values for Degradable Organic Carbon (DOC) according to IPCC (2012) can be seen in Table 1 and the default values for Default fraction disslimilated DOC (DOCf), Fraction of CH4 in landfill gas (F), Mehane Recovery (R), and Oxditaion Factor (OX)) provided by the IPCC to complete the calculation of CH4 emissions can be seen in Table 1.

In his journal entitled "Composition of Waste and Potential Greenhouse Gas Emissions in Domestic Waste Management: A Case Study of the Winongo Final Disposal Site, Madiun City", Kiswandayani *et al.* (2016) said that the results of greenhouse gas emissions are made equivalent in tons of CO_2 eq/year uses the Global Warning Potential (GWP) index and can be converted into tons of CO_2 eq / year with the formula: CH4 equivalent = 25 x CH_4 emissions.

1) Waste reduction analysis

Waste reduction is waste that can be reduced in the waste bank. Waste reduction can be seen from the type of waste and the amount of waste that enters the waste bank within a certain time. To obtain the reduced amount of waste in urban waste, the data on waste generation in the waste bank and the number of customers in the waste bank that have been obtained previously are processed first into a material balance. A new paradigm in waste management by involving the people of Tanuwijaya (2016). The material balance prepared includes the following data.

a) Total waste goes to all waste banks

b) Total incoming waste from the population (population taken from the number of customers of all waste banks)

Table 1. The DOC default value and the dry weight content of solid waste in Denpasar City

Garbage Component	Dry matter content (%)	Degraded organic carbon (%)		DOC content of dry waste (%)		Total carbon content (%) dry weight		Fossil carbon fraction (%) of total carbon	
	Standard	Standard	Range	Standard	Range	Standard	Range	Standard	Range
Paper/Carton	90	40	36-45	44	40-50	46	42-50	1	0-5
Textile	80	24	20-40	30	25-50	50	25-50	20	0-50
Food waste	40	15	8-20	38	20-50	38	20-50	-	-
Wood waste	85	43	39-46	50	46-54	50	46-54	-	-
Garden waste	40	20	18-22	49	45-55	49	45-55	0	0
Napies	40	24	18-22	60	44-80	70	54-90	10	10
Rubber & leather	84	(39)	(39)	(39)	(39)	67	67	20	20
Plastic	100	-	-	-	-	75	67-85	100	95-100
Metal	100	-	-	-	-	NA	NA	NA	NA
Glass	100	-	-	-	-	NA	NA	NA	NA
Etc	90	-	-	-	-	3	8-5	100	50-100

Source : IPCC, 2012.

Table 2. IPCC default value for methane gas calculation

Calculation Variable	Value
MCF	0,4
DOCF	0,5
F	0,5
R	0
OX	0,1

Source: IPCC, 2012.

From the difference in the amount of waste produced by residents of Denpasar City and the amount of waste that enters all waste banks, a reduced amount of waste will be obtained.

% Reduction = Total waste in Denpasar City - Total waste goes to the waste bank

2) Calculation of greenhouse gas emissions

The calculation of greenhouse gas emissions is done manually using MS Office Excel and interpreted in graphs and figures in tonnes of CO_2eq / year. The formula for calculating greenhouse gas emissions in composting processes is as follows.

Information:

Mi = Mass of composted waste (Gg/year)

Efi = Emission factor in the composting process (g CH_4/Kg)

R = Total CH_4 emission recovery (Gg CH_4)

For the emission factor (EF) used in the calculation according to the IPCC (2012) GL default value, the EF value can be seen in table 3 below.

Table 3. Emission factor (EF) default IPCC 2006 GL (Tier 1)

Biological processing technology type	CH_4 emission factor (g CH_4/kg of waste)	
	Dry weight base	Wet weight base
Cosmposting	10 (0.08-20)	4 (0.03-8)

Source: IPCC, 2012.

3. Result and Discussion

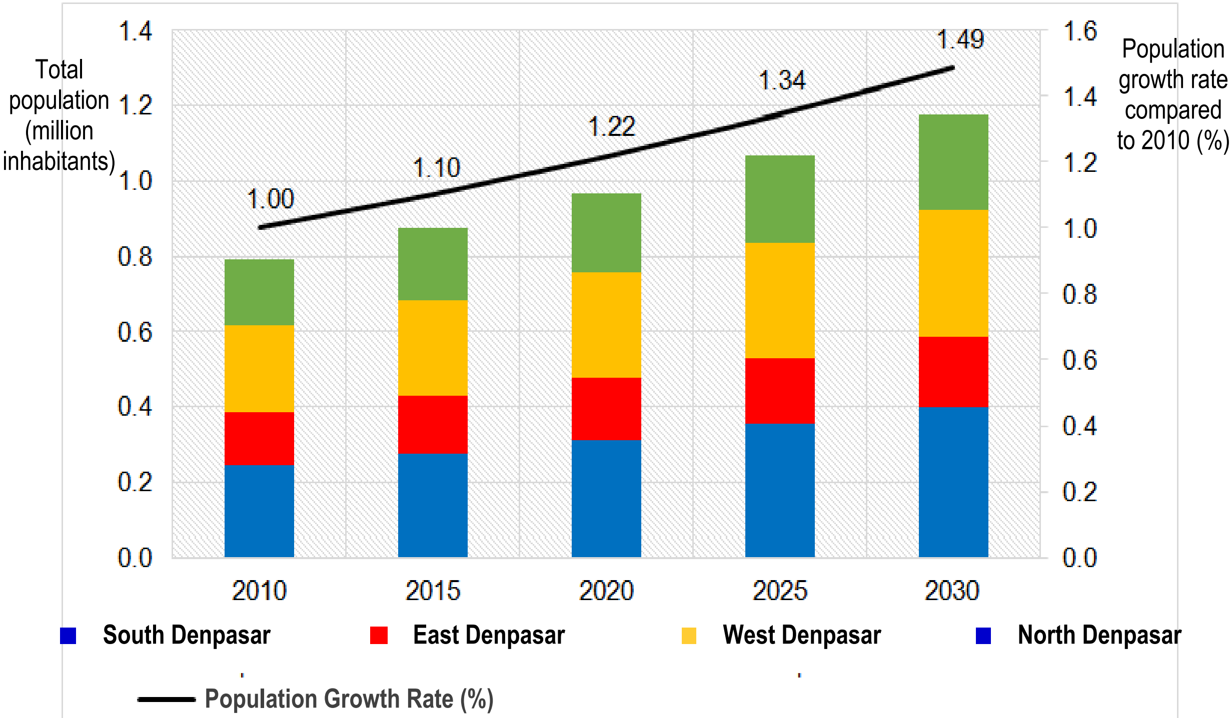
In calculating the level of greenhouse gas emissions generated by the domestic solid waste sub-sector, greenhouse gas emissions are calculated since 1990 even though landfills used to collect waste have been operating since 1984 (already in accordance with IPCC guidelines where the minimum calculation is counted back 10 years. backwards from the base year 2010). The population projection has been calculated since 1990 (related to the amount of waste generated). The estimated population of Denpasar City for the period 1990-2000 uses the same size assumption as the population growth period for the 2000-2010 period in each sub-district in Denpasar City. Furthermore, the population growth projection for the 2019-2030 period uses the population growth rate for the 2010-2019 period based on data from each district. Total Population and Growth Rate in Denpasar City by District are presented in Table 4 and the results of the population projection are presented in Figure 2.

Table 4. Total population and growth rate in Denpasar City based on district

Districts	Total population (thousand inhabitants)			Population growth rate (%)	
	2000	2010	2019	2000-2010	2010-2019
South Denpasar	152,69	246.31	305.4	4.90	2.42
East Denpasar	100,6	139.13	160.2	3.30	1.58
West Denpasar	156.8	230.72	273.6	3.94	1.91
North Denpasar	122.35	176.84	207.9	3.75	1.81
Total	532.44	793.00	947.10		

Source: BPS Bali Province and BPS Denpasar City, 2020

Figure 2 Projections of population growth in Denpasar City until 2030



Source: Processed from BPS Bali Province and BPS Denpasar City, 202)

Waste management in urban areas is generally carried out through 3 stages of activity, namely: collection, transportation and final disposal. The amount of waste generation for each resident in Denpasar City based on the sub-district is presented in Table 5. In West Denpasar District, it is estimated that the highest waste generation yield is 0.6 kg/person/day. Then followed by the Districts of South and East Denpasar with the amount of waste generation reaching 0.57 kg/person/day. In North Denpasar District, the waste generation rate is estimated at 0.56 kg/person/day. Based on these data, it is estimated that the average waste generation generated by Denpasar City residents in a period of 1 year is 0.21 tonnes/person/year. In Figure 3, the estimated waste generation in Denpasar City for the 2010-2030 period is presented.

Table 5. Estimation of waste generation in Denpasar City based on district

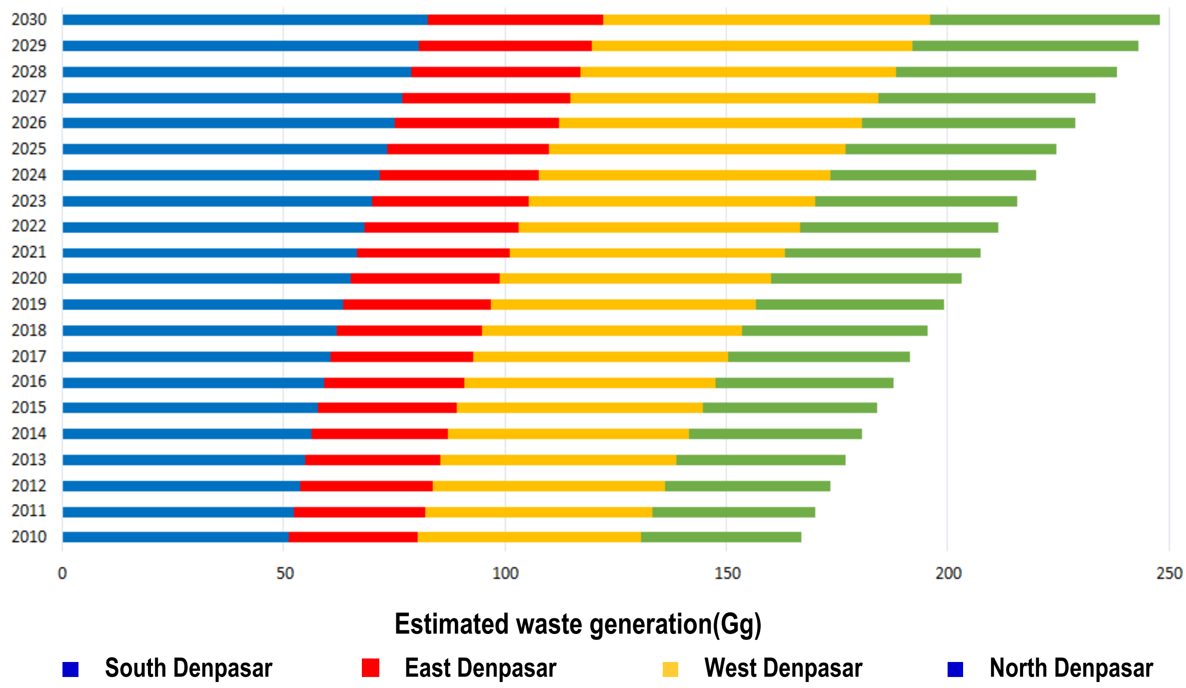
Districts	kg/person/hari
South Denpasar	0,57
East Denpasar	0,57
West Denpasar	0,6
North Denpasar	0,56

Source: Denpasar City Environment and Sanitation Service, 2020

Most of the domestic waste generated in Denpasar City (52%) is collected and disposed of in the Suwung landfill. The rest is partially processed outside the landfill, burned openly by the community, and is not treated / ignored. The percentage of domestic waste distribution in Denpasar City by district is presented in Table 6.

In calculating the greenhouse gas emissions produced in landfills, information on the composition of waste and its dry matter content (DMC) is required as presented in Table 7.

Figure 3: Estimated waste generation in Denpasar City for the period 2010-2030



Source: Processed by the Denpasar City Environment and Sanitation Office, 2020

Table 6. Distribution of domestic waste in Denpasar City based on district

Garbage distribution	Unit	Districts			
		South Denpasar	East Denpasar	West Denpasar	North Denpasar
The amount of waste transported	%	52	52	52	52
Amount of processed waste	%	15	10	40	5
Not transported/spread out	%	26.4	30.4	6.4	34.4
Open burning	%	6.6	7.6	1.6	8.6

Source: Denpasar City Environment and Sanitation Service, 2020

The various mitigation actions taken are a form of effort to reduce the level of greenhouse gas emissions, both locally, regionally, nationally and internationally. These mitigation actions can be carried out in various sectors, for example in the energy, transportation, waste management, industry, and agriculture and forestry sectors. Indonesia's participation and commitment in efforts to reduce the level of greenhouse gas emissions is stated in Indonesia's First NDC document in 2016 which is translated into various types of mitigation actions. Regionally, each province and district/city in Indonesia also plays a role in reducing the level of greenhouse gas emissions, including the Regional Government of Denpasar City. The mitigation actions for reducing greenhouse gas emissions that have been carried out by the Denpasar City Government are composting and recycling which are presented in this document.

Table 7. Composition and DMC of garbage at the final disposal site of Suwung, Denpasar City

No.	Garbage Component	Garbage Composition (%)[1]	Dry Matter Content (%)[2]
1	Food	17.71	19.13
2	Gardens and Parks	45.71	30.19
3	Wood	1.16	71.76
4	Paper and Carton	7.36	65.63
5	Textile	2.75	64.58
6	Nappies	2.31	31.76
7	Rubber & leather	1.10	76.52
8	Plastic	19.26	
9	Metal	9.54	
10	Glass	1.15	
11	Etc (Ash, dust)	0.95	
Total		100	

Source: Department of Environment and Hygiene of Denpasar City (2020), Udayana University

3.1 Regulatory Support Regarding the Bali Provincial Low Carbon Development Plan

In 2012, the Provincial Government of Bali enacted the Governor of Bali Regulation Number 49 of 2012 concerning Regional Action Plans for Greenhouse Gas Emission Reduction as a form of the Bali Government's commitment to reducing GHG emission levels in its region in line with regional development targets. In the document, it was agreed that the mitigation actions to be carried out were between 2010 and 2020. In this report, Denpasar City has conveyed the achievements of reducing greenhouse gas emissions. This achievement can be part of the achievements that have been successfully carried out by the Bali Provincial Government. Based on the Pergub document, this report is an integral part of efforts to reduce greenhouse gas emissions in Bali Province.

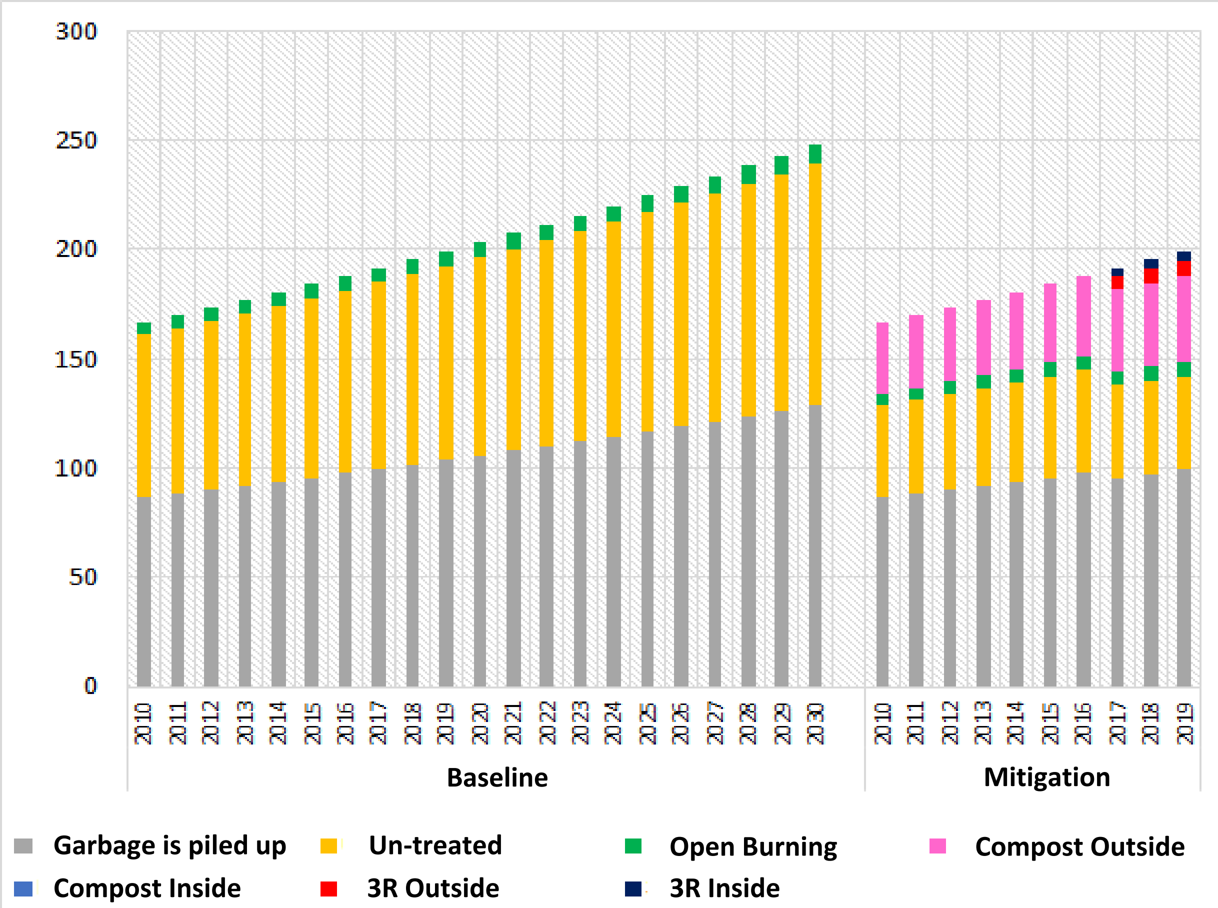
Over time, the involvement of the Government of Indonesia in the international community regarding greenhouse gas emissions has increased. This is shown in Indonesia's First NDC document in 2016. In response to this, the Provincial Government of Bali in an effort to reduce the level of greenhouse gas emissions in its region stipulates Bali Governor Regulation Number 39 of 2019 concerning Regional Action Plans for Sustainable Development Goals of Bali Province 2019-2023 . The Governor Regulation acts as a stepping stone / guideline for the Bali provincial government in launching a work plan that contains targets, policy directions, and strategies for achieving the Sustainable Development Goals in Bali Province.

Furthermore, in early 2020, the Bali Provincial Government has signed a memorandum of understanding on the Regional Low Carbon Development Plan with the Ministry of National Development Planning. The Regional Low Carbon Development Plan will serve as a guideline for the Bali Government in carrying out continuous mitigation actions in the future which are implemented through synergies in dealing with climate change and economic growth. Various forms of action were chosen to be planned to be implemented including the following:

1.Bali Clean Energy Concept,
2.Policies regarding the use of battery-based electric motors,
3.Limitation of single-use plastic waste
4.Source-based waste management, and
5.Organic farming systems. Waste Distribution Based on Baseline Scenarios and Mitigation in Domestic Solid Waste Sub-Sector

Mitigation actions that have been carried out in an effort to reduce the level of greenhouse gas emissions in the domestic solid waste sub-sector in Denpasar City are composting and recycling (3R) activities. In calculating the achievement of reducing greenhouse gas emissions, it is the difference between the greenhouse gas emissions produced in the baseline scenario minus the greenhouse gas emissions produced in the mitigation scenario. The difference in greenhouse gas emission levels in the baseline and mitigation scenarios is due to differences in activity data on differences in waste distribution in each scenario. In the baseline scenario, the waste generated is partially dumped into a landfill, the rest is burned openly by the community or left alone. Whereas in the mitigation scenario, the waste generated is partially dumped into a landfill, the rest of the waste is processed through composting and recycling mitigation actions, leaving a small amount of waste that remains to be burned openly or left alone. In addition, waste disposed of in landfills is partially processed into compost or recycled. The distribution of waste in both scenarios is presented in Figure 4.

Figure 4. Waste distribution in baseline and mitigation scenarios



3.2 Achievement of Greenhouse Gas Emission Reduction in Denpasar City

Waste management in general includes waste generation control, waste collection, transfer and transport, processing and final disposal (Kartikawan 2014). With the mitigation action in the form of composting and recycling in Denpasar City, the benefits obtained are reduced volume of waste generation and reduced levels of greenhouse gas emissions due to domestic solid waste management. The achievement of reducing greenhouse gas emission levels in the solid waste sub-sector by the Denpasar City Government is presented in Figure 5. Furthermore, Figure 6 presents the weighting of achievements in reducing greenhouse gas emissions from composting and 3R activities since 2011. At the beginning of the mitigation implementation, steps / the only mitigation action taken is composting.

2011 was the first year composting activities were carried out so that no reduction in greenhouse gas emissions was achieved. The achievement of emission reduction from composting activity was obtained in 2012 with an achievement of 2.6 Gg CO_2e. In 2017 until now, the mitigation action taken has increased with recycling activities. In 2019, the achievement of GHG emission reduction reached 17.2 Gg CO_2e by weighting the reduction in GHG emissions from composting of 15.1 Gg CO_2e and the rest from 3R activities of 2.1 Gg CO_2e.

Achievements in reducing greenhouse gas emissions based on mitigation actions in the domestic solid waste sub-sector in Denpasar City for the period 2010 to 2019 are presented in Figure 7. Achievements in reducing greenhouse gas emissions in Denpasar City by 2019 amounted to 17.2 Gg CO_2e with weighted emission reduction greenhouse gas from composting is 15.1 Gg CO_2e and the rest from 3R activity is 2.1 Gg CO_2e.

As a concrete action in reducing greenhouse gas emissions in Denpasar City, there are several steps that must be taken:

1.Intervening in policy by implementing composting practices starting from the household level on a small scale, offices, companies, waste banks, hotels and communities in all mediums and building large-scale composting areas supported by strong systems and institutions.

2.Extending the 3R action more broadly by involving various competent parties in the waste sector.

3.Provide rewards and funishment strictly in accordance with applicable regulations, especially waste sorting at the household level, such as if the waste is not sorted, don't transport it and provide transportation advice that has been separated between organic and inorganic waste.

4.Capturing greenhouse gas emissions in landfills and used for fuel.

5.To make the reduction of greenhouse gas emissions a regional policy that should be translated into a regulation.

Figure 5. Achievements in reducing greenhouse gas emissions from the domestic solid waste sub-sector in Denpasar City for the period 2010 to 2019

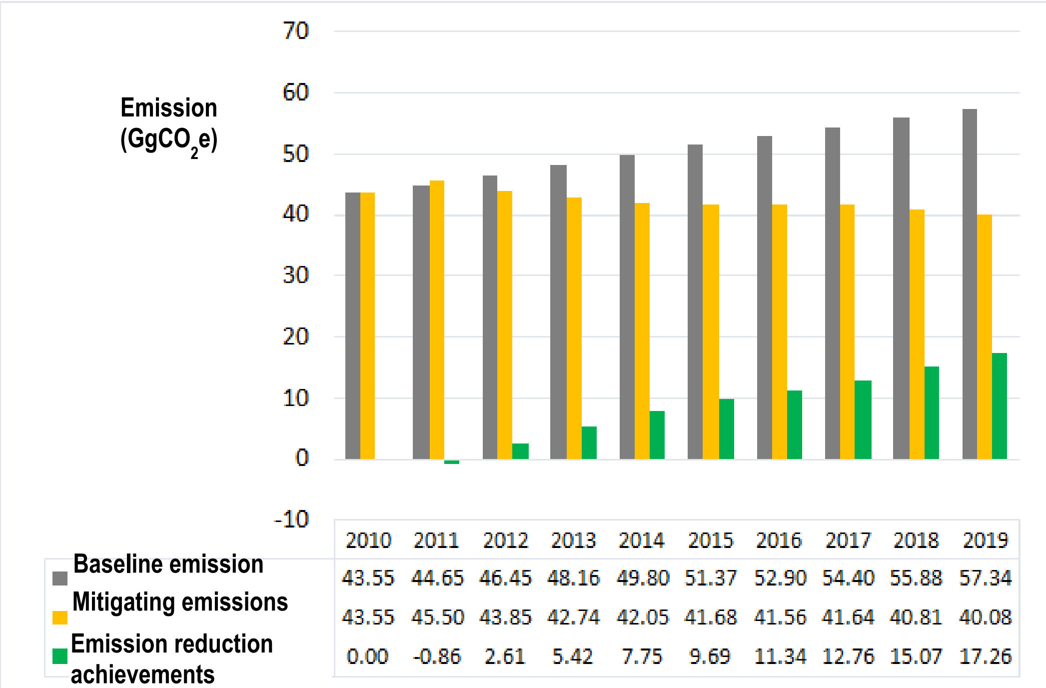


Figure 6. Weighting achievement of reducing greenhouse gas emissions from composting and 3R

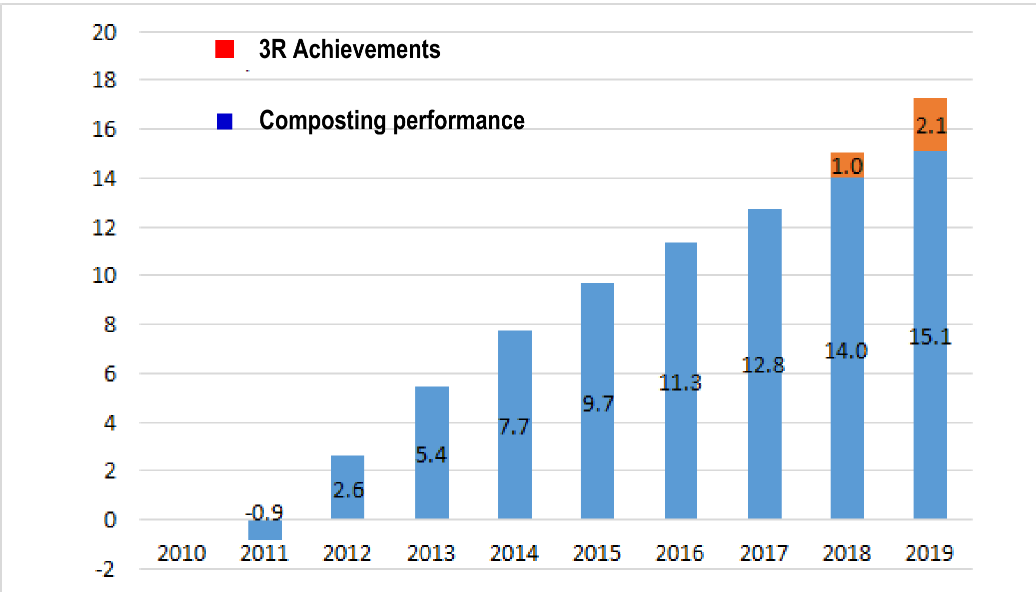
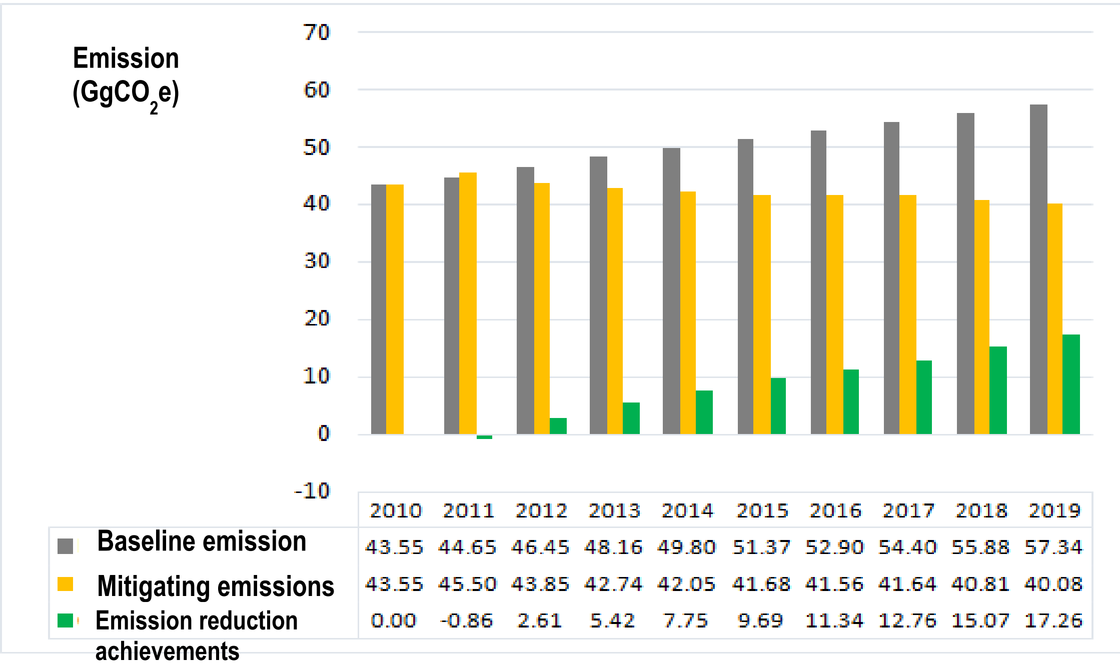


Table 8. Achievements in Reducing Greenhouse Gas Emissions on Mitigation Actions in Denpasar City in 2019

Sector	Mitigation Action	Baseline emission level	Baseline emission level	Emission reduction	Supporting document description
		Gg CO_2e			
Waste	Composting	57.3	42.2	15.1	Methodology (Tier 1 IPCC 2006 GLs) Baseline, Mitigation, Reduction refers to the 2020 document on Domestic Solid Waste Mitigation of Denpasar City. 'Greenhouse Gas Calculation Results'
	3R	57.3	55.2	2.1	Methodology (Tier 1 IPCC 2006 GLs) Baseline, Mitigation, Reduction refers to the 2020 document on Domestic Solid Waste Mitigation of Denpasar City. 'Greenhouse Gas Calculation Results'
		57.3	**40.1**	**17.2**	

Figure 7. Reduction of greenhouse gas emissions in the sub-sector of domestic solid waste in Denpasar City for the period 2010-2019



The result of reducing greenhouse gas emissions by 17.26 tonnes is a real step, even though it is the start of a movement to reduce greenhouse gases. The reduction of greenhouse gas emissions has not been carried out by policy intervention from the local government and this is the next thought. Poor waste management will damage the environment and contribute to one of the greenhouse gas emissions. One of the efforts to reduce greenhouse gas emissions in waste management is through the composting process of processed organic waste that can be sold commercially, both compost and biodigester products (Indartik *et al.* 2018) which avoids the formation of greenhouse gases.

Conclusion

Greenhouse gas emissions come from garbage dumped in landfills and from burning household waste. The reduction or reduction in greenhouse gas emissions during the last 10 years comes from composting activities of 15.1 Gg ton CO_2e e and 3R activity of 2.1 Gg ton CO_2e e.

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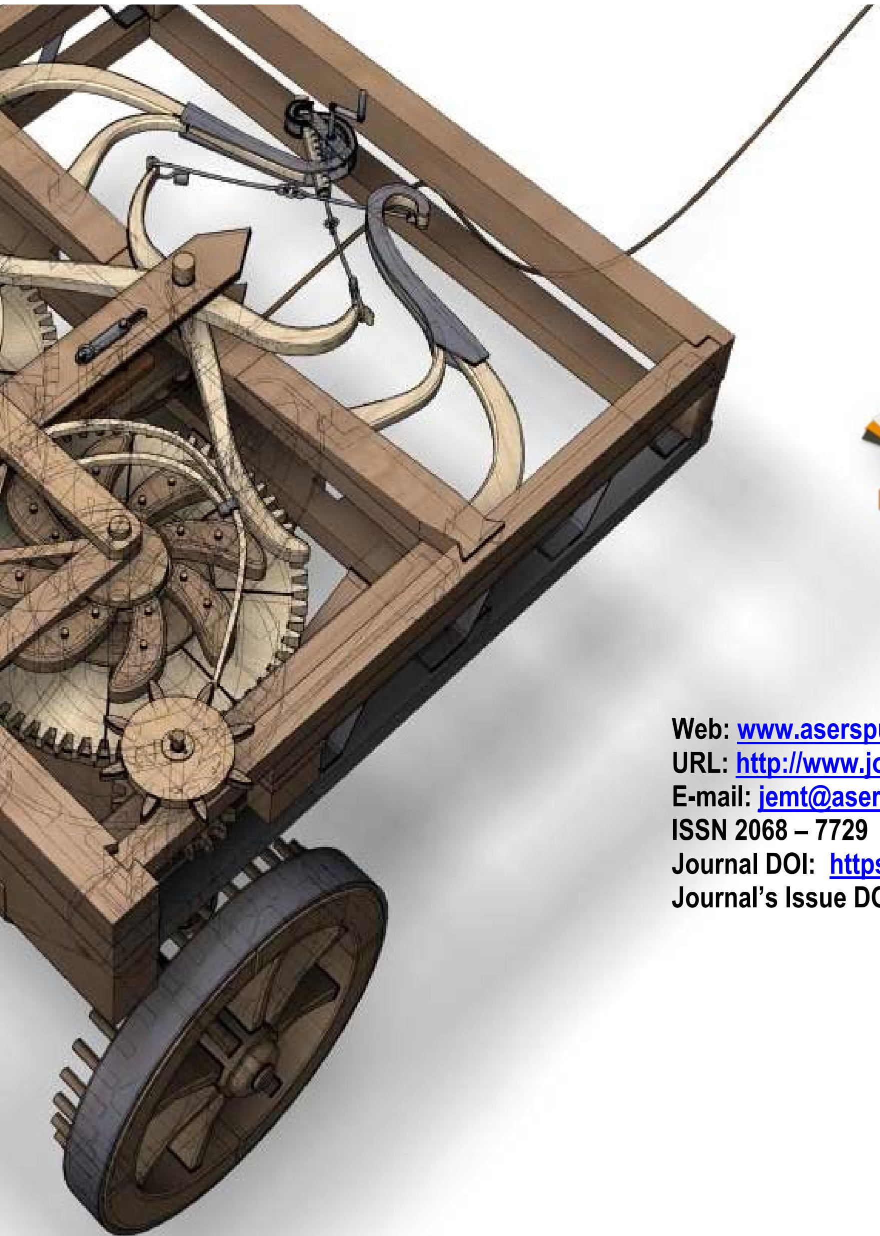

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