As the highest populated country (around 261.1 million) in Southeast Asia with a growth rate of 1.1% per year (World Bank, 2016), Indonesia faces serious problems related to the environment. Population growth and urbanization have resulted in an increase in the amount of urban waste and become one of the main responsibilities of the city government. Good and affordable management of municipal solid waste (MSW) is one of the main challenges of the 21st century and is becoming increasingly complex in line with the increasing quantity of solid waste, weak policies or strategies for handling waste, lack of financial support, low involvement of the private sector, inefficiencies, and low community involvement in handling municipal waste. The challenge exists in all stages of solid waste management including storing, collecting, transferring, transporting, and treatment with tendency to rise at the end, landfill.

Managing city solid waste is one of the key responsibilities of the municipal government. In Indonesia, the source of municipal solid waste mostly flows from households and then from traditional markets. Solid waste management (SWM) in Indonesia is usually associated with the formal and informal sectors. The formal sector includes government agencies in the regions and formal business institutions, while the informal sector consists of individuals, groups and small businesses involved in activities that are not registered and not formally regulated. In activities related to municipal waste, the informal sector refers to recycling activities carried out by garbage scavengers or waste pickers and its buyers or users.

Unfortunately, SWM has not been among top priorities for most local governments. People generally think that as long as rubbish is collected from their household, their waste problem has been solved.

For most regional executive leaders, SWM is about garbage collection. As long as the trash has been stacked and collected, the problem was "invisible and need not be thought of". Problems of limited financial resources, inadequate infrastructure and lack of localized technical expertise can create opportunities for private sector investment. Waste landscapes have changed as market liberalization arise from a traditionally been a public service sector to become a privatized market through active private public partnerships.

Indonesia and the Philippines as well as parts of China and India are Asian countries facing the greatest waste management challenge, based on projected waste generation rates and relative affluence to deal with the problem. Household solid waste in Indonesia is mostly landfilled without any treatment and not even incinerated. Landfills are the main source of methane which is considered to be responsible for about 20% of the recent increase in global warming. Landfills are also source of carbon dioxide gas, which together with methane are both 'greenhouse gases'. Therefore, the options of waste management that will reduce CH_4 and N_2O emissions will be seen as a very favourable choice. Projects that implement emission-reduction or emission-limitation commitment under the Kyoto protocol can be considered as vital solutions, for instance landfill gas-to-energy (or waste-to-energy) and anaerobic digestion projects, which generating income and reducing greenhouse gases at the same time. Improving the capacity of the landfill to treat waste require planning and management of solid waste (SWM) in the future, such for Bantar Gebang landfill that treats Jakarta's waste which would exceed its capacity in 2019.

Figure 1. Municipal solid waste in Asia

Country	Waste generated per kg/person/day		increase / decrease
	2015 (base)	2025 (projected)	
China	1,02	1,70	▲ 66,7%
India	0,34	0,70	▲ 105,9%
Indonesia	0,52	0,85	▲ 63,5%
Japan	1,71	1,70	▼ 0,5%
Philippines	0,50	0,90	▲ 80%
Singapore	1,49	1,80	▲ 20,80%
South Korea	1,24	1,40	▲ 12,90%

Source: World Bank Straits times graphics

Jenna R. Jambeck, assistant professor of environmental engineering from the University of Georgia, in 2015 research estimates that residents or households in Indonesia can produce 0.52 kg/person/day of waste. According to 2015 data of Environment and Forest Ministry, averagely every Indonesian produces 0.76 kg of waste per day. By using the projection of the National Development Planning Agency (Bappenas) in 2013 regarding the projected total population of Indonesia in 2018 of 265.05 million, at the end of this year Indonesia would generate 201,438 tons per day of solid waste in all regions of Indonesia covering 1,905,570 km^2 areas which administratively divided into

34 provinces. The problem will be increasingly acute considering that Indonesia is the largest archipelagic country in the world which consists of almost 17,504 islands.

Quoted from Geotimes.co.id, the total amount of waste generation in Indonesia reaches 175,000 tons per day or 0.7 kilograms per person or around 64 million tons/year (Geotimes, 2015) and almost 10% are plastic waste. According to the Indonesia Solid Waste Association (InSWA), plastic waste generation in Indonesia is around 5.4 million tons per year and makes Indonesia the second largest plastic waste contributor in the world after China. A lot of plastic waste is finally dumped into the sea. Every year at least 12.7 million metric tons of plastic waste worldwide which is produced on land is dumped into the sea.

Directorate General of Waste and Hazardous Materials Management of Environment and Forestry Ministry predicts that by 2019, the whole waste generation in Indonesia will reach 68 million tons of waste per year, and plastic waste generation is estimated to reach 9.52 million tons or 14 percent of total waste. To overcome this, the government issued Presidential Regulation number 18 in 2017 concerning National Policies and Strategies for Household Waste Management and Household-like Waste (Jakstranas). The government also set the latest targets related to waste management, namely waste reduction by 30 percent and waste management by 70 percent in 2025. Currently, the waste reduction only reaches 2.12 percent, still far below the 30 percent target.

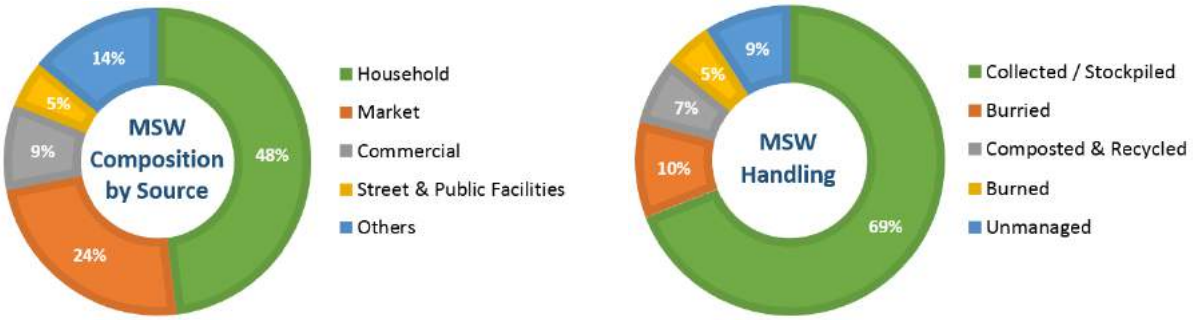
Figure 2. World plastic waste by country, 2014

Rank	Country	Percentage of waste that is mismanaged	Quantity of mismanaged plastic waste (MMT/year)	Percentage of global mismanaged plastic waste	Quantity of plastic marine debris (MMT/year)
1	China	76	8.82	27.7	1.32–3.53
2	Indonesia	83	3.22	10.1	0.48–1.29
3	Philippines	83	1.88	5.9	0.28–0.75
4	Vietnam	88	1.83	5.8	0.28–0.73
5	Sri Lanka	84	1.59	5.0	0.24–0.64
6	Thailand	75	1.03	3.2	0.15–0.41
7	Egypt	69	0.97	3.0	0.15–0.39
8	Malaysia	57	0.94	2.9	0.14–0.37
9	Nigeria	83	0.85	2.7	0.13–0.34
10	Bangladesh	89	0.79	2.5	0.12–0.31
11	South Africa	56	0.63	2.0	0.09–0.25
12	India	87	0.60	1.9	0.09–0.24
13	Algeria	60	0.52	1.6	0.08–0.21
14	Turkey	18	0.49	1.5	0.07–0.19
15	Pakistan	88	0.48	1.5	0.07–0.19
16	Brazil	11	0.47	1.5	0.07–0.19
17	Burma	89	0.46	1.4	0.07–0.18
18	Morocco	68	0.31	1.0	0.05–0.12
19	North Korea	90	0.30	1.0	0.05–0.12
20	United States	2	0.28	0.9	0.04–0.11

MMT = million metric tons

Source: Jambeck et al.2015

The 175,000 tons of waste is dominated by household waste (44.5%) which is mostly food waste. This food scrap or kitchen waste can potentially be composted. The Ministry of Environment and Forestry (KLHK) stated that the waste management was done by transporting and stockpiling at the Final Disposal Sites (69%), buried (10%), composted and recycled (7%), burned (5%), and the rest was unmanaged (7%) such as being thrown into a river or sea, being left on vacant land, etc. Domestic waste is the biggest contributor (60-90%) of river pollution in Java and Sumatra. Waste management is still concentrated in Final Disposal Sites (TPA) without going through the 3R process (reduce, recycle, reuse) in the origin of wastes by involving community participation.



Municipal Solid Waste (MSW)

Solid waste is defined as any garbage, refuse, sludge from waste treatment plant, water supply treatment plant, or air pollution control facility and other materials, including solid, liquid, semisolid, contained gaseous resulting from industrials, commercials, mining and agricultural operations from community activities (Moeller, 2005). Waste generation rates are affected by socioeconomic development, degree of industrialization, and climate. Generally, the greater the economic prosperity and the higher percentage of urban population, the greater the amount of solid waste produced.

Figure 3. Sources and Types of Municipal Solid Waste

Sources	Typical waste generators	Types/Components of solid waste
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, glass, wood, metals, ashes, special wastes (e.g. bulky items, consumer electronics, batteries, white goods, oil, tires), and household hazardous wastes
Commercial	Stores, hotels, restaurants,	Paper, cardboard, plastics, wood, food wastes, glass, met-
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping wastes, food wastes, packaging, construction and demolition materials, hazardous wastes, ashes, special wastes
Institutional	Schools, government center, prisons, hospitals	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes (same as Commercial)
Municipal services	Street cleaning, landscaping, parks, beaches, water and wastewater treatment plants, other recreational areas	Street sweepings; sludge; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Concrete, steel, wood, dirt, etc.
Process	Heavy and light manufacturing, chemical plants, refineries, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off-specification products, slog, tailings
All of the above should be included as "municipal solid waste."		
Agriculture	Crops, vineyards, orchards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes, hazardous waste (e.g., pesticides)

Source: World Bank.

Waste has the potential to damage the environment through pollution to soil, water and air. Indonesia with the fourth largest population in the world is currently facing serious problems in handling solid waste, especially those generated by households. This is a big problem for large cities that are densely populated such as Jakarta, Surabaya, Bandung and others as the population increases in these areas.

The high generation of waste per day occurred in Java, such as Jakarta, Surabaya and Semarang, while outside Java occured in Banjarmasin, Samarinda, Denpasar, and Makassar. The readiness of concerned authorities is needed so that the waste produced every day can be managed properly. Percentage of volume of waste transported per day illustrates the readiness of each region in handling waste produced. High waste production if not accompanied by good countermeasures will cause pollution. Production and volume of household waste that can be picked up and transported per day in provincial capitals throughout Indonesia in 2016 is presented in Figure 4.

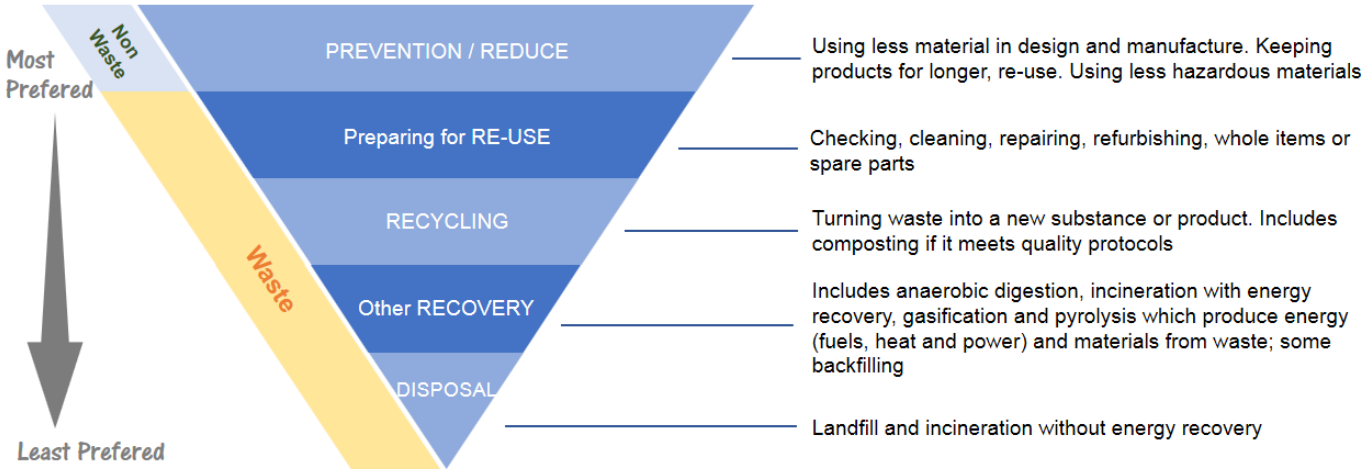
Figure 4. Waste generation and volume of transported trash per day in 2016

No	Provincial Capital City	Estimate of Daily Garbage Production (m^3)	Volume of Garbage that Daily Transported (m3)	Percentage of Treated Garbage (%)
1	Banda Aceh	800,97	703,45	87,82
2	Medan	1.700,00	1.564,85	92,05
3	Padang	520,00	505,20	97,15
4	Pekan Baru	872,02	331,28	37,99
5	Jambi	1.517,10	924,74	60,95
6	Palembang	no data		
7	Bengkulu	1.072,87	449,57	41,90
8	Bandar Lampung	1.287,02	1.158,32	90,00
9	Pangkal Pinang	426,40	346,26	81,21
10	Tanjung Pinang	672,07	272,77	40,59
11	DKI Jakarta	7.099,08	6.016,30	84,75
12	Bandung	1.469,00	1.100,00	74,88
13	Semarang	5.080,51	4.445,00	87,49
14	Yogyakarta	904,80	787,20	87,00
15	Surabaya	9.710,61	5.237,70	53,94
16	Serang	1.638,00	848,00	51,77
17	Denpasar	3.719,00	3.625,00	97,47
18	Mataram	300,00	196,65	65,55
19	Kupang	655,00	504,00	76,95
20	Pontianak	1.709,50	1.486,00	86,93
21	Palangkaraya	800,00	425,00	53,13
22	Banjarmasin	3.471,00	3.331,50	95,98
23	Samarinda	3.212,66	2.002,34	62,33
24	Tanjung Selor	no data		
25	Manado	no data		
26	Palu	920,00	600,00	65,22
27	Makasar	5.931,40	5.623,61	94,81
28	Kendari	221,91	166,09	74,85
29	Gorontalo	486,24	335,00	68,90
30	Mamuju	383,00	208,00	54,31
31	Ambon	146,00	131,00	89,73
32	Ternate	60,64	43,23	71,29
33	Monokwari	272,79	165,00	60,49
34	Jayapura	no data		

The increased solid waste is caused by, among others, population growth, urbanization, industrial development and modernization. It led to an increase in demand for food and other necessities, so the daily amount of waste produced by humans and households continues to increase.

The hierarchy of waste management reflects the sustainability of each waste management option. Any waste must be handled by using the highest possible option from the hierarchy in order to be as sustainable as possible. Most of the time and effort must be used to prevent waste in the first place. If it cannot be prevented, then reuse it. If it cannot be reused, recycle it. If you can't recycle, do recovery and so on. Waste disposal must be the last option to do.

Figure 5. The hierarchy of waste management



Sustainable waste management is a strategic approach that includes all sources and aspects of waste management from generation, segregation and transfer to treatment, recovery and disposal in an integrated system, with an emphasis on stakeholder participation and resource recovery. The sustainable approach adopts the waste hierarchy as

The recommended waste approach are :

Reduce – waste minimisation initiatives by businesses and households to reduce the amount of waste produced

Reuse – reuse waste and avoid energy-consuming reprocessing

Recycle – reprocess waste for further use

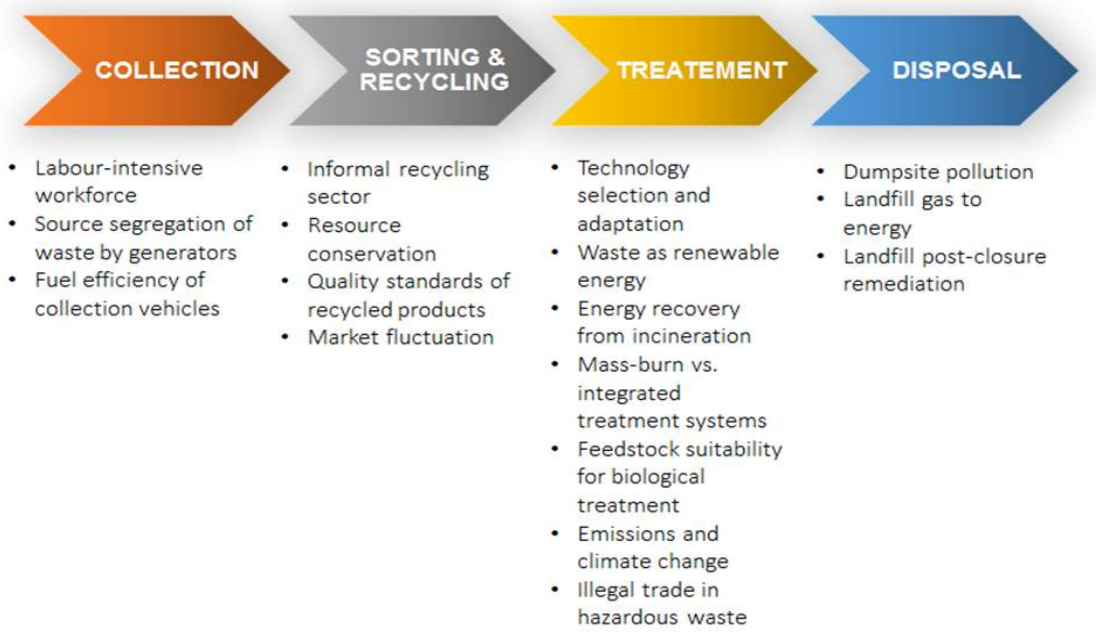
Energy recovery – generate energy from waste using a variety of technologies such as incineration

Disposal – put waste in landfill sites

The waste problem is not merely a pure material disposal but an integral part of socio-economic, governance and environmental discussions on issues of urbanization and sustainability. Sustainable waste management is a strategic approach in an integrated system that covers all aspects and sources of waste management ranging from waste generation, segregation and transfer to treatment, recovery and disposal with a system emphasis on all stakeholder participation and resource recovery.

The sustainable approach adopts the waste hierarchy as a very useful framework by ranking waste management options according to their impact on the environment and managing holistically all aspects of environmental, social and governance issues across the full waste value chain to avoid ‘spillover’ costs so this approach will provide an opportunity to generate greater financial return. The waste value chain can be represented by four key components namely collection, sorting and recycling, treatment and disposal.

Figure 6. Environment Social and Governance issues across waste value chain



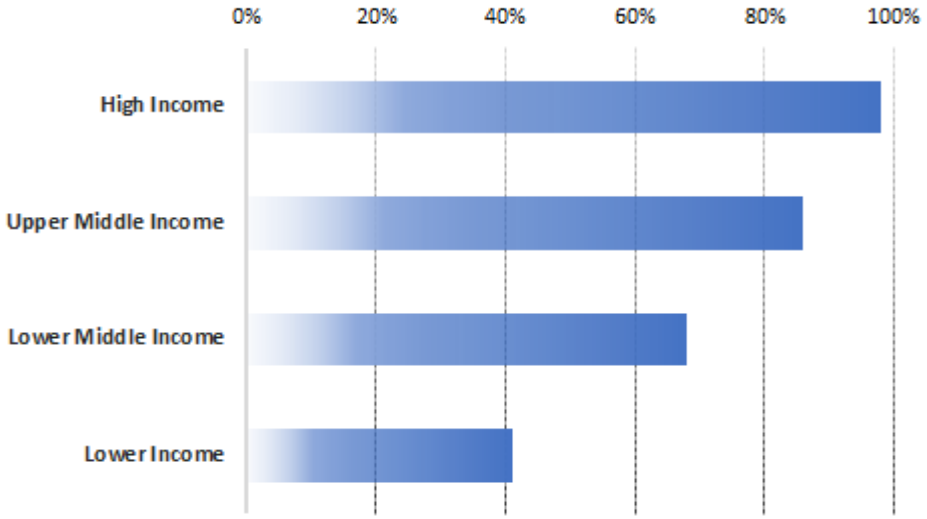
Waste collection is the activity of collecting solid waste from the point of generation (residential, industrial commercial, institutional) to the point of treatment or disposal. Municipal solid waste is collected in several ways:

1. **House-to-House**: Waste collectors visit each individual house to collect trash. Users generally pay fees for this service.
2. **Curbside Lifting**: Waste generators leave their trash directly outside their homes in accordance with the designated pick-up schedule with local authorities.
3. **Community Bins**: Waste generators carry their trash into community trash bins which are placed at fixed points in the neighborhood or around the residence. MSW is then taken by the local government (municipality), or the designated party, according to a set schedule.
4. **Self Delivered**: Waste generators send their trash directly to disposal sites or transfer stations, or by hiring a third party operator (or local government).
5. **Contracted or delegated services**: Business institutions hire companies (or municipalities with municipal facilities) that arrange waste collection schedules and billing costs to customers. The city government often gives licenses to private operators and may designate waste collection locations to encourage collection efficiency.

The data shows that the average rates of trash collection in a country is directly related to the level of national income. Low-income countries have low levels of waste collection rates while high-income countries have higher levels of collection rates. Higher-income countries tend to have higher waste collection efficiency even though with less budget for solid waste management allocated to collection. In low-income countries, collection services constitute the largest share of municipality's solid waste management budgets (in many cases between 80% to 90%), yet the waste collection rates tends to be much lower, leading to lower collection frequency and efficiency. In high-income countries, although waste collection costs can be less than 10% of the municipality's budget, the average collection rate is usually more than 90% where the collection method tends to be mechanized, efficient, and as often as possible. Although the total collection budget increases every year, the proportion tends to be lower be-

cause other budget items increase. Figure 7 shows the average percentage of waste collection by country's income .

Figure 7. Waste Collection Rates by Income



Indonesia is the sixth largest emitter in the waste sector (Kunzler, M., 2010) so that it is necessary to evaluate GHG emissions from various waste management systems (SWM) in Indonesia and formulate appropriate greenhouse gas emission mitigation strategies.

Total GHG emissions in Indonesia from all emitter sectors in 2010 amounted to 1,377,982 Kilo tons of CO_2e. The waste sector emissions contribute around 11.4% to Indonesia's total greenhouse gas emissions (SNC, 2010). The waste management sector is very important for local governments because it is closely related to environmental and health aspects. Not only that, the mitigation potential of the waste sector and its relation to the development objectives make the waste sector very instrumental in designing Indonesian Nationally Appropriate Mitigation Actions (NAMAs).

Figure 8. National GHG emission reduction targets

Sectors	2020 GHG emission reduction targets (Gton CO_2e)	
	NAMAs	Supported
	26%	**41%**
Forestry and Peatland	0.672	1.039
Waste	**0.048**	**0.078**
Energy and Transport	0.036	0.056
Agriculture	0.008	0.011
Industry	0.001	0.005
Total	**0.767**	**1.189**

Source: National Action Plan for GHG emission reduction (RAN-GRK)

NAMAs are climate policies and measures in developing countries within different economic sectors (including transport and waste). NAMAs can catalyse additional financial support or technical assistance from international donors under a condition that such actions:

- Lead to substantial, quantifiable greenhouse gas (GHG) emission reductions, contributing to global climate change mitigation efforts;
- Have positive impacts on the local sustainable development (SD) conditions of the country and the sector that the NAMA covers;
- Are aligned with the national policy, institutional and regulatory framework.

Figure 9. Projection of Indonesia's GHG Emissions

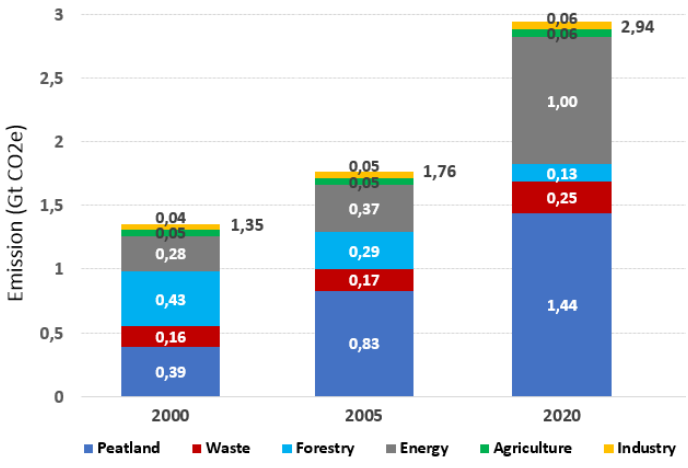
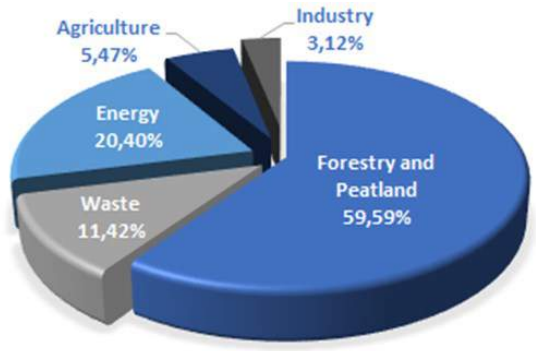


Figure 10. GHG Emission Contributor by sector for year 2000

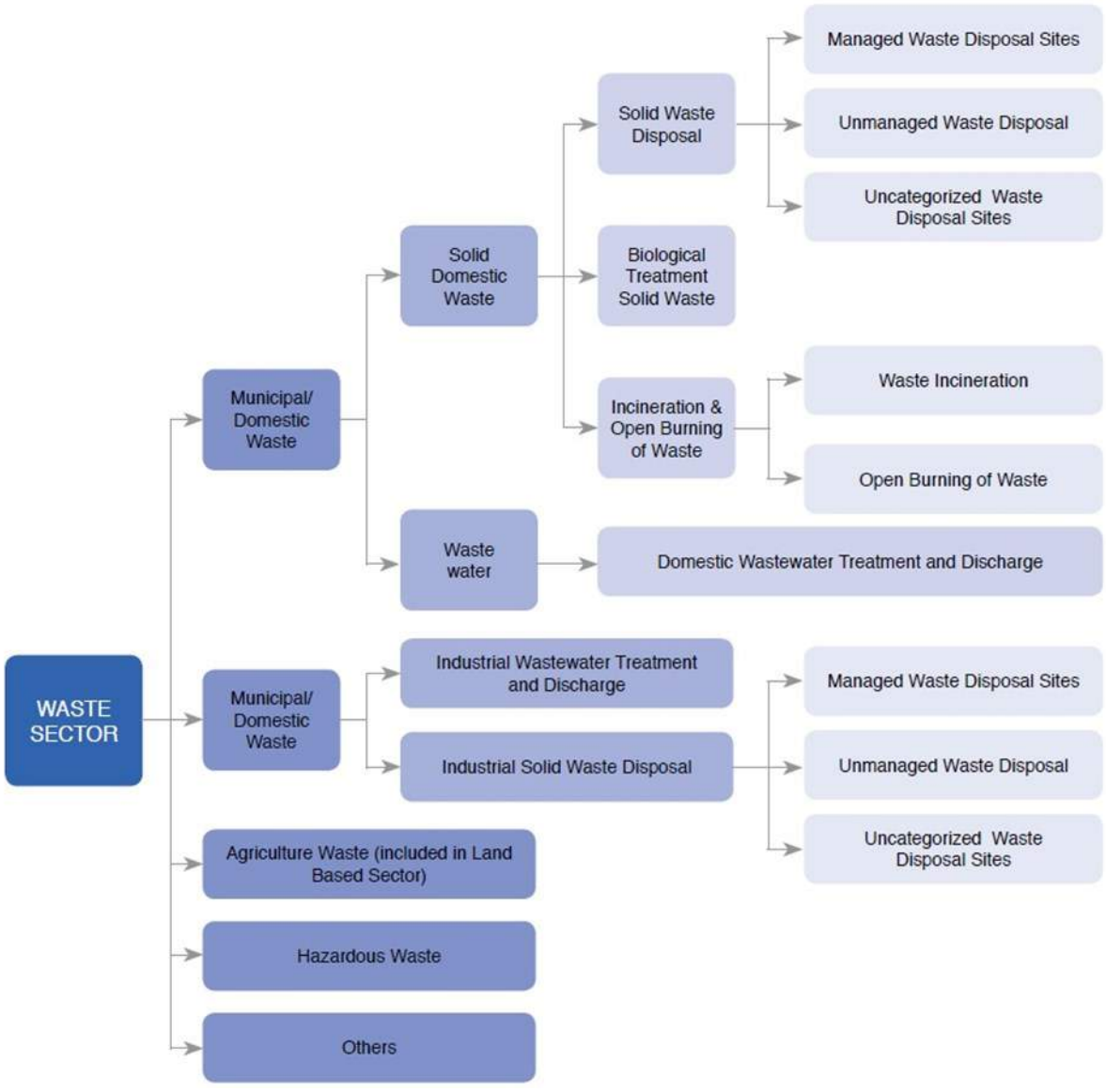


Source: Second National Communication (SNC)

All types of pollution both air, soil and water pollution are caused by improper management of solid waste. Injudiciously waste disposal pollutes surface and ground water supplies. In urban areas, solid waste plugs waterways, creating puddles for insect breeding and result in flooding during the rainy season. Uncontrolled waste burning and improper incineration contribute significantly to urban air pollution. Greenhouse gases are produced from decomposition of organic waste in landfills, and untreated leachate pollutes surrounding soil and water bodies. These negative environmental impacts are only the result of solid waste disposal; and does not constitute major environmental degradation resulting from the extraction and processing of materials at the beginning of the product life cycle. In fact, as much as 95 percent of the environmental impact occurs before an object is discarded as MSW.

According to UNEP's 2006 IPCC (Intergovernmental Panel on Climate Change) Guidelines, sources of emissions from the waste sector are found in four main categories: solid waste, biological treatment of solid waste, combustion and open burning waste and wastewater treatment and disposal, as shown in Figure 11.

Figure 11. Categories of GHG emissions sources within the waste sector



Waste can be separated into several key categories according to type and characters, as well as arrangement method and organization in handling it (see Figure 11). In general waste management GHG main sources are categorized as:

1. Solid Waste
   i. Landfill (TPA)
      - Well managed landfill
      - Poorly-managed landfill (open dumping)
      - Dumping sites categorized between well -managed and poorly managed
   ii. Biological Processing
   iii. Incineration and open burning
      - Incineration
      - Open burning
   iv. Handling and processing of industrial solid waste (including sludge)

2. Liquid waste
   i. Processing and disposal of domestic liquid waste
   ii. Processing and disposal of industrial liquid waste

3. Other wastes
   i. Clinical and B3 wastes
   ii. Agricultural waste

Key drivers for **sustainable waste management** are identified:

1. Rapid population growth
2. Increasing purchasing power making waste management service more affordable
3. Rapid urbanisation and industrialisation leading to environmental degradation
4. More stringent environmental regulations in response to domestic pollution
5. Global response to climate change through adaptation, mitigation and carbon pricing
6. Greater Asian government commitment and investment to improve the quality of waste services
7. Improved capacity of domestic waste management firms and related industries to develop the local market
8. More open economic policies allowing for gaps in domestic supply to be bridged by encouraging private participation and foreign investment

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