Contribution of Municipal Solid Waste Management to Decarbonization in Laos

BounEua KHAMPHILAVANH[1, 2*] and Toshihiko MASUI[3]

[1] School of Industrial Engineering and Economics, Tokyo Institute of Technology
2-12-1 Ookayama, Meguro-ku, Tokyo 152-8550, Japan
[2] Department of Climate Change, Ministry of Natural Resources and Environment
P.O.Box: 7864, Nongbeuk Village, Sikhottabong District, Vientiane Capital, Laos
[3] National Institute for Environmental Studies
16-2 Onogawa, Tsukuba-shi, Ibaraki 305-0053, Japan
**E-mail: euamaster@gmail.com*

Abstract

This study used the AIM/CGE [Laos] model to assess contribution of sustainable municipal solid waste management (MSW) to decarbonization in Laos by introducing a "waste-to-sources" approach including policies such as increasing the waste collection rate and solid waste recycling, which uses waste as energy. In Laos, common practices for handling solid wastes are direct dumping and open burning, and a government report (MONRE, 2022) on the state of pollution in Laos has noted that along with from road transport emissions, which are a main source of urban air pollution, improper waste disposal also threatens urban air quality in the main cities of Laos. Our model sets two scenarios: a business as usual (BaU) scenario in which waste dumping practices before treatment by households remain unchanged in the future, and a countermeasures (CM) scenario in which direct waste dumping decreases significantly under the assumption of the waste collection rate reaching 100% by 2050. Greenhouse gas (GHG) emissions from MSW management under the BaU scenario increase by a factor of nearly seven by 2050. However, by introducing MSW recycling, GHG emissions can be reduced to 93% in 2050 compared to those of the BaU scenario. An increase in recycling rates will provide more recycled materials to the production sector, which will result in decreased GHG emissions in the sectors to which the recycled materials are provided. In the recycling sector, however, the result will be an increase in energy-related carbon dioxide (CO_2) emissions. To achieve decarbonization in Laos, performing material recycling through energy-efficient processes will be important.

Key words: decarbonization, MSW management, sustainability

1. Introduction

Increased human-induced greenhouse gas (GHG) emissions resulting from fossil fuel burning have disrupted the carbon cycle balance in the Earth's natural system, resulting in extreme global climatic changes (Taskinsoy, 2019). Net-zero GHG emissions by 2050 is proposed as Laos's long-term strategy. The main source of GHG emissions in 2014 in Laos was the agriculture, forestry and land use (AFOLU) sector, which emitted 18,800 $GgCO_2eq$, accounting for about 78% of the country's total emissions. The second largest source of emissions was the energy sector, which emitted 3,800 $GgCO_2eq$ (15%). The rest, industrial processes and products use (IPPU) and waste accounted for 5% and 2% of the national emissions, respectively (MONRE, 2020). Although countermeasures to energy-related CO_2 are regarded as most important in 2050 in proportion to changes in income growth, other GHG emission sources will have to be considered to achieve net-zero emissions.

Population growth and economic advancement are the main factors motivating people to migrate to, settle in and work in the main cities. This is the root of rapid urbanization. People living in the cities can afford to consume more products than those living in other areas. More consumption drives increased waste generation, particularly of municipal solid waste (MSW). When MSW is treated improperly, it can generate GHG emissions. Generally, a common challenge in developing countries is the low rate of solid waste collection. When it is collected, the common ways of treating it are open dumping and burning. In the developing world, due to budget constraints, low-skilled workers and lack of technology, landfilling is the ordinary method of waste disposal (Kumar & Sharma, 2014).

Nowadays, the Lao PDR government faces challenges to achieving its goals of a green economy and sustainability (JICA, 2021). Particularly, the impact of rapid urbanization in recent years has resulted in the remaining capacity of final disposal sites in cities becoming insufficient. Waste collection rates remain low and vacant lots are not properly treated. Even though final disposal sites for waste exist in the main prefectures, a lack of human resources, technology, equipment and financing prevent the creation of environmentally sound landfills, and problems such as GHG emissions are still apparent.

The Lao PDR government plan for 2021–2025 (MPI, 2021) puts a remarkable priority on achieving by 2025 a goal of effective conservation of the natural environment based on green economy and sustainability. As activities to be undertaken between 2021 and 2025 to achieve this goal, it mentions the following items in relation to waste reduction: promoting green and sustainable development by establishing systems for waste management and reduction; and applying mechanisms to manage, eliminate and reduce waste generation while facilitating the application of the 3Rs (reduce, reuse, recycle) Principle in Laos's main municipalities (GGGI, 2018). The related policies and strategies for managing decarbonization in the energy and AFOLU sectors are already in place, but there is no strategy on sustainable MSW management at the national level. Therefore, the plan recommends strategically preparing for such a situation by prioritizing major cities for improvement according to the severity of the waste problem, and by considering the similarity of problems such as low collection rates and improper disposal, and the applicability of countermeasures to the problems of other cities.

Current solid waste management practices in Laos are primarily based on a "collect and dispose" approach that overlooks the enormous potential for converting waste into resources. The adoption of a waste-to-resource approach has the potential to contribute to national development priorities, since this approach is at the top of the waste management hierarchy pyramid (Hoornweg & Bhada-Tata, 2012; UNEP, 2013). This analysis assesses the effectiveness of introducing a waste-to-resource approach in Laos to reduce GHG emissions from the solid waste sector.

Adoption of a waste-to-resource approach is recommended and being considered as a pilot program for MSW management in Vientiane, the capital of Laos. This approach has the potential to reduce GHG emissions from disposal sites, and it is believed that it will have the ability to ensure a certain level of segregation, enabling conversion into a product and energy (GGGI, 2018) and possibly leading to indirect GHG emission reductions in other sectors.

The objective of this study is to analyze the adoption of a "waste-to-resource" approach in Laos through a comparison of GHG emissions from municipal solid waste management by applying a national scale computable general equilibrium (CGE) model.

2. Methodology and Data

2.1 The Method

The AIM/CGE [Laos] model developed by the Asia-Pacific Integrated Model (AIM) team (Masui et al., 2011; Khamphilavanh & Masui, 2020) was revised to enable it to estimate GHG emissions by introducing the "waste-to-resource" approach for municipal solid waste management in Laos, such as increases in waste collection rates and recycling rates. AIM/CGE [Laos] is a national-scale computable general equilibrium model with recursive dynamics, disaggregating a total of 41 commodities, as shown in Table 1. The revised model includes MSW, which is categorized into five waste types; organic wastes (48%), plastics (18%), paper (7%), glass (6%), steel (4%) and others (17%). It is assumed that all MSW per capita is generated from the household sector in proportion to per capita income, and that the share of each waste type will be the same up to 2050. The generated MSW is collected and treated in the recycling sector (No. 20 in Table 1), or uncollected and self-disposed. In the recycling sector, the collected MSW is treated, and the recyclable part of the treated waste is recycled with the rest of it being dumped at a final disposal site. Recycled plastic, paper, glass and steel wastes are supplied to the related material markets. The organic wastes can be recycled to fertilizer (chemical products in the model) or electricity. The total dumped waste consists of uncollected self-disposed waste and residue after treatment. Figure 1 illustrates the waste flow in this model.

Each production sector inputs capital, labor, energy and material, and produces its specific commodity, as shown in Fig. 2. Most of the elasticities are assumed to be 0 within a year, but the share parameters are updated to correspond to new investment annually. The recycling sector can produce recycled material in addition to providing MSW collection and treatment services. GHG emissions from the fossil fuel combustion and production processes in each sector are taken into account. Recycling costs, however, are not reflected due to a lack of information.

2.2 The Data

The main data used in developing the AIM/CGE [Laos] model were based on the Laos input-output (IO) table of 2014 (ADB, 2018). The information related to waste generation in this study was gained from the national statistic yearbook (MPI, 2018).

Based on JICA's initial survey (JICA, 2021), the

Table 1 List of 41 commodities in *AIM/CGE [Laos]*.

1.	Crops *
2.	Livestock *
3.	Forestry *
4.	Fishing
5.	Mining and quarrying
6.	Food, beverages and tobacco
7.	Textiles and textile products
8.	Leather, leather products and footwear
9.	Wood and products of wood and cork
10.	Pulp, paper, paper products, printing and publishing
11.	Coke and nuclear fuel
12.	Refined petroleum
13.	Chemicals and chemical products
14.	Rubber and plastics
15.	Other non-metallic minerals
16.	Basic metals and fabricated metal
17.	Machinery, etc.
18.	Electrical and optical equipment
19.	Transport equipment
20.	Manufacturing, etc.; recycling
21.	Electricity [hydropower and coal thermal power]
22.	Water
23.	Construction
24.	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
25.	Wholesale trade and commission trade, except of motor vehicles and motorcycles
26.	Retail trade, except of motor vehicles and motorcycles; repair of household goods
27.	Hotels and restaurants
28.	Inland transport
29.	Water transport
30.	Air transport
31.	Other supporting and auxiliary transport activities; activities of travel agencies
32.	Post and telecommunications
33.	Financial intermediation
34.	Real estate activities
35.	Renting of machinery & equipment and other business activities
36.	Public administration and defence; compulsory social security
37.	Education
38.	Health and social work
39.	Other community, social and personal services
40.	Private households with employed persons
41.	Biofuel

*Sectors requiring land.

amount of solid waste generated in Laos in 2015 was 1.3 million tons and it is assumed that the solid waste generation per capita will increase linearly. In addition, it is assumed that the ratio of each kind of solid waste to total waste will be the same up to 2050. The ratio of collection to generation of each waste in 2014 is set at 34% and the ratio of recycling to collection of waste in 2014 is set at 10%. In this analysis, due to a lack of data, it is assumed that extending waste collection and recycling in the waste management sector can be implemented with no additional costs.

2.3 The Scenarios

In this study, two scenarios are presented, the business as usual (BaU) and countermeasure (CM) scenarios. The BaU scenario assumes that the present situation will continue, including the state of air pollution in the main cities, which is caused by improper waste treatment (MONRE, 2022), and that there is no additional waste management policy in this scenario. The average GDP growth rate from 2020 to 2050 is set at 5.7% per year, while the population growth rate during the same period is assumed to be 1.2% per year. In the BaU scenario, it is assumed that the share of MSW, collection

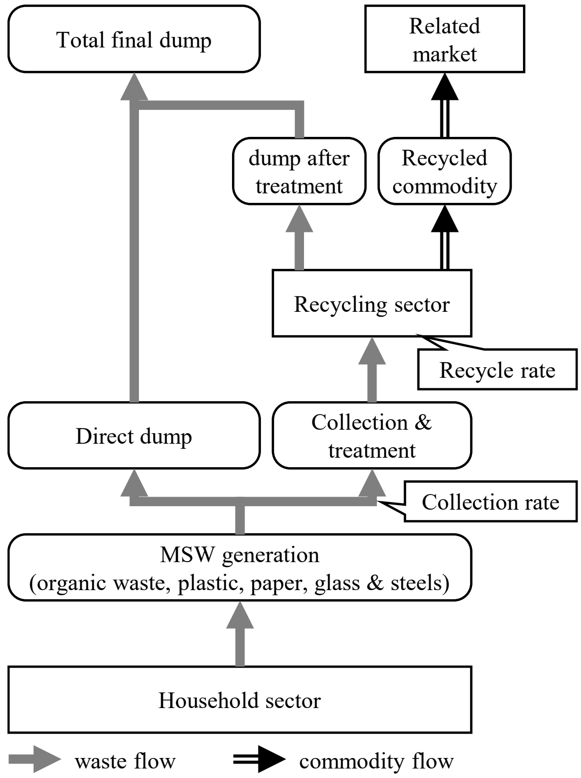
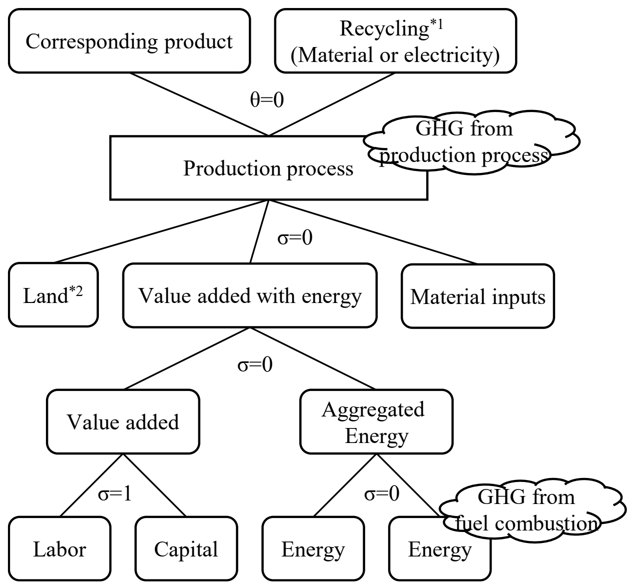


Fig. 1 MSW flow in this model.



*1: Only the recycling sector can produce the related material or electricity.
*2: Land is used in the agriculture and forestry sectors.
σ: Elasticity of substitution
θ: Elasticity of transformation

Fig. 2 Production process.

rate of MSW and MSW recycling rate will not change in the future.

In the CM scenario, the socio-economic assumptions are the same, except that adoption of a "waste-to-resource" approach for MSW management is initiated. In this paper, the following two targets on MSW collection and treatment are assumed in the CM scenario: (1) the MSW collection rate will increase from 34% in 2014 to 100% in 2050, and (2) the MSW recycling rate will increase from 10% in 2014 to 40% in 2040 and 80% in 2050. The contribution of these targets to GHG emission reduction in Lao is assessed for the CM scenario.

3. Results and Discussion

3.1 GDP

In the CM scenario, extension of material recycling is assumed. When comparing the GDP value between the BaU and CM scenarios, it can be seen that in the CM scenario there will be some negative impact on the GDP, which will be reduced by about 0.3% by 2040 and 0.7% by 2050 compared with the BaU scenario, as shown in Fig. 3. The cost of waste recycling is not considered in this analysis. When the cost of recycling is taken into account, it may have an additional negative impact on GDP.

3.2 Final Waste Disposal

Waste generation will increase in proportion to increases in income levels. As a result, final waste disposal in BaU will also increase, as shown in Fig. 4. The total final disposed waste, which consists of both uncollected waste self-disposed by households and residue after treatment, keeps growing by a factor of about 6.6 times by 2050 compared to that in 2014.

In the case of the CM scenario, because of the increased MSW collection rate to 100% by 2050, direct waste dumping by households will gradually decrease compared to the BaU scenario, with direct waste dumping reaching zero by 2050. At the same time, the amount of treated MSW will increase, but because of the increased recycling rate, treatment residues will also increase by 2050 compared to in the base year but this increase is lower than that in the BaU scenario. As a result, the total final waste disposed in 2050 in the CM scenario will be only 16% as big as that of the BaU scenario.

3.3 GHG Emissions from MSW Management

Under the BaU scenario, the GHG emissions from MSW management will increase by almost seven times from the base year; the emissions in 2014, 68 ktCO_2eq, are likely to increase to 240 ktCO_2eq in 2050. By introducing MSW recycling under the CM scenario, however, the GHG emissions arising from direct disposal of organic wastes can be reduced, and as a result, the GHG emissions from MSW management can be reduced by 16% in 2030 and 93% in 2050 compared to those of the BaU scenario (Fig. 5).

The total GHG emissions from all sectors, except the AFOLU sector, in the BaU scenario will increase by a factor of about three from 2014 to 2050. In the case of the CM scenario, the total GHG emissions in 2050 will be almost the same as emissions under the BaU scenario, as shown in Fig. 6. The small contribution of sustainable solid waste management to reducing GHG emissions from solid waste treatment is small compared to total emissions. In the CM scenario, the GHG emissions in the sectors to which the recycled materials are provided will decrease because of increased recycling and greater availability of recycled materials to use. On the other hand, because the amount of treated MSW will increase in the recycling sector in the CM scenario, the energy-related CO_2

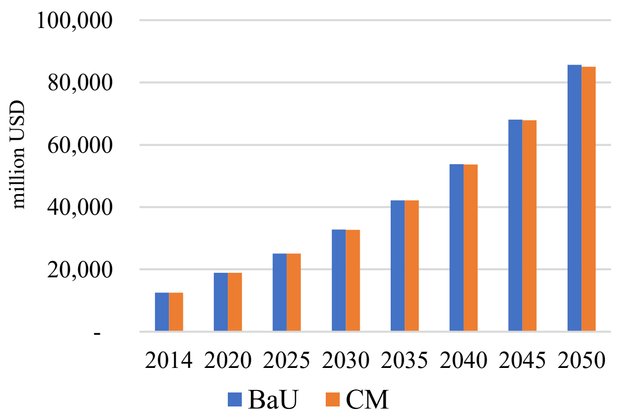


Fig. 3 Gross Domestic Product (GDP) of Laos.

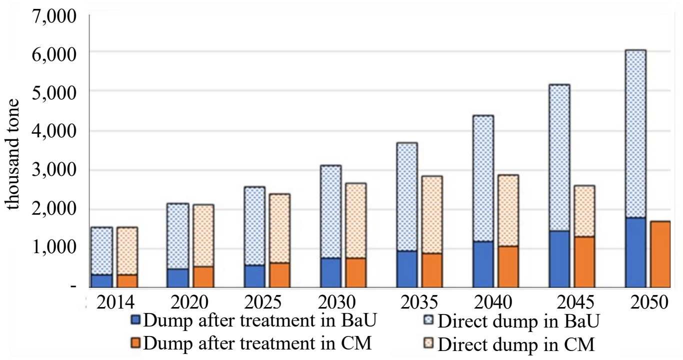


Fig. 4 Final waste disposal.

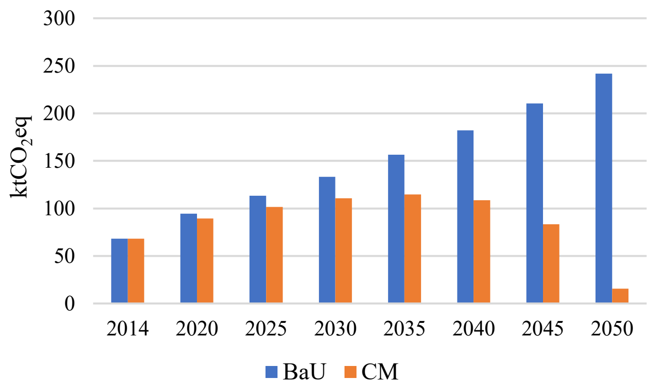


Fig. 5 GHG emissions from MSW management.

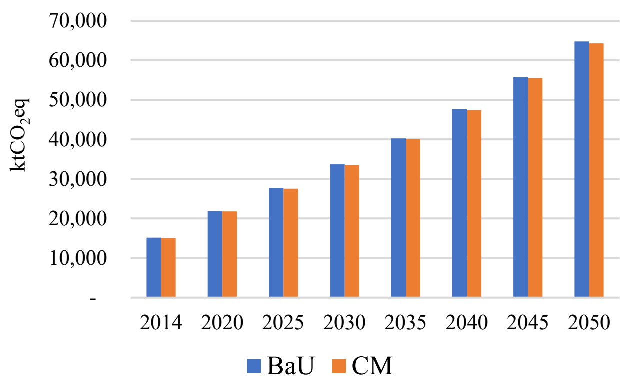


Fig. 6 Total GHG emissions in Laos.

emissions in this sector will increase compared to the BaU scenario by 2050. These results indicate that GHG mitigation actions will be important in the recycling sector. In addition, due to economic growth, GHG emission rebound effects can be observed. In this analysis, mitigation actions aside from SWM recycling have not been considered, but to avoid rebound effects, countermeasures in various sectors should be taken into account, particularly in the urbanization and economic sectors.

4. Conclusion

This paper has assessed the contribution of MSW management to decarbonization in Laos by analyzing the adoption of a "waste-to-resource" approach as a countermeasure policy for sustainable MSW treatment. Adopting this action will have significant impacts on final waste disposal and, in particular, direct waste dumping by households will decline slightly. Due to the increased recycling rate, however, treatment residues will gradually increase. By promoting MSW recycling, emissions from direct disposal of organic waste can be decreased. In addition, because of the increased recycling rate, the GHG emissions from the sectors to which the recycled materials are supplied will decline. The increased amount of treated MSW in the recycling sector, however, will result in an increase in energy-related CO_2 emissions.

In Laos, furthermore, as in other developing countries, the common practices for handling solid waste are dumping and open burning. Based on the MONRE report (2022) on the state of pollution in Laos, which noted that in addition to emissions from road transport–a main source of urban air pollution, improper waste disposal is a threat to urban air quality in the main cities. Sustainable MSW management, particularly adoption of a "waste-to-resource" approach, will have the potential to contribute to national development priorities and sustainable and green growth, for instance. In addition, sustainable MSW management will contribute to the achievement of several United Nations Sustainable Development Goals (SDGs). For example, a cleaner environment resulting from improved solid waste management practices could support healthier lives and well-being of populations (SDG 3). Other SDGs could be indirectly promoted through sound waste management practices, such as SDG 7 on affordable and clean energy, if solid waste is harnessed in the form of energy.

Regarding future research, since recycling costs were not considered in this analysis, the macro-economic impacts may have been underestimated, so in future work, we will have to consider recycling costs in this analysis. In a net zero assessment, all mitigation options will have to be considered and actions to avoid rebound effects should be considered, such as the banning of plastic bags or implementation of a pricing-by-the-bag policy.

Acknowledgement

This research was performed under the Environment Research and Technology Development Fund JPMEERF 20192008 and JPMEERF20221002 of the Environmental Restoration and Conservation Agency of Japan.

References

Asian Development Bank (ADB) (2018) Economic indicators for Southeastern Asia and the Pacific, Input-Output Tables. ISBN 978-92-9261-426-3. Manila, Philippines.

Global Green Growth Institute (GGGI) (2018) Solid waste management in Vientiane, Laos. Situation assessment and opportunities for waste-to-resources. Vientiane, Laos.

Hoornweg, D. and Bhada-Tata, P. (2012) What a waste: a global review of solid waste Management. World Bank, Washington D.C.

Japan International Cooperation Agency (JICA) (2021) Data collection survey on waste management sector in Laos. Vientiane, Laos.

John Taskinsoy (2019) Global cooling through black chain to avoid catastrophic climate changes by 2050 (29 November 2019).

Kumar, A. and Sharma, M.P. (2014) Estimation of GHG emission and energy recovery potential from MSW landfill sites. *Sustainable Energy Technologies and Assessments*, 5: 50–61.

Masui T., Matsumoto K., Hijioka Y., Kinoshita T., Nozawa T., Ishiwatari S., Kato E., Skukla P.R., Yamagata Y. and Kainuma M. (2011) An emission pathway for stabilization at 6 Wm2 radiative forcing. *Climate Change*, 109: 59–76.

Ministry of Natural Recourses and Environment (MONRE) (2020) First Biannual Updated Report (BUR1) (24 July 2020), Vientiane, Laos.

MONRE (2022) Report on pollution situation in Laos. Vientiane, Laos.

Ministry of Planning and Investment (MPI) (2018) National statistic yearbook. Vientiane, Laos.

MPI (2021) National socio-economic development plan (2021–2025). Vientiane, Laos.

United Nations Environment Programme (UNEP) (2013) Guidelines for National Waste Management Strategies. UNEP, Paris.

BounEua KHAMPHILAVANH

BounEua Khamphilavanh, who majored in industrial engineering and economics, serves as deputy director of the Greenhouse Gas Mitigation Division, Department of Climate Change, Ministry of Natural Resources and Environment, Laos, where he has been in charge of promoting and facilitating decarbonization by collaborating with partners, particularly through cooperation with the Ministry of the Environment of Japan and the Institute for Global Environmental Strategies (IGES) to support low-carbon development activities that have been promoted through the joint crediting mechanism (JCM). He also cooperates and collaborates with the AIM team and International Research Network for Low Carbon Societies (LCS-RNet) to develop decarbonization scenarios, specifically for Laos.

Toshihiko MASUI

Prof. Masui received his Ph.D. from the Graduate School of Engineering Osaka University. He joined NIES as a researcher in 1998. He has held his current position since April 2022 after serving as senior researcher and director. He has a concurrent appointment as a visiting professor at the Tokyo Institute of Technology School of Engineering. His research focuses on development of the Computable General Equilibrium Model, one of the component models of the Asia-Pacific Integrated Model being developed at the National Institute for Environmental Studies, and application of the model to assessing climate change mitigation measures. Prof. Masui currently serves as Social Systems Division Director at NIES.

(Received 13 October 2022, Accepted 28 December 2022)