MATERIAL FLOWS ANALYSIS OF PLASTIC IN THAILAND

by

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A study of the plastics materials flow analysis in Thailand was aim to show the flow of plastic materials through production, consumption, and waste management based on the year 2013 and projection to the year 2020. This paper finds the plastic waste generation increasing steadily in line with population growth and increasing consumption. In addition, the simulation under waste management three scenarios includes the following: the business as usual, increasing recycled rate set on the National Solid Waste Management Master Plan (2016-2021) and increasing in rate of energy recovery by the Alternative Energy Development Plan 2015-2036. The plastic material flow analysis has shown that the implementation of the National Solid Waste Management Master Plan (2016-2021) or the Alternative Energy Development Plan 2015-2036 can reduce uncollected waste and improper waste disposal. Moreover, there is benefit by adding value from recycled materials and energy recovery.

Key words: *plastic, material flow analysis, waste management, Thailand*

Introduction

Thailand's economic growth has resulted in the production and consumption of plastic products that have increased steadily over the years. The plastic products comprise of packaging, automobile parts, medical devices, construction and equipment, housewares, electrical and electronic appliances, and footwear. The consequences of production and consumption have caused an increase in plastic waste, which contributes to the problem of waste management in the country. During the year 2003-2013, the amount of waste increased steadily from 14.32 million tons per year to 26.77 million tons per year, nearly ⅕ of them was a plastic waste. The 80% of plastic waste from packaging, which is discarded after consumption, has given rise to the problem of waste management in the country [1]. In addition, the municipality solves the problem by landfilling, however, the action contributes to an ongoing problem for waste management with regards to a lack of landfilling site. Moreover, with the amount of plastic waste increasing the issue not only leads to a higher cost of the waste collection but creating a burden on the budget of the local government that is trying to find a more sustainable way for waste management. As mentioned, if there is no proper waste management plan it will cause some serious environmental problems for Thailand in the near future.

In Thailand, plastic waste is generated from two main sources – industrial processing and household consumption. The amount of plastic waste collected and transported for disposal process can take advantage of the waste that comes out in the form of reuse, recycling, and

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waste to energy. Therefore, the integrated waste management that is located on the concept of the system is a combination of technical and non-technical aspects, which consists of four stages: source reduction/reuse, recycling, composting, and energy recovery. The idea of treatment and disposal is a reasonable approach has been used quite often in Thailand.

Materials flow analysis (MFA) has been widely applied for environmental education, particularly in waste management. Previous studies, 83 articles that were found on MFA has been used as analytics to make decisions on waste management policy [2] such as the MFA for assessing solid waste management in Germany [3], the MFA to find waste management solutions in Oahu, Hi., USA [4], an applied MFA of paper in Korea [5], the results of a municipal solid waste management planning based on an extensive utilization of material and substance flow analysis [6], an assessment on the current municipal solid waste management system in Lahore, Pakistan [7], The MFA to quantify the flows and accumulation of tire waste in Thailand [8]. The application of the MFA to investigate the stock and flow of plastic included the use of MFA to make an understanding about plastics materials flow in India for an application to determine plastic waste management planning, especially on plastic waste recycling [9], MFA to draw plastic flow in Austria and Poland for presenting plastic waste management [10], MFA to assess the amount of plastic materials flow and stock in Serbia [11]. Similarly, there is a study on using the MFA method as a tool to monitor the flow and stock of Thailand, whereas the work is aimed to deploy planning on plastic waste management [12].

This study determined the amount of plastic waste and plastic waste management in Thailand from 2013 by using MFA. The main objective was to identify and quantify the flow and stock of plastic waste in Thailand. The results are expected to be useful for the relevant authorities who need to make careful planning decisions on the waste management policy.

Methodology

The MFA is an analytical method to quantify flows and stocks of materials or substances in a well-defined system. The MFA is based on the law of mass conservation. The mass that enters a system must, by conservation of mass, either leave the system or accumulate within the system. Mathematically, the mass balance for a system is [13]:

$$\sum_{k_I} \dot{m}_{\text{input}} = \sum_{k_O} \dot{m}_{\text{output}} + \dot{m}_{\text{storage}} \tag{1}$$

where the number of system flow is denoted by k_I and k_O are input and output, and $\dot{m}$ denotes flow or flux. In general, $\dot{m}_{\text{storage}}$ or stock is calculated by the difference in input and output from the overall system. In this research, a material balance approach was adopted as the main methodology to investigate the stocks and flows of plastic generation, and to assess the various management options adopted in Thailand for the year 2013. The MFA was used in the study to analyze the flow of plastic, which was adopted in the management of resources, environmental management, and waste management. The flows and stocks of materials are presented through the processing of materials. The quantities of each flow and stock are assessed and illustrated in the material flow. The important issue is the balance of input and output of material flow, which is carefully checked and calculated. The process of MFA included the following: defining the problem and specific objectives, selection of relevant substances, system boundaries, processes, and material goods, assessment on the mass-flows of goods and substance concentrations in goods, substance flows calculated, and simulation of scenarios [13].

The material flow of plastics in Thailand consists of six processes in the boundary. The import of system boundary means that the materials are inputted in the system boundary such as plastic resins from the petrochemical industry, resins and products. Meanwhile, the ex-

port of system boundary includes the products and recycled materials. In addition, the stock of system boundary means that the materials are being used or stored in the system boundary. Six processes in boundary are manufacturing, plastic consumption, collection and transportation, recycling, disposal and open environment. The details of each process are as follows.

- *Manufacturing*: the raw material used in the production consists of the masterbatch from petrochemical industry, imported plastic pellet, and plastic recycling to produce products such as packaging, automobile parts, medical devices, construction and equipment, housewares, electrical and electronic appliances and footwear, *etc*; the product has been used for domestic consumption and export.
- *Plastic consumption*: is domestically consumed and imported; the plastic products consumed consist of durable goods or long-lived product and non-durable goods or short-lived product; the durable goods that are consumed do not quickly wear out, or more specifically, one that yields utility over time rather than being completely consumed in one use; such plastic products that are durable goods are in the form of a furniture, construction equipment, electrical and electronic appliances, auto parts, housewares, and agricultural equipment; the long-term applications are accumulated in the system boundary of plastic material flow known as the stock *in use*; meanwhile, non-durable goods are the opposite of durable goods; they may be defined either as goods that are immediately consumed in one use or ones that have a lifespan of fewer than three years such as packaging, footwear, or medical devices; in the year 2013, the percentage of short-lived and long-lived products is 61.1 and 38.9% [14]; the long-term applications are accumulated in the system boundary of plastic material flow which is called as the stock *in use*.
- *The collection, transportation, and disposal*: the waste collection is different depending on the sources; the plastic waste from the industry was collected and transported by the industrial operator or contractors; the community plastic waste was implemented by the local government agencies; however, the final disposal of plastic waste is done by landfilling from the local authorities.
- *Recycling*: there are two main sources of recycling feedstock such as industrial plastic waste that is made by the manufacturing sector and community plastic waste generators like household, offices, business sectors, and restaurants supplying their wastes to waste buyers *e. g.*, waste shops, plastic recycling factories, and middle dealers; waste pickers and landfill scavengers also sell plastic wastes to waste shops; plastic waste is processed into the recycled material, which is used as raw material in manufacturing and some products are exported to foreign countries; in addition, the recycling plastic waste is processed to become a source of energy such as refuse derived fuel, plastic to oil, combustion into thermal energy and power generation, which is operated by the private sector and local governments.
- *Disposal*: the plastic waste remaining after the material recovery is part of the recycling and waste to produce energy, which alters the disposal method of landfilling.
- *Open environment*: the uncollected wastes and improper disposal are the main environmental issues; after the collection and transportation, municipal plastic wastes were not properly disposed, such as being dumped out in the open.

In this study, three scenarios were set to evaluate the plastic waste management situation in 2020. The first is called business as usual (BAU). This scenario presents the percentage of each management way in 2020 which is the same as the percentage in the base year of 2013. The growth of plastic waste generation depends on plastic consumption which is determined by the population size. For the year 2020, the estimated population is at 70.1 million [15]. Secondly, on increasing the rate of recycled waste collection and sanitary landfill, the scenario was set with consideration from the National Solid Waste Management Master Plan (2016-2021) [16]. The plan

has set a target to increase the recycling rate by 21% of industrial waste and 30% of municipal solid waste (MSW), waste collecting rate by 40% and sanitary landfill rate by 40% for the year 2011. Finally, the increase in waste to energy scenario was set with consideration from the Alternative Energy Development Plan 2015-2036 (AEDP 2015) [17]. According to the Ministry of Energy the goal is to increase the rate of energy recovery from waste that comprises of electricity generated from industrial waste as 50 MW and MSW by 500 MW, thermal energy from waste by 495 kiloton of oil equivalent (KTOE) and pyrolysis oil that equals 0.53 million liter per day within 2036.

Data

The data sets were compiled, extracted and analyzed from both primary and secondary sources. Primary data were collected through field investigations/observations, surveys, and interviews with key stakeholders in waste plastic management chains. Survey questionnaires were issued in 2013 and 2014 to stakeholders in key sectors within the plastic industry in Thailand. The survey included major plastic manufacturers, distributors, retailers, plastic waste collectors (both formal and informal), plastic recovery units, and recycling operators. Similarly, expert consultations were carried out with key stakeholders, both in the government, and private sector. The sample groups were chosen from relevant individuals and organizations related to plastic waste management in Thailand. The study consisted of gathering 1050 questionnaires that were collected from waste collectors, waste buyers and waste recyclers in 11 provinces such as Chiangmai, Lampang, Udonthani, Khonkean, Nakhon Ratchasima, Chachoengsao, Nakhon Pathom, Phang Nga, Nakhon Si Thammarat, Surat Thani and Bangkok, fig. 1. Secondary data were gathered from Thai organizations involved in the statistical production of plastic waste plastic, recycling technology and research, law and policy. The data was collected from websites, research, books, and annual reports. The sources of data were from [13, 18-20] the Pollution Control Department, Petroleum Institute of Thailand, Plastic Institute of Thailand, The Office of Industrial Economics, and Office of the National Economics and Social Development Board. The tool used for drawing and analyzing the material flow of plastic is the STAN 2.5 software.

Figure 1. The 11 selected provinces in Thailand, source: https://images.google.co.th/

Results and discussion

The material flow of plastic in Thailand

The flow of plastic material started from the petrochemical industries, which produced 7827481 tons of virgin material. The

flow composed of both raw materials that were from domestic and imported goods, meanwhile 1101329 tons were from the domestic recycled material. Plastic product exported 2130270 tons, while 5774872 tons was domestically consumed. At the state of plastic consumption in 2013, the amount of plastic product consumption was 6782565 tons. 5774872 tons was from domestic production and the plastic product imported was at 1077693 tons. As a result of the consumption, plastic waste amounted to 4049890 tons. The quantities of plastic waste about 3560595 tons were collected and transported to a disposal site by the local government. In this process, 765883 tons of the plastic waste was recycled by the local government's staffs and independent merchandisers. The plastic waste amounted to 220949 tons, which was incinerated for generating energy. The residual of the plastic waste amounted to 1986648 tons, which was disposed of by landfilling. However, some of the plastic wastes were uncollected. Insanitary refuse that was disposed of weighed in at 489295 tons and 587115 tons, respectively. The recycle benefit consisted of the recycled material and energy recovery. The number of the material that was recycled was about 1101329 tons and it was used as raw material for the production processes and 482712 tons was exported. Meanwhile, the energy recovery or so-called waste-to-energy (WtE) were accounted to be 135239 tons by the industrial sector, and 220949 tons by the local government. The disposal process, the total weight of 2084163 tons of plastic waste was disposed of by landfilling. The plastic waste equaled to 2041885 tons from the local government and the amount of 42278 tons from industries. In addition, the plastic waste, which affected the environment, was accounted to be 1076410 tons. It consisted of uncollected waste that equaled to 489295 tons, and improper plastic waste disposal was 587115 tons, as indicated in fig. 2.

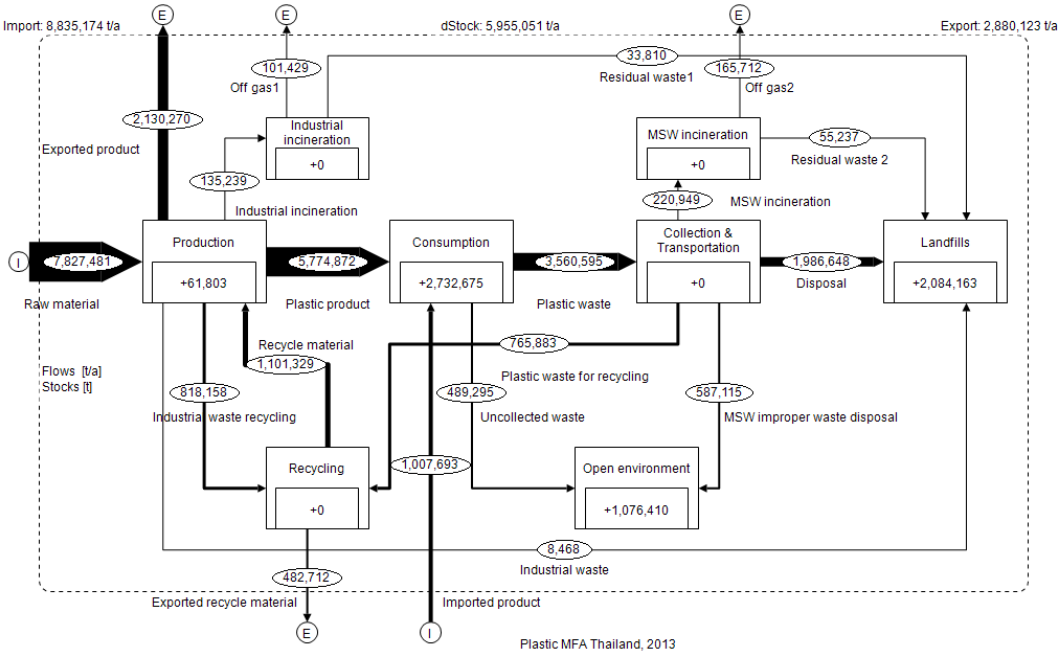

Figure 2. The MFA of plastic in Thailand for the year 2013

With regards to the relations of Thailand plastic production, consumption and waste in 2013 found that the process used raw materials in the production of 8835174 tons. The amount of plastic produced is consumed in the domestic sector which amounted to 5774872

tons, and 2130270 tons were exported abroad. Meanwhile, the import of plastic products for consumption in the amount of 1007693 tons was the total domestic consumption of plastics that equaled to 6782565 tons. The result of MFA of plastic in Thailand for the year 2013 shows that the volume of plastic waste disposed was 60% of the consumption that is being dumped in the same year. The investigation into the use of the material recycle and energy recovery found that only a small number was compared to 14.55% of the consumption of plastic products. Thus, each year there is waste that must be disposed of up to 3063058 tons or 45.16% of total plastics consumption. Moreover, almost all of the local governments in Thailand had to go through a waste disposal by landfilling. Therefore, it is a barrier for the local government in plastic waste management. They have to decide whether to increase the budget to collect and transport to a shortage of space for landfills or find some other sustainable measure, but doing the latter may also present a serious threat to the environment and public health. For such a situation in the near future, if the population and economic activity in Thailand keep on rising it will have an impact on the amount of plastic waste, thus creating an environmental crisis in Thailand.

Prediction of plastic waste management in 2020

In the near future, if the population and economic activity in Thailand keep on rising it will have an impact on the amount of plastic waste, thus creating an environmental crisis in Thailand. However, to deal with the problem of plastic waste, the government agencies have to determine a solid policy to reduce plastic waste. The Ministry of Natural Resources and Environment has already implemented the National Solid Waste Management Master Plan (2016-2021). The policy includes a 3R measurement to promote recycling of materials and increasing waste collecting and sanitary landfill rate by the government. In addition to The Ministry of Energy has the AEDP 2015. This plan is on promoting the usage of alternative energy to 30% within 20 years, replacing fossil fuel such as oil and natural gas, while reducing the dependency on energy import. One of the alternative energy is to convert waste as a form of generating power to promote energy for the small and medium local administration. Furthermore, there is an efficient government policy for supporting sustainable waste management in Thailand.

This study has set three scenarios which indicate the possibility of plastic waste management in Thailand. In Scenario 1, the BAU is presented as the percentage of each management way in 2020, which is the same as the percentage in the year 2013. The amount of plastic waste generated by consumer changes because the population has increased from 68.25 million in 2013 to 70.10 million in 2020 whereas the results of plastic consumption increased from 6822565 tons to 7007376 tons. The growth of plastic consumption will have an increase in the plastic waste generated also. There are plastic wastes making the landfill rise up to the amount of 2140804 tons. The open environment has increased to 1105568 tons and recyclable materials have accumulated to 1626950 tons. Likewise, the proportions of plastic waste to consumption are 30.55%, 15.78%, and 23.22%, respectively, fig, 3.

In Scenario 2 the changes and impacts of the National Solid Waste Management Master Plan (2016-2021) were predicted. The goals of this plan included having 21% of recycling rate in industrial waste and 30% of MSW, waste collecting rate by 40%, and obtaining 40% of sanitary landfill rate in 2020. From the MFA, there is reused plastic in consumption that equals 197200 tons. Comparing waste management with the BAU scenario, a number of plastic wastes to landfill increased to 2233916 tons, open environment decreased to 663341 tons, and recyclable materials have gone up to 2041271 tons. The ratios of plastic waste to consumption are 31.88%, 9.47%, and 29.13%, respectively, fig. 4.

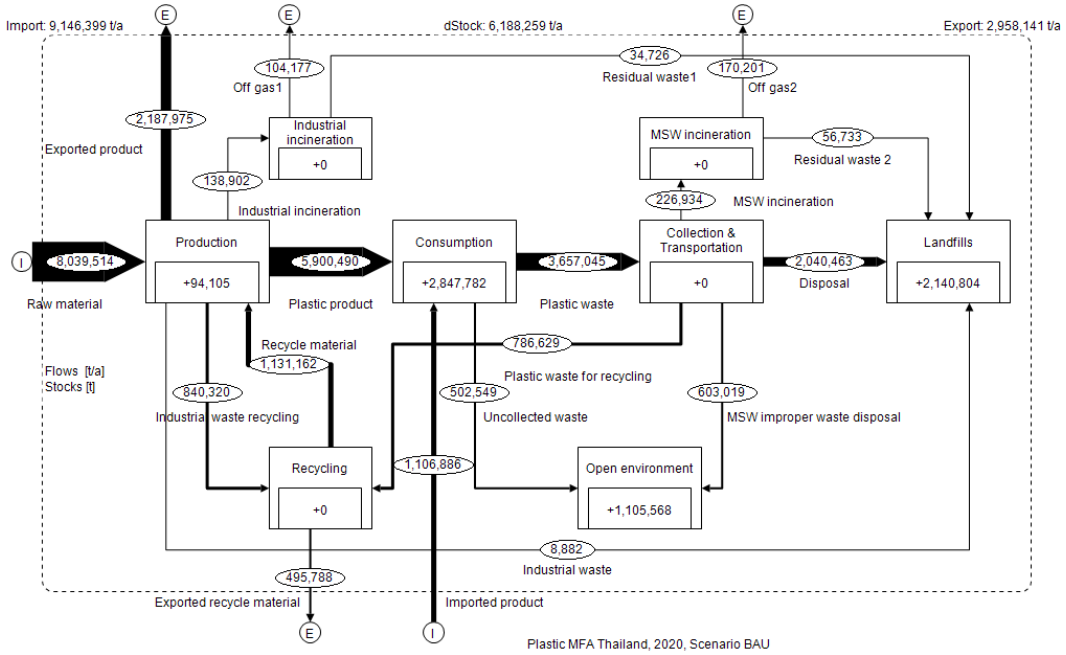

Figure 3. The MFA of plastic in Thailand for the year 2020, Scenario BAU

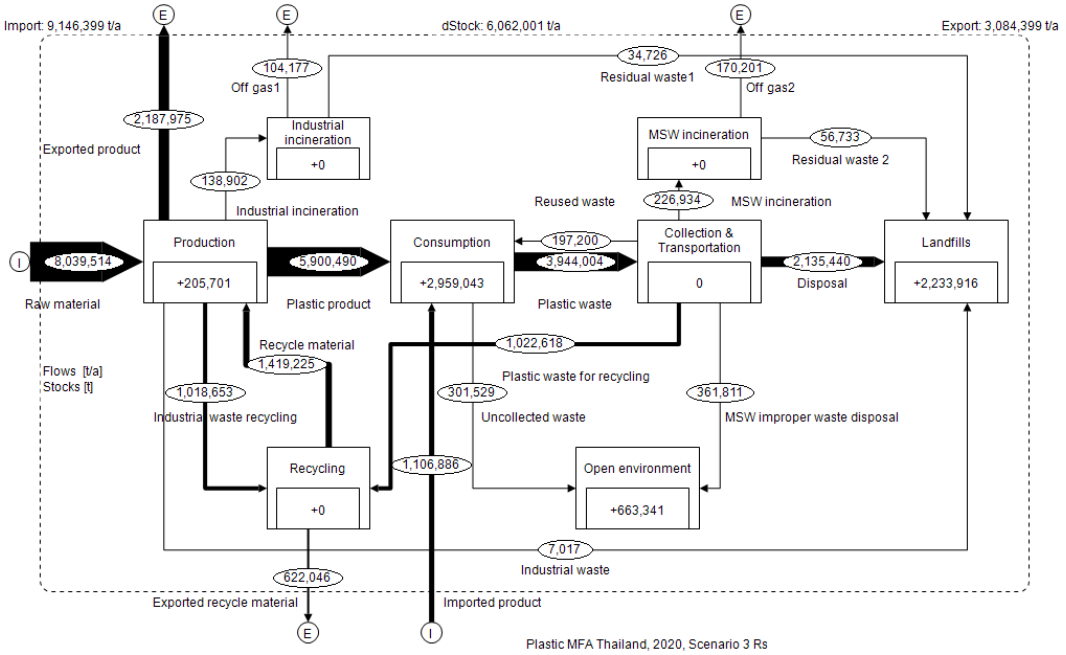

Figure 4. The MFA of plastic in Thailand for the year 2020, Scenario: 3Rs, the National Solid Waste Management Master Plan (2016-2021)

Scenario 3 presents the flows of plastics and plastic wastes based on the AEDP 2015 to achieve 50 MW of electricity generation from industrial waste and MSW by 500 MW, 495 KTOE of thermal energy from waste and 0.53 million liter per day of pyrolysis oil within 2036. However, considering the goals of the plan in the year 2020 found that the energy recovery rate and alternative fuel used will increase by recovering the electricity generation from industrial waste as 15.9 MW and MSW by 136 MW, thermal energy from waste by 121.27 KTOE and pyrolysis oil equaling 0.144 million liters per day. For this scenario, there is the feedstock recycling for plastic wastes amount of 477332 tons used as a raw material to energy. Consideration in waste management based on AEDP 2015 is compared with the BAU scenario that indicates the amount of plastic wastes for landfill will rise up to 2254347 tons, open environment decreased to 732854 tons and recyclable materials reduced to 1550938 tons. Meanwhile, the ratios of plastic waste to consumption are 32.17%, 10.46%, and 22.13%, respectively, fig. 5.

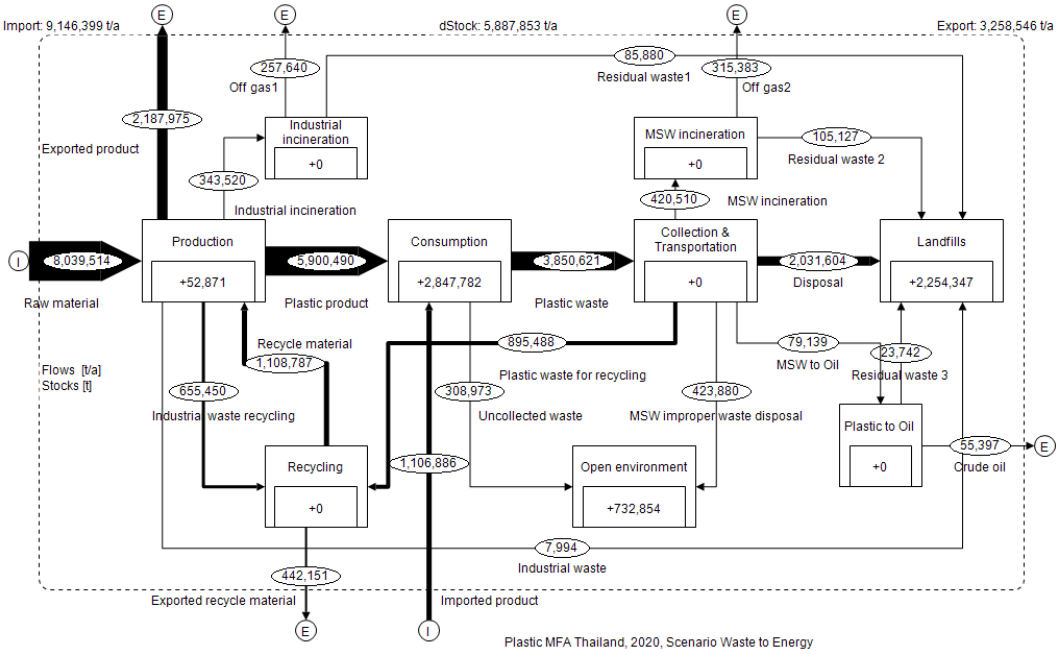

Figure 5. The MFA of plastic in Thailand for the year 2020, Scenario 3: waste to energy, AEDP 2015

Comparison of plastic waste management scenarios

In this study, considering a change in the amount of plastic depends on the number of population in 2020, which may have an impact on the change in consumption of plastics and plastic waste generation. Consequently, the comparison of plastic waste management scenarios will be on the changes in plastic consumption. The plastic MFA represents the ratios of landfill, open environment and recyclable materials to consumption in each situation which includes the following: Scenario 1 (BAU) was 30.55%, 15.78%, and 23.22%, Scenario 2 (3Rs) was 31.88%, 9.47%, and 29.13%, and Scenario 3 (WtE) was 32.17%, 10.46%, and 22.13%, respectively. Comparing of waste management, according to Scenario 2 with scenario1 has found that the stock in consumption process increases due to a rise in reuse rate. There are increased benefits from the 3R measurements such as an increased volume of recycled mate-

rials and open environment reduction. Meanwhile, comparing Scenario 3 and Scenario 1 has found that there are more benefits from increasing in energy recovery and open environment reduction, fig. 6.

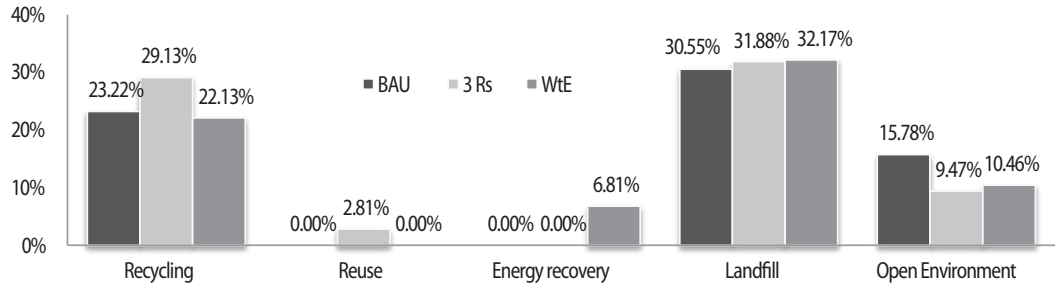

Figure 6. Plastic waste management scenarios

Conclusions

The plastic MFA based on the year 2013 and projection to the year 2020 showed that Thailand faced the problem of plastic waste generation has been increasing steadily with population growth and increasing consumption. The result of this study indicated that the future view of the current situation is the same besides other than the population growth. Therefore, the amount of plastic consumption will rise from 6822565 tons to 7007376 tons, as a result, the amount of uncollected waste will increase by 489295 tons to 502549 tons, while improper waste disposal will rise up from 587115 tons to 603019 tons in 2013 and 2020, respectively.

The consideration of the efficiency of government policy is to solve problem that consists of the National Solid Waste Management Master Plan (2016-2021) where the plan has a target to increase the rate of recycled, waste collecting and sanitary landfill, and the AEDP 2015 is setting a goal to increase the rate of energy recovery from waste. The plastic MFA has shown that both plans can reduce uncollected waste and improper waste disposal. In addition, the benefit from both plans can build added value from recycled materials and energy recovery. However, both of the waste management plans have to be aware of the achievements in the implementation. The first approach relies on increasing the recycle rate which requires an understanding and co-operation of the stakeholders, while driven success also depends on the pricing mechanism to purchase recycled materials. For the second approach, the cost of investment for energy recovery and price of energy is a main contribution to the operation. Therefore, if the government wants to be successful in plastic waste management then it should be encouraged to reduce these restrictions by increasing efficiency and promoting sustainable development.

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