Problem Chosen	2020 MCM/ICM Summary Sheet	Team Control Number
E		2012496

Reduce Plastic Waste for a Greener Future

Summary

The earth is gradually being covered with plastic waste. In order to help solve the problem of plastic pollution, we have established a model to determine the maximum levels of single use plastic product waste that can safely be handled without further environmental damage. We also propose an evaluation system to determine the plastic waste reduction responsibility of each country by using a variety of indicators. Finally, according to the established overall reduction target and the responsibility of each country, we propose the measures to be taken to achieve this target, the implementation timeline of the measures and the impacts of them.

If we want to avoid further damage to the environment, the maximum amount of plastic waste should be within our disposal capacity. Therefore, we define a parameter named **Annual Maximum Plastic Waste Generation (MaxWG)**, which represents the world's annual maximum amount of waste that can be handled. We develope MaxWG formula as the product of two parameters - **Plastic Waste Disposal Capacity (WDC)** and **Actual Plastic Waste Generation (AWG)**. Plastic waste process capability is equal to the proportion of recycled and incinerated plastic waste in each year, which increases over time. Therefore, we first calculate the **Annual Plastic Production (AP)** according to the fitting prediction function, and then calculate the plastic waste production of each industry based on the proportion of plastic production and the plastic waste generation rate in each industry. The sum of the plastic waste of each industry is the actual total plastic waste generation.

Based on the results, we can conclude that if we want to reach an environmental safe level, then we need to reduce global waste generation to the **Annual Maximum Plastic Waste Generation (MaxWG)**, while the global waste reduction target is equal to the **Actual Plastic Waste Generation (AWG)** minus MaxWG. In order to solve the fairness problem of waste reduction task allocation, we establish an evaluation system called **National Plastic Waste Generation Responsibility Index (NRI)**, which is determined by various influencing factors. We use **TOPSIS-entropy** method to get the value of NRI, so fairness adjustment is completed. We suggest that ICM uses NRI for reference to let each country solve the problem of global plastic waste flooding in a more suitable way.

Next, we propose different waste generation reduction measures suitable for different countries, and estimate the possible impacts of these measures on people's lives, environment and industry. The impacts of the environment is discussed from the ocean and land, and **DPSIR** model is introduced in the analysis of the ocean, which shows the feedback of the marine environmental state to the social measures. In terms of industry, we focus on the impacts of waste reduction measures on the packaging industry and the oil industry. The former currently accounts for the largest proportion of plastic production in the plastic industry, while the latter provides raw materials for plastic production.

Finally, we write a memo to ICM, including a realistic global target minimum achievable level of global disposable plastic product waste, and visually demonstrated global waste generation reduction plan with a timeline.

Contents

1 Introduction

1.1 Problem Background

Because of the advantages of waterproof, durable, light and low price, plastic has been widely used in recent years, which brings great convenience to human life and industrial production. But at the same time, a large number of plastic waste also brings serious environmental pollution. With the rapid increase of global plastic production, a large number of plastic waste can not be disposed correctly and dumped into the ocean, drifting around with the current, marine plastic pollution is becoming increasingly serious, threatening the marine ecosystem and biodiversity, affecting socioeconomic life and human health. Disposable plastic refers to the plastic that turns into garbage or hardly reuses once used in production and life,which is an important part of plastic products. Although disposable plastic products are very convenient, the waste they produce (such as waste plastic bags, packaging bags) will pose a great threat to the survival of organisms and seriously affect species diversity. Birds, turtles, fish, and mammals (such as whales) are increasingly wounded or killed by swallowing plastic or being entangled with plastic mesh. It is observed that in some parts of the ocean, the amount of plastic waste is six times that of plankton [1].

Not only is the ocean, a growing number of disposable plastic garbage will also affect the ecological balance of the land, enter the food chain, thereby affecting human health. Disposable plastic garbage fragmentation occurs under the action of physical chemistry and becomes the main source of micro-plastics. Smaller micro-plastics are more easily absorbed by low nutrition level microorganisms. The micro-plastics consumed by microorganisms contain toxic plasticizers and absorb a large number of organic substances harmful to the human body (such as polycyclic aromatic hydrocarbons, DDT, etc.) [2–4], which is released into the food chain by the microorganism, seriously endangering human health, so it is urgent to control the disposable plastic pollution.

1.2 Our work

Based on the definition that the recycled and incinerated plastic waste will not cause further damage to the environment, while the landfill waste will, we build a model to quantify the maximum level of waste that can be recycled and incinerated in the world every year.

We also establish an evaluation system called **National Plastic Waste Production Responsibility Index (NRI)**, which fairly distributed the responsibility of plastic waste reduction, and well balanced the waste production and processing capacity of each country.

In the second section, we list the abbreviations and explanations of the variable names used, and in the third section, we give our general assumptions. The fourth section defines the MaxWG model and explains the specific definition. In the fifth part, the **National Plastic Waste Production Responsibility Index (NRI)** is defined, which solves the fairness problems that may be encountered in the process of task allocation, and puts forward suggestions to ICM on how to solve these problems according to NRI.

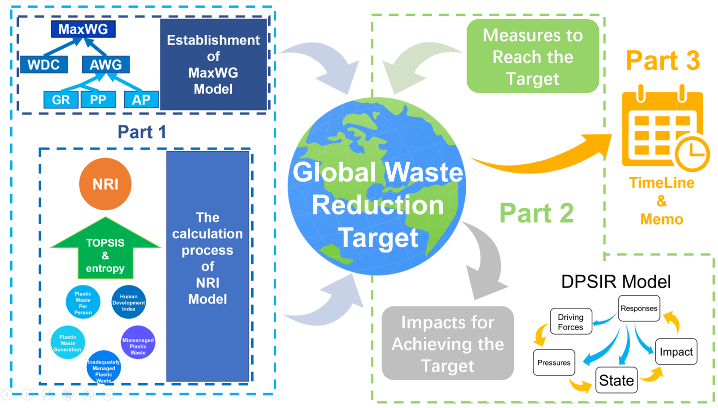


Figure 1: The flow chart of this paper

In the sixth part, a target for the minimal achievable level of global single-use plastic waste is determined, and the specific measures to reduce plastic waste generation and the possible impacts of these measures are discussed, especially in the analysis of marine environment, DPSIR model is introduced. The seventh part discusses the advantages and disadvantages of our overall model. Finally, a memorandum to ICM is written, including the time line for achieving the minimum global plastic waste standards and the factors that may accelerate or hinder the achievement of the goals and schedule.

2 Symbol Descriptions

The primary notations used in this paper are listed in Table 1.

Table 1: Notations

Symbol	Definition
$MaxWG$	Annual Maximum Plastic Waste Generation
WDC	Plastic Waste Disposal Capacity
AWG	Actual Plastic Waste Generation
GR_i	Plastic Waste Generation Rate by Industrial Sector
PP_i	Plastic Production Percentage by Industrial Sector
AP	Annual Plastic Production
NRI	National Plastic Waste Generation Responsibility Index
HDI	Human Development Index
$NWGP$	National Plastic Waste Generation Proportion
GWR	Global Waste Reduction Target
NWR	National Waste Reduction Target
ICM	International Council of Plastic Waste Management
$DPSIR$	Drivers, Pressures, State, Impact and Response Model of Intervention

3 General Assumptions

- The data we collect from the online databases are reliable, accurate and consistent with other databases. Since our data sources are all websites of international organizations, it is reasonable to assume that the quality of their data is very high.
- This paper does not consider scientific and technological breakthroughs when the model is built, such as the development of new plastic substitutes or the generation of new plastic waste processing technologies, and forecasts are made in full accordance with the current development trend.
- Because the topic does not clearly state what time span is used to quantify the amount of plastic waste, we assume that the annual data are taken.
- Due to limited data, we believe that the percentage of plastic production by every industry does not change over time.
- Because dumping plastic waste directly into the ocean is not an advocated behavior, there is no statistical data for the waste treated in this way. We assume that there are only three ways to deal with the waste: recycling, incineration and landfill.
- When the evaluation model was built, the indicator data for the countries we ignored had little effect on the calculation of weights and results.
- The disposal of plastic waste is a complex interdisciplinary issue of international significance. This question contains variables related to climatology, politics, economics, ecology, geology, and many other disciplines. It is not possible to fully simulate every possible relevant factor. Therefore, our model makes some assumptions and simplifications

4 Annual Maximum Plastic Waste Generation Model

To make the problem clearer, we have further defined "no further environmental damage". Taking one year as the time span, we think that when the global plastic waste production does not exceed the global processing capacity, it can be defined as plastic waste will not cause further damage to the environment.

The **Waste Disposal Capacity** (WDC) is a number between 0 and 1, which indicates the percentage of garbage that can be properly handled. This value can be used to measure the strength of a country's capacity to properly handle the plastic waste. Proper waste disposal capabilities that do not further damage the environment, including recycling and incineration [5], while landfills are not among our consideration. The specific reasons will be detailed in 4.1.4.

Although there is no directly available data on annual plastic waste, we can predict the total annual plastic production in the future, and then multiply it by a coefficient representing the conversion rate of plastic waste to obtain the **Actual Plastic Waste Generation** (AWG).

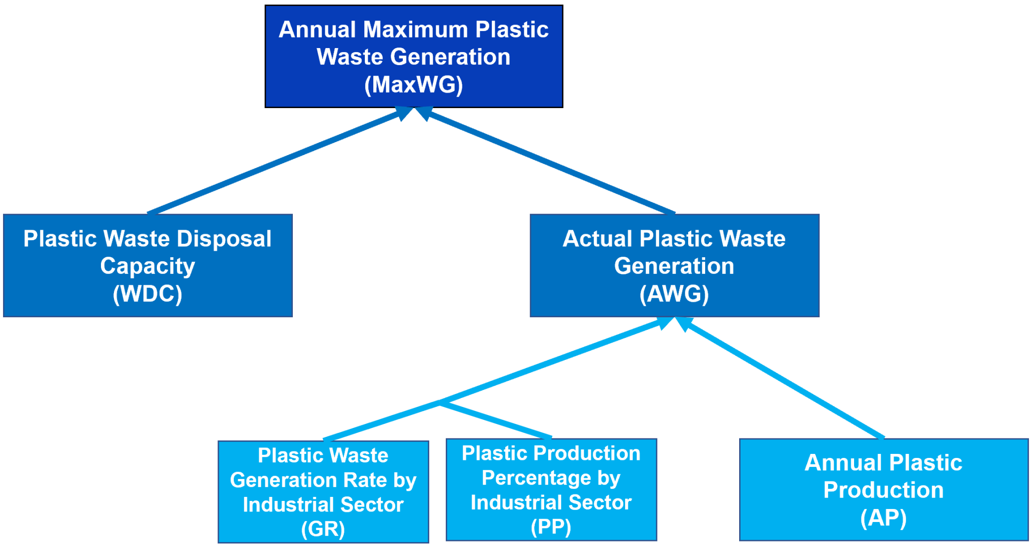


Figure 2: The process of calculating $MaxGW$

By multiplying **Plastic Waste Disposal Capacity** (WDC) by **Actual Plastic Waste Generation** (AWG), the maximum annual generation of plastic waste without further damaging the environment can be obtained, named **Annual Maximum Plastic Waste Generation** ($MaxWG$) (1):

$$MaxWG = WDC \times AWG \tag{1}$$

It is an ideal amount of waste, in tons, that can be disposed of every year without further threat to the environment, and will keep increasing over time.

4.1 Construction of AP

We define **Annual Plastic Production** as AP. We analyze the data of the last 35 years [6]and use the cftool application in Matlab to fit the relationship between time and global annual plastic production, and obtain several functions of time and global annual plastic production. Among them, the exponential function has the best fitting effect and smallest SSE. The function is as follows(2):

$$AP = 1.138 \times 10^{-35} \times e^{0.04977t} \tag{2}$$

With this function, if we know the exact year, we can predict the amount of plastic generation. In 2020, for example, we can predict global plastic production is roughly 522.53 million tons.

4.2 Construction of AWG

In order to define AWG, we use two sets of coefficients, namely, plastic waste **Generation Rate by Industrial Sector** (GR) and **Plastic Production Percentage by Industrial Sector** (PP). The former coefficient represents the percentage of plastic products that will eventually become plastic waste in a certain industry, and the latter represents the plastic production proportion of a certain industry in the total plastic production.

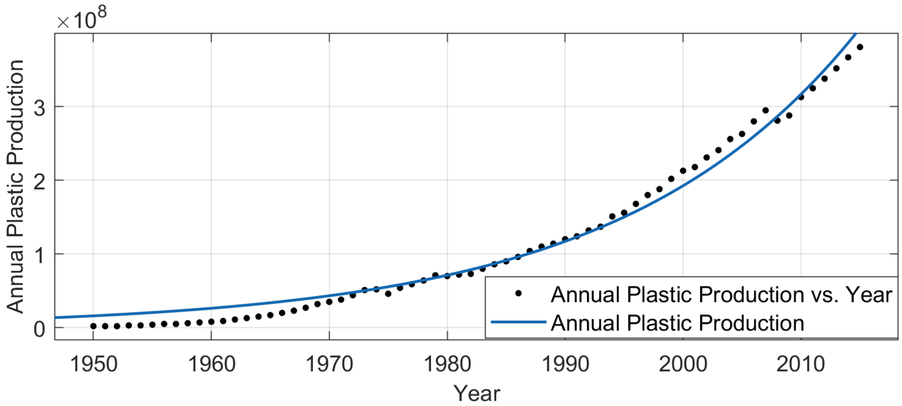


Figure 3: The curve of annual plastic production (AP)

Table 2: Sets of Coefficients [6]

Industry	PP	GR
Packaging	0.358722359	0.96575342
Building and Construction	0.159705160	0.20000000
Other sector	0.144963145	0.71186441
Textiles	0.115479115	0.80851064
Consumer & Institutional Products	0.103194103	0.88095238
Transportation	0.066339066	0.62962963
Electrical/Electronic	0.044226044	0.72222222
Industrial Machinery	0.007371007	0.33333333

By multiplying these two coefficients, we can get the plastic waste generation rate for a particular industry. Base on this, by summing the waste generation rates of various industries and multiplying by the **Annual Plastic Production** (AP), we can get the **Actual Plastic Waste Generation** (AWG)(3):

$$AWG = (GR_1 \cdot PP_1 + GR_2 \cdot PP_2 + \cdots) \times AP = \sum_{i}^{n} GR_i \cdot PP_i \times AP \tag{3}$$

4.3 Construction of WDC

Intuitively, **Plastic Waste Disposal Capacity** (WDC) is the percentage of waste that is properly disposed of, so it can be used to measure the capacity to properly handle waste.

There are two proper ways to dispose of waste, incineration and recycling. There is no doubt that recycling is the most environmentally-friendly and efficient way to handle it, but firstly, not all plastics can be recycled, such as LDPE and polystyrene. Secondly, the quality of plastic is often reduced during recycling. For most recyclable plastics, are usually suitable for recycling only once, it means recycling only delays, rather than prevents, the plastic from ending up in landfills or incinerators [7]. So in addition to recycling, we need another plan to deal with the plastic waste.

Our choice is incineration. According to the research of Eriksson and Finnveden (2009), the Global Warming Potential (GWP) and Total Energy Use (TEU) brought by incineration are significantly less than landfill. Landfills cause great harm to the environment because of the mismanagement of landfill resources in many countries and regions. In many cases, they end up in open dumps, mines, etc. This uncontrolled disposal facility can leave the surrounding environment vulnerable to plastic contamination. And it is risky that plastic waste will end up in the ocean. Even well-managed landfills can still have a negative impact on the environment because of the non-degradability of disposable plastics, which can bring toxins to the soil. However, modern incinerators have largely solved the problem of dioxins and other toxins [8]. At present, though, incinerators are often heavily regulated only in high-income countries. Unsafe or open burning of plastic remains common in low-and middle-income countries where environmental regulations are less stringent. However, if standards are harmonized globally and appropriate technologies and methods are applied, incineration can become a universally safe solution.

In conclusion, proper waste disposal includes recycling and incineration(4):

$$WDC = \frac{Incinerated + Recycled}{Landfill + Incinerated + Recycled} \tag{4}$$

By analyzing the percentage of the above three plastic processing methods in 146 countries and regions from 1980 to 2015 [6], and by using the cftool application in Matlab, we fit the relationship between time and WDC, and obtain several functions. Among them, the linear function has the best fitting effect, with $R^2 = 0.9956$ (5):

$$WDC = 0.01323t - 26.22 \tag{5}$$

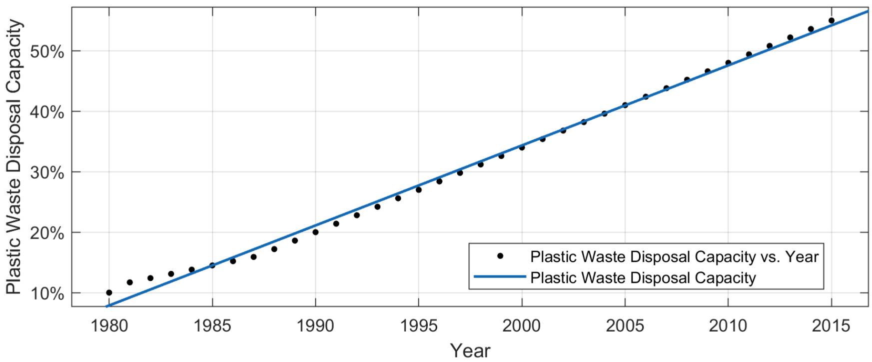


Figure 4: The curve of plastic waste disposal capacity (WDC)

If we know the year, we can put it into the formula to predict the WDC for that year. For example, by 2020, WDC will be about 50.46%.

4.4 Construction of MaxWG

Based on the definition and functionalization of the above variables, we can summarize and integrate the function of **Annual Maximum Plastic Waste Generation** ($MaxWG$), which is(6):

$$MaxWG = WDC \times AWG = WDC \times \sum_{i}^{n} GR_i \cdot PP_i \times AP \tag{6}$$

and it equals to(7):

$$MaxWG\,(t) = (0.01323t - 26.22) \times 0.7420 \times 1.138 \times 10^{-35} \times e^{0.04977t} \tag{7}$$

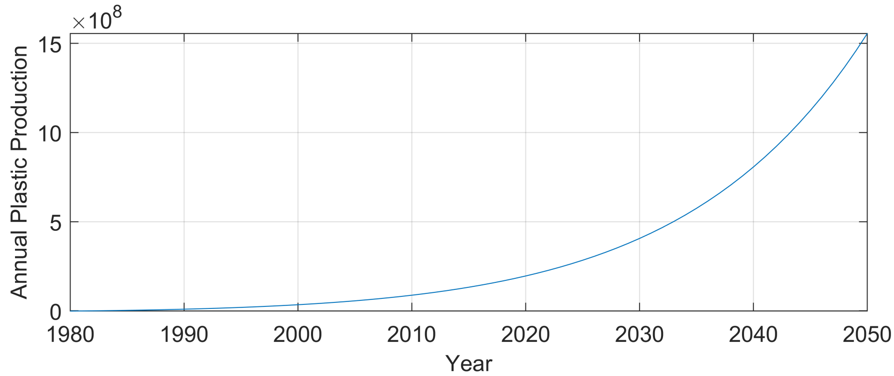


Figure 5: The curve of annual maximum plastic waste generation ($MaxWG$)

With this function, we can predict $MaxWG$ for a given year. For example, we can predict that the $MaxWG$ will be approximately 195.64 million tons in 2020.

4.5 Sensitivity Analysis

It is important to verify the impact of individual indicators on the MaxGX model. WDC is the percentage of waste that is properly disposed of, which can be used to measure the capacity to dispose of waste. Therefore, WDC has a critical impact on the model. If there is a major technological breakthrough, such as a significant improvement in waste collection efficiency, an effective policy established, or the large-scale promotion of modern waste incineration technology in the world, WDC will be significantly improved. We assume that WDC will become 150% of the original. If the growth rate of plastic waste is much faster than we expect, then the capacity to properly dispose of waste will not be able to keep up with the increase of waste generation, in which case we assume that WDC becomes 50% of the original. If the change in WDC have a significant impact on the value of MaxGX, then it indicates that MaxWG is sensitive to WDC. Here are the function curves:

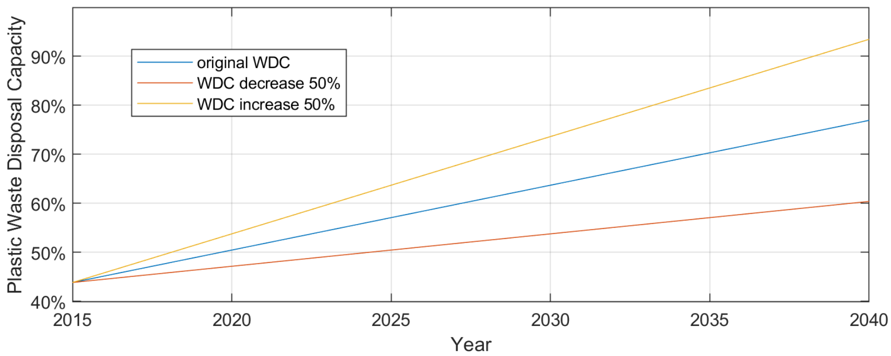


Figure 6: The original and adjusted curve of WDC

It can be seen that changes in WDC will result in large changes in the MaxGW function curve and the final result, which indicates that our model is sensitive to this indicator.

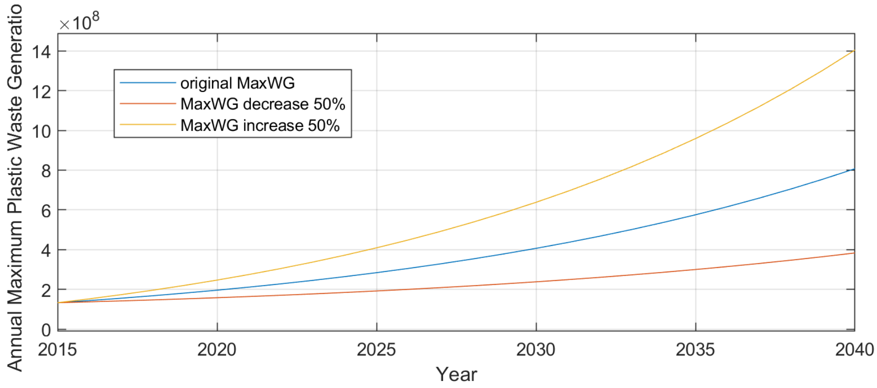


Figure 7: The original and adjusted curve of $MaxWG$

5 Reduce Plastic Waste to an Environmentally Safe Level

5.1 National Plastic Waste Generation Responsibility Index

Reducing the amount of plastic waste in the world to an environmentally friendly level is a huge and complex task, which requires the cooperation and joint efforts of all human beings. In order to allocate the task of reducing plastic waste generation to various countries more accurately, and calculate the work considering specific constraints in different regions, we have established an evaluation system, which involved five different evaluation factors: Human Development Index, Mismanaged Plastic Waste by country, Inadequately Managed Plastic Waste by country, Total Plastic Waste by country and Plastic Waste per Person by country(8).

Figure 8: Evaluation factors of NRI

We use the data of these factors to measure waste generation, policy effectiveness in reducing the use of single-use plastics, levels of economic development, and capacity to dispose of plastic waste of each country. The final result of this system is our **National Plastic Waste Generation Responsibility Index (NRI)**.

In our evaluation system, countries with higher NRI tend to account for a larger share of the world's total plastic waste generation, and therefore should take more responsibility and contribute more to the process of reducing plastic waste. However, because developing countries are often constrained by their level of economic development, they may take on responsibilities beyond their capacity. So we have introduced HDI regulation that tilts the distribution of tasks slightly towards developed countries with better capacity to dispose of plastic waste, so as not to overload developing countries and make it impractical to get the job done.

We combined entropy weight and TOPSIS method to get NRI. First of all, we standardlized the original data, and then we used entropy weight method to calculate the objective weight of each evaluation index by using the information of the data itself. Then we introduce AHP method to get the subjective weight, correct the objective entropy weight, and get the final weight. Finally, we used TOPSIS to get the NRI of each country.

Evaluation steps based on the TOPSIS-entropy Method

In the evaluation problem of m evaluated countries and n evaluation indexes, the original index value of the i^{th} evaluated city on the j^{th} index is denoted as u_{ij} (where $i = 1, 2...m; j = 1, 2...n$), set up the initial matrix $U = \left(u_{ij}\right)_{m\times n}$

Step1: Standardized Processing of Raw Data

First of all, dimensionless processing parameter values to eliminate dimension influence. The standardized matrix is denoted as X, and for each element in X (8):

$$x_{ij} = \frac{u_{ij}}{\sqrt{\sum_{i=1}^{n} u_{ij}^2}} \tag{8}$$

The normalized matrix $X = \left(x_{ij}\right)_{m\times n}$ is obtained, where x_{ij} is the standardized value of the i^{th} country on the j^{th} index.

Step2: Use Entropy Weight Method to Calculate the Objective Weight

(1) Calculate the proportion of the standardized value of the index. Carry out the proportion transformation of the standardized data of each index in the standardized matrix $X = \left(x_{ij}\right)_{m\times n}$. Calculate the proportion of the i^{th} sample in the j^{th} index and consider it as the probability used in the calculation of relative entropy. The formula of p_{ij} for each factor in the probability matrix P is as follows (9):

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{9}$$

(2) Calculate the information entropy of each index and the information utility value, then normalize the entropy weight of each index. For the j^{th} index, its information entropy can be calculated as (10):

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln\left(p_{ij}\right) \tag{10}$$

(3) Then calculate the entropy weight w_j of each index (11):

$$w_j = \frac{1 - e_j}{n - \sum_{j=1}^{n} e_j} \tag{11}$$

Step3: Use the Subjective Weight to Correct the Objective Weight

AHP method was introduced to obtain the subjective weight, which was used to correct the objective weight. The modified combined weight is (12):

$$w_j^0 = \frac{\lambda_j w_j}{\sum_{j=1}^{n} \lambda_j w_j} \tag{12}$$

Step4: Use TOPSIS for Comprehensive Evaluation

Construct a standardized data-weighted decision matrix. The normalized matrix $X = (x_{ij})_{m\times n}$ after dimensionalization is multiplied by the modified index weight vector $w^0 = (w_1, w_2, \cdots, w_n)$, as shown in the formula $Y = (y_{ij})_{m\times n} = \left(w_j^0 x_{ij}\right)_{m\times n}$.

Then define the Euclidean distance between the i^{th} evaluation object and the maximum value as D_i^+, and the Euclidean distance between the i^{th} evaluation object and the minimum value as D_i^-. We can now calculate NRI of the i^{th} evaluated country (13):

$$NRI_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{13}$$

According to the principles of the TOPSIS method, we know that the NRI of all countries add up to 1.

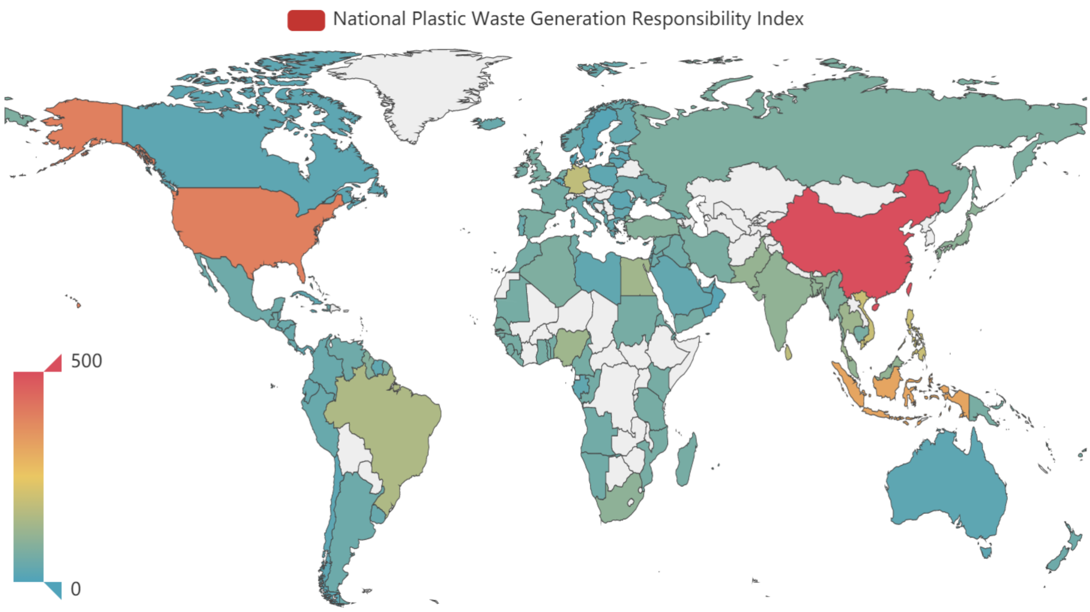


Figure 9: NRI by country (For the convenience of drawing, the value of NRI in the figure is uniformly expanded by 1000 times. And values greater than or equal to 500 are shown in red)

5.2 Global Waste Reduction Target and Equity Issues

By combining the model given in part 4, we can know the Annual Maximum Plastic Waste Generation that we can handle. Therefore, we can obtain the **Global Waste Reduction Target** (GWR) through the following formula (14):

$$GWR = AWG - MaxWG \tag{14}$$

Once the overall targets have been set, how to distribute the task fairly among countries and get them implemented have become our top priority. Because different development levels will lead to differences in waste generation amount and processing capacity, which need to be taken into account when assigning tasks. If the task is assigned only according to the National Plastic Waste Generation Proportion (NWGP), it may cause equity issues. At this point, the NRI we obtained in part 5.1 can play a key role in maintaining equity.

NRI plays an important role as a reference index in assigning waste reduction tasks. According to NRI, we can make fair adjustments based on the National Plastic Waste Generation Proportion (NWGP). The adjusted National Waste Reduction Target (NWR) is (n is the total number of countries) (15):

$$NWR = GWR \times \frac{(1 + NRI)}{(n+1)} \times NWGP \tag{15}$$

The adjusted NWR means that the higher the NRI is, the greater the responsibility should be, which means a bigger share than the original NWGP to be undertaken. And vice versa.

5.3 Suggestions for ICM

Therefore, we suggest that ICM should not only propose a minimum environmentally safe target, but also inform the specific responsibilities of each country according to the NRI. There are many factors that cause the plastic waste to flood. We need to take appropriate measures according to the specific situation of each country, so that they can reduce the generation of plastic waste in a more suitable way.

For example, in high-income countries, plastic waste per capita is usually very high. However, richer countries tend to have more effective waste management systems, which means that less waste is poorly managed, so the reduction of overall waste is their main task rather than optimizing the management system. Most poorly managed waste tends to come from low income countries, where large coastal populations and rapid industrialization mean that waste management systems cannot keep pace with economic development, so they should develop management system as soon as possible.

At the same time, developed countries have more scientific research capacity, so they can invest more resources in scientific research and development. This includes developing degradable alternative materials for plastics [9], improving plastic recycling technology to improve its efficiency, developing cleaner and more efficient plastic incineration technology, making full use of the incineration process to generate electricity and heat, and so on.

However, developing countries often do not have such strong scientific research strength, and there are more plastic pollution caused by improper management in developing countries [6]. Therefore, developing countries can improve from the perspective of policy supervision, such as implementing stricter plastic restrictions or accelerating industrial upgrading and transformation. Reduce plastic waste emissions by developing better policies and strictly enforcing them. In addition, developed countries can also import waste to reduce this regional imbalance.

6 Measures and Impacts of Reducing Plastic Waste

6.1 A Target For the Minimal Level

According to the global largest annual production of plastic waste, and responsibility of each country for reducing the generation of plastic waste, it is not difficult to find out that as long as each country bears its own responsibility, reduces the production and use of plastic and uses alternative materials and products, the global plastic waste volume can reach a minimum level, that is, when the processing capabilities can handle the amount of waste in that year. Because the amount of plastic waste we now generate is far more than the maximum processing capacity we get from the model, so reducing generation to the maximum processing capacity is already our upper limit, which is an extravagant goal, so it can be our target minimum achievable level.

6.2 Measures to Reach the Target

As economies, living standards, demand for and use of disposable plastics may vary in different regions, we propose several ways to reduce plastic waste and discuss which types of countries are more suitable for which measures: developing alternative materials, implementing specific policy, and using media impacts.

6.2.1 Development and Promotion of Alternative Materials

The United States, France, Germany and other developed countries with highly developed science and technology often generate more waste. And according to NRI, the proportion of their responsibility is high. So in addition to contributing to reducing plastic production, these countries should put more effort into alternative materials research and development, increase investment in the research of degradable plastics, the promotion of biodegradable plastics or looking for other alternative materials to fulfill their high-grade responsibility. Specific measures include: (a) promote the implementation of the recognition standards for degradable plastic products; (b) by the means of mass production of raw materials to reduce production costs; (c) introduce advanced enterprises, foster a good industrial and market environment, encourage and guide the development and promotion of new plastics and substitutes [10].

6.2.2 Different Policies in Different Regions

It can be seen from the figure that various countries and continents have different degrees of control over plastic bags.

For developed countries, it is recommended to cut off the supply of plastic bags in some pilot areas. We have good reasons to believe that this will not have a great impact on people's lives, because people in developed countries have high education level, strong environmental awareness, high economic level, and can afford the cost of other bags (paper bags, cloth bags, handbags, schoolbags, etc.).

For some developing countries and economically backward areas, cutting off the supply of plastic bags will cause great inconvenience to people's lives, so it is not recommended to stop the supply of plastic bags, but to tax plastic bags according to the

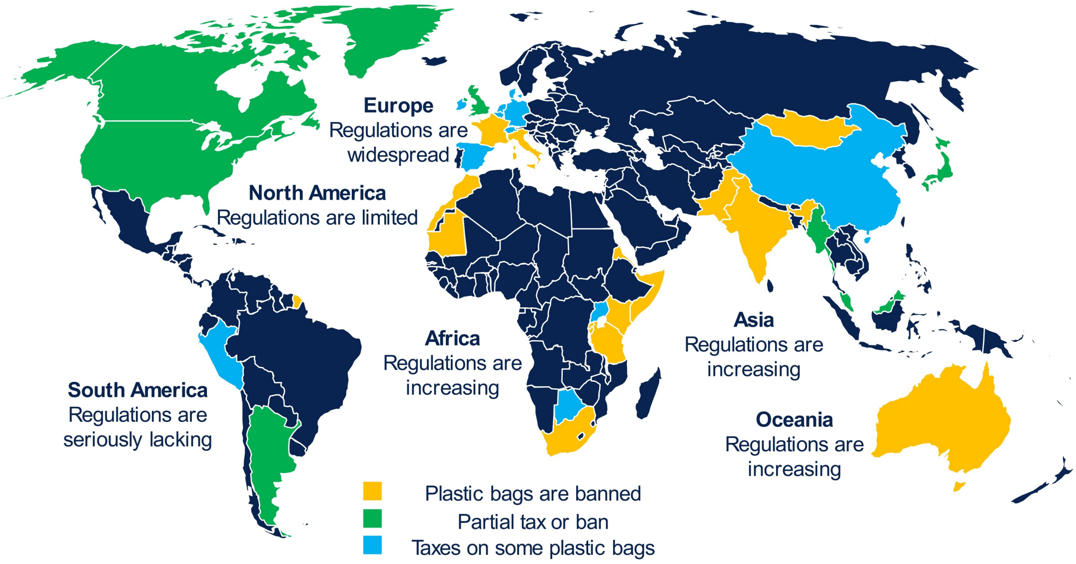


Figure 10: Plastic Bag Regulations (adapted from Elekhh - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=32400659)

practice of other countries. They should follow the practice of other countries in taxing plastic bags and use the proceeds to invest in specific environmental projects and recycling industries to maximize the public interest.

Developing countries also need to improve the responsibility system of disposable plastic waste producers. For domestic and industrial waste containing disposable plastic, each grass-roots waste transfer station can adopt the methods of rejection, fines, collection of sorting fees, etc. So they can solve the problem of sorting and recycling of disposable plastic waste as far as possible at the initial stage of garbage collection and transfer [10].

6.2.3 Media Publicity to Raise Awareness

The media (including radio, television, Internet, news, newspapers, etc.) should increase the publicity of the government's relevant policies, increase the supervision and reporting the public's implementation of the new policies, increase the popularity of plastic hazards and how to reduce the use of plastic in life and work. The guidance of public opinion by the media can promote the self-discipline of social members, improve the awareness of the environmental impacts of disposable plastics, and let the public actively reduce the use of disposable plastic [11].

6.3 Impacts for Achieving an Environmentally Safe Level

6.3.1 Impacts on Human Life

In order to reach the standard of environmental safety, there must be restrictions on the use of plastic products in people's lives, especially the disposable plastic bags. For countries that have begun to collect taxes on plastic bags, the tax value may be further increased, or even the supply of plastic bags may be cancelled. For countries that do not tax plastic bags and use them a lot, they may start to tax plastic bags. At the beginning, it will definitely make people feel uncomfortable. People will also increase the use of plastic substitutes. For example, in September 2016, France passed a new law requiring that 50% of disposable plastic tableware, such as dishes, cups and forks, must come from biological materials, and can be used for composting degradation in the home. The ban will come into effect in 2020 [12]. The European commission has also proposed to ban the use of 10 single-use plastic products, including cotton swabs and plastic straws, and let manufacturers bear the cost of cleaning up waste [13]. On world oceans day 2015, UNEP called on all countries to phase out the use of plastic microbeads in personal care products and cosmetics. The United States, Japan, the European Union, the United Kingdom and other countries and regions started to take corresponding measures to ban the use of plastic microbeads in care products [14]. Plastic tableware, plastic straws and cosmetics containing plastic beads are all frequently used products in daily life, but in order to achieve the lowest level of plastic production, the use of their substitutes is also an inevitable trend. It's a huge impact on people who are dependent on them.

6.3.2 Impacts on the Environment

Marine Environment

We use the DPSIR model to analyze the impact of achieving the target minimum plastic waste generation on the marine environment. DPSIR is developed as an indicator system to measure the environment and sustainable development. It divides the evaluation indexes of a natural system into five modules: Driving Forces, Pressure, State, Impact and Responses, reflecting the feedback of environmental state on social measures.

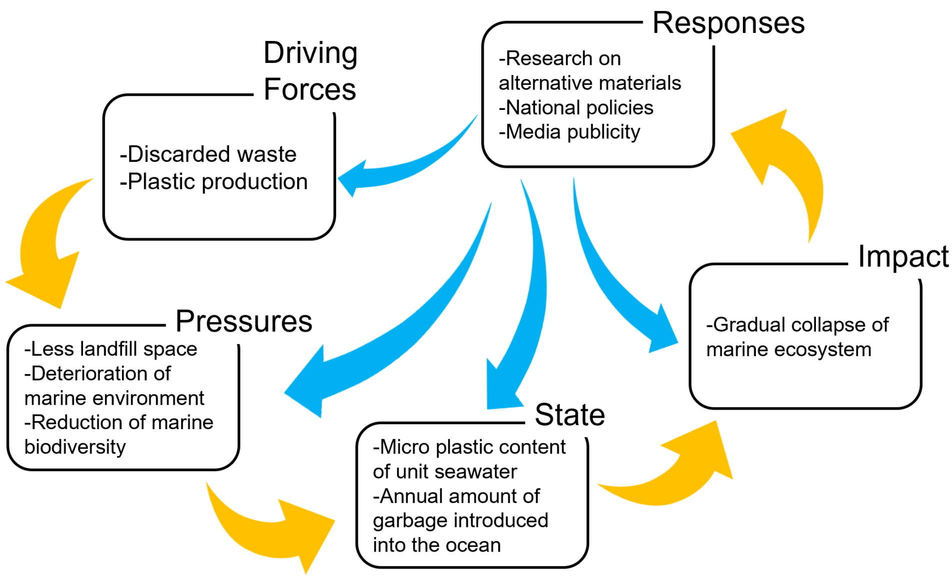


Figure 11: DPSIR model for analyzing marine environment

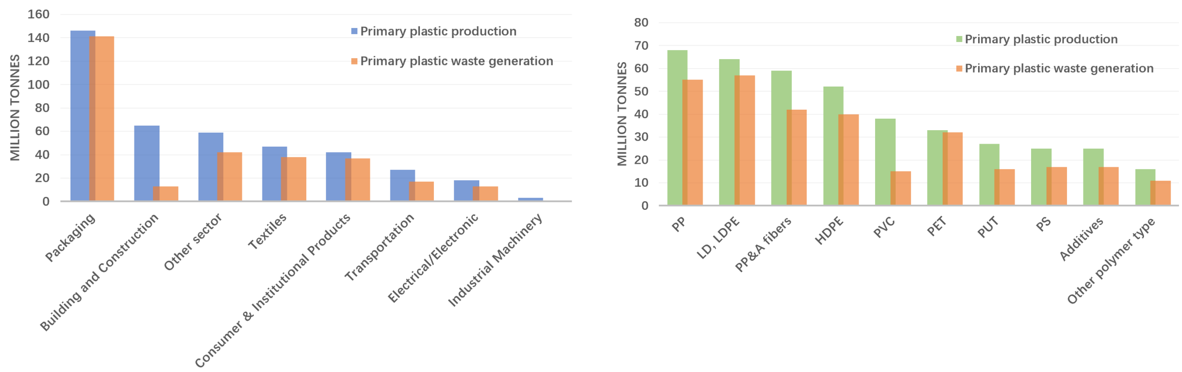
We set the current state of the ocean is State, and there are many indicators to evaluate this state, such as the micro plastic content of unit seawater, the amount of garbage dumped into the ocean every year, etc. it is estimated that about 3% of the global plastic waste enters the ocean every year. About 8 million tons in 2010 [15], which is a frighting number. The driving force is that a large number of unrecycled and incinerated wastes are landfilled, and the plastic production of various plastic industries is growing exponentially. The pressure is caused by driving factors, such as: less and less underground landfill space, deterioration of marine environment, and reduction of marine biodiversity. The impact is the gradual collapse of marine ecosystem, so our response to this is the measure we mentioned earlier from the perspective of alternative material, government policies and media publicity. In this way, we can see from the DPSIR diagram that our response will affect the state of the ocean and improve current state. Every year, the amount of garbage dumped into the ocean will gradually decrease. The government will organize fishermen to catch the floating plastic garbage to reduce the content of micro plastic in the ocean. At the same time, the marine ecosystem will gradually recover, and the number of fish, turtles and marine mammals that die from eating plastic will decline every year, and the marine resources will remain in a sustainable use state.

Terrestrial Environment

Micro-plastics entering the soil through various methods such as discarding, landfilling, etc., will gradually age on the surface due to long-term weathering in nature, ultraviolet radiation, and interaction with other components in the soil. Under the influence of factors such as ion exchange, the capacity of soil to adsorb heavy metals, antibiotics and other organic pollutants is enhanced, which changes the physical and chemical properties of the soil and affects the soil ecosystem [16].

After the amount of plastic waste reduces to an environmentally safe level, no more waste and harmful substances will enter the soil and affect the soil structure. Soil quality will improve, world grain production may increase, and the quality of groundwater resources will improve.

6.3.3 Impacts on the Multi-trillion-dollar Plastic Industry



(a) According to industrial sector (b) According to polymer type

Figure 12: Plastic production and Waste Generation

From the figure 12, we can see that the packaging industry is the industry with the largest plastic generation and the largest amount of plastic waste. Therefore, once the use of plastic is reduced, it will have a huge impact on the packaging industry. It can be predicted from the table that express package bags and clothing and food packaging bags will be greatly reduced. Amazon India recently stated that it will replace all disposable plastic packaging, such as air pillows and foam packaging, with paper pads by June 2020. It is not difficult to speculate that the use of new materials mainly affects the cost of packaging. Paper packaging materials will be more expensive than plastic packaging, and as a large number of paper packaging materials are put into use, the price may also rise, which means that the cost of packaging will rise again, leading to a decline in people's purchase.

Table 3: Plastic Products Commonly Used in Various Industries

Industry	Commonly Used Plastic products
Packaging industry	Express packaging bags, clothing and food packaging bags
Medical service industry	Infusion set, syringe, brine bag, test tube
Agriculture	Agricultural film, pesticide packaging
Catering	Disposable tableware, straw, beverage bottle

From the table 3, it can be inferred that if various industries are supposed to reduce the production of plastic waste, the catering industry will definitely reduce the production of disposable tableware, straws and beverage bottles, and the medical service industry will also reduce the production of infusion machines, syringes and brine bags, etc. We know that plastic is extracted from petroleum. To achieve the goal of minimizing plastic waste, we must reduce the production of plastic, which will have an impact on the petroleum industry. It is estimated that the oil consumed by plastic production each year accounts for the global oil consumption between 4% and 8%, about 6% [17] of global oil consumption. If we can reduce our dependence on plastics and use clean energy and products, it will be economically important for countries lacking oil, and help them reshape the plastics industry and energy industry chain. It is also profitable for oil-rich countries, where the precious non-renewable resource can be used where it is needed more. The above examples can show that the reduction of plastic waste will not only have an impact on the specialized plastics industry, but will also have an impact on other industries.

7 Strengths and Weaknesses

7.1 Strengths

- It is reasonable to regard landfill as a waste disposal method which is harmful to the environment. Because most countries do not dump the waste at the right place while dumping them into open-air landfills, mines, etc. A large proportion of such waste flows into the ocean, pollutes the water and harms marine plants and animals.
- In order to avoid the interference of human factors, TOPSIS-entropy is used to determine the responsibility of reducing plastic waste. Therefore, the model is objective and persuasive.
- After calculating the maximum annual plastic waste that can be handled, we got the target for the minimal achievable level of global waste of single-use plastic products. We came up with an innovative NRI evaluation system to figure out each country's responsibility for waste reduction, and to figure out what each country is responsible for in order to minimize the goal. This is an innovation point.

- We used the DPSIR model to analyze the impact of achieving the target minimum plastic waste generation on the marine environment. DPSIR model is a conceptual model of the evaluation index system widely used in the environmental system, which is developed as an index system to measure the environment and sustainable development. DPSIR divides the evaluation indexes of a natural system into five modules: driving forces, pressure, state, impact and responses. It can show the response of the marine environment to different measures intuitively and logically.

7.2 Weaknesses

- To simplify our model, recycling and incineration are considered as the capacity to deal with plastic waste. But in fact, incineration also causes damage to the atmosphere.
- When predicting the timeline, due to the lack of relevant data, we made a lot of hypotheses and assumptions, some of which may deviate from reality. Therefore, the accuracy of our model may be influenced by them.
- When calculating the NRI, the indicator data we used did not include certain countries, which led to the absence of NRI results in certain countries.

Memorandum

To: International Council of Plastic Waste Management (ICM)
From: Team 2012496
Date: February 17th, 2020
Subject: Our Analysis and Suggestions on the Global Plastic Waste Problem

In accordance to your requests, we establish a customized model to significantly reduce, or even eliminate, single-use and disposable plastic product waste.

1. Annual Maximum Plastic Waste Generation Model

First, we build a model to quantify the amount of waste that can be recycled and incinerated globally each year as the maximum amount which will not cause further damage to the environment. The key findings are:

(1) There are three ways to dispose of plastic waste: recycling, incineration and discarded. Discarded waste is the amount of waste that we need to reduce. The percentage of discarded waste is decreasing by a significant percentage year by year, and our capacity to deal with them is increasing. But just increasing processing power is not enough. Plastic production must be reduced from the source.

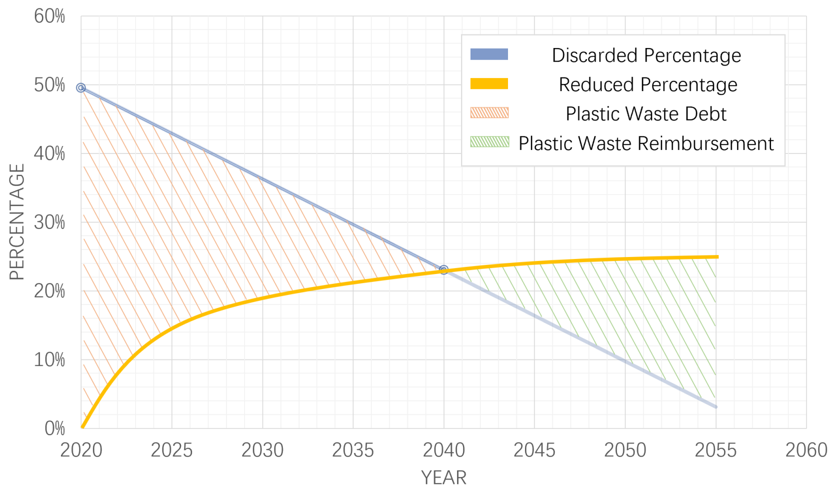


Figure 13: Timeline to reach the goal

Table 4: Reduction targets and the predicted discarded plastic waste in million tons

	2020	**2025**	**2030**	**2035**	**2040**
Predicted discarded plastic waste (Mt)	192.08	213.45	231.58	242.9	242.13
Reduction Target (Mt)	0	69.62	121.18	171.77	242.13

(2) We set a global annual waste reduction target in table 4. Because our plan has just been put forward in 2020, so we don't expect the world to reduce plastic waste generation immediately. From 2020 to 2040, as long as both developed and developing countries formulate policies in accordance with their national conditions and NRI indicators, the annual global waste generation reduction percentage will increase year by year. In 2025, for example, we should have achieved the goal of reducing waste generation by 69. 62 million tonnes, compared with an estimated 213.45 million tons of discarded waste. The timeline and the relationship between the two trends is shown in figure 13.

(3) As can be seen from the figure 13 and table 4, before reaching the balance point around 2040, there is still a large part of garbage cannot be handled. This part is visually presented in the figure with the orange shadow. The waste in the orange shadow, which is landfilled, named Plastic Waste Debt. After the balance point, we will have redundant processing capacity every year, which can be used to deal with our previous Plastic Waste Debt. This part with green shadow is called the Plastic Waste Reimbursement.

(4)

Table 5: Circumstances that may accelerate or hinder the achievement of the timeline

	Circumstances
Accelerator	1. A major breakthrough in degradable plastic technology. 2. Countries conscientiously perform the tasks assigned by ICM. 3. Find a new plastic substitute, which is affordable and easy to produce.
Hindrance	1. The outbreak of global natural disasters or wars affects global technological innovation and development. 2. Economic crisis and insufficient research funds. 3. The population growth is too fast, plastic demand and consumption increase greatly. 4. Countries only care about their own development and do not fulfill the tasks assigned by ICM. 5. It is difficult to break through the technology bottleneck of degradable or other alternative materials.

2. Suggestions

(1) Most poorly managed waste tends to come from low-and middle-income countries, where large coastal populations and rapid industrialization mean their waste management systems cannot keep pace with the economic development, so we suggest them to improve their plastic waste management systems as soon as possible.

(2) Developed countries have strong scientific research capabilities, so they should invest more resources in research and development, including the development of alternative biodegradable plastic materials and the improvement of plastic recycling technology to improve its efficiency. Developed countries should also reduce regional imbalance by importing waste. They have more efficient waste management systems, which means less poorly managed waste, so helping poorly managed countries dispose of more plastic waste would be a huge contribution.

(3) Developing countries have more plastic pollution due to improper management, so they are supposed to make improvements from the perspective of policy supervision, such as implementing stricter plastic restrictions or accelerating industrial upgrading and transformation. Develop better policies and strictly enforce them to reduce plastic waste generation.

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