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The Chemical Industry's Future Vision on the Chemical Recycling of Plastic Waste

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Japan Chemical Industry Association (JCIA)

I. Introduction

As discussions and measurements on global environmental issues including climate change and plastic waste, have progressed across the world, there have been more calls for concrete actions to be taken to reduce greenhouse gas (GHG) emissions.

In response to the world-wide depletion of resources due to increased population on a global scale; rapid changes of the international waste management system that is restricting imports of plastic waste in China and Southeast Asian nations by their regulations; and glowing global environmental issue on marine plastic litter, the government of Japan has been implementing various measures on climate change and resources circulation by the related laws, regulations and policy documents. The government deems it necessary to transform from a "linear" economy based on a mass production, mass consumption and mass disposal pattern to a "circular" economy system, which advances on minimize the input of resources and energy as well as the environmental impact caused by waste and carbon dioxide.

As for marine plastic litter, the Japanese government formulated the "Japan's Action Plan for Marine Plastic Litter" with a focus on how to prevent of littering, illegal dumping and unintentional leakage of waste into the oceans without restricting economic growth and to realize the "Osaka Blue Ocean Vision", that is to reduces additional pollution by marine plastic litter to zero by 2050. In the action plan, the government determined key measures; 1/promotion of proper waste management system, 2/prevention of littering, illegal dumping and unintentional leakage of waste into the oceans, 3/collection of scattered waste on land, 4/collection of plastic litter in the oceans, 5/innovation in development of alternative materials, 6/collaboration with stakeholders, 7/international cooperation with emerging countries by sharing best practices and 8/research on actual situations and development of scientific knowledge.

Moreover, through the activities of the Japan Initiative for Marine Environment (JaIME)[1)], various measures to foster the effective and circular use of plastic resources have been implemented. These include LCA (Life Cycle Assessment) studies on the reduction of environmental impacts (caused by CO_2 emissions and energy use) through the effective use of plastic waste in an objective and scientific way, as well as training seminars to help ASEAN countries improving

their waste management capabilities.

Toward a transition to a circular economy, it is necessary to foster the circular use of all kinds of resources. To this end, the Japan Chemical Industry Association (JCIA) recognized it is the urgent challenge to achieve the efficient and circular use of plastic waste in response to world issues, such as resource limitations due to global increased population, plastic litter and climate change. In May 2017, JCIA announced the "Chemical Industry's VISION on Global Warming Countermeasures", in which JCIA noted that the chemical industry should work for the "carbon circulation of raw materials" as a solution provider and promote the reuse of waste. Plastic waste can be an important domestic resource for Japanese chemical industry by effective using and recycling it as resources. JCIA recognizes more efficiently using and repeatedly recycling plastics waste can enhance the "carbon circulation" and can be useful measures to substantially mitigate GHG emissions.

"Chemistry" has a potential in which various substances including waste can be converted into useful materials for the environment and for people. The chemical industry is capable of actualizing the possibilities and should play a central role in generating the innovation required for the solution of global issues. Accordingly, JCIA organized the Working Group for Review of Long-Term Strategy on the Chemical Recycling of All Types of Plastic Waste (WG on the CR of Plastic Waste) under its Technical Affairs Committee with the participation of experts from its member companies, its member associations and the fields of chemical recycling. The purpose of the WG on the CR of Plastic Waste is to develop the chemical industry's future vision and strategic goals for the issue of plastic waste toward 2050 and beyond, and to show the industry's action plan to achieve the vision. JCIA expects that the vision will be considered when long-term strategies toward forming to a circular economy by all stakeholders in Japan and in the world.

II. The chemical industry's future vision on the chemical recycling of plastic waste

(1) Picture of mid-21st century society

Many chemical products currently used in society are made by using carbon in fossil-based resources. These products have supported various other industries and our day-to-day life by being widely used not only in materials and consumer products but also in a range of manufacturing processes. Even in a "post-coronavirus society- New Normal", which is predicted to be quite different from what has come before, chemical products will surely continue to be used in large quantities because of their unique product performances and their advanced functionality.

However, there will be required to shift away from fossil feedstock as the source of carbon toward use of plastic waste as feedstock by establishing the system of "carbon circulation of raw materials". For energy sources, it is estimated that the use of fossil resources will also substantially decrease and demand of waste as fuel sources will be increased. As each country has taken various measures to reduce its GHG emissions, social systems based on hydrogen and electrical energy have steadily been established and renewable energy will become a mainstream as a secondary energy source toward the striking reduction of GHGs emitted from fuel combustion.

(2) Chemical industry as a solution provider

In order to realize a "True Circular Society" that is the recycling system, in which resources keep being used efficiently and repeatedly, with a substantial reduction in GHG emissions and with conserving resources, the chemical industry will propose and provide chemistry-based product designs and usage scenario and also will propose and supply the materials necessary for the realization. To this end, the industry is expected to foster the following technologies and business model, that ensure the chemical industry is a solution provider:

1) establishment of carbon circulation,
2) process and energy innovation, and
3) selection of an environment-focused business model and establishment of social infrastructure

The future vision focuses on the chemical recycling of plastic waste, which can be expected to make great contributions to the establishment of carbon circulation.

(3) Roles of chemical recycling of plastic waste in achieving a "carbon and resources circulation"

There are 3 major methods that contribute to achieve a carbon and resources circulation; such as chemical recycling (CR), mechanical recycling (MR) and energy recovery (ER).

CR enables plastic waste to be converted into its feedstock with its original performance and to use the feedstock back to new product production process by material circulation. This is thus capable of upcycling and is an effective material circulation method to which the chemical industry can contribute by making the best use of chemical industry's characteristics.

MR contributes not only to material circulation, but also to GHG emissions reduction. It should therefore be more utilized, but there is a case in which recycling post-use plastics repeatedly is limited because of downgraded product

quality. In the case, virgin materials and recycled materials are therefore needed to be mixed.

ER currently plays an important role to help some plastics, which are difficult to be recycled because the plastic waste contains unnecessary materials that cannot easily be separated out. However, in the incineration of plastic waste for power generation, large amounts of GHGs will be emitted if the power generation efficiency is low. ER should therefore be substantially reduced in the future.

It is necessary to clarify the significance and roles of each recycling method as options, while also reviewing environmental impacts by its LCA study.

(4) CR technologies leading by the chemical industry

At present, there are two major methods defined as CR; “circular CR” (breaking down plastic waste into chemical raw materials, such as monomers, gases and oil (including conversion to oil by the use of a coke oven) and “one-way CR” (using plastic waste as a blast furnace reducing agent or as a carbon source in a coke oven).

The latter CR method is applied to plastic waste that is too difficult to sort and thus can contribute as alternative to reducing the use of coke. This method has already industrialized in society on a relatively large scale. However, it is difficult for the public and consumers to get a clear image how the “one-way CR” contributes to minimize the amount of plastic waste. It is also hard to gain the understanding and support by the public and consumer, who are the key player to sort plastic waste.

The chemical industry aims to focus on and promote “circular CR”, which is easier for the public to understand and is more visible how the “circular CR” technologies contribute to material circulation.

(5) Target value for social implementation of CR that the chemical industry aims for

The chemical industry has determined to set its concrete targets and to show its future direction, which is estimated in a realistic manner, in consideration of the CLOMA (Japan Clean Ocean Material Alliance)[2)]’s targets set in its Action Plan.

As the basis to set the targets, JCIA estimated the total discharge amount of plastic waste by assuming that the amount will be reduced by about 200,000 tons per decade in reference to the actual results in “Flowchart of plastic products, plastic waste and resource recovery 2018*)”, published by the Plastic Waste Management Institute[3)]. Also, assuming that the recycling of plastic waste will be greatly promoted across Japan by the improvement of waste recycle system for

the collection, sorting and recycling of plastic waste, JCIA has set the target of increasing the chemical recycling amount of plastic waste up to about 1.5 million tons per year by 2030 and up to about 2.5 million tons per year by 2050, in order to accelerate the social implementation of circular CR system toward making the maximum contribution to the recycling of plastic waste in the chemical industry.

Also referring to the Japanese government targets that aims to "double the use of recycled materials by 2030" while considering their applicability in "Japan's Resource Circulation Strategy for Plastics", JCIA estimated the amount treated by MR shown as reference values in the below table. Considering the Government targets, moreover, based on the idea that plastic waste can be one of Japan's important domestic resources, the chemical industry will take measures to reduce the amount of plastic waste exported overseas and to make the simple incineration and landfilling of the waste minimize as much as possible.

Table: Targets to be achieved under the future vision, estimated by JCIA

	Actual* **(10,000 tons/year)**	**Target (10,000 tons/year)**		Remarks
Year	2018	2030	2050	
Total plastic waste discharge	892	870	830	Estimated based on the results shown in the Flowchart
Amount treated by circular CR	23	**150**	**250**	Target
Sum of waste by MR	208	More than 300	More than 350	Reference value

* Source: "Plastic Products, Plastic Waste and Resource Recovery [2018]" by the Plastic Waste Management Institute

III. Toward the realization of the future vision

JCIA set the guiding principle and prioritized the action plan toward the realization of the "The Chemical Industry's Future Vision on the Chemical Recycling of Plastic Waste".

(1) Guiding principle

Toward the realization of the future vision, the chemical industry will build a system that enables it to play roles as a solution provider. The system will target all the CR processes from IN to OUT by paying attention to the whole value chain related to the circular use of plastic waste.

The chemical industry will foster industry-government-academia collaboration to build a system to ensure the stable supply of plastic waste on a scale that is necessary to commercialize CR as a business. The industry will also work to increase the economic feasibility of the CR as a business and will work to create a CR market by development and installation of highly efficient CR technologies that can demonstrate the superiority of CR from the viewpoint of LCA in a circular economy (which means "from the cradle to the cradle" rather than "cradle to grave"), and by introducing a system to make chemically recycled products recognized by society.

(2) Aware the significance of CR as an option for resources circulation

To achieve "The Chemical Industry's Future Vision on the Chemical Recycling of Plastic Waste", it is essential to raise public awareness of CR's indispensability for resources circulation and for GHG emissions reduction. In the CR process, it is much less work to sort plastic waste, which is repurposed as raw materials for CR, and to be able to remove impurities from plastic waste compared with the MR process.

In addition, more diverse waste plastics, including so-called dirty plastics can be recycled by CR. The deliverables directly from the CR of plastic waste are degradants and mixtures, but these can be converted, for example, by refining and fractional distillation, into basic chemicals as raw materials, which have an equal quality to that from fossil resources and can be used as feedstock.

CR is the only method that plastic waste as raw materials are processed to make new product in the material circulation system. The chemical industry recognizes that CR is the only method to produce basic chemicals from plastic waste and that it is necessary to establish verification systems for CR process. Also, the chemical industry will step up its CR technologies to increase resources circulation efficiency and minimize the use of additional energy.

The significant CR technical innovation enables resources to keep circulating efficiently and repeatedly and brings more GHG emissions reductions. In particular, in Japan, which is not blessed with fossil resources, it is important to build the resources circulation system in the nation and to move away from natural resources dependence by importing fossil fuels from abroad as much as possible.

(3) Form an infrastructure to collect, sort, treat and stably supply plastic waste

The chemical industry will foster industry-government-academia collaboration to establish a new system to collect, sort and treat plastic waste as a material and to ensure the stable supply of plastic waste with stable quality in an amount that is necessary for the success of CR at commercial scale. The industry will also protect the health and safety of labors at the facilities treated recycled plastics. In

particular, it will implement initiatives below shown and the chemical industry will proactively adopt and take the measures, that are now under examination by the government's council.

1) Build a rational collection, sorting and treatment system
2) Establish a large scale and highly efficient collection system
3) Build a data platform for plastic waste and establish a waste management system for the integration of processes from collection to the supply of plastic waste

(4) Promote the development and actual implementation of CR technologies in society

In the future vision, it is focused on "circular CR" technologies, that are for recycling plastics waste into monomers, gasification and liquefaction, including conversion to oil/liquefaction by a coke oven. However, only a few in the "circular CR" technologies are currently in actual use. In order to gain widespread use of the "circular CR" technologies in society, it is important to develop innovative CR technologies in addition to securing a stable supply system of waste plastics as mentioned in previous clause.

The current status that applicable "circular CR" technologies for various types of plastic waste are as explained as follows;
Chemical recycling into monomers is promising high recycling rate because of the small recycling loop in process. But the materials chemically recycled into monomers are limited to PST (Polystyrene), MMA (Methyl methacrylate), PET (Polyethylene terephthalate) and some others, and it is applied to only plastic waste that contains a single material at a high rate in the collection and sorting process. Depending upon the purity and types of materials from waste, it is therefore important to consider which method to choose CR or MR as appropriate.

As for chemical recycling into oil, even the waste mixed by various plastic materials can be applied. In the case of treatment by using a naphtha cracker, PP (Polypropylene), PE (Polyethylene) and PST (Polystyrene) that have high CH (hydrocarbon) content and do not contain oxygen, are suitable. However, even if the plastic waste contains sulfur, nitrogen or oxygen, these substances can be removed by oil refining. In the case, a wider range of plastic materials are allowed to be treated that enables to increase the amount of plastic waste.

For the gasification technologies in CR, the targeted plastic waste can be more expanded to the plastic waste that cannot be treated by MR or cannot be converted to monomers or oil/liquefaction through CR. Gasification can use any dirty level of waste plastics, which are currently treated by Energy Recovery (ER) and landfill.

In addition to promoting the conventional MR of PVC (Polyvinyl chloride) waste, the polyvinyl chloride industry has supported to research and develop technologies to foster the CR of PVC (Polyvinyl chloride) waste, including the separation technology to extract PVC resin and chlorine from the waste. In the future, along with the development of various CR technologies, wider types of plastic waste can be treated by CR.

These technologies have basically been developed by each company, but JCIA will support and encourage each company's technology development to scale up and industrialize CR technologies, such as to reduce the use of energy, to cut the necessary cost, and to make plastic waste into monomers by the CR, which is still far from the commercialization, through industry-government-academia collaboration as much as possible

(5) Social implement of CR by Public financial support

Through industry-government-academia collaboration, the chemical industry will work toward obtaining financial supports to invest chemical recycling facilities, for which vast equipment investment is required. On the other hand, SMEs and local communities also play essential roles for the establishment of a circular economy. The industry will support employment promotion and local SMEs' revitalization by using existing local infrastructure provided by the private capital.

If CO_2 is proactively utilized in the CR process to convert plastic waste into other chemical materials, it is desirable to offer incentives according to the amount of CO_2 consumed for the conversion.

(6) Improve the value of plastic waste in resource circulation

In order to promote the industrialization of the recycling of plastic waste, the chemical industry has worked for CR technologies innovation to maintain the quality of recycled plastics same as virgin plastics as an essential technology. The CR has already been implemented outside Japan as the recycling rate of plastic waste has increased. It is critical to create and support ideas and needs such as the use of chemical recycled plastic products contributes to the environment and is valued and cool among consumers and consumer products manufacturers.

(7) Ensure traceability and develop certification system for recycled plastic quality

The chemical industry will build a series of systems, including a certification system to ensure the safety and a sense of ease of recycled plastics to the public. The systems will help consumers understand the social value brought by recycled plastics, and then develop a market for recycled plastic products. Specifically, through industry-government-academia collaboration, the chemical industry will move chemical recycling forward by certification based on by globally

recognized standards, for example, ISO standards. The standards specify the three key processes of chemical recycling: recycling into monomers, converting the recycled monomers into polymers, and processing the recycled polymers into products. The industry will also develop quality standards and process standards on chemical recycling technologies, and the standards for recycled products, which define content rate of recycled materials. In addition, the industry will consider creating a conformity assessment system and marking system, which can visually appeal to consumers, like the Eco Marking Program.

(8) Assess chemical recycling by Life cycle assessment (LCA) methodology

It is expected that total GHG emissions from energy use will decrease because of reduction of energy use for chemical recycling by technologies innovation and because of increase of using renewable energy as a major energy source in society. Additionally, in order to gain the general public's understanding regarding chemical recycling, the chemical industry will assess and publish environmental impacts, including GHG emission reduction brought by chemical recycling processes by considering the mass balance approach and by using LCA methodology.

JCIA has decided to take the following actions toward the strategic directions mentioned above:

(1) To get all the collective effort in the chemical industry and to formulate programs to develop chemical recycling-related technologies by the collaboration through industry-government- academia, in order to build and realize a "True Circular Society".
(2) To propose an international certification system for contributing to a substantial reduction of plastic waste overseas and for the global deployment of the Japanese chemical industry's technologies with economic rationality.
(3) To build a collaboration system that transcends conventional industrial boundaries and to propose reviewing the legal systems that ensure the stable supply of plastic waste in order to generate forsocial innovation across the value chain

IV. Conclusion

Through the JCIA member companies' innovation, the chemical industry has tackled plastics waste issues proactively to reduce, reuse and recycle the waste as resources to keep circulating efficiently and repeatedly. Toward the achievement of a carbon-neutral society by 2050, the chemical industry aims to significantly reduce GHG emissions from plastic waste. To this end, the industry will work to reverse the ratio of the one-way use of plastic products to the circular use of plastics. Chemical recycling led by the industry' technologies will be recognized an important recycling method that will help increase the plastic recycling rate. The chemical industry will sincerely strive to the following items:

1) To reduce the use of fossil resources substantially;
2) To demonstrate chemical industry as a solution provider;
3) To achieve the chemical recycling technologies industrialized, which make plastic waste into gases, monomers and oil; and
4) To set and achieve relevant numerical targets.

It is clear that there are extremely difficult challenges to implement the global Warming Countermeasures and to establish post-COVID-19 social system -New Normal domestically and globally. Accordingly, all industries should cooperate with each other and make all possible efforts toward the difficult challenges.

JCIA and its all stakeholders are committed making all possible efforts for contribution to establish a "True Circular Society" as a solution provider. JCIA earnestly expects that its stakeholders to refer to the future vision that helps the stakeholders to develop their specific programs/action plans to realize the strategic goals in the vision together.

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1) Japan Initiative for Marine Environment (JaIME)
In order to deliberate, plan, conduct, and promote measures as Japan's chemical industry including the plastic industry in view of the spirit of "Responsible Care" regarding the marine plastic problem which is being recognized as a political and global environmental issue, 22 companies centering on the Directors of the JCIA inaugurated "Japan Initiative of Marine Environment" (hereinafter called JaIME) on September 7, 2018.
Currently, 47 companies and organizations as members and three organizations as supporting members (as of March 31, 2019) have joined JaIME where the five organizations, the Japan Chemical Industry Association, the Japan Plastics Industry Federation, the Plastic Waste Management Institute, the Japan Petrochemical Industry Association, and the Vinyl Environmental Council, manage the joint secretariat.
For more information: see page 7
https://www.nikkakyo.org/sites/default/files/JCIA_annual_2019E.pdf

2) Japan Clean Ocean Material Alliance (CLOMA)
Japan Clean Ocean Material Alliance (CLOMA) was established in January 2019, consisting of companies responsible for consumer product supply chains. In order to solve current issues in marine plastic litter, it is necessary to collect plastic litter while also making efforts to prevent more plastics from flowing into the ocean. Leveraging the technology and knowhow accumulated by Japan's industrial community, CLOMA endeavors to accelerate innovation for the 3R (reduce, reuse and recycle) and alternative materials, and to encourage extensive plastic recycling through public-private partnerships.

For the CLOMA Action Plan:
https://cloma.net/wp-content/uploads/2020/08/CLOMA-ActionPlan_Eng-ver1-1-2.pdf
For the summary of the Action Plan:
https://cloma.net/wp-content/uploads/2020/09/CLOMA_actionplan_%E5%86%8A%E5%AD%90_%E8%8B%B1%E8%AA%9E%E7%89%88.pdf

3) Plastic Waste Management Institute（PWMI）

Originally founded in December 1971 as the Plastic Management Research Association, the Plastic Waste Management Institute (PWMI) received its current name in July of the following year as operations expanded. For the last 40 years or so, PWMI has endeavored to research and develop technology for the optimal processing and effective use of plastic waste and to publicize its findings.
PWMI's objectives were newly established in April 2013 as "surveying and researching the recycling of plastic waste and contributing to a reduction in environmental load by the total recycling of plastic, and helping plastic-related industries to expand their business soundly and contributing to the creation of a society capable of sustainable growth."
For the material flow diagram: see age 4 and 5
https://www.pwmi.or.jp/ei/siryo/ei/ei_pdf/ei49.pdf