20-D-0592
September 11, 2020

JCR provided pre-issuance verification report to PET Refine Technology Co., Ltd.

JCR conducted pre-issuance verification of PET Refine Technology's Green Loan as an approved verifier of Climate Bonds Initiative.

*Please see the pre-issuance verification report of PET Refine Technology's Green Loan as per the attached.

Pre-Issuance Verification Report of Long Term Loans borrowed by PET Refine Technology Co., Ltd.

Assurance Conclusion

Based on our limited assurance procedures, as described in this statement as of 31/January/2020, nothing has come to our attention which causes us to believe that Long Term Loans borrowed by PET Refine Technology Co., Ltd. does not meet the requirements of the Climate Bond Standard v2.1.

Scope of Work

PET Refine Technology Co., Ltd. is preparing to borrow the loans and intends to use the proceeds to finance investment in chemical recycling facility of consumed PET bottles (the "Eligible Green Projects").

PET Refine Technology Co., Ltd. commissioned JCR as an independent approved verifier Under the Climate Bonds Standard to conduct the Pre-issuance verification with Limited Assurance of the Green Loans (hereinafter, "Loan").

JCR engaged in this assurance services from 25 November 2019 to 31 January 2020.

Independence and Quality Control

JCR stipulates the rules in order to maintain its independence and to control its quality of this verification in its Code of Conduct, which is disseminated in its website.

https://www.jcr.co.jp/en/criterion/

Criteria

The Criteria for our procedures ('the Criteria') were:

• The Climate Bonds Standard v2.1 ('CBS') and the Waste Management Criteria (V1.0) dated December 2019

Responsibilities of PET Refine Technology Co., Ltd.

PET Refine Technology Co., Ltd. is responsible for the collection, preparation and presentation of the subject matter in accordance with the Criteria and for maintaining adequate records and internal controls that are designed to support the Loan.

Responsibilities of JCR

JCR is responsible for reviewing the information and documentation provided and developed by PET Refine Technology Co., Ltd. to assess the Green Loan's alignment with the CBS requirements:

- Conformance with the selection of nominated projects & assets requirements
- Conformance with the internal processes & controls requirements
- Conformance with the reporting requirements

JCR is conducting the following procedures for verification;

- Requesting the entity to provide qualified and reliable information for verification to JCR.
- Assessing the alignment of the Loan to Climate Bonds Standard and associated documentation provided by the Entity.
- Interviews of the Entity's relevant staff and managers related to the Eligible Green Expenditures to be financed by this Loan and those who plan the corporate's sustainability strategy.
- Assessment of evidences provided by PET Refine Technology Co., Ltd. against the Climate Bonds Standard 2.1. and the Waste Management Sector Criteria (December 2019)
- Setting up an internal committee to generate this Assurance Report and its conclusions.
- Providing this Limited Assurance Report.

The Limited Assurance Procedures are in accordance with relevant general principles & professional standards of independent auditing, and in line with the International Standard on Assurance Engagements other than Audits or Reviews of Historical Financial Information (ISAE 3000).

Level of Assurance

A limited assurance engagement consists of making enquiries and applying analytical, appropriate testing, and other evidence-gathering procedures sufficient for us to obtain a meaningful level of assurance as the basis for providing a negative form of conclusion and, as such, do not provide all the evidence that would be required to provide a reasonable level of assurance. The procedures performed depend on the assurance practitioner's judgement including the risk of material misstatement of the specific activity data, whether due to fraud or error.

While we considered the effectiveness of Management's internal controls when determining the nature and extent of our procedures, our review was not designed to provide assurance on internal controls. We believe that the evidence we have obtained is sufficient and appropriate to provide a basis for our conclusion.

Restriction on Distribution and Use of Assurance Report

This verification report for Climate Bonds Certification including all documentation provided alongside is intended for the use of PET Refine Technology Co., Ltd. and the Climate Bonds Standard Board. The present document may be disseminated by PET Refine Technology Co., Ltd., CBI and JCR. CBI and JCR agree to publish the report with the consent of PET Refine Technology Co., Ltd.

Verifier's Signature

Japan Credit Rating Agency, Ltd.

ATSUKO KAJIWARA

Supervisor, Chief Sustainable Analyst
Sustainable Finance Evaluation Department

HIROYA KAKIUCHI

Sustainable Finance Analyst
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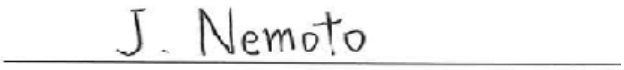

JUNYA NEMOTO

Environmental Scientist
Green Finance Promotion Department
Environmental Division

[31 January 2020]

ANNEX 1: Pre-Issuance Checklists

1.Selection of Nominated Projects & Assets		
Climate Bonds Standard Requirement	**Findings**	**Requirement Met**
1.1. The Issuer shall establish, document and maintain a decision-making process which it uses to determine the continuing eligibility of the Nominated Projects & Assets. This includes, without limitation: **1.1.1**. A statement on the environmental objectives of the bond. **1.1.2**. A process to determine whether the Nominated Projects & Assets meet the eligibility requirements specified in Part B of the Climate Bonds Standard.	The borrower establishes and documents a decision-making process which it uses to determine the continuing eligibility of the nominated projects and assets in its green finance framework (Annex 2). It includes a statement on the environmental objectives and a process to determine the nominated projects. Evidenced documents: Annex 2; Green Finance Framework (hereinafter, ANNEX 2)	✔
1.2. All Nominated Projects & Assets which are proposed to be associated with the bond shall meet the bond's documented objectives as stated under Clause 1.1 and will conform to the eligibility requirements under Part B of the Climate Bonds Standard.	The nominated project is a new investment to refurbish and resume operation of a plant located in Kawasaki City, Kanagawa Prefecture, which are facilities for chemical recycling of consumed PET bottles. (For more details of the project, please refer to ANNEX 2 and ANNEX 3, Technical Report produced by E&E Solutions (hereinafter, "ANNEX 3")). This nominated project is in line with the environmental objective of PET Refine Technology, that is, to contribute to realize a circular economy. JCR, together with sub-contractor E&E Solutions, an environmental technical expert, implemented technical verification of the project's eligibility as a Climate Bonds through documents provided and onsite examinations. JCR and E&E Solutions found that, with respect to the above procedures, the use of proceeds conform to the	✔

	eligibility requirement of Requirement 9 (Climate Bonds Taxonomy) under Part B of the CBS and the Waste Management Criteria as of December 2019. Among the sectors prescribed in Waste Management Criteria, the project conforms to "Material recycling: post-consumer waste facilities which recycle the secondary raw materials (plastic bottles) cease to be waste and are sold to be used as secondary raw materials. Evidenced documents: ANNEX 2, ANNEX 3	
1.3 The Issuer shall document the Nominated Projects & Assets which are proposed to be associated with the bond and which have been assessed as likely to be Eligible Projects & Assets. The Issuer shall establish a list of Nominated Projects & Assets which can be kept up-to-date during the term of the bond.	The borrower clarified its green eligible project category in its ANNEX 2. It submitted a list including description of the use of proceeds and fund allocation plan to the lender and to JCR. Evidenced documents: ANNEX 2	✔
1.4. Nominated Projects & Assets shall not be nominated to other Certified Climate Bonds unless it is demonstrated by the Issuer that distinct portions of the Nominated Projects & Assets are being funded by different Certified Climate Bonds or that the existing Certified Climate Bond is being refinanced via another Certified Climate Bond.	Due to the following reasons, the eligible green projects and assets are not nominated to other Certified Climate Bonds (all debt instruments included in the definition in CBS including green loans). 1) It is the first green bond issued by PET Refine Technology. 2) All the proceeds are planned to use for new investments. Evidenced documents: Simulation Cash Flow	✔
1.5 The expected Net Proceeds of the bond shall be no greater than the Issuer's debt obligation to the proposed Nominated Projects & Assets, or the Fair Market Value of the proposed Nominated Projects & Assets which	JCR affirmed that net proceeds of the loans are no greater than the borrower's debt obligation to the proposed nominated projects through the investment plan submitted by the borrower.	✔

are owned by the Issuer.	Evidenced documents: Investment Plan including simulated cash flows	

2. Internal Processes & Controls		
Climate Bonds Standard Requirement	**Findings**	**Requirement Met**
2.1. Tracking of proceeds: The Net Proceeds of the bond can be credited to a sub-account, moved to a sub portfolio, or otherwise tracked by the Issuer in an appropriate manner and documented.	The borrower will manage the proceeds by separated sub-account exclusively for this project. It will prepare a management ledger in order to check the allocation status by items monthly. The management process will be the subject of an internal and external audit to be conducted by a professional accountant in order to ensure appropriate internal controls. Evidenced documents: ANNEX 2, Management ledgers	✔
2.2. Managing unallocated proceeds: The balance of unallocated Net Proceeds can be managed as per the requirements in Clause 6.2	The borrower will manage unallocated proceeds in a separated account as cash or cash equivalents in accordance with the requirement stipulated in Requirement 6.2. of CBS. Evidenced documents: ANNEX 2	✔
2.3 Earmarking funds to Nominated Projects & Assets: An earmarking process that can be used to manage and account for funding to the Nominated Projects & Assets and enables estimation of the share of the Net Proceeds being used for financing and refinancing.	Earmarked funds for the eligible green project will be managed and funded in accordance to the fund allocation plan and its process. It is clarified that all the proceeds will be used for new investment. Evidenced documents: Fund raising and allocation plan, ANNEX 2	✔

3. Reporting Prior to Issuance		
Climate Bonds Standard Requirement	**Findings**	**Requirement Met**
The Issuer shall disclose in the Bond Disclosure Documentation:		
3.1. The investment areas, as provided in Clause 9.1, into which the Nominated Projects & Assets fall.	The borrower will disclose to the lender its investment areas into which the green eligible projects fall through the following documents; Evidenced documents: ANNEX 2, ANNEX 3 and Investment Plan with simulation cash flows.	✔
3.2. The intended types of temporary investment instruments for the management of unallocated proceeds in accordance with Requirement 2.2.	The borrower will disclose to the lender the intended types of temporary investment instruments as cash and cash equivalent in ANNEX 2. Evidenced documents: ANNEX 2	✔
3.3. The Verifier selected by the Issuer for the pre-issuance and the post-issuance engagements.	The borrower selected JCR (including technical assessment made by E&E Solutions) for the Verifier of pre-issuance and the post-issuance engagements. The borrower will disclose to the lender the verification report and technical assessment report to the lender. Evidenced documents: Annex 2 and ANNEX 3	✔
3.4. Whether periodic Assurance Engagements will be undertaken during the term of the bond to reaffirm conformance with the Climate Bonds Standard, and the expected frequency of any periodic Assurance Engagements	JCR will undertake periodic assurance engagements within 12 months after the implementation of the loans and annually during the repayment period to reaffirm conformance with the CBS. Evidenced documents: Verification application form（JCR-PRT contract）	✔

4. Climate Mitigation Checklist		
Climate Bonds Standard Requirement	**Eligibility Criteria**	**Met**
Recycling and Reuse (Table 6, page 11 of the Waste Management Criteria, December 2019)	The secondary raw materials (such as steel, aluminum, glass, plastics) cease to be waste and are sold to be used as secondary raw materials.	✔

5. Climate Adaptation and Resilience Checklist		
Climate Bonds Standard Requirement	**Findings**	**Requirement Met**
Section 1: The issuer identifies the climate related risks and vulnerabilities to the asset/site		
Processes are in place (as part of both the asset design and ongoing management) to assess key risks to the assets from a changing climate. These key risks should include the following, plus any others felt to be of concern for the operation of these assets. The risks should be identified and interpreted in terms of the impact on the asset and the related effects for the business – e.g. impact on operating feasibility and schedules, and potential system outages, impact on maintenance requirements etc. N.B. This list taken from World Banks Climate and Disaster Risk Assessment Tool ● Temperature changes, and extremes in temperature ● Extreme precipitation and flooding ● Drought ● Sea level rise and storm surge	● The Borrower has established a Crisis Management Manual (contingency plan) which addresses possible damages from typhoon, high tide, extreme water, flood, etc. incorporating climate change risks and stipulates countermeasure policies in the disaster prevention rules. ● The Manual is planned to be reviewed annually after the evacuation drills will be conducted. ● The plant is located in a special disaster prevention area based on Japan's relevant laws and is identified as special operation office. It locates in the area where the laws designate any facilities located in this area as a special operation office. A special operation office is responsible for preventing the disasters. In order to do so, they prepare disaster preventing equipment/facilities in its plant and it is also required to establish disaster prevention rules. These are the obligations of the designated special operation offices under the law. ● The hazard map made by the local government of Kawasaki-City, the plant may be susceptible to flooding in case of high tides. In order to adapt and mitigate this risk, the plant area is 1	✔

● Strong winds How these affect the asset or site in question will be highly variable and will be for the issuer to identify and relate to their operations. These assessments should use climate information, modelling and scenarios from a peer-reviewed source. This assessment should be done regularly. The frequency of the assessment will depend on the nature of the climate related risks and vulnerabilities, and should be specified by the issuer and reported against in subsequent annual reporting.	meter higher than the neighboring lands. Risk assessments are made utilizing government published data. From the above, JCR affirms that processes are in place to assess key risks to the assets from a changing climate. Evidenced documents: Relevant laws (Oil complex disaster prevention acts), Crisis Management Manual, Total Risk Management System, facilities disaster mitigation measures	
Section 2: The issuer identifies the impacts in larger context (spatially and temporally) beyond the asset/site (i.e. the impacts of the underlying assets and projects on the broader ecosystem and stakeholders in that ecosystem)		
Processes should be in place (as part of both the asset design and ongoing management) to assess the impact of the waste management asset on the climate resilience of other stakeholders in the social, economic and environmental system in which it operates and how to mitigate or reduce any negative impacts These assessments address: Any ways in which waste management facilities might affect the climate resilience of other users/stakeholders? Any ways in which waste management facilities improve the adaptation capacity of other users/stakeholders? For example, they may include: Impact on water quality and quantity for	● The plant has established disaster prevention rules and its members of staff participate in the region's disaster prevention committee to share the possible adverse impacts from the disasters in larger context. ● The wastewater from the plant is appropriately treated and is released to the outside as clean water. Waste is treated as industrial waste materials and part of it will be sold as recycling materials. ● In the event of fire, necessary evacuation plans are stipulated. The plant has set up self-powered generation facilities in case of blackout. ● The plant is located in industrial area and, therefore, there are no schools, hospitals or housing in its proximity. Based on the above, JCR confirms that:	✔

other users in the basin Waste and pollution emitted Fire hazards	• processes are in place (as part of both the asset design and ongoing management) to assess the impact of the asset on the climate resilience of other stakeholders in the social, economic and environmental system in which it operates • The facility has processes in place that mitigate or reduce any negative impacts on other stakeholders Evidenced documents: Relevant laws (Oil complex disaster prevention acts), Crisis Management Manual, Total Risk Management System, facilities disaster mitigation measures	
Section 3: The issuer has designed and implemented strategies to mitigate and adapt to these climate risks and vulnerabilities		
An adaptation plan has been designed and is being implemented to address the risks identified in the assessments above. The issuer has designed or amended asset maintenance plans to ensure that scheduled maintenance is sufficient to cope with the ongoing impacts of climate change; and a plan has been established to govern how to approach emergency maintenance needs arising from sudden climate change impacts (e.g. extreme storms). The issuer has training, capacity and governance arrangements in place for how the organisation will deal with the impacts of exceptional events (e.g. droughts, floods, severe pollution events, extreme storms, winds etc.).	● The borrower has established a Crisis Management manual. It stipulates periodical training, emergency process, etc and it will be revised, if necessary, after considering any new risk assessment. ● The plant aligns to disaster prevention plans in the bay area in Kawasaki-City as well as to regional adaptation plans. ● The plant has nominated a disaster prevention administrator and members of staff are periodically trained accordingly. ● In order to prevent heat illness, the facility's management team will educate members of staff to drink water and rest sufficiently. In addition, a safety committee will also conduct training sessions to members of staff. Based on the above, JCR confirms that facility has a policy to mitigate and adapt to the climate risk. Once the plant will re-open, it is planned to operate in	✔

The issuer has monitoring and reporting systems and processes to identify high risk scenarios. The issuer has contingency plans to address disruption to operations or loss of the asset and any resulting environmental or social damage. The issuer has processes for feeding risk assessment back into decision-making. The issuer has a budget allocated to implementing the adaptation plan and has a named member of staff responsible for its implementation. The issuer complies with any existing broader or higher-level adaptation plans, such as NAPAs.	compliance with the rules and process described above. Evidenced documents: Relevant laws (Oil complex disaster prevention acts), Crisis Management Manual, Total Risk Management System, facilities disaster mitigation measures.	

ANNEX 2: Green Finance Framework PRT

ANNEX 3: Technical Due Diligence Report of Chemical Recycling Plants (Technical Evaluation Report on Qualified Green Projects)

ANNEX 4: List of Verification Procedures Performed by the Verification Team to Verify Compliance of the Green Loan with CBS

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foreseeable or unforeseeable.

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JOB No.: C-4900554-RT3

ANEEX 3
Tentative English Translation

Technical Due Diligence Report
for Chemical Recycling Plants

2020 January

E&E Solutions Inc.

Disclaimer

This report shows the results of technical due diligence work for chemical recycling plant which is planned by Pet Refine Technology Co., Ltd. (hereinafter, “PRT) as a subsidiary of Japan Environment Design Co., Ltd. (hereinafter, “JED”).
In this report, the technical aspects are evaluated on the basis of interview with PRT and review of existing materials based on E&ES expertise and experiences.
It should be noted that the results presented in this report are not definitive and may not be covered all facilities of the project.
E&ES evaluates based on referenced documents and information, but are not responsible for any damage caused by errors in these materials or information.

CONTENTS

1. Introduction

PRT is the company which conducts PET bottles recycling business, who possesses proprietary chemical recycling technologies to decompose the used PET bottles into molecular level and produce PET resins.

In 2004, Pet Reverse Co., Ltd., the predecessor company, established a recycling plant with government subsidy as a business operator in Eco-Town[1], Kawasaki City. In 2008, Toyo Seikan Co., Ltd. succeeded the business in the year, and the company name was changed to Pet Refine Technology Co., Ltd. (PRT). In April 2018, the company transferred its shares from Toyo Seikan Co., Ltd. and became a wholly owned subsidiary of Japan Environment Design Co., Ltd.

The plant operation was shut down in August 2017, and capital investments are currently planned to resume the operation. As it is planned to procure some of the capital investment funds through green loans, the purpose of this report is to evaluate the Chemical Recycling Plant of PRT.

2. Project Evaluation Method

In this evaluation, the following items are selected.

Evaluation items	Details of evaluation
Environment	Energy input and CO_2 emissions (energy balance) Input of substances and materials (material balance)
Technology	Comparison with virgin materials/Comparisons with a similar technology
Management system	Disaster-prevention measures (including BCP) and environmental management system

[1]The " Eco-Town Project" is the basic initiative for the formation of an environmentally conscious economy and society in the region based on the government's "Zero Emissions Initiative".
At the same time, this project aims to promote advanced environmentally conscious town development by promoting it as a cornerstone of regional development. The Kawasaki City Eco-Town is the first certified area in Japan.

3. Business Overview

(1) Corporate Data

Company name	PET Refine Technology Co., Ltd.
Representative	Masaki Takao
Established	October 2008
Capital	80 Million yen
Shareholders	Japan Environment Design Co., Ltd. 100%
Employees	11 (as of October 2018)
Location	12-2, Ogimachi, Kawasaki-ku, Kawasaki-City, Kanagawa (Ogimachi area of Kawasaki Eco-Town)
Factory land area	50,970m^2
Business	Chemical recycling from PET bottles using the BHET method

Assumptions after re-operation (Source: Business Plan in May 2019)

Re-operation period	October 2020
Production and sales	(1) From PET bottles to PET bottles Chemical recycling: up to 23,000 tons per year (maximum) (2) From PET bottles to raw materials from which PET products are made Material recycling: Maximum annual flakes of approximately 9,600 tons Pelletize approx. 3,000 tons
Total sales	6,772 Million yen

Fig. 3-1 shows the appearance of the factory and Fig. 3-2 shows the overall view of the factory.

Figure 3-1 Appearance of the Plant

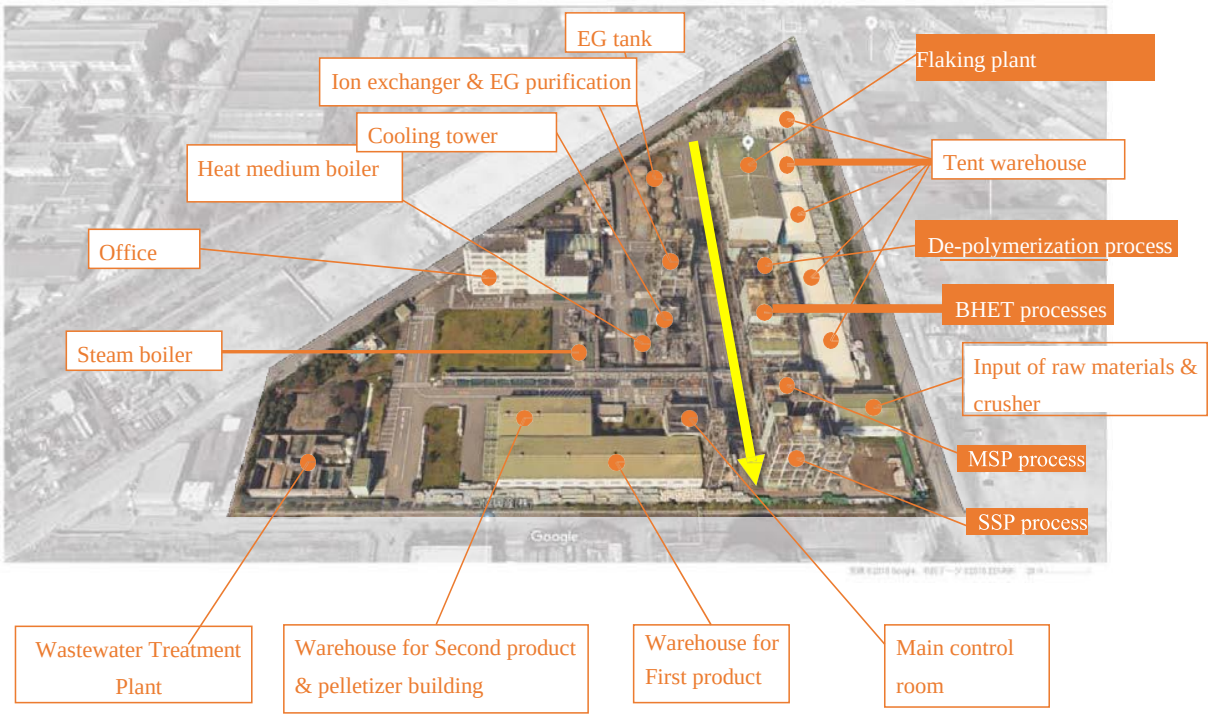

Figure 3-2 Overall Plant Chart

(Source: Summary of PET Refinery Technology Co., Ltd.)

(2) The Process

This plant consistently conducts from the pretreatment of used PET bottles to the production of PET resins by chemical recycling. Although some other chemical recycling plants are developed as technical pilot projects, this recycling plant was operated as a commercial plant from 2009 to 2017.

In this plant, chemical recycling is carried out using the BHET method, which is a proprietary technology. The BHET method is a chemical decomposition process "Depolymerization" of PET resins with many impurities. Then, BHET (bis-2-hydroxyethyl terephthalate) is generated, and the technology is used to remove contaminants, increase purity, and polymerize it back into PET resins. The recycling process by the BHET method is divided into (1) flaking process, (2) depolymerization and purification process, and (3) polymerization process.

Table3-1 The Recycling Process by the BHET Method

(1) Flaking process	• PET bottles used as raw materials are carried in bales (compressed and packed lumps) • Separate cans, labels, and other different products from the bale, and remove contaminants by separating them by wind or specific gravity in the pulverizing and sorting process. • After removing contaminants, crush into small pieces about 15mm on a side to make pet flakes.
(2) Depolymerization and purification process	• Depolymerization with ethylene glycol • After depolymerization, BHET crystallization is produced by decolorizing with activated carbon or removing metallic ions with cation-exchange resins. • Purify BHET to make purified BHET
(3) Polymerization process	• Purified BHET is polymerized to form PET resins.

Process characteristics

- Used PET bottles are put into a pre-treatment facility after they are transported and converted into flakes. Flakes (15mm sq.) used as raw materials for their chemical recycling and flakes (typically 8mm sq.) sold as raw materials for material recycling to other companies are produced.
- By depolymerization and purification process, all contaminants such as catalysts and colorants can be removed.
- Activated carbon used for de-colorization is recycled in the plant and reused.

Process update after re-operation

- The introduction of a new alkali cleaning facility makes it possible to recycle unvalued low-quality bales that were previously simply incinerated.
- Although the water usage volume and wastewater volume increase for alkaline cleaning, a part of wastewater is reused through the treatment of a new primary wastewater treatment facility.

Characteristics of PET resins produced by this process

- It is possible to produce high-purity PET resins equivalent to virgin materials.
- The PET produced through this process has been approved as NOL (No Objection Letter: Opinion Letter that it is acceptable for food-contact container applications) by U.S. Food and Drug Administration (FDA). Therefore, all PET produced by this technology can be used as PET bottles for drinking use.
- Since 2012, Ajinomoto General Foods Co., Inc. (currently Ajinomoto AGF Co., Inc.) has used these PET resins as a container for PET-bottled coffee.

4. Project Evaluation [Environment]

(1) Energy Input and CO_2 Emissions (Energy Balance)

The energy input at this plant is electricity and city gas. Table 4-1 and Table 4-2 show the annual electric power consumption and annual city gas consumption in each process in the re-operation plan. The total annual power consumption in the re-operation plan is 29,239,486kWh, and the annual city gas consumption is 9,087,154Nm^3.

Table 4-1 Annual Electricity Consumption in Each Process

Process	Electricity consumption （kWh）
Flaking process	4,243,776
Depolymerization and purification process	16,067,038
Polymerization process (melt polymerization)	5,806,337
Polymerization process (solid layer polymerization)	3,122,334
Total	29,239,486

Table 4-2 Annual Gas Consumption in Each Process

Process	Gas consumption （Nm^3）
Flaking process	353,283
Depolymerization and purification process	6,430,257
Polymerization process (melt polymerization)	1,729,264
Polymerization process (solid layer polymerization)	574,349
Total	9,087,154

In FY2015, the annual electricity consumption was 23,702,400kWh and the annual consumption of city gas was 6,645,600Nm^3. The results in FY2015 show lower energy consumption, but it is not possible to make a simple comparison with the data value of the re-operation plan because production and plant operating hours are different. For these reasons, comparison is made based on the energy consumption per amount of production. The results are shown in Table 4-3 and Table 4-4.

Table 4-3 Comparison of Electricity Consumption per Amount of Production

Item	FY2015	Re-operation plan
Annual Electricity Consumption (kWh)	23,702,400	29,239,486
Amount of production of PET Resins (t)	17,640	22,649
Electricity Consumptions per Amount of Production (kWh/t)	1,344	1,291

Table 4-4 Comparison of City Gas Consumption per Amount of Production

Item	FY 2015	Re-operation plan
Annual Gas Consumption (Nm^3)	6,645,600	9,087,154
Amount of production of PET resins (t)	17,640	22,649
City Gas Consumption per Amount of Production (Nm^3/t)	377	401

Expected energy consumption of equipment planned to be renewed differs from that of FY 2015, which is measured by equipment manufacturers. Electricity consumption per amount of production is 1,344kWh/t in FY 2015, that of the re-operation plan is 1,291kWh/t, city gas consumption per amount of production is 377Nm^3/t in FY 2015, and that of the re-operation plan is 401Nm^3/t. Energy consumption per amount of production by re-operation is expected to increase or remain at the same level compared to that in FY 2015.

The annual power consumption of the plant under the re-operation plan is multiplied by the 0.000496 tCO_2 /kWh of the emissions coefficient of the Tokyo Electric Power Grid in FY 2018. The amount of CO_2 emissions of the plant is 14,503t. In addition, the annual city gas consumption of the plant under the re-operation plan is multiplied by the 2.23 tCO_2/1,000Nm^3 of the emissions coefficient of city gas under Greenhouse Gas Emissions Calculation, Reporting and Disclosure System. The amount of CO_2 emissions of the plant is 20,264t. The sum of 14,503tCO_2 emissions from electricity and 20,264tCO_2 emissions from city gases is 34,767t of annual CO_2 emissions. This value is divided by 22,649t of planned amount of production, so the CO_2 emissions per amount of production are 1.54tCO_2 /t.

(2) Input of Substances and Materials (Material Balance)

Table 4-5 shows the material balance between input and output of each process.

In the re-operation plan, the plant will receive 24,741t of bales per year, produce 19,551t of flakes decontaminated, and commercialize 22,649t of PET resins by the BHET method.

In each process, chemical substances are introduced in order to carry out chemical reactions, and waste and wastewater are generated in the process of the reaction. The total input is 33,890t, and the total output is 32,082 t. Although there is a difference between these values, it is considered that this difference is caused by some substances flowing out into the wastewater. The treatment of main wastes and wastewater discharged from the process will be described later in Chapter 6. Project Evaluation [Management System].

Table 4-5 Material Balance for Chemical Recycling

Input	Amount (t)	Process	Emissions	Amount (t)
Waste PET bottle bale	24,741	Flaking process	PET bottle cap	990
			Waste plastic, process waste	2,285
			Wastewater sludge	164
Depolymerization catalyst	202	Depolymerization and purification processes	Diethylene glycol ester	4,378
Wastewater treatment chemicals (Excluding neutralizing agents)	44		Waste plastic, process waste	186
Wastewater treatment neutralizer*	0		Wastewater sludge	31
NaOH for reusing ion exchange resins	205		Discharged water in the process of dehydration from ethylene glycol	94
HCl for reusing of ion exchange resins	283			
Terephthalic acid	5,251	Polymerization process (melt polymerization)	Waste plastic	46
Ethylene glycol	2,865		Wastewater sludge	10
Isophthalic acid	284		Produced water	1,202
Antimony trioxide	7			
Phosphoric acid	4			
Cobalt acetate	4			
		Polymerization process (solid layer polymerization)	Waste plastic	46
			Products of PET resins	22,649
Input	33,890	Total	Output	32,082

* It is neutralized and discharged with wastewater.

5. Project Evaluation [Technology]

(1) Comparisons between BHET Method Used in This Project and the Ordinary Production Process

In this evaluation, we compare the chemical recycling (BHET method) used in this project with the production of PET resins from petroleum-derived virgin materials (ordinary production processes).

A similar comparison has been made by National Institute of Advanced Industrial Science and Technology (2004). Table 5-1 shows the system boundaries of environmental impacts in chemical recycling and in ordinary production process.

Table 5-1 Comparison of Processes and System Boundaries

Processes	System boundary
Chemical recycling	・Carried-in Bales ~ Monomerized~ PET resins ・Treatment of Residue
Ordinary production processes	・Carried-in Bales~ Simple incineration ~ Reclamation ・Crude oil ~ Production of PET resins

Source: Compiled from National Institute of Advanced Industrial Science and Technology (2004)

In this report, the effects of reducing CO_2 emissions from various chemical recycling methods and ordinary production process are calculated. The results are shown in Figure 5-1. The "alternative system" indicates the ordinary production process, and the "waste treatment" indicates simple incineration in the graph. Since the CO_2 generated by this incineration process is CO_2 derived from petroleum, which is a raw material of virgin materials, it can be considered as CO_2 due to the use of petroleum resources.

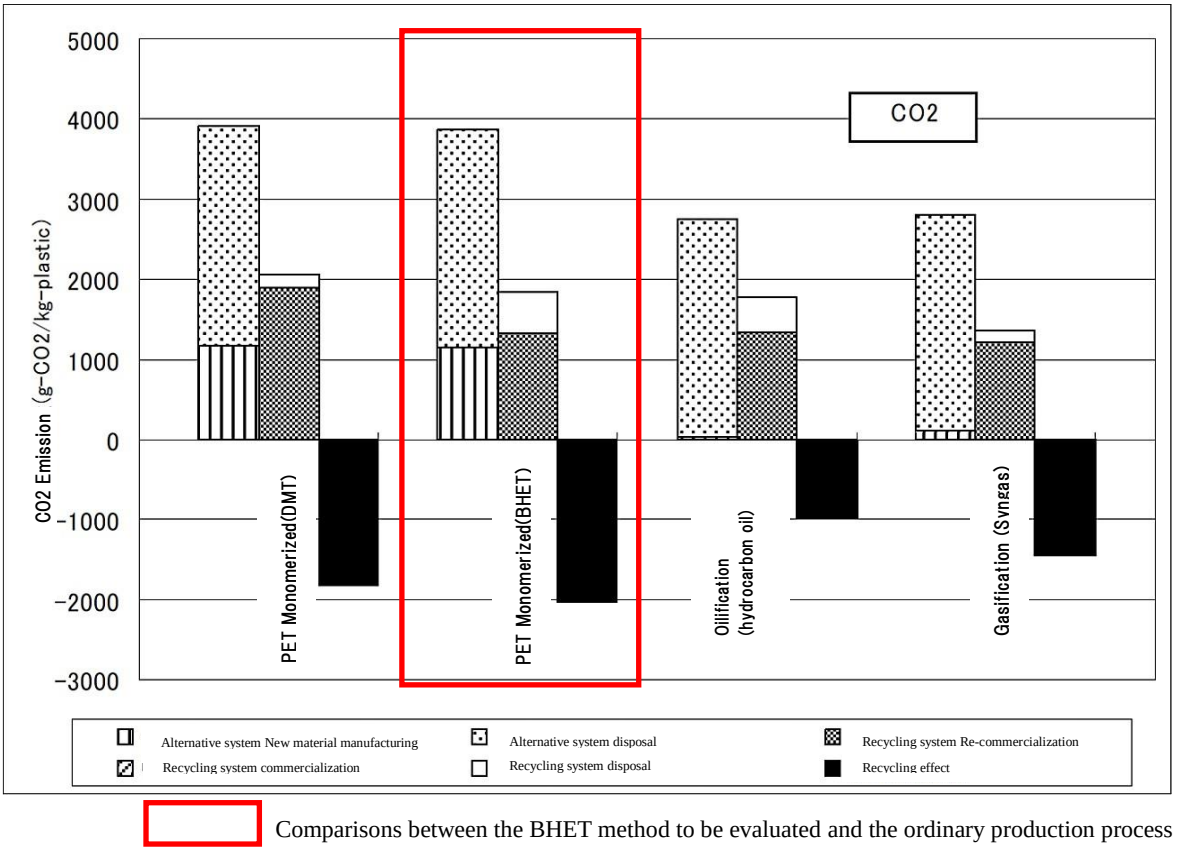

Fig. 5-1 Effects of Recycling by Chemical Recycling on CO_2 Emissions

Source: National Institute of Advanced Industrial Science and Technology (2004)

According to Fig. 5-1, CO_2 emissions in ordinary production process are approximately 3,800gCO_2/kg plastic whereas CO_2 emissions in the BHET method used in this project are approximately 1,800gCO_2/kg plastic. Therefore, it is considered that CO_2 reduction effects are approximately 2,000gCO_2/kg plastic. In the case of the ordinary production process, most of the CO_2 emissions are from waste treatment, so it leads to CO_2 emission generation (about 2,700gCO_2/kg plastic) associated with the use of petroleum resources as raw materials. Therefore, even if the energy efficiency of the PET production plant has improved drastically since 2004 when this report was prepared, CO_2 emissions of ordinary production process seems to remain higher than that of the BHET method. Thus, it is considered that the CO_2 reduction effect by the BHET method has kept compared to ordinary production method.

In conclusion, chemical recycling (BHET method) used in this project can reduce CO_2 emissions compared to ordinary production processes.

(2) Comparison with a Similar Technology

Mechanical recycling is a method other than chemical recycling for "bottles to bottles" in which used PET bottles for foods are made into raw materials and reused as new PET bottles for foods. In Japan, Kyoei Industry Co., Ltd. succeeded in commercialization of mechanical recycling plant for the first time.

The mechanical recycling process consists of two steps: flakes making process and pellets making process. First, flakes are produced by a usual material recycling process such as grinding and washing. The flakes are subjected to a condensation polymerization reaction under special conditions of vacuum and high temperature to remove contamination, and then pelletized. A condensation polymerization reaction is a reaction in which a plurality of compounds are combined (condensed) while removing small molecules (e.g., water) in the molecules of each other, and they are connected in a chain to form (polymerize) a polymer. This reaction makes it possible to recover the intrinsic viscosity (IV value) of the resins and to produce regenerated resins with a high IV value suitable for PET bottles.

As chemical recycling and mechanical recycling are compared, it is difficult to completely remove all contaminants and colorants, and to use recycled resins for high-performance applications in mechanical recycling. It is also necessary to perform advanced washing in the pretreatment stage. However, it is said that large-scale facilities are not required as large as chemical recycling, and energy consumption and production cost can be suppressed.

Meanwhile, in chemical recycling, contaminants and different materials are removed by the depolymerization and repolymerization process, so that it is possible to accept waste PET bottles of low quality which have not been used as raw materials. In addition, since the same quality as virgin resins can be ensured, it is highly versatile such as being able to cope with high-performance applications.

At current, 2019, 50 PET bottle recycling facilities of 45 companies have been registered in Japan (in the second half of FY2019). The recycled raw materials (flakes, pellets, polyester raw materials) are used in various applications, such as PET bottles, sheets used in food trays and blister packs, automobile interiors, textiles for clothing, and molded products such as pouches for food products. As shown in Fig. 5-2, about 27% of the 276,400t of total PET resins recycled in FY2018 were recycled into PET bottles.

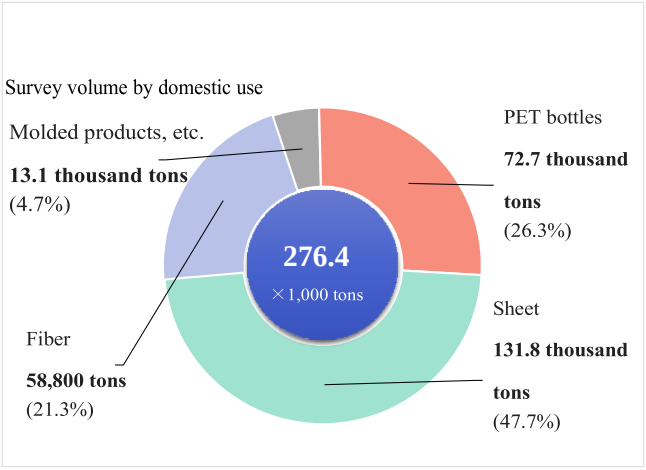

Fig. 5-2 Breakdown of Recycled PET Resins by Uses (FY2018)

Source: Prepared from The Council for PET Bottle Recycling (2019)

Figure 5-3 shows the amount of recycled flakes for domestic use over the past five years. Although the total amount of recycled flakes used has been on an increasing trend, looking at each intended use, the demand for bottles to bottles has been increasing, almost doubling in the past five years.

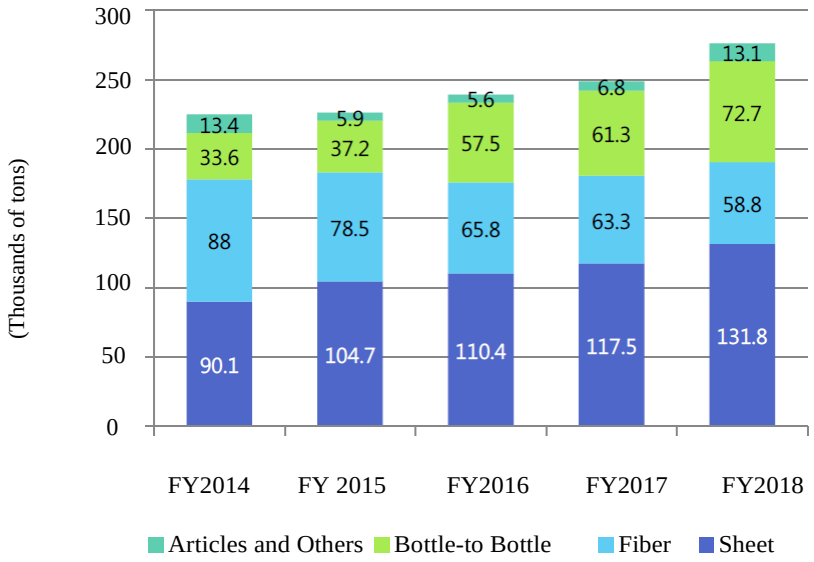

Fig. 5-3 Amount of recycled flakes by domestic use

Source: Prepared by The Council for PET Bottle Recycling

In recent years, the marine plastic problem has attracted attention, and beverage manufacturers and others are actively using recycled materials for PET bottle containers of their own products.

Table 5-2 Targets for PET Bottle Recycling by Beverage Manufacturers

Company Name	Policies and plans	Goal
Kirin Holdings Company, Limited	Kirin Group Plastic Policy	We change 50% of PET resin used in Japan into recycled resin by 2027 We achieve 100% effective use of PET bottles by 2030
The Coca-Cola Company	Global Plan for a Society with Zero Waste	We promote collection and recycling of all bottles and cans used in products by 2030
Suntory Holdings Limited	Plastic basic policy	By 2030, we will switch 100% of all PET bottle materials used globally to recycled materials and vegetable-derived materials, aiming to achieve zero new use of fossil-derived materials.
Evian (Danone)	Circular Brand by 2025	We make PET bottles from 100% recycled plastic by 2025
National Federation of Soft Beverages	Plastic resource recycling declaration of the soft drink industry	The soft drink industry comes together, and in cooperation with customers, governments, local governments and related organizations it aims for 100% effective use of PET bottles by FY2030

Source: Prepared from each company's website

Currently, only a part of waste PET bottles is recycled into PET bottles, but demand for bottles to bottles is increasing year by year. It is also anticipated that the demand for recycled PET resins for applications other than bottles will increase.

For this reason, in mechanical recycling, which initial investment is small and entry is easy, it is expected that the number of new entrants and existing operators who will start expanding the capability of existing plants will increase. However, stable procurement of high-quality waste PET bottles containing few contaminants will become difficult from the cost point of view. In order to meet vigorous demand, chemical recycling, which can utilize low-quality waste plastics containing many impurities and waste plastics that are difficult to recycle, such as multilayered structures, as raw materials, can be said to be technically superior. As of December 2019, this chemical recycling plant is the only one in Japan, and the technology of PRT is highly regarded as superior.

Incidentally, by expanding the size of the pretreatment facility and introducing equipment such as alkali cleaning in this re-operation, efficiency improvement and capacity expansion for the preparation of high-quality PET bales as raw materials from low-quality plastic will be realized. This will make it possible to supply raw materials to other mechanical recyclers in addition to in-house processing.

Chemical recycling and mechanical recycling are expected to coexist exploiting their respective characteristics in expanding markets.

6. Project Evaluation [Management System]

(1) Disaster Prevention and BCP (Business Continuity Plan)

In recent years, weather disasters such as wind and flood damage caused by typhoons and heat stroke caused by record-breaking heat have increased, and the importance of business continuity plans (BCPs) and disaster prevention plans is growing among enterprises. In addition, in the case of the project, which is a chemical plant, preparation of appropriate measures for risk avoidance and reduction are required in advance so as to minimize the damage by fires and explosions in the event of disasters.

1) Crisis Management (Emergency Response) Manual

The Crisis Management (Emergency) Manual developed by Japan Environment Design Co., Ltd., the parent company of PRT, is applied to the project. This manual stipulates prior agreements and emergency responses to implement effective crisis management associated with disasters and accidents that are expected to occur during plant operations of Japan Environment Design Co., Ltd., and corresponds to the BCP (Business Continuity Plan). The responsible department for Emergency Response will be set at the plant site and head office, and a dual response will be taken. Evacuation drills are conducted once a year in accordance with this manual.

This manual is to be reviewed regularly.

2) Responsibilities as a specified facility under the Act on the Prevention of Disaster in Petroleum Industrial Complexes and Other Petroleum Facilities

Ogimachi area where the plant is located is designated as a special disaster prevention area specified in the Act on the Prevention of Disaster in Petroleum Industrial Complexes and Other Petroleum Facilities, and the plant is designated as a specified plant in the area. Specified plants are responsible for preventing disasters, and are obliged to establish specified disaster prevention facilities, etc. and to prepare disaster prevention regulations, etc.

From the above 1) to 2), it is considered that the disaster response is appropriately carried out even after the re-operation.

(2) Environmental Management

Before stopping previous operations, PRT established an Integrated Management System (TMS) document in April 2017 that integrates the Quality Management System and the Environmental Management System. TMS has identified the environmental aspects of the company's business and established practical rules for implementing environmental management activities.

Major environmental impacts from the plant include wastewater, air emissions, noise, and waste.

1) Wastewater

General industrial wastewater from the plant is treated at wastewater treatment facility within the plant site and discharged into the public sewerage system. On the other hand, wastewater containing high-concentration dioxane generated in the ethylene glycol dehydration process is expected to generate about 4,700t per year according to the re-operation plan, and is scheduled to be treated as industrial waste.

2) Air emission

The process generates nitrogen oxides (NOx) as air pollutants. In the past operation, emission measurements and reports to the government were carried out in accordance with the Air Pollution Control Act.

3) Noise

Crusher and blower are installed into the flaking plant, and the plant is designated as control area for category III by working environment measurement. It is stipulated that workers engaged in work within the category III area shall use noise prevention equipment as necessary. Since the plant is located in an industrial area, and there are no private houses, schools, hospitals, etc. in the surrounding area, the impact on the surrounding environment due to noise is considered to be minor.

4) Waste treatment

Plastic waste and sludge from wastewater treatment process are categorized as industrial waste, and about 2,800t are generated in total in the re-operation plan and disposed of in accordance with regulations.

As by-product in the process, caps and labels of waste PET bottles and ethylene glycol, which cannot be regenerated with a large amount of impurities, are generated, but they are scheduled to be sold.

It is considered that the environmental protection measures described in 1) to 4) above are appropriately managed when the integrated management system is maintained and operated after the re-operation.

7. Summary

(1) Overall Evaluation

Since PET bottles are containers for drinking purpose, safety standards and consumer requirements are high, and the quality standards required for recycled materials are more stringent than other use of PET.

At present, more than 80% of waste PET bottles are recycled (from The Council for PET Bottle Recycling (2019)), but most of them are recycled into other types of products through material recycling (see Fig. 5-2). That is, as the materials of the PET bottles, virgin materials mainly derived from petroleum are used. In order to increase the ratio of recycled materials in raw materials for PET bottles, the chemical recycling subject to this evaluation, which is the technology that enable bottle-to-bottle recycling, is considered to play an important role in the PET bottle recycling market. The reason for this is the following.

- Contribution to the circular economy

In May 2019, the Japanese government published the “Resource Circulation Strategy for Plastics" as a strategy to comprehensively promote the recycling of plastic resources. The Strategy states, "Based on the basic principles of the Basic Act on Establishing a Sound Material-Cycle Society, we will optimize material recycling, chemical recycling, and heat recovery in accordance with the quality and nature of the segregated and sorted plastic resources, thereby maximizing the effective use rate of resources." In the Strategy, chemical recycling is regarded as an effective means for maximizing the effective utilization rate of resources.

- Contribution to the effective utilization of limited resources

According to the Subcommittee for Resource Circulation Strategy for Plastics (2018) of the Central Environment Council, it is expected that the amount of plastic disposed will continue to increase globally. Although crude oil used as raw materials of plastics accounts for only a few percent in total (Society for Recycling and Use of Plastics (2019)), plastic production consumes petroleum, and it is necessary to reduce the amount of crude oil usage for plastics from the viewpoints of saving of exhaustible resources and countermeasures against global warming.

In addition, it has been pointed out that Japan has the second largest volume of waste containers and packaging (per capita) in the world, and import restrictions on plastic waste have come to be enforced in China and other Asian countries. Therefore, it is necessary to establish a resource recycling system within Japan more than ever before.

Based on this background, chemical recycling, which can effectively utilize waste PET bottles, is very useful from the viewpoint of waste reduction.

- Indirect contribution to marine plastic issues

Marine pollution caused by marine plastic debris is spreading on a global scale, and international discussions have been made on emission prevention of plastic into the ocean, reduction of plastic waste, development of alternative materials, etc.

According to the "Resource Circulation Strategy for Plastics" mentioned in the previous paragraph, the Japanese government has indicated that they have a plan to introduce a system for collection and recycling, and at the same time, recycling of plastics will be promoted, and improper disposal of illegal dumping, which are one of the causes of marine plastics, will be reduced through the system. It is also expected that if local municipalities collect coastal drifts and other items appropriately, they will not be incinerated or landfilled and will be used as raw materials for chemical recycling.

In the above, chemical recycling, which can utilize low-quality waste plastics containing many impurities and waste plastics that are difficult to recycle, such as multilayered structures, as raw materials, is likely to expand in the future, and the technology of PRT, which has no competition in Japan, is extremely superior. The technology adopted in this project is considered to be important for raising the ratio of recycled materials in the raw materials of PET bottles and ensuring the effective use of resources.

(2) Points of Concern and Confirmation

1) Various regulations and demands for environmental conservation are expected to be further strengthened in the future, and systematic approach of environmental management is important. The management system evaluated in "6. Project Evaluation [Management System]" was established when this plant was operated by Toyo Seikan. Therefore, in order to perform appropriate environmental management after re- operation, it is considered that these mechanisms are updated and maintained. Therefore, it is desirable to monitor the future environmental management system and its implementation status.

2) In this evaluation, as shown in (1) of "4. Project Evaluation [Environment]", the energy consumption per amount of production due to re-operation increases by a level equivalent to the previous level, and therefore, the plant was evaluated as not directly contributing to the demand of low/decarbonized society. However, there is a possibility that the amount of CO_2 generated may be reduced indirectly and additionally as a result of efforts to conserve energy and to reuse energy for electricity. Therefore, it is advisable to monitor the actual amount of energy consumed and the amount of CO_2 generated after re-operation and the state of fluctuations in the amount of energy consumption and the amount of CO_2 generated after re-operation and to confirm the continuous efforts by operators.

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Attached Materials (Results of On-Site Inspections)

	Flake building (pretreatment process) ● Both warehouses and pretreatment facilities are larger than production facilities in order to cope with seasonal fluctuations in raw materials arrival, such as increased demand for PET bottles in the summer.
	Bales in the flake building ● The removal of contaminates is carried out by crushing, wind power sorting and specific gravity separation. ● Cut into 16 mm square PET flakes.
	Equipment in the flake building ● The equipment is scheduled to be renewed for re-operation. ● By introducing an alkali cleaning facility, waste PET bottles of low quality can also be recycled.

	BHET processing facility ● Depolymerization →De-colorization →Removing metallic ions ● The activated carbon used for de-colorization is regenerated in the field and recycled.
	Facilities of the BHET processing building ● The latest inspection by the Japan Boiler Association was July 31, 2019, and the inspection validity period was July 30, 2020.
	BHET processing facility ● Although some of the piping, insulation, building floor, handrails, etc. are deteriorated, the damaged part is managed, and emergency measures are taken. ● The piping will be inspected and replaced with new piping if necessary.

	BHET processing facility ● In order to prevent deterioration, nitrogen is sealed in unused piping.
	Tanks for ethylene glycol
	Ion exchanger and ethylene glycol refinery

	Wastewater treatment plant ● All wastewater in the project is collected and treated at this plant, and discharged into out of the project facilities.
Fire and Disaster Prevention, etc.	
	Foam extinguishing system (head)
	Fire pump unit ● Inspections are performed once a year after the plant stops.

	Installation status of fire extinguishers ● The storage box is installed on a table to prevent deterioration.
	Tent warehouse building ● Used for storage of raw materials, etc. ● There was no damage during the event of 2019 Typhoons (No. 15, 19).
	Product warehouse ● Since PET products are used for drinking purpose, raw materials and products are stored and managed respectively.