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Measuring the Readiness of Plastic Packaging and Containers Recycling Technologies in Japan with J-TRA Methodology

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1. Introduction

Plastic waste production worldwide has reached an unprecedented rise. Without proper recycling, the disposal of plastic waste may induce various environmental issues. Severe environmental and health damages have been observed in soil, air, water bodies, and animal and human beings. In response to China's import ban on plastic waste in 2017, the Japanese government established the resource circulation strategy for plastic waste, aiming to recycle or reuse 60% plastic containers and packaging by 2030. Reused disposable plastic is now considered a valuable product, and new systems revolved around plastic-waste recycling technologies undergo a developing phase. There are mainly three types of plastic container and packaging recycling technologies in Japan (Figure 1): material recycling (MR), chemical recycling (CR), and thermal recycling. This study aims to identify the readiness level of MR and CR plastic containers and packaging recycling technologies used by companies in Japan by employing the Japan Technology Readiness Assessment (J-TRA) methodology.

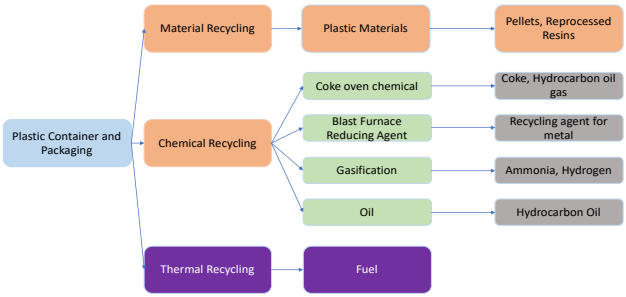

Figure 1 Simplification of the recycling process in Japan (JCRPA, 2020)

2. Methodology

The J-TRA is a methodology used in many industries to measure technology maturity from idea generation to commercialization. The methodology was an adaptation from the original Technology Readiness Assessment (TRA) developed by The National Aeronautics and Space Administration (NASA) in the United States (Ihara, Pandyaswargo, & Onoda, 2018). The adaptation was conducted to meet the characteristics of the Japanese technology development and market.

Table 1 The J-TRA TRL Scoring matrix (Ihara, Pandyaswargo, & Onoda, 2018)

TRL	A (Market)	B (Development)	C (Integration)	D (Verification)	E (Safety)	F (Commercialization)	G (Cost and risk)
1	A-1	B-1		D-1			
2	A-2	B-2		D-2			
3	A-3	B-3	C-1	D-3	E-1	F-1	G-1
4	A-4 A-5	B-4	C-2	D-4	E-2	F-2	G-2
5	A-6	B-5	C-3	D-5	E-3	F-3	G-3
6	A-7	B-6	C-4	D-6	E-4	F-4	G-4
7	The equipment and systems have been finalized. Manufacturing and introduction processes have been completed.						
8	Manufacturing and introduction processes have been completed and are in the stage of mass production of products.						

To conduct a J-TRA, a compliance checklist (Table 1) is applied to the technology development status. The actual and full questions of the compliance checklist could be accessed from the Japanese Ministry of Environment website (Japan minister of the environment, 2016). There are seven parameters (market, technology development, technology integration, verification in terms of reducing environmental burdens, safety, commercialization, and the related cost and risk) considered by the J-TRA methodology. Based on these parameters, the technology readiness level (TRL) is determined. A TRL ranges from 1 (least ready) to 8 (almost ready).

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3. Data and Materials

We collected information about the technologies used in Japanese recycling companies from the Japan container and packaging recycling association database (2021). Of 35 companies listed in the database, 90% are using MR technology, and 10% are using CR technology. The type of plastic materials recovered from the MR process is Polyethylene-based resin raw material (PE), Polypropylene-based resin raw material (PP), Polyethylene-based resin Raw materials (PS), Resin raw materials mainly composed of polyethylene terephthalate (PET), and PE / PP mixed resin raw materials. The output of the CR process is synthetic gas (mainly composed of hydrogen and carbon monoxide) and industrial raw materials. We applied the J-TRA methodology to determine the technology readiness levels of MR and CR technologies by extracting information from the company websites.

4. Result and Conclusion

Figure 2 shows the TRL of CR and MR technologies used in the analyzed Japanese plastic container and packaging recycling companies. The left radar chart presents the TRL result of CR technologies, including CR1 (Coke oven chemical feedstock) which has the highest integration level; CR2 (gasification), and CR3 (blast furnace reducing agent) with the lowest commercialization and cost level among the other technologies because of the output recycling data was not present in the company websites. The radar chart on the right side presents the TRL results of the MR technologies. In general, the MR technology readiness level is higher than the CR technology especially on the "commercialization" level. However, some MR technologies still have space for improvement in the performances on the "safety" and "verification" parameters. The safety and verification status of each company was determined by whether or not they have acquired the following standards: (1) The International Organization for Standardization (ISO9001 & ISO14001) reporting the high environmental and safety performances based on routine monitoring, and (2) other environmental performance reports such as the actual measurement and amount of CO_2 reduction. To clarify the exact technical differences between the MR technologies used in each company, a further study including an interview with each company is required.

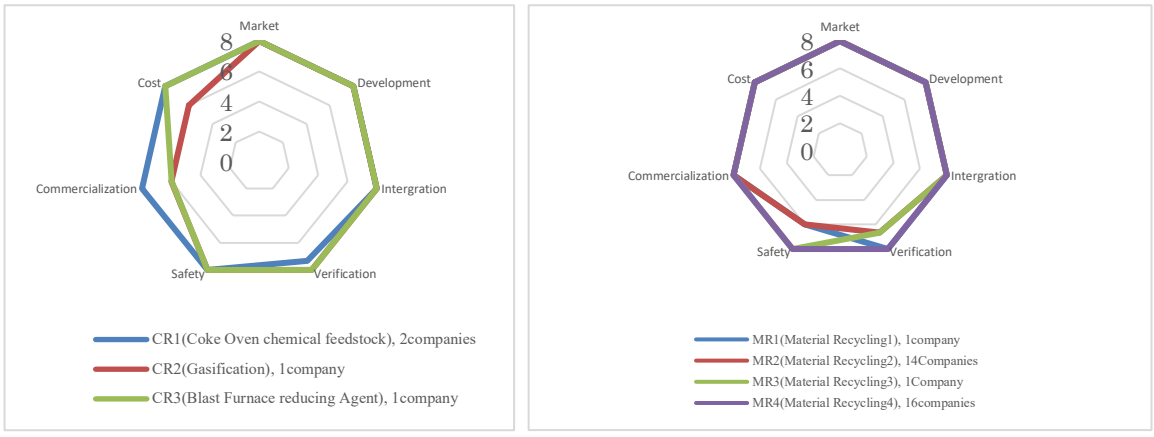

Figure 2 TRL of Plastic Packaging and Containers Recycling Technologies in Japan

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