Microwave Chemical

Chemical Recycling by Microwave Technology

26th January 2024

Microwave Chemical Co., Ltd.

Transitioning from Fossil Fuels to the Era of Electricity

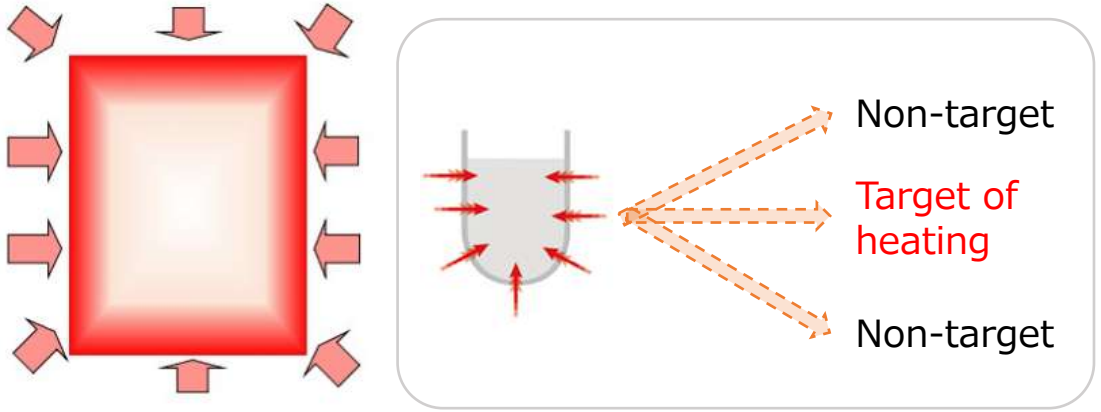
A Key Player to Realize Industrial Electrification

Microwave

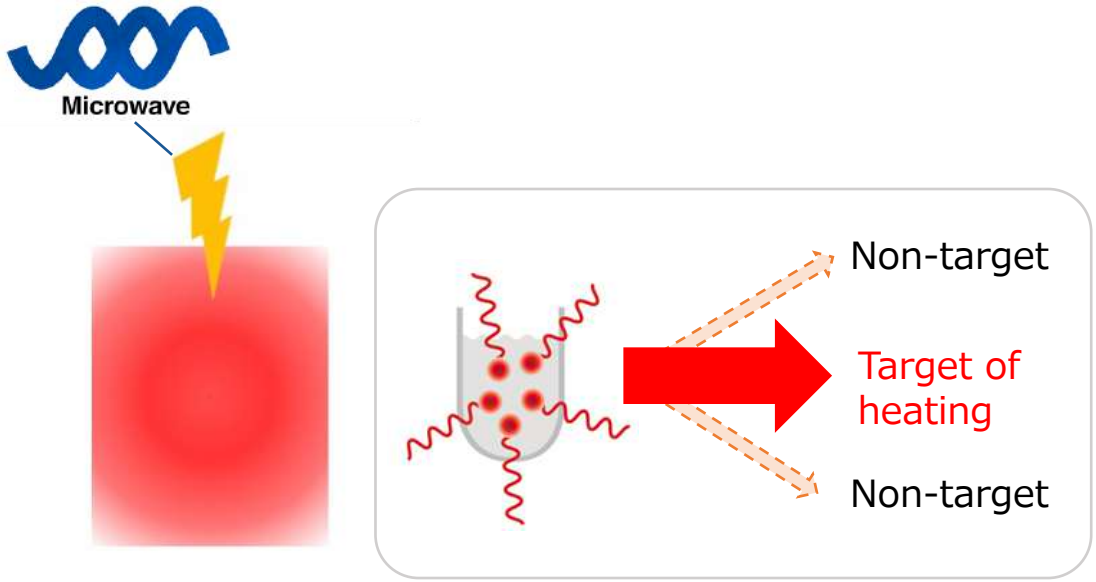
Highly Effective Energy Transfer Method

Microwave transfers energy to the only target material

directly, selectively and rapidly



Normal Heating
(external heating)



Microwave Heating
(internal heating)

Benefits of Adopting Microwave Technology

01
Impact on Process

Saving Energy

Energy consumption

1/3

Electricity consumption can be cut to 1/3 of that of conventional methods.

Higher efficiency

Heating time

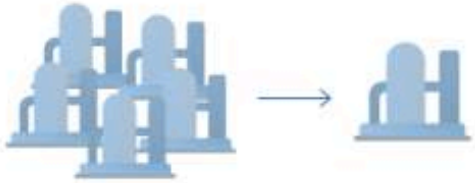
1/10

Reactions can be made more efficient than conventional methods.

Compact

Ground area

1/5



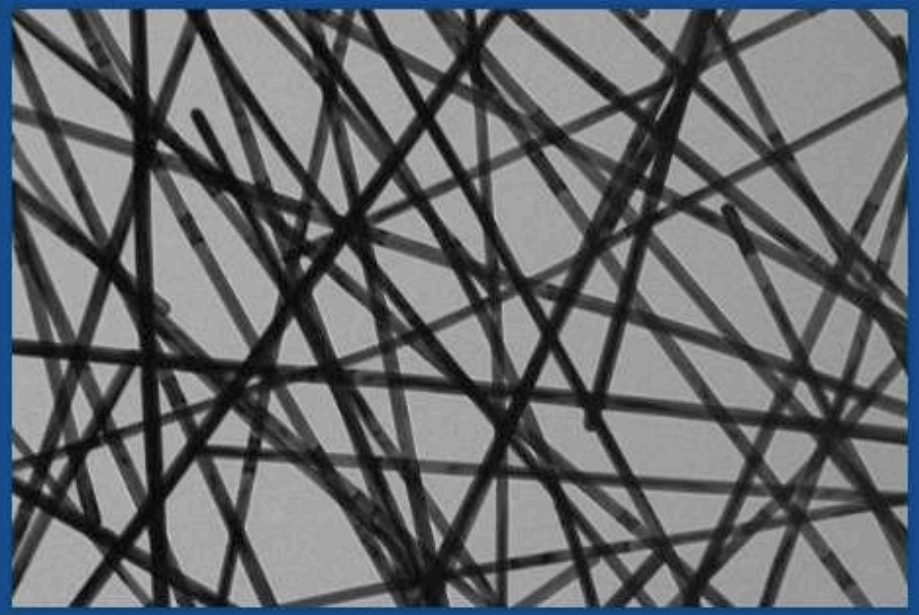
Single-stage synthesis is now possible, instead of the conventional two stages.

Benefits of Adopting Microwave Technology

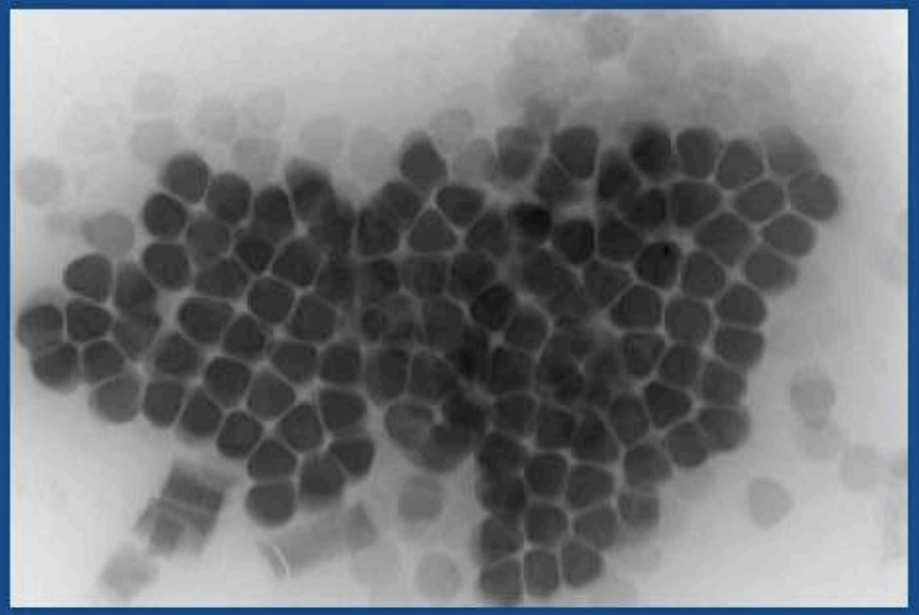
02

Impact on Product

We can develop novel, high-quality materials whose manufacturing was previously not possible.



Silver nanowires

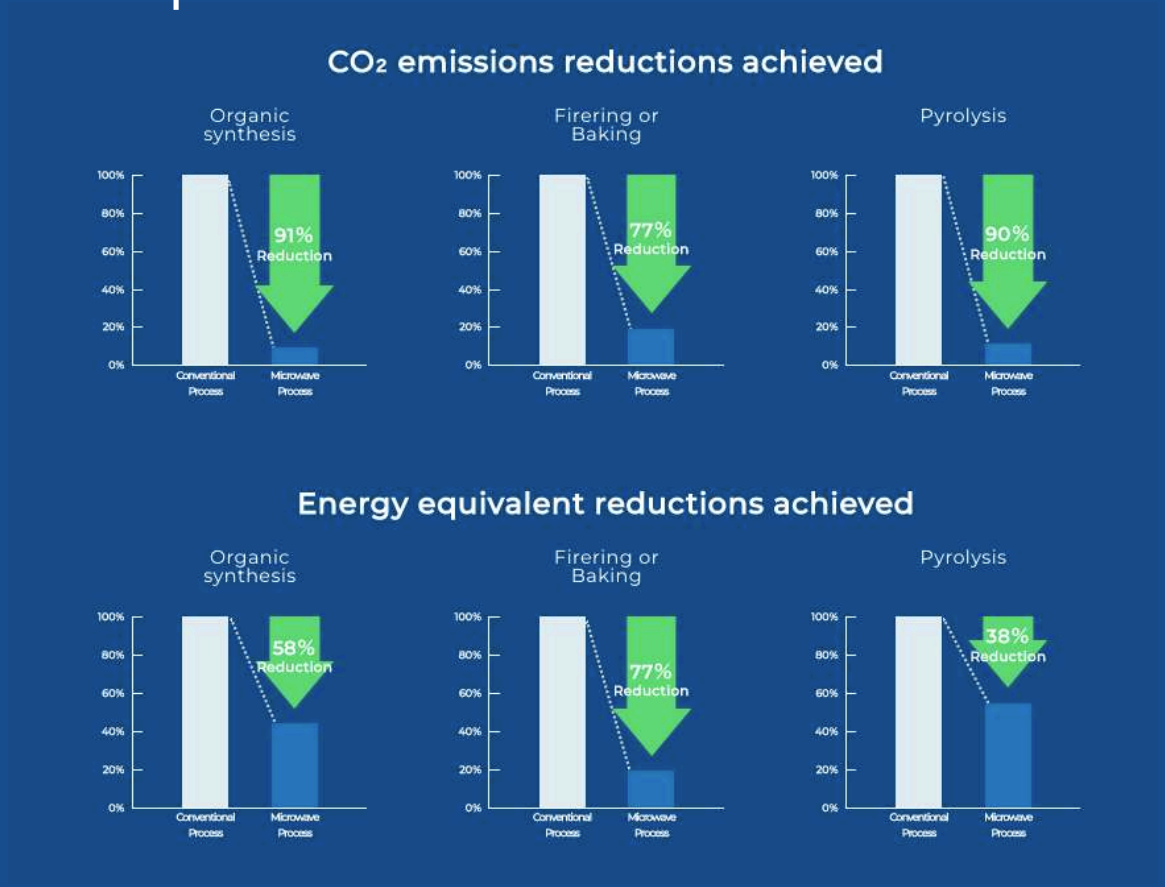


Nanoparticles

Benefits of Adopting Microwave Technology

03

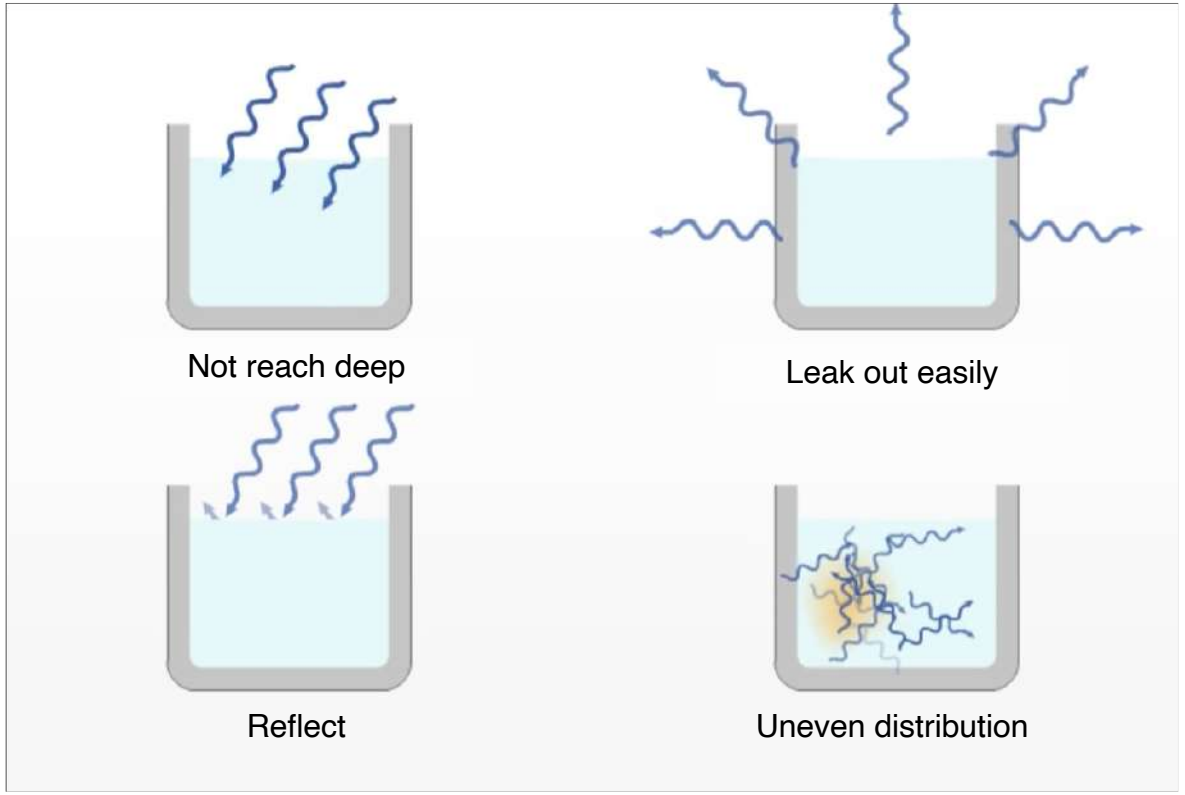
Impact on Carbon Neutral Product



Challenges in Industrial Applications of Microwaves

- In the chemical industry, valuable experimental results utilizing microwaves have been extensively reported in scientific papers since the 1980s. However, due to the nature of 'waves,' controlling and scaling up (upsizing) at the industrial level has been challenging, making commercialization difficult.

The Challenges of Control in Manufacturing Processes

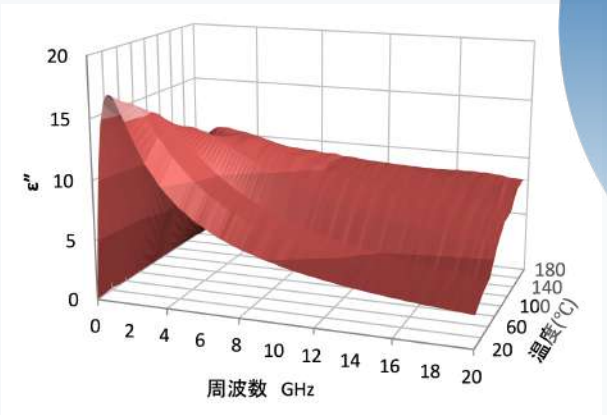


Addressing These Challenges Through Our Unique Approach

- We poured a huge amount of time and effort into creating the following two designs that defied the convention.

Reaction system design

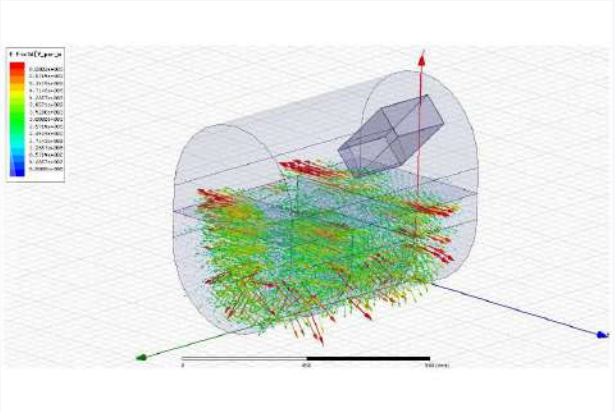
What to transfer energy to



Microwave Technology Platform

Reactor design

How to transfer energy to



The World's First Industrialization of Microwave Chemical Processes.

- We have successfully demonstrated manufacturing at a scale of 3,300 tons per year, complying with regulations.

Application Examples

World's First Industrialization

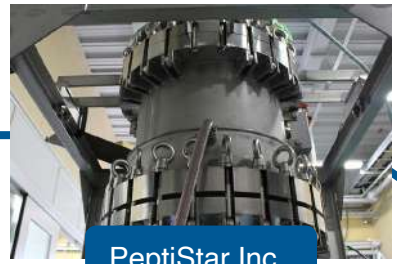
Fatty Acid Esters - 3 kt/y

Food Additives - 1 kt/y

TAIYO KAGAKU Co. Ltd.

Polymers - 1 kt/y

Peptide Pharmaceuticals
(30 L, GMP)



PeptiStar Inc.,

ASR, SMC, PU Recycling

Mitsui Chemicals, Inc.

PMMA Recycling

Mitsubishi Chemical Corp.

Carbon Fibers

Mitsui Chemicals, Inc.

Mining Development

QST

Hydrogen

SUMITOMO CHEMICAL Co., Ltd.

Freeze-drying

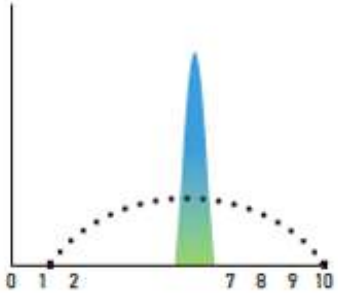
Asahi Group Foods, Ltd.

PlaWave® - Technology Platform for Chemical Recycling -

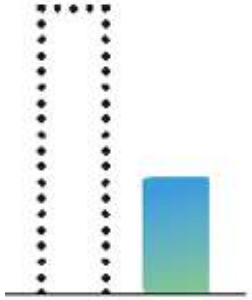
- We have established a versatile technology platform for a variety of plastic types and samples.

PlaWave

High Selectivity



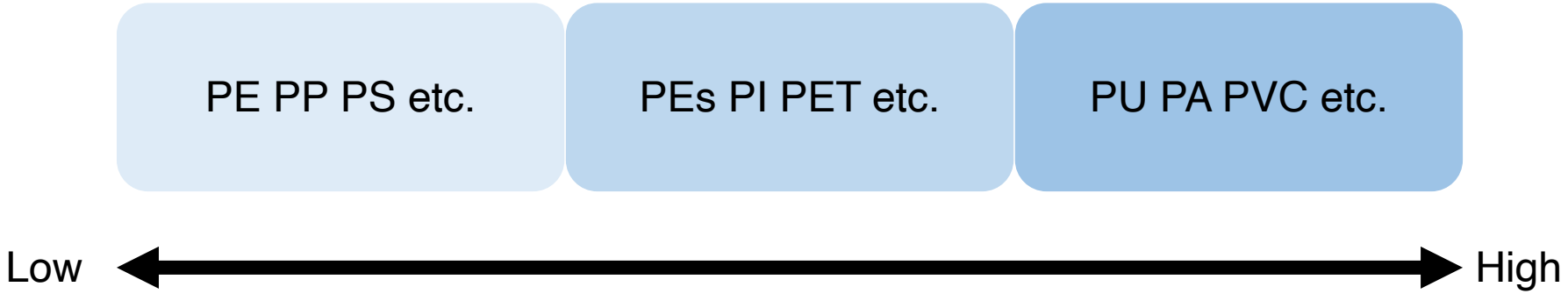
High Efficiency



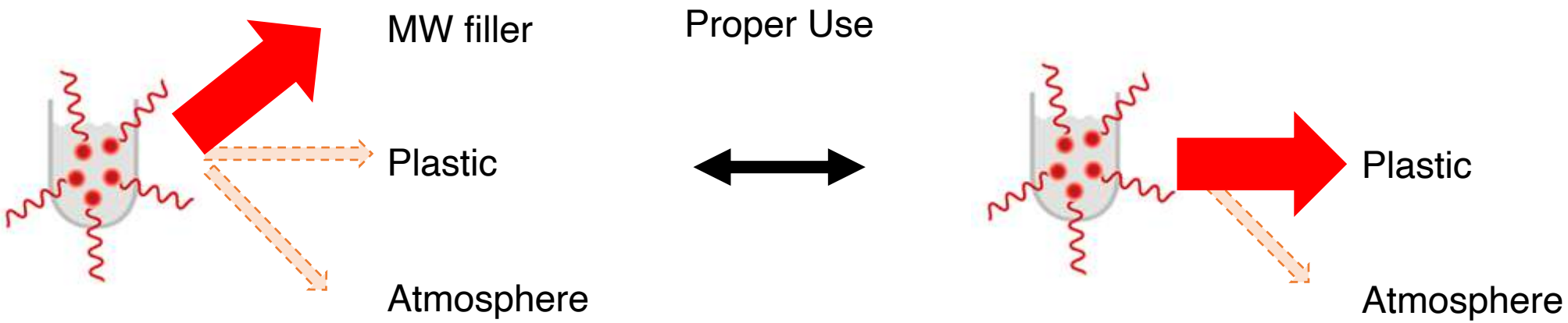
Space-Saving

Reaction Design

Microwave absorption characteristics of plastics



Reaction Design



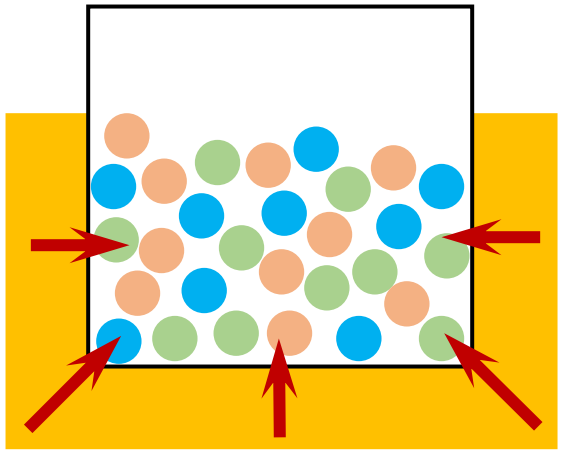
Reaction Design for Plastics with High MW Absorption Capacity

Pyrolysis of PMMA by Microwave

PMMA is heated by microwave without fillers because PMMA has high microwave absorption capacity.

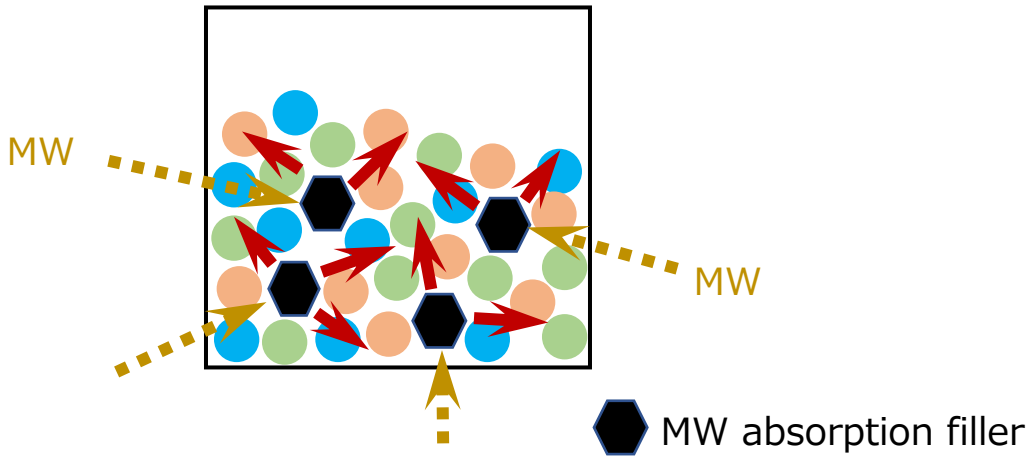
Reaction Design for Plastics with Low MW Absorption Capacity

Conventional



Flame, hot air, hot water, oil bath, electric heater and etc.

Microwave

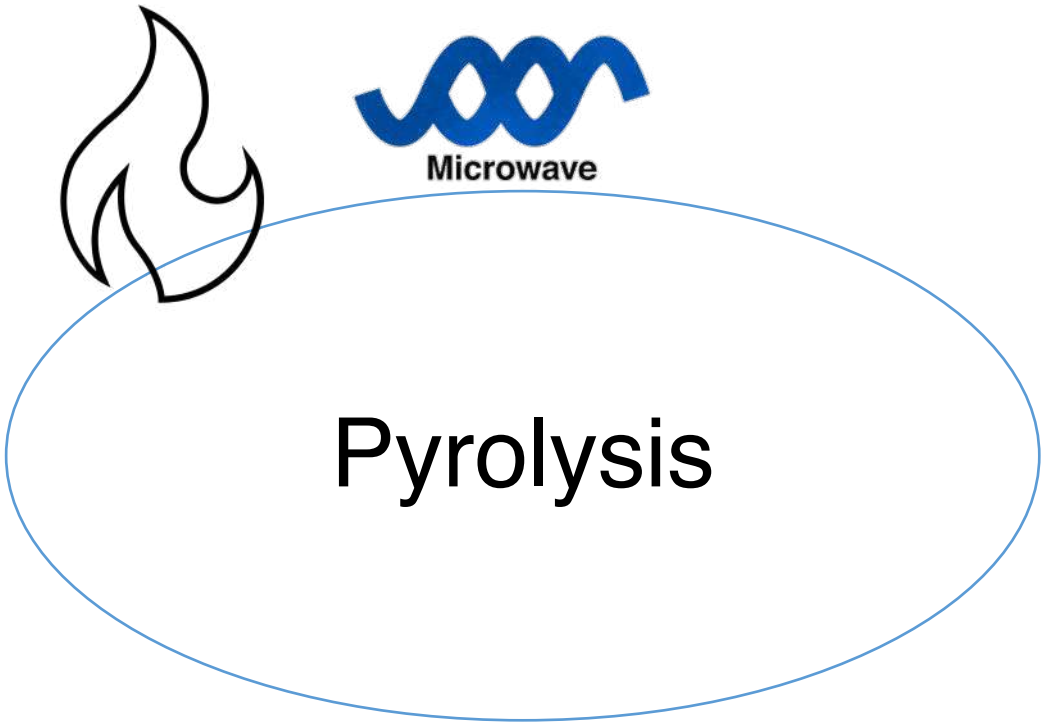


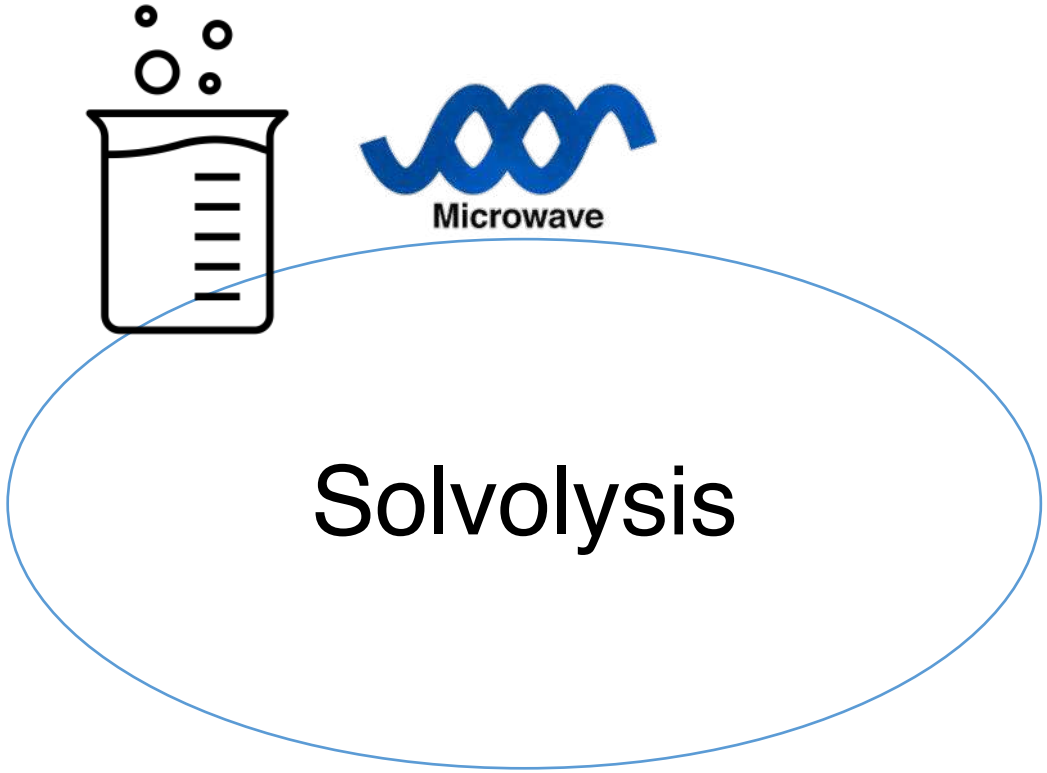
Microwave can supply energy to the target directly

Conventional Technology	PlaWave
Indirect heating	Direct heating
Mass heating	Selective heating
Surface heating	Internal heating
—	Rapid heating

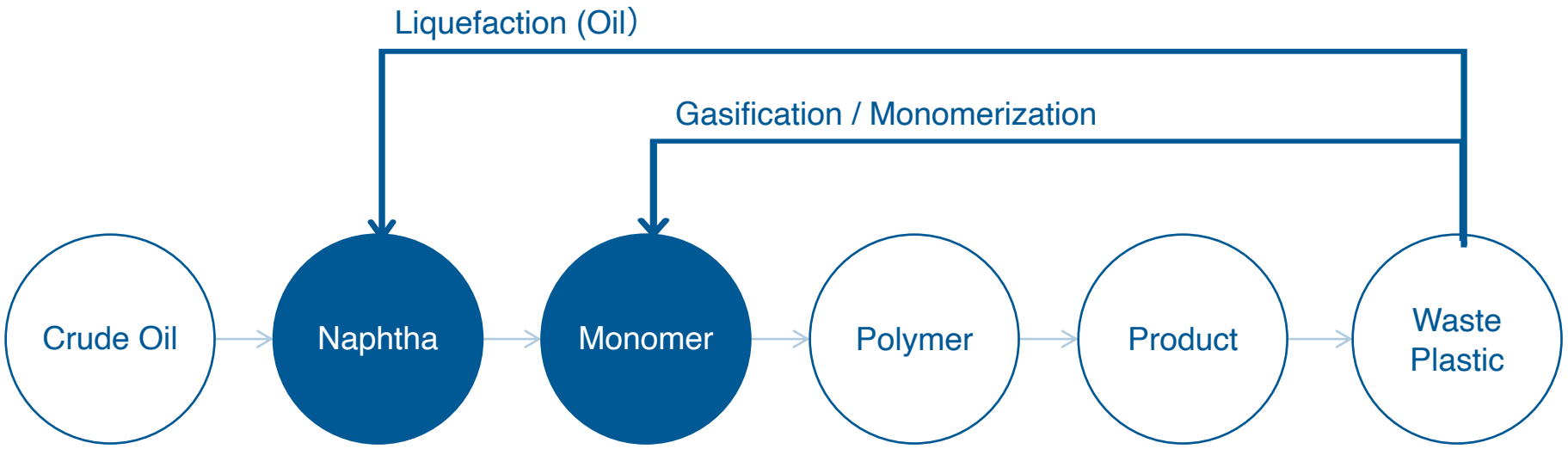
PlaWave for Pyrolysis and Solvolysis

- Reaction Design should be changed according to the target material and product





Direct Monomerization by PlaWave and Product Creation

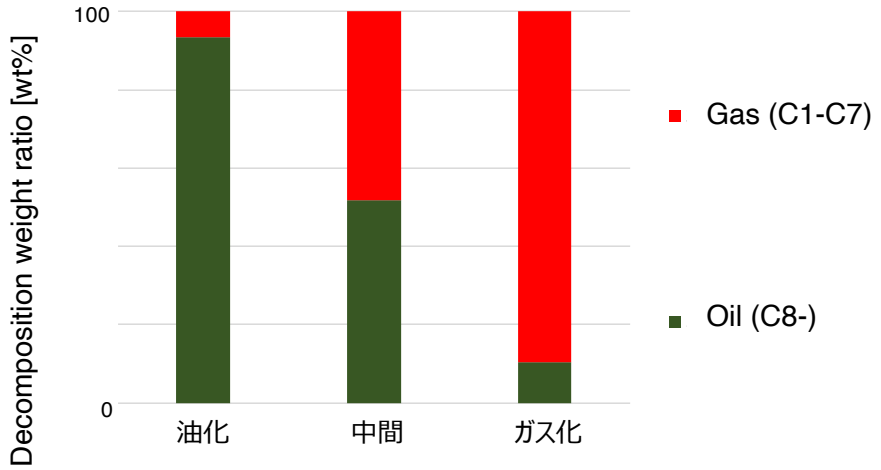


MW Depolymerization Factor

- ✓ Microwave (frequency, output and etc.)
- ✓ MW filler (type, quantity and etc.)
- ✓ Others (atmosphere, pressure and etc.)

Decomposition products can be created separately by abundant control factors

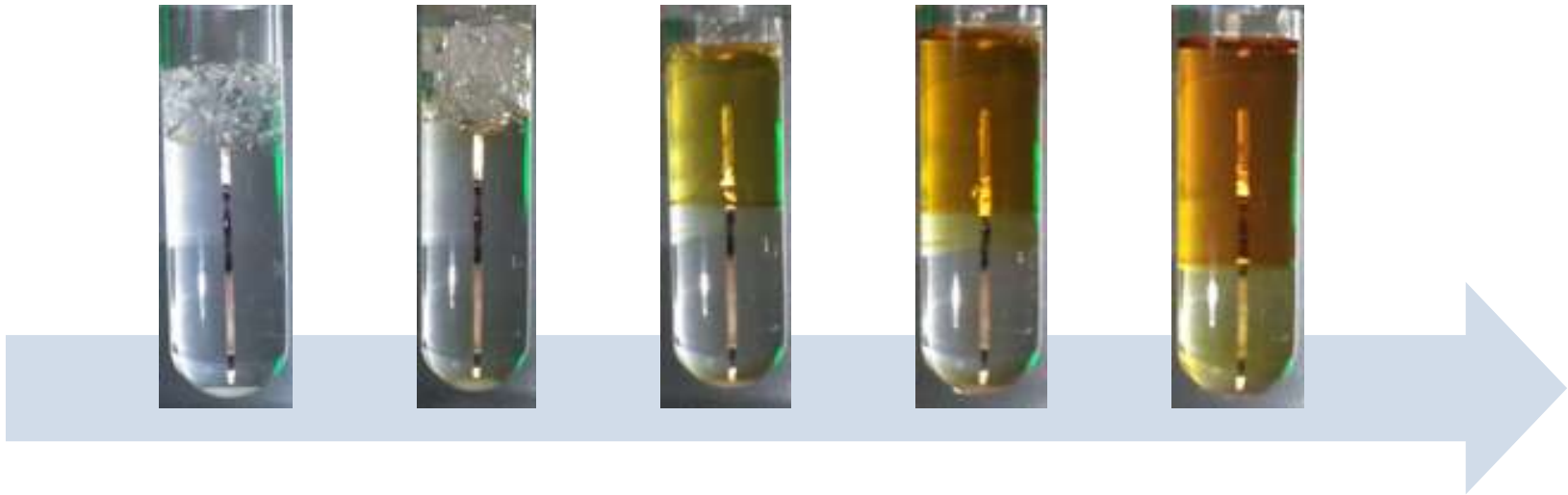
Image of Products from Depolymerization by PlaWave



Examples of Solvolysis

Microwave irradiation causes the plastics to decompose and the solvent to form two layers

➡ The target decomposition products are extracted from the upper and lower layers, respectively.



Advantages of PlaWave

Advantages of Microwave Pyrolysis

① High Cyclicity： Mixed plastics can be decomposed

② High Productivity：Short process time, high yield/selectivity, low energy cost and small footprint

③ Safety：Precise temp control and the nature of microwave can lower explosion and combustion risk

Process	Cyclicity	Productivity					Safety *
	Mixed Plastic	Process Time	Yield	Selectivity	Energy Cost	Foot Print	
Conventional Pyrolysis	Possible	Slow	Low	Low	High	Large	Normal
Depolymerization	Impossible	High to Slow	High	Low	High	Large	Normal
PlaWave	Possible	High	High	High	Low	Small	Good

* MW does not heat gas and oil from plastics therefore combustion risk is low

Bench and Pilot Facility of PlaWave

Examples of Chemical Recycling Projects

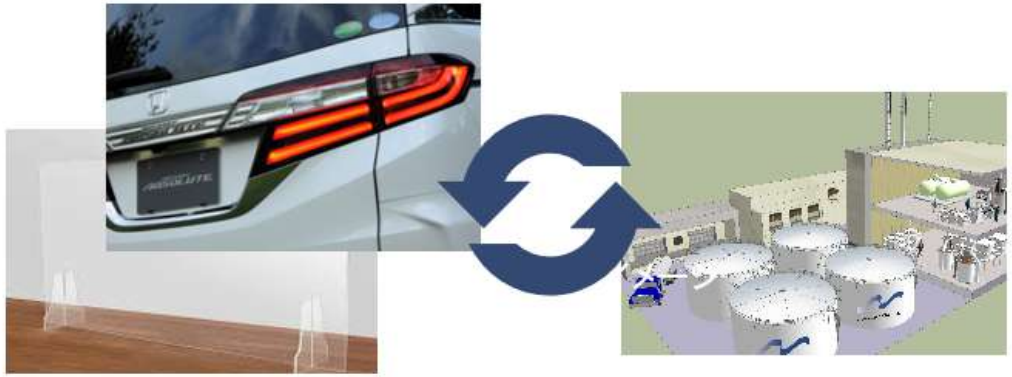
	Partner company	Target Plastic	Status
1	Mitsubishi Chemical	PMMA	Large-scale demo from FY2021 ▶ Planned commercialization in FY2025
2	Mitsui Chemicals	ASR (automobile shredder residue)	Small-scale demo from FY2021
3	Mitsui Chemicals	SMC (sheet molding compound)	Small-scale demo from FY2021
4	Mitsui Chemicals	Soft Polyurethane Foam	Small-scale demo from FY2022 ▶ Planned commercialization in FY2025
5	RESONAC	Recycled plastic containers and packaging	Fundamental development in FY2021
6	Seven-Eleven Japan	Polystyrene, Polypropylene etc.	A small-scale distributed system demo by FY2025
7	Asahi Kasei	Polyamide 66	Small-scale demo from FY2023 ▶ Planned commercialization in FY2025

Furthermore, we are advancing several projects simultaneously..

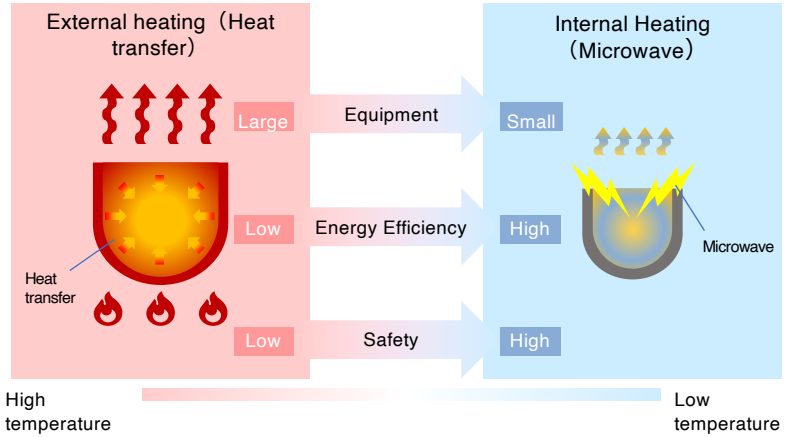
PMMA (Acrylic Plastic) with Mitsubishi Chemical

MITSUBISHI CHEMICAL × Decomposition of acryl resin

HONDA



Circular Economy



External heating requires a heat source above the temperature of the object to be heated and requires large equipment. Microwaves can heat directly from the inside, which not only makes the device smaller and more energy efficient, but also improves safety because the device does not need to be heated above the temperature of the object to be heated

Customer Benefit Reduction of CO2 and energy cost, safety and small footprint

Phase 1 Laboratory Development → Phase 2 Pilot Development → Phase 3 Installation → Phase 4 Constant Revenue Generation

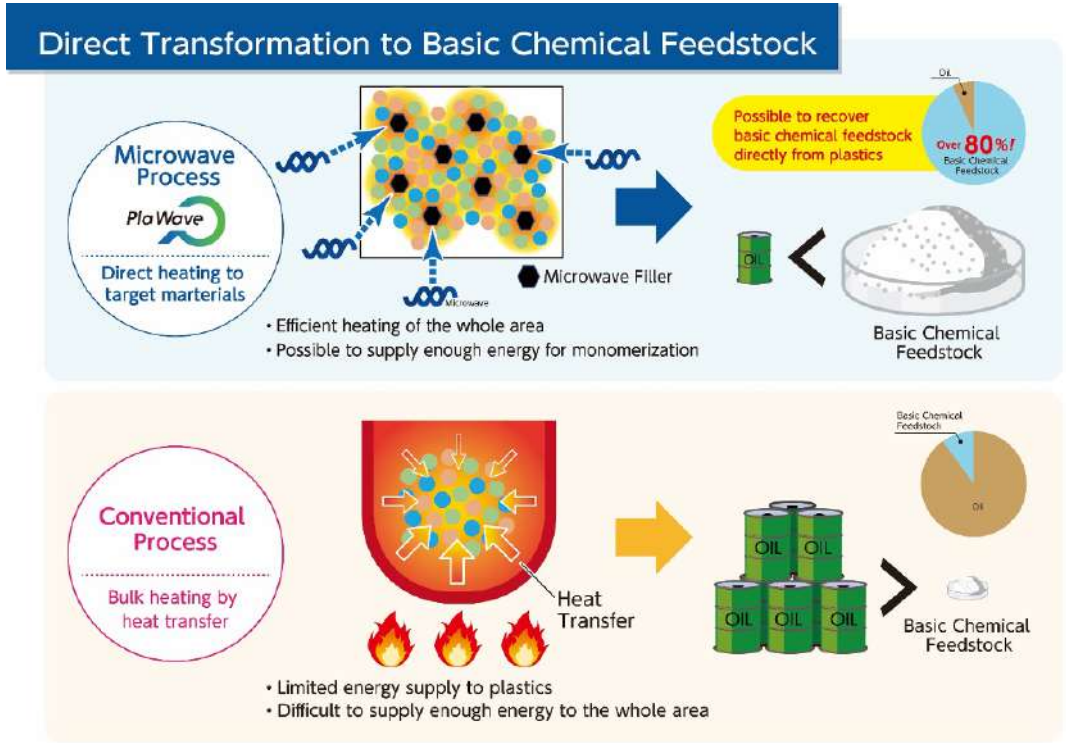
Commercial shipment to start in 2025 (plan)

Packaging Plastic with Resonac

Joint development of microwave-based chemical recycling technology to directly decompose used plastic into basic chemicals such as ethylene and propylene.

- ✓ MWCC will utilize microwave based plastic decomposition platform “PlaWave” to deal with various waste derived from containers and packaging goods.
- ✓ Resonac has been engaged in chemical recycling operations since 2003 at Kawasaki Plant, producing clean hydrogen and ammonia through thermal decomposition.

Image produced by MWCC, does not represent actual business



Collaboration Achievements

Recycling of PMMA

Mitsubishi Chemical Corp.

#Compact Equipment

#High Purity

#Safety

Recycling of Plastic Container Packaging

Resonac Corp.

#CO_2 Reduction

#High Yield

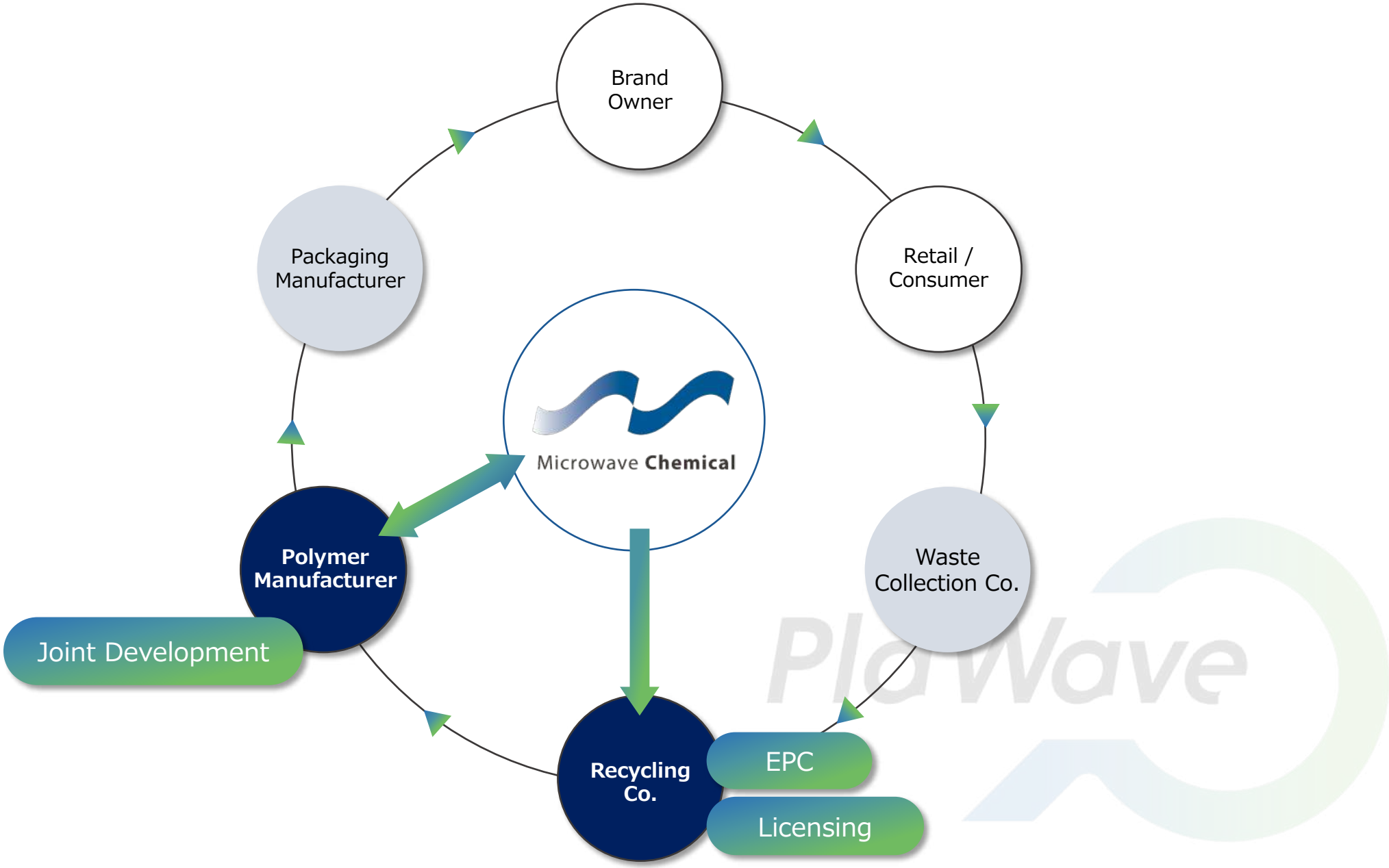
Demonstration of small distributed system

Seven-Eleven Japan Co., Ltd.

#Compact Equipment

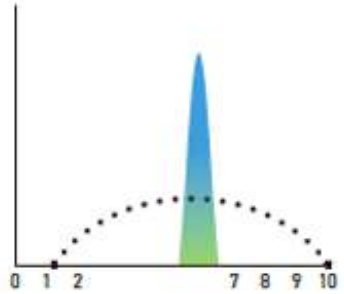
#CO_2 Reduction

MWCC's Business Model of Chemical Recycling



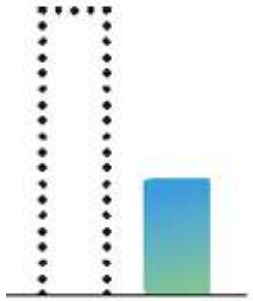
Centralized and Distributed System

- PlaWave enables an optimal recycling model by combining a large centralized system and a small distributed system.



High Selectivity

By selecting a decomposition process tailored to the target decomposition products, we can improve purity and achieve high yields.



High Efficiency

By directly and rapidly transferring energy to the target material, we can achieve chemical recycling with less energy consumption.

Space-Saving

Combining high-speed processing using microwaves with compact utility facilities allows for space-saving.

Large-scale Centralized and Small-scale Distributed System

- We aim to make an optimal recycling model by combining a large centralized system and a small distributed system by using PlaWave

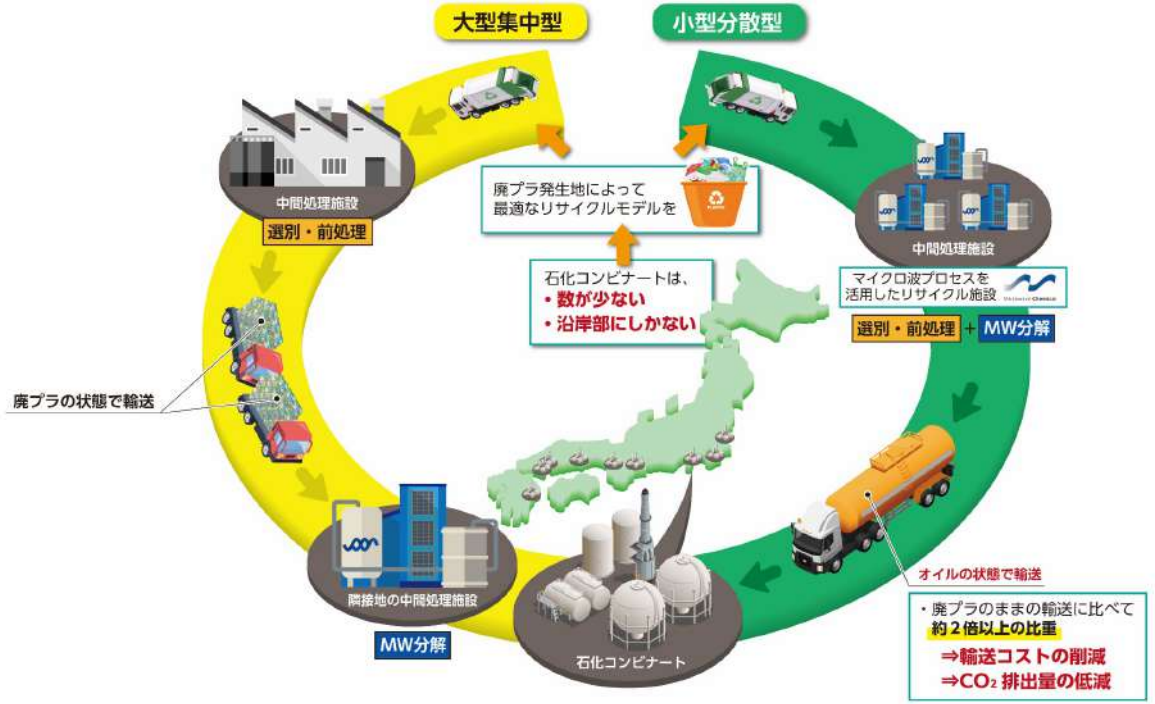
PlaWave

Small & Distributed Model with Seven Eleven Japan

Awarded the Osaka Prefecture “Carbon Neutral Technology Development and Demonstration Program” together with Seven-Eleven Japan for distributed recycling system.

- ✓ Most of the chemical recycling project is "large-scale centralized system” with capacity of thousands to tens of thousands of tons per year.
- ✓ This project focuses on "distributed system”.
- ✓ Project focuses on building highly efficient eco-system.

Image produced by MWCC, does not represent actual business



Microwave Chemical

Make Wave,
Make World.

世界が知らない世界をつくれ

Thank you for your attention

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