



Second Generation MethylMethAcrylate

LIFE PlasPLUS Event
01/02/2022

Simon van der Heijden

 **HEATHLAND** | Now Part of Trinseo

**Project
Presentation**



This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement N° 820687.



Signage



Decorative



Vehicles



Sanitary



Solid Surface

PMMA has numerous applications



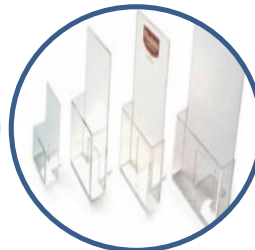
Construction



Furnitures / Displays



Advertisement, others



Flat screens



Future: Composite



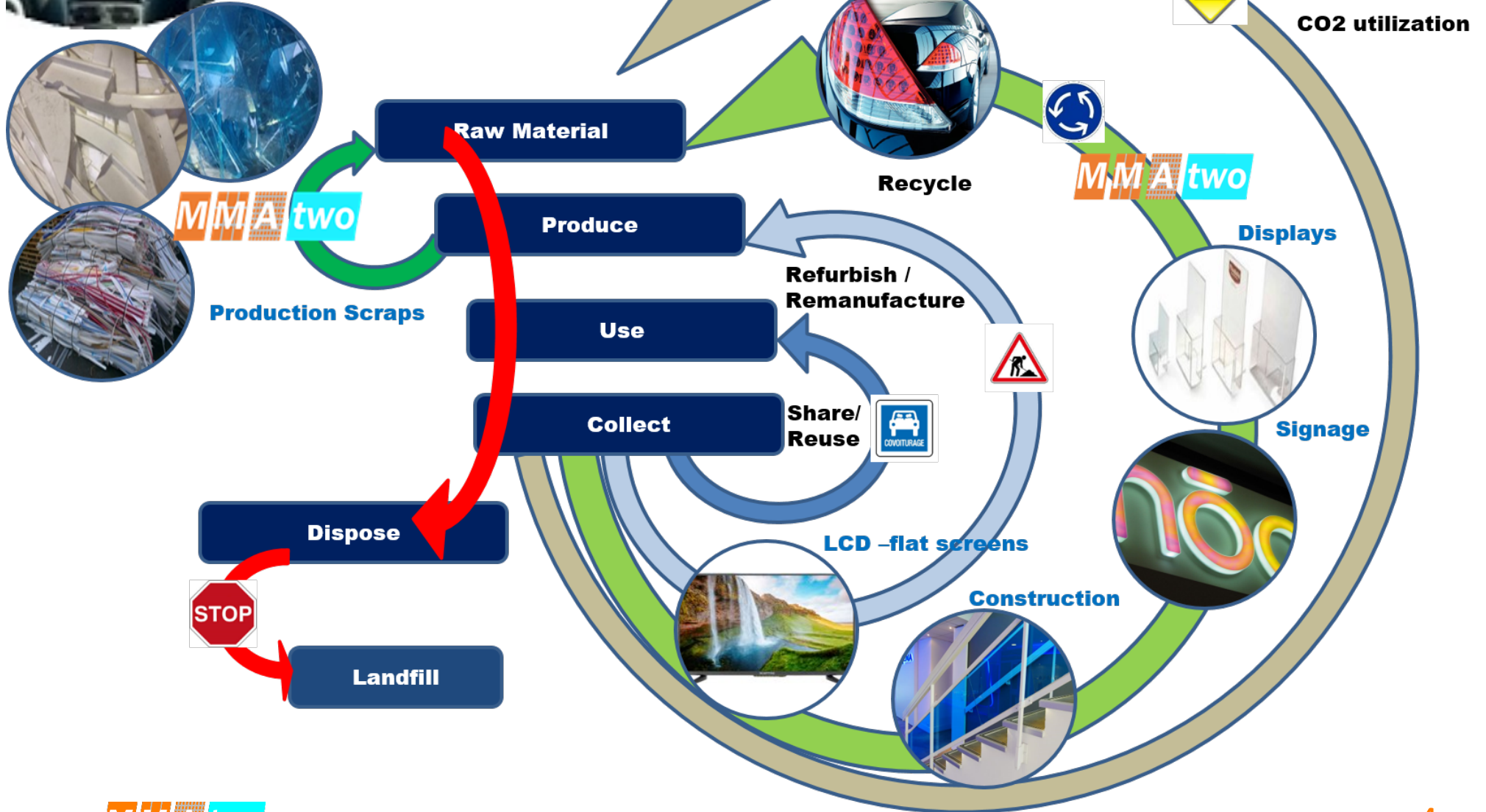
Production waste



End-of-life

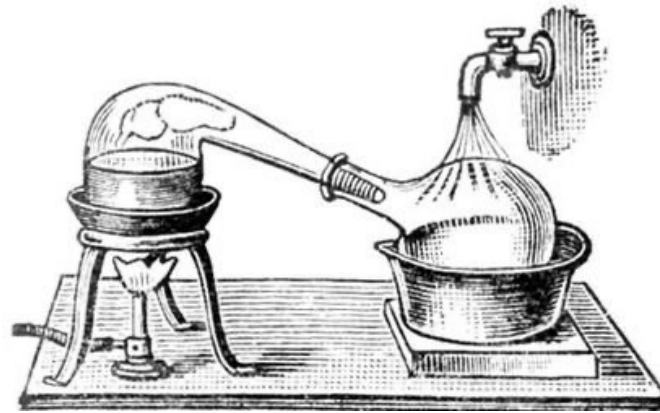
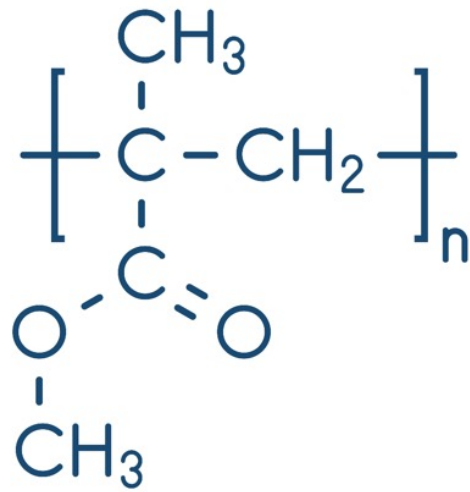
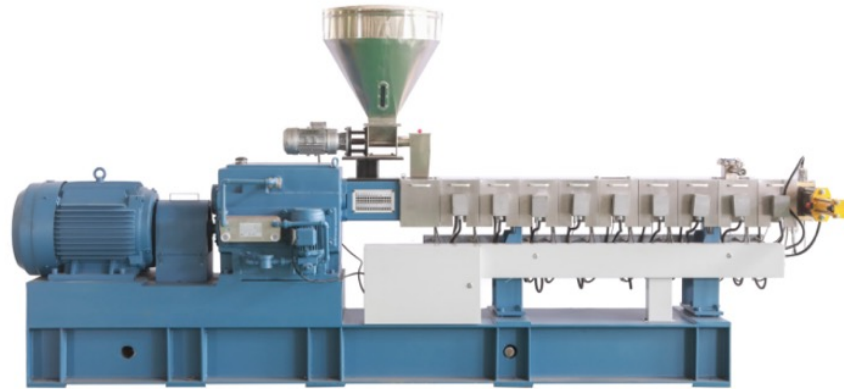


Circular Economy





Recycling PMMA





Dry Distillation Still reactor



Rotating Drum reactor

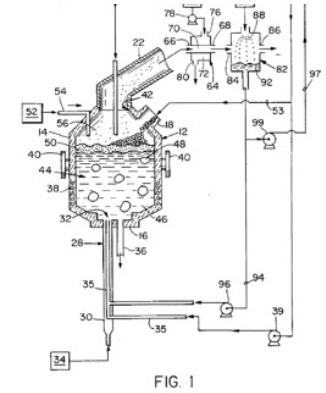
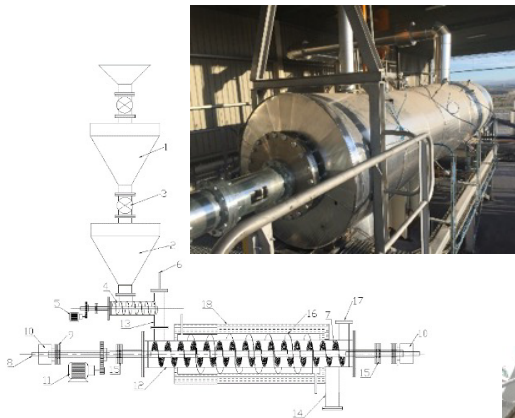


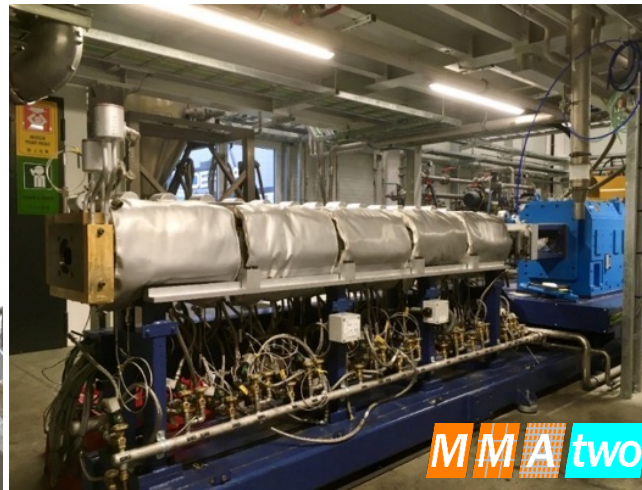
FIG. 1

Molten Metal reactor



Auger reactor
(w or w/o circulating solid)

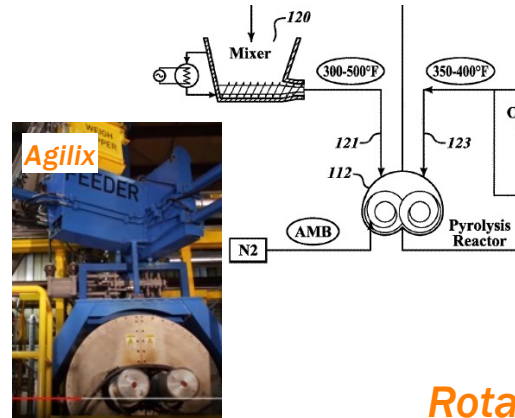
Twin-Screw reactor



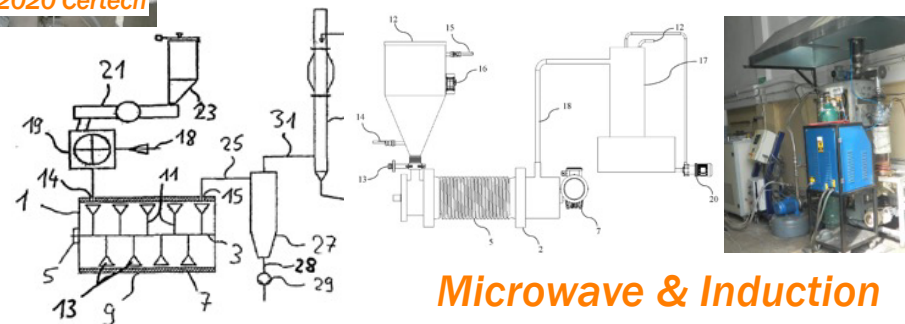
MMAtwo



© 2020 Certech



Rotating Paddle reactor



Microwave & Induction reactors



Picture borrowed From Recycling Technologies

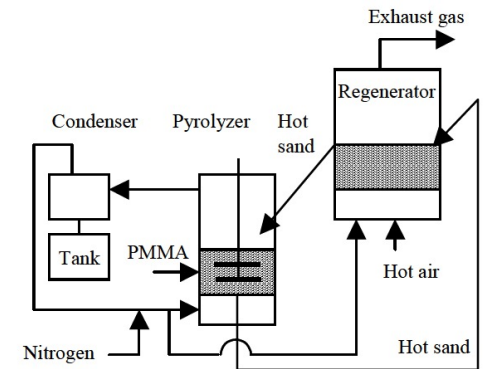


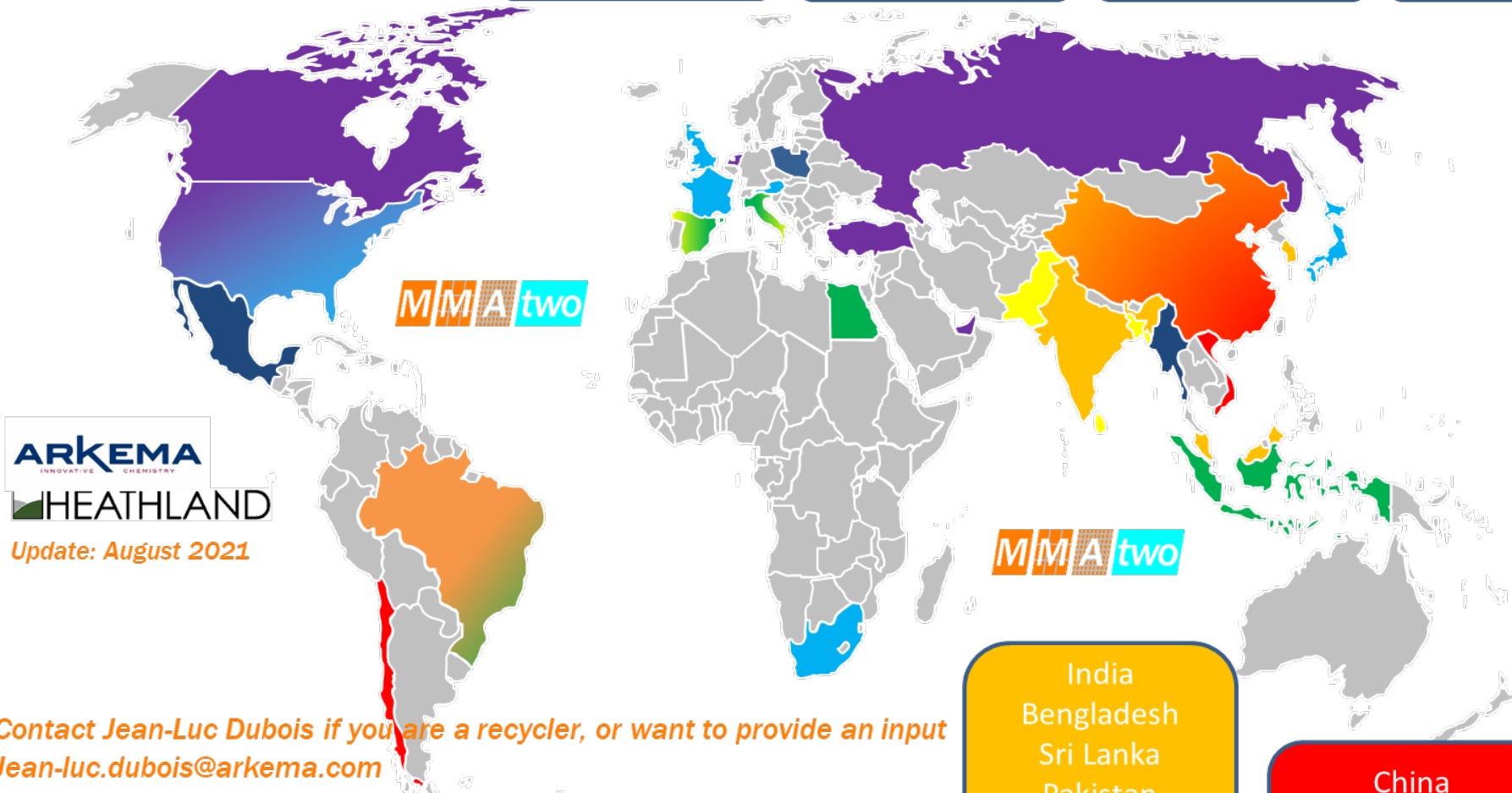
Fig.1 Apparatus

Fluid Bed reactor 6

Regenerated Methyl Methacrylate World Map

ment, Confidential until Oct 1st 2026

- Closed facility
- Molten metal Technology
- Dry distillation Technology
- Rotating Drum Technology
- Other (FB, MW, Ind.) Technology
- Possible new plant



ARKEMA
INNOVATIVE CHEMISTRY
HEATHLAND
Update: August 2021

Contact Jean-Luc Dubois if you are a recycler, or want to provide an input
Jean-luc.dubois@arkema.com

Americas
5 000 t+
5-10 companies

Europe
7-10 000 t
3-5 companies

Middle East
5-10 000 t
6 companies

India
Bengladesh
Sri Lanka
Pakistan
Malaysia
20 -30 000 t+
>30, leaders

China
Vietnam
100 000 t
Many, 2 leaders



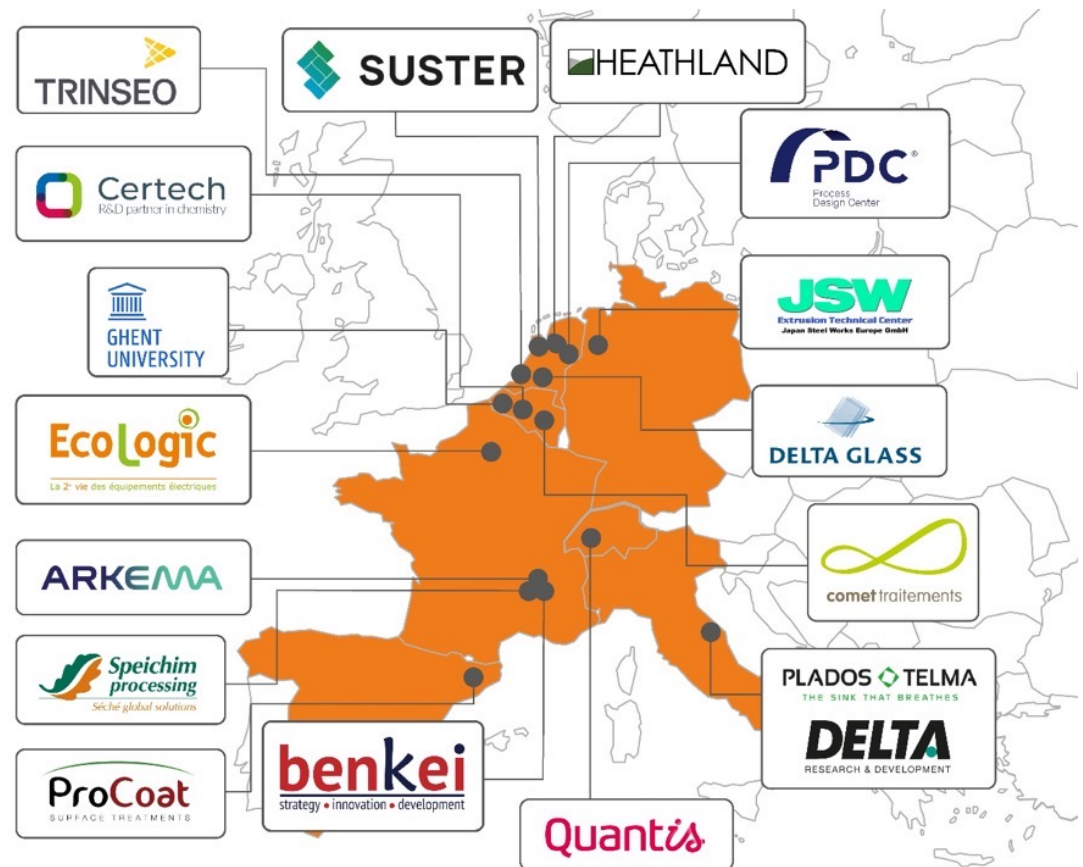
Simon van der Heijden - MMAtwo - February 1st 2022

Recycled MMA World Map
Prepared by Jean-Luc DUBOIS (Arkema)
with Simon Van der Heijden (Heathland)



MMAtwo project at a glance

- Second generation Methyl MethAcrylate
- Innovation Action – Grant Agreement N° 820687
- 14 partners from 6 different countries
- 8.9 M€ budget (6.6 M€ grant)
- From 01/10/2018 to 30/09/2022
- Production in Europe around 300.000 tons annually; recycling capacity in Europe around 8.000 tons annually.
- Objective: Construction of a new value chain for post-production and end-of-life PMMA waste recycling in collaboration with producers, waste collectors, processors, end-users and the academic community through depolymerization and recovery of MMA, using a lead free environmentally friendly and accessible technology (continuous process).





MMAtwo methodology



Collection M36 Main results

Collection of samples

Focus on EoL PMMA



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PMMA extrusion grade



EoL waste from restaurants



PMMA graffiti high barrier

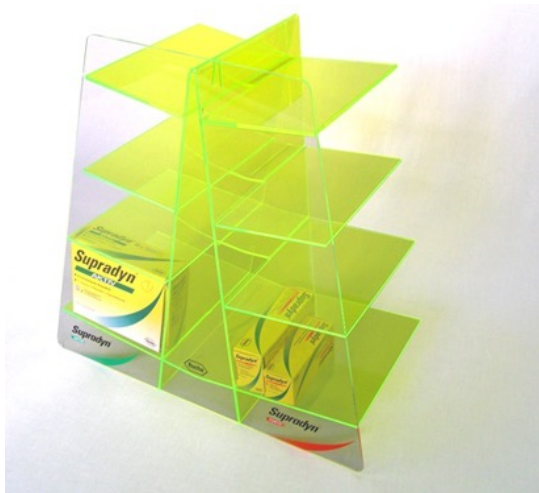


Collection M36 Main results

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Collection of samples

EoL through strategic partnerships



PMMA from office furniture



PMMA from deconstruction



PMMA from shopping decoration



Collection M36 Main results

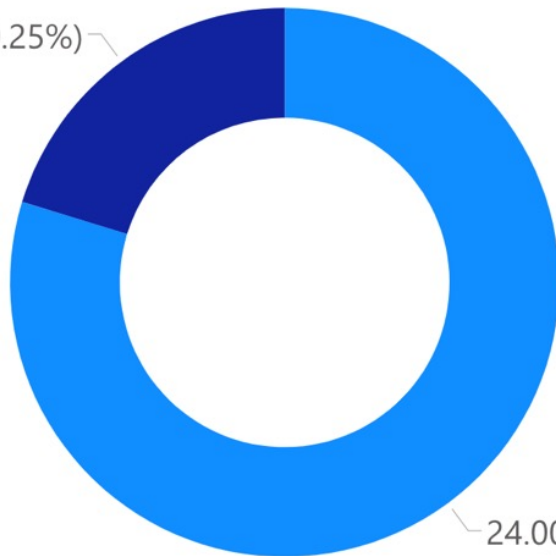


Mapping of sources

Identified feedstock out of targeted 27.000 tons annually

End-of-Life

6.095K (20.25%)



Post-Production

● Post-production waste (Tons) ● End-of-life waste (Tons)

Contaminants

PE film



Other



PVC



No contaminant

Paint/coating

Glassfibre



Pretreatment: M36 Main results



Pretreatment: PMMA/PVC separation

- Issues: Not liberated particles
- New technology implemented
- Trials on-going to improve purity and yield



Not liberated particles



Best quality as established by Heathland, Visually



Best quality as established, Visually: 100%



Pretreatment: PMMA/PVC separation

Highly efficient process

PMMA/PVC mixture from Heathland :
Laboratory NIR Automated Analysis of plastics regrinds

HEATHLAND
PMMA/PVC 23-08-2021
Quantity analyzed gr.

Average yield: 87%



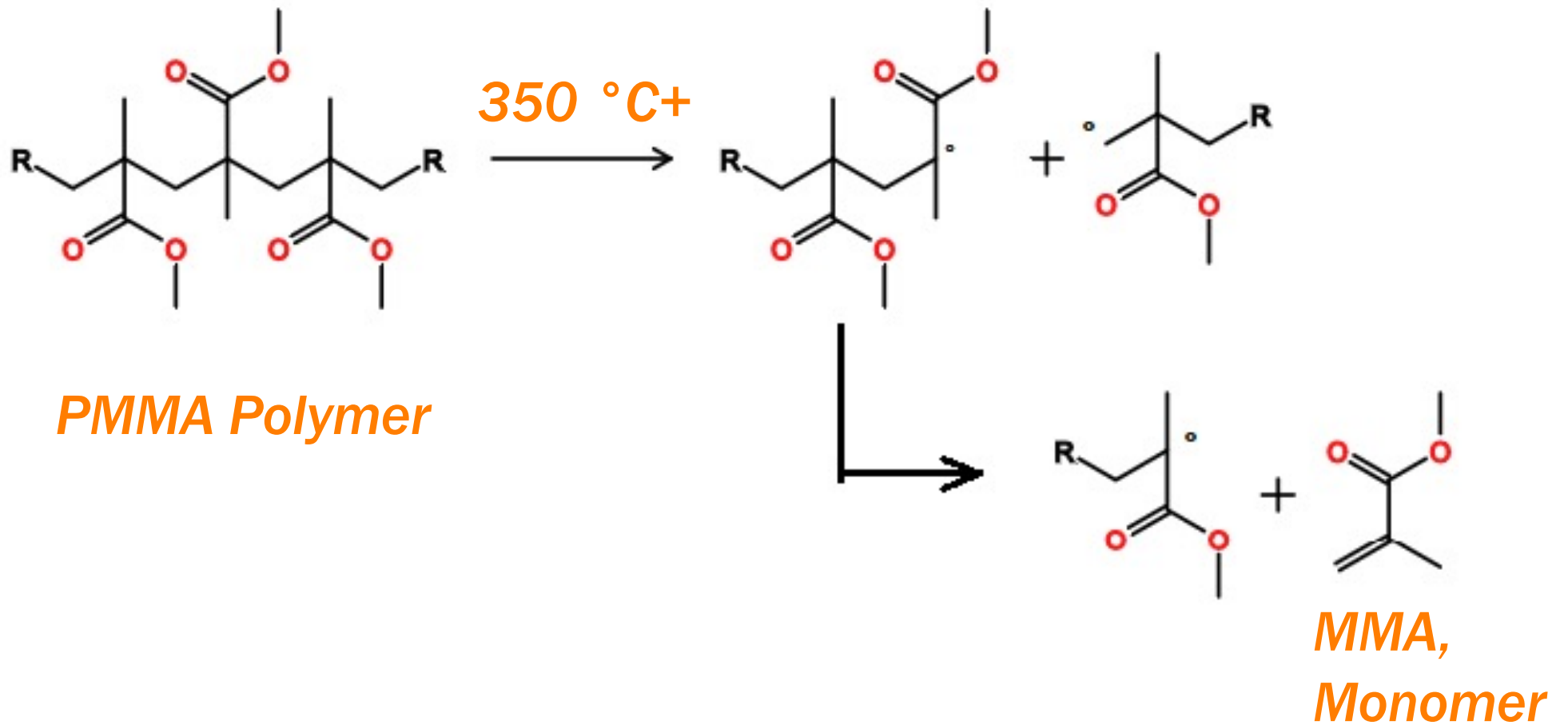
NIR Analysis results

Main components	1 st run on all sample		2 nd run on all sample		Average	
	%	ppm	%	ppm	%	ppm
PMMA	99,518%	995.183	99,490%	994.897	99,504%	995.040
PVC	0,018%	175	0,026%	257	0,022%	216





PMMA Thermal depolymerization process Radical Unzipping Mechanism



MMAtwo first depolymerization pilot tests completed (June 2020)



Recycled Methyl Methacrylate through PMMA depolymerization

Pilot Tests – October and November 2020





MMAtwo

Second Generation MethylMethAcrylate

Pilot Tests June 28th-July 2nd 2021

LONG TEST RUNS CAMPAIGN

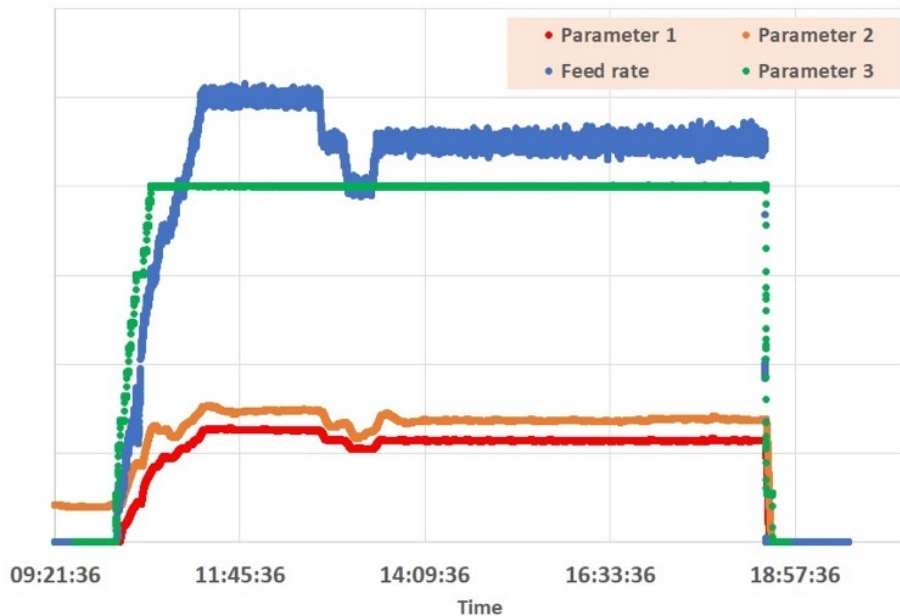


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Test June 29th 2021





Second Generation MethylMethAcrylate

Pilot Tests October 25th-29th 2021

5th TEST CAMPAIGN – MOST CHALLENGING MATERIALS



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MMA Purification: M36 Main results

Purification by distillation



S42P15-PD06-21

sample	%										
								MMA			
S42P15-PD06- load 1	0,1	0,2	1,7	0,08	0,04	0,12	0,01	89,5	0,05	0,5	8,2

- All rMMA samples are optical grade A quality
- All known impurities are < 0,1 %
- All unknow impurities are < 0,05 %

S42P15-PD06-PUS1



samples							MMA			Yield on MMA %	Yield on crude %
S42P15-PD06- PUS1-load 1 ; drum 1	ND	0,01	0,03	0,01	0	99,82	0,04	0,03	95,3	85,3	
S42P15-PD06- PUS1-load 1 ; drum 2	ND	0	0,03	0,01	0	99,8	0,04	0,03			

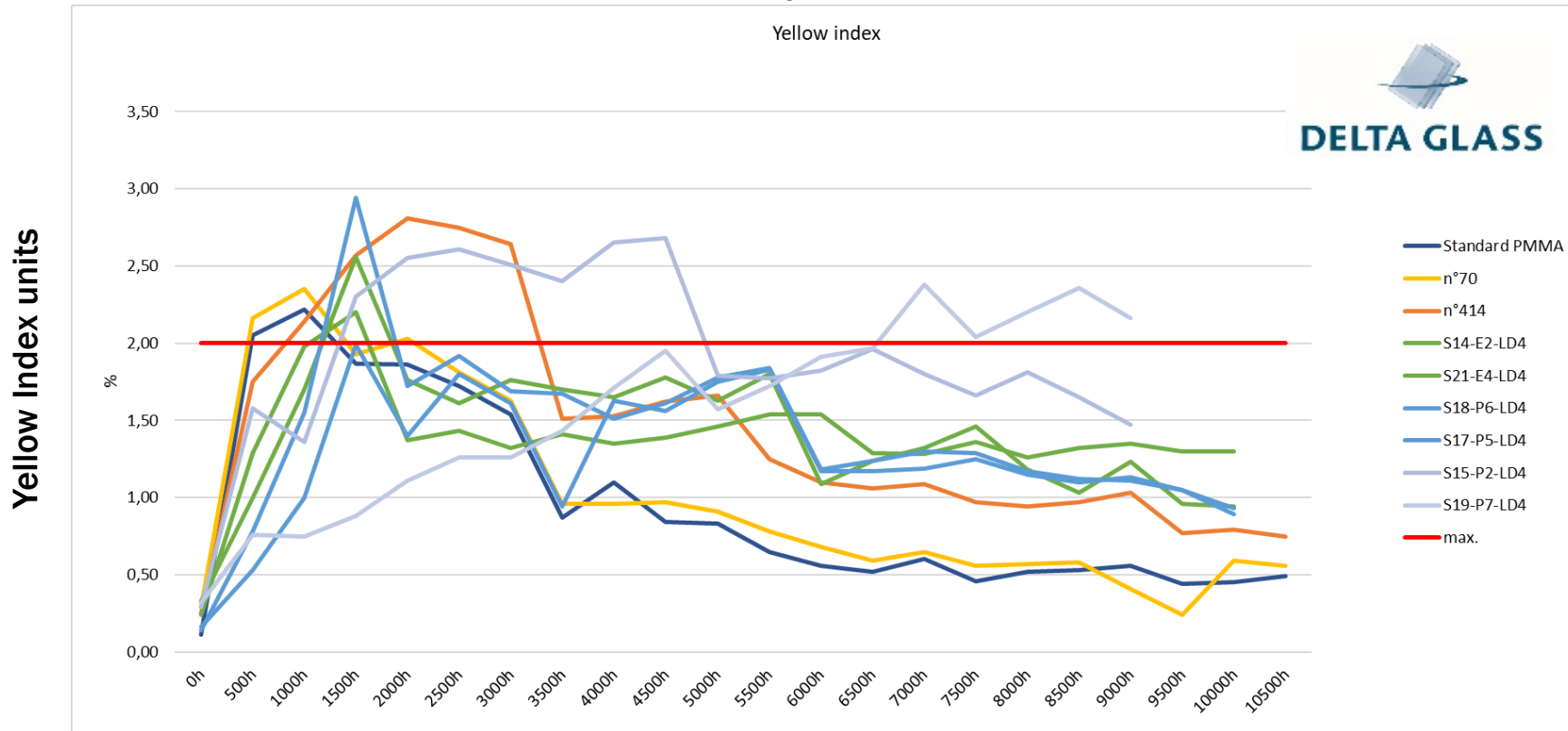


Applications: M36 Main results

Evaluation of the rMMA in optical grade PMMA applications

Yellow index according to ASTM E313 :

Yellow index evolution : OK at 10500h (early samples) and 9000-10000h (second series)

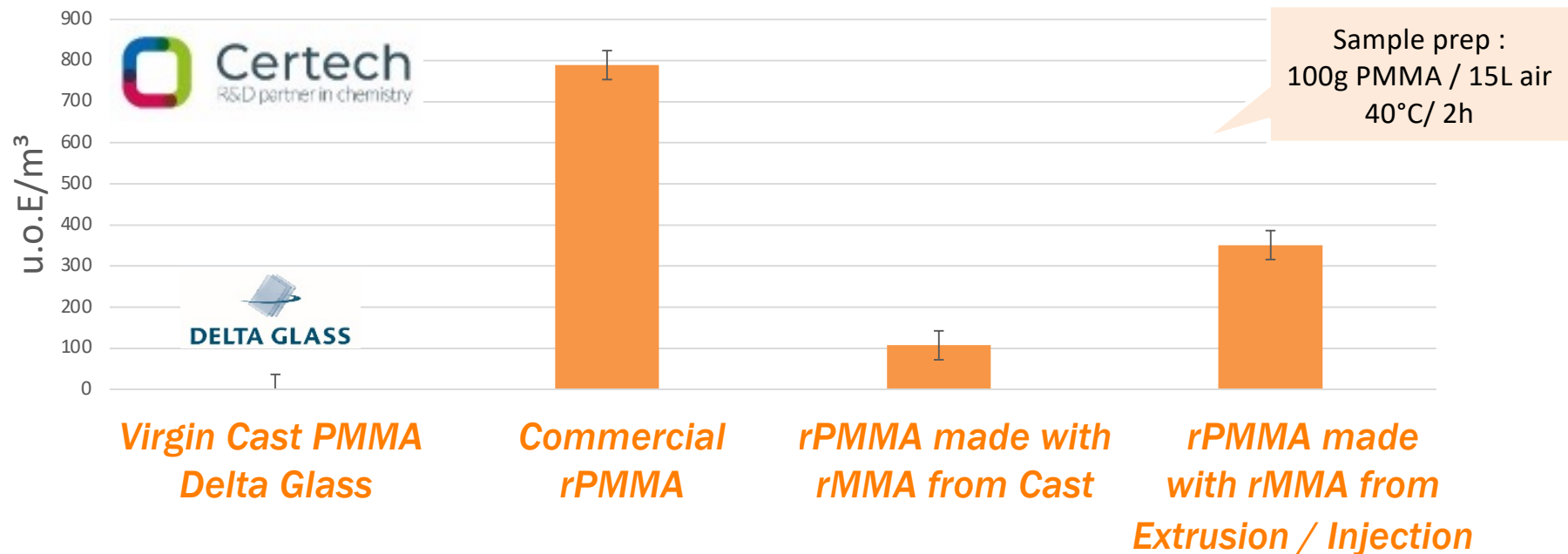




T4.1: Evaluation of the rMMA in optical grade PMMA applications

Odour evaluation from Delta Glass cast sheets

Dynamic Olfactometry on rPMMA



A difference between olfactometric results is considered as significant when at least a factor 2 is observed between 2 evaluations

- Virgin cast PMMA ≈ 0
- Commercial rPMMA more odorous than MMAtwo samples (nb same during thermoforming 5min. @ 180 °C - feedback Delta Glass)



Applications: M36 results **PLADOS** **TELMA** THE SINK THAT BREATHES

Evaluation of recycled glass fibres and recycled inorganics

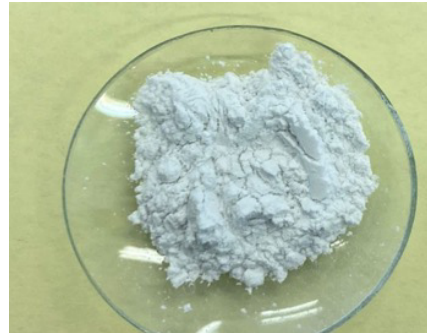
Cast derived rMMA



r-PMMA



milled recycled Glass Fibers



+

Lab tests → **positive**
First pilot trials (r-MMA+r-PMMA)
→ **positive**



Avenna



Chrome



Milk white



**Nanostone
black**



Deep black

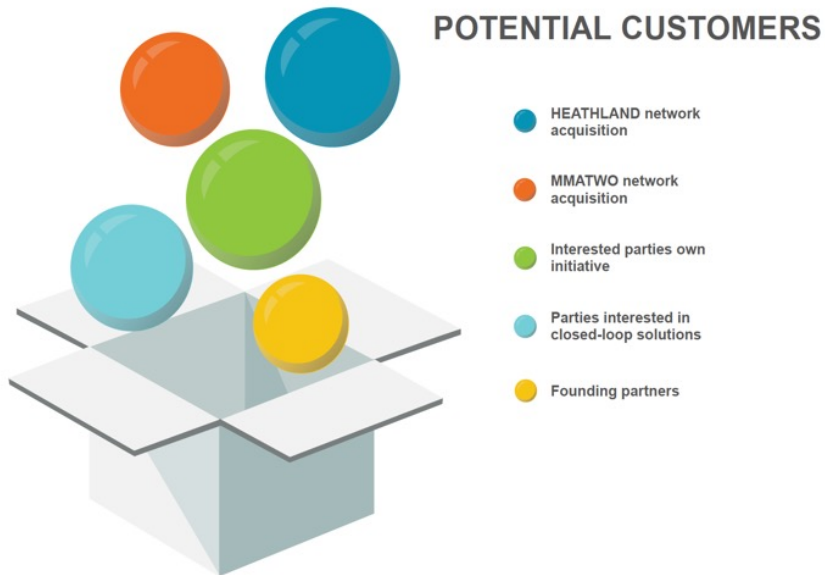






rMMA Market: M36 Main results

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TO COME SOON
(1) Technical Data Sheet
(2) Samples

Analysis certificate recovered Methyl Methacrylate	
Items	Figures
MMA purity (by GC)	99.8 %
Acidity as Methacrylic acid	< 5 ppm
Water content	400 ppm
Colour	≤ 10 APHA
Methyl Acrylate + Ethyl Acrylate	0.12 %
Methyl Isobutyrate	0.04 %
Density at 20 °C	0.943
Stabilizers: Topanol A or MEHQ	as requested

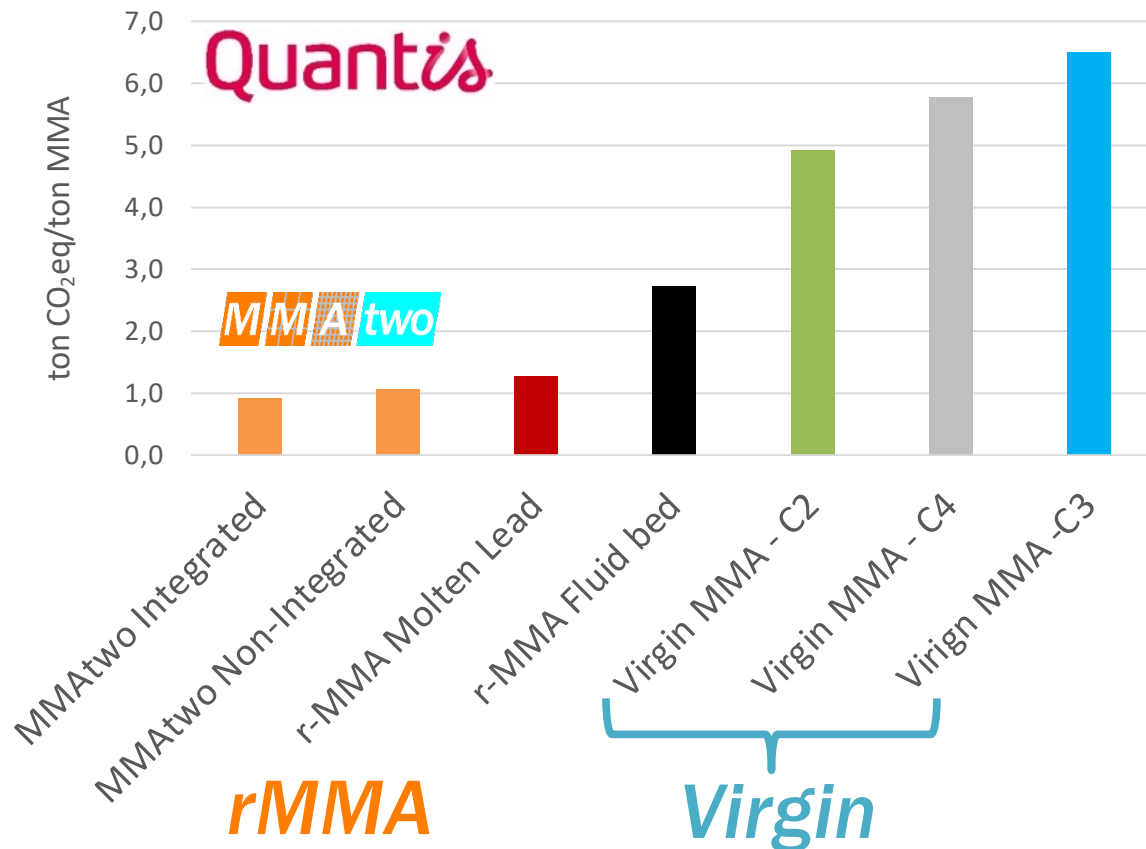


Grade	Purity	Comments
	99.8%	Comparable to virgin MMA in REACH registration.
	99.5%	
	99%	
	98%	



LCA: M36 Main results

Benchmarking with virgin technologies



Main Results

- Compared to virgin production, there is a large impact reduction (more than -75%) depending on the technology
- Compared to other recycling technologies, the impact reduction ranges between -20% to -60%
- More recycling processes to come soon

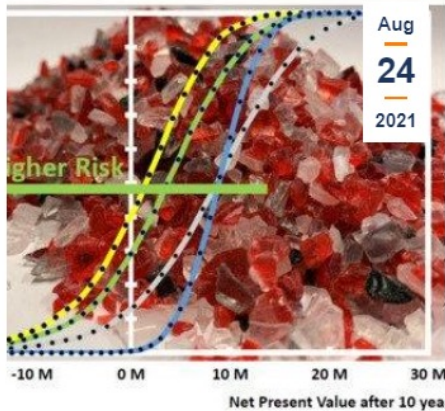
Data sets:

Virgin MMA: C2 route (3), C3 route (3), C4 route (3)
 R-MMA: Lead Bath (3+1); Fluid Bed (2),
 Rotating Drum (3), Dry Distillation (5), Stirred Tank (3)
 Dry Distillation with biomass as energy Source (3)





Communication and Dissemination M36 Main results



Publication

Publication

Check our third project publication (ARKEMA)

[Read more](#) ▶



International Directory for the Bio-based Businesses (IBIB)

Non classé

MMAtwo is part of the "International Directory for the Bio-based Businesses" (IBIB). Have a look at our profil <http://bio-based.eu/ibib/>

[Read more](#) ▶

Pilot trials – June 2021

Non classé

Back on track! The MMAtwo consortium continues to put it's innovative PMMA recycling technology to the test, benefitting from the improvements that were made over the last months. In this 4th trial campaign we are producing every day as much as we previously used to produce in an entire week! Thereby proving not only MMAtwo's...

[Read more](#) ▶

MMAtwo finalist of the Renewable Material Conference contest

Non classé

MMAtwo is part of the 6 finalists for the award "Renewable Material of the Year 2021". MMAtwo has been selected between 36 innovative and excellent submissions from all over the world. The six nominees convinced the advisory board with brand-new applications that aim to avoid or



Academic Dissemination: M36 Main results



Risk Analysis on PMMA Recycling Economics

by Jacopo De Tommaso [†] and Jean-Luc Dubois ^{*}

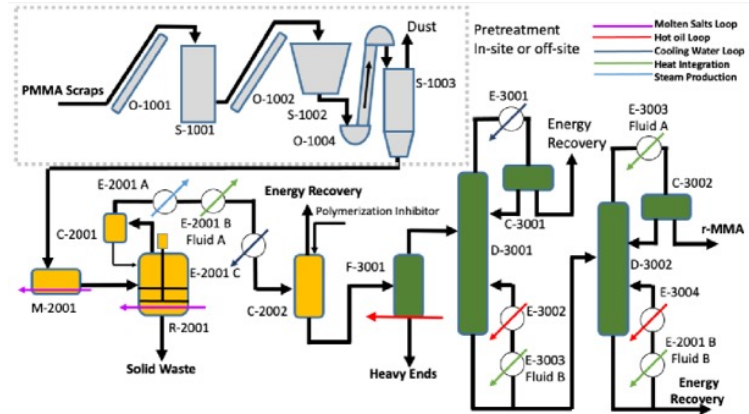
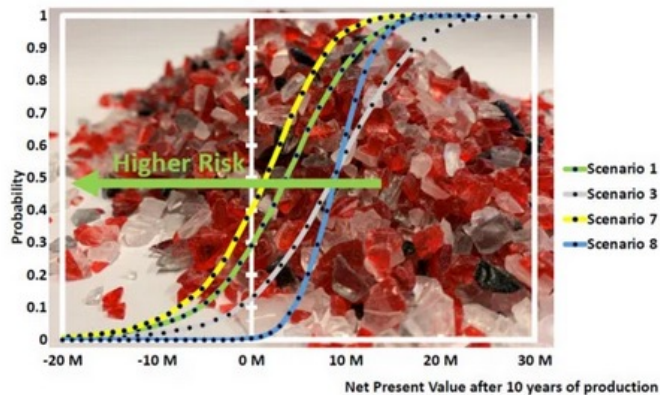
ARKEMA France, 420 Rue d'Estienne d'Orves, 92705 Colombes, France

^{*} Author to whom correspondence should be addressed.

[†] Current address: Chemical Engineering, Polytechnique Montréal, Montréal, QC H3T 1J4, Canada.



Polymers **2021**, *13*(16), 2724; <https://doi.org/10.3390/polym13162724>



Paper

Connecting polymer synthesis and chemical recycling on a chain-by-chain basis: a unified matrix-based kinetic Monte Carlo strategy

Kyann De Smit, Yoshi W. Marien, Kevin M. Van Geem, Paul H. M. Van Steenberge and Dagmar R. D'hooge

Polymer synthesis and subsequent depolymerisation/degradation are linked at the molecular level.

The article was first published on 22 Jul 2020

React. Chem. Eng., 2020, *5*, 1909-1928

<https://doi.org/10.1039/D0RE00266F>



Open Access Review

Progress in Reaction Mechanisms and Reactor Technologies for Thermochemical Recycling of Poly(methyl methacrylate)

by Eli K.C. Moens, Kyann De Smit, Yoshi W. Marien, Alessandro D. Trigilio, Paul H.M. Van Steenberge, Kevin M. Van Geem, Jean-Luc Dubois and Dagmar R. D'hooge

Polymers **2020**, *12*(8), 1667; <https://doi.org/10.3390/polym12081667> - 27 Jul 2020





Footprinter

Developed in collaboration between:



Jonathan Ouziel,
Andrea Corona



Marek Blahusiak
Juraj Hrstka



Jean-Luc Dubois

Environmental Benefits Calculator

The MMAtwo Project aims at constructing a novel and fast growing PolyMethylMethAcrylate (PMMA) recycling value chain based on the production of «Second Generation MethylMethAcrylate (MMA)» from post-consumer and post-industrial PMMA based products.

The technology is a cost effective and efficient recycling process with **reduced energy consumption and CO₂ emissions**, that aims to **reduce the utilization of primary fossil resources** in the process industry by at least 30%.



An innovative **lead-free recycling technology** leading to **energy consumption and carbon footprint reductions**.

Calculator

Calculate the **environmental impacts** of MMAtwo technology and value chain to **recycle Plexiglass (PMMA)** and the environmental benefits compared to other technologies.

[Learn more about the study](#)

Quantity (between 1 and 1,000,000 kg)

1 kg kg

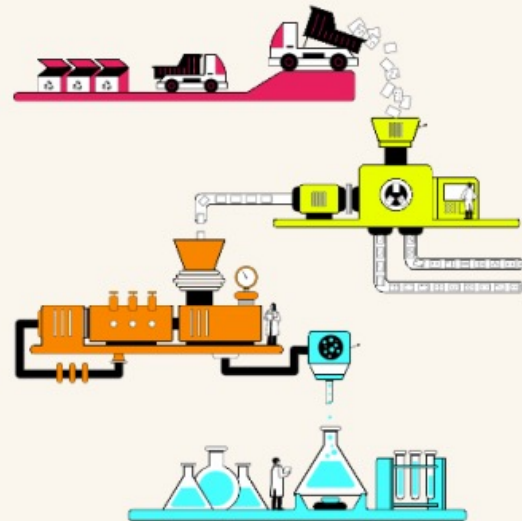
PMMA scraps to recycle kg

r-MMA to purchase kg

r-MMA Purity

Market/Region

Purity of Scraps



Comparison

of the approximated environmental impacts of the batch*

	MMAtwo	Virgin MMA C2
purity of rMMA	99.50%	100.00%
climate change impact	0.66 kg CO ₂ -eq	3.04 kg CO ₂ -eq
water utilization	n/a [†] m ³	0.22 m ³
resource use, fossil	1.66 MJ	63.2 MJ

* Data not yet available. Currently being modelled and will be available soon.

Environmental benefits of MMAtwo vs. Virgin MMA C2

climate change impact	-79%	water utilization	-	resource use, fossil	-98%
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Website address : <https://www.mmatwo.eu>

UN Sustainability Goals

9 INDUSTRY, INNOVATION
AND INFRASTRUCTURE



12 RESPONSIBLE
CONSUMPTION
AND PRODUCTION



13 CLIMATE
ACTION



17 PARTNERSHIPS
FOR THE GOALS



Thank you for your attention