First successful depolymerization trials in June, October and November 2020

Word by Project Coordinator Simon van der Heijden

Halfway through the project's initial lifespan, MMAtwo is on track to create a lasting impact on the way we handle PMMA waste within the European Union. At the time of writing this newsletter, 3 campaigns trialing MMAtwo's innovative technology have been successfully completed, with a 4th campaign planned in Q1 2021. Already we have seen that the technology provides solutions to convert all types of PMMA waste, including difficult to recycle End-of-Life PMMA waste, into virgin-like quality MMA. And with many partnerships formed throughout the PMMA waste value chain, MMAtwo is set for successful commercial deployment of its technology too. Because for PMMA, conversion to MMA by means of depolymerization offers huge advantages, as outlined in this newsletter. MMAtwo therefore creates a viable and competitive business whilst saving resources allowing waste to be regenerated cycle after cycle after cycle.

Complementarity of Mechanical recycling and Depolymerization

PMMA is present on the market as Cast, Extruded and Injection grades. Cast has a high molecular weight. Extrusion and Injection grades contain comonomers added to inhibit depolymerization when the polymer is reheated to get its final shape. Cast PMMA cannot be recycled mechanically, and although it would be possible for the other grades, they are often coloured which would allow only dark products. In addition, collected scraps are mostly mixed cast and extrusion, which are not easily distinguished. Mechanical recycling is only for a small share of post-industrial products, and depolymerization complements it effectively.

PMMA depolymerization is already an industrial reality

MMAtwo is mapping the existing MMA regeneration plants (see below in WP2 section). Several dozens of plants have been identified representing several 10 000 tons annual capacity. See also the comments from current market players at the end of the newsletter.

Regenerated MMA achieves virgin-like quality

Depolymerized crude MMA can be purified to virgin like quality (see below WP3 section) and regenerated MMA can be used in the same applications including high optical properties cast PMMA (see below WP4 section).

PMMA depolymerization reduces the Green Houses Gases emissions

MMAtwo benchmarks its technology with virgin MMA, without taking into account avoided emissions from incineration, since incineration or landfilling are not considered viable options in the future. Significant reductions are possible (see below in WP5 section).

MMA regeneration consumes a small amount of energy

Virgin MMA production requires a lot of energy, but depolymerization which takes place with an unzipping radical process, demands a small amount of energy (see below in WP5 section)

Polymer to Polymer yields, Views on chain of custody, Impact from substances of concern and additives, will be reported in next newsletters.

MMAtwo 3 major objectives:

- Construct a **new PMMA depolymerization value chain in Europe**, covering the whole value chain of the PMMA lifecycle with both production waste and end of life waste
- Avoid down-cycling through **reactive regeneration** (depolymerization)
- Develop an **innovative metal-free technology** enabling depolymerization of lower quality waste.

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MMAtwo is divided into 7 Topics (so called Work Packages)

WP1: Collection of scraps and pretreatment,

WP2: Depolymerization,

WP3: Purification,

WP4: Exploitation, end-users tests, business analysis,

WP5: Techno-economic and environmental assessment,

WP6: Project management,

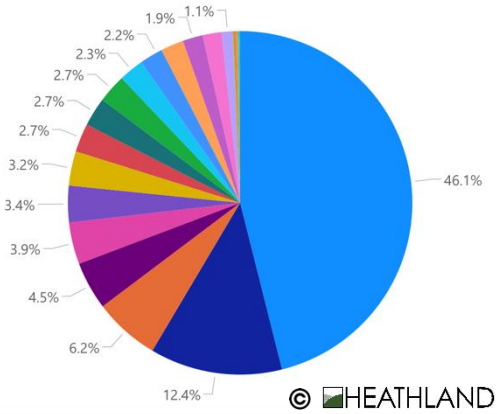
WP7: Communication, dissemination and academic outreach.

Main results achieved since May 2020

WP1 - **Ecologic**, assisted by **Heathland**, performed a countrywide research in France to map sources of End-of-life PMMA waste originating from WEEE. As PMMA is used in many Flat Panels Displays (FPD) as a light guide panel, the amount of PMMA waste from WEEE is steadily increasing. The research identified the main sources of PMMA from WEEE, the ways to recover PMMA from WEEE cost-effectively and a seamless process to convert this type of PMMA into either rPMMA or rMMA.

Through **MMAtwo's unique pretreatment technology** the PMMA was prepared for optimal recovery in WP2, resulting in near-virgin quality raw material. The research was extrapolated from France to Europe, in collaboration with WEEE collection centers to map total available feedstocks, now and in years to come.

Identified MMAtwo waste by resulting pretreated feedstock



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Further progress was booked on automatic separation of PMMA and PVC by **Heathland**, using a specialized process to reach suitable feedstock for depolymerization. Research was done on waste streams from **Arkema** and **Delta Glass**, where analysis was performed by **Certech** and **Comet**.

A broad spectra of different PMMA waste types was pretreated into ready feedstock for conversion into crude rMMA.

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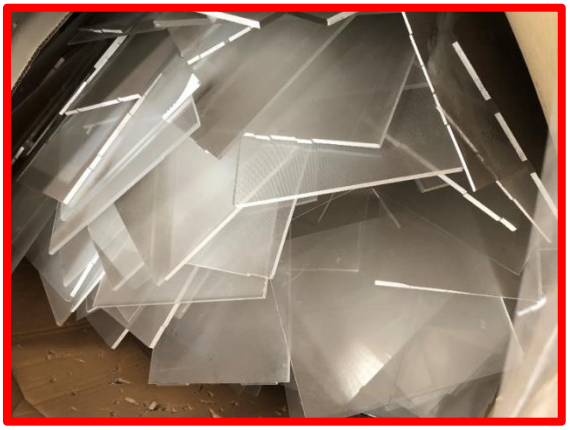

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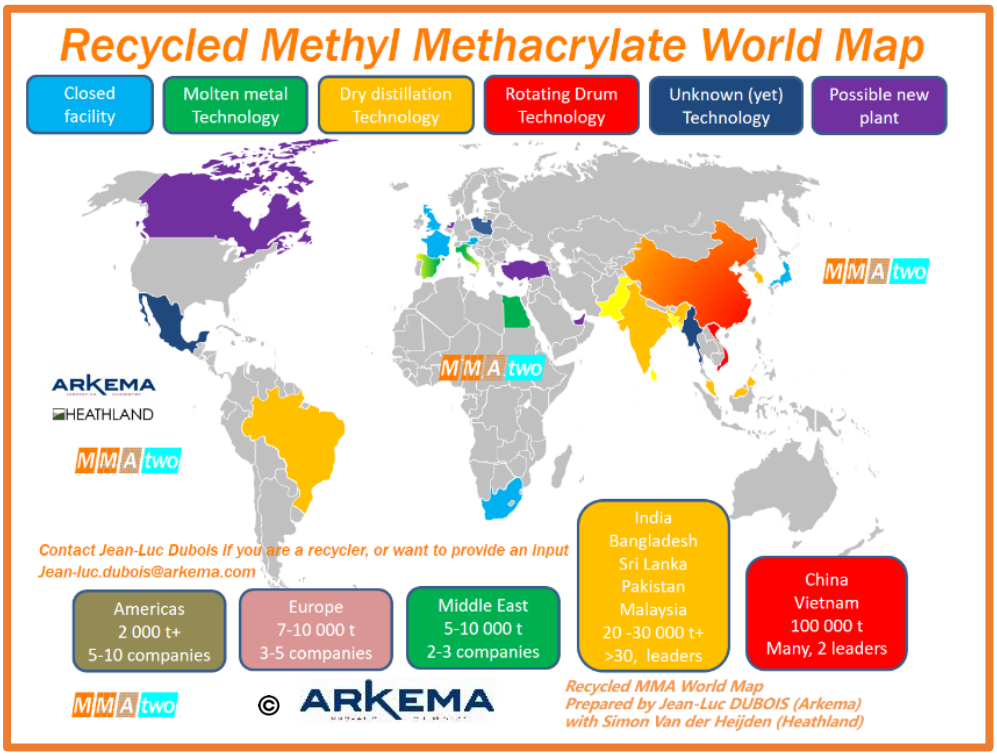
WP2 - PMMA depolymerization has moved from the laboratory to the pilot scale, with 3 test periods in June, October and November 2020. During these tests, in which partners **Arkema**, **Heathland**, **Japan Steel Works Europe** and **PDC** contributed, several different types of PMMA (Post-Industrial and End-of-Life) materials have been processed. The unit operated better at above design capacity, and the limitation was the storage capacity. The pilot was operated above 1000 t annual capacity for several hours, producing high quality crude MMA.

During the November 2020 tests, out of a dozen of materials, End of Life WEEE waste was processed (left sample and material on the picture) and clear crude MMA was produced. A first composite material was also depolymerized (right sample and material) which will be also further purified in the coming month.

© JSW HEATHLAND ARKEMA PDC

MMAtwo continues the mapping of the PMMA depolymerization plants in the world, together with their current capacities and technologies (done by **Heathland** and **Arkema**). The mapping is a continuous exercise aiming to show to the stakeholders (producers, customers, public authorities…) that PMMA can be and is already depolymerized in significant amount, and that more can be done with our new technology with a potential of fast adoption.

People aware of existing facilities are encouraged to report to Jean-Luc Dubois (jean-luc.dubois@arkema.com) (**Arkema**) who is updating the mapping on regular basis.



WP3 - **Speichim** moved the purification, from laboratory scale to the pilot scale, on the crude MMA obtained from the first depolymerization trial in **Japan Steel Works Europe**. The same encouraging results were obtained at both scales (laboratory and pilot). The purity of the recovered MMA was very high: 99.8%. The recovered MMA was successfully tested.

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

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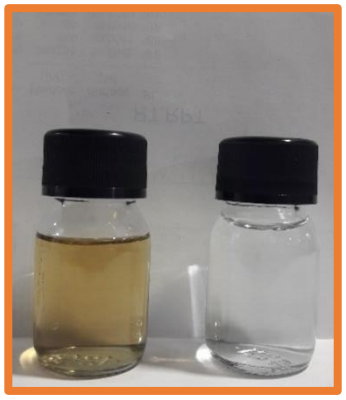

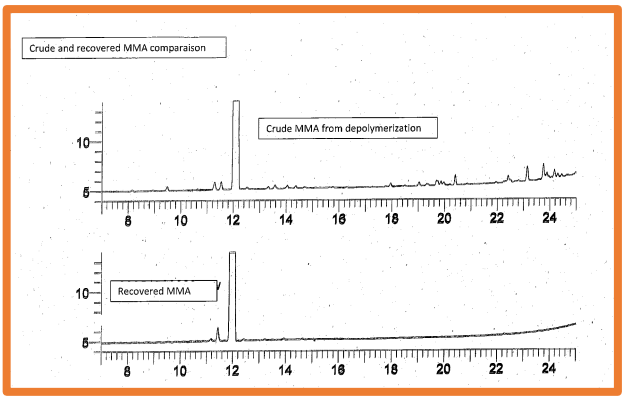

Purification pilot plant. Left: Crude MMA, Right: Regenerated MMA. Crude and regenerated MMA.

© Speichim processing Certech R&D partner in chemistry

WP4 - The purified rMMA obtained during the first depolymerization pilot trials mentioned above was used in production by **Delta Glass** in order to successfully manufacture standard sheets with dimensions 1600 x 2600 x 3 mm^3 from which a first caravan window was produced (see pictures).

Left: industrial cast sheet made from pilot trial rMMA, right: caravan window obtained from the same cast material.

© DELTA GLASS

Evaluation of various rMMAs from lab scale depolymerization as well as the purified pilot plant rMMA has been finalized and validated for structural composite applications by **Arkema** and for kitchen sink applications by **Delta Plados** (see picture). **Certech** showed that the main odorous intensities of structural composite materials originate from residual monomers and comonomers, recombination products and most likely degradation products. This is equivalent to what is observed with virgin material.

Left: preparation of fully recycled syrup (mixture of pilot plant rMMA and post-industrial rPMMA scrap), center and right: first prototype sinks ("Avena" and "Deep Black" compositions) obtained with said syrup.

© DELTA RESEARCH & DEVELOPMENT PLADOS TELMA THE SINK THAT BREATHES

Heathland received further interest for the project from several third parties from industry following the MMAtwo webinar organized by **UGent** on September 15, 2020.

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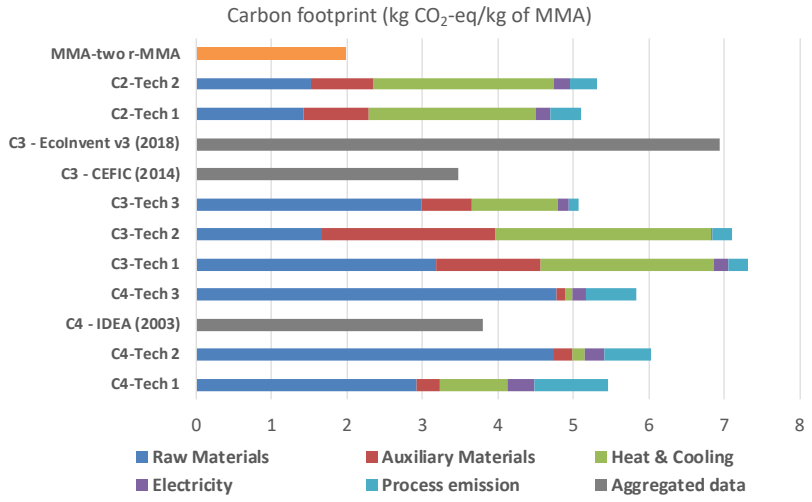
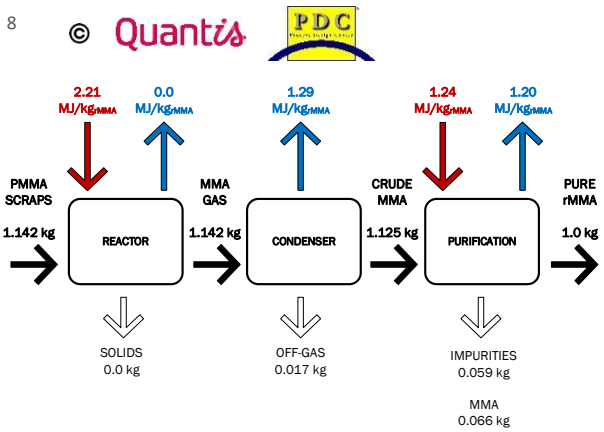
WP5 - **Quantis** has refined LCA results for benchmark technologies, taking into account the different routes for virgin MMA production and including reference datasets from recognized environmental databases.

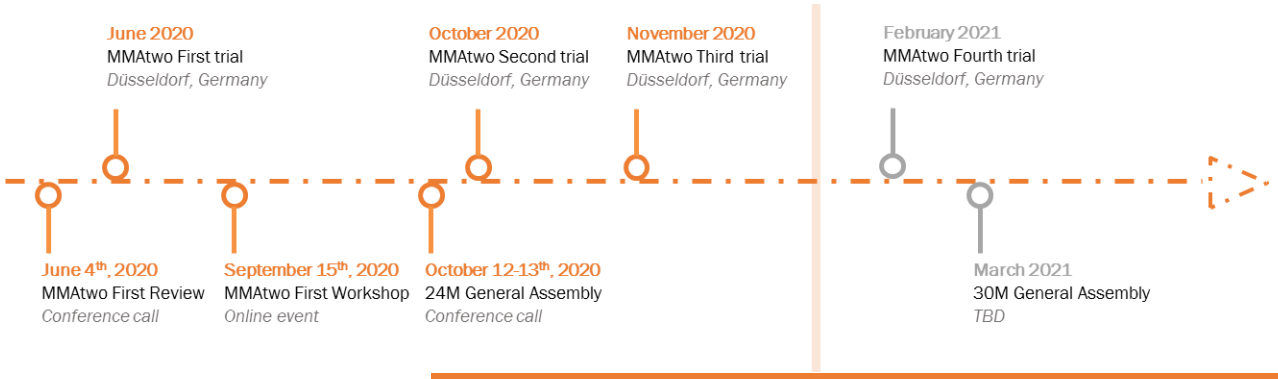


- Cx routes were developed on mass end energy balance (with no energy optimization) – C2: Ethylene-based, C3: Acetone-based, C4: isobutylene/t-butanol-based routes
- EcoInvent and CEFIC datasets represent European average production from real plants
- IDEA dataset represents Japanese average production from real plants (C4).
- Virgin MMA Carbon footprint ranges from 3.5-7 kg CO_2-eq/kg MMA
- Initial results for MMAtwo technology show an impact reduction -44% to -73% depending on the virgin technology considered

Based on process design and simulation performed by **PDC**, MMAtwo partners will soon be able to test the sensitivity of rMMA environmental footprint depending on feedstock purity and operating conditions. Here is an example of mass and energy balance of rMMA production from pure PMMA scraps without heat integration.



MMAtwo Main events



Are you interested to contribute to the MMAtwo project or do you simply want to stay informed about all our news?

Please let us know by completing the following form

www.mmatwo.eu/contact/

MEET US THERE

- *9th Conference on CO2-based Fuels and Chemicals, 23 & 24 March 2021, Cologne, Germany*
- *Renewable Materials Conference, 18-20 May 2021, Cologne, Germany,*
- *AMI Plastics Recycling Technology, 20 - 21 October 2021, Vienna, Austria*
- *11th ICIS World Phenol-Acetone Conference, Date and place to be confirmed*

Thank you for participating to our workshop on polymer recycling last September !

Slides are available on our project website in the newsroom section

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Words from our stakeholders

A European study, dated about one year ago, found that about 57 billion euros are lost every year due to lack of efficient recycling or simply recycling. This illustrates the importance of recycling, in terms of economy and environment. The recycling regeneration of MMA is a definitively good move towards circular economy for Europe

PMMA recycling project is an important pioneering project clearly showing, like some other projects that old technics can be dramatically improved, allowing recycling and circular economy to become a technical and economic reality.

Philippe Salemis, Methacrylate Sector Group Manager, CEFIC, Brussels

'Today the actual technology and plants allow to reprocess high quality MMA, from PMMA waste of different colors, as well as from cast than extruded sheets, which cannot be mechanically recycled, realizing a real ''closed loop process''.

The goal of reprocessing wastes to a very high quality substance (MMA) is a reality, with a reduction of CO2 emissions by 70 % with respect to virgin MMA.

The new process in MMAtwo will allow to reprocess very complex PMMA wastes, unlikely to be reprocessed with the actual technologies, to highly pure MMA.

Antonella Annunziata, Madreperla CEO

The chemical recovery of any "plastic" is generally not understood, most believe that you can only blend as a solid as in the case of PVC or rubber compounds or only recover a very low purity monomer only suitable for a fuel source. PMMA is one of the very few polymers that can be converted / de-polymerised back to the original monomer and at very high purity allowing you to use the distilled DMMA in place of virgin MMA. It can also be de-polymerised again from the solid sheet form without the DMMA losing any of its properties which is unique to the chemical recovery process.

The PMMA recovery plants use relatively little water or other utilities during the conversion process in relation to the vast amount of water and energy needed to produce virgin MMA. There is obviously a waste / by-product from any chemical plant that must be disposed of in the correct manner but this represents a very small percentage of the overall recovery and benefit that is gained. The major drawback from any recovery unit is the collection, sorting and preparation of the "scrap" feedstock. Certainly the work MMAtwo has done to date in this regard is very encouraging.

Bob Fowler, PMMA recycling consultant