Mixed plastic waste

Sustainable valorisation solutions for material & energy recovery

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Webinar Report

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Mixed Plastic Waste: Sustainable valorisation solutions for material & energy recovery

Foreword

IEA Bioenergy Task 36 - Material and Energy Valorisation of Waste in a Circular Economy - seeks to raise public awareness of sustainable energy generation and resource recovery from biomass residues and waste fractions including MSW (Municipal Solid Waste) as well as to increase technical information dissemination. This webinar represents one of several workshops/webinars that Task 36 organizes. It focuses on advanced technologies for resource recovery from waste, which is critical in the transition from a linear to a circular economy.

As outlined in the 3-year work programme, Task 36 seeks to understand the effect that initiatives along the waste and value chain have in the deployment of bioenergy and the roles of energy recovery in a circular economy, as well as identify technical and non-technical barriers and opportunities needed to achieve this vision.

Past workshops in this 3-year work programme have explored sustainability aspects in the energy from waste from a regional perspective with a workshop series with three events, each one with different focus: Waste-to-energy in South Africa (on-line, November 2022), Organic and plastic waste resource recovery in North America (on-line, July 2023) and Food waste (Hybrid/Dublin, October 2023).

See http://task36.ieabioenergy.com/ for links to the workshops/webinars.

Disclaimers

The workshop was organized by members of Research Institutes of Sweden (RISE) and Karlsruhe Institute of Technology (KIT). The views and opinions of the workshop attendees, as summarized in this document, do not necessarily reflect those of IEA Bioenergy Technology Collaboration Programme nor those from RISE, KIT or any country member participating in IEA Bioenergy Task 36.

Practical details

IEA Bioenergy Task 36 digital webinar was held on November 18th, 16.00-18.00, CEST, on Zoom. The webinar was organised by Mar Edo (RISE, Sweden) and Dieter Stapf (KTI, Germany) who also moderated the event with 310 attendees.

Link to the recording: https://youtu.be/FL0aMzAS0mk

Introduction

Finding sustainable solutions for handling of plastic waste has already been a relevant question for many years due to the vast volumes generated worldwide and their impact on the environment.

If we talk about mixed plastic wastes in particular, its heterogenous compositions pose an extra challenge. They contain not only hydrocarbon polymers, but also heteroatoms, additives such as fillers, pigments, plasticizers or flame retardants, and other types of contaminants such as food waste, biomass, inserts or metals among others. This is a challenge for high quality recycling and for that reason they might end up being incinerated or landfilled losing with it resources and impacting negatively the environment.

New technological pathways are being explored with the aim of providing solutions to a more sustainable handling of mixed plastics wastes. Mechanical recycling is becoming more and more important in establishing the carbon cycle to recover material and reduce CO2 emissions. Chemical recycling (specifically pyrolysis and gasification) starts to play an important role in handling mixed plastic waste, provided that the main challenges to scale up plants for chemical recycling are overcome and, therefore, it is considered now as complementary to the existing mechanical recycling. Advance sorting (sensor-based) technologies are meant to pave the way to a more efficient sorting of mixed plastic waste in the future: they might help to adjust the operational parameters of mechanical and chemical recycling of mixed plastic waste plants in the future to increase feasibility and efficiency.

This webinar brought light to advanced technical solutions that led to a more sustainable valorisation of this waste stream and bring us closer to circularity in the field of plastic waste management.

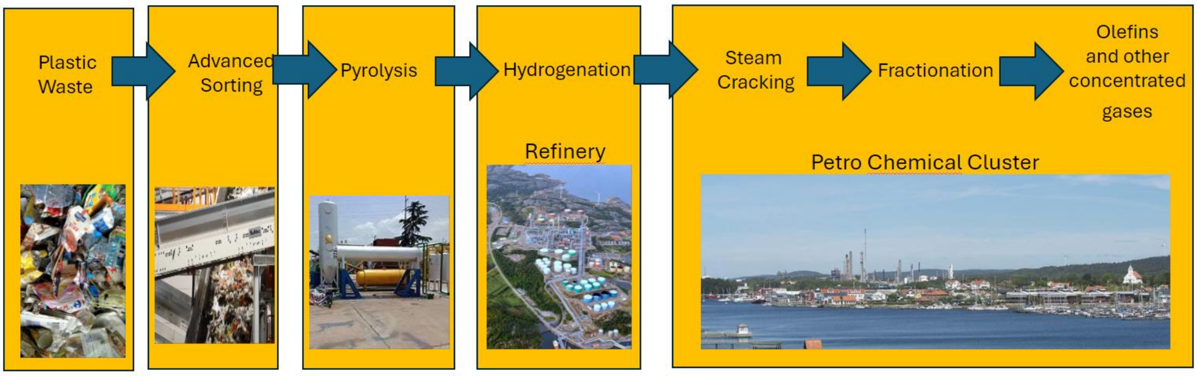

Figure 1. Steps in the conversion of mixed plastic waste into high value chemicals. Source: Chalmers University of Technology.

Presentations summary

Alternative pathways to incineration of mixed plastic waste. Circular Plastics for closing the carbon cycle. Salar Tavakkol, KIT, Germany.

Mr. Tavakkol presented examples of mixed plastic waste following different conversion routes.

Organic-rich fraction from mechanical recycling automobiles. It is estimated that ca 9.2M tones of mixed plastic waste per year are generated worldwide after shredding of end-of-life vehicles. Flamer retardants, additives and fillers pose a barrier for mechanical recycling of this waste stream, as well as small metals pieces and impurities.

The study shows that when shredder light fraction (SLF) is pyrolyzed, up to 42 wt.% pyrolysis oil yield could be reached. Regarding carbon efficiency, 68 wt.% of the carbon ends up in the pyrolysis oil and 32 wt.% in the off gases. Steam cracking of upgraded pyrolysis oil results in more than 50 wt.% of carbon recovery as it turns into high value chemicals which is a higher recovery that would be expected if the SLF would be incinerated.

Mr. Tavakkol also presented the results from the climate change impact assessment for different thermal conversion routes to treat mixed waste plastic, where for this difficult-to-recycle waste stream gasification/syngas production (Oxo and methanol) resulted in the lowest climate change impact, while incineration with energy recover resulted in the highest- this conclusion is, of course, subjected to the type of feedstock used.

Based on the studies presented, it seems feasible to adopt in the future mixed plastic waste sorting strategies that aim at sorting mixed fractions based on polymer content and/or degree of contamination rather than monomer (polymer) type fractions

Regarding chemical recycling, heteroatom contamination remains as the main challenge in terms of costs, resources and design of the plant for the future of chemical recycling.

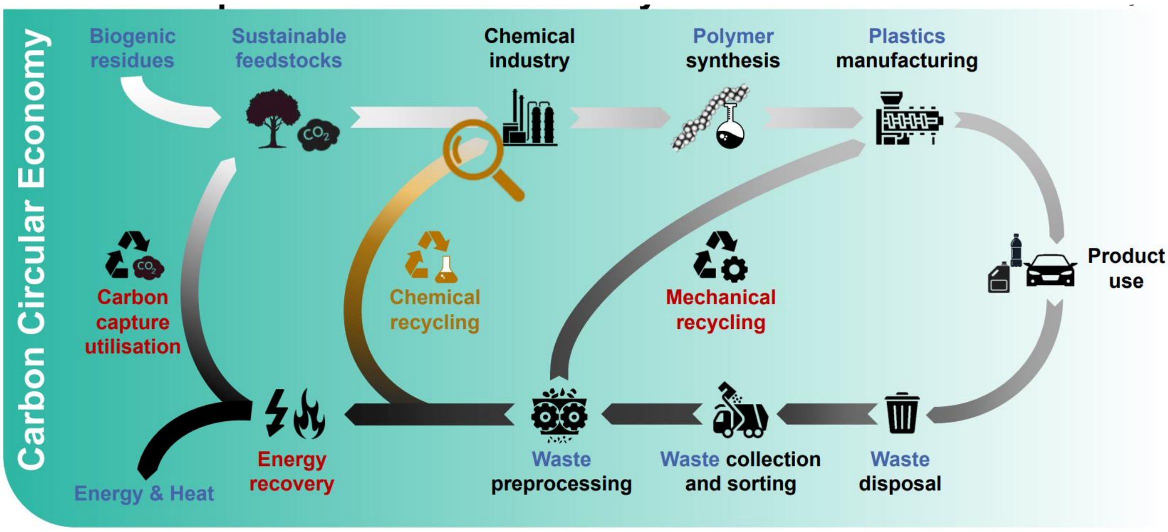

Figure 2. Perspective for plastic lifecycle combining different technology to efficiently increase circularity of plastics. Source: KIT.

Link to presentation (pdf): Karlsruhe Institue of Technology, KIT_Alternative pathways to incineration of mixed plastic waste._ Salar Tavakkol.

Site Zero: one step closer to circular economy for plastic packaging from households. Richard Jansson, Svensk Plaståtervinning, Sweden.

Mr. Richar Jansson opened his talk presenting the main contributors to the overall inefficiency in plastic packaging managing: 1. Increasing amounts are generated worldwide; 2. Wide range of different plastic types is used and combined leading to more complex packaging designs; 3. Households' behavior in terms of consumption and sorting; and 4. Lack of infrastructure for advanced sorting and high-quality recycling.

Site Zero is an advance sorting plant owned by Svensk Plaståtervining which is privately owned by the Swedish plastic packaging industry, and that was built to contribute solving the plastic packaging challenge in Sweden. Site Zero is a fully automatized plant with capacity of 200,000 tons that operates with 50 NIR stations where up to 12 different mono polymer types can be targeted and sorted out to be used as feedstock for mechanical recycling. Even with such a sorting strategy, there is a residual/remaining fraction (refuse derived fuel, RDF) that is a partly a mixed of polymers (i.e. multilayers films materials) that cannot be sorted out in mono fractions and partly other non-target materials (i.e. material wrongly sorted by households). This material is typically sent to energy recovery. However, Stite zero has now implemented a last sorting step to recover the mixed plastics from the remaining fraction. In this way, the mixed plastic fraction recovered could potentially be used as feedstock in chemical recycling (i.e. pyrolysis, gasification) while what is left (i.e. textiles, cardboards) would end up in energy recovery.

Next steps for Site Zero (after 2025): 1. Washing and granulation on site to avoid exporting materials for this treatment and reduce climate impact associated with its transportation. 2. The process will not leave to 100% clean stream and there will always be a reject (i.e. textiles or paper with plastic film) fraction that needs to be sent to energy recovery where CCS/CCU would play an important role in reducing carbon dioxide emissions.

The reason why Svensk Plaståtervining prefer sending material for mechanical instead of chemical recycling is the lower energy consumption and well stablished infrastructure.

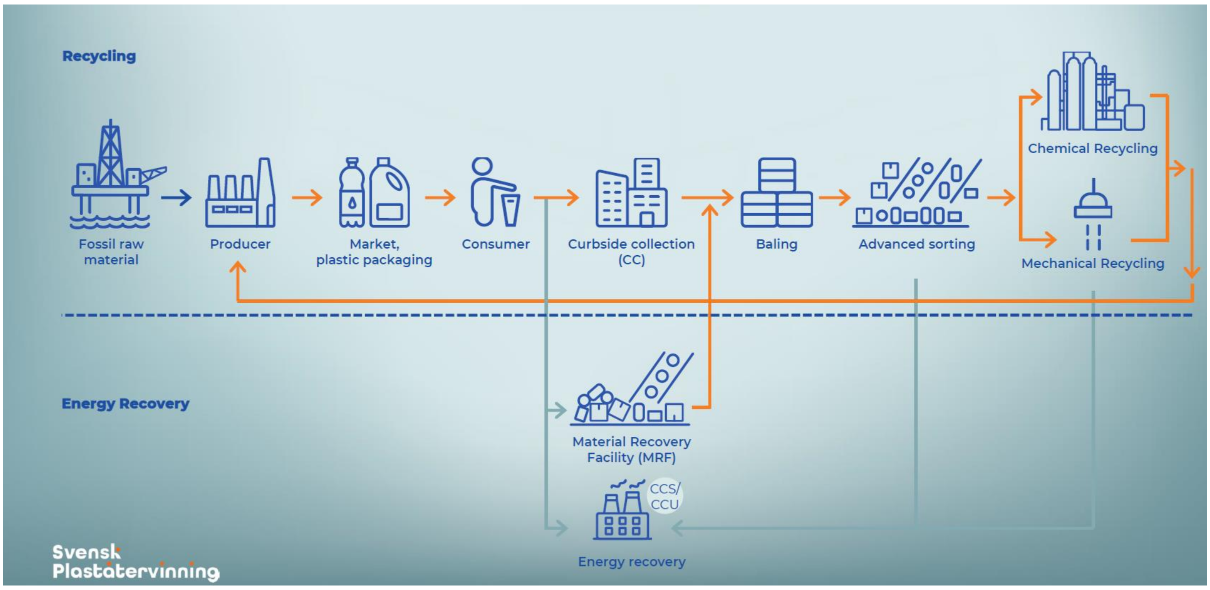

Figure 3. Site Zero recycling system scheme including the new units that might be added to the process in the coming years. Source: Svensk Plaståtervinning.

Link to presentation (pdf): Swedish Plastic Recycling_Site Zero, one step closer to circular economy for plastic packaging from households_Rickard Jansson -

Conversion of mixed plastic waste into petrochemical feedstock- insights in ARCUs pyrolysis process, Marco Tomasi Morgano, ARCUS Greencycling Technologies GmbH, Germany.

ARCUS is Germany's first commercial plastic-to-plastic pyrolysis plant for mixed plastic waste. Its role in the value chain is to connect the waste sector with the petrochemical industry by providing waste-based feedstock (mixed plastics waste including multilayer, PET and PVC) to the second one to produce plastics again, getting closer to circularity in the plastic value chain.

Despite pyrolysis has been used in many applications since a long time ago, it is not yet a well stablished process and still requires development and lots of issues needed to be overcome during the start-up of ARCUS' plant. ARCUS' process demonstration unit has capacity for treating 4,000 tons of mixed plastic per year and produces 2,500 tons per year of pyrolysis oil that are sold to customers. Before entering the process, the feedstock needs to be shredded and pelletized to increase bulky density to ensure the stability of the process. About 85 wt.% of the polymers in the feedstock are polyolefins and a the most common contaminants in the feedstock are stones, metals or aluminium sheets. The process can absorb the variation in the feedstock composition to deliver a pyro-oil with constant composition. Up to date, the ARCUS' has delivered more than 100 tons of pyro-oil to customers.

Regarding emissions, polyaromatic hydrocarbons (PAHs) are generated in the gas-phase reactions; dioxins and furans (PCDD/Fs) are three orders or magnitude below limitations set by national authorities, and heavy metal concentrations are in the range of µg/kg except Si and P that are above 1 mg/kg.

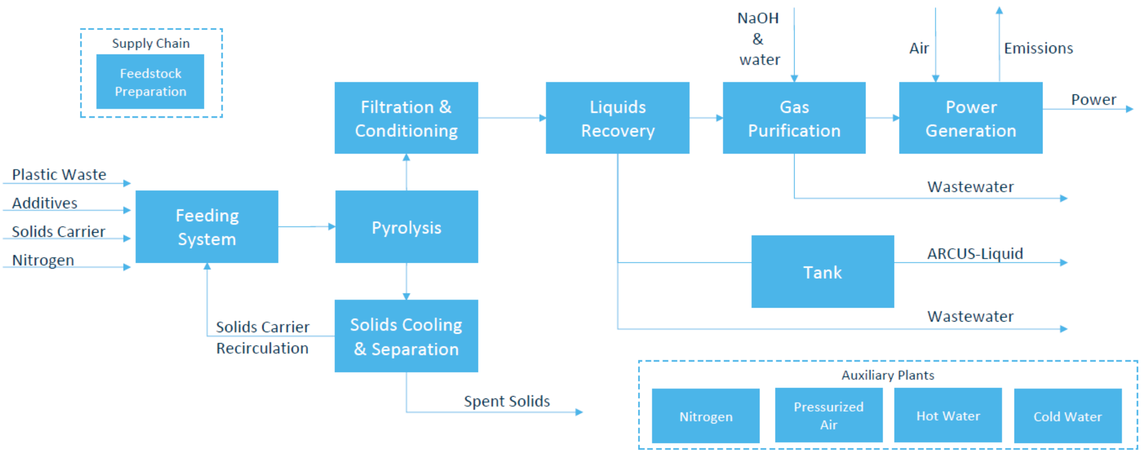

Figure 4. ARCUS' demonstration unit process diagram for conversion of mixed plastic waste to chemical. Source: ARCUS Greencycling Technologies GmbH.

Link to presentation (pd)f: ARCUS Green Technologies_ Conversion of mixed plastic waste into petrochemical feedstock._Marco Tomasi

Thermal cracking for recycling of plastics and contaminated pyrolysis oils, Henrik Thunman, Chalmers University of Technology, Sweden.

Mr. Thunman posed the question at the beginning of his presentation: Is it possible to design a steam cracker process that could handle contaminated, charring, and ash-containing materials, and produce a gas that could be sent to the fractionation unit in petrochemical industry?

The answer is yes but, if fossil feedstocks want to be replaced by waste streams such as mixed plastics at scale in existing petrochemical clusters, more robust steam crackers processed need to be introduced.

Mr. Thunman suggest use of fluidized bed reactors as a viable and robust solution. This approached has been tested at semi-industrial scale at Chalmer University of Technology. Steam cracking at Chalmers is carried out in 12 MW research boiler that can handle up to 230 kg PE/h or 320 kg PET/h. Different kinds of feedstocks have been tested in the reactor, such as mixed plastic waste, ASR (automated shredder residue), animal fat, textiles, tetra pack, pyrolysis and vegetable oil. The mixture of hydrocarbon obtained contained both valuable products for the chemical industry and others can only be used for heating purposes of the process.

This kind of reactor would allow to expand the feedstock base, reduce the need for advanced sorting, remove the hydrogenation step at the biorefineries, and go directly to fluidized bed stream cracking combined with gas conditioning. For commercial uses, it would be beneficial to use solid plastic waste or crude pyrolysis oil. The pyrolysis oil does not require to be hydrogenated or decontaminated beforehand, which expands the range of usable feedstocks and simplifies decentralized pyrolysis processes.

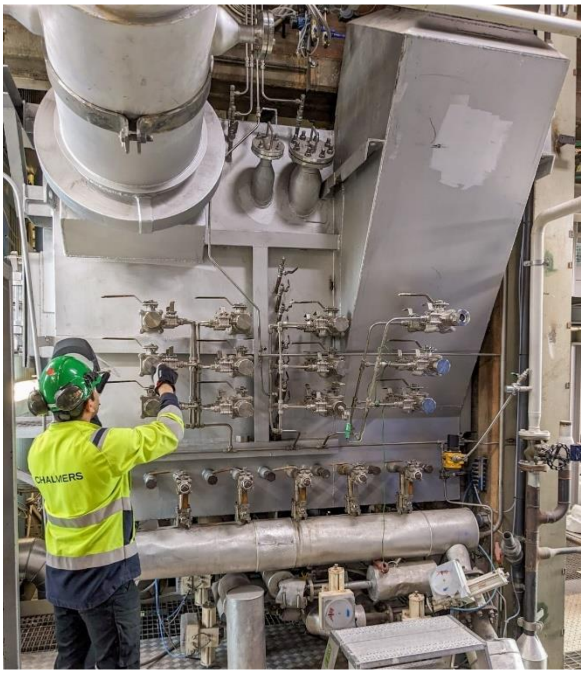

Figure 5. Integrated stream cracker at Chalmer University of Technology. Source: Chalmers University of Technology.

Link to presentation (pdf): [Chalmers University of Technology_Cracking of plastics and contaminated pyrolysis oils_ Henrik Thunman]

Concluding remarks

The webinar presentations clearly showed that there are technical solutions that already have and that might potentially have an impact on paving the way towards a circular handling of mixed plastic wastes.

The main conclusions from this webinar are summarized below:

1. In the future, it seems feasible to adopt mixed plastic waste sorting strategies that aim at sorting mixed fractions based on polymer content and/or degree of contamination rather than monomer (polymer) type fractions.

2. Advanced sorting technologies are in continues development. These plants are successful in transforming mixed plastic waste into a feedstock with less heteroatoms that could lead to a more efficient chemical and mechanical recycling. However, this is not enough to make plastic packaging part of the circular economy. Suitable systems for collection of packaging waste and design of materials for reducing the complexity of the material that is on the market are also key in this journey; as well as changing in behavioural aspects.

3. Pyrolysis is a robust technology that can be used to treat complex mixed plastic waste. ARCUS has developed a pyrolysis process demonstration unit that is able to absorb the variation in the feedstock composition to deliver a pyrolysis-oil fulfilling the quality requirements of chemical feedstock.

4. Thermal systems based on fluidized bed - stream cracking combined with gas conditioning have the potential to treat mixed plastic waste while reducing the needing for advanced sorting and removing the hydrogenation step at the biorefineries.