Brightsite

Transforming industry

Biomass & Recycling

Using biomass and recycling plastic essential to a carbon-neutral circular economy

There’s a lot of work to be done to achieve a climate-neutral and circular chemical sector by 2050. The large-scale use of plastic waste streams and biomass to replace fossil resources are crucial steps toward a carbon-neutral and circular economy. Brightsite’s program line 2, ‘Reduction of emissions by replacing naphtha and natural gas usage’, examines a number of routes to obtaining circular resources. In this article, Kim Ragaert (Professor of Circular Plastics, Maastricht University) and Rinke Altink (Program Manager, Biobased Feedstocks & Plastics Recycling, Brightsite/ TNO) discuss the current challenges surrounding the use of biomass and the recycling of plastics.

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Closed Carbon Cycle

To meet climate goals, it is essential not only to focus on the energy transition, but also on the resource transition. The fossil resources used to produce chemicals and materials must be replaced by renewable carbon sources. Chemelot wants to be fully circular in carbon flows by 2050. “We want to achieve this goal by using polymers created from biomass and plastic waste to make new products. Even in a circular economy, the chemical sector needs to use carbon because it’s impossible to produce plastic without it. This is why we need to replace fossil resources with sustainable carbon sources. And a number of different routes to do so. Biomass and the recycling of plastic waste streams are two parallel trajectories that, in combination, have great potential,” explains Altink.

Plastic ≠ the enemy

Ragaert is keen to emphasize that plastics are not the enemy. “Plastics are a relatively new material. They are part of, and a valuable addition to, our lives; without plastics we wouldn’t have phones, cars, and a whole lot of other products. We don’t have the option of going back to a time without plastics. Because it is still a young material, setting up recycling of it takes time to get off the ground. Currently, less than 30% of plastic in the European Union is recycled; the global figure is just 9%, so we have a lot of work to do. Now is the time to take recycling to the next level, to include plastics in the circular economy,” says Ragaert. The European Union has ruled that 55% of plastic packaging material must be recyclable by 2025, increasing to 100% by 2030. The EU has also set itself the objective of recycling 50% of all plastics by 2032.

Chain approach to make plastics more sustainable

Plastic comes in many different varieties with a wide range of properties and functions, each of which is important in specific applications. But this diversity - and the different waste streams it produces - can present a challenge for the recycling system. “We will have to try to rationalize those flows. It’s also important to understand that there is no cure-all solution to the problem; biomass alone isn’t the answer, and nor is mechanical or chemical recycling (see the ‘Recycling technologies’ box). We need to adopt a multipronged approach and that requires coordination between all parties in the value chain. That already starts with ‘design for circularity’ at the so-called start-of-life, the product design. At end-of-life, we must move towards different recycling methods that tackle specific fractions side by side. We must also develop more effective and innovative methods for sorting plastics and pre-treatment methods. The cleaner the resources we put into the process, the higher the quality of the circular products we get out at the end. Until recently, less and therefore thinner material was the main priority in the development of packaging material, by way of sustainability. All kinds of thin layers of different types of plastic with different functionality are therefore combined, but that makes recycling difficult,” emphasizes Ragaert.

“At Brightsite, we look at these different fractions and ask ourselves: which fractions are most challenging and why? How can we convert these fractions into something else? What pre-treatment do they need when they come out of the separation system? For each fraction, we need to find the most robust, low-cost and simple solutions. You could also ask yourself whether sorting and pre-treatment centrally in one place or decentrally in different places is the most convenient. Recycle-by-design, in other words thinking about the end of their lifespan when designing packaging or products, is the future. However, you cannot achieve 100% recovery of carbons in material in practice. These shortages are currently being supplemented by naphtha from petroleum. In the long run, we want to compensate for this from biomass,” explains Altink.

Kim Ragaert, *Professor of Circular Plastics, Maastricht University:*

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Recycling technologies

Chemical and mechanical recycling are both promising techniques and recently physical recycling has also emerged as a third route. In mechanical recycling, plastic is sorted, ground, washed and re-extruded into a pellet. More and more is being invested in pre-treatment techniques to increase the quality of the incoming plastics. The quality after mechanical recycling is the best for relatively clean streams of a single polymer. Physical recycling (or dissolution) has potential as a pre-treatment step for both chemical and mechanical recycling. By using a solvent that dissolves one polymer and not others, it is possible to separate different polymers or to remove labels.

In both mechanical and physical recycling, the polymer chains that make up plastics are not cut up. This does happen with chemical recycling and the building blocks are later rebuilt into new plastics. There are many variants within chemical recycling, of which depolymerization and pyrolysis are the best known. The quality and purity of the material to be recycled is also important for chemical recycling. There is no so-called ‘silver bullet’ that converts complex, heavily contaminated material fractions into high-quality polymers. Chemical recycling makes it easier to comply with food contact approval legislation than mechanical recycling, but this is offset by energy-intensive processing that also sets its requirements in terms of purity. Ragaert: “We need both chemical and mechanical recycling, they complement each other in terms of applicability.”

Circular plastics made from sugar

“We’re researching whether biomass can be used as a raw material for plastic. Biopolymers are present in all kinds of places in nature; the cellulose fibers in wood are just one example. These natural polymers also have a diverse range of characteristics for different functions. It’s a misconception to think that we need to make biodegradable plastics; that’s not the solution. In this way we lose the building blocks of our product. It is important that we make plastics from biomass that are easily recyclable. In essence, biomass is no different from petroleum, you just carry out different chemical reactions to produce products. Biomass as a raw material for the chemical industry has difficulty growing, partly due to a bad image. It is an even younger branch of sport than plastics and here too we have to find out what we can and cannot use. There are a number of suitable plant species with high yields and fast rates of growth. In the Netherlands, sugar beet is a great potential resource for plastic. Sugar beet crops are robust and are already grown on a large scale. What’s more, sugar beet absorbs more CO_2 from the air per hectare than any other crop. From a material perspective, too, sugar beet is a wonderful resource because it has a very high carbon content; sugar is made up of carbon and oxygen. Initially, we want to use sugar beet as a resource for polyester raw materials, which is an oxygen-rich polymer. Then we want to move on to polymers with a lower oxygen content, such as bio-based polyethylene. We still don’t know exactly what we’ll need to make this happen and how much energy the process will consume. The technology required to use sugar as an alternative resource is currently in development and progress has been made. The supply situation is more of an issue. We’ll need to work closely with the agricultural sector to create a win-win situation for both industries. The coalition that produced the national growth fund proposal ‘Agri-Based Chemicals’ is just one example of this partnership in action,” says Altink.

In an ideal scenario, fossil resources would be replaced with similar molecules so that existing systems and equipment could still be used. “This approach would avoid the need to develop new processes and build new plants. At the moment, crude oil products have still the lead over biomass; crude oil can be sourced free of charge from the earth and the processes have been optimized over hundreds of years. Alternatives can be more competitive by applying CO_2 pricing,” says Altink.

Rinke Altink, *Program Manager Brightsite/TNO:*

“We must look at the entire system holistically. To do so, we need to shift our mentality.”

Collaboration is crucial

Collaboration is crucial for converting biomass into resources for plastics, as well as scaling up these processes and the successful recycling of (bio)plastics. “We’ve still got a lot of work to do to make plastics more sustainable; in fact, we are just getting started. We need to deploy multiple recycling technologies simultaneously and we need to do so quickly,” says Ragaert. “We must look at the entire system holistically and make sure that each facet is in tune with its counterparts to achieve the perfect balance. To do so, we need to shift our mentality,” adds Altink.

Kim Ragaert

Prof. Kim Ragaert joined the Faculty of Science and Engineering at Maastricht University as a Professor in Circular Plastics in September 2021. Her work focuses on the mechanical recycling of plastics. With a background in mechanical engineering and material science, Ragaert has an affinity for structure-property-processing relationships in polymers and product design using plastics. She is keen to contribute to a more sustainable role for plastics and she uses her knowledge to help make this controversial material circular. Before joining Maastricht University, Ragaert was a head lecturer at Ghent University, where she established a well-known research group for the sustainable use and recycling of plastics. In 2020, she was awarded the prestigious title of 'European Plastics Recycling Ambassador' in recognition of her work on plastic recycling. "I am passionate about working with students, fellow scientists and companies as part of the unique synergistic ecosystem of Chemelot," says Ragaert.

If you would like to find out more about the sustainable use and recycling of plastics, please contact Kim Ragaert.

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Rinke Altink

Rinke Altink joined Brightsite/TNO as a Program Manager for Biobased & Plastics Recycling in April 2021. Altink has thirty years of experience acquired at DSM Research in Geleen, where he held roles in various business units after completing his degree in organic chemistry. He has been involved in projects and programs on topics such as process improvement, waste reduction, capacity expansion, and energy reduction in bulk and fine chemical processes. Since 2004, Altink's work has focused on the sustainability of bulk chemistry. He helped to develop an integral water management system for the Chemelot site and worked on a major biobased product process development project. Altink is responsible for Brightsite's program line 2, 'Reduction of emissions by replacing naphtha and natural gas usage', which aims to replace fossil resources with waste materials and biomass. Altink: "I want to use my passion for chemistry to contribute to the sustainable development of chemical processes in Geleen and beyond."

If you would like to find out more about how fossil resources can be replaced with waste materials and biomass, please contact Rinke Altink.

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