Waste2Aromatics II

Public summary

Aromatics cover 40% of the global chemical market. The most promising bio-based route towards functionalized aromatics is based on biomass-derived sugars and proceeds via furan platform chemicals. Today, worldwide research efforts on the production of these furans are focused on using refined sugars and agricultural residues as feedstock. However, techno-economic assessments revealed that these 1st and homogeneous 2nd generation feedstocks are too costly for economically feasible production of bulk aromatics such as phenol and phthalic anhydride.

Therefore, TNO, the waste processing industry and other value chain partners have teamed up as the Waste2Aromatics (W2A) consortium within shared research program Biorizon, to develop technology that enables conversion of low-cost biogenic waste in a single step into furans. The possibility to convert these heterogeneous, low-cost feedstocks creates high-value valorization potential for the waste processing industry and sustainable and cost-effective feedstock for the chemical industry.

In Waste2Aromatics - phase I (W2AI) combinations of biogenic waste streams and conversion technology were assessed for their feasibility in the production of furans, both experimentally and techno-economically. The following feedstock-technology combinations were then identified to be techno-economically feasible: i) source separated organics via Steam technology and ii) sewage sieve fraction or diaper fill via Bi-Phasic Reactor (BPR) technology.

Encouraged by these results, a renewed Waste2Aromatics consortium of TNO, AEB, Orgaworld, Twence, Waternet, STOWA, Port of Amsterdam, Vereniging Afvalbedrijven, Biobased Delta, SABIC, Zeton and Knowaste joined knowledge and efforts to further develop the techno-economically promising lab-scale concepts of W2AI towards pilot-scale implementation. Main objective of Waste2Aromatics – phase II (W2AII) was to deliver the information required to make an investment decision on the realization of a pilot plant: a market evaluation for produced bio-based chemicals, an updated and extended business case analysis (BCA), a pilot blueprint and a plan on how to advance towards the realization of a pilot plant.

Together with a market expert the market potential of the three platform chemicals produced with W2A technology were evaluated: furfural (FF), HMF and Levulinic acid (LA). Current FF market is 400 kton/a and is expected to grow in the coming decade as a result of increasing interest for its application as sustainable building block for the chemical industry, e.g. via the Biorizon platform technology towards bio-aromatics. Especially W2A technology has potential in the FF market, since utilization of biogenic waste as feedstock allows cost-competitive domestic production.

The markets for LA and HMF are currently limited. Although both have been identified as versatile and high-value bio-based building blocks, they lack production technology that allows robust, year-round production.

When W2A technology allows steady and high-quality production of LA and HMF from economically attractive biogenic waste feedstocks, there is potential for these products in the specialties and commodities markets.

Within W2AII, the W2A BCA model was updated with new information regarding the conversion processes and extended with the downstream processing (DSP) units required for product recovery, as determined during expert workshops and experimentally verified in W2AII. Also, the recycling of heat and extraction solvents was taken into account. The updated and extended BCA revealed promising business cases with production costs within the market price range (Figure 1).

The updated and extended BCA revealed that application of the Steam process for the conversion of cellulose-rich solid waste feedstocks (>30% dry weight) results in a promising business cases with production costs within the market price range.

In addition, the BCA revealed that valorization of waste feedstock slurries (<30% dry weight) via BPR technology is currently not economically attractive due to the low volumetric productivity and the required costs to recover the complex product mixture. Alternatively, for the conversion of solid waste feedstock slurries, the Bio-slurry Conversion Reactor (BCR) concept was identified, resulting in higher volumetric productivity and a less complex product mixture affording an economically feasible valorization technology. The conversion of solid waste feedstock slurries using the BCR concept was validated at lab-scale, giving promising preliminary yields.

Although the BPR did not appear to be an economically attractive concept for the conversion of solid waste feedstock slurries, BCA did reveal that its application for the conversion of crude sugar solutions can be economically attractive. Potentially, conversion of biogenic waste feedstocks could be preceded by a hydrolysis step, yielding crude sugar solutions. The BPR concept was proven to be scalable in TNO's BPR setup by continuously converting solutions of glucose and xylose at 10 L/h-scale, whilst achieving similar yields as obtained at lab-scale.

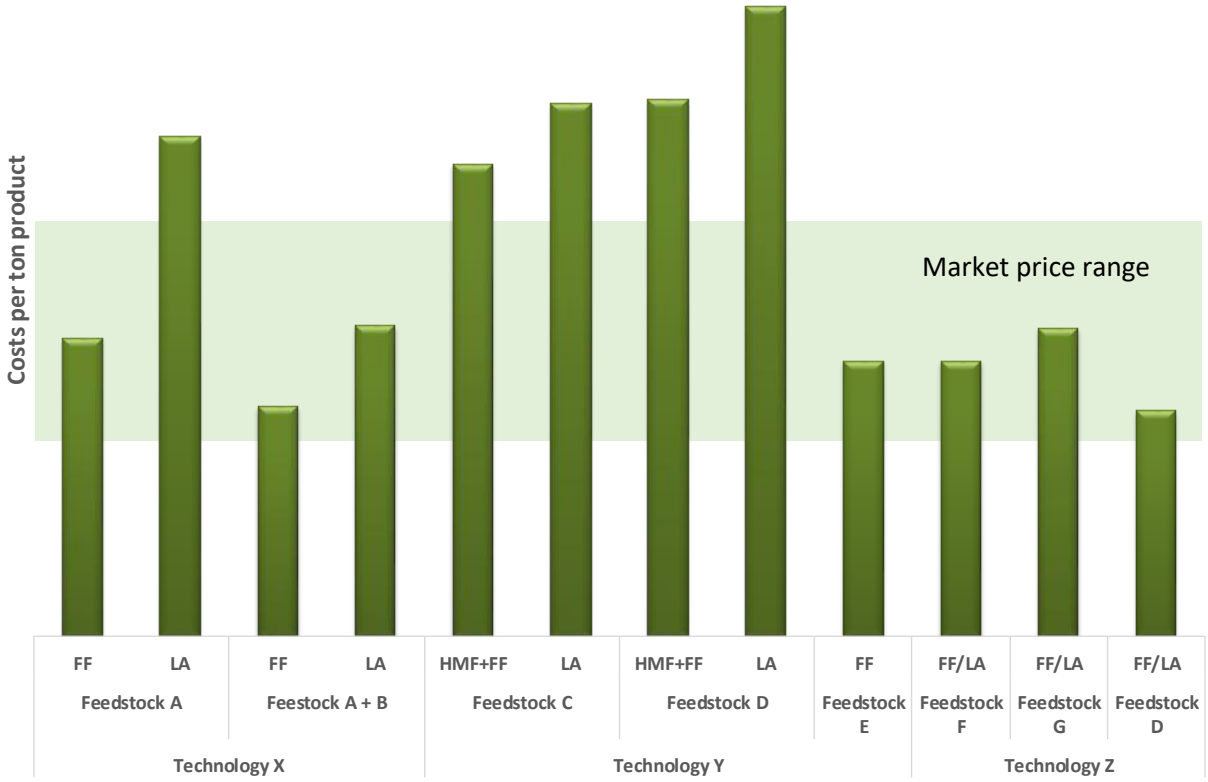

Figure 1. Selection of results of business case analysis of different technology-feedstock combinations. FF = furfural, HMF = 5-(hydroxymethyl)furfural and LA = levulinic acid.

Guided by the results obtained in the extended BCA, the consortium decided to focus on the realization of a steam pilot blueprint and to further develop the BCR concept in preparation of a follow-up project. Based on consultation of experts within and outside of the consortium, on literature and on experimental results for pre-treatment, conversion and product recovery as obtained within W2AII, Zeton realized a preliminary blueprint for the steam pilot.

This steam pilot blueprint gives insight in the outlines and scale of the envisioned pilot plant and allows pilot construction parties, such as Zeton, to swiftly come to a full design upon an investment decision from the W2A partners. To further detail the blueprint and to be able to request quotations from equipment suppliers, more experimental details are required. These details are to be obtained from scaled-up conversion and DSP experiments. Unfortunately, the envisioned experiments were not completed within the W2AII project due to problems encountered with feedstock transport abroad, where the for the Steam process most representative reactor (continuous screw reactor with continuous steam flow) is available for testing.

Next step in pursuing the promising business case of the Steam pilot is completion of a successful test in the envisioned reactor. This test will deliver, apart from proof-of-concept, the kg-scale samples that are

required to define the dimensions of the DSP equipment. In addition, these samples will allow to assess the quality and corresponding value of products and residues (fermentability, combustibility and compostability).

Next step in pursuing the valorization of solid waste feedstock slurries via the BCR concept would be validation at kg-scale. This activity will provide technical information for an extended business case analysis and the realization of a pilot blueprint. Based on experimental proof-of-concept and consultation of pump and conversion technology experts, the required experimental setup for validation at kg/h-scale was identified.

In conclusion, experimental and analytical efforts within W2AII revealed the following:

- The growth potential of the FF market and the potential of the HMF and LA markets;
- The processes required to most optimally pre-treat feedstock, recover and purify the formed products and residues, and recycle heat and solvent;
- The valorization routes that are techno-economically feasible, as identified with updated and extended BCA models, and that can be developed towards pilot-scale;
- The benefit of mixing feedstocks, which apart from reduced seasonal dependency, can lead to improved productivity;
- A blueprint for a Steam pilot for the conversion of solid waste feedstocks (>30% dry weight);
- Insight in the sustainability of the Steam process;
- The steps towards scale-up of the two most promising valorization routes for Steam and BCR technology, based on learnings from the scale-up activities.