Biorizon - The way to aromatics

Bio Joop Groen

This is a case study of a waste to aromatics technology development project titled Biorizon undertaken by TNO, a Dutch organization in association with Attero, AEB, Orgaworld and the Dutch waste management Association. Two technologies were experimented with success, details of which are outlined in this article.

Introduction

Dutch households produce a total of almost five million tons of household waste each year. The Waste2Aromatics project explored various ways of using carbohydrates (sugars) in waste streams as feedstock for the production of biobased aromatics. As one of the partners in Biorizon, TNO was involved in this project, as were Attero, AEB, Orgaworld, and the Dutch Waste Management Association. The partners' efforts have been crowned with success. The technologies they selected proved to be highly efficient at converting sugars in waste into useful building blocks. Also – importantly – various business cases have been worked out which, according to the calculations, are very promising. This generated sufficient material and enthusiasm for a follow-up project, which is currently being developed within Biorizon's framework.

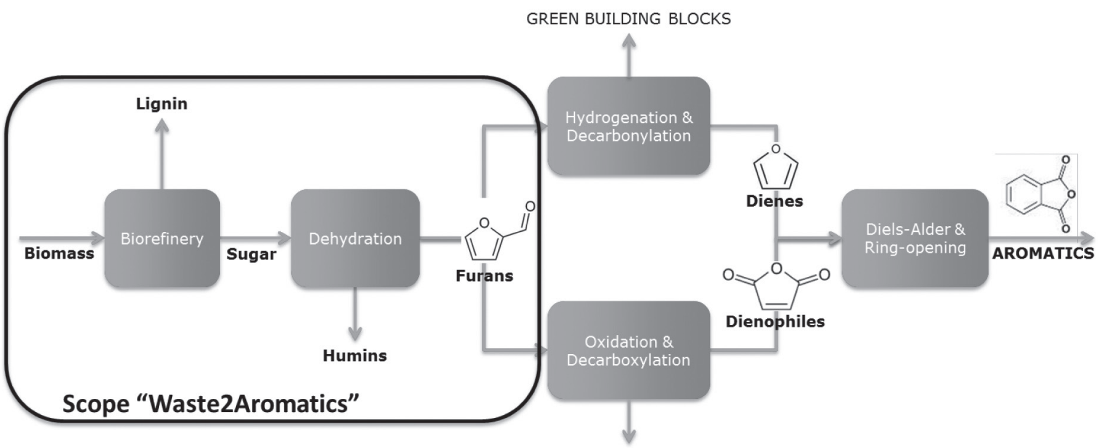
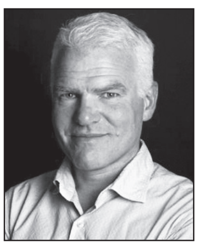


Figure 1 As part of Biorizon's "Sugars to Aromatics" programme line, the Waste2Aromatics project plays a crucial part in developing technology capable of supplying furans cheaply.



Joop Groen studied Process Engineering and Business administration (MBA) and he is also a certified coach for personal development. Joop started his career with the General Electric company in the Engineering Plastics division where he worked for 17 years. In 2005 Joop joined TNO, the Dutch organization for applied research where he held various leadership positions in automotive and monitoring systems. Since 2012 Joop joined the sustainable chemistry and biobased economy team as senior manager new business development, where he is responsible for initiating large new programs and projects, such as Biorizon

From heterogeneous waste to aromatics, via furans

As illustrated in Figure 1, the Waste2Aromatics project is part of Biorizon's "Sugars to Aromatics" programme line. This line focuses on converting sugar-rich biomass into furans: semi-finished products which serve as the basis for subsequent reactions to synthesise bio-aromatics or other "green" building blocks.

To produce bio-aromatics from household waste, cellulose (or hemi-cellulose) contained in the organic fraction must be converted to furans. Two different techniques were used for this chemical/catalytic conversion (see Figure 2):

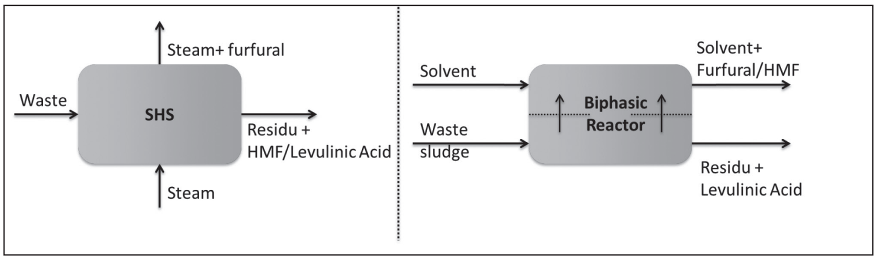


Figure 2 Simplified overview of flowchart

1. Superheated steam (SHS) technology is particularly suitable for processing relatively dry and coarse material. It uses steam to bring the biomass up to the reaction temperature, and to extract the furans from the waste. In this way, furfural (from C5 sugars) is completely removed, while Hydroxymethylfurfural (HMF, from C6 sugars) is only partly removed, undergoing further reactions to form Levulinic acid.

2. Bi-phasic reactor (BPR) technology is suitable for processing wet fractions. Here, the biomass is mixed with water to form a slurry, then heated to facilitate the conversion of sugars to furans. Any furans formed in the slurry are directly incorporated into the solvent, as the former is in constant, intensive contact with the latter. This approach largely avoids any unwanted side reactions.

Advantages of SHS & BPR: higher yields and a positive business case

What both selected technologies have in common is that they immediately extract any furan that has formed from the aqueous reaction mixture. As a result, it is no longer available for side reactions and/or subsequent reactions. This greatly limits the latter reactions, thus yields are higher and there is the potential for positive business cases.

Compared to most existing technologies, these two technologies have a number of other significant advantages:

1. A single homogeneous, semi-finished product with a relatively high market value (i.e. furans)is synthesised from the heterogeneous waste.

2. The conversion takes place at much lower temperatures than in gasification, for example.

3. Once the valuable sugar-rich fraction has been removed from the biomass, the residue can be processed further, in energy generation for example.

Expertise on the conversion of heterogeneous waste streams

Heterogeneous waste streams are, potentially, excellent sources of sugar-rich biomass. However, companies throughout the world had relatively little experience in using these techniques to process non-separated waste streams. Accordingly, the aim of the project was to assess the suitability of heterogeneous waste streams for such conversion.

At the start of the project, nine different waste streams were selected and extensively analysed for properties that were relevant to the target technologies. Based in particular on the levels of sugar contained in the complex structure of the waste streams and on its dry matter content (%DM), three waste streams (including organic waste) were selected for further study, in close consultation with

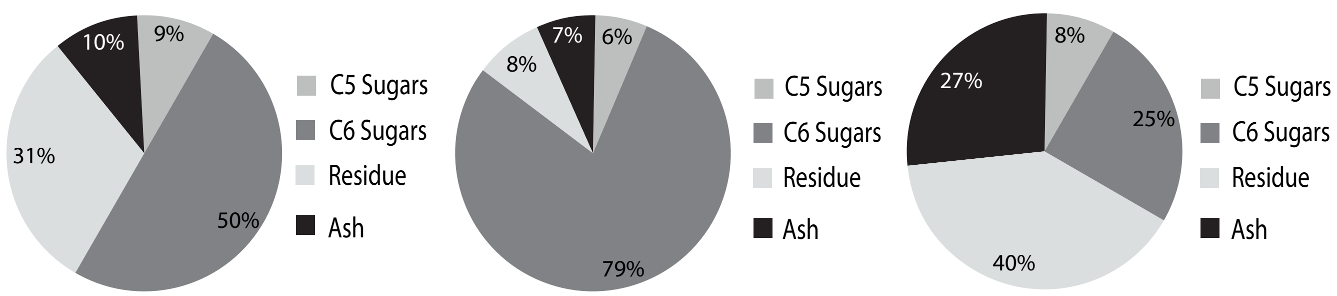


Figure 3 Key properties of waste streams (organic waste is on the right).

the partners. The composition of these three waste streams is shown in Figure 3.

Experiments have been carried out on these waste streams to assess the selected technologies, in terms of potential yields.

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Result: SHS & BPR technologies are highly efficient

The technologies selected proved to be highly efficient at converting waste into furans. The experimental yields obtained in this project ranged from 10% to 45% for HMF, from 50% to 80% for furfural, and from 60% to 70% for levulinic acid. These results alone are very promising, yet there is plenty of potential for further improvement.

Business cases: very positive

These positive results provided a basis for the business case analyses that were carried out. A mathematical model has been used to calculate various scenarios. These scenarios took a wide variety of relevant parameters into account, such as gate fee, product price, investment, capacity, biomass concentration during processing, and process-specific parameters such as utility costs, as well as the consumption and cost of solvent, salt and catalytic acid.

The analyses showed that, potentially, a substantial range of profitable scenarios can arise for the production of chemicals at prices that are in line with market prices.

Follow-up research: further specify business case parameters

These positive results in the context of the Waste2Aromatics project generated sufficient material and enthusiasm for those involved to take the first steps towards a follow-up project. A sensitivity analysis was carried out to determine which of the aforementioned parameters exert the greatest influence on the business case. These would then be the focus of attention in the follow-up project. The results of this analysis were then used to define the scope of the follow-up project. The project activities are designed to improve yields, reduce production costs and boost confidence in the technology by realizing an initial scaling-up step (involving the creation of a processing facility with a production capacity of 1-10 kg/hour). This project's final deliverable involves designing a pilot plant for the conversion of waste into furans.

The new project, embedded in the Biorizon roadmap for sugars (see Figure 4), will have a close relationship with other projects within Biorizon, in which the semi-finished products created here will be processed further into biobased building blocks and, ultimately, into bio-aromatics.

Biobased aromatics offer profitable and sustainable prospects for the chemical industry

Aromatics are one of the main raw materials used by the chemical industry. Aromatics are currently extracted from oil, which leads to the emission of CO_2. The Biorizon Shared Research Center, initiated by TNO, VITO and Green Chemistry Campus, develops technologies to extract aromatics from plant residues. This reduces dependency on oil, leads to lower CO2 emissions, and provides profitable and sustainable prospects for the chemical industry and the supply industry.

• Further details about Biorizon: www.biorizon.eu

• For more information about (participation in) the Waste2Aromatics follow-up project or Biorizon please contact Monique Wekking (+31 (0)6 46 84 73 58).

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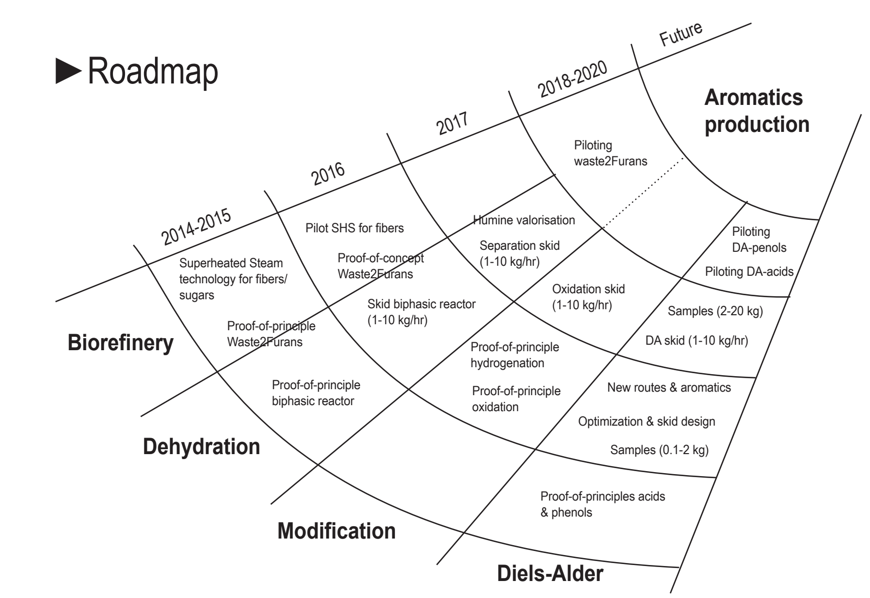

Figure 4 Scope of follow-up project