Institute for Sustainable Process Technology

ReBBBloCS

Renewable Building Blocks from Complex and wet waste Streams

MOOI-regeling 2022

(Missie gedreven Onderzoek, Ontwikkeling en Innovatie)

MOOI422006

20/08/2024

ISPT

Introduction.

The project "Renewable Building Blocks from Complex and wet waste Streams" (ReBBlocS) is registered by RVO as MOOI422006. The project is coordinated by Institute for Sustainable Process Technology (ISPT), and its participants are Alucha, BioBTX, Bostik, Brightsite, Chemcom, CHemportEurope, DOPS BV., EEW, ESD-SIC, PeelPioneers, Q8Research, Recell, Riwald, RUG, SABIC, Sappi, Smurfit Kappa, Spark904, TejinAramid, Twence, University of Twente, VNP, and the WUR. Starting 1 August 2024 GF Biochemicals, Natures Principles, and OCI will join the project group.

The project has started on the 1 August 2023, and will run for a period of 4 years.

This report is the non-confidential report of activities, progress, and results of the first year of the project.

The ReBBloCS project is part of the Separations For Circularity cluster of ISPT.

General summary of the ReBBloCS project.

Motive.

A large share of CO2 emissions by industry is related to the production of fossil-based chemicals (approximately 3.6Mton oil was used in the petrochemical industry in 2021), and all this oil will be converted in CO2 at the end of life of products, if these products are not recycled. By transitioning towards circular and biobased (bulk and platform) chemicals, the CO2 emissions of this sector can be strongly reduced. The rising prices of conventional (oil-based) feedstock have further intensified the incentive for industry to transition towards alternatives. However, as seen today, the quantities of potential biobased/circular input streams to provide these chemicals is by far not enough to source the demand of industry. Therefore, the aim of industry is to efficiently use all available alternative, circular, and renewable feedstock; this includes the so-called complex and mixed waste streams. When value chains are in place that enable valorization of currently wasted complex and mixed waste streams, it allows the paper and (specialty) chemicals industry to achieve this goal towards reducing its environmental impact.

Goal of the project.

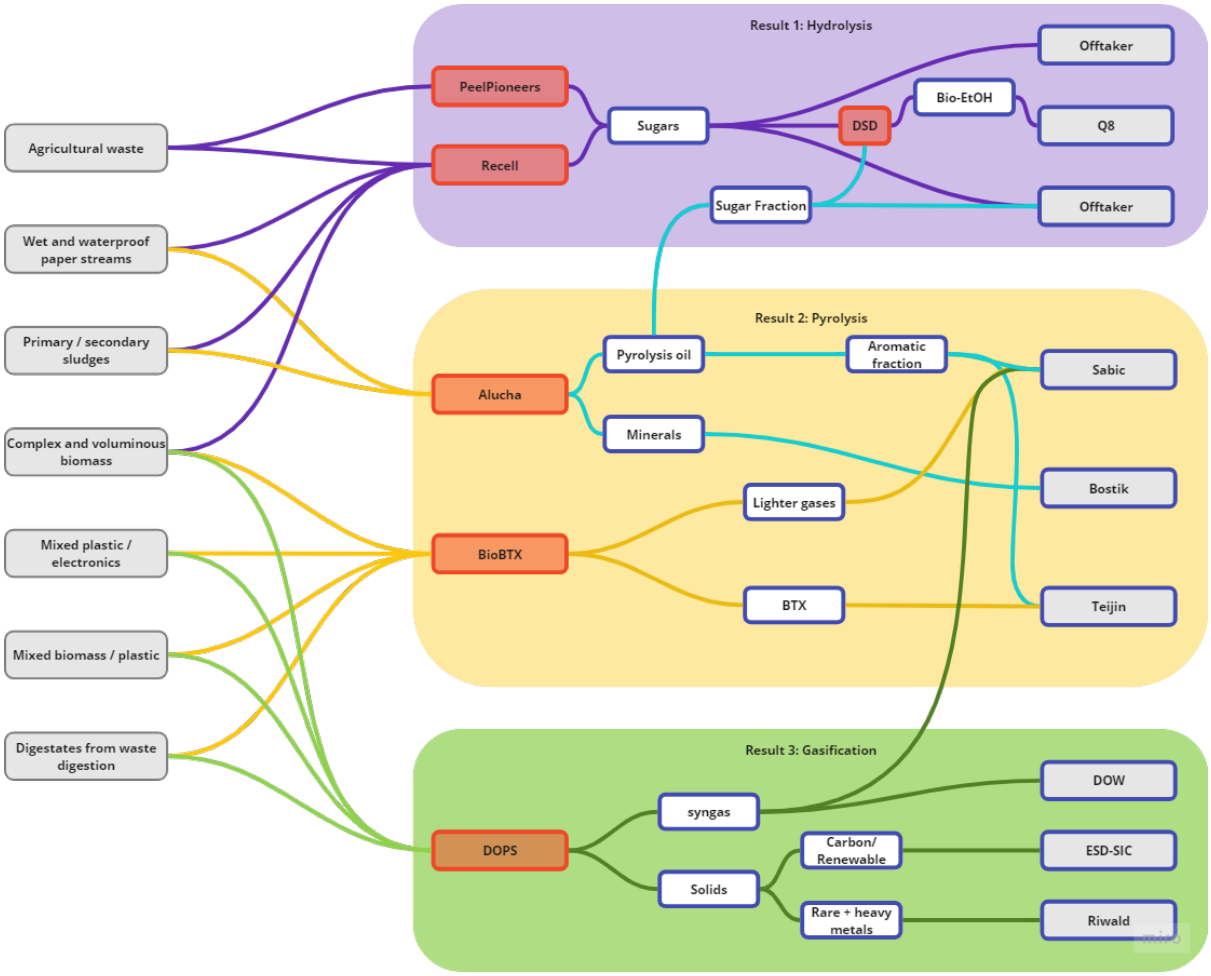
To provide industry with circular and biobased bulk and platform chemicals, new value chains need to be developed, where 'challenging' waste sources (e.g., agro/food residues, mixed biomass/plastic, sludges etc.) are converted through innovative technologies (based on hydrolysis, pyrolysis & gasification) into new chemicals. These chemicals can be used to replace current fossil-based chemicals. In the ReBBloCS project these value chains are developed in collaboration with relevant stakeholders (private sector, technology providers & knowledge institutes). The goal is to close the carbon cycles of the specific bulk- and platform chemicals considered by ReBBloCS as much as possible by utilizing and valorizing (fractions of) the considered complex waste streams.

Activities.

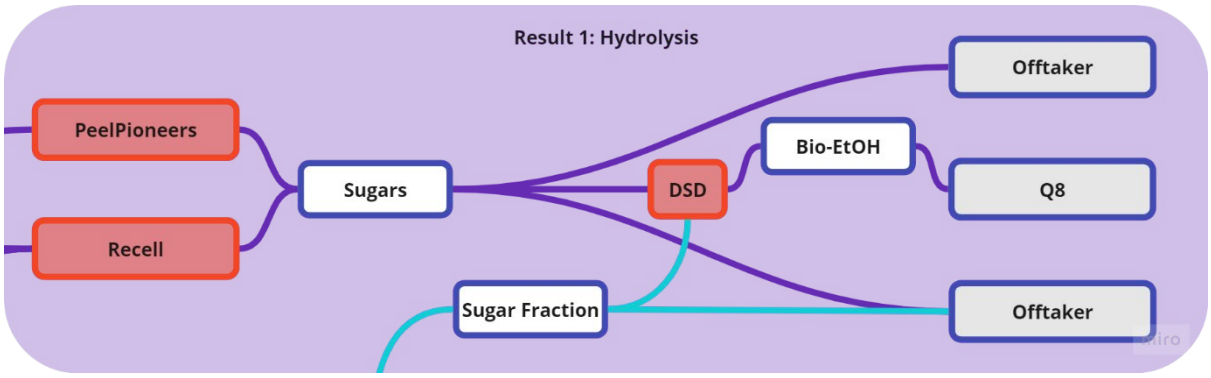
The activities of the project are structured along the following perspectives:

- *Increasing the technological readiness levels*: The technology providers and knowledge institutes will develop the required conversion technologies and value chains. Value chains goes along the path of: Source (waste) à pre-treatment à conversion (hydrolysis/pyrolysis/gasification) à post-treatment à Circular & biobased chemicals for industry.
- *Solving non technological issues:* The development of the decision tool allows partners to determine which route is viable in which instance. Also, relevant stakeholders will address legislative and policy related issues paving the way for successful implementation of circular solutions & value chains.
- *Ensuring implementation:* Through learning communities, knowledge dissemination and implementation strategies societal and industry awareness is strengthened and uptake of the developed value chains by industry is ensured.

Progress and results of ReBBloCS year 2023-2024.



Result 1: Hydrolysis.



In result 1 waste streams are converted into valuable building blocks using hydrolysis. These waste streams at least include agricultural waste, wet and waterproof paper streams, primary & secondary sludges, and complex and voluminous biomass streams. Recell, PeelPioneers, and DSD are the technology providers in this workstream.

Just before the kick-off of the project one end-user had decided to leave the project. In the year 2024 a second end-user iMENZ Bio-engineering, had to declare bankruptcy. GF Biochemicals, Natures Principles, and OCI will cover the activities of these two organizations in the future course of the project.

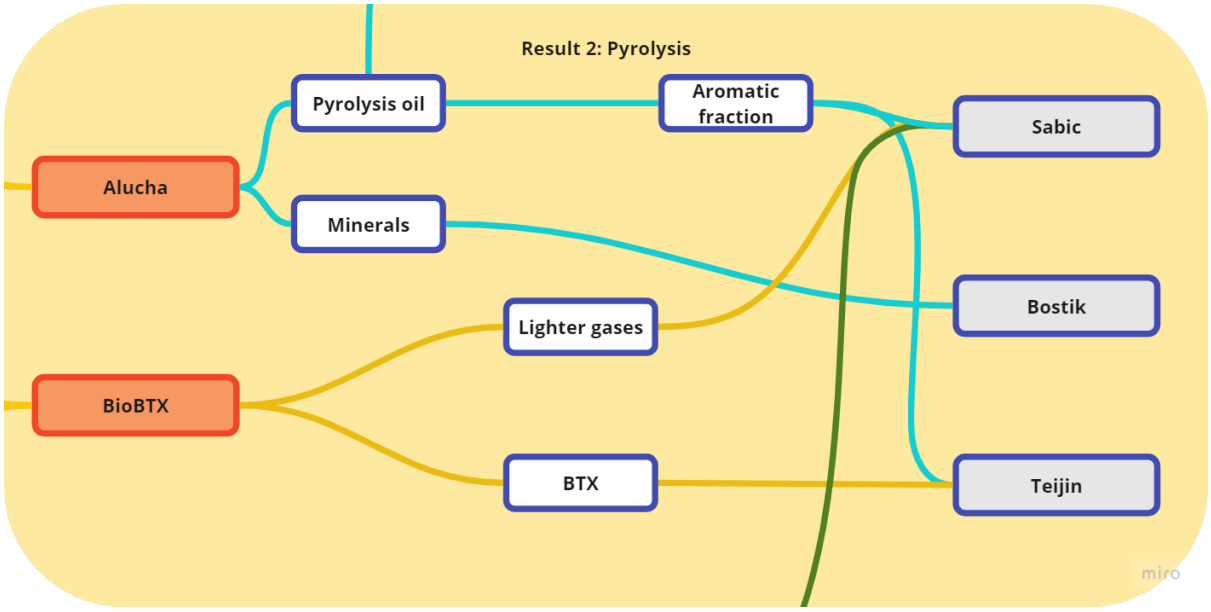
Activity 1.1: Conversion of biomass to carbohydrates.
The first steps in this activity include the specifying the contents from streams provided by the feedstock providers for biomass carbohydrates. The resulting specification sheet has now been fully developed. In the upcoming period, the DSD-process can be tested on several streams, also creating input for Recell (residual cellulose) and the glucose end-users (Q8, GF Biochemicals, Natures Principles, OCI). PeelPioneers has been successful in running their pilot operation on Orange Peels.

Activity 1.2 Conversion of tertiary cellulose with Recell Chem Technology.
Also, for this activity, specification sheets of streams from feedstock providers needed to be developed. This activity focusses on tertiary cellulose. Tertiary cellulose screens from Smurfit Kappa have now been used as feedstock for Recell Chem Technology. Furthermore, successful pilot operations have been run on WWTP and paper fractions by Recell. In the upcoming period, technology development and product quality validation with end-users will be central.

Residuals from the processes in this activity have been sent to Result 2 and 3, meaning that the first steps toward a full value chain for the waste streams coming into this activity is in development. This interaction will be intensified next year.

Activity 1.3: Glucose on market spec.
For this activity, specification sheets of sugars for industrial users have been developed. The first results on the fermentability of these sugars have been analysed by an industrial user. When the new-end users are integrated into the project, this activity will continue. Optimizing the product quality will create a feedback loop with activity 1.1 and activity 1.2.

Result 2: Pyrolysis.



In result 2 waste streams are converted into valuable building blocks using pyrolysis. Use waste streams include carbon rich waste such as plastic and biomass, paper sludge and screening rejects from the paper industry. Twence, EEW, Riwald, Smurfit Kappa and Sappi are waste providers for this work package. BioBTX and Alucha are technology providers and Sabic, Bostik and Teijin are end users of the produced building blocks. University of Twente, Spark904 and EMI Twente are knowledge institutes providing knowledge, research and services to other work package members.

Activity 2.1: BioBTX pyrolysis studies on biomass.
For this activity, the specification sheet related to the feedstock i.e., type of Biomass to be tested needs to be prepared. In 2025, a few runs will be carried out on the miniplant and process optimization will be carried out.

Activity 2.2: BioBTX pyrolysis on plastic from post-consumer electronic devices and industrial waste streams.

In this activity, feedstock analysis has been completed by SPARK 904 for the feedstock provided by Riwald Recycling to BioBTX. The University of Twente has identified two feedstocks provided by Twence ideal to produce Benzene, toluene, and Xylene (BTX). These feedstocks will be tested in the Mini plant at BioBTX in Q4 2024.

BioBTX has successfully completed runs on the Mini plant with the different feed streams obtained from the recycling of electronics equipment (WEEE) provided by Riwald Recycling. Analysis of pyrolysis oil has been completed by SPARK 904, as well as analysing the contaminants present in the oil. In Q4 2024, the process parameters in the Mini plant will be optimized to (further) increase BTX yield and process stability. Additionally, the viability of the feed stream from Smurfit Kappa for BTX production will be evaluated.

Activity 2.3: Alucha pyrolysis studies on paper sludge and fine screening rejects.

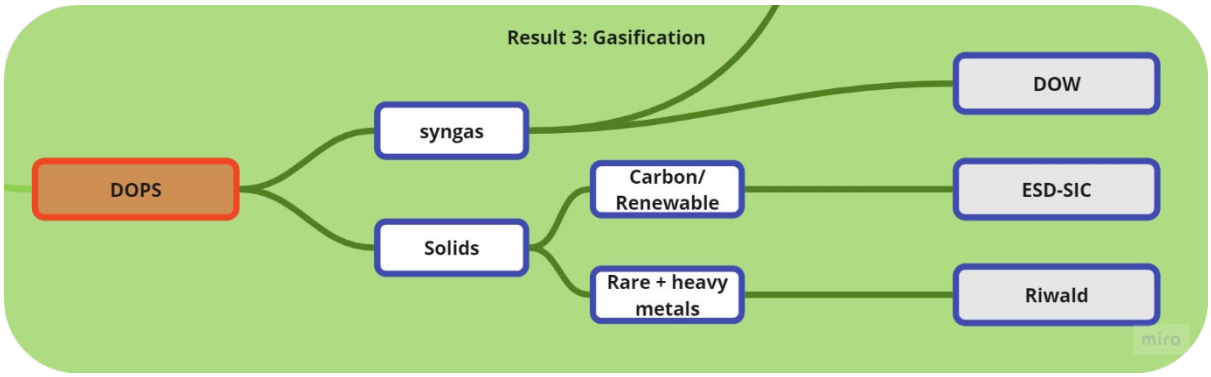
The first step in this activity is, to analyse the composition of the paper sludge streams provided by the feedstock suppliers. Alucha has received the first batch of paper sludge and fine screen reject samples from Sappi and Smurfit Kappa between 2023-2024.

- The initial round of feedstock characterisation has been evaluated with respect to the expected product quality of Circular Calcium Carbonate. Currently, the paper mills and Alucha are assessing consistency of the feedstock over the span of a year.
- Within this activity Spark904 has examined the initial batches of feedstock from both paper mills, as well as their recovered minerals (Alucha lab test). The preliminary assessments of contaminants and the first-round selection of the feedstock stream from each paper mill have been completed.
- The feed stock specification sheet is currently being developed for the paper sludge streams.
- Along with the end customer, the quality of the CCC—from these two paper mills—is being evaluated collaboratively.

Planning 2025:

- The second round of a representative feedstock stream selection will be assessed and examined in Q4 in preparation for the Alucha pilot plant test.
- A preliminary laboratory experiment aimed at producing modest amounts of CCC for end customer evaluation will be conducted.
- Alucha plans to run the pilot plant on selected paper sludge in 2025 to produce enough test material for application tests on industrial scale by the end user Bostik.

Result 3: Gasification



In result 3 waste streams are converted into valuable building blocks (syngas and solid residue) using DOPS proprietary gasification technology “Direct Carbon Immobilisation” to strip hydrocarbons from waste material. Used waste streams include hydrocarbon rich waste such as WEEE, plastics and biomass, also dried paper sludge and screening rejects from the paper industry.

Twence, Riwald and Smurfit Kappa have provided various testing waste materials of different grades and composition. Also, from process activity 1.1 (ReCell hydrolysis) the residual waste stream is a potential feedstock for the gasification process.

The tests for the conversion of these low-grade wastes are scheduled for the summer/autumn of 2024, the laboratory set-up is now fully operational to accommodate these tests, it took more effort to handle the different types of waste streams (i.e. fluffy vs hard material handling and feeding systems). The activities are part of milestone 3.1.

Together with EMI Twente a plan is developed about the refining/upgrading the quality of the products by application of membrane technology if necessary for downstream processing.

After the conversion tests, sample materials of the products (syngas and solid residue) will be made available for activity 3.2 and 3.3.

The first-year information was shared with WP4 to give input for the generic MILP model.

Result 4: Total value chain analysis.

This work package aims to develop decision support models that can be used to optimize the design and planning of multi-waste valorization systems. This part of the projects mainly builds on a PhD project at Wageningen University, for which the PhD student started in October 2023, and a detailed research plan been written. The 4 main research questions that will be answered are:

1. What are the key factors influencing the design and planning of multi-waste valorization systems and how can they be considered in a decision support model?

2. How to quantify the trade-offs between economic and environmental indicators as well as identify the implications on supply chain configurations of multi-waste valorization systems when considering multiple objectives?

3. What strategies could be implemented to improve the robustness of multi-waste valorization systems, considering the inherent uncertainties in the waste streams and valorization technologies?

4. How to distribute the benefits and burdens (economic and environmental) of the efficient network among multiple actors in multi-waste valorization systems?

The first version of a generic optimization model capturing the key dynamics of multi-waste valorization chains is currently under development, which will be the main result related to the first research question. The initial data collection from feedstock and technology providers has been completed and has been the basis for the modelling work. The data collection will be extended during the remainder of the project to address the specific aspects mentioned in the remaining research questions.

Result 5: non-technological challenges.

Chemical recycling routes face not only technical challenges; non-technical issues such as limiting legislation. This work package focusses on these challenges and aims to either find temporary solutions or instigate structural change in the system.

This result consists of several elements. These elements are in part dependent on the activities and results of other work packages. Therefore, the results 5.1, 5.2, and 5.3 are just starting up now.

Activity 5.4 Addressing legal constraints and solutions.

The first step for this objective was to specify what the project group(s) need. There are several initiatives running on alternatives to existing legislation. To prevent ReBBloCS from inventing the wheel for a second time, the first step was taking by making inventory of ongoing initiatives. The second step is finding a role for the ReBBloCS consortium, either within these running projects or to fill in a white space. For this the UTwente is currently in the process of hiring a MSc student for a Master thesis.

Result 6: Knowledge dissemination.

Activity 6.1 Waste Valorization to Building Blocks Platform.

The ReBBloCS project is part of the Separations For Circularity program of ISPT. During the program meetings, three per year, the ReBBloCS project work package leaders have presented current progress and challenges. Furthermore, individual partners in the project have presented at

program meetings to further elaborate on their participation in this MOOI project and highlight their technology.

Knowledge from the cluster will be used in several activities, such as 5.4.

Activity 6.2 involvement and education of students.

The project partners have given several guest lectures; see the table under "Publications & public dissemination". Two MSc theses have been started, with a third MSc thesis position being published at the UTwente.

Contribution to MOOI program goals, spin-offs and mission.

ReBBloCS recognizes the integrated approach that is needed to achieve the sustainability goals, as written in policy article 4, for the Dutch industry. To close value chains and achieve a circular economy it is of utmost importance that stakeholders work together on developing innovative alternatives for current linear processes. It includes the main technical and societal themes as well as policy alignment, environmental impact studies and skill development. Multiple building block value chains are explored in parallel and at multiple sectors/industries to accelerate the transition and implementation at system level.

Currently the main building blocks for industry (bulk and platform chemicals) are "virgin" materials based on fossil sources, resulting in a mostly linear system, while end-of-life phase scenarios of the products have not been considered during development. ReBBloCS will focus on shifting the industries perspective on "waste". In close collaboration with separation and conversion technology providers ReBBloCS aims for transforming un(der)valorized complex streams into circular building blocks that are useful for industry partners and can replace the fossil-based chemicals without losing quality (or even quantity). Maximum impact is aimed at, with the focus on carbon-rich streams found in for example complex mixed biomass/plastic, wet paper streams and sludges. When waste and side streams are recycled as new useful building blocks, the carbon cycle is largely closed. A strong emphasis is on developing a decision tree, based on quantitative sustainability assessments like LCA, for the different waste streams and routes towards building blocks. Hereby not only environmental impact is considered, but also economic impact (i.e. cost-effectiveness) and relevant social aspects.

ReBBloCS thus aims to have an excellent contribution to the objectives of mission C, the MOOI theme Industry.

There have been no spin-offs yet.

Publications & public dissemination.

Date	What	Where?	Links (if available)
2023 March	Media coverage	AfvalOnline	https://afvalonline.nl/archief?searchall=ReBBloCS&categorie=
2023 July	BOSTK ReBBloCS page	Bostik	https://www.bostik.com/belgium/nl_BE/media/news/construction/emea/netherlands/bostik-benelux-news-20072023-rebblocs-renewable-waste/
2023 August	WUR ReBBloSC page	WUR	https://www.wur.nl/en/project/renewable-building-blocks-from-complex-and-wet-waste-streams.htm
2023 August	ISPT ReBBloCS page	ISPT	https://ispt.eu/projects/renewable-building-blocks-from-complex-and-wet-waste-streams-rebblocs/
2023 September - 2024 June	MSc thesis – Thomas Heijmans	WU	
2023 September 07	Media coverage Utoday	Utoday	https://www.utoday.nl/science/73212/afval-omzetten-in-waardevolle-bouwstenen-voor-de-industrie
2023 September - 2024 June	MSc thesis – Mark van de Sol	WU	
2024 June 17	BNR Duurzaam (national radio broadcast)	BNR	https://www.bnr.nl/podcast/duurzaam/10550175/deze-nieuwe-reactor-maakt-van-afval-weer-grondstoffen
2024 May 22	Guest lecture in course Biobased Logistics	WU	
2024 May 29	Guest lecture in course	WU	

	Biobased Logistics		
2024 May 29	Media coverage Change.inc	Change.inc	https://www.change.inc/industrie/deze-revolutionaire-reactor-maakt-van-afval-weer-gas-en-andere-nuttige-grondstoffen-41022

Learn more about the project.

To learn more of the project, please contact:

Gerard van Binsbergen (Project leader)

Gerard.binsbergen-van@ispt.eu

Irene ten Dam (Program manager Seperations for Circularity – ISPT)

Irene.tendam@ispt.eu

Het project is uitgevoerd met Topsector Energie subsidie van het Ministerie van Economische Zaken en Klimaat, uitgevoerd door Rijksdienst voor Ondernemend Nederland. De specifieke subsidie voor dit project betreft MOOI-subsidie ronde 2020