Driving on bark, building with nutshells

UNRAVEL

A Unique Refinery Approach to Valorise European Lignocellulosics

UNRAVEL in a Nutshell

Our European UNRAVEL project will demonstrate a sustainable and economically feasible biorefinery for the conversion of second generation biomass, such as forestry and agricultural residues, into chemicals and building materials. The FABIOLA™ fractionation process lies at the heart of our work. To develop an innovative lignocellulosic value chain we aim to:

- Develop a pre-extraction process optimised for upgrading mixed lignocellulosic biomass streams prior to fractionation
- Achieve at least 80 percent delignification, 90 percent glucan recovery, 80 percent yield of monomeric hemicellulose sugars and less than 1 percent solvent loss after fractionation
- Achieve at least 95 percent lignin recovery and 99 percent (non-condensed) solvent recovery from the liquor
- Develop an economically viable process for purifying the hemicellulose hydrolysate to subsequently ferment the hemicellulose sugars efficiently into chemical building blocks
- Achieve over 90 percent sugar conversion, over 20 percent reduction of hydrolysis time and 20 percent reduction of enzyme dosage through optimisation of MetZyme® SUNO™ enzyme cocktail composition
- Demonstrate partial depolymerisation of FABIOLA™ lignin aiming to create more suitable building blocks for biobased products.
- Further refine the FABIOLA™ lignin applicability using METNIN™ enzymatic lignin fractionation technology
- Establish a series of high-value lignin applications such as PUR/PIR insulation foams and lignin-based additives in bitumen for roofing applications
- Show a 30 percent reduction in operating expenses through lower overall energy consumption and costs compared to a benchmark pre-treatment process
- Demonstrate an overall reduction of at least 15 percent in the carbon footprint compared to the state-of-the-art bio-based operation

In UNRAVEL the mild biomass fractionation process FABIOLA™ is applied, matured and upscaled. This process has been patented by consortium partner TNO and has a large potential for improving the cost-effective pre-treatment of lignocellulosic biomass.

The Challenges

Economic growth in a post-petroleum society

Innovation is needed to realise the European transition towards a post-petroleum society while decoupling economic growth from resource depletion and negative environmental impacts. A key task to achieve this is the creation of novel bio-based value chains by developing new biorefinery technologies and optimising the use of sustainable feedstock for innovative added-value products that respond to market needs. We will contribute to the development of new building blocks for different bio-based products from second generation biomass of European origin.

Sustainable biomass

One of the major challenges in creating long-term benefits is to find sustainable and industrially viable biomass that does not compete with land-use for food production or that could pose the risk of natural habitat loss. One promising solution lies in using biomass residues that originate from forestry or agriculture such as bark, wheat straw or nutshells.

Efficient fractionation

To be able to use all valuable components present in a certain feedstock an efficient integrated biorefinery process is required. Currently, the presence of non-lignocellulosic compounds (e.g. fatty acids or proteins) and the inefficient fractionation of lignocellulosic biomass into its main constituents seriously hinders the use of plant-based residues for economic purposes.

Benefits and Impacts

Creating novel cross-sector value chains for the European bioeconomy

UNRAVEL uses a mix of lignocellulosic feedstock - such as forestry, agricultural and food processing residues - to produce high value compounds for a number of applications. UNRAVEL products include extractives, lignin-based polyols for PUR/PIR foams, lignin-based additives in bitumen and chemical building blocks from the sugar fractions such as malic or xylonic acid. Improved processing developed and upscaled by UNRAVEL open new product applications and pave the way for entirely novel value chains.

Upgrading low value residues to high value products

Forestry residues and bark, as well as nut shells and excess of straw not used for soil improvement and live-stock use are nowadays mainly deployed for generating heat and power. This is also the fate of the lignin and hemicellulose from current biorefineries and pulp and paper mills. By using these underutilised feedstocks UNRAVEL will generate new quality platform chemicals and advance their conversion and application for the food industry and (fine) chemicals sectors.

Reducing costs and environmental impacts of processes

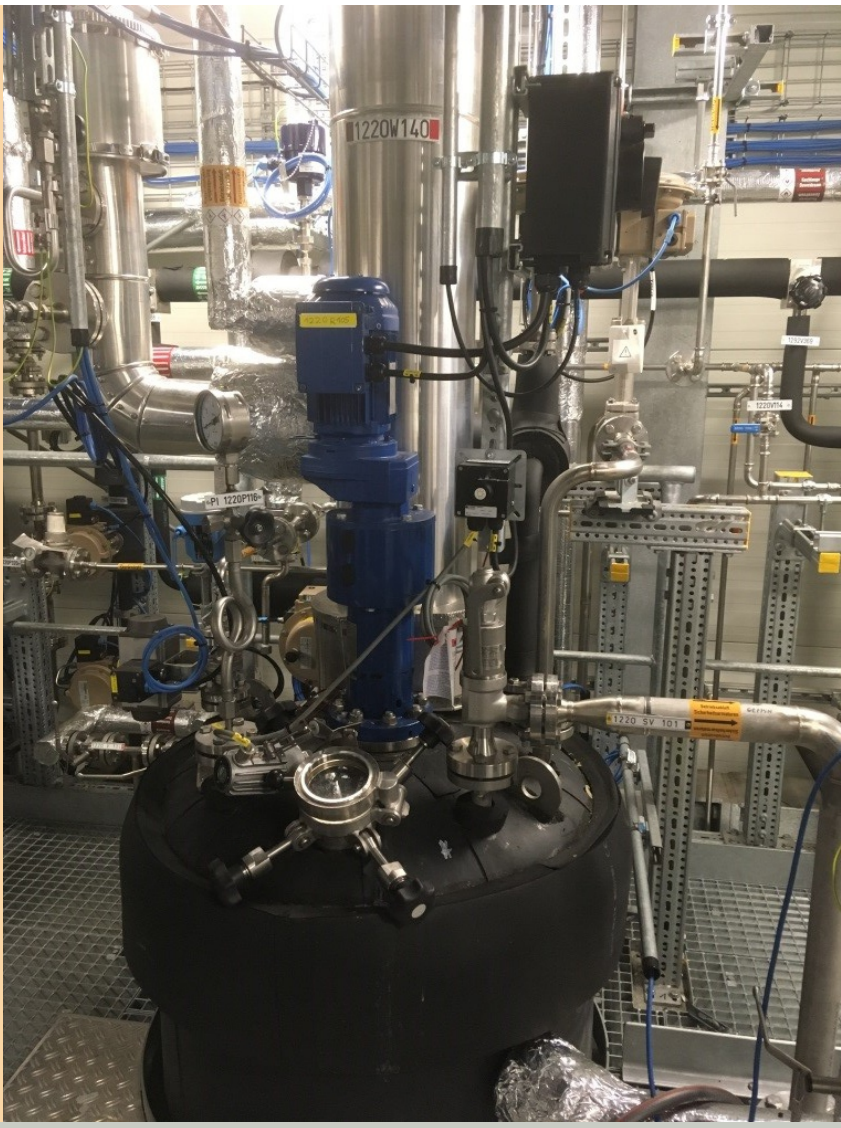
By reducing the operating temperature of the fractionation process and using acetone as solvent, UNRAVEL reduces the operational costs (OPEX) of biorefinery processes by at least 30%. Acetone compared to common ethanol-water solvents requires less energy during solvent recovery and, when combined with lower operating temperatures, leads to lower solvent losses. Lower OPEX will allow more competitive pricing of resulting products. The targeted process improvements will also significantly reduce the environmental impact of biorefinery processes. Further, the use of tailored enzymes results in a reduction of the enzyme dosage compared to generic solutions.

The FABIOLA™ Fractionation Process

The TNO FABIOLA™ process (fractionation of biomass using low-temperature acetone) offers an optimal total valorisation of lignocellulosic biomass and efficiently fractionates it into a cellulose pulp with good enzymatic hydrolysability, a high yield in monomeric hemicellulose sugars and a less-condensed lignin.

The FABIOLA™ process has been proven at lab-scale for several feedstocks including wheat straw, corn stover, birch and beech. In order to scale up the process, the translation from lab to pilot scale conditions will be evaluated to determine optimal reaction conditions for the UNRAVEL pilot plant.

Furthermore the effect of process conditions on lignin characteristics, corrosion and solvent losses will be investigated.



Developed and patented by TNO, the mild acetone organosolv process FABIOLA™ shows great potential for improving the pre-treatment of lignocellulosic biomass, such as wheat straw, corn stover and various hardwoods like poplar, beech and birch as regards cost-effectiveness and quality of resulting compounds.

The UNRAVEL Cascading Biorefinery

To be able to use all valuable components that are present in a certain feedstock an efficient integrated biorefi
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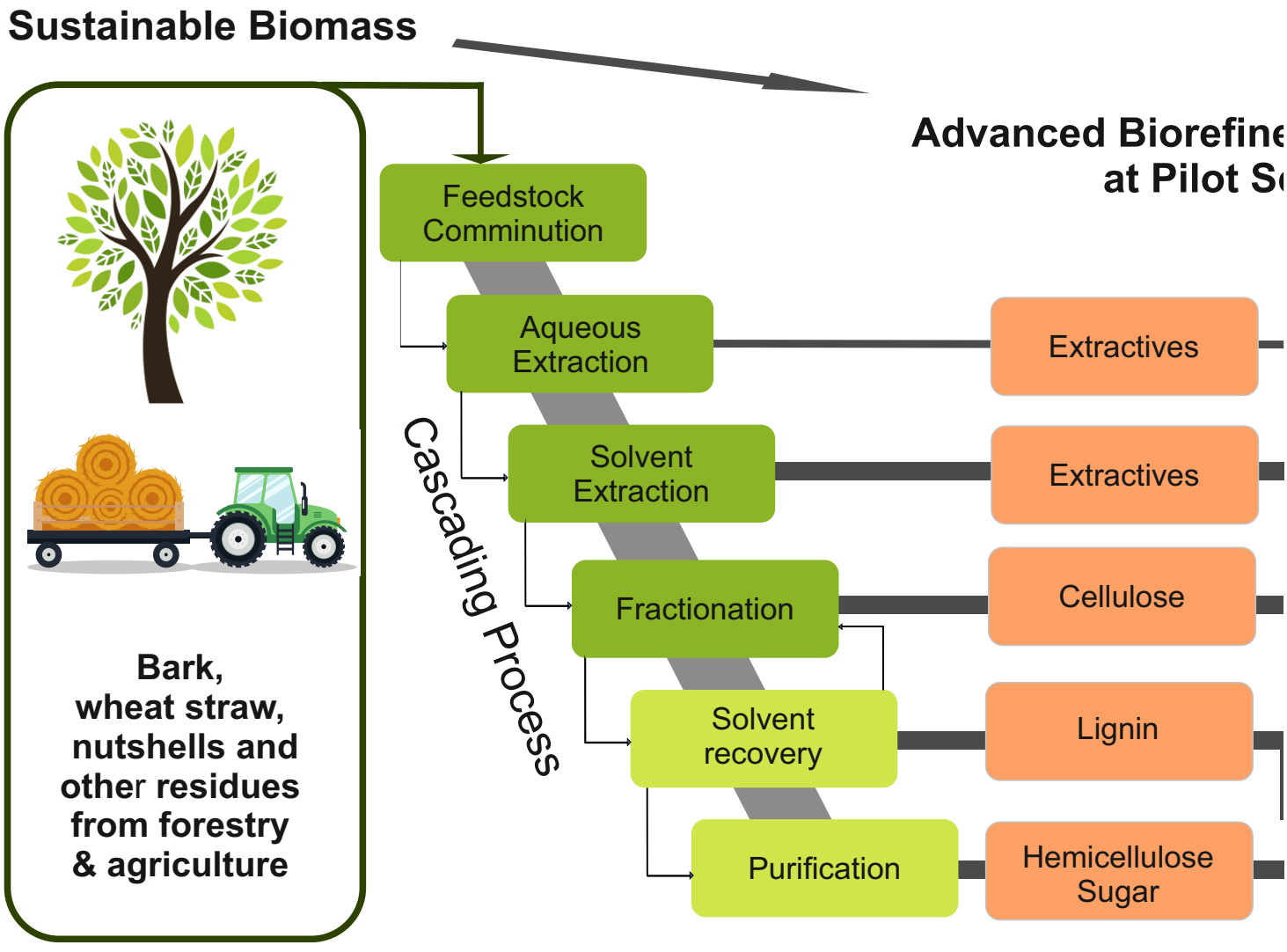
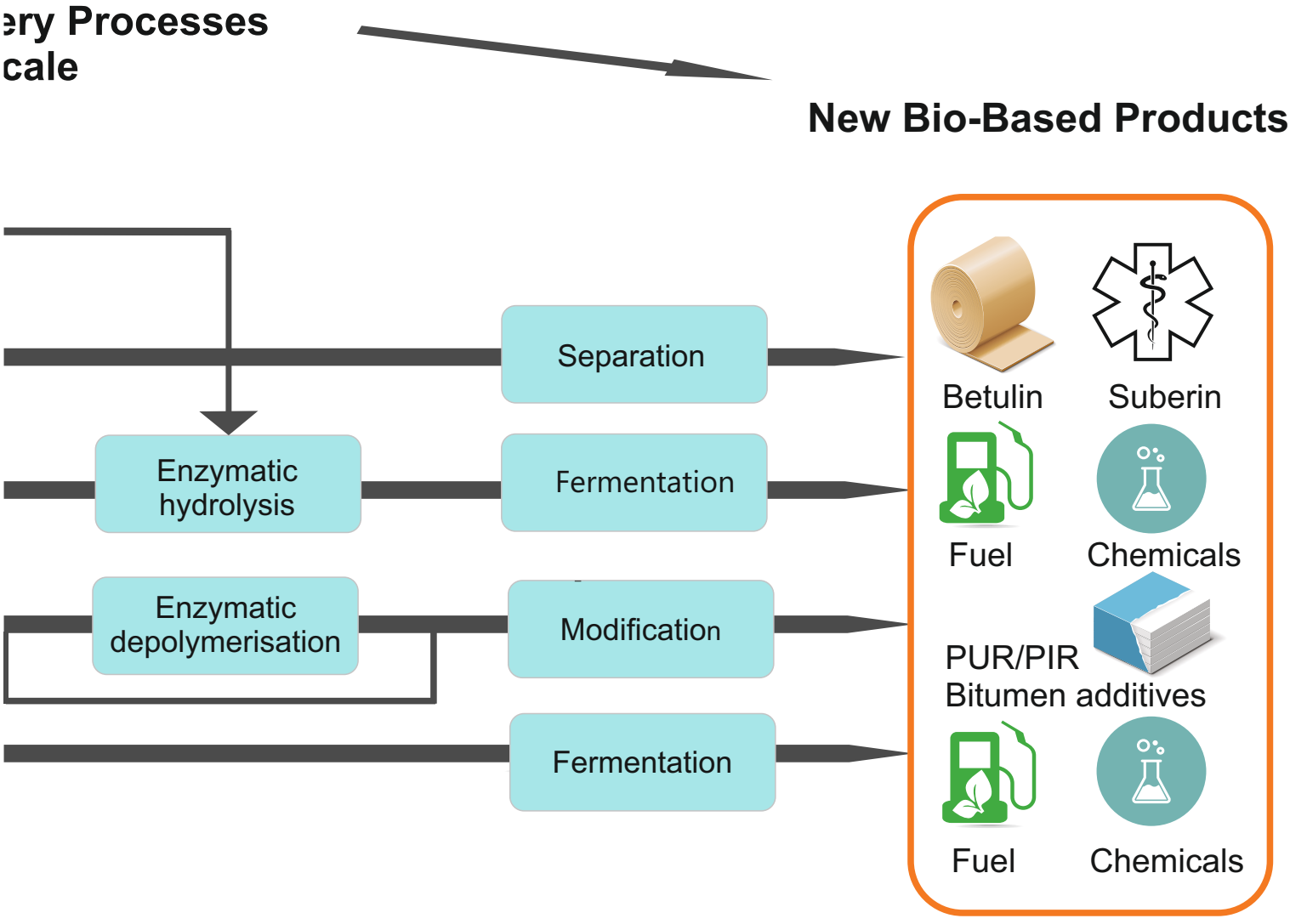
forestry and food processing residues will result in high yields of components. Another breakthrough that will
and the purity of resulting biorefinery products.



UNRAVEL develops advanced pre-treatment, separation and conversion technologies for complex
cellulose and hemicellulose fraction suitable for biochemical conversions. The technologies encom
the subsequent downstream processing to isolate and convert the lignocellulosic constituents into

nery process is required. Currently, the presence of non-lignocellulosic compounds (e.g. fatty acids or proteins) and plant-based residues for economic purposes. In UNRAVEL the mild biomass fractionation process FABIOLA™ is app- potential for improving the cost-effective pre-treatment of biomass. The fractionation of pre-extracted agricultural, be achieved in UNRAVEL is the increased homogeneity of the feedstock composition by pre-extraction of biomass



lignocellulosic biomass to produce usable lignin fragments, and monomeric sugars from the pass pre-extraction, the FABIOLA fractionation process using low-temperature acetone and high-value applications. UNRAVEL scales up the processes from lab to pilot scale.

Feedstock pre-extraction

Removing non-lignocellulose components prior to fractionation increases the feedstock homogeneity and biorefinery product purity. In addition, this novel finding enhances the feedstock flexibility for a biorefinery plant at commercial scale.

The technology development focuses on the lignocellulose enrichment of roadside grass, wheat straw, birch branches and almond shells. Increased biomass availability at lower prices and the valorisation of extractives can significantly improve the economy and sustainability of biorefineries.

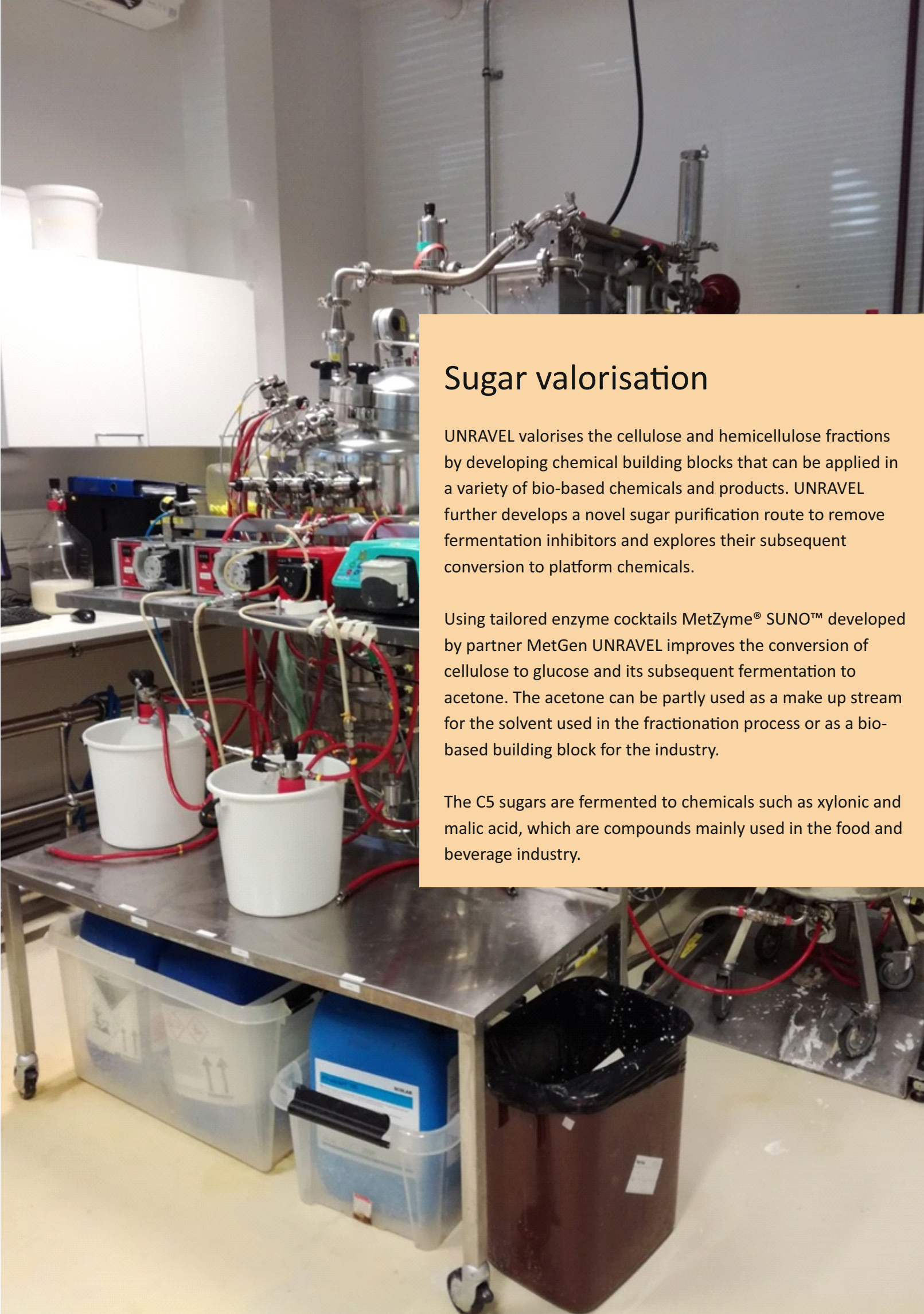
Together, UNRAVEL partners Celignis and TNO develop these processes further and evaluate valuable compounds that can be extracted and valorised with betulin being one of the target compounds.

Lignin valorisation

Lignin valorisation is one of the key aspects of UNRAVEL. The FABIOLA™ lignin shows superior properties for depolymerisation compared to technical lignins and opens novel application possibilities. UNRAVEL partner MPDG designed and built a unique continuous lignin precipitator and tested it at pilot scale. Tests resulted in high lignin yields without common issues such as intensive reactor cleaning.

The FABIOLA™ lignin is treated using METNIN™ enzymatic lignin fractionation technology developed by MetGen for partial depolymerisation to further improve lignin based product characteristics and increase the economic viability of the process.

UNRAVEL targets lignin applications in PUR/PIR insulation foams and as additive in bitumen for roofing materials.



Sugar valorisation

UNRAVEL valorises the cellulose and hemicellulose fractions by developing chemical building blocks that can be applied in a variety of bio-based chemicals and products. UNRAVEL further develops a novel sugar purification route to remove fermentation inhibitors and explores their subsequent conversion to platform chemicals.

Using tailored enzyme cocktails MetZyme® SUNO™ developed by partner MetGen UNRAVEL improves the conversion of cellulose to glucose and its subsequent fermentation to acetone. The acetone can be partly used as a make up stream for the solvent used in the fractionation process or as a bio-based building block for the industry.

The C5 sugars are fermented to chemicals such as xylonic and malic acid, which are compounds mainly used in the food and beverage industry.

Our project team

The UNRAVEL consortium brings together specialists with expertise of the entire value chain from feedstock composition, chemical pulping and pre-treatment, enzymes production, polymer chemistry, separation and reactor engineering, techno-economic and sustainability assessments and knowledge dissemination, communication and exploitation. The active involvement of three SMEs and two large enterprises, active in wood pulping and the production of lignin-based building materials, strengthens a market-driven approach and commercial exploitation and implementation of the results generated in the UNRAVEL project.

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