PURE: Prototyping emerging products from lignocellulose by zero waste pathways

Grand challenge

Due to increasing resource insecurity and climate concerns, there is an urgent need to change our linear, fossil fuel-based practices and implement circular economy approaches that use renewable resources as raw materials to manufacture the products essential to our everyday life.

This need is also well reflected in current policies, such as the European Green deal (European Commission, 2019) and increased customer demand for high-quality, sustainable, bio-based chemicals (Close, 2021). A circular economy approach will have to be adapted in almost all industrial sectors, requiring efficient use of renewable resources and innovative upcycling strategies for waste streams (European Commission, 2020). Consequently, the chemical industry is under tremendous pressure to accomplish this transformation.

There is no doubt that this transition will be very difficult to achieve. Traditional industrial practices typically add functionality to simple, low-functionality hydrocarbons (alkanes, alkenes) via selective oxidation strategies (Sun and Barta, 2018). Renewable resources, such as lignocellulose or fats and oils, however, naturally occur as complex mixtures and are inherently more functionalised (i.e. oxygenated) compounds. Hence, they require cost- and energy-intensive pre-treatment techniques besides typically reductive synthesis strategies to tap into their full potential.

Adobe Stock © davit85

Research basis

In our research programme, we believe that the development of a true bio-based infrastructure requires fundamentally novel chemical methods compliant with the inherent challenges posed by these renewable feedstocks while at the same time being environmentally benign. To effectively compete with conventional petrochemical routes through low-cost reaction routes, our research programme addresses three key points:

- Maximising renewable carbon use by high-yielding procedures.
- Full alignment of synthetic routes with the main principles of green chemistry, thus aiming for zero-waste production.
- Targeting high-performance products with minimal to no adverse effect on health and the environment.

Project aim

Within the ERC Proof of Concept project PURE, the products of the iterative 'CLEAVE and COUPLE' concept are used to investigate sustainable and potentially minimised pathways from biomass to platform chemicals and their subsequent conversion to value-added products or intermediates. CLEAVE (Deuss *et al.*, 2015; Santi *et al.*, 2020; Sun *et al.*, 2018) relates to the depolymerisation of lignin or lignocellulose to specific (aromatic) platform chemicals in high yield and COUPLE (Elangovan *et al.*, 2019; Liu *et al.*, 2019; Sun *et al.*, 2018) refers to the diversification of these platform chemicals by innovative chemical catalysis. This approach embraces the inherent complexity of the renewable starting material and ensures more sustainable, non-toxic and waste-free routes to the desired products while maximising overall efficiency. The target compounds display valorisation potential in a wide range of industries, including agriculture, food/feed, fuels/energy and pharmaceutical sectors.

fully bio-based speciality chemicals. Within PURE, the following goals are pursued:

- Investigate the industrial feasibility of selected manufacturing routes from raw material to specific products and provide proof of concept for scalability of selected routes.
- Identify the most promising product classes allowing feasible business case development and attracting industrial interest.
- Identify ideal commercial entry points via market and competitor analyses besides building a strong IP portfolio.

Impact

The future-proof manufacturing concepts introduced in PURE include modular and scalable green synthetic routes that can process various waste streams (of different types and origins) to create products with tuneable physicochemical properties for a fast adaptation to customer demands. PURE is connecting the upcycling of high-volume renewable waste streams such as lignin (100 Mt/a (Yoo and Ragauskas, 2021)) with the constantly increasing customer demand for sustainable and green products. Thus, stimulating and strengthening local and circular economies, reducing fossil fuel dependencies, and contributing to the UN sustainable development goals 'industry, innovation and infrastructure' and 'responsible consumption and production'. Further, an industrial-scale implementation of 'CLEAVE and COUPLE' would help reduce CO_2 emissions and reach the net-zero greenhouse gas emissions goal set by the EU for 2050 (European Commission, 2019) by aiding in a paradigm shift towards using renewable and abundantly available waste resources.

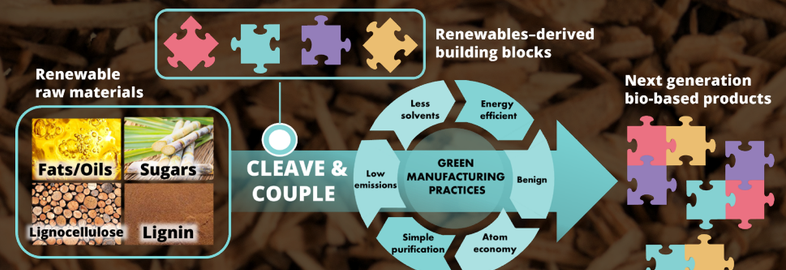

Figure 1: PURE's vision and value proposition.

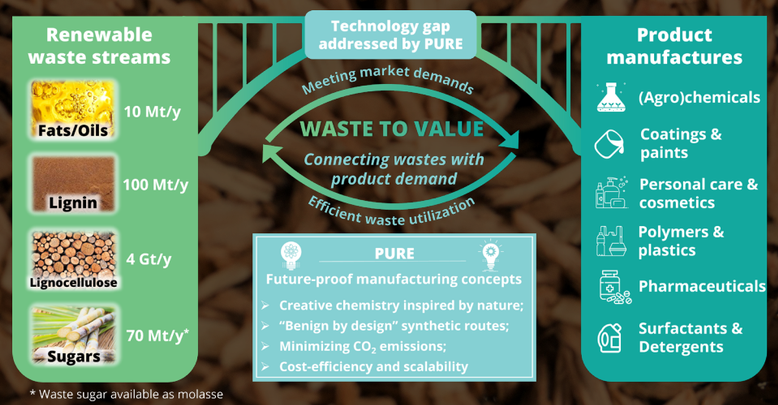

Figure 2: The PURE approach to a greener chemical industry.

References click here

PROJECT NAME

PoC PURE

PROJECT SUMMARY

This ERC PoC project studies the viability of lignocellulose-based resources for the synthesis of potentially fully bio-based speciality chemicals. It aims at introducing novel and sustainable yet cost-effective chemical manufacturing processes to a multi-billion market. Its objectives are to confirm the feasibility of upscaling it to an industrially relevant scale, outlining a solid strategy delineating the optimum product-market fit and paths towards commercialisation.

PROJECT PARTNERS

The PURE project is based at the Institute of Chemistry at the University of Graz.

PROJECT LEAD PROFILE

Prof. Barta is a leading academic expert in the field of green chemistry, catalysis and renewable resources.

She has a pronounced international mindset, having received training in RWTH-Aachen, University of California Santa Barbara and Yale, followed by an independent academic career since 2013 at the Stratingh Institute for Chemistry in Groningen and is currently a full professor at the University of Graz. She is elected secretary of the EuChemSoc Green Chemistry division, co-chair of the Gordon Conference in Lignin, member of Young Academy of Europe and Chief of Editorial board of ChemSusChem. She is the recipient of the ERC Starting Grant 2015, VIDI Grant 2015, ERC Proof of Concept Grant 2019, EIC Transition Grant 2021, the 2019 NCCC Award and the 2020 ACS Sustainable Chemistry & Engineering Lectureship Award.

PROJECT CONTACTS

Prof. Katalin Barta
Heinrichstraße 28/EG 8010 Graz AUSTRIA
+43 316 380 5323
katalin.barta@uni-graz.at
http://bartagroup.org/
@Barta_Lab

FUNDING

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme under grant agreement No. 875649.