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Innovative Cellulose Products

BioRural Knowledge-exchange Workshops: Advancing the European Rural Bioeconomy

Small-scale biorefining solutions – overview and challenges

The Key to Unlocking Bioeconomy

Blaž Likozar

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Outline

- The Concept
- Relevance
- Reference
- Partners
- Results
- Challenge
- Project Design
- First Slovenian Biorefinery

The Concept

The utilization of **biomass** as a **versatile raw material** for **different industrial products** – advancing in approaching bio-economy faster.

The **Local2Local** principle – **abundant, diverse and mixed residual biomass** as a feedstock for **locally-sourced materials' production**.

Sustainability, efficiency and flexibility – **modular equipment design**/the **integration** of **best available mature techniques**.

Eliminate the **bottleneck of biomass resource fractionation**, while **downstream value chains have already been established**.

Modularity mostly applies to **appending operations upstream or downstream**, the heart being the **production of cellulose**.

Relevance

Rich but under utilized raw material sources

- Wood biomass of app 5 million m^3/year - 60% exported
- Significant values of agricultural and industrial biomass residues – less then 30% utilized, mainly for the energy production

Strong industrial structure following the trends in transformation to bio-based

- Value chains established representing the core of the Slovenian export industries

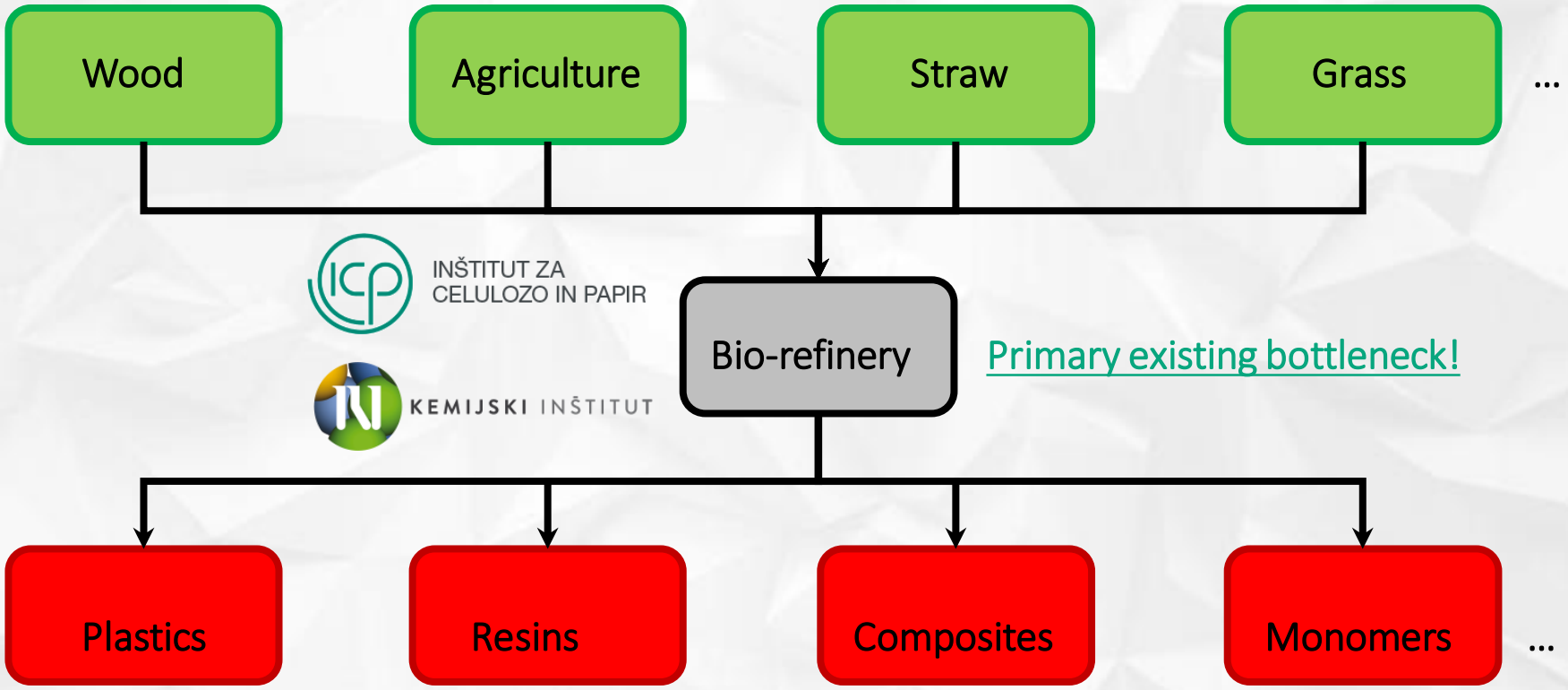
Strong knowledge base on material development and engineering

- Slovenia is among frontrunners in biopolymer research

BUT

The gap in the possibilities for valorization of the available feedstock and materials towards the end product.

Relevance


Wood
Agriculture
Straw
Grass
...
INŠTITUT ZA
CELULOZO IN PAPIR
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Bio-refinery
Primary existing bottleneck!
Plastics
Resins
Composites
Monomers
...

Relevance

...we have already had it.

(Vipap)

It is again becoming strategic!

Reference

„Networks for the transition to circular economy “ are 1 of 9 S4 (Slovenia’s Smart Specialization Strategy), coordinated by a national cluster-like entity, Strategic Research and Innovation Partnership (SRIP): SRIP – Circular Economy

CEL.CYCLE, Discarded Potentials of Biomass, the largest flagship R&D program in the Priority Area „Networks for the transition to circular economy“

Advancing Sustainable Circular Bioeconomy in Central and Eastern European countries: BIOEASTsUP

Central European Leaders of Bioeconomy Network: CELEBIO

Bridging gaps in Bioeconomy: from Foresty and Agriculture Biomass to Innovative Technological solutions: BRIDGE2BIO

APPLAUSE - Alien Plant Species from harmful to useful with citizens' led activities, EU Urban Innovation Action project

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CelCycle, Strategic RDI Program - "Potential of biomass for development of advanced materials and bio-based products"

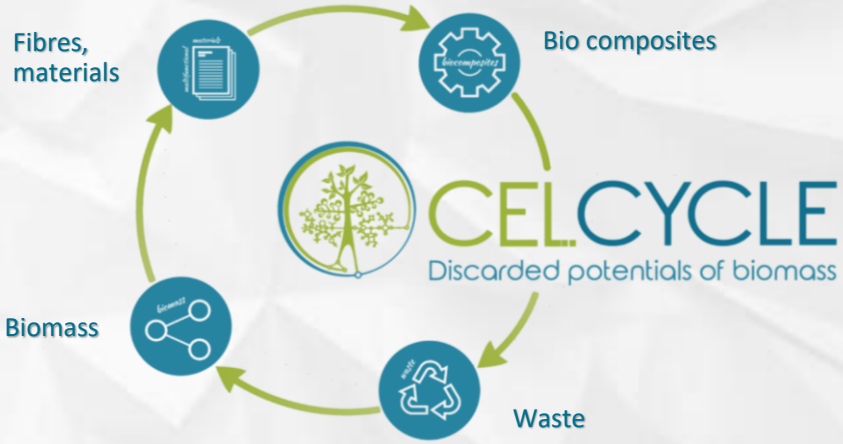
Development of advanced processes and products in the entire circuit; from biomass fractioning, use of building blocks in different products, to re-use and final recovery of waste.

Interdisciplinary and cross-sectoral partnership

- 26 partners out of which 17 industrial

Science	Industry sectors
Material science	Paper and board
Wood science	Chemical
Biotechnology	Construction
Chemistry	Automotive
Engineering	Textile
Machinery	Energy, logistics

Cascading use of biomass



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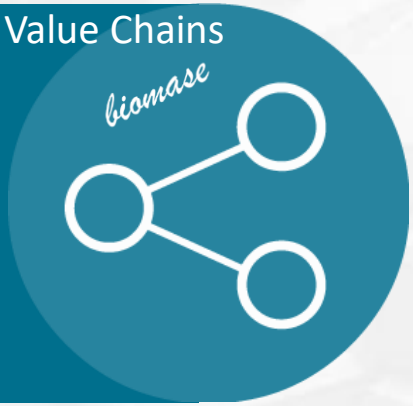
Value Chains



SECTION 1

Valorization of biomass potential and development of bio-based products

- Lignocellulosic biomass database
- Digestion of biomass & isolation of components (DES)
- Nano/micro cellulose
- Green chemicals (coatings, adhesives, resins)

National Institute of Chemistry

Pulp and Paper Institute

University of Ljubljana, Biotechnical Faculty

Faculty of Polymer Technology

Slovenian National Building And Civil Engineering Institute

ZEL-EN razvojni center energetike d.o.o.

Papirnica Vevče d.o.o.

Melamin, kemična tovarna d.d.

Mitol, tovarna lepil d.d. Sežana

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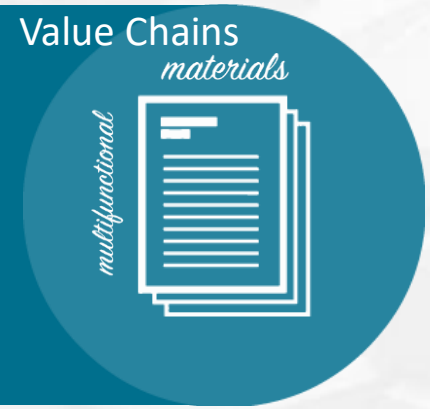
Value Chains



Development of advanced and multifunctional materials with integrated nanocellulose and environmentally acceptable additives

SECTION 2

Pulp and Paper Institute
National Institute of Chemistry
University of Ljubljana, Faculty of Natural Sciences And Engineering
University of Ljubljana, Biotechnical Faculty
University of Maribor, Faculty of Mechanical Engineering
Jožef Stefan Institute
Predilnica Litija d.o.o.
Silkem, Proizvodnja zeolitov d.o.o.
Papirnica Vevče d.o.o.
ZEL-EN razvojni center energetike d.o.o.
Kolektor Sisteh d.o.o.
Slovenian National Building And Civil Engineering Institute

- Paper/board with improved and new FUNCTIONALITIES
- Improved BARRIER and SENSORY PROPERITIES
- SMART PACKAGING with printed sensors
- YARN with functional cellulose fibers

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Value Chains

biocomposites

SECTION 3

Products with higher proportion of bio-based components and improved functionalities for different industries

- Bio-based filtering materials

- Thin polymer composites

- Battery separators

- Insulating materials

University of Maribor, Faculty of Mechanical Engineering
Pulp and Paper Institute
National Institute of Chemistry
University of Ljubljana, Biotechnical Faculty
University of Ljubljana, Faculty of Natural Sciences And Engineering
Faculty of Polymer Technology
Slovenian National Building And Civil Engineering Institute
Plastika Skaza d.o.o.
Veplas group d.d.
Kolektor Sisteh d.o.o.
Jelovica hiše d.o.o.

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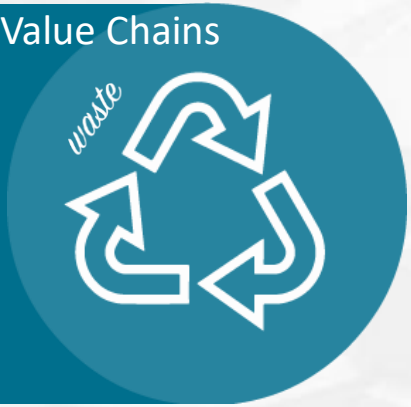
Value Chains



Slovenian National Building And Civil Engineering Institute
Pulp and Paper Institute
Luka Koper, Pristaniški in logistični sistem d.d.
ZEL-EN razvojni center energetike d.o.o.
Papirnica Vevče d.o.o.
University of Ljubljana, Faculty of mechanical Engineering
Faculty of Polymer Technology
Kolektor Sisteh d.o.o.
National Institute of Chemistry
Petrol, Slovenska energetska družba d.d.
Pulp and Paper Institute
Slovenian National Building And Civil Engineering Institute
ZEL-EN razvojni center energetike d.o.o.

Development of procedures for biological and mechanical processing of solid waste into products with added value

SECTION 4

- **Production of enzymes from biological treatment of waste**
- **Re-use of waste in other industries**

SECTION 5

- **Production of energy from waste with a high water content**

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Partners

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SILKEM

PETROL
Energija za življenje

belinka perkemija

nanocrystacell

Univerza v Ljubljani
Naravoslovnotehniška fakulteta

beti

Univerza v Ljubljani
Biotehniška fakulteta

KOLEKTOR
KOLEKTOR GROUP

JELOVICA

UNIVERZITET U NOVOM SADU
TEHNOLOŠKI FAKULTET NOVI SAD

KOLIČEVO KARTON
Proizvodnja kartona d.o.o

INŠTITUT ZA CELULOZO IN PAPIR
Innovative Cellulose Products

CINKARNA

FTPO
Fakulteta za tehnologijo polimerov

VIPAP
VIPAP VIDEM KRŠKO
Proizvodnja papirja in vlaknin d.d.

ZEL-EN

LUKA KOPER
Port of Koper

B&B
PAPIRNICA VEVČE
LABELS AND FLEXPACK

Litia
PREDILNICA LITIJA

Melamin

Univerza v Ljubljani
Fakulteta za strojništvo

MITOL

ZAG
ZAVOD ZA GRADBENIŠTVO SLOVENIJE
SLOVENIAN NATIONAL BUILDING AND CIVIL ENGINEERING INSTITUTE

Univerza v Mariboru
Fakulteta za strojništvo

Institut "Jožef Stefan", Ljubljana, Slovenija

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Results

Numerous **innovation**s have been developed (15 innovations, 7 patents pending, 8 new products) and 5 **new value chains** created. Joint research (over 250 researchers from academia and industry) on **technology and product lines** are performed:

- Comprehensive **database** of over 60 different biomass residual streams validated for potential use
- **Advanced processes** of biomass fractionation and converting; **nanocellulose** produced from residual biomass sources, **green chemicals** to be used in coating, resin and adhesive industries
- **Bio-based packaging** with improved **barrier properties** and **functionalities**
- **Bio-based functional products**; high performing **filtering and insulating materials**, lightweight and thermostable **bio-composites** for different applications (automotive, electrical industry)
- **Enzymes** produced from **biological decomposition** of waste
- **Advanced processes** for end waste treatment and **material recovery**; mechanical, biological decomposition, innovative **Waste-to-Energy system**

Challenge

R&D, performed in different process/product chains, have **reached** the **TRL level** of **5–6**.

Possibility to follow **ambitious bio-economy trends** is hindered by the **lack of facilities** to support the **integration** of technologies, **demonstration** and further production **scale-up** of potential end products.

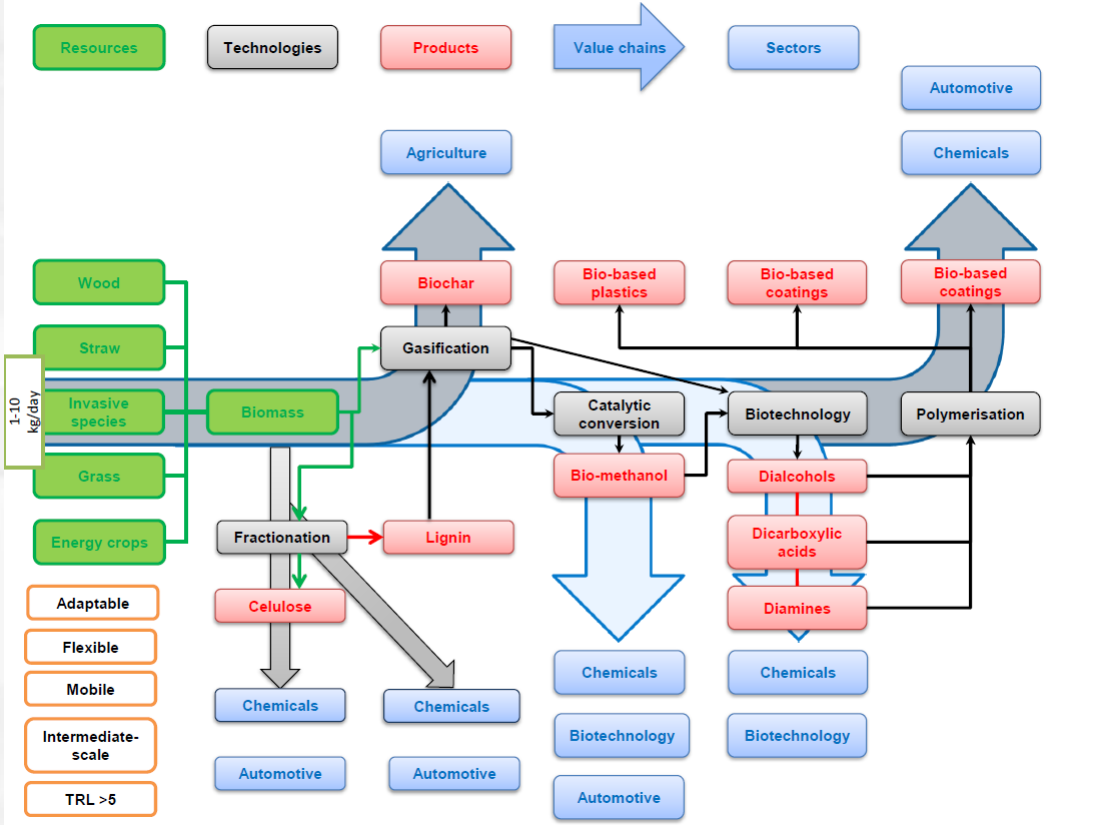
Intermediate process infrastructure is **needed** for the valorisation of the feedstocks towards certain piloted products, thus helping to **prove, validate and commercialise viable business cases**.

A strong supporting **interest from all stakeholder partners** is expressed to create a small to medium size bio-refinery pilot plant that would build on:

- the **implementation of knowledge,** expertise and experience,
- the utilization of the local renewable resources of **diverse abundant biomass**,
- the **validation of the markets** for the emerging business opportunities in different industrial sectors, and
- the development of **new value chains**.

Project Design

Local (hence smaller) bio-refinery concept (Slovenia) (< 1000 kg/day)



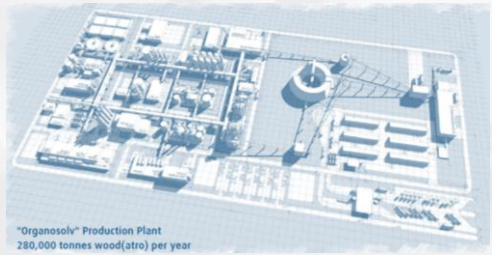
Project Design

Three possible scenarios:

1. **Mobile fractionation unit**
2. **Industrial hall**
3. **Industry site**

(Linde, 2015)

…but mobile



Timeline: M1–M6: PI&D project; M6–M12: balances; M12–M24: construction; M24 –M36: demonstration.

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First Slovenian Biorefinery!

Biomass (Bio)Refining Research Laboratory,
Velenje (Slovenia)

Reference project: Fraunhofer CBP, Leuna

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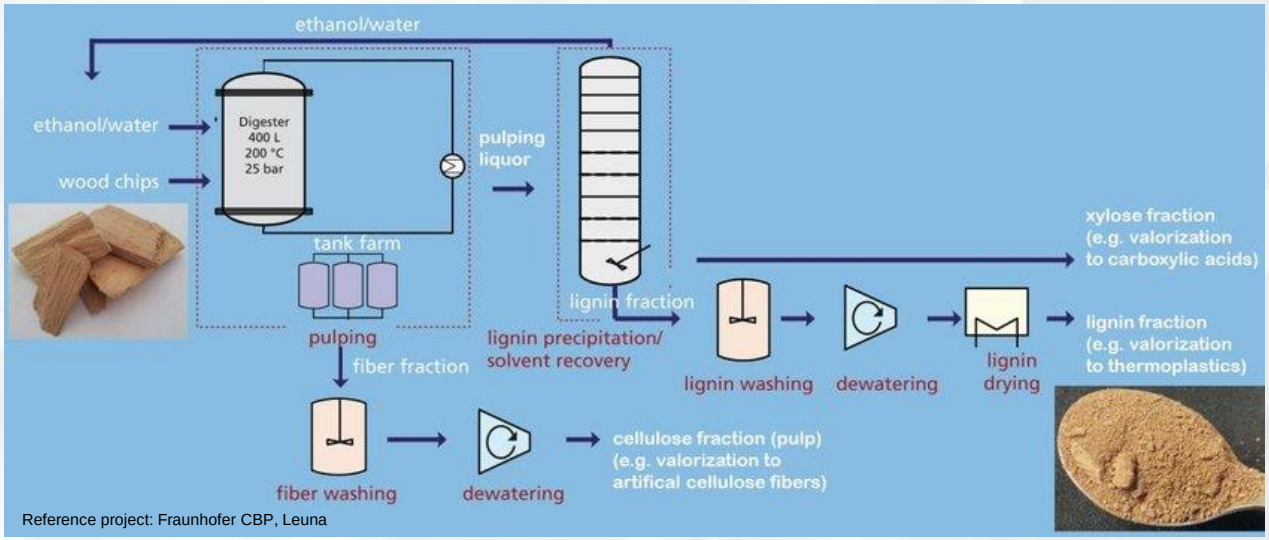
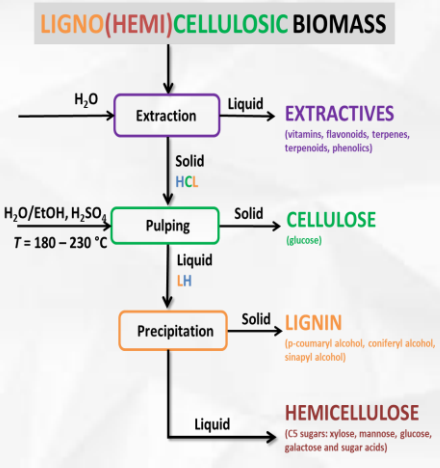
Biomass (Bio)Refining Research Laboratory



Reference project: Fraunhofer CBP, Leuna



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First Slovenian Biorefinery

Biomass (Bio)Refining Research Laboratory,
Velenje (Slovenia)

- Investment costs (estimation) 3 – 5 M€ (from planning till startup), depending on the capacity (1.000 kg – 10.000 kg/day)
- Direct new jobs created in the plant -> 10 – 20
- Indirect effect of creating new jobs (local and regional):
  - Upstream – collecting, sorting, transportation of biomass, recycling
  - Downstream – use and converting of biorefinery products (cellulose, chemicals) into products in chemical, polymer and packaging industry
- Reduction of (bio)waste generation and disposal

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Want to know more?

Articles about biomass valorization (Open Access):

Davide Benedetto Tiz et al. 2023, https://doi.org/10.1021/acssuschemeng.3c03248

Hren et al. 2023, https://doi.org/10.3390/pr11051393

Marinič et al. 2023, https://doi.org/10.1016/j.renene.2022.12.055

Ročnik et al. 2022, https://doi.org/10.1016/j.cej.2022.137309

Jasiukaitytė-Grojzdek et al. 2020, https://doi.org/10.1021/acssuschemeng.0c06099

Horizon EU projects:

- GreenLOOP: https://www.greenloop-project.eu/en/home/
- ESTELLA: https://estellaproject.eu/
- HyPELignum: https://www.hypelignum.eu/

ESTELLA

GREEN-LOOP

HyPELignum

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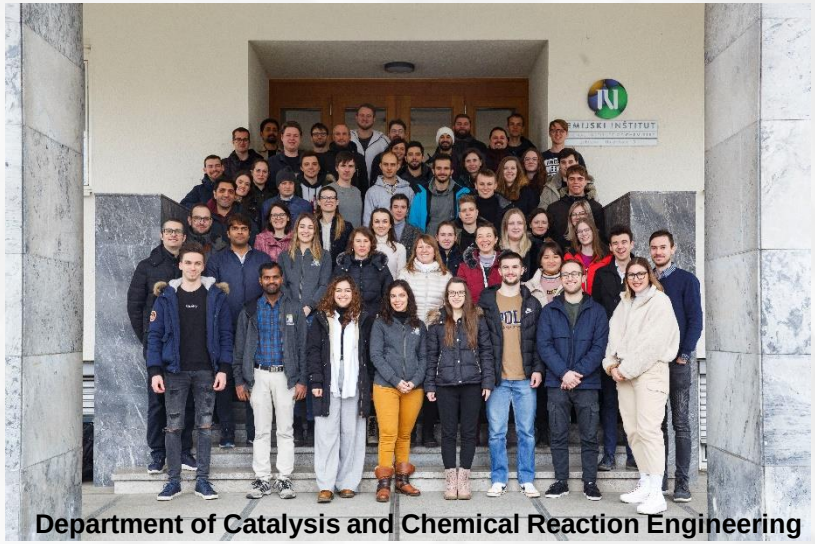
Thank you for attention provided!

Even when we approach emerging low-carbon economy, **we will maintain a carbon-based resource society** (the world around us is carbonaceous), while we have only two sustainable resources: biomass and CO_2.



Department of Catalysis and Chemical Reaction Engineering