CIRCULAR SYSTEMS IN ACTION: CASCADE UTILIZATION AND INDUSTRIAL SYMBIOSIS

Summary

Cascade utilization and industrial symbiosis are central to unlocking the full potential of green biomass. In trans4num, we explore how every part of the plant—from protein to pulp and brown juice—can serve new value chains across food, feed, packaging, and energy.

The need

In today's agricultural and industrial systems, a significant portion of biological resources is either wasted or underutilized. While green biomass like grass and clover is rich in valuable components—such as fibers, sugars, and nutrients—most of its potential remains untapped after initial processing for protein.

Traditional value chains often stop at the primary product. However, sustainability and economic resilience require that we go further—transforming secondary outputs (like pulp and brown juice) into inputs for new value chains. This is known as cascade utilization

At the same time, industrial decarbonisation pathways, such as Power-to-X (PtX) technologies, are creating new resource flows like excess heat and biogenic CO_2. These flows, if coordinated wisely, can serve as inputs for agriculture and green refining.

Unlocking this interconnected potential will require:

- New business models and partnerships across sectors
- Investment in R&D to mature low-TRL technologies
- Supportive policy and regulatory frameworks
- Regional planning to enable physical co-location and material exchange

Without coordinated action, we risk losing both valuable resources and opportunities to lead in green innovation.

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The benefits

Full-value recovery:
Green biomass contains much more than just protein. Press cake (pulp) and brown juice left after protein extraction can be further processed into valuable products for multiple sectors.

Climate-friendly production:
These processes reduce agricultural waste and carbon emissions, while enabling local production of packaging, textiles, fuels, and building materials.

Industrial synergies:
Residual heat, carbon, and process water from Power-to-X (PtX) systems can be reused in biorefineries, creating closed-loop, resource-efficient value chains.

Economic development:
Cascade utilization and PtX symbiosis support the emergence of new green industries, jobs, and regional development—positioning northwest Jutland as a hub for climate-smart innovation.

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trans4num solution

Cascade Utilization of Green Biomass

The green biorefining process begins with protein extraction, but it doesn't end there. What remains—pulp and brown juice—has substantial commercial and environmental value:

- Pulp (pressed plant fiber):
  - Can replace wood fibers in products like cardboard, insulation, and bioplastics
  - Can be further refined into cellulose for high-end uses like textile production or packaging
  - Has the advantage of lower lignin content compared to wood, easing purification processes
- Brown Juice (sugar- and nutrient-rich liquid):
  - Used for precision fermentation to grow targeted microorganisms for food, feed, or pharma
  - Can be converted into ethanol or other biofuels
  - Offers potential as a biogas substrate or as part of organic fertilizer systems

Together, these streams can power new circular business models rooted in sustainability and zero-waste principles.

Industrial Symbiosis with Power-to-X

PtX technologies—such as hydrogen production from renewable electricity—produce valuable by-products like excess heat and CO_2, which can feed into green refining operations:

- Excess heat can dry protein pastes, evaporate brown juice, or power fermentation processes
- Process water from refining can be cleaned and reused in hydrogen production
- Biogenic CO_2 and leftover biomass can feed into biogas or biochar production—supporting climate-smart energy cycles

By co-locating facilities, industries can exchange heat, water, and nutrients—reducing costs, emissions, and resource loss. This model is particularly powerful in regions like northwest Jutland, where strong agricultural traditions, renewable energy capacity, and innovation leadership create ideal conditions for integrated green value chains.

What were the challenges / limitations in the implementation process?

- Limited maturity of cascade-processing technologies
- Need for strategic co-location of industries (PtX and biorefining)
- Lack of standard frameworks for sharing residual flows across sectors

What kind of resources do you need to implement the proposed solution?

- Policy support and investment in infrastructure
- Industrial-scale R&D and tech development
- Agreements for resource sharing between facilities

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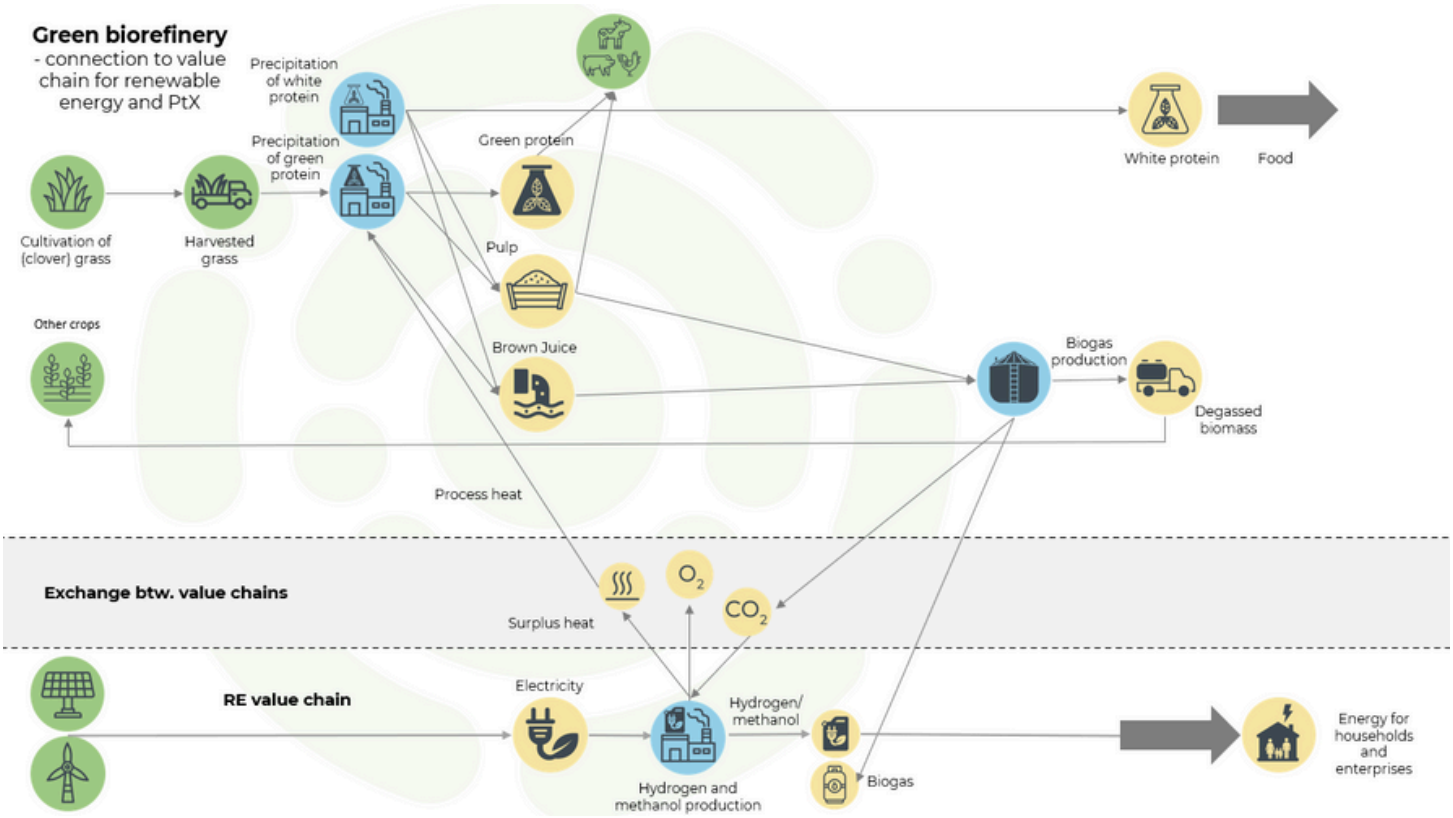
More information

- trans4num Danish NBS site



Learn more about the project at https://trans4num.eu/en/

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