



AUSTRIAN **biocYCLES**

BIO-BASED INDUSTRY
AS PART OF THE
CIRCULAR ECONOMY

EXECUTIVE SUMMARY

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Y. Reinberg, T. Steffl, M. Gronalt, E. Gonglberger, J. Thaler, M. Müller, A. Biebl, J. Niederwieser, J. Kisser



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MOTIVATION

CONTENTS & OBJECTIVES



1.1 MOTIVATION

Numerous strategies at national and EU level, as well as a large number of scientific publications emphasize the importance of using biogenic waste and side streams for a transformation towards a circular bioeconomy that does not require fossil fuels. According to the principles of the circular economy, only residual materials that are no longer usable as materials are sent for thermal recycling. In its “Updated Bioeconomy Strategy”¹ (European Commission 2018), the EU writes that the European bioeconomy should include sustainability and cyclability as the core, whereby this bio-based industry should also be renewed, not least with the creation of new value chains based on organic waste material flows. The even more “up-to-date” publication of the cornerstones of the European Green Deals² suggests further ambitious steps in the direction of viable bioeconomy.

Although there are already a large number of biorefinery concepts for using the different biomasses, these have so far only been implemented at an industrial scale in a few areas. An important prerequisite for an increased establishment of biorefineries is the determination of logistical and economic factors.

1.2 CONTENTS & OBJECTIVES

The aim of the “Austrian BioCycles” project was to stake out the cornerstones of what a future networking of biogenic material flows in a combination of local and central biorefinery units could look like on a technological and logistical level.

The relevant biogenic material flows (waste, by-products, biomass currently used for energy or animal feed) were determined and located at the federal state level. In the next step, usage paths and biorefinery concepts were developed and the theoretical substitution potential (replacement of fossil products) was calculated using conversion factors. A comparison with production from primary biomass was made on the basis of the area required for cultivation. In order to estimate the feasibility of using the determined biomass, a logistic model for a delivery network was developed using straw as an example. With the involvement of experts, possible ecological and economic as well as effects on regional development were assessed in order to determine possible risks and opportunities. Technical questions and research policy recommendations for action that resulted from the research were collected and described in a list.

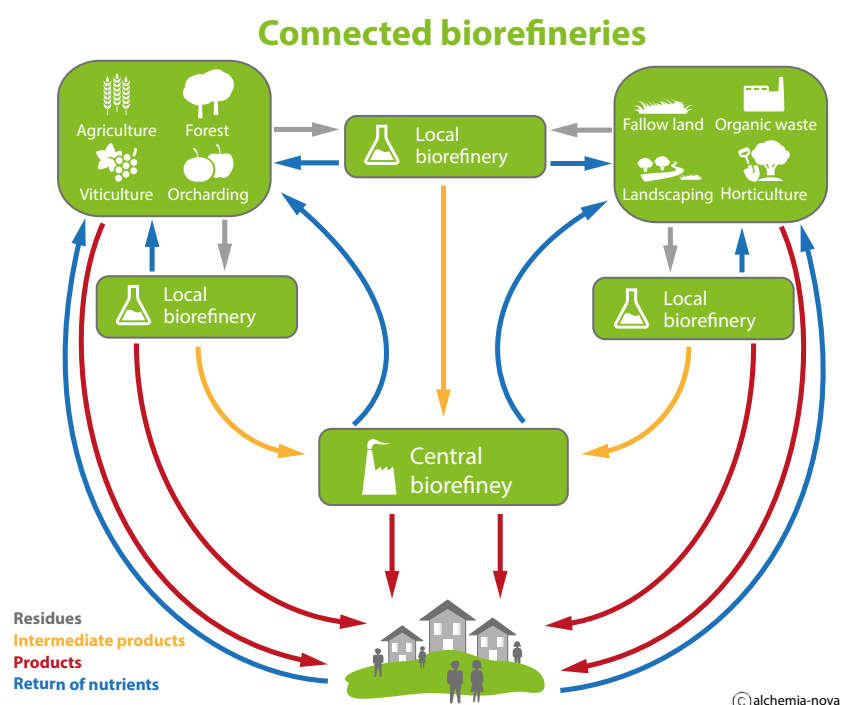


Figure 1: Concept of networked biorefineries (own illustration)

1 European Commission: https://ec.europa.eu/research/bioeconomy/pdf/ec_bioeconomy_strategy_2018.pdf, 14.01.2020

2 European Commission: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en, 14.01.2020

METHODOLOGICAL APPROACH



1.3 METHODOLOGICAL APPROACH

The relevant material flows were based on data from public statistics (qualitative and quantitative), clustered into cultivation and harvesting, processing trade and industry, as well as waste generation and other material flows. In the quantification, content overlaps were avoided as much as possible. The results were presented as bar graphs and as a tile graph.

For the material flows determined, biorefinery concepts and usage paths were created using literature research and the respective TRLs were assessed. Conversion factors based on literature information were used to calculate the substitution potential. Sugar beets and miscanthus (for pyrolysis oil) were used to compare the area of production from primary sources. The nutrients nitrogen and phosphorus contained in the material flows were also estimated using values from the literature.

At the same time, 21 guide-based expert interviews were carried out. Among other things, an assessment of the most promising biomass and products was requested. Technical and other obstacles were also queried.

Using straw, pruning and sewage sludge as an example, the biomass quantities were localized at community level using GIS as the basis for the supply chain design. The further steps in the supply chain design were carried out using the example of straw and pyrolysis with subsequent synthesis to dimethyl ether (DME) (Bioliq® process). The potential pyrolysis sites were limited to existing infrastructure and a minimum of biomass (14 kt). Scenarios for a decentralized or central synthesis plant were calculated relative to the distance between the potential locations. A cost-optimized delivery network was calculated (locations, capacities) via programming of a logistic planning model.

The ecological and economic effects of the increased use of secondary biomass were assessed in two workshops with experts.

The research questions and recommendations for action ascertained in the project were compiled from the literature, from the expert interviews and from an expert workshop.

RESULTS

RELEVANT MATERIAL FLOWS

**BIOREFINERY CONCEPTS,
PRODUCTS &
SUBSTITUTION POTENTIAL**

1.4 RESULTS

1.4.1 RELEVANT MATERIAL FLOWS

In the determined biomass from agriculture, namely liquid manure, green fodder (assuming 30% of the quantities currently fed) and straw (accumulated quantity minus 52% for remaining in the field and litter) represent the largest residue flows from dairies, the sugar industry and animal processing (70% of the quantities produced). The largest wet masses were determined from the statistics of the energy and waste management with municipal waste water, wood waste, lye from the pulp industry and energy wood. With regards to dry matter, the theoretically available amounts of wood waste (especially wood chips), energy wood (especially log wood), green fodder, liquid manure and straw stand out, of which the material use is entirely preferable to the energetic. The total amount of wood currently used thermally was accordingly included to determine the material potential. Figure 2 shows a comparison of dry matter in overview.

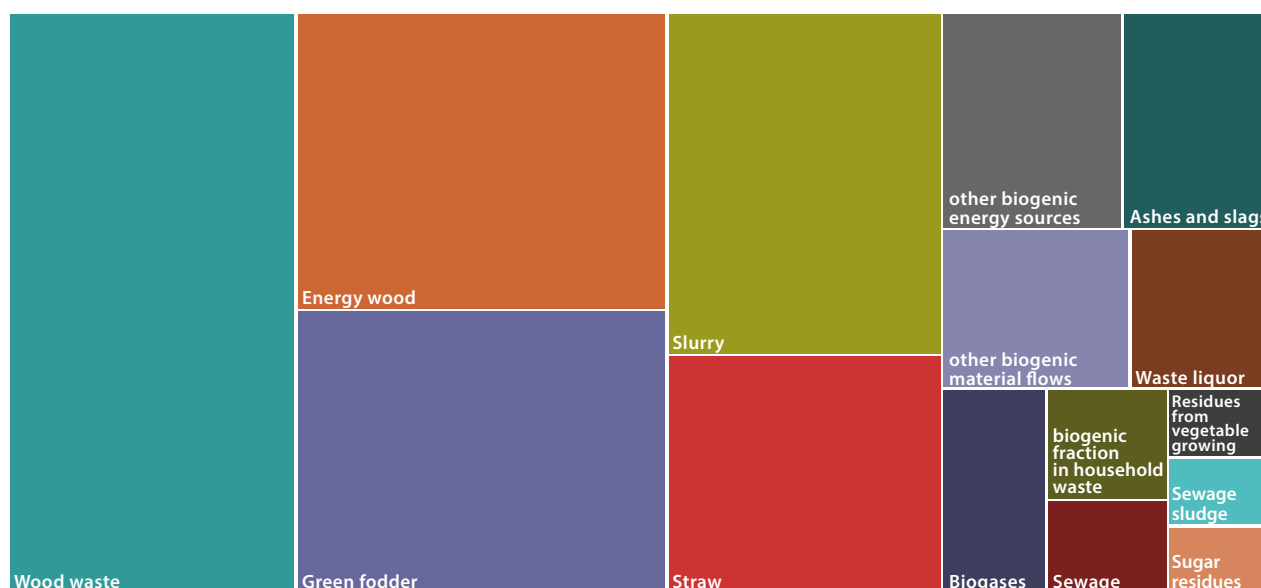


Figure 2: Comparison of relevant bio-based material flows as dry matter (own illustration)

Compared to available figures at EU level, relatively large amounts of milk are processed in Austria (136 kg milk products / capita) and a lot of solid biomass is burned (more than twice the amount per capita compared to the EU) -Average) (Eurostat 2020)¹²³⁴

1.4.2 BIOREFINERY CONCEPTS, PRODUCTS & SUBSTITUTION POTENTIAL

In addition to the overview of the currently available literature regarding biorefinery concepts for the different material flows, conversion factors for their conversion into products were determined. It should be emphasized that the options presented in the publications as preferred usage paths often concern uses that do not allow a direct comparison with fossil-based products. For example, the production of enzymes or bacteria for crop protection is described as the most promising added value from organic waste (Vea, Romeo, and Thomsen 2018), but no substitution potential for these options could be calculated. Therefore, mostly raw materials such as ethanol, lactic acid or methane were used as products for the determination of the substitution potential. Thus, the production of these substances does not automatically correspond to the most promising usage paths for implementation in Austria. To determine the choice of usage pathway, the question of substitution potential needs to be addressed. The calculated product quantities also show that for some material flows the raw material quantities required for conversion to basic chemicals would not be available in order to manufacture them in a large plant. Since the TRLs (Technology Readiness Levels)

1 Eurostat: <https://data.europa.eu/euodp/en/data/dataset/u33K8GiiMFYGN7HyHUNhg>, 20.01.2020

2 Eurostat: <https://ec.europa.eu/eurostat/web/products-datasets/product?code=tgs00096>, 20.01.2020

3 Eurostat: https://ec.europa.eu/eurostat/web/products-datasets/-/apro_mk_pobta, 20.01.2020

4 Eurostat: <https://ec.europa.eu/eurostat/web/energy/data/energy-balances>, 20.01.2020

BIOREFINERY CONCEPTS, PRODUCTS & SUBSTITUTION POTENTIAL

ness Level) of most of the technologies identified so far are 4-6 (testing on a laboratory scale up to the first prototype without long-term operation), both the conversion factors are subject to great uncertainty and important steps in the development up to market maturity.

Using the example of the lignocellulose category (more than 50% of the determined dry matter), the material flows involved (Figure 3) and the representation of a usage path (hydrothermal liquefaction, Figure 4) can be found in the following graphics. The same graphics were also created for the other material flows.



Figure 3: Composition of the relevant potential of the category lignocellulose in kt (7kt energy grasses not shown in the graphic) (own illustration)

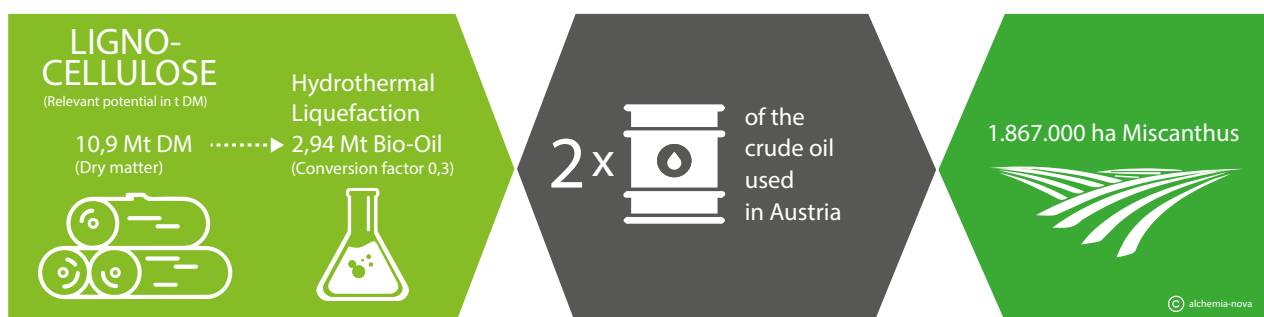


Figure 4: Theoretical substitution potential by HTL of lignocellulose (own illustration) calculated according to (Arturi, Kucheryavskiy, and Søgaard 2016; Steffl et al. 2018; Jungbluth et al. 2007)

In summary, it can be stated that if the influence of the material flows among themselves is neglected, there is theoretically a substitution potential of 5.2 Mt of fossil products and thus 2.4 times the amount of material used for fossil raw materials (Steffl et al. 2018). A “classic” production methodology from primary biomass would require the equivalents of 2 million hectares of arable land – corresponding to 1.5 times the agricultural area of Austria.

However, since the material flows under consideration are currently used almost entirely for thermal purposes, as animal feed, or as fertilizer, a real potential is undoubtedly at a fraction of the theoretical substitution potential. The experts surveyed see real potential primarily in straw, sewage or sewage sludge, organic waste and liquid manure. The enormous quantities of material in the Austrian timber industry also show great promise, competing with direct biomass combustion, in particular.

LOCATION OF THE BIOMASS

LOGISTICS NETWORK & ECONOMY

1.4.3 LOCATION OF THE BIOMASS

Location placement for 16 material flow categories was carried out at the federal state level on the map of Austria. Figure 5 shows the relevant potential of lignocellulose as an example. In this example, a selection of biomass plants, woodworking companies and sawmills was drawn as the place of production and also of potential further processing.

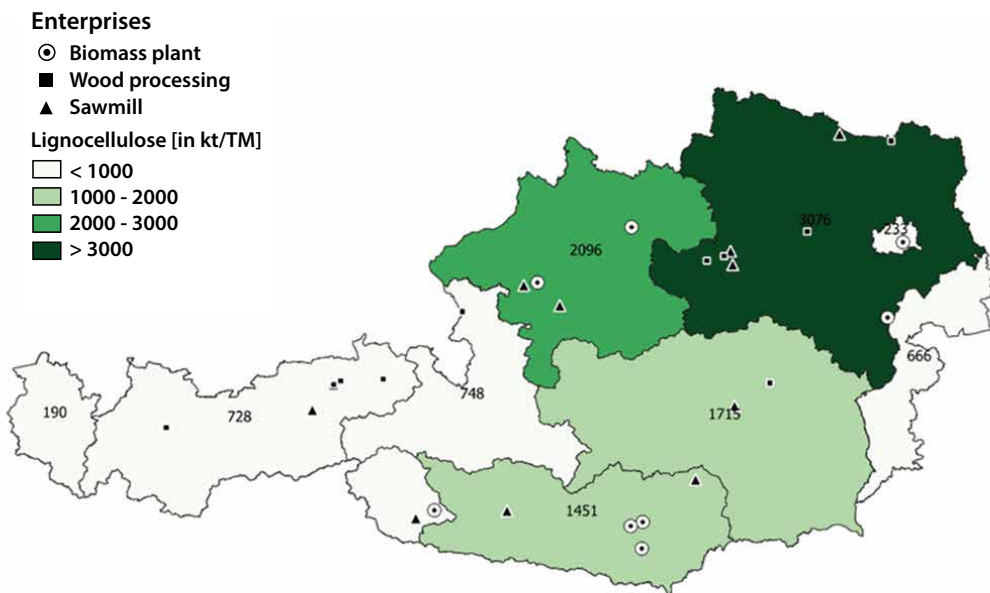


Figure 5: Relevant potential of lignocellulose at the federal state level with biomass plants, wood processing companies and sawmills (selection) (own illustration)

1.4.4 LOGISTICS NETWORK AND ECONOMY

A mathematical optimization model for the use of the Bioliq® straw process was created to determine a cost-minimal secondary raw material supply network, which calculates the cost-minimal design (number of locations and transport routes). The determined relevant potential on a community basis serves as an input variable. Transport costs and the construction and operating costs of the biorefineries were used as cost parameters. These costs could be derived from estimates of comparable work. In the integrated version of the logistics concept, the biomass is transported directly to a central pyrolysis and synthesis plant, while in a decentralized version (see Figure 6) there are several pyrolysis plants for the production of “slurry” which is then processed in a synthesis plant.

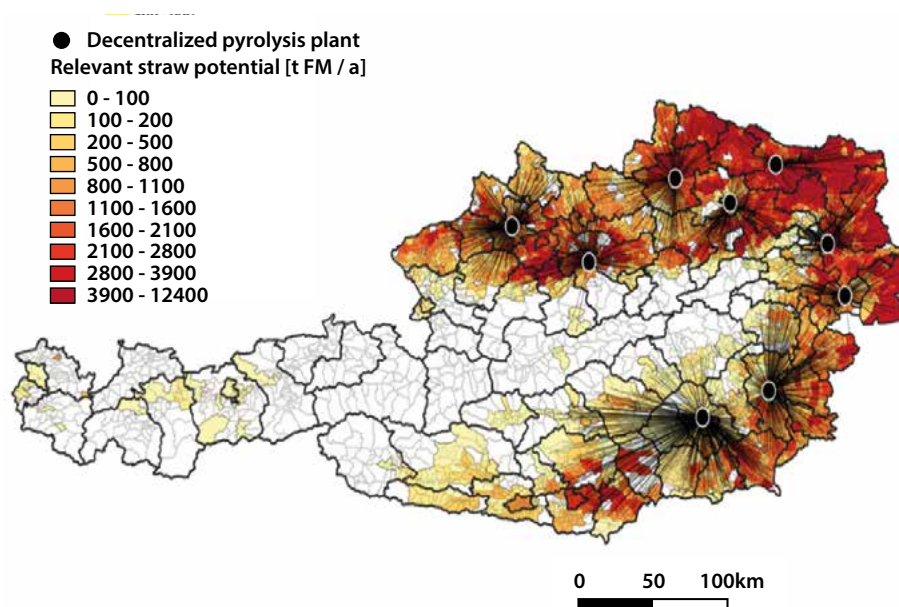


Figure 6: Decentralized logistics concept for straw with regional pyrolysis plants (own illustration)

LOGISTICS NETWORK & ECONOMY



The model calculations result in total costs (processing costs + investments) of € 1,072 million for the decentralized and € 998 million for the central logistics concept. The proceeds from the sale of excess electrical energy from the synthesis plant are already included in these results. These amount to around € 26 million in the decentralized concept and around € 17 million in the central concept. These revenues are reduced by the resource consumption-dependent costs of the synthesis and are included in the variable synthesis costs of the two concepts examined. With a processed slurry volume of 1,207,440 t, this results in € 21.4 million for the decentralized or € -11.89 million for the central concept. The one-time investments for the construction of the technical infrastructure (pyrolysis and synthesis plants) estimated from literature data amount to around € 795 million in the decentralized or € 743 million (~ € 52 million; -6.5%) in the central logistics concept.

Figure 7 compares the total costs of the calculated logistics networks. Both logistics concepts have the same raw material, synthesis construction and synthesis fixed costs. In the decentralized concept, costs for slurry transport amounting to around € 13 million are incurred in the second distribution stage. In the decentralized network, pyrolysis fix costs fall by around € 30 million. In the central concept, the pyrolysis fix costs are around € 22 million and are therefore around a quarter (-26.5%) lower in comparison. This is due to economies of scale and economies of scale in the case of plants with higher capacity. The biggest difference in costs can be seen in the variable pyrolysis costs. In the decentralized concept, these amount to around € 33 million, which corresponds to around 20 times the cost of the central solution at € 1.6 million (+ 1920%).

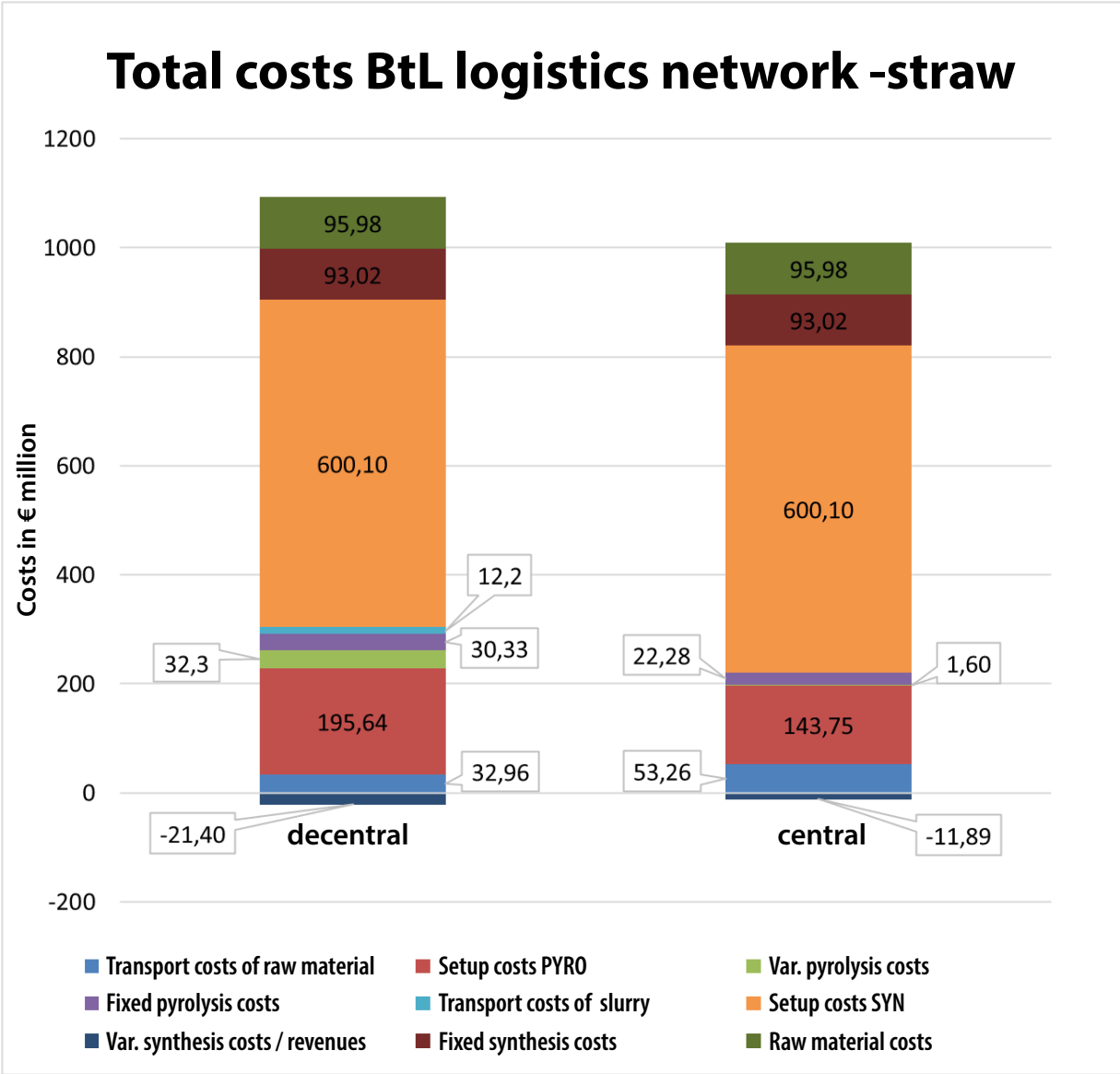


Figure 7: Total costs of BtL straw logistics network (own illustration)

ECONOMIC & ECOLOGICAL IMPACTS

TECHNOLOGICAL RESEARCH NEEDS & RECOMMENDATIONS FOR ACTION

OUTLOOK

1.4.5 ECONOMIC AND ECOLOGICAL IMPACTS

The effects of the increased use of secondary biomass are considered positive from an economic point of view and with regard to regional development; however, the competitiveness of bio-based products without CO₂ pricing was questioned and the importance of maintaining and increasing biodiversity and soil health was emphasized.

The assessment of the ecological effects by the interviewed experts emphasised the risks of removing too much nutrients from agriculture (pruning and straw as a raw material instead of being brought into the soil) and the accumulation of pollutants (e.g. when using sewage sludge).

1.4.6 TECHNOLOGICAL RESEARCH NEEDS AND RECOMMENDATIONS FOR ACTION

The demand for technological research lies especially with:

- energy and cost-efficient **separation technologies**,
- optimization of **conversion technologies** (including fermentation, catalysts), and
- **analytical processes** for bio-based raw materials and products.

Recommendations for action by the experts include:

- Good mix of thematic and open-ended funding programs that have practical relevance through **stakeholder involvement**
- **Linking** national tenders to **EU research policy**
- **Coordination between different grants and sponsors**
- Formats to intensify **exchanges between stakeholders**
- Strengthen **applied research** in university operations
- Protection from failure in the “**Valley of Death**”
- Incentives to **share research infrastructure**
- Promotion of **interdisciplinary research**
- **Increase in funding**

1.4.7 OUTLOOK

For the implementation of biorefinery concepts for the use of the collected material flows, detailed studies are necessary on the real availability and the prices of the biomass, taking into account competition with the energetic use and use as feed, the respective framework conditions of the selected biorefinery concept, and the detailed marketing strategy to enable market entry.

Although the direct combustion of biomass does not comply with the circular economy concept (thermal recycling only at the end of the longest possible cascade cycle), an integration of the material and energy use is important for a sustainable biorefinery, in which all fractions are recycled. For an economic implementation, strategic and political decisions must be made that bring about the withdrawal of the preference for the thermal use of biomass. Necessary also, is the pricing of CO₂, putting an end to the impression that fossil-based products are better.

As soon as a higher proportion of the biomass is used, the return of the nutrients to the fields must also be ensured. In terms of the circular economy, the safe use of wastewater or sewage sludge is essential, since it also contains all essential plant nutrients in addition to phosphorus.

Which usage paths can actually be implemented for the different material flows depends not only on the available raw material quantities but also on the achievable added value from the various fractions. In addition to the possibility of converting biomass to substances already used in fossil refineries (such as ethylene or methane), it is also possible to establish new bio-based refineries with the use of alternative raw materials (maintaining a higher level of the organisms' synthetic performance).

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Figure 5: Relevant potential of lignocellulose at the federal state level with biomass plants, wood processing companies and sawmills (selection) (own illustration)

Figure 6: Decentralized logistics concept for straw with regional pyrolysis plants (own illustration)

Figure 7: Total BtL logistics network straw (own illustration)

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Please find the full list of literature in the full version of the report:

<https://nachhaltigwirtschaften.at/de/publikationen/austrian-biocycles-biobasierte-industrie-kreislaufwirtschaft.php>

3.2 INTERNET

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United Nations: <https://sustainabledevelopment.un.org/sdgs>, 30.08.2019

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