HEMI-COAT

Conversion of hemicellulose to coatings

36th CORNET call

D1.1
Estimation of feedstock potential (woody biomass and wood hydrolysate) from industry in Belgium and Germany

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Disclaimer

This deliverable has been prepared in the context of the funded project HemiCoat in in the framework of the Collective Research Networking (Cornet) supported by the Federal Ministry for Economic Affairs and Climate Action (BMWE, funding code 01IF00399C) through the AiF (German Federation of Industrial Research Associations e.V.) based on a decision taken by the German Bundestag and by the Walloon region as funding with the n° 2310168 (Convention number).

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Abbreviations

Abbreviation	Description
BE	Belgium
CEPI	Confederation of European Paper Industries
DE	Germany
DM	Dry Matter
EU	European Union
FAO	Food and Agriculture Organization of United Nations
n.a.	Not available
NUTS	Nomenclature des Unités territoriales statistiques (Nomenclature of territorial units for statistics)
PSE	Pressure Steam Explosion
VDP	German Pulp and Paper Association/ DIE PAPIERINDUSTRIE e. V.
t/a	tons per year

1. Executive summary

D 1.1 Estimation of feedstock potential (woody biomass and wood hydrolysate) from industry in Belgium and Germany of the HemiCoat project assesses the biomass potential of hemicellulose hydrolysates arising from industrial processes in Belgium and Germany. The analysis focuses on wood and non-wood pulp production sites and lignocellulosic biorefineries, where hemicellulose-rich side streams are generated but are currently underutilised and largely incinerated, despite their limited energy value and significant potential for conversion into bio-based products.
The report briefly addresses the availability of woody biomass in Germany and Belgium. However, since the purification process developed within HemiCoat directly targets hemicellulose in a residual hydrolysate, the main focus of the analysis is on this specific stream. The study combines literature research, statistical data, industry consultation, and company-level process analysis to estimate the technical biomass potential of hemicellulose. Results were validated against international and national databases and mapped spatially to provide an overview of resource availability at regional and facility levels.

Hemicellulose is identified as an abundant yet underexploited fraction of industrial processes focusing on cellulose extraction, with recovery potential strongly influenced by biomass type and process technology. While traditional pulp production continues to dominate, emerging non-wood and multi-product facilities, as well as early initiatives in lignin and biochemical extraction, demonstrate innovation pathways toward valorisation.

This deliverable provides a basis for the following *D 1.2 Up-scaling of woody biomass and wood hydrolysate potential from industry to EU lev*el, the market analysis, business case development, and process integration studies. It highlights the opportunity to redirect hydrolysate streams toward value-added bio-based materials, contributing to resource efficiency, industrial decarbonisation, and the development of new applications.

2. Introduction

The growing demand for sustainable and renewable materials highlights the increasing importance of biomass valorisation, due to its abundance and main use for energy production(1). Lignocellulosic resources and their derivative fractions, such as hemicellulose, are generated as a by-product or residue, e.g. in pulp production and lignocellulose-based biorefinery processes, which is the second largest forest-based sector in the European Union (EU) (2). Hemicellulose represents an underutilised resource with significant potential for conversion into value-added bio-based products such as coatings and surfactants.

The aim of Task 1.1 is to conduct a detailed biomass potential analysis of hemicellulose, which will serve as a foundational input for the subsequent market analysis and business case development. This task involves comprehensive mapping of relevant industrial sectors and facilities (wood and non-wood pulp mills and lignocellulosic biorefineries) where hemicellulose-rich hydrolysis side streams are generated in the following called multi-product plants. The analysis integrates both a theoretical assessment based on literature data and a technical biomass potential estimation that accounts for the biomass type as well as current and emerging process technologies.

The biomass potential definition and categorisation follows the description of Brosowski et al., who defined 77 by-products, residues and wastes in detail (3). The theoretical biomass potential quantifies the maximum productivity of biomass under optimal management, whereas the technical biomass potential includes biomass-specific restrictions which could limit its use as a raw material or source of energy (4).

The assessment emphasizes the identification of key feedstock sources and the quantification of recoverable hemicellulose volumes within targeted regions, providing data to inform strategic value chain development, investment decision-making, and scalability evaluation. By linking biomass availability with process-specific recoverable fractions, this work supports the advancement of circular bioeconomy approaches in Belgium and Germany's pulp and biorefinery industries.

A national overview of woody biomass potential is provided for both Germany and Belgium, including current utilization streams, where data is available. While other approaches started extracting hemicellulose from sawdust, such as by the company Boreal Bioproducts, the processes developed in the HemiCoat project are not based on wood itself, but rather on hemicellulose obtained from certain types of hydrolysates. In Germany, sawdust is already widely used, whereas these hydrolysates are commonly incinerated, e.g as black liquor or spent liquor, although their sugar content has a very low energy value, as the energy comes from the lignin (5). Therefore, HemiCoat focuses on valorising and mapping the hemicellulose biomass potential of industrial hydrolysates.

Complementary data from national, international and statistical bodies have been reviewed to validate findings from desk research and stakeholder interviews. Variability across feedstocks such as hardwood, softwood, and annual crops such as silphium or their residues like straw, but also processes including kraft, magnesium-bisulfite, and pressure steam explosion (PSE) are explicitly considered to refine estimations of hemicellulose hydrolysate potential and to map industrial production sites spatially.

The outcomes of this task establish a robust platform for developing innovative hemicellulose valorisation pathways under subsequent project work packages.

3. Data and Methods

Multiple methods were used to determine the feedstock potential of woody biomass, and in particular, where and how much hemicellulose hydrolysate is generated in industrial production processes, as the latter is our main focus. To identify sectors and products that have hemicellulose hydrolysate as by-product, initial discussions among project partners and interviews with companies from the user committee, and with the German Pulp and Paper Association ("Die Papierindustrie" or VDP) provided a preliminary overview.

In a second step, desk-based internet research was conducted to identify companies producing hemicellulose as by-product, residue, or waste. Where essential information on hemicellulose side streams, feedstock inputs, output products, or production volumes were publicly unavailable but necessary for the later potential estimation, companies were contacted directly.

To validate the findings from the desk research and ensure that all main stakeholders of the industries have been included, statistical data and reports from The Confederation of European Paper Industries (Cepi), the Food and Agriculture Organization of the United Nations (FAO), and VDP were used to compare results. Results from this validation step provide information about the potential to automise calculation based on EU and country statistics for future updates and the later hemicellulose hydrolysate biomass potential analysis for EU27. However, as these data are only available at the national level and lack company-specific details, they could serve as general indicators only.

At present, hemicellulose is not systematically tracked by companies or governmental bodies. As a result, there are no official figures available. Moreover, the volume of hemicellulose hydrolysate is highly dependent on the input materials used and the specific processes applied. Therefore, literature values on the hemicellulose content of input materials, outputs, and side streams were collected, analysed, and synthesised. As mentioned, the volume varies due to different input materials and processes, as well as the hydrolysate composition, which may be important to the purification process. Including the input–process–output relationship, the technical biomass potential is differentiated into a process-related technical potential of hemicellulose.

In a final step, the process-related technical biomass potential of hemicellulose at company level was combined with the company location and mapped spatially at the local level using the open source software QGIS.

3.1. Interviews

To assess the availability and application potential of hemicellulose in Germany and Belgium, semi-structured interviews were conducted with a diverse set of stakeholders (see Annex: Interview Guide). The interview guide was adapted depending on the expertise and background of the interviewees to allow for targeted and context-specific information gathering.

Stakeholders were selected to provide insights from both a political-strategic and an operational-industrial perspective. The interviewees were grouped into two categories:

Association Level

- **German Pulp and Paper Association**
  Represents the interests of the pulp and paper industry in Germany. The association offers a broad overview of raw material use, industrial processes, and regulatory developments in the sector.
- **German Bioethanol Industry Association (Bundesverband der deutschen Bioethanolwirtschaft e.V.)**
  Represents producers of bioethanol in Germany. The association brings in expertise on the valorisation of biomass, renewable feedstocks, and market dynamics from both an economic and policy standpoint.

Company Level

- **Mercer Rosenthal**
  A traditional wood pulp producer that recently expanded its portfolio to include lignin extraction from black liquor.
- **Fibers365**
  A company specialising in the production of pulp and hydrolysates from annual agricultural residues such as straw, offering alternative fibre sources.
- **OutNature**
  A manufacturer of pulp from regionally grown annual plants such as silphium (silphium perfoliatum). The company supplies large retailers, including the Schwarz Group (Lidl, Kaufland).
- **Creapaper**
  Known for its grass-based paper production. The company is exploring the use of digestate from biogas plants, particularly the wet fraction, as a potential input for their paper production, where hydrolysate would be a by-product. The company supplies, e.g. OTTO, McDonald's, and Mondi with grass pellets for their packaging
- **JRS**
  A major German plant-based fibre manufacturer operating a straw pulp production facility, contributing insights into large-scale processing and biomass logistics.

3.2. Hemicellulose hydrolysate biomass potential estimation

As hemicellulose is not yet considered as a standalone product, companies typically only provide data on pulp production volumes, feedstock inputs, and general production processes. To estimate the technical process-related hemicellulose potential, a matrix was developed to represent the relationship between biomass, process, and final product. This matrix enables the derivation of hemicellulose content in hydrolysates produced during industrial processing. An overview of the matrix structure and the share of hemicellulose included in the different materials is provided in Section *4.3,* Table 3. The matrix was filled with literature data. If multiple values were available for a specific feedstock or process, average values were applied to calculate the hemicellulose potential. Only input material and processes used in the identified companies in Belgium and Germany are considered. The matrix is designed to be extendable if more processes and input materials need to be added from the EU27 screening for deliverable D1.2 or in the future.

The estimation starts with the hemicellulose share in the input material and traces it through to the resulting hydrolysate (waste product). The hydrolysate may appear under different names depending on the process used, such as black liquor or spent sulphite liquor. Not all plants publish (all) the needed data or provided them upon request. Hence, some data had to be estimated based on similar production conditions.

For so-called multi-product plants, reliable calculations are currently challenging. These facilities are still in early commercial stages or pilot testing phases, and process details are often confidential. Each plant operates with specific configurations, and the three user committee companies involved in the project requested that no internal data is published. As a result, these companies were excluded from the technical hemicellulose potential analysis. Only publicly available literature and data were considered in the analysis, e.g., the location.

The hemicellulose hydrolysate that arises as a waste, by-product, or residue from industrial production represents the technical biomass potential. Due to the high variability in composition, volume, and the presence of disruptive substances, depending on the type of input biomass and the specific processes applied, this potential must be assessed as a technical process-related biomass potential.

The **technical process-related biomass potential** of hemicellulose is calculated as following:

$$\frac{(Hemicellulose\ in\ input\ material \cdot Process\ related\ hemicellulose\ share)}{100}$$

During the extended desk research phase, additional information, e.g., company addresses and ownership, were collected. These data can be integrated into a Geographic Information System (GIS) and combined with the process-related biomass potential to enable spatial mapping.

While multi-product plants were excluded from the biomass potential estimation due to data limitations, their locations were still included in the spatial mapping to reflect the full industrial landscape.

4. Results

4.1. Woody biomass

Germany

According to the most recent report of the Agency for Renewable Resources (FNR), the total forest area in Germany amounts to 11.5 million hectares, with nearly 50% privately owned. In addition to forest resources, short-rotation plantations cover approximately 6,600 hectares in 2025. However, their utilization is still limited to energy purposes (6).

Data from the Thünen Institute indicates that total log harvest in Germany in 2023 ranged between 71 and 73 million m^3 in total. The institute emphasizes that official logging statistics still underestimate actual harvesting volumes, although in recent years reported values have approached more realistic levels. With regard to the material use of primary wood, the Thünen data show that the sawmilling industry represents the major consumer, with 37 million m^3 in 2023. By contrast, only 5 million m^3 were processed in the pulp industry, while pellet and briquette production accounted for approximately 1 million m^3. Energetic wood use reached 23 million m^3 in 2023, most of which originated from private households (7). The paper industry reports that future forest disturbances are likely to increase as a consequence of climate change, leading to a reduction in wood quality. As a result, a portion of the available raw material may no longer be suitable for use in pulp production, thereby driving up the prices of higher-quality wood.

In addition, growing competition from the pellet industry is exerting further upward pressure on wood prices (8).

The roundwood statistics provided by Eurostat ("for_remov" dataset) confirm these findings, reporting 10.7 million m^3 in the category "pulpwood, round and split" for 2023 (9). Comparable data are also available from FAOSTAT (10) and the FAO Pulp and Paper Report (11). An overview of all the collected data from Germany and Belgium is given in Section *4.3*. Table 2: Pulp production comparison Eurostat and desk research.

Furthermore, the data published in the DBFZ DE Biomass Monitor at DBFZ indicates that in 2020, the theoretical potential of forest residues (including logging residues, sawdust, and other industrial by-products) amounted to approximately 60 million tons (t) dry matter (DM). From this total, only about one third was considered technically available. Of this, 5.4 million t DM were already used for energetic purposes, leaving an additional 6.6 million t DM still potentially mobilizable in 2020 (12). Nevertheless, the German Pulp and Paper Association (VDP) highlights that very little residue from sawn mills or other residual wood is currently used in the pulp industry. Nevertheless, the VDP report highlights that minimal residue from sawn mills or other residual wood is currently used in the pulp industry. Therefore, it may only become more interesting as roundwood availability declines (8).

The conducted interviews with stakeholders further highlight growing interest in the use of annual crops, such as straw and silphium, for pulp production. Germany's agricultural land area totals 16.6 million hectares, of which a substantial share is dedicated to cereal cultivation, thus generating correspondingly high straw availability. Silphium currently covers about 10,000 hectares. Although the FNR reports that the entire cultivation is dedicated to biogas production (6), the interview results with OutNature suggest that this area is likely underestimated given that material use is also evident.

Natural fibre use for material applications in Germany has declined slightly in recent years, from 132,000 t in 2018 to 106,000 t in 2023 (6). According to the DE Biomass Monitor, the theoretical biomass potential of wheat straw varies considerably over time. In 2020, the potential was estimated at 26 million t DM, of which 7 million t DM are technically available. Of this technically available potential, approximately 4.5 million t DM were already utilised for material purposes, leaving 2.4 million t DM still mobilizable in 2020 (12).

Belgium

For Belgium, national forest data are not reported at a unified level, as the regions of Flanders, Brussels, and Wallonia maintain separate institutional reporting systems. According to (13), the total forest area in Belgium amounted to 689,000 hectares in 2020. However, Belgium did not submit data on logging or pulpwood removals to Eurostat. Corresponding estimates are available from FAO statistics and are discussed in Section *4.3*. Table 2.

According to STATBEL, the total area under cereal cultivation in Belgium was approximately 325,377 hectares in 2022 (14). Furthermore, the DBFZ EU Biomass Atlas provides an estimate of the biomass potential of straw for Belgium of 1.8 million t DM (15). A comparable residue database to that of the DBFZ DE Biomass Monitor, differentiating the various biomass potentials and current uses, is not available for Belgium.

4.2. Interviews

As some information from the interviews, such as analysis results, is confidential and can easily be traced back to the individual companies, the information collected about processes and analytics is not included here. The main focus is set on current challenges and opportunities in the industry for hemicellulose production.

The interviews yielded valuable input on feedstock availability, technological developments, and industrial needs, helping to contextualise the role of hemicellulose within existing and emerging value chains.

Current Status of the Industry

The German pulp and paper sector, represented by the VDP, shows a well-established infrastructure for fibre sourcing and processing. According to VDP, the industry's core product remains traditional pulp for paper and packaging, with by-products such as biogas and methane being secondary outputs. Certification and compliance with EU standards are generally widespread, contributing to stable raw material supply chains. Industrial-scale processes like PSE have been more commonly used for biomass processing in recent years. However, the available volumes of hemicellulose-rich residues from primary production remain moderate, with limited quantities of side streams (8).

From company-level perspectives, firms such as Mercer Rosenthal and Fibers365 are actively developing alternative valorisation routes for hemicellulose and lignin fractions. Mercer Rosenthal, traditionally a wood pulp producer, has recently expanded into lignin extraction from black liquor to diversify revenue from side streams. Fibers365 focuses on processing annual agricultural residues (e.g., straw) to produce pulp and hydrolysates, highlighting the industrial utilization of alternative feedstocks (16). Fibers365 is a good example of the conversion of a paper mill into a non-wood pulp plant. Currently, trials are being conducted with straw, grass, and other annual plants. However, the aim is to use the fermentation residues from biogas plants for fibre production and to produce other materials such as lignin and hemicellulose (16). These companies confirm the integration of hemicellulose valorisation into existing fibre value chains but note that processes remain at an industrial pilot or early commercial scale, which in the future will support the pulp business.

Challenges

Both associations and companies point to several challenges constraining hemicellulose utilization. The VDP stresses that the availability and quality of raw material will decline in the next two decades due to the effects of climate change. Additionally, because of its high density, wood is not transported far from the logging site to the production facility. As high-quality biomass residues such as straw or paludiculture crops have low density and require cost-intensive transport, their logistics feasibility is likewise limited. The limited scale of hemicellulose-rich residues compared to cellulose mass puts economic limits on standalone hemicellulose processing facilities. Further market development is needed for more investment into the exploitation of residual hydrolysates (8, 17).

Companies report technological and market challenges. For example, although Mercer Rosenthal has expanded its portfolio, lignin and hemicellulose recovery remain technically complex and economically sensitive due to varying feedstock qualities and fluctuating market demand. Identifying profitable downstream applications is crucial, but still an evolving field (8, 18, 16, 19). Moreover, companies like Creapaper and OutNature focus on alternative fibre sources such as grass or silphium, but emphasize the need for stable biomass supply contracts and technological optimization, which currently represent hurdles (20, 21). Although there is a high interest and willingness to explore new valorisation pathways, economic efficiency is the most important factor (20).

Opportunities

Across stakeholder groups, the valorisation of hemicellulose is linked with sustainable circular economy principles. Opportunities include:

- High energy surplus provides the potential to exploit the sulphite spent and black liquor fraction, but exploit parts of it for material use.
- In bioethanol production, C5 sugars usually remain in the fermentation left over and could be extracted.
- Developing regional biomass value chains integrating agricultural residues, paludiculture and forestry residues to reduce transport costs and improve feedstock diversity.
- Leveraging EU policy incentives and certification schemes to enhance the development of hemicellulose feedstocks in industrial applications.
- Expansion of the product portfolio, thereby increasing independence and revenue.

Future Outlook

Associations envision gradual growth in secondary biomass valorisation, driven by policy frameworks supporting renewable materials and the circular bioeconomy, such as the Circular Economy Action Plan, Renewable Energy Directive or the EU Waste Framework Directive. The German Pulp and Paper Association is highly supportive of alternative ways to reduce process residues and generate more product valorisation.

On the industrial side, companies express cautious optimism. Cellulose producers foresee increasing integration of hemicellulose-derived products, especially if technical maturity and logistics improve. Innovations that enable the conversion of hemicellulose sugars, supporting bio-based chemicals and materials as promising markets. Firms like fibers365 and Creapaper anticipate niche products in specialty papers or bio-composites could open new revenue streams once production scaling occurs. OutNature highlights the growing importance of annual fibres in the production cycle, since the input of fresh pulp will decline, but recycled paper requires a certain amount of fresh fibres (20).

4.3. Hemicellulose hydrolysate biomass potential estimation

Biomass amount

During the interviews and discussions with the HemiCoat partners in the first step, pulp, furfural, and lignin have been identified as products with hemicellulose hydrolysate as a potential residue during the production process. Extensive desk research identified 11 companies operating commercially in Belgium and Germany that have hemicellulose hydrolysate as a by-product, waste, or residue of their production processes.

Table 1 presents the collected data of companies and the necessary data for estimating the process-related technical biomass potential of hemicellulose hydrolysate. Whenever data was unavailable but estimates were possible, this data was added with a mark. The estimation factor is derived from literature or reference companies using the same materials and processes. Estimation was not possible for multi-product companies since too many variables were missing.

Six out of the eleven companies are classical wood-pulp mills which have already been operating for at least several decades. Essity is listed with its two production lines twice since both are operating at a commercial level, but with different processes, which is important for the later estimation. Four companies use annual plants and/or their residues, five companies use hardwood, and two use softwood as input material. The majority is still producing pulp as their main product. Only UPM and Minagro are focusing on biochemicals. The processes used vary, with kraft, sulphate, and magnesium-bisulfite being the main types in the countries of interest. For annual plants, the preferred process is PSE. This treatment does not require any additional chemicals, which is a great advantage compared to the previously mentioned methodologies. Two of the multi-product plants use different acids. Burgo Ardennes is the only pulp producer in Belgium, with an annual production capacity of 400,000 t. A comparable amount is produced by Mercer Rosenthal in Germany. This company is also of interest as it has started extracting lignin from its black liquor residue in a pilot facility. If this concept is successful, it could also be applied to Germany's largest pulp producer, Mercer Stendal, which produces 740,000 t per year.

These lignin test facilities and new multi-product companies demonstrate the need for pulp producers to find new sources of income and show a general shift in products and market needs. The second production line at Essity, which has been operating since 2021 and handles only straw, also shows that wood pulp factories are no longer being built but are diversifying to additional products. The pressure on the pulp-producing companies is also reflected in the Cepi statistics report, showing a steady decline in the number of European pulp mills (2010: 172; 2024: 129) and amount of total pulp production (2010: 39 million t; 2024: 34 million t) in Europe from 2010 onwards (22). Also, InDUfed, a Belgian platform uniting the pulp and paper association, federation of paper producers, and the glass industry, states in its 2020 report that in Belgium the pulp production declined by 12 percent from 2019 to 2018 due to high raw material prices (23).

Table 1: Companies with residual hemicellulose hydrolysate in Belgium and Germany

Company	Country	Main product(s)	Process	Feedstock	Feedstock input [t/a]	Production output [t/a]	Type
Burgo Ardennes	BE	Pulp	Kraft	Hardwood	1,500,000	400,000	wood-pulp plant
Essity Mannheim	DE	Pulp	Magnesium-bisulfite	Hardwood	349,206 (estimated)	220,000	wood-pulp plant
Essity Mannheim	DE	Pulp	Magnesium-bisulfite	Wheat straw	77,777 (estimated)	35,000	wood-pulp plant
fibers365	DE	Pulp, lignin	PSE	Wheat straw, gras	n.a.	n.a.	non-wood pulp plant
LXP group	DE	Pulp, lignin, ethanol, gas	Acids (phosphor)	Wheat straw	n.a.	n.a.	multi-product plant
Minagro	BE	Agrochemicals	n.a.	Plant based	n.a.	n.a.	multi-product plant
Mercer Rosenthal	DE	Pulp	Kraft	Softwood	900,000	360,000	wood-pulp plant
Mercer Stendal	DE	Pulp	Kraft	Softwood	1,541,666 (estimated)	740,000	wood-pulp plant
OutNature GmbH	DE	Pulp	PSE	Silphium perfoliatum	15,300	n.a.	non-wood pulp plant
Sappi Ahlfeld	DE	Pulp	Magnesium-bisulfite	Hardwood	190,476 (estimated)	120,000	wood-pulp plant
Sappi Ehingen	DE	Pulp	Magnesium-bisulfite	Hardwood	238,095 (estimated)	150,000	wood-pulp plant
UPM Leuna	DE	Bio-based chemicals,	Acids (sulfur)	Hardwood	n.a.	n.a.	multi-product plant

For the comparison of resource-intensive, desk research-based data with statistically available figures, the datasets of national associations, InDUfed in Belgium and VDP in Germany, as well as those of European and global organizations, including Cepi, Eurostat, and FAO, were examined. National associations did not provide specific data on production volumes or the number of pulp-producing companies. Cepi publishes timely annual reports on the total number of mills and overall pulp production in Europe, but without differentiation by country. Eurostat, on the other hand, offers country-level data for total pulp production as well as for different pulp production types. However, this dataset is only released at the end of the following year, so the most recent available data currently refers to 2023. This reporting lag may contribute to discrepancies in the comparison with desk research findings, especially as Cepi data indicate a steady decline in the number of pulp mills (22). Nevertheless, Eurostat provides a time series dating back to 2015, which also shows a continuous decline in pulp production in this period.

Table 2 presents a comparison between the findings from desk research with corresponding figures from Eurostat and FAO. For Germany, the various datasets are relatively well aligned, enabling estimation of pulp production volumes for companies that did not disclose specific data. In contrast, significant discrepancies are observed for Belgium: Eurostat and Burgo Ardennes (company-reported website data) differ greatly. For Belgium, Eurostat only supplies data for 2018 and 2019, and only for wood-based pulp production without additional classification, rendering the desk research the more reliable source in this case.

Alongside Eurostat, the FAO also provides statistics on pulp production and conducted a comprehensive survey between 2023 and 2025, explicitly covering pulp and paper production from a variety of raw materials (including wood, straw, bamboo, among others) and processes (11). For Germany, there is little difference between chemical pulp production figures from the desk research and Eurostat; however, not all subcategories are reflected in the FAO survey, and categories suggest that all pulp production in Germany is from wood, omitting straw pulp entirely.

If adequate Eurostat data are available and national reporting is comprehensive, Eurostat offers high potential for automated data collection and robust estimation of biomass potential at the NUTS-0 level. Should national data be unavailable, or for non-EU countries, the FAO survey provides a summarised overview of pulp production with limited detail. Consistent national reporting to Eurostat in the future would enable valuable time-series analyses for evaluating hemicellulose potential in diverse pulp production processes.

Table 2: Pulp production comparison Eurostat and desk research

	Data source (year)	**Chem pulp**	**Kraft pulp**	**Sulfite pulp**	**Other pulp**
		in 1000 t	in 1000 t	in 1000 t	in 1000 t
Germany	Desk research (2025)	1,590	1,100	490	35
	EU stats (2023)	1,511	1,108	404	48
	FAO survey (2025)	1,623	-	-	-
Belgium	Desk research (2025)	400	400	0	0
	EU stats (2023)	168	nd	nd	nd
	FAO survey (2025)	450	-	-	-

Hemicellulose share

The results of the interviews and initial desk research indicate that hemicellulose hydrolysate is primarily generated as a residue, waste, or by-product during both wood-based and non-wood pulp production. Non-wood pulp production utilizes annual, lignocellulose-rich crops, including grain straw, grasses, and silphium. While the literature provides well-established data regarding hemicellulose content in the solid input materials, information on the proportion of hemicellulose in the resulting hydrolysate is scarce. This lack of data suggests that the recovery or utilization of hemicellulose from hydrolysate has not been a focus to date, as it has typically been combusted with lignin and other components.

Both literature and interview findings suggest that particularly high concentrations of hemicellulose hydrolysate can be achieved when straw is used as the feedstock. Nonetheless, OutNature emphasised current challenges associated with the presence of silicates in straw-derived hydrolysate solutions. As hydrolysate from straw has not yet been tested at DBFZ, it remains uncertain whether silicates would present obstacles in purification processes. At present, the volume of commercially produced straw pulp remains limited. Consequently, despite generally lower hemicellulose concentrations in black liquor and sulphite spent liquor, these streams represent the primary sources of hemicellulose hydrolysate due to the relatively high annual pulp production from wood.

Table 3: Average share of hemicellulose in lignocellulosic solid input materials (for reference) and in residual hydrolysates after processing these materials

Share of hemicellulose in %	Process	Hardwood	Softwood	Straw
Solid input material		24 (24, 5, 25–29)	23 (24, 30, 27, 28, 26, 29)	36 (24, 31, 32, 26, 33)
Residual hydrolysate	Kraft	40 (5)	37 (5, 34)	
	Magnesium-bisulfite	20 (24)	28 (34)	93 (34)
	PSE			75 (31, 35, 33)

Shares of hemicellulose represent the average. References are listed in brackets.

Hemicellulose hydrolysate is also found in modern lignocellulosic biorefineries, referred to here as “multi-product plants” because they do not focus on a single product but rather generate a range of products from low to high value. Notably, these facilities already treat different sugar streams (C5 and C6) as valuable products. As a result, their processes are often designed to valorise all fractions of wood and annual plants. However, while there has been significant progress in lignin and biochemical production, further research is still required to fully develop the hemicellulose-related part of the value chain. Literature data is negligible and so far, not sufficient to provide a scientific basis for the technical biomass potential estimation.

Locations

Figure 1 shows the type of company and the process used. Notably, the two Essity production lines shown in Table 1 are divisions of the same company but two production sites lines at the same site. For Germany, company clusters are evident in the south and east, while Belgium has only two companies. Due to the country's size and the Belgian infrastructure, these companies are also in proximity to one another. Overall, most of the companies use Magnesium-bisulfit or the kraft process.

When the formula for technical process-related biomass potential is applied to the researched data on a NUTS-3 spatial scale, hemicellulose hot spots occur in relation to the amount of hemicellulose presented Figure 2. The darker the colour of the NUTS-3 region, the higher the amount of hemicellulose. As expected, the highest concentration of hemicellulose is found at Mercer Stendal, given the high volume of pulp produced there. Nevertheless, three regions in southern Germany are relatively close together. They also have similar processes and input materials, which could offer logistical advantages when planning a purification process plant or facility that uses the hemicellulose from these companies as an input for new applications.

However, it should be considered that this map does not yet include multi-product plants. This naturally increases the actual potential.

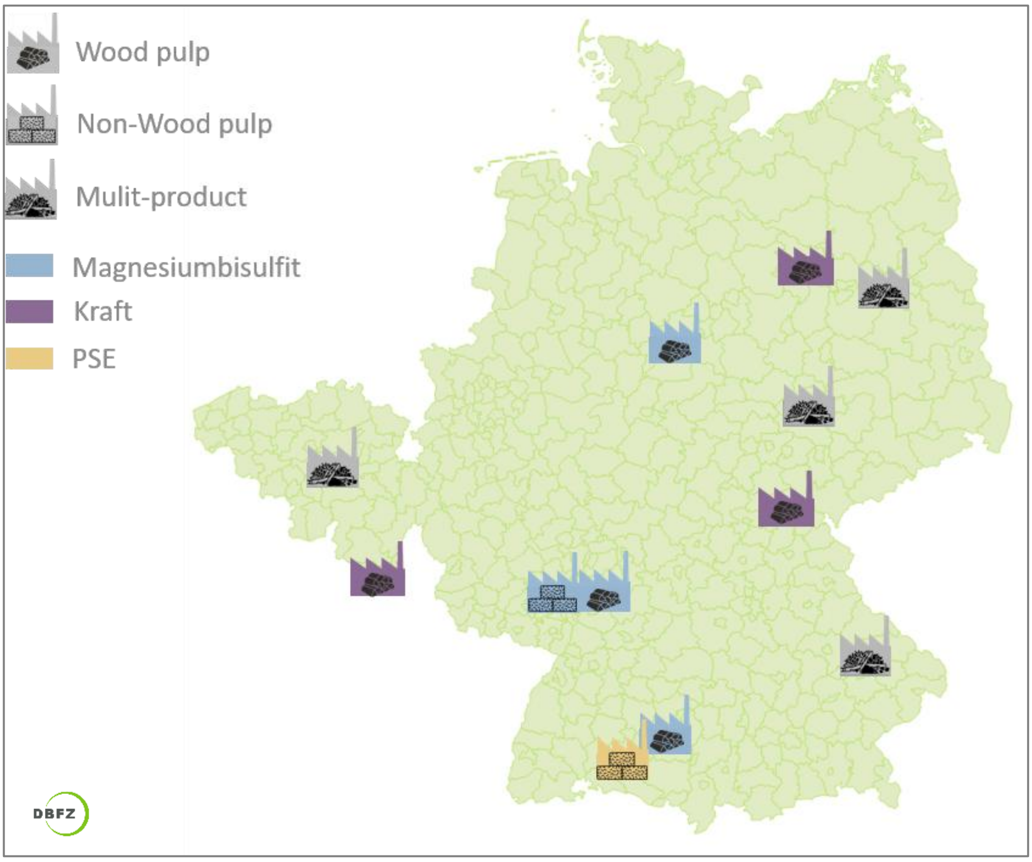

Figure 1: Type of company and process map

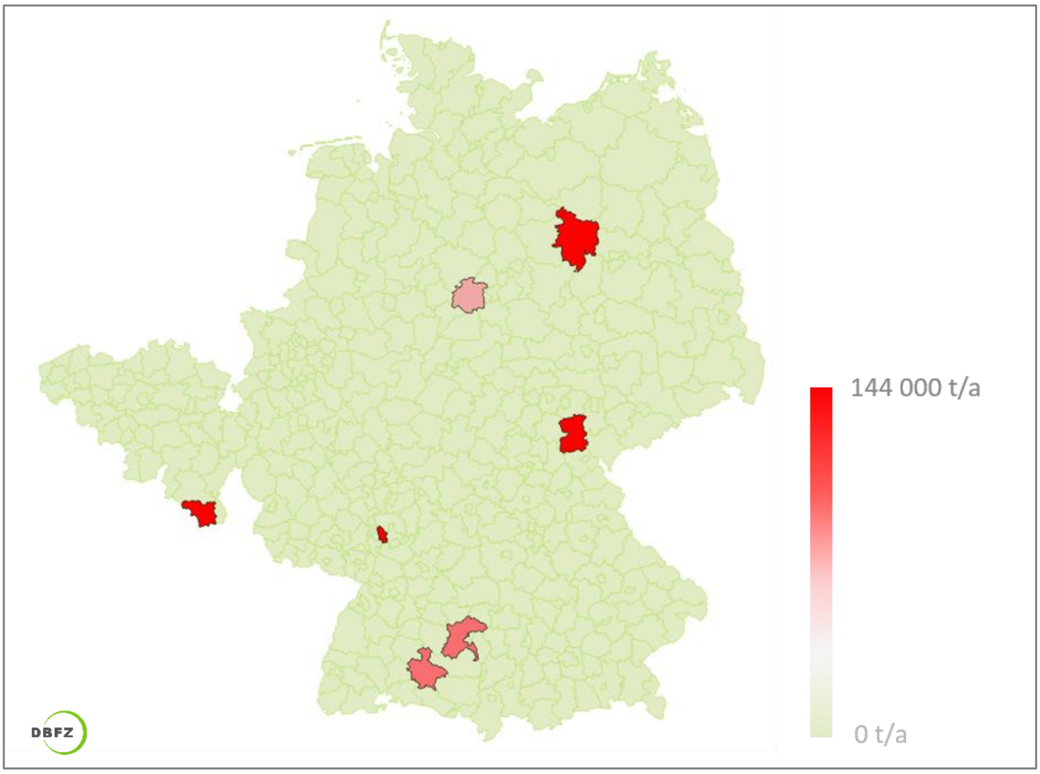

Figure 2: Technical process-related biomass potential map of hemicellulose

5. Conclusion

Hemicellulose hydrolysate exhibits considerable variability depending on the feedstock and the production processes employed. This should be considered when developing extraction and purification processes. Nevertheless, substantial quantities of residual hydrolysate and hence hemicellulose can reach up to 144,000 t/a at an individual industrial pulp production site in the research area. The companies interviewed expressed strong interest in adopting extraction and application technologies, should they become available. Currently, the utilization of black liquor and spent liquor for purposes other than energy generation remains limited in both Germany and Belgium. The valorisation of by-products, residues, and wastes represents a promising strategy for both the wood and non-wood pulp sectors, enabling them to diversify product offerings and maintain lignin and sugar streams as valuable, long-term components within the production system. This trend will gain momentum if wood becomes a more expensive resource due to availability limitations and potentially longer transport distances.

The ongoing transition from fossil-based to renewable raw materials and intermediates has been accompanied by a rise in the number of multi-product companies in recent years. Notably, UPM, one of Europe's largest producers, is poised to commence commercial-scale production soon. While UPM and other firms are continuing to optimize their processes and broaden their product range, significant development is still required. Additionally, further regulatory guidance and policy incentives are needed to foster market uptake, as biogenic products often remain economically uncompetitive compared to fossil-based alternatives.

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Annex

Interview Guide

Interview Questionnaire HemiCoat Biomass Potential

If necessary, send questionnaire in advance

Introduction:

- Project HemiCoat: Overview, objectives
- Purpose of the survey

Data usage

- Explanation that the interview will be recorded
- Explanation of how data will be used
- Request to clearly communicate sensitive data

Main section

1. Since when has your company existed?
2. Which products are produced?
3. How much is produced?
4. Which biogenic raw materials are used and where are they sourced from?
5. What processing steps are there?
    a. What pre-treatments are there?
    b. What are the main processes?
6. What residues and waste materials are generated and where in the production process?
7. Which process is used to produce the cellulose (sulfite or kraft process or other)?
8. How much residue is generated and what is the ratio to the input raw material?
    a. Is there knowledge of the chemical composition?
9. Are there rough estimates of how much hemicellulose is present in the residue stream?
10. Are the residue streams already being used?
    a. If yes, how? At what price are they possibly sold?
    b. If not, how are they disposed of? Are there any costs? What waste category?

11. Are there already ideas to further develop the residue streams into concrete products?
12. Which other companies in this field are you aware of?

End

- Thank you!
- Would you like to receive further information about the project and results?