Task 2.3 Regional Biomass and Nutrient Availabilities in Upper Austria

February 2024

Kristina Pammer, Gabriele Wolkerstorfer, Luise Dauwa, Melanie Eggel

Table of contents

1 Regional biomass and nutrient availabilities in Upper Austria

1.1 Introduction

1.1.1 Background

Upper Austria is a state in mid-North of Austria and an economic hotspot with different types of industries. The most important sectors are automotive, environmental engineering, chemistry, material processing such as metals, plastics, paper, and wood. Additionally, (bio-) energy and the food industry also contribute to the Upper Austrian economy. [1]

Austrian food production generates between 13.5 billion euros and 20 billion euros annually, consists of 3,500 companies (250 of which are counted as large-scale food production - companies with 50 or more employees and/or over 250 million euros in sales) and employs 70,000 people. The 250 large companies turn over between 90 and 95% of the goods. The food and beverage industry can be divided into the following sectors (in alphabetical order):

- Baked goods
- Beer
- Delicatessen/Spices
- Fats/Oils
- Meat
- Vegetable and fruit processing
- Beverages
- Milk/Dairy
- Frozen foods
- Sugar/Sweets

1.1.2 Scope

Food waste arises along the entire value chain - agriculture, production, trade, gastronomy, and households. Many projects already deal with the two ends of a food value chain - production in the field and waste in households.

In this project we would like to focus on by-products in food production.

A study "Waste Avoidance in Austrian Food Production" surveyed companies with a market share of 22% and then extrapolated the figures for Austria. From this it can be concluded that in Austria 1,338,000 t (+/-1%) of organic by-products are generated in food production.[2].

In total, 121,800 tonnes (+/- 6%) of avoidable food waste are generated in food production in Upper Austria every year. This value was collected in a survey of large-scale productions, which turn over between 90% and 95% of all goods. This value is calculated based on the member statistics of the Chamber of Commerce Food Industry Association[3].

The graph shows that almost half of all avoidable food waste is generated in the bakery sector (51,700 tonnes +/-12%). 35,000 tonnes of this are bread and bakery products that food retailers return to producers as part of free returns. In beer breweries within the production process, 5,700 t of avoidable biowaste is generated, according to this study[3].

---

[1] Land Oberösterreich - Betriebsansiedlung (land-oberoesterreich.gv.at)
[2] www.fabbiogas.eu,
[3] Abfallvermeidung in der österreichischen Lebensmittelproduktion, Österreichisches Ökologie-Institut. Wien, 2017

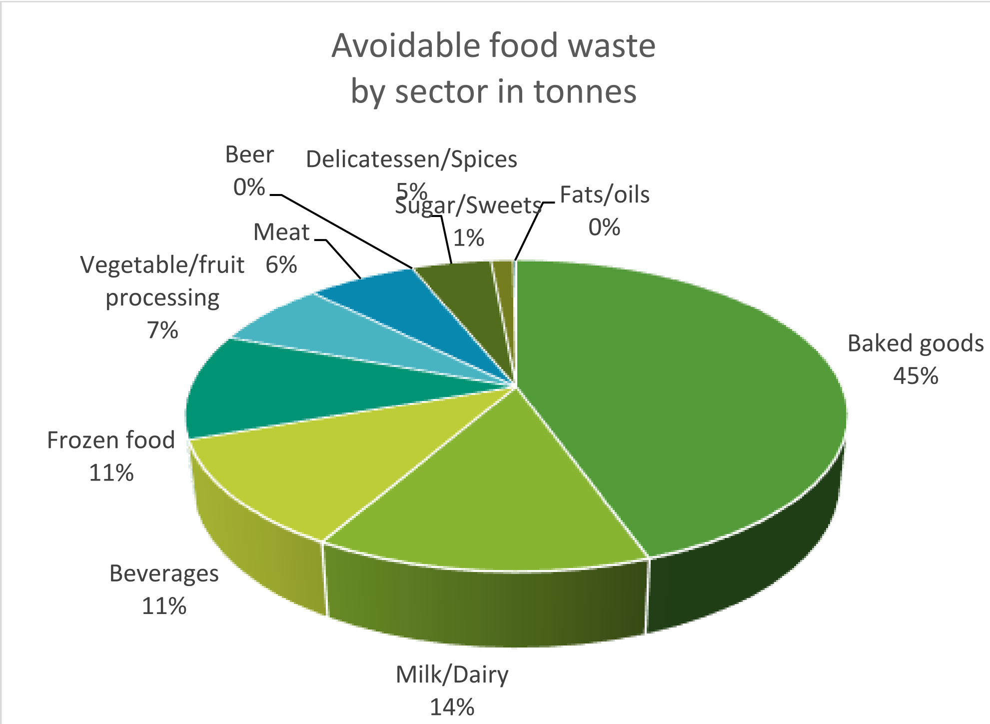

Figure 1: Avoidable food waste by sector in tonnes[3]

Bakeries and the baked goods industry is one of the largest food industries in the food sector in Upper Austria. The food produced here and, more specifically the food waste, is of great importance for Upper Austria and will therefore be examined more closely in the SCALE-UP project. The good cooperation with the bakery sector also makes it possible that the results of the project are given great attention and are included in future decisions in the sector as well as in the individual companies.

With 324 breweries in 2021, Austria has one of the highest brewery densities in the world and 67 breweries[4] in Upper Austria. 118 of these are so-called microbreweries with an annual beer output of up to 1,000 hectolitres. Most of the beer is sold through normal food retailers, with only around 17 per cent of total consumption being consumed in restaurants. In terms of annual beer consumption, Austria ranks second behind the Czech Republic but ahead of Germany and Poland[5].

The distinction between avoidable food waste and non-avoidable organic materials here is very important and can be defined as follows:

- non-avoidable organic by-products/residues/wastes that are generated during food production and are not suitable for human consumption (e.g. bones, blood, slaughterhouse waste, sour whey, pomace, ...). These must be disposed of, recycled, or further processed accordingly.
- Preventable food waste such as pre-packaged products, overstocked food, returned goods or edible raw products that are waste and must be disposed of. Returned goods are products that are transported back to the producer by the retailer when they are not sold and are offset.

The reasons and causes for food losses in production are manifold and range from the manufacturing process, cleaning, quality assurance measures to overstocking and overproduction as well as returns, transport damage or foreign bodies in the product.

The most frequently cited reason for the generation of avoidable food waste is the manufacturing process, at 44%. All other causes were mentioned in roughly equal proportions [6]. For this reason, we

[4] https://brautopo.webnode.at/oberoesterreich/
[5] https://de.statista.com/themen/4398/alkoholkonsum-der-oesterreicher/#topicOverview
[6] Abfallvermeidung in der österreichischen Lebensmittelproduktion, Österreichisches Ökologie-Institut. Wien, 2017

will also take a closer look at the manufacturing processes within the framework of the SCALE UP project.

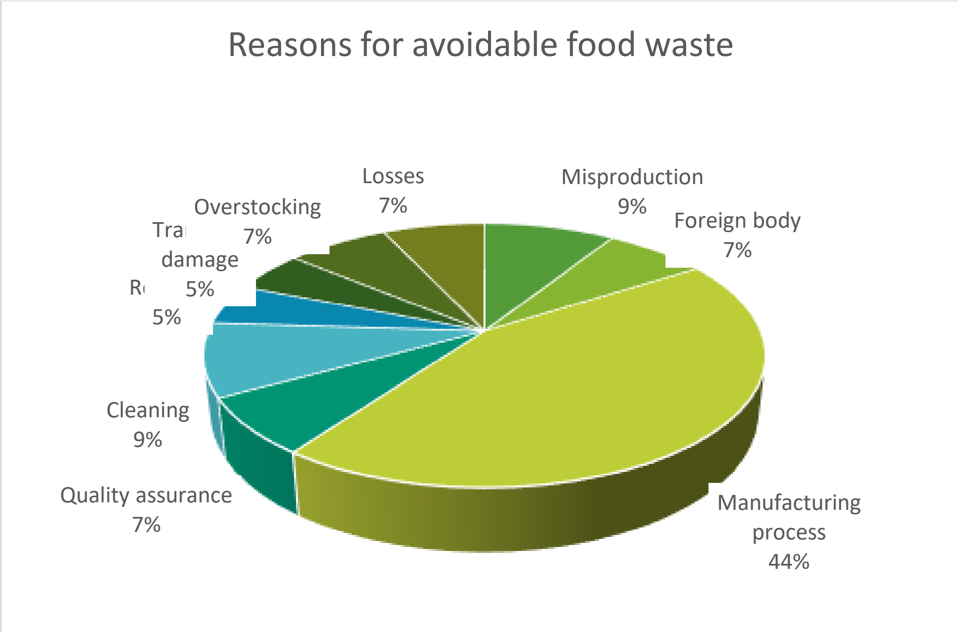

Figure 2: Reasons for avoidable food waste[3]

Are nutrients a constraint in the sustainable harvesting of biomass reducing its availability?

Nutrients from food manufacturing byproducts can be both beneficial and detrimental to sustainable biomass harvest, depending on several factors, including the type of byproducts, their quantity, and how they are managed. Here are some important considerations:

Beneficial aspects:

a. Fertilizing effect: Some byproducts, such as compost from food waste, can act as a natural fertilizer and increase soil fertility. This can promote the growth of biomass crops.
b. Circular economy: the use of by-products from food production in agriculture can be part of a sustainable circular system in which resources are used efficiently.
c. Waste reduction: The use of food by-products in biomass production can help reduce waste and provide environmental benefits.

Hindering aspects:

a. Competition for resources: if the use of food byproducts in biomass production competes with the use of these byproducts for animal feed or other purposes, this could affect availability.
b. Quality of byproducts: The quality and composition of food byproducts can vary, and some could contain contaminants or undesirable substances that impede biomass crop growth.
c. Transportation and storage: transportation and storage of byproducts may incur costs and energy consumption, which may affect environmental sustainability.
d. Overuse: overuse of food byproducts in biomass production could reduce the availability of these resources in the long term and have negative impacts on food production.

Overall, the impact of food byproducts on sustainable biomass harvest depends on careful planning and management. An integrated approach that considers circular economy and waste minimization can help maximize the benefits and minimize the drawbacks. It is important to consider the local context and specific circumstances to make the best possible decisions regarding the use of food byproducts in biomass production.

Is it possible to use part of the biomass as compost of fertiliser?

Currently, the by-products of food production in Upper Austria or residues of production end up to a very large extent in composting plants, in sewage treatment plants or in biogas plants and are subsequently applied to the fields as fertiliser. However, a lot of energy is lost in the process. The goal is not only to use the nutrients as fertiliser, but to put the residues to a higher-value use.

Are there any innovative applications of nutrients?

In Upper Austria there are various innovative applications for the recycling of nutrients from food waste. As already mentioned, a large part of the residues and thus nutrients from food production in Upper Austria are reused in biogas plants or composting plants or used as feed for farm animals in agriculture. Unfortunately, there are no concrete figures on how high this share is.

In the medium to small-scale sector, there are numerous initiatives, innovations, and ideas on how nutrients from food waste residues can be recycled to a higher value. Some innovative examples:

- The use of food waste to produce bio-fertilisers: Through special processes such as drying and fermentation, the nutrients can be extracted from the waste and processed into high-quality fertilisers.
- Using food waste to produce insect protein. Insects such as mealworms or the larvae of the soldier fly can be fed with the waste and produce high quality protein that can be used as feed for livestock, etc.
- There are also projects in which food waste is used to produce bioplastics. Through special processes, the organic components of the waste can be converted into biodegradable plastics.

1.2 Biomass Availability

Before going into greater details about the availability of the chosen streams for this report, it is interesting to look at all biomass streams that can be observed in Austria. The figure below shows a variety of different streams, including imported biomass in red but also agricultural streams in dark green, forestry-related streams in brown and particularly interesting for nutrient recycling, residual materials & by-products for recycling in light orange. The graphic is an interesting overview to keep in mind as this report particularly dives into agricultural use and the related streams.

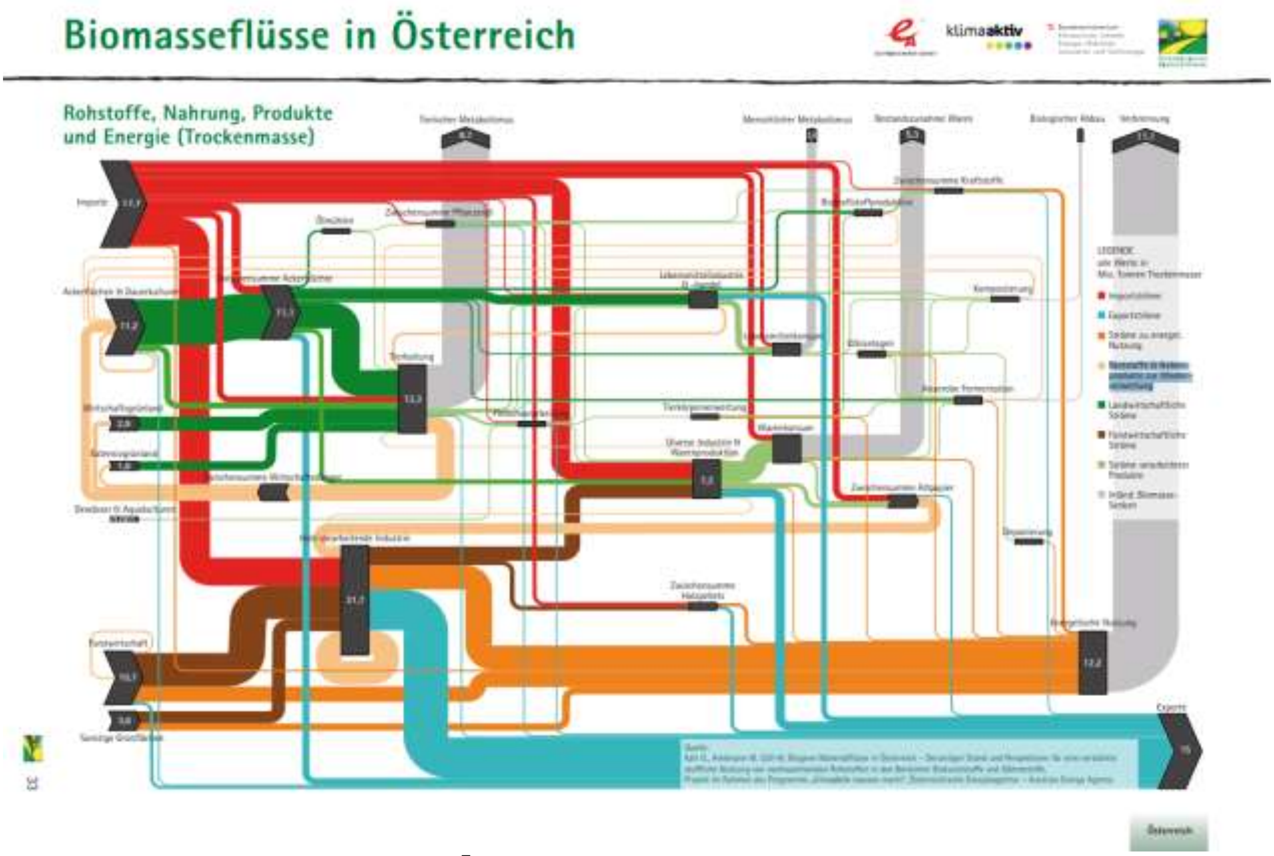

Figure 3: Biomass streams in Austria[7]

[7] Bioenergie Atlas Österreich. Österreichischer Biomasse-Verband, Wien, 2023.

1.2.1 Biomass availability feedstock 1 – Side products of beer production

Before getting into detail about all the different side streams that occur and to what extent, it makes sense to take a brief look at the overall beer production process and at what point different side streams occur specifically.

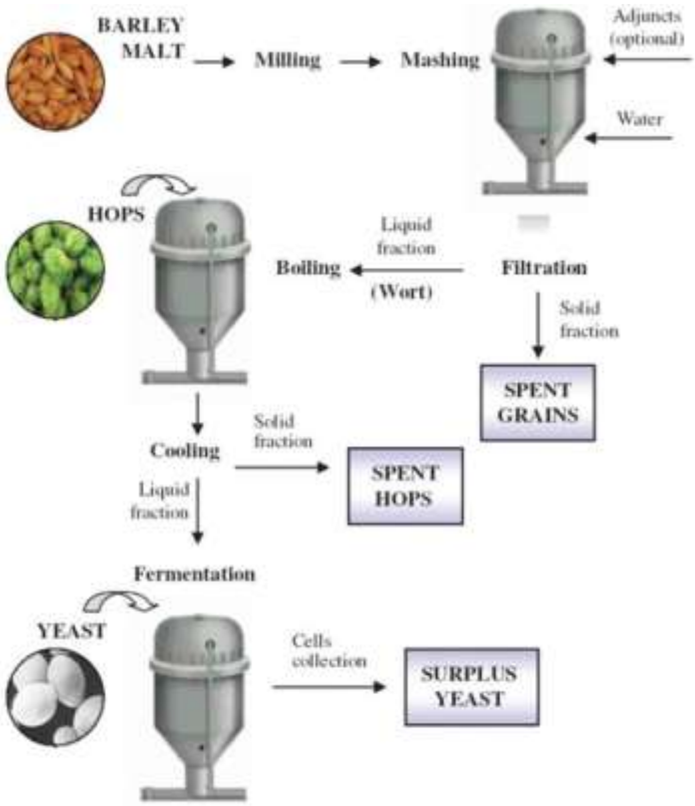

Figure 4: Beer production process and related side streams occurring during the process[8]

In February 2012, a questionnaire survey of the Austrian brewing industry was carried out by the Federal Environment Agency. The responses cover around 82% of the Austrian market and show that around 17.4 kg of spent malt is produced per hectolitre of beer[9]. In 2020, 2,8 million hectolitres of beer were produced in Upper Austria[10]. This results in a generation of the waste type SN 11404 "spent grains" of about 151,400 tons. A similar figure of 170,000 tons is obtained for the generation of spent grains using the information from KEPPLINGER & ZANKER (2004)[11] that about 20 kg of wet spent grains are generated per hectolitre of beer.

According to evaluations of eBilanzen (data as of February 2012), about 21 tons of SN 11405 "spent hops" were treated as input of waste treatment plants in 2010. It is assumed that this corresponds to the generation of this waste[9].

---

[8] Shiomi, Naofumi (2018). Current Topics on Superfoods. ISBN: 978-1-78923-209-7

[9] Reisinger, H., Domenig, M., Thaler, P. & Lampert, C. (2012). Rückstände aus der Nahrungs- und Genussmittelproduktion. Materialien zur Abfallwirtschaft. Umweltbundesamt. Report REP-0403, Wien, 2012

[10] Statistische Daten über die österreichische Brauwirtschaft. Verband der Brauereien Österreichs, Wien, 2021.

[11] Kepplinger, W., & Zanker, G. (2004). Die Verwertung von Biertrebern im Brauereiverbund. in *DepoTech* (S. 189-196). Verl. Glückauf.

A percentage representation of the organic waste and residues produced by an Austrian brewery is shown in Figure 3. At 78.2%, brewer's spent grains represent the largest share of production-specific waste in terms of volume and are the most energy-rich fraction due to their chemical composition (HERFELLNER ET AL. 2006)[12].

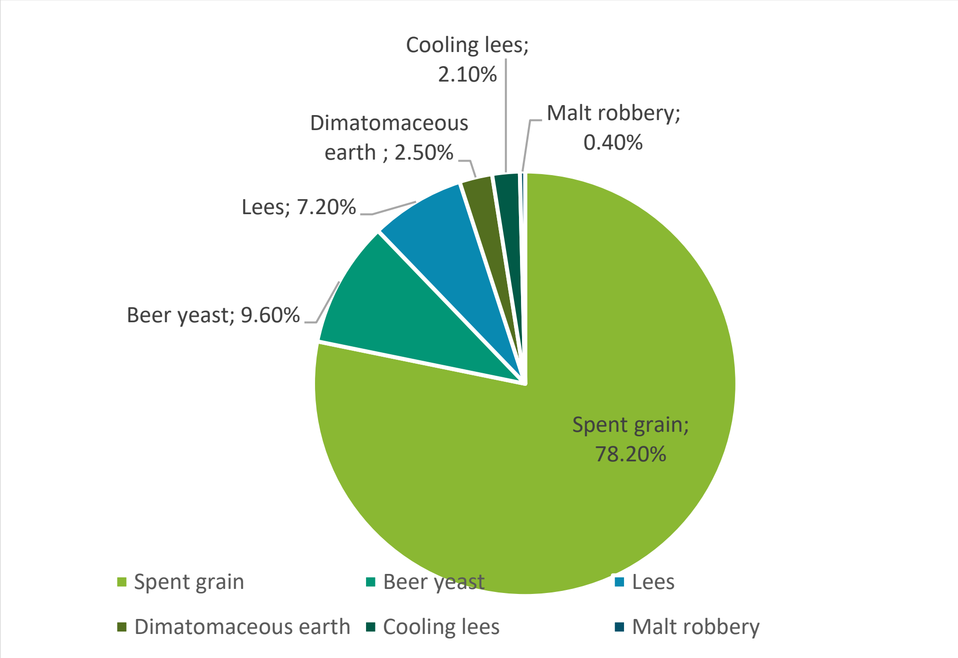

Figure 5: Example of the distribution of waste volumes in an Austrian brewery[12]

In 2004, a total of about 150,000 t of spent malt, malt kernels and malt dust were produced, yeast and yeast-like residues about 12,000 t. In the BAWP 2006, these wastes are assigned to the new waste code of the Waste Catalogue Ordinance, number 921**Error! Bookmark not defined.**. Almost the entire volume of biogenic residues from the breweries is passed on to the animal feed industry or to agriculture. The revenues achieved here are quite low. In 2004, only about 300 t were landfilled[13].

According to FNR (2006), the following biogenic residues are produced per hectoliter of beer: - 20 kg spent grains, - 2.4 kg yeast and tank bottoms, - 2.4 kg trub, - 0.5 kg kieselguhr (sludge), - 0.1 kg malt dust. This information corresponds to the questionnaire evaluation from 2012, where 12 breweries (82% of the Austrian market) were surveyed. They stated that around 17.4 kg of malt spent grain is produced per hectoliter of beer[9]. Spent grains represent by far the largest proportion of biogenic residues in terms of volume and are thus the relevant substrate of a large-scale biogas plant. For the sake of completeness, however, the forms of utilization of yeast, tank bottoms, diatomaceous earth and wastewater are also described.

[12] Bärnthaler, J. Bergmann, H., Drosg, B., Hornbachner, D., Kirchmayr, R., Konrad, G. & Resch, Ch. (2008). Energiesysteme der Zukunft. Technologie, Logistik und Wirtschaftlichkeit von Biogas-Großanlagen auf Basis industrieller biogener Abfälle. Endbericht. Projektnummer 812785.

[13] LEBENSMINISTERIUM (2006a): Bundesabfallwirtschaftsplan 2006; ISBN 3-902 010-70-3; URL: http://www.bundesabfallwirtschaftsplan.at/

Table 1: Production, raw materials, and utilisable waste materials at Brau Union ***Error! Bookmark not defined.***

Year: 2005	Amount	Brau Union	Österreich
Produktion			
Bier	[hl]	5.071.740	8.785.000
Rohstoffe			
Malz	[t]	80.777	139.920
Rohfrucht	[t]	940	1.628
Hopfen	[t]	32	56
Summe	**[t]**	**81.749**	**141.604**
Verwertbare Altstoffe			
Trebern	[t]	80.132	138.802
Trockentrebern	[t]	0	0
Malzstaub	[t]	151	262
Hefe/Geläger	[t]	6.013	10.416
Summe	**[t]**	**86.296**	**149.480**

Spent grain (Treber)

As can be seen from various sources, the spent grain content per hectoliter of beer is between 17.4 and 20 kg and accounts for around 80% of the total waste generated by breweries. According to feedback from the Austrian beer industry[9], BSG is utilised for following:

- 4 % as food,
- 93 % as animal feed and
- 3 % as input for biogas production

An example of five breweries that participated in the data collection indicated that they use their spent grains as animal feed in agriculture. The annual volumes of spent grains produced range from 450 t to 18,095 t per site. The revenues obtained range between 7.80 and 12 €/t[9,12]. This also corresponds to the information provided by the first Styrian spent grains distributor, which indicates a revenue of about 10 €/t[14].

The advantages of using spent grains as feed are:

- Higher basic feed performance due to higher dry matter intake
- Low metabolic load due to rumen-stable protein
- Health-promoting and milk-producing
- Economic efficiency

[14] Erster Steirischer Trebervertrieb (2007). Zusammensetzung und Analyse der getrockneten Bierhefe. www.treber.at

As a result, spent grains are used as feed for dairy cows, cattle for fattening and pigs. Furthermore, brewer's grains are successfully used for feeding game, sheep and horses[14]. The high content of essential amino acids, especially lysine, gives brewer's yeast a very good amino acid supplement to fattening rations. Fresh brewer's yeast is also a valuable supplementary feed in every fattening ration because of its high mineral and vitamin content[15].

In principle, this makes brewers' grain a very nutritious option for animal feed. However, it is difficult to digest, so it is only used in moderation. Alternative uses, e.g. as a substrate for mushroom cultivation, would therefore make sense. Small quantities could also be used in flours and to produce baked goods. The achievable prices are estimated at 5 - 10 euro cents. This corresponds to 5 to 10 times the proceeds from the current disposal method[12], but is considerably lower than the proceeds from animal feed utilisation[9].

Good brewers' grains smell like bread, but only have a short shelf life as mould forms after just a few days. Leitgeb, 2001[16], describes an emergency solution: fresh spent grains can be stored under water for a few days, but this produces mainly lactic acid. However, ensiling is more favourable.

Due to the material composition, spent grains are in theory suitable for composting. However, due to long residence times and considerable emission problems, composting is not practical. At present, the utilization of spent grains as animal feed is largely assured and economically the best option if possible.

The material utilization of spent grains in the building materials or baked goods industry is also possible. Heineken's spent grains fractionation process is another possibility for recycling spent grains. In this process, the fractions fibres (husks), proteins and liquid are separated from each other and recycled individually. In addition to the provision of thermal energy during the combustion of the fibres, economic viability is also to be achieved through the sale of spent grains protein. However, the market prices for this are based on those of soybean meal, which is available at low cost on the world market. The higher production costs for spent grains protein cannot be covered by this [12].

The disposal or recycling of organic residues is an increasing problem for breweries due to high disposal costs and fluctuations in potential sales markets. Rising transport and energy costs as well as the high energy content of organic brewery waste make energy recovery options for brewery residues increasingly interesting[12].

According to verbal statements, a large proportion of brewer's grains are processed in biogas plants, especially by smaller breweries. Unfortunately, no exact figures could be obtained. Different sources of organic wastes and by-products for co-digestion show their approximate biogas yields of yeast and yeast sludge from breweries of 400 – 800 m3 per ton organic solids[17].

Table 2: Substance data of spent grains[18]

Dry matter content DS (in mass%)	Organic dry matter content (in % of DS)	N (in % of DS)	P (in % of DS)	Gas yield (in m^3/t DS)
25	66-95	4,5	0,65	468

Furthermore, spent grains can be separated into a fibre-rich, a water-rich and a protein-rich fraction. The individual parts can then be further processed according to their properties. The first fraction can

15 Südtreber (2023). Gesund&wirtschaftlich füttern mit GVO-freien Produkten
16 Leitgeb, r. (2006). Einsatz von instrudriellen Nebenprodukten in der Rinderfütterlung. 2. Viehwirtschaftliche Fachtagung BAL Gumpenstein
17 Braun, R. & Wellinger, A. (2003). Potential of Co-digestion. IEA Bioenergy. Task 37 – Energy from Biogas and Landfill Gas.
18 ARCHEA Service GmbH - ein 100% Tochterunternehmen der ARCHEA Biogas N.V., Eindhoven (NL)

be used in paper production, the second as a substrate for growing mushrooms and the third as fish feed[9].

Yeast and trub (Hefe, Geläger)

Yeast is sold to feed producers at a price of approx. 7 €/t. The Obermurtaler Brauereigenossenschaft recycles its tank bottoms (267.3 t/a) partly in composting and partly as animal feed. According to the brewery cooperative, this results in annual transport costs of about €10,000. Brewery #24 utilizes about 2,250 t/a of tank bottom yeast as animal feed and in a biogas plant. The sales price for tank bottom yeast was given as 1.50 €/t. Another future utilization possibility of yeast is the coating of e.g., tablets. This is currently used mainly in the pharmaceutical industry. The material has advantageous properties, such as complete suspend ability in water and low permeability of oxygen. Another possible application is as an additive in seasonings, e.g., soup seasoning, etc., and as a substrate for mushroom cultivation beds[12].

Table 3: Substance data of yeast (DS = dry substance) [18]

Substance	Dry matter content DS (in mass%)	Organic dry matter content (in % of DS)	N (in % of DS)	P (in % of DS)	Gas yield (in m^3/t DS)
Yeast	10	92	723	62	67
Yeast, pressed	25	92	660	62	152
Yeast dried	90	92	610	61	505

Dimatomaceous earth (Kieselgur)

Diatomaceous earth is a naturally occurring mineral raw material used as a filter aid. Diatomaceous earth as a residual material is currently composted, which causes costs in the amount of about 50 to 60 €/t. The Obermurtaler Brauereigenossenschaft incurs annual removal costs of around 8,000 € for 110.5 t of diatomaceous earth, i.e., around 72 €/t[12].

Wastewater (Abwasser)

Within a study from 2007 the amount of wastewater in breweries was analysed. One brewery generated about 36.8 t of wastewater containing yeast and beer residues in 2006, which was discharged into the sewer. Information on the composition of the wastewater (e.g., TS content) is not available. Other breweries have their own biogas plant in which the wastewater is fermented. The daily gas yield is about 140 m^3. A combined heat and power plant (CHP), which was installed for electricity generation and heat utilization, had to be taken out of operation due to technical problems. The gas utilization was rebuilt, and the biogas is now used directly via a combi burner[12].

1.2.2 Biomass availability feedstock 2 - Side and waste streams bakery products

In this sector, 90% of the market is shared by commercial bakers and 10% by industrial companies. It also includes the flour milling, baking agent and pasta industries. In production, a surplus of 1.5% to 2% is common to meet certain deliveries[19].

A distinction must be made here between by-products that are generated in the manufacturing process during production and finished bakery products that are left over in sales as scrap goods. By-products of production are mainly dough types[19].

210,000 tonnes of bread and baked goods end up as waste in households, retail, and food production in our country every year. This amount corresponds to one fifth of avoidable food waste in Austria. In comparison, the people living here consume between 490,000 and 650,000 tonnes of bread and pastries every year.

Figure 6: Avoidable bread and bakery waste along the value chain in Austria. Translations: Households (purple), Supermarkets (ocher), Production (dark blue), Gastronomy, unknown (light blue) (Source: Pulswerk GmbH)[198]

In bakeries alone, around 52,000 tonnes of bread and pastries end up as waste every year. These are often so-called free returns from supermarkets: this mainly refers to bread and pastries that the bakeries first deliver to the supermarket in the form of chilled dough pieces and then receive back as baked goods that could not be sold. The bakeries credit the supermarkets for the quantity returned, so the supermarkets do not suffer any financial losses, disposal problems or risks[20]. Especially weather and seasonal factors influence the quantity of returned goods[19].

In addition to the free returns that go back to the bakeries, 13,000 tonnes of bread and pastries remain in the supermarkets every year[20].

---

[19] Hietler, P., Hopfner, C. & Pladerer, C. (2017). Abfallvermeidung in der österreichischen Lebensmittel-produktion. Österreichisches Ökologie-Institut.

[20] Hietler, P., Hopfner, C. & Pladerer, C. (2021). Brot ist kostbar! Ohne Mist! Handlungsanleitung zur Reduktion von vermeidbaren Brot- und Backwarenabfällen entlang der Wertschöpfungskette. Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie

Table *4* shows the average shares of recycling routes for used baked goods from 44 Austrian bakeries. Only a very small portion of avoidable food waste ends up in residual waste (> 0.3%)[20].

Table 4: Recycling routes for used bakery products from 44 Austrian bakeries[9]

Recycling route	Shares in %
Feeding	86,6
Internal utilization (e.g. breadcrumbs)	3,3
Social Institutions	3,3
Biogas Production	4,8
Composting	1,8
Residual Waste (waste incineration plant or MBT)	0,01
Other Utilization (e.g. alcohol production)	0,03

By-products generated in manufacturing process.

Within this report we focus on by-products (dough) that are generated in the manufacturing process in bakeries and industry. Based on the reports of a well-known bakery producer, the waste dough production amounts to 3.5% of the bakery production[9]. If this percentage is applied to the total baked goods produced in Austria of about 599,000 tons (STATISTIK AUSTRIA 2010), this results in an annual generation for SN 11111 "Dough" of about 21,000 tons[9].

Dough comes from [9]

- Industries producing baked goods (bread industry) and pasta,
- commercial bakeries and pastry shops,
- private bakeries and pastry shops,
- food retailers with associated bakeries that bake semi-finished products and offer them "fresh from the oven".

A study in Switzerland allocated different sources of losses. As the situation and culture in Switzerland is similar, the amount can be assumed as equal in Upper Austria[21]:

Cereals and bakery products:

- The losses in the production of small rolls (gate to gate) in very large baking plants amount to an annual average of 4 %, based on the final product dry matter (confidential).
- In biscuit production, losses of 6.1 % to 16 % occur, depending on the product and the process used, in relation to the quantity produced. The greatest losses are generated by the cutting process for biscuits, where a large bar is first produced and then cut up (confidential information from a large manufacturer).

Finished products:

- The losses incurred in the production of fresh pasta also depend on the type of product and range from 3.75 % to a maximum of 34 % (confidential information from an SME).

[21] Baier, U., Mosberger, L., Gröbly, D., Buchli, J. & Müller, C. (2016). Organische Verluste aus der Lebensmittelindustrie in der Schweiz. Massenflussanalyse nach Branchen. Ursachen / Verwertung. Wissenschaftlicher Schlussbericht ZHAW.

Ideas on how dough waste can be recycled:

- **Returning products (re-work)**
  In many cases, surplus or faultless goods that have been removed from the production process can be returned to it. Bakeries refer to this as "re-work". A certain proportion of dough pieces or finished baked goods can be reused in production. Many bakeries produce sourdough or a so-called cooked piece from old bread. Sliced and toasted bread from the previous day is finely ground and mixed with water. This mixture is combined with sourdough and flour to form a dough. Processing into breadcrumbs or bread cubes is another option. In this way, waste can be channelled into the highest added value and reprocessed into food[20]. According to verbal information from an Upper Austrian SME, the proportion of dough pieces reworked in this company is between 80 and 90%.

- **Processing raw materials**
  If bakeries have unsaleable bread leftovers in the production process, these can be processed into other products through suitable co-operations. There are many examples of this, such as the use of old bakery products as a raw material for "bread beer" or the distillation of gin from old bread, but also the production of "bread crisps " [20].

- **Waste dough is particularly suitable for utilisation in biogas plants.**
  Reisinger, H. et al (2012)[9] assume, that more than half of the annual amount of overproduced dough that cannot be re-worked into production, is used in biogas plants.

Table 5: Substance data of old bread[18]

Substance	Dry matter content DS (in mass%)	Organic dry matter content (in % of DS)	N (in % of DS)	P (in % of DS)	Gas yield (in m^3/t DS)
Old bread	65	97	760	53	479

1.3 Nutrient Availability

1.3.1 Nutrient availability nutrient 1

The following tables show relevant nutrient contents in the spent grains of beer production from different sources:

1.3.1.1 Spent grain:

Table 6: Source - Biertreber (suedtreber.de); Composition and analysis of spent grains[22]

Composition and analysis of brewer's grains/spent grains:			
		Fresh	**Silaged**
Dry matter (in %)		21,8 - 24,7	23,6 - 27,1
Nutrients	Crude protein	22,5 - 27,5	22,3 - 26,3
	Crude fat	5,5 - 9,5	6,6 - 10,8
	Crude fiber	16,2 - 21,2	17,6 - 22,4
	Crude ash	3,8 - 6,2	3,7 - 6,7
	Nitrogen-free extracts	40,0 - 47,0	37,3 - 45,7
	Starch		7,9 - 9,2
	Sugar		1,3 - 1,6
	Calcium	0,27 - 0,49	0,20 - 0,46
	Phosphor	0,57 - 0,77	0,43 - 0,73
	Sodium	0,10 - 0,90	0,23 - 0,45
	Magnesium	0,17 - 0,27	0,10 - 0,34

[22] Biertreber (2023) https://suedtreber.de/biertreber (Date: 28th of Aug. 2023)

Table 7: Crude nutrient content of spent grain[23]

Crude nutrient content of spent grain:		
Crude nutrient	**g/kg**	**dry matter %**
Crude protein	521	52,1
Crude fat	16	1,6
Crude fibre	25	2,5
Raw ash	81	8,1
N-free extractives	357	35,7
Sugar	13	13

Table 8: Minerals and trace elements in spent grain [15]

		Frisch	Siliert
		von – bis	von – bis
Trockensubstanz (in %)		21,8 – 24,7	23,6 – 27,1
Nährstoffe (in % der TS)	Rohprotein	22,5 – 27,5	22,3 – 26,3
	Rohfett	5,5 – 9,5	6,6 – 10,8
	Rohfaser	16,2 – 21,2	17,6 – 22,4
	Rohasche	3,8 – 6,2	3,7 – 6,7
	N-freie Extraktstoffe	40,0 – 47,0	37,3 – 45,7
	Stärke		7,9 – 9,2
	Zucker		1,3 – 1,6
Mineralstoffe (in % der TS)	Calcium	0,27 – 0,49	0,20 – 0,46
	Phosphor	0,57 – 0,77	0,43 – 0,73
	Natrium	0,10 – 0,90	0,23 – 0,45
	Magnesium	0,17 – 0,27	0,10 – 0,34

[23] Erster Steirischer Trebervertrieb (2023). Zusammensetzung und Analyse der getrockneten Bierhefe. www.treber.at

Table 9: Trace elements, amino acids, vitamins and fatty acids from brewer's grains[15]

Spurenelemente (in mg je kg TS)		Aminosäuren (in % der TS)		Vitamine (je kg TS)		Fettsäuren (in % des Fettes)
Eisen	190	Lysin	1,1	Vitamin B1	1,26 mg	8:0
Zink	85	Methionin	0,6	Vitamin B2	0,91 mg	10:0
Mangan	50	Cystin	0,5	Vitamin B6	0,62 mg	12:0
Kupfer	14	Asparaginsäure	1,4	Vitamin B12	38,90 mcg	14:0
Kobalt	0,18	Threonin	0,9	Folsäure	0,07 mg	16:0 (Palamitins.)
Selen	0,10	Serin	0,8	Nicotinsäure	38,90 mg	18:0 (Stearins.)
		Glutaminsäure	4,3	Ca-d-pant.	3,03 mg	18:1 (Ölsäure)
		Prolin	2,0	Biotin	140,00 mcg	18:2 (Linolsäure)
		Glycin	0,9	Vitamin E	25,70 mg	18:3 (Linolens.)
		Alanin	1,0			20:0
		Valin	1,3			22:0
		Isoleucin	0,9			22:1
		Leucin	1,6			24:0
		Thyrosin	0,7			Rest
		Phenylalanin	1,1			
		Histidin	0,5			
		Arginin	1,2			

Table 10: Feed value of spent grains according to DLG feed value tables and latest studies [15]

Futterwert von Biertreber lt. DLG-Futterwerttabellen:

ME/MJ	NEL/MJ	XP g	UDP g	nXP g	RNB g
11,2	6,7	249	97	185	+ 10

nach neuesten Untersuchungen wird der Futterwert von Biertreber wie folgt bewertet:

ME/MJ	NEL/MJ	XP g	UDP g	nXP g	RNB g
11,4	6,8	260	159	229	+ 5

Table 11: Raw material and energy content per kg dry matter of spent grains compared to selected protein feeds and cereals.

Tabelle 1: Rohnährstoff- und Energiegehalte je kg Trockenmasse von Biertrebersilage im Vergleich zu ausgewählten Eiweißfuttermitteln und Getreide
(Quellen: DLG 1997, 2001, 2009, 2011, LfL Gruber Tabelle 2014, Spiekers 2009)

Futtermittel	TM	XF	XL	XS	XP	nXP	RNB	UDP	NEL
	g	g	g	g	g	g	g	%	MJ
Biertreber, frisch	240	178	82	49	253	185	+11	40	6,4
Biertreber, siliert	247	160	88	17	249	188	+10	40	6,7
Biertreber, getrocknet	900	170	68	42	259	198	+10	45	6,2
Sojaextraktionsschrot	880	68	14	69	500	291	+34	30	8,6
Rapsextraktionsschrot	880	143	21	0	392	254	+22	35	7,1
Weizen/Gersten-schlempe, getrocknet	940	74	27	27	372	266	+17	40	7,4
Weizen	880	29	13	662	138	172	-5	20	8,5
Ackerbohnen	880	89	10	422	298	195	+15	15	8,6
Erbsen	880	67	9	478	251	187	+10	15	8,5

Abkürzungen: TM = Trockenmasse; XA = Rohasche; XF = Rohfaser; XS = Stärke; XP = Rohprotein; nXP = nutzbares Rohprotein; RNB = Ruminale Stickstoffbilanz; UDP = unabbaubares Rohprotein (Durchflussprotein, engl. undegraded protein); NEL = Nettoenergie-Laktation; ME = Umsetzbare Energie (engl. Metabolisable energy); MJ = Mega Joule

Brewer's grains are a valuable, high-protein feed (Futtermittel) with high levels of nXP (usable crude protein) and UDP (undegradable crude protein). In terms of energy concentration, they are positioned between basic and concentrated feeds and have a medium energy concentration compared to concentrated feeds. Brewer's grains can be described as a high-fiber feed. Their use in the feeding of ruminants, taking into account their specific protein properties, and can make a significant contribution to a sufficient protein supply.

1.3.1.2 Yeast

The table shows the nutrient content of brewer's yeast. Analysed by a company that sells brewer's yeast for feeding to livestock[18].

Table 12: Minerals and trace elements in yeast'***Error! Bookmark not defined.***

Element	Unit	Amount
Ca	g	3,3
P	g	33
Mg	g	2,6
K	g	24
Na	g	2,44
Fe	mg	560
Mn	mg	59
Zn	mg	92
Cu	mg	64
Mo	mg	1,25
Co	mg	0,4
Fe	mg	2,15
Se	mg	0,11

1.3.2 Nutrient availability nutrient 2

Following table contains an overview of the composition of macronutrients in different bread types.

Table 13: Macronutrient content [% per 100 g] in common bakery products [24].

Macronutrient	Bread type		
Content in [%]	**Wheat roll/bun**	**Bread**	**Whole-grain bread**
Water	29,5	43,7	38,8
Carbohydrates	55,5	41	43
Protein	8,7	6,9	7,3
Fiber	3	6,2	8,1
Fat	1,9	1,1	1,2
Vitamins & Minerals	1,4	1,1	1,6

1.3.2.1 Doughs:

No nutrient contents could be determined for dough pieces resulting from production. However, as the nutrient content should not change because of processing and baking, the nutrient values of stale bread can be used.

1.3.2.2 Old bread:

Bread that did not go on sale or was left over during the sale (best-before date exceeded, sorted out as food) is currently mainly fed to animals or processed into gas in the biogas plant. Only hygienic bread may be fed (e.g., no mouldy bread).

Scrap bread has a high sodium content. 1 kg of old bread in the ration reduces the need for the need for cattle salt by 10 g. Limiting factors in the feeding of dairy cows are the high starch content and the lack of structural effect.

[24] LandschafftLeben. https://www.landschafftleben.at/lebensmittel/brot/gesundheit (Seen: 10.11.2023)

Table 14: Comparison of ingredients per kg dry matter of stale bread[25]

2. Inhaltsstoffe pro kg Trockenmasse von Altbrot im Vergleich (ZIFO 2014)

	Altbrot	Gerste	Weizen
Trockenmasse [g/kg FM]	650	880	880
Rohprotein [g]	123	125	137
nXP [g]	175	165	170
UDP [%]	10,0	25,0	20,0
Lysin [g]	3,3	4,43	3,35
Methionin [g]	1,8	2,02	1,78
Energie [MJ NEL]	9,40	8,21	8,53
Energie [MJ ME]	14,44	13,00	13,40
Stärke und Zucker [g]	702	627	707
Zucker [g]	60,0	25,0	31,8
Rohfett [g]	30,0	25,0	20,0
Rohfaser [g]	14,0	50,0	30,0
Rohasche [g]	28,0	2,3	1,7
Kalzium [g]	0,9	0,7	0,7
Phosphor [g]	2,5	4,0	3,8
Natrium [g]	4,1	0,3	0,2
Kalium [g]	5,0	5,0	5,0

[25] Schuster, H., Moosmeyer, M. & Rauch, P. (2014). Futtermittelblatt Rind Altbrot. LfL Tiernährung.

Table 15: Nutrient content of feed materials[26]

Quelle: StoffBilV vom 14.12.2017, Tabelle 4; fachlich erweitert durch Bayerische Landesanstalt für Landwirtschaft (LfL) - Basisdaten, Stand: November 2018

TS = Trockensubstanz; **RP**- Rohprotein; **FM** = Frischmasse

Einzelfuttermittel	Produktart und Erläuterungen	RP-Gehalt	TS-Gehalt	Nährstoffgehalt				
				N	P	P_2O_5	K	K_2O
		[% in TM]	[%]	[kg/dt FM]				
Einzelfuttermittel allgemein								
Ackerbohne	Korn	30	86	4,10	0,52	1,19	1,16	1,39
Altbrot		15	65	1,56	0,07	0,16	0,33	0,40
Apfeltrester		8	22	0,29	0,04	0,09	0,15	0,18
Backabfälle		12	88	1,70	0,23	0,53	0,88	1,06
Bierhefe	flüssig	53	10	0,84	0,11	0,25	0,15	0,18
Biertreber	siliert	25	25	1,00	0,15	0,34	0,02	0,02

1.4 Discussion of the Results

Concerning the availability of biomass in the two chosen streams, a few statements can be made. Firstly, though breweries overall make up a small share of food waste in Austria, the density of breweries still makes them an interesting branch to investigate further. With a variety of different waste material comes a variety of use. The most financially beneficial and logistically doable repurposing is still animal feed.

Looking at the bigger stream of by- and waste products of bakeries, we observe that only an incredibly small percentage is wasted. Even when just looking at excess dough produced, there are several alternatives that include re-working the overproduced material back into the initial process, turning them into raw material in a different production line or using them in biogas plants producing biogas and biofertilizer.

Breweries create several kinds of biomass. The decision was made to look more closely at two of them: spent grain and yeast. Both are nutrient-heavy biomass streams, with spent grain specifically being heavy in protein. This connects directly to its use in animal feed, but also makes it a resource that needs to be used wisely as to not overfeed in terms of protein. With yeast, phosphorus and potassium stand out as macro minerals. These two are both relevant for humans as well as crops as in the latter, they contribute heavily to the growth of the plants.

For dough, data were used from studies on old bread. Here we can see that nutrient value is lower than in brewery waste-products. It should be noted that the nutrients apply to finished baked goods that are deemed “old”. Not to dough prior to processing.

---

[26] Grunert, M. (2020). Nährstoffgehalte von Einzelfuttermitteln. Landwirtschaft/Pflanzenbau. (10.11.2023: https://www.landwirtschaft.sachsen.de/download/Tab_33_Naehrstgeh_Einzelfutterm_2020_06_05.pdf
)

1.5 Conclusions and Recommendations

1.5.1 Conclusions

The decision of why these two streams were investigated becomes apparent when looking at them side by side. Bread and baked goods stand out in terms of amount, there is significantly more bread available as a waste stream. The following table provides an overview of available biomass streams as well as an approximation for the price per ton of the specific streams:

	Biomass in tons	Percentage used in feed	Price per ton
Spent grains	150k-170k	93%	€ 7,8 - € 12
Yeast	12k	unknown	€ 7
Bread	210k	86%	Not publicly available
Dough	21k	Unfit for use in animal feed	Not publicly available

For bread and dough, there are existing contracts between bakeries/supermarkets and feed producers. However, arrangements are not published and the price per tonne is unknown.

There is no indication that the available amount of biomass is insufficient, still, with increased biomass demand or market shifts to other routes, this can change. Close monitoring remains necessary.

Residues can be utilized well for animal feed or biogas production. For dough, however, reworking, either in the same or a different process, are considered better options.

For nutrient recycling, the following routes exist and are applied depending on product quality and availability of conversion systems in the area.

1. The residues are used for animal feed; animals produce meat and dairy products; manure is digested producing biogas and the digestate is upgraded to bio-fertiliser and nutrients are returned to the field.
2. The residues are used as co-digestion material producing biogas and bio-fertiliser and nutrients are returned to the field.
3. The residues are composted, and nutrients are returned to the field.

1.5.2 Recommendations

Two major points stand out that are equally important and closely connected. Firstly, we recommend looking more deeply into logistics. Creating reliable transportation for the incurred bio waste is crucial to ensure a deliberate use of as much material as possible, the closing of loops and the reduction of waste under the principle of repurposing.

Secondly, we see a huge opportunity in connecting production processes. What can be considered biomass in one process can be a raw material in another. A very easy example is that leftover dough can be used to make bread chips. This is still thinking within the same industry. Better is that this thinking is extended to distilleries, biogas plants, sewage plants and other stakeholders. Here, the SCALE-UP project and its platforms offer a good starting point for inter-sectoral thinking outside of one's own industry.

Overall, the way bakeries are handling their side streams and the minimal amount of food that is eventually declared waste, can be taken as an example for other sectors. Processes have been designed efficiently and while there is room for improvement, little biomass is left unused. Biomass availability is stable, and the use has been well organised through process optimization.

For nutrient recycling, financial considerations are dominant. This does not guarantee the best ecological way nutrients are used. If residues can directly be used for bioproducts or materials, this should be preferred as it saves crops, land use and nutrients. Only when this is no longer possible, they should be used for composting of biogas production. This **cascadic use** of resources can be both an interesting starting point for researchers in terms of biomass stream optimization as well as policies and laws that have proven in the past to vastly expedite the speed at which change is implemented.