BIOMASS AND INNOVATION POTENTIAL OF RESIDUES, BY-PRODUCTS AND OTHER SUSTAINABLE FEEDSTOCK FOR BIOBASED PRODUCTS IN FOUR SOUTH BALTIC AREA REGIONS

2019/06/23

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Biomass and innovation potential of residues, by-products and other sustainable feedstock for biobased products in four South Baltic Area regions

June 2019

Authors
Thomas Prade (editor), Swedish University of Agricultural Sciences (SLU), Sweden
Mark Booker Nielsen, Tyge Kjær, Roskilde University, Denmark
Max Mittenzwei, Beate Cuypers, Daniel Schiller, University of Greifswald, Germany
Moritz Westkämper, Agency for Renewable Resources, Germany
Dariusz Mikielewicz, Rafał Andrzejczyk, Paweł Dąbrowski, Jan Wajs, Gdańsk University of Technology, Poland
Johanna Lund, Anna Ekman Nilsson, Research Institutes of Sweden (RISE), Sweden

Please cite the reports as: Prade, T., Andrzejczyk, R., M. Booker Nielsen, B. Cuypers, P. Dąbrowski, A. Ekman Nilsson, T. Kjær, J. Lund, D. Mikielewicz, M. Mittenzwei, D. Schiller, J. Wajs and M. Westkämper (2019). *Biomass and innovation potential of residues, by-products and other sustainable feedstock for biobased products in four South Baltic Area regions,* Interreg project *Bioeconomy in the South Baltic Area: Biomass- based Innovation and Green Growth* - BioBIGG

Project title	Bioeconomy in the South Baltic Area: Biomass- based Innovation and Green Growth For information on the project please check https://biobigg.ruc.dk/
Project acronym	BioBIGG
Work Package	WP4 – Material flows and innovation potentials of agro-industrial value-chains
Deliverable	D4.1 – Report on mapped material flows of biological resources along agro-industrial value-chains
Copyrights	All rights reserved to the partners in BioBIGG. Copyright © 2019 BioBIGG
Published by	BioBIGG

Summary
The global economy is currently in a transition from a fossil-based to a biomass-based economy, not least in the European Union. This growing bioeconomy is in need of sufficient, adequate and sustainable biomass resources as production feedstock. For this feedstock, two kinds of biomass sources are possible. By-products from processing of primary biomass and purpose-grown biomass. Utilising the by-products from processing of primary biomass holds the promise of high resource efficiency and low environmental impact. However, even supply of by-products can imply a (high) cost and purpose-grown sustainable feedstocks such as crops not competing with food and feed production should also be considered when discussing a sustainable feedstock base for the bioeconomy.

The aim of this report is to assess the potential amounts of biomass feedstock that could be made available to a growing bioeconomy in Europe. This assessment was carried out for four major values chain in the primary production sectors for each of four investigated South Baltic Area (SBA) regions in Denmark, Germany, Poland and Sweden. Furthermore, opportunities and bottlenecks for implementation of the utilisation of the different feedstocks were assessed as a synopsis to each feedstock.

For processes and product value chains where bulk feedstocks are required, straw and woody residues are already available, both in terms of volume and technology. Still, large-scale use of residues might not yet be feasible and in terms of priorisation of residues and feedstocks, valorisation should aim at replacing fossil-based products and services and not only concentrate on feedstocks that occur in large quantities. There are a number of by-products, expecially in the food industry sector, that contain valuable compounds or are suitable for fermentative use. Energy recovery is an option for all residues, but it should always be considered if material and compound recovery is possible prior to a final energy and plant nutrient recovery step.

Additional sustainably produced feedstocks from agriculture may be available in large quantities as well and have the advantage that quality can be controlled and adjusted to the process needs. The feedstocks presented in this report are considered sustainable in the sense that competition with food and feed production is minimised. For evaluating the overall sustainability of products based on these feedstocks, case-specific assessment should be carried out, e.g. in the form of LCA studies.

Finally, there is a strong need to reduce uncertainty and encourage investment by increasing transparency, first, by providing precise information on the availability of of feedstocks and, secondly, by ensuring a low environmental impact of of innovative biomaterials and bioenergy.

Contents

1. The regions included in the assessment

1.1 Denmark

Region Zealand is one of five Danish regions and located in the eastern part Denmark and consists of 17 municipalities and located in the eastern part of Denmark. The population is approximately 830,000 inhabitants and the region covers a land area of 722,400 ha[1]. The number of farms is approximately 5,671 and total arable land use 468,638 ha, which accounts for approximately 18 percent of the total arable land area in Denmark and providing and unique opportunity for development of innovative biomass-based solutions within the bioeconomy.

Table 1. General data on Region Zealand

Parameter	Unit	Value
Population	[persons]	830,000
Total area	[ha]	722,400
Arable land area	[ha]	468,638
Pasture and grassland land area	[ha]	42.874
Forest land area	[ha]	99,709

Figure 1: The Region Zealand of chosen as the region in focus for the BioBIGG project for the Danish part of the South Baltic Area. Bornholm is not included in the assessment[2].

[1] Danmark statistik bank: AREALDK1, 2017

[2] https://da.wikipedia.org/wiki/Region_Sj%C3%A6lland#/media/File:Sj%C3%A6lland_in_Denmark.svg

1.2 Germany

Mecklenburg-Western Pomerania

MWP[3] is located in the north-east of Germany. It shares borders with Brandenburg in the south, Lower Saxony in the south-west and Schleswig-Holstein in the west, as well as to the polish region Pomerania in the east. The north of MWP is the coast to the Baltic Sea.

Figure 2. Region of Mecklenburg-Western Pomerania in Germany[4]

Table 2. Data refers to the region of Mecklenburg-Western Pomerania[5]

Parameter	Unit	Value
Population	[persons]	1,612,100
Total area	[ha]	1,347,600
Arable land area	[ha]	1,076,100
Pasture land area	[ha]	268,400
Forest land area	[ha]	558,010

MWP is the most sparsely populated and most rural German federal state. The majority of the population lives along the Baltic coast, while the south and the inland in the east of the country are sparsely populated. Nevertheless, MWP covers over 8% of the agricultural land in Germany.

[3] MWP = Mecklenburg-Western Pomerania
[4] https://de.wikivoyage.org/wiki/Mecklenburg-Vorpommern (last access: 18.01.2018
[5] Statistisches Datenblatt 2017. Ministerium für Landwirtschaft und Umwelt. Mecklenburg-Vorpommern.

1.3 Poland

Poland is divided into 16 regions, called voivodeships (Regions). Three of them belong to the South Baltic Area, i.e. West Pomerania, Pomerania and Warmia and Mazury Regions.
According to the data provided by EUROSTAT, bioeconomy is already one of the largest and most important components of the Polish economy. Gross value added in bioeconomy sectors in the years 2009-2013 averaged annually to about 63.5 billion €, representing more than 19% of gross value added produced in the national economy. The bioeconomy sector in Poland employs more than 4.7 million people, representing more than 30% of employees in the whole economy. The voivodeships: Pomerania, West Pomerania and Warmia and Mazury were chosen to represent the Polish engagement in the bioeconomy within the BioBIGG Interreg project.

Pomeranian Region is located in the middle of Polish South Baltic Area. The territory of the Region is 1,829,300 ha, which puts the region eighth in Poland. The region is divided into 16 powiats, 123 municipalities and 8 towns having a status of municipality. The population is approximately 2,309,400 inhabitants (eighth in the country) and the region covers 5.9% of Poland. The number of farms is approximately 60,900 and the area with arable land is 759,900 ha [6,7]. The density of population in the region is 126 persons per square kilometer. On the territory of the region there are practically no natural resources except for sands, gravel and clays. The region features significant participation of forests in its land amounting to 36%, whereas average afforestation of the country is about 28%. Soils of the region are rather low fertile, except for the area of Żuławy Wiślane (fen soils).

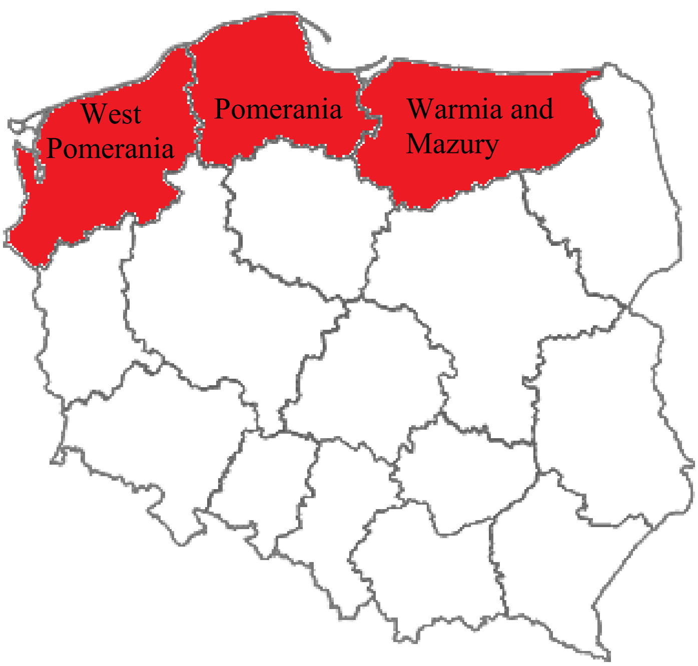

Figure 3. Schematic view on the regions chosen as representative Poland (marked in red).

[6] Statistical Yearbook Pomorskie Voivodship 2016, Statistical office in Gdańsk
[7] Waste management plan for the Pomeranian Voivodship 2022 (in Polish)

Table 3. General data on the voivodeships: Pomerania, West Pomerania and Warmia and Mazury, Poland.

Parameter	**Unit**	**Value**[8]
Population	[million persons]	5,483,649
Total area	[km^2]	65,340
Arable land area	[ha]	2,598,084
Pasture and grassland land area	[ha]	605,492
Forest land area	[ha]	2,250,500

Regions play an important role in the further development of the bio-based economy in Europe as they can support the establishment of (regional) innovative value chains. They are also best situated to identify the locally available feedstocks (from agriculture, agrofood, forestry, residual and side streams, etc.) that can trigger the bio-based economy.

In 2017 the Pomeranian Region has signed a Letter of Intent with the Bio-based Industries Consortium (BIC) to promote sustainability in Europe's chemical industry[9].

Poland's bioeconomy is traditionally centered on agriculture, forestry and food processing. The agri-food sector is dominated by large groups (both national and foreign origin). Forestry is largely state-owned, and supplies the pulp and paper as well as furniture industries. Poland is the 4th largest world exporter of furniture. Chemical and pharmaceutical industries have a sizeable role in the country's economy, with the latter witnessing a growth of more than 60% in the last ten years. It is an important sector in the nation's economy, accounting for almost 20% of employment and 10% of the total production volume.

Although there is not yet a published bioeconomy strategy, bio-based industry elements are prominently exposed in Poland's Smart Specialisation Strategy (2014).

Analysis of the waste issue encountered significant problems, as the waste is not yet quantified on the basis of particular companies. In some cases the data for waste is missing. In the following assessment for the Pomeranian Region we will map materials flows from food processing industries in value chains perspective.

[8] Central Statistical Office, Population. The condition and structure of the population and natural movement in the territorial cross-section. State for 30 June 2017 [access on 2017-10-21] (in Polish).
[9] Bioeconomy regions in Europe, November 2017
https://biconsortium.eu/sites/biconsortium.eu/files/publications/BIC_GA_Brochure_Bioeconomy_regions_in_Europe_Nov_2017.pdf

1.4 Sweden

The county of Skåne was chosen to represent the Swedish engagement in the bioeconomy within the BioBIGG Interreg project.

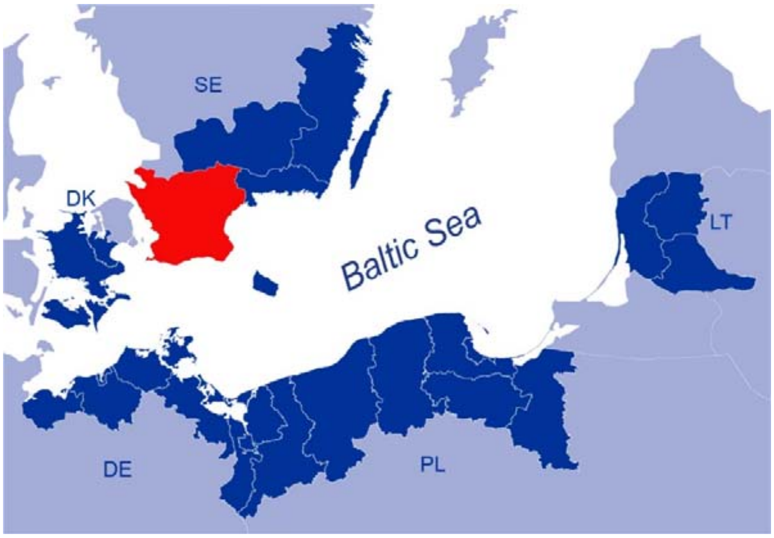

Figure 4. Schematic view on the regions included in the Interreg South Baltic Programme, with the country of Skåne chosen as representative Swedish region used in the present assessment (marked in red).

Table 4. General data on the county of Skåne, Sweden.

Parameter	Unit	Value
Population[10]	[million persons]	1,322,193
Total area[11]	[km^2]	10,939
Arable land area[12]	[ha]	442,157[a]
Pasture land area[13]	[ha]	55,780[a]
Forest land area[14]	[ha]	420,000[b]

[a] Average for 2013-2017
[b] Average productive forest land for 2012-2016.

[10] SCB. 2018. Folkmängd i riket, län och kommuner 31 december 2017 och befolkningsförändringar 1 oktober–31 december 2017. Totalt, (Ed.) S. Sweden. Örebro, Sweden.
[11] Region Skåne. 2018. Quick Skåne Facts, Vol. 2018, Region Skåne. Kristianstad, Sweden.
[12] SBA. 2018. Åkerarealens användning efter kommun och gröda, hektar. År 1981-2017, (Ed.) Swedish Board of Agriculture. Jönköping, Sweden.
[13] SBA. 2018. Betesarealens användning efter län/riket och gröda. År 2003-2017, (Ed.) Swedish Board of Agriculture. Jönköping, Sweden.
[14] RST. 2018. Tabell 2.1 - Skogsmark fördelad på ägoslag enligt skogsvårdslagen efter År, Län, Tabellinnehåll och Ägoslag, (Ed.) S. Riksskogstaxeringen. Uppsala, Sweden.

2. Material flow in main value chains

2.1 Straw residues

2.1.1 Regional resources in Denmark

Assessed by Mark Booker Nielsen and Tyge Kjær, Roskilde University, Denmark

Arable land in the region Zealand accounts for 65.8 percent of the total land area in the region. This is a bit higher than the share of arable land in the rest of Denmark (61.1 percent) and is the highest share of arable land for any country in Europe[15,16,17].

The crops dominating the cultivation is wheat and barley with approximately 60 percent of arable land in Region Zealand. Other widely cultivated crops are rapeseed (8%), industrial seeds (8%) and sugar beets (7%)[18]. Most of the harvest from the crops cultivation is used as feed for livestock.

The pig production in Region Zealand is relatively small compared with other regions in Denmark with a total of 1,265,279 livestock in 2016 accounting to approximately 10 percent of the total Danish pig production. The dairy production is also relatively small with 81,614 livestock amounting to approximately 5 percent of total Danish dairy production[19].

Only a small amount is use for production of food and beverages. The main residual from the cereal grain production is straw. The main use of straw in the region is energy production on combined heat power plants (CHP) within the region and in the Capital Region of Denmark.

Products along the value chains and utilization today

As previous descripted a big amount of the cereal grain in the region is used as feed for livestock and only an amount for production of food products and beverages.

The main residual from the cereal grain production is straw that is mainly use of for energy production on combined heat power plants (CHP) within the Region Zealand and in the Capital Region of Denmark. The use of straw has been quite stable for the last 5 years with an average of 413,000 tonnes per year, but a smaller amount of 68,000 tonnes is also being use as bedding material and 61,000 tonnes as feed.

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[15] Statistics Denmark, AREALDK1 (2016), http://www.statistikbanken.dk/AREALDK1
[16] Statistics Denmark, BDF11 (2016), http://www.statistikbanken.dk/BDF11
[17] https://www.indexmundi.com/facts/indicators/AG.LND.ARBL.ZS/map/europe
[18] Statistics Denmark, AFG07 (2016), http://www.statistikbanken.dk/AFG07
[19] Statistics Denmark, KOMB07 (2016), http://www.statistikbanken.dk/KOMB07

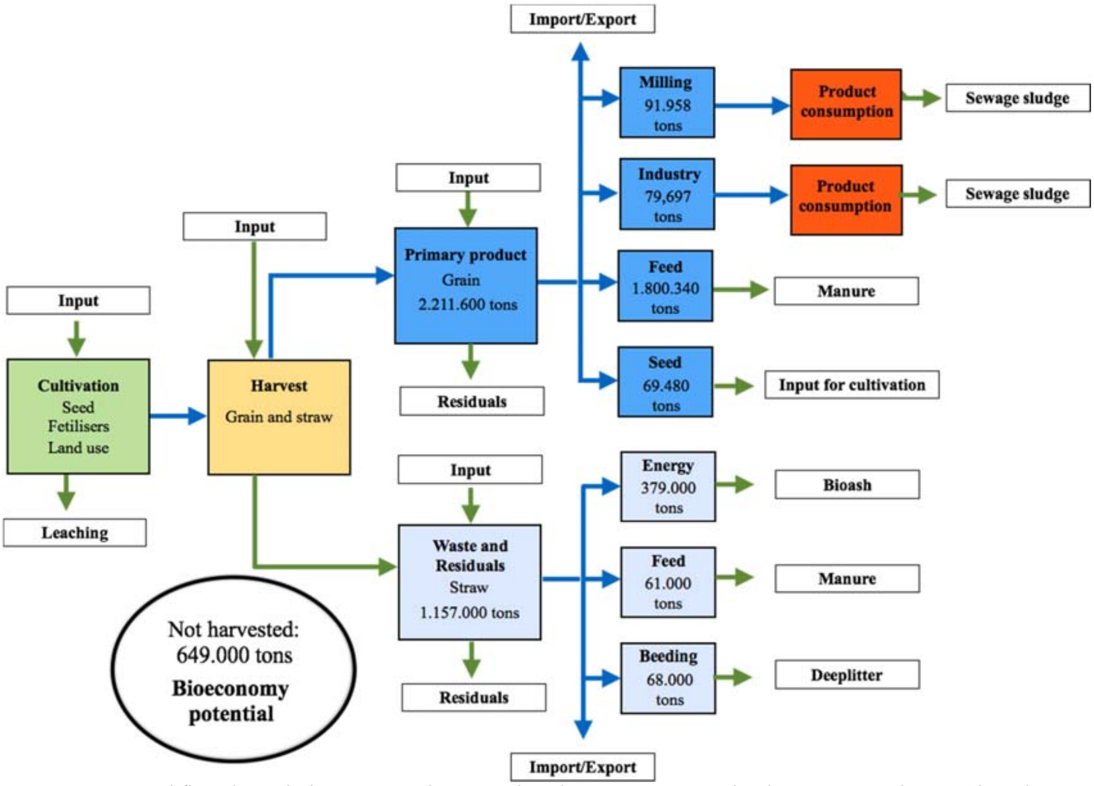

Figure 5. Material flow through the grain production value chain in Region Zealand. Preparation by RUC based on mapping of material flow.

Quantification of feedstock, products and residues

Table 5. Land use for production in Region Zealand [1000 ha][20]

Production	2012	2013	2014	2015	2016
Grain production, total	306.5	283.5	288.6	296.5	292.9
Winter wheat	136.7	137.4	152.4	149.4	143.6
Spring wheat	4.3	3.2	2.7	2.9	3.1
Rye	5.7	8.5	7.6	8.5	6
Triticale	1.5	1.1	1.2	1.4	1.2
Winter barley	14.4	15.8	13.6	11.7	11.2
Spring barley	138.2	112.2	106.7	118.8	123.5
Oats	4.3	4.1	3.3	2.7	3.6
Maize to maturity	1.3	1.2	1.2	1.1	0.8
Raps, total	23.6	46	43.6	47.8	40.1
Winter raps	23.1	45.7	43	..	..
Spring raps	0.5	0.3	0.5	..	..
Legumes seed, total	1.3	1.2	2	2.1	2.4
Peas	1	0.9	1.3	1.3	1.3

[20] Statistics Denmark, HST77 (2018), http://www.statistikbanken.dk/Hst77

Table 6. Average grain yields in Region Zealand [hkg/ha][21].

Production	2012	2013	2014	2015	2016
Grain production	73.6	74.3	77.8	79.4	70.7
Winter wheat	83.2	83.1	87.7	88.7	82.5
Spring wheat	55.5	62.1	42.6	43.6	51.1
Rye	74.9	71.3	66.4	65.7	70.4
Triticale	54	51.7	64.1	61.1	53.7
Winter barley	69.7	68.1	71.7	71.1	67.2
Spring barley	65.7	66.1	67.5	71.5	58.8
Oats	57.6	53.5	46.6	52.9	44.9
Maize to maturity	60.2	55.1	46.8	64	60.5
Raps, total	41.5	42.6	43.6	43.1	32.7
Winter raps	41.9	42.7	43.9	..	..
Spring raps	22.9	28	18.7	..	..
Legumes seed, total	50.5	38	45.6	54.1	40.5
Peas	51.5	38.7	46.6	55.4	40.7

Table 7. Cereal grain production in Region Zealand [1000 t]

Production	2012	2013	2014	2015	2016
Grain production, total	2254.2	2105.5	2243.6	2355.3	2070.8
Winter wheat	1137.4	1141.1	1336.3	1324.8	1184.7
Spring wheat	24.1	19.9	11.4	12.5	15.8
Rye	42.8	60.6	50.4	55.7	42.1
Triticale	8.1	5.6	7.6	8.8	6.3
Winter barley	100.2	107.6	97.4	83.2	75.4
Spring barley	909	742.2	719.8	849	725.7
Oats	25	22.1	15.2	14.5	16
Maize to maturity	7.6	6.5	5.6	6.9	4.9
Raps, total	98.1	195.7	190	206.2	131.2
Winter raps	96.9	194.9	189	..	..
Spring raps	1.1	0.8	1	..	..
Legumes seed, total	6.5	4.6	9.2	11.1	9.6
Peas	5.2	3.3	6.2	7.1	5.3

[21] Statistics Denmark, HST77 (2018), http://www.statistikbanken.dk/Hst77

Quantification of straw use and residues

Table 8. Crops contribution to the total straw production in Region Zealand [1000 t][22]

Production	2012	2013	2014	2015	2016
Straw, total	1346	1,354.8	1,425.6	1,318.9	1,157
Straw from grain production, total	**1,254.5**	**1,176.3**	**1,250**	**1,313.4**	**1,152.2**
Winter wheat	625.6	627.6	735	728.6	651.6
Spring wheat	12	9.9	5.7	6.2	7.9
Rye	34.3	48.5	40.4	44.6	33.7
Triticale	6.5	4.5	6.1	7	5
Winter barley	55.1	59.2	53.6	45.8	41.4
Spring barley	499.9	408.2	395.9	466.9	399.1
Oats	15	13.2	9.1	8.7	9.6
Maize to maturity	6.1	5.2	4.5	5.5	3.9
Raps, total	**88.3**	**176.2**	**171**	**185.6**	**118.1**
Winter raps	87.2	175.5	170.1	..	..
Spring raps	1	0.7	0.9	..	..
Legumes seed, total	**3.3**	**2.3**	**4.6**	**5.6**	**4.8**
Peas	2.6	1.7	3.1	3.6	2.7

Table 9. Standard factors for straw production and grain yield relationship[23]

Crop	Straw-grain ratio
Winter wheat	0.55
Spring wheat	0.50
Rye	0.80
Triticale	0.80
Winter barley	0.55
Spring barley	0.55
Oats	0.60
Winter raps incl. non-food	0.90
Spring raps incl. non-food	0.90
Peas	0.50
Legumes seed	0.50

[22] Statistics Denmark, HALM (2018), http://www.statistikbanken.dk/HALM, 2018
[23] https://www.dst.dk/da/Statistik/dokumentation/statistikdokumentation/hoesten-af-korn--raps-og-baelgsaed

Table 10. Current straw use in Region Zealand [1000 t]

Use	2010	2011	2012	2013	2014	2015	2016
Total amount of straw[24]	1,210	1,174	1,346	1,355	1,426	1,319	1,157
Energy production[25]	510	442	385	449	361	369	379
Feed	106	93	116	92	87	97	61
Bedding material	60	77	76	83	63	49	68
Not harvested	534	563	770	730	914	804	649

Table 11. Straw import and export in Region Zealand [1000 t]

Import/export	2010	2011	2012	2013	2014	2015	2016
Import (assumption)	0	0	0	0	0	0	0
Export to The Capital Region of Denmark - for energy production[26]	214	152	102	161	86	84	86

Table 12. Characterization of winter wheat straw

Parameter	Unit	Wheat straw
DM content [27,28]	[%]	80-90
Methane potential	[m^3/tonne]	245
N content[29]	[g/kg]	5.3
P content	[g/kg]	0.90
K content	[g/kg]	17.0
Protein content	[%]	3.3
Hemicellulose content[30, 31]	[%]	21-35
Cellulose content	[%]	25-30
Lignin content	[%]	15-19
Starch	[%]	0
Sucrose	[%]	0
Ash	[% of DM]	3.1

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[24] Statistics Denmark, HALM (2018), http://www.statistikbanken.dk/HALM, 2018
[25] Energiproducenttælling 2009-2016, Energistyrelsen
[26] Energiproducenttælling 2009-2016, Energistyrelsen
[27] Fodermiddeltabellen 2017, https://svineproduktion.dk/Viden/Paa-kontoret/Oekonomi_ledelse/Beregningsvaerktoejer/Fodervaerktoejer
[28] https://www.ecn.nl/phyllis2/Browse/Standard/ECN-Phyllis#strow
[29] Biogasdatagrundlaget regneark, NIRAS 2012
[30] Prasad Kaparaju et al., 2009. Effect of reactor configuration on biogas production from wheat straw hydrolysate, Department of Environmental Engineering, Technical University of Denmark.
[31] Danmarks potentiale for afgrødebaseret biobrændstofproduktion i år 2020, 2008, DTU Risø

Material flow for grain production

Table 13. Current material flow in Region Zealand (2016)

Step 1 – Cultivation	**Unit**	**Current**
Land use [32]	[ha]	335,400
Energy use [33]	[TJ]	4,659
Nitrogen (N)	[t]	53,337
Phosphates (P) [34]	[t]	8,250
Potassium (K)	[t]	24,399
Pesticides	[t]	?
Seed	[t]	40,782
Step 1 – Harvest		
Grain production, total	**[t DM]**	**2,211,600**
Straw harvest potential, total	**[t DM]**	**1,157,000**
Not harvested straw - Left on fields	[t DM]	649,000
Straw harvested for energy production in CHP plants	[t DM]	379,000
Straw harvested for feed	[t DM]	61,000
Straw harvested for bedding material	[t DM]	68,000
Total biomass	**[t DM]**	**3,368,600**
Step 2- straw harvest		
Total grain production, total	[%]	100
Total straw harvest potential, total	[%]	100
Not harvested straw - Left on field	[%]	56
Straw harvested for energy production in CHP plants	[%]	33
Straw harvested for feed	[%]	5
Straw harvested for bedding	[%]	6
Step 3- Grain and straw use		
Grain after loses	[t DM]	**2,211,600**
Import[32]	[t DM]	128,273
Export	[t DM]	440,108
From stock	[t DM]	143,754
Milling	[t DM]	91,958
Industry use	[t DM]	79,697
Feed use	[t DM]	1,800,340
Seed	[t DM]	69,480
Straw use		

[32] Statistics Denmark, KORN (2018), http://www.statistikbanken.dk/KORN
[33] Energiforbrug i landbruget
[34] Based on norms for optimal distribution of crops per hectare

Straw harvested for energy production in CHP plants	[t DM]	379,000
Straw ash (3.5%)[35]	[t DM]	13,365
Deposited	[t DM]	
Use for concrete production	[t DM]	
Bio-ash use for cultivation	[t DM]	
Straw harvested for bedding material	[t DM]	61,000
Deep litter to biogas plants	[t DM]	0
Used for cultivation	[t DM]	
Straw use for feed	[t DM]	60,000
Manure used for cultivation	[t DM]	

[35] Halm til energi, Inbiom

2.1.2 Regional resources in Germany

Assessed by Moritz Westkämper, Agency for Renewable Resources, Germany

Straw is a residue product, which accumulates during the cereal production respectively harvesting. It can be dried on the field. With not more than 18 % moisture it is possible to store it, either on the field or in storage halls. Cereals are usually harvested between June and August.
There are different ways to use the straw. The vintage way is to use straw as bedding for animals but the energetic use is becoming more and more interesting.[36]
More than half of the arable land in MWP[37] is used for crop and grain production (52.7 %). This number equals 567,000 ha and means that MWP has the biggest production land in East-Germany. In the region, 20-25 % of the arable land are used for winter wheat in 2016.[38]
First, straw is used as bedding material in order to ensure reproduction of organic soil substances. Annually, there are 26 million tonnes straw, 9.5 million tonnes of oleiferous plants and grain maize as well as 3 million tonnes beet tops (2011) available in Germany[39]. Overall, there are appr. 40 Mio t of straw in Germany from which 50.000 tonnes are used for energy production annually.[40]

There is an ongoing discussion about how much straw needs to be left on the arable land in order to ensure a secure humus balance. The proposed leftover of straw varies from 10 % to more than 50 %. It is obvious that these proposed numbers rely on different soil quality and environment circumstances.[41]

[36] For more information visit the exemplary cases on the BioBIGG homepage
[37] MWP = Mecklenburg-Western Pomerania
[38] Kaltschmitt, Martin, et. al.: Angebaute Biomasse. In: Energie aus Biomasse. 2009. S. 108ff.
[39] Data in dry matter (DM)
[40] Dr. Vetter, Armin: Stroh – goldwerter Rohstoff für die Bioenergie. DBFZ-Jahrestagung 2014. S45f.
[41] Nachhaltig nutzbares Getreidestroh in Deutschland (Juli 2008). IFEU Positionspapier. p. 3f.

Quantification of feedstock, products and residues

Table 14. Crop cultivation area [ha] for selected crops in Mecklenburg-Western Pomerania [42,43]

	2005	2006	2007	2008	2009	2010[42]	2015[42]	2016[42]
Cereals (without grain maize)	639580	630120	616848	651800	644410	559168	56740	555543
Bread cereals	373220	366280	367276	396020	398540			
Wheat	317380	311470	299207	321350	322600	350264	35180	342096
Common wheat	316350	310290	298450	320700	321480			
Winter wheat	311010	305830	295477	316390	317840	347968	34830	331035
Summer wheat	53300	44600	29730	43100	36400	2296[44]	3500[44]	2600[44]
Durum wheat	10300	11700	7574	6500	11200			
Rye	549100	538900	670939	736900	749400			
Maslin	9400	9200	9753	9700	10000	62787[45]	60900[45]	55635[45]
Fodder cereals	266370	263840	249571	255780	245870			
Barley	194680	202530	191687	196170	187790	119085	12960	134431
Winter barley	134450	148330	142405	141820	145170	114576	12260	121610
Summer barley	602300	542000	492819	543500	426200	4509	700	12821
Oat	209900	183700	177831	179500	162600	5604	8800	7182
Mixed grain	26200	24800	19974	17800	17200			
Triticale	480800	404600	381036	398800	401100	15256	11300	11908
Grain maize (incl. CCM)	443100	401000	403210	520500	464300	4631	3400	2964
Grain maize	343500	301800	307483	415300	359800			
Corn cob mix	99600	99200	95727	105100	104600			
Oil seeds	139240	148320	157862	140470	150680			
Rape and canola	134390	142900	154817	137070	147120			
Winter rape	132310	140990	153861	136340	146440			
Summer rape, winter and summer	20900	19000	9567	7300	6800			
Grain sunflowers	27100	32000	19161	24900	23600			
Flax	14400	13700	6087	4200	4100			
Other oil seeds	6900	8500	5199	4900	7900	252700[46]		229500[46]

Table 15. Grain/straw ratio for selected cereals (data extracted from Table 14)

Crop	Straw ratio
Wheat	1:0.8
Rye	1:0.9
Barley	1:0.9
Oat	1:1.1

[42] https://www.laiv-mv.de/static/LAIV/Abt4.Statistisches%20Amt/Dateien/Publikationen/Statistisches%20Jahrbuch/Aktuell%20nach%20Kapiteln/20_Land-_und_Forstwirtschaft_Fischerei.pdf (Last access: 05.07.2018)
[43] Gurgrel, Andreas; Stölken Bodo (2011): Nährstoff- und Humusbilanzen beim Einsatz von Biogasgärresten in Betrieben mit Anbau von Silomais in Mecklenburg-Vorpommern. Landesforschungsanstalt für Landwirtschaft und Fischerei Mecklenburg-Vorpommer. Institut für Acker- und Pflanzenbau. S. 1.
[44] Summer wheat incl. durum wheat
[45] Rye and maslin
[46] https://www.laiv-mv.de/static/LAIV/Statistik/Dateien/Publikationen/Z%20Faltbl%C3%A4tter/Z%20961/Z961%202016%2001.pdf (accessed 15.02.2019)

The following graph shows that the distribution of cereal cultivation in MWP in 2016. It is obvious that winter wheat (59.6 %), winter barley (21.9 %) and rye (10.0 %) are the dominant cultivated cereals.

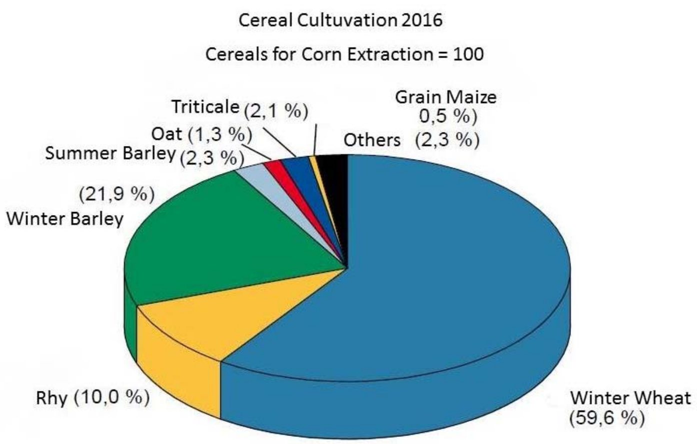

Figure 6. Cereal cultivation in Mecklenburg-Western Pomerania in 2016 [47]

With >600,000 tonnes DM of straw and stubble supply in 2012, MWP belonged to the areas with the largest amount of agricultural biomass coming from straw and stubbles. Other regions can be found in Northern France, Northern Ukraine, central Germany and East Anglia.[48]
In MWP approx. 4.5-6 tonnes per hectare of cereal cultivation area are produced per year. Figure 7 shows the quantity of annually produced cereal straw in Germany relative to the area cultivated with cereal crops [t/ha/a] (avg. of the years 1999, 2003 and 2007) and therefore belongs to the areas in Germany with the highest rate of produced cereal straw.
Below you can see the crop yield of several cereals in MWP from the years 2016 and 2016.

Table 16. Crop yield of several cereals [dt/ha] in Mecklenburg-Western Pomerania[49]

Cereals	**2016**	**2017**
Grain maize and CCM	62.3	27.2
Winter wheat	67.7	57.1
Rye and maslin	52.0	52.9
Winter Barley	58.7	79.1
Summer Barley	41.7	49.1
Oat	40.3	43.3
Triticale	44.6	51.2
Rape, Canola and Winter Rape	26.6	29.7
Summer Rape, Canola and Summer Rape	17.2	-

[47] https://www.laiv-mv.de/static/LAIV/Abt4.Statistisches%20Amt/Dateien/Publikationen/Statistisches%20Jahrbuch/Aktuell%20nach%20Kapiteln/20_Land-_und_Forstwirtschaft_Fischerei.pdf (Last access: 05.07.2018)
[48] Atlas with regional cost supply biomass potentials for EU 28, Western Balkan Counties, Moldavia, Turkey and Ukraine. In: S2Biom Project Report (19.04.2017). D1.8. Issue: 1.1.Figure 7. p. 22
[49] https://www.laiv-mv.de/static/LAIV/Statistik/Dateien/Publikationen/C%20I%20Bodennutzung%20und%20Anbau/C%20103/C103%202017%2000.pdf (Last access: 06.07.2018)

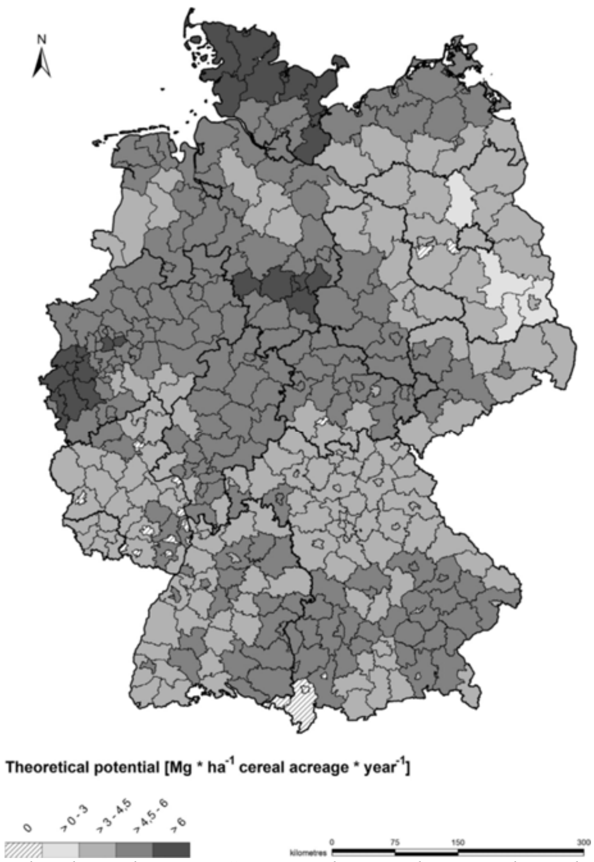

Figure 7. The quantity of annually produced cereal straw in Germany relative to the area cultivated with cereal crops [t/ha/year] (average of the years 1999, 2003 and 2007)

Table 17. Cereal straw potential in Mecklenburg-Western Pomerania [Mt/a][50]

Theoretical potential	Technical potential	Lower straw requirements	Higher straw requirements	According to the dynamic humus method
2839	1575	1417	1245	509

Table 17 shows the theoretical and technical cereal straw potentials in MWP, and furthermore, how assumptions about the straw required for upholding the soil organic carbon balance lead to lower sustainable straw protentials for soils with lower and higher “humus demand”. The sustainable straw potential according to requirements as calculated by the dynamic humus method also takes the sources of nitrogen into consideration and assumes a lower contribution to soil organic carbon from straw.

[50] C. Weiser et al.(2014): Integrated assessment of sustainable cereal straw potential and different straw-based energy applications in Germany. In: Applied Energy Journal. 114. p. 758.

2.1.3 Regional resources in Poland

Assessed by Dariusz Mikielewicz, Rafał Andrzejczyk, Paweł Dąbrowski & Jan Wajs, Gdańsk University of Technology, Poland

Pomeranian region (pomorskie) is dominated by crop production with little participation in animal husbandry. This region contain mainly large-scale farms that facilitate straw handling logistics. Warmia and Mazury and West Pomeranian (zachodniopomorskie) regions have also a surplus of straw that should be used to make benefits. Cereal straw is a biomass source used in Poland mainly for purposes of e.g. heating purposes, as well as bedding for animals, plant cover, mats and fertilizers. It should be emphasized also that recently the straw has been often used as a fuel in the co-firing process. However, changes in the proportion of plants and the increase in its demand for mushroom production were resulted in deficiencies of this raw material on the local market and significant increase in prices. In general, the same as in Sweden, cereal and oilcrop straw in Poland are much decentralised resources. We have described the straw value chain based on the example of straw used to mushroom substrate production. It should be noted that Poland are the largest producer of mushrooms in UE [51]. What is more in north part of Poland there are localized the biggest mushroom companies (e.g. Pieczarki Mazurskie Fedor in Warmia and Mazury region – an example of which will be discussed in the further and the typical feedstock handling chain for straw there is presented in Fig. 2.). Similarly as in Sweden if straw is not to be removed, it is usually (partly) chopped in the combined harvest of the grain. The chopped straw is then incorporated into the soil together with the remaining stubble. If the straw is to be removed, the straw is often cut, but not chopped inside the combine harvester and put back onto the field. After windrowing (and further field drying), the straw is pressed in to bales. Bales can have different sizes (on average: mass=250-400kg and diameter 120-160mm), of which mostly the larger rectangle bales are used for large-scale resource handling. In baling, the density of the straw is increased considerably to reduce the transportation costs. The recent communication with the Pieczarki Mazurskie Fedor representatives indicate that due to some economic reasons the chopped straw is mainly left on the field for nourishing the soil. For that reason the market price of straw soared to about 250 PLN per tonne (about 60€/tonne).

For post-baling operations different transportation logistics are available, e.g. loading on tractor- or truck-drawn trailers. Also for storage of straw a variety of solutions are available including non- or partly covered stacks, completely covered tubes, as well as roofed or in-house storage. Mushrooms companies usually use non-covered stacks.

[51] https://www.agrofakt.pl/polska-produkcja-pieczarek/

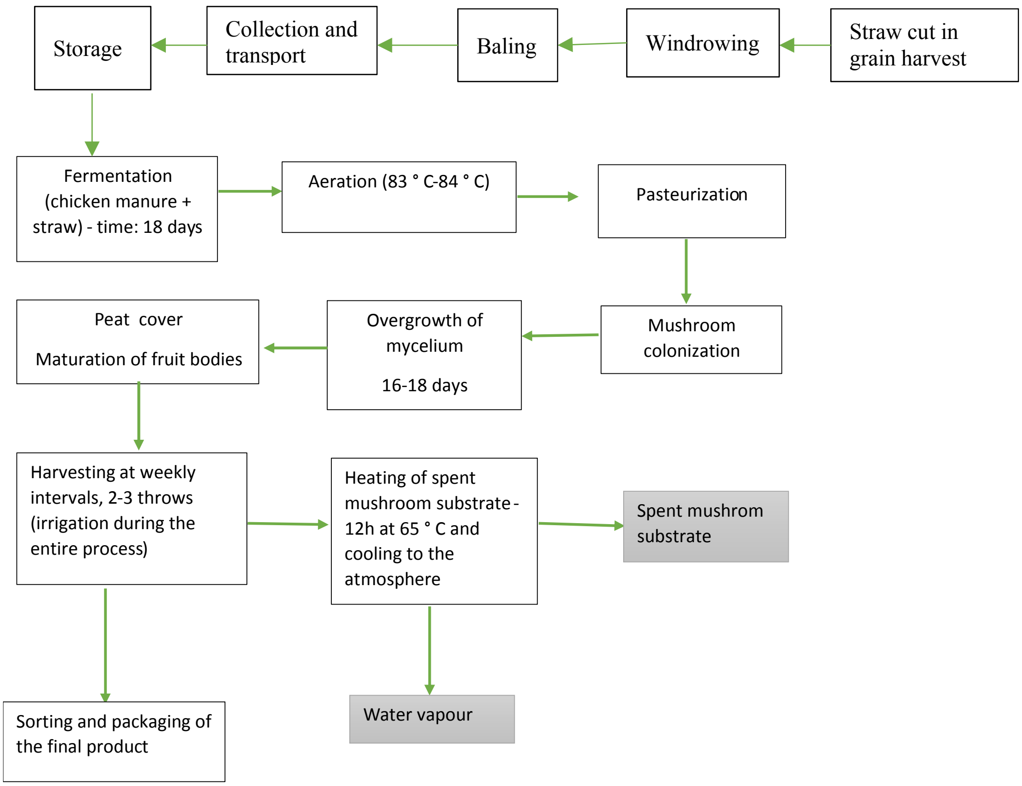

Figure 8. Typical feedstock handling chain for straw in Poland.

Products along the value chain and utilization today

Straw is a by-product from cereal grain and oilseed production. No further by-products occur until storage of the straw. Other by-products from cereal grain and oilcrop seed production were outside the focus of this study and were not further investigated.

Quantification of feedstock, products and residues

Cereals and oilcrops are grown on large areas in Pomerania, West Pomerania and Warmia and Mazury regions. Data about cultivation of these crops are shown in Table 18.

Table 18. Average cereal and oilcrop cultivation area for the Polish SBA regions for the year 2017 and share of total Polish cultivation area for these crop types[52,53,54].

SBA region	Cereals		Oilcrops	
	[ha]	[%]	[ha]	[%]
Pomerania	401,800	5.2	80,100	8.9
West Pomerania	408,400	5.3	100,800	11.0
Warmia and Mazury	368,900	4.8	69,200	7.5

[52] Stastitical yearbook 2017, Statistical office in Gdańsk
[53] Stastitical yearbook 2017, Statistical office in Olsztyn
[54] Stastitical yearbook 2017, Statistical office in Szczecin

Cereal crops include winter wheat, spring wheat, winter barley, spring barley, winter rye, spring rye winter, spring oat, winter oat, winter triticale, spring triticale, whereof wheat and triticale are the predominant cereal crops. Oilcrops include rapeseed, turnip and oilflax, whereof rapeseed represents the major oilseed crop in Poland. West Pomerania is by far the most important region for oilcrop production in north part of Poland.

By-products/residues along the chain and end products

The total technical potential of straw in Pomerania, Warmia and Mazury and West Pomerania regions is around 6,624,000 tonnes annually[55] of which about 55% is derived from wheat and oat production (Figure 9). Straw from other cereals and from oilcrops represent 35% and 10% of the total straw potential. The theoretical potential of straw is significantly larger than technical. It is because of the fact that theoretical straw potential is estimated based on relation between grain mass and straw mass in whole mass of plant. Nevertheless according to the recent literature this approach can give large calculation errors. Here, a grain/straw mass ratio of (1:0.46) was used for calculating the theoretical straw potential [56]. Finally total potential of Poland as far as straw was calculated as 22,337,000 tonnes. In calculations of technical straw potential the following cases were excluded:

1. Straw demand for bedding
2. Straw demand for direct animals feeding
3. Straw incorporated into the soil (fertilizer).

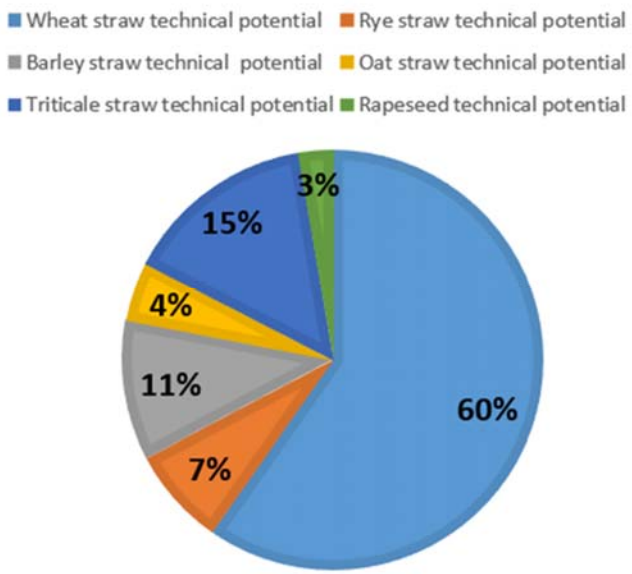

Figure 9 Straw technical potential for different cereals in Pomerania, Warmia and Mazury and West Pomerania Regions regions[57,58,59]

[55] http://biomasa.pw.iung.pl/geoportal_wizualizacje_wynikow.html#wojewodztwa
[56] Wiesław Denisiuk, SŁOMA – POTENCJAŁ MASY I ENERGII, Inżynieria Rolnicza 2(100)/2008
[57] dr Małgorzata Rogalska, Rynek Biomasy stałej w Polsce.
[58] Report by Instytut Upraw Nawożenia i Gleboznawstwa w Puławach
[59] GUS Produkcja Upraw Rolnych i Ogrodniczych w 2016 r.

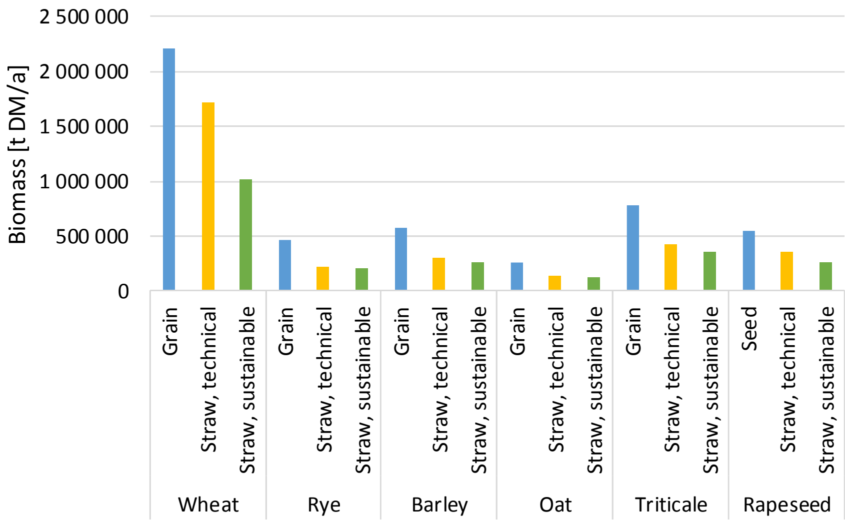

Figure 10. Grain production and straw potential [t DM] for different crop types in the Pomerania Warmia and Mazury and West Pomerania regions[58,59]

In 2009, the major part of the removed straw was used as bedding material in animal husbandry and used in energy purposes[57] (Figure 11). Other major uses included direct feeding and soil fertilization.

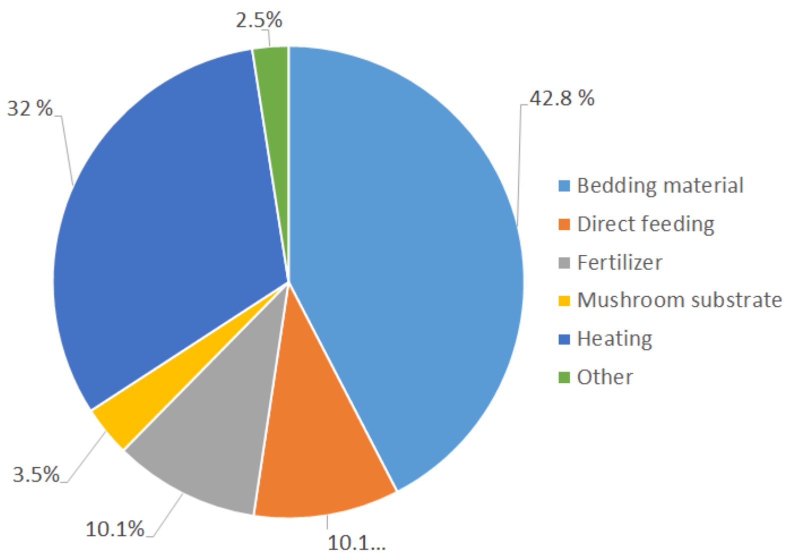

Figure 11. Utilisation pathways for straw and other crop residues in Poland 2009[60]

In terms of cereal straw availability as feedstock, the Pomerania region is the one with the highest feedstock intensity. This region has the largest technical potential for wheat and oat straws. These cereals they are the most common crops in north part of Poland (see Figure 12-Figure 17).

[60] Małgorzata Rogalska, PhD - Market of Solid Biomass in Poland (in Polish)

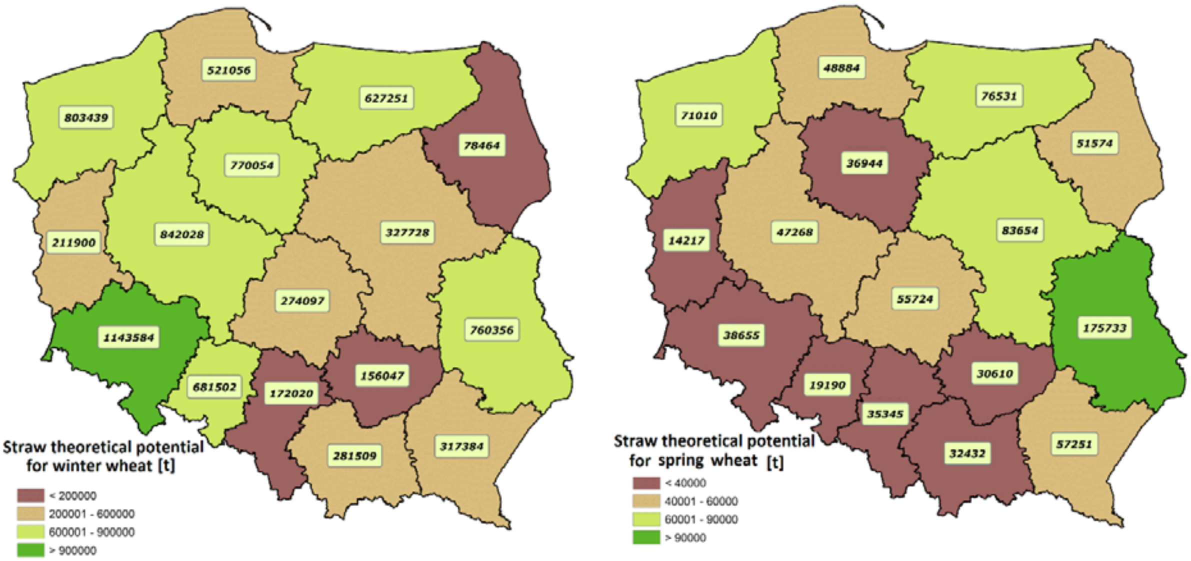

Figure 12. The technical potential of straw for wheat in Poland. Data represents average (2011-2015)[58]

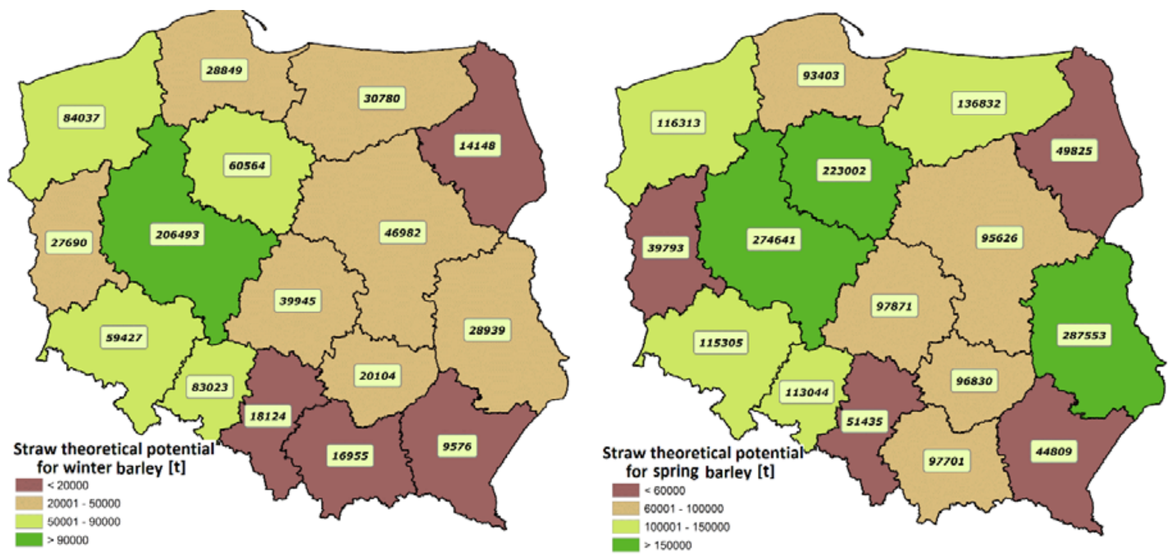

Figure 13. The technical potential of straw for barley in Poland. Data represents average (2011-2015)[58]

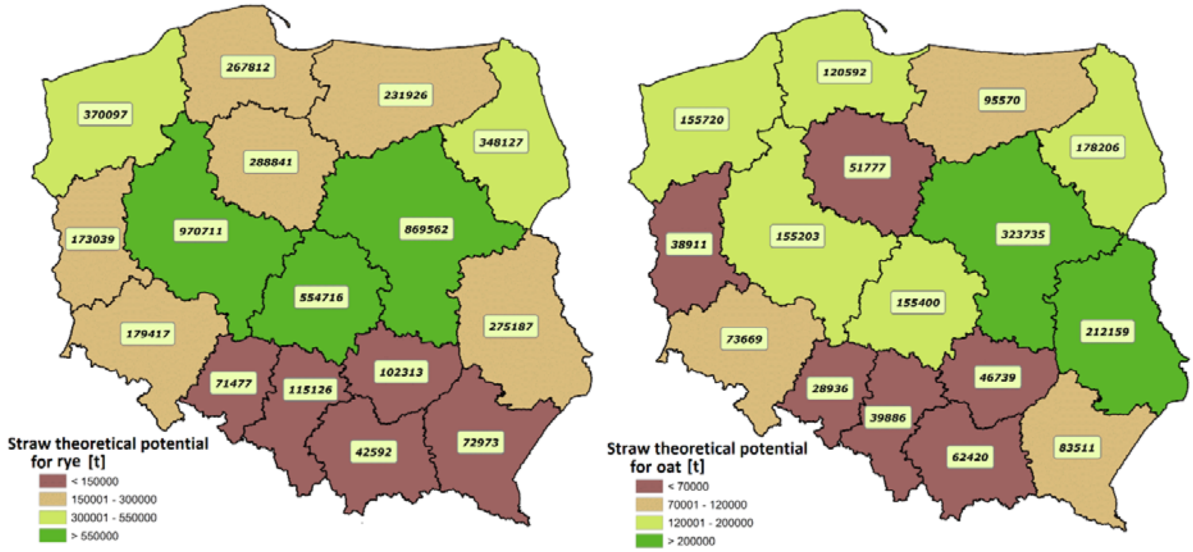

Figure 14. The technical potential of straw for rye and oat in Poland. Data represents average (2011-2015)[58]

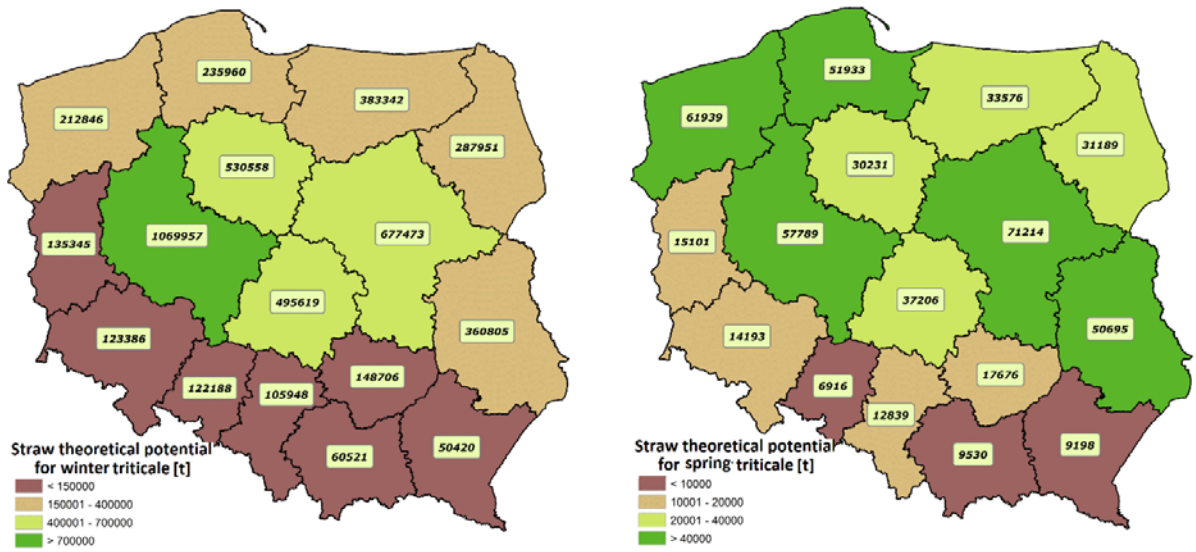

Figure 15. The technical potential of straw for triticale in Poland. Data represents average (2011-2015) [58]

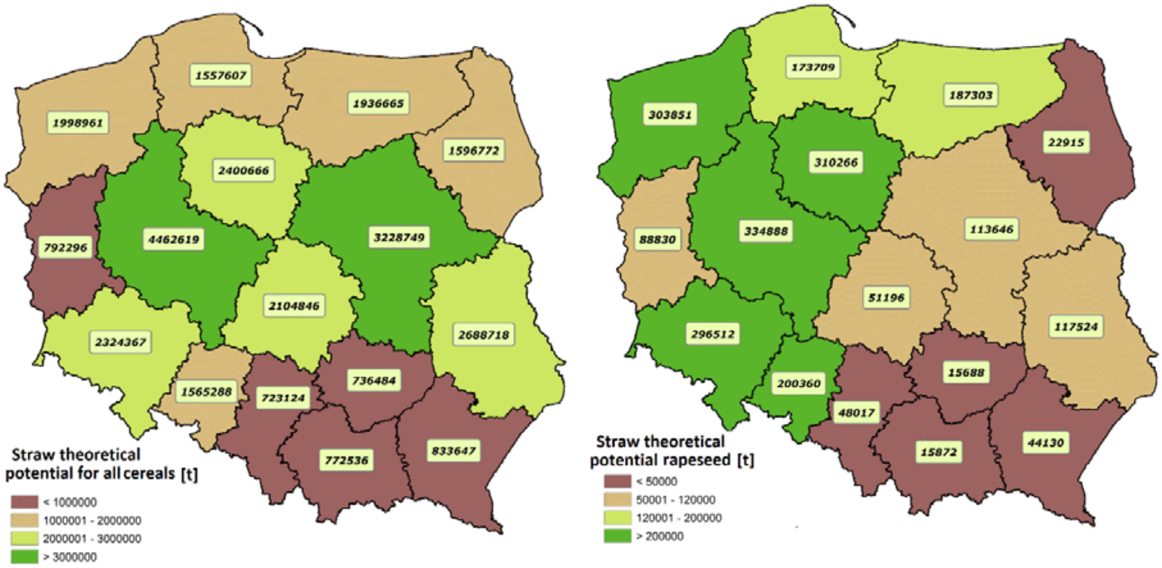

Figure 16. The technical potential of straw for all cereals and rapeseed in Poland. Data represents average (2011-2015) [58]

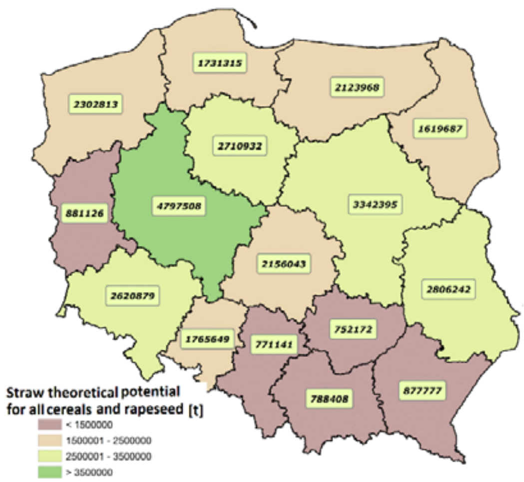

Figure 17. The technical summarized potential of straw for all cereals and rapeseed in Poland. Data represents average (2011-2015) [58]

Characterization of feedstock, products and residues

Table 19. Typical straw composition and properties for selected cereals[61].

Parameter	Unit	Wheat straw	Rye straw	Triticale straw	Barley straw	Rapeseed straw
C	[% DM]	45.6	46.6	43.9	47.5	47.1
H	[% DM]	5.8	6.0	5.9	5.9	5.9
O	[% DM]	42.1	41.9	43.5	45.6	39.3
N	[% DM]	0.5	0.5	0.4	0.5	0.8
S	[% DM]	0.082	0.085	0.056	0.089	0.270
Cl	[% DM]	0.19	0.4	0.26	0.4	0.47
Ash	[% DM]	5.7	4.8	6.0	4.8	6.2
Heating value	[kJ/kg]	17.2	17.5	17.1	17.5	17.1

Table 20 Composition of typical straw and different kinds of manure [62]

Parameter	Unit	Cattle manure	Pig manure	Horse manure	Sheep manure	Av. for straw	Spent mushroom substrate
DM	[%]	20.99	21.44	24.71	26.82	90	40
N	[% DM]	0.47	0.51	0.54	0.75	0.6	0.69
P_2O_5	[% DM]	0.28	0.44	0.29	0.38	0.2	0.36
K_2O	[% DM]	0.65	0.68	0.9	1.19	1.5	0.92
CaO	[% DM]	0.43	0.44	0.43	0.58	-	4.8
MgO	[% DM]	0.15	0.18	0.16	0.19	-	0.28
Na_2O	[% DM]	0.1	0.11	0.06	0.12	-	-
P	[% DM]	-	-	-	-	-	0.16
K	[% DM]	-	-	-	-	-	0.76
Ca	[% DM]	-	-	-	-	-	3.43
B	[mg/kg DM]	20.9	15.9	13.6	18.4	0.6	-
Cu	[mg/kg DM]	21.5	22.5	12.3	18.4	0.2	7.9
Mn	[mg/kg DM]	345	288	270	290	1.6	110
Mo	[mg/kg DM]	1.66	1.57	0.94	1.23	-	-
Zn	[mg/kg DM]	173	213	94	112	-	51
Co	[mg/kg DM]	1.8	1.46	1.02	0.86	-	-

[61] dr inż. H. KARCZ, mgr inż. M. KANTOREK, mgr inż. M. GRABOWICZ, prof. dr hab. K. WIERZBICKI, Możliwość wykorzystania słomy jako źródła paliwowego w kotłach energetycznych (The feasibility of straw as a fuel source for power generating boilers), przemysłowe & kotły XI-XII/2013
[62] Test results provided by Fedor Mazurskie Mushrooms, 2018

Mass balance

Table 21. Mass balance for the production of mushrooms on a straw-based substrate.

		Today
Step 1		
Straw	[t DM]	8 710
Poultry manure	[t DM]	8 710
Peat	[t DM]	1 300
Total	[t DM]	18 720
Step 2		
Compost	[%]	100
Compost	[t DM]	18 720
Step 3		
Spent mushroom substrate	[t DM]	15 600

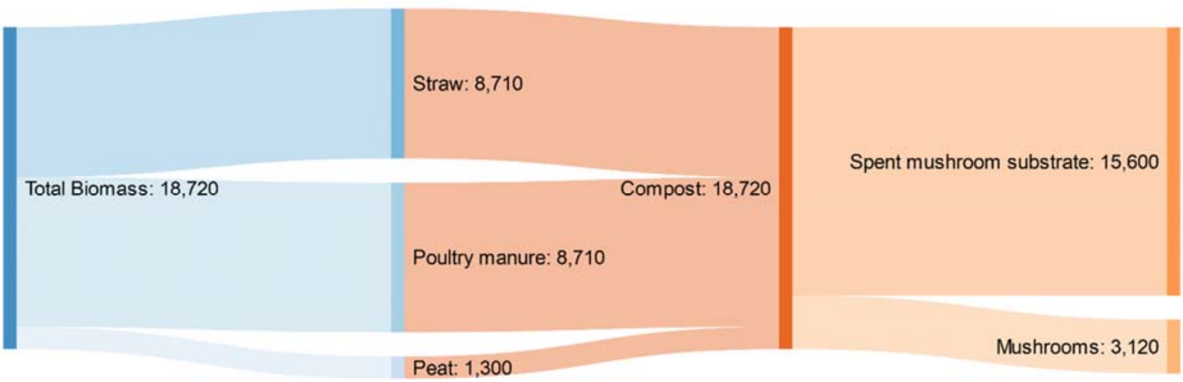

Figure 18. Mass balance for the production of mushrooms on a straw-based substrate.

2.1.4 Regional resources in Sweden

Assessed by Thomas Prade, Swedish University of Agricultural Sciences

The region of Skåne is characterised by a large share of agricultural land, with good soils promoting the production of cereals and oilcrops, which typically represent a large share in typical crop rotations in the Swedish SBA regions.

Cereal straw is a biomass source traditionally used for purposes of e.g. bedding material but also for construction and heating purposes. Currently, straw is not used in Sweden as an industrial resource in the same extent as for instance in Denmark, where straw has been developed as a major feedstock by means of a subsidy system and policy measures[63]. Straw as a solid fuel for combined heat and power production in Skåne was investigated but plans for a straw boiler in Örtofta were abolished due to difficulties in receiving an environmental permit[64], despite sufficient availability of straw[65]. This was mainly due to the extent of the expected environmental impact from straw transport, which many people in the vicinity of the planned power planned opposed.

In general, cereal and oilcrop straw are much decentralised resources, but with a well-developed and mature supply chain. Therefore, we have described the value chain of straw in terms of a potential value chain, not in the form of specific cases.
If straw is not to be removed, it is usually (partly) chopped in the combine harvest of the grains. The chopped straw is then incorporated into the soil together with the remaining stubble. If the straw is to be removed, the straw is often cut, but not chopped inside the combine harvester and put back onto the field. After windrowing (and further field drying), the straw is pressed in to bales. Bales can have different sizes, of which mostly the larger rectangle bales are used for large-scale resource handling. In baling, the density of the straw is increased considerably to reduce the transportation costs.

Figure 19. Typical feedstock handling chain for straw.

For post-baling operations different transportation logistics are available, e.g. loading on tractor- or truck-drawn trailers. More advanced systems with self-loading bale trailers are known to be used from North America. Also for storage of straw a variety of solutions are available including non- or partly covered stacks, completely covered tubes, as well as roofed or in-house storage.

Products along the value chain and utilization today

Straw is a by-product from cereal grain and oilseed production. No further by-products occur until storage of the straw. Other by-products from cereal grain and oilcrop seed production were outside the focus of this study and were not further investigated.

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[63] Bentsen, N.S., Nilsson, D., Larsen, S. 2018. Agricultural residues for energy - A case study on the influence of resource availability, economy and policy on the use of straw for energy in Denmark and Sweden. Biomass and Bioenergy, 108, 278-288.
[64] Löfstedt, D. 2012. Sex år för att få tillstånd att bygga värmeverk, Second Opinion. Enskede, Sweden.
[65] Mattsson, J.E. 2006. Affärsutveckling - Närodlade stråbränslen till kraftvärmeverk. Landscape Management and Horticultural Technology, Swedish University of Agricultural Sciences. 2006:8.

Primary production

Cereals and oilcrops are grown on large areas in Skåne and cultivation of these crops cover on average 50 and 10% of the total arable land area, respectively (Figure 20). Cereal crops include wheat, barley, rye, triticale and oat, whereof wheat and barley are the predominant cereal crops with 85% on average. Oilcrops include rapeseed, turnip and oilflax, whereof rapeseed represents the major oilseed crop in Sweden.

The Swedish counties within the SBA region represent 27 and 44% of the cereal and oilcrop cultivation area in Sweden, respectively. Skåne is by far the most important county in the Swedish SBA region for both cereal and oilcrop production, representing 80 and 89% of the cultivation area, respectively.

Table 22. Average cereal and oilcrop cultivation area for the Swedish SBA regions for the years 2012-2016 and share of total Swedish cultivation area for these crop types[66].

SBA region	Cereals		Oilcrops	
	[ha]	[%]	[ha]	[%]
Skåne	219679	21	44940	39
Blekinge	10189	1	1028	1
Kronoberg	8556	1	237	0
Kalmar	36908	4	4343	4
Sweden	1036756	100	115149	100

Within Skåne, the 10 largest municipalities hold more than 60% of the cereal and oilcrop cultivation area (Figure 20).

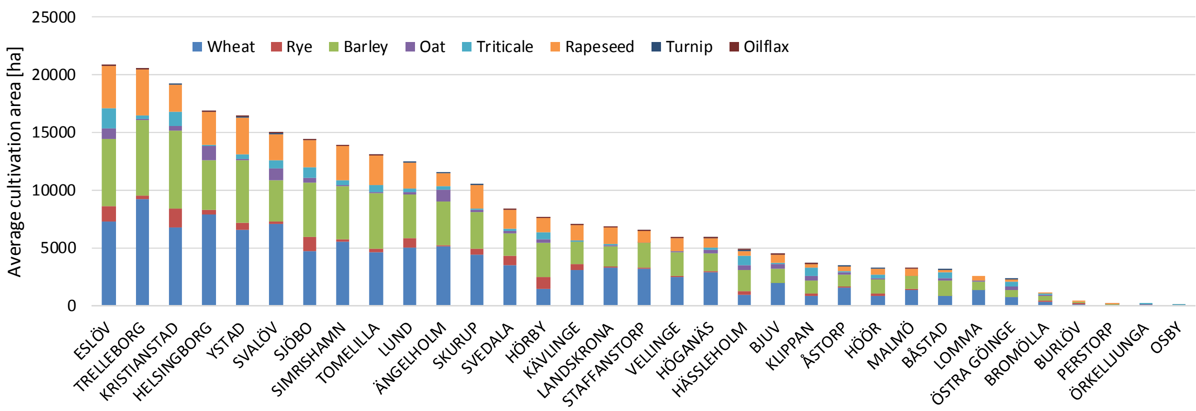

Figure 20. Average cultivation area of cereals and oilcrops in Skåne´s municipalities for the years 2012-2016 [67].

[66] SBA. 2018. Åkerarealens användning efter kommun och gröda, hektar. År 1981-2017, (Ed.) Swedish Board of Agriculture. Jönköping, Sweden.
[67] SBA. 2018. Åkerarealens användning efter kommun och gröda, hektar. År 1981-2017, (Ed.) Swedish Board of Agriculture. Jönköping, Sweden.

By-products/residues along the chain and end products

Straw potentials were calculated from grain yield and crop- and county-specific grain-straw ratios as presented by Henriksson & Stridsberg[68] in combination with recovery coefficients for straw as presented by Nilsson & Bernesson[69]. The full calculation method is described in Prade et al.[70].

The technical potential of straw in Skåne is around 785,000 tonnes annually, of which about half is derived from winter wheat production (Figure 21). Straw from other cereals and from oilcrops represent 34% and 17% of the total straw potential. Of the produced cereal and oilcrop straw, 29% or approx. 227,000 tonnes are not removed due to weather conditions or for reasons of soil fertility maintenance and 38% or approx. 299,000 tonnes are removed for various uses. The remaining 33% or approx. 260,000 tonnes could be removed sustainably for additional applications.

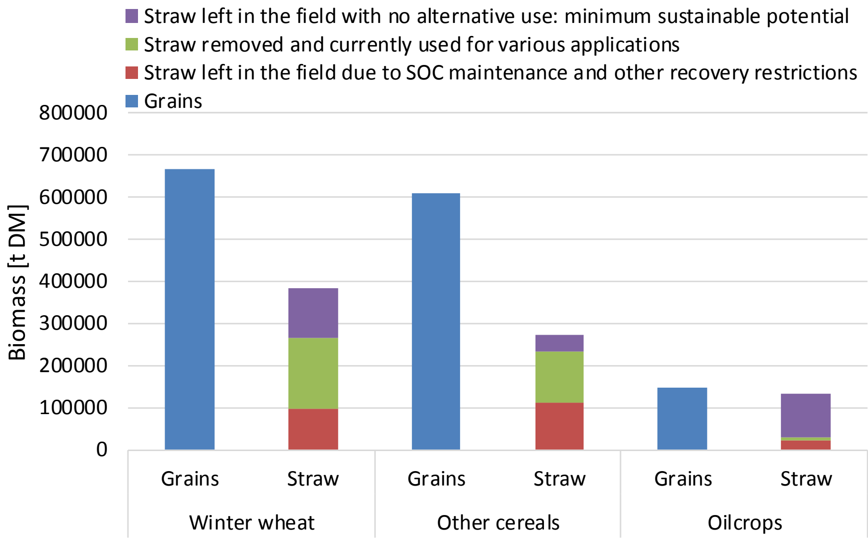

Figure 21. Grain production and straw potential in tonnes of dry matter [t DM] for different crop types in the county of Skåne based on average grain production 2012-2016. All straw fractions together represent the technical potential for each column.

In 2012, the major part of the removed straw was used as bedding material in animal husbandry (Figure 22). Other major uses included heating and direct feeding.

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[68] Henriksson, A., Stridsberg, S. 1992. Möjligheter att använda halmeldning till energiförsörjningen i södra Sverige. Department of Agricultural Engineering, Swedish University of Agricultural Sciences.
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[70] Prade, T., Björnsson, L., Lantz, M., Ahlgren, S. 2017. Can domestic production of iLUC-free feedstock from arable land supply Sweden's future demand for biofuels? Journal of Land Use Science, 12(6), 407-441.

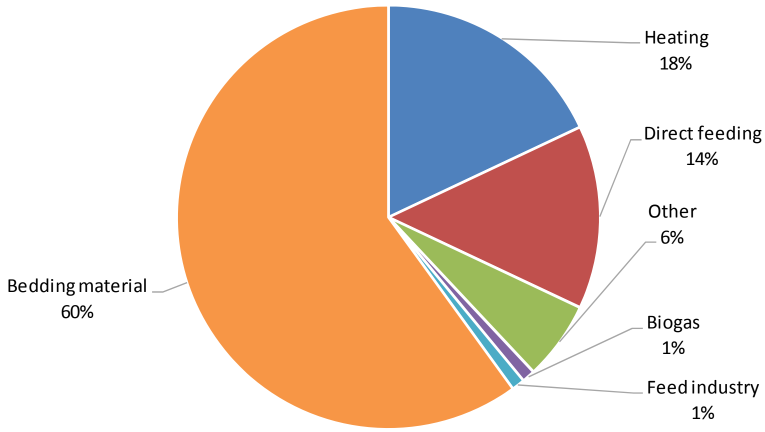

Figure 22. Utilisation pathways for straw and other crop residues in Skåne 2012[71].

In terms of cereal straw availability as feedstock, the southern and western part of Skåne are the areas with the highest feedstock intensity, larger than 60 t DM/km^2 (Figure 12).

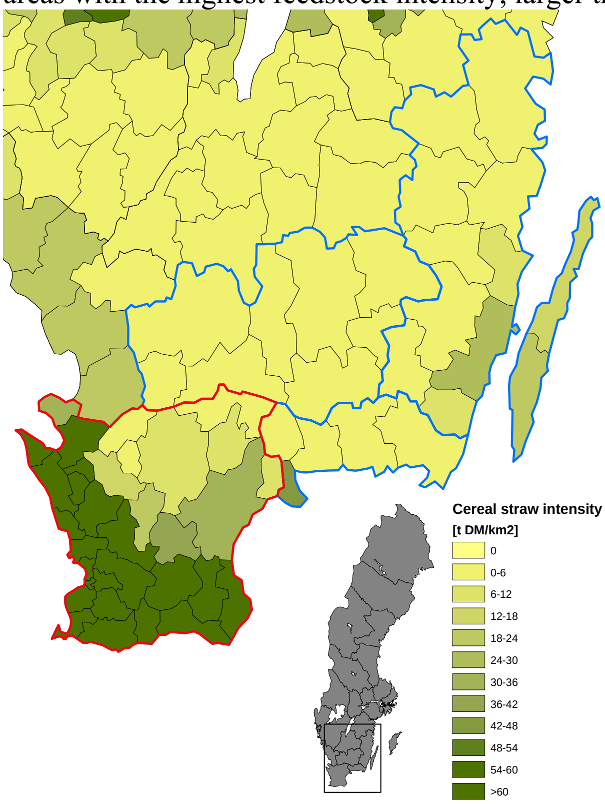

Figure 23. Cereal straw intensity in tonnes dry matter per square kilometre [t DM/km^2] representing the technical potential of straw in Skåne (red outline) and the other Swedish Interreg South Baltic regions (blue outline). Data represents average (2013-2017) crop cultivation areas and 2016 normal yields (2001-2015 data basis)[72].

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[71] SCB. 2013. Odlingsåtgärder i jordbruket 2012. Träda, slåttervall, vårkorn, höstspannmål samt användning av halm och blast. Statistics Sweden.
[72] Prade, T., Björnsson, L., Lantz, M., Ahlgren, S. 2017. Can domestic production of iLUC-free feedstock from arable land supply Sweden's future demand for biofuels? Journal of Land Use Science, 12(6), 407-441.

Characterization of feedstock, products and residues in value chain

Table 23. Typical straw composition and properties for all cereals, winter wheat and barley only as well as for oilseed rape.

Parameter	Unit	Cereal straw[a-l]				Winter wheat[a-e, g, i-l]				Barley[i,k,l]				Oilseed rape[k,l]			
		mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n
Protein content	[g/kg d.b.]	3.8	1.5	10	75	3.9	1.8	10	58	4.0	2.5	6	11	10.25	0.5	32	8
Hemicellulose content	[wt% d.b.]	38.3	28.8	51.5	21	37.9	28.8	51.5	18	41.2	32.5	46.0	3	42.0	36.0	45.0	3
Cellulose content	[wt% d.b.]	26.3	10.5	39.1	21	26.8	10.5	39.1	18	23.6	22.0	25.7	3	22.0	19.0	27.0	3
Lignin content	[wt% d.b.]	18.2	8.0	30.0	21	18.3	8.0	30.0	18	18.0	15.0	23.0	3	19.3	18.0	20.0	3
Sugar compostion																	
C5 - Arabinan	[wt% d.b.]	3.9	2.4	7.6	4	2.7	2.4	3.1	3	7.6	7.6	7.6	1	n/a			
C5 - Xylan	[wt% d.b.]	17.5	8.9	21.2	4	20.3	19.2	21.2	3	8.9	8.9	8.9	1	n/a			
C6 - Mannan	[wt% d.b.]	0.4	0.2	0.8	3	0.6	0.3	0.8	2	0.2	0.2	0.2	1	n/a			
C6 - Galactan	[wt% d.b.]	4.1	0.7	9.1	3	1.6	0.7	2.4	2	9.1	9.1	9.1	1	n/a			
C6 - Glucan	[wt% d.b.]	34.9	32.3	38.2	4	35.7	32.3	38.2	3	32.5	32.5	32.5	1	n/a			
HHV	[MJ/kg d.b.]	18.3	15.3	21.9	63	18.2	15.3	20.7	47	18.5	15.7	21.9	10	19.8	17.6	22.0	8
ash content	[wt% d.b.]	6.4	1.3	12.2	86	6.6	1.3	12.2	66	6.0	2.7	10.5	12	5.7	2.9	9.7	10
IDT	[°C]	917	720	1160	13	885	800	940	6	975	720	1160	4	1170	900	1500	6
C	[wt% d.b.]	45.7	37.1	49.0	69	45.7	41.6	48.3	51	45.6	37.1	47.5	10	46.4	38.9	51.1	8
H	[wt% d.b.]	5.6	4.2	6.5	69	5.6	4.2	6.5	51	5.7	5.3	6.1	10	5.7	4.4	6.9	8
O	[wt% d.b.]	41.1	10.2	52.3	67	40.8	10.2	52.3	50	42.0	40.1	46.3	9	40.3	30.8	52.1	8
Cl	[wt% d.b.]	0.39	0.02	2.06	72	0.40	0.02	2.06	53	0.42	0.27	0.98	11	0.32	0.03	0.98	10
N	[wt% d.b.]	0.61	0.24	1.65	75	0.62	0.28	1.65	58	0.63	0.40	0.99	11	1.64	0.08	5.05	8
P	[wt% d.b.]	0.08	0.01	0.29	60	0.08	0.01	0.18	45	0.10	0.03	0.21	8	0.25	0.06	1.12	9
K	[wt% d.b.]	1.00	0.03	2.10	68	1.01	0.16	1.78	51	0.93	0.23	1.38	10	0.89	0.25	1.74	9
S	[wt% d.b.]	0.13	0.01	0.43	71	0.14	0.03	0.43	54	0.12	0.01	0.33	11	0.40	0.21	0.77	7
Si	[mg/kg d.b.]	14391	2777	34000	59	15959	4339	34000	44	9286	2777	17052	9	1200	363	3548	9
Ca	[mg/kg d.b.]	3228	440	7719	64	3193	888	7719	48	3463	1721	5306	9	11044	3516	17000	10
Mg	[mg/kg d.b.]	797	100	3200	62	804	154	1986	47	715	236	1735	8	1676	109	6079	9
K	[mg/kg d.b.]	9969	320	21000	68	10088	1567	17806	51	9303	2278	13800	10	8870	2508	17447	9
Na	[mg/kg d.b.]	732	29	6908	62	758	29	6908	48	438	37	1795	8	1039	47	4908	8
P	[mg/kg d.b.]	833	77	2900	60	777	77	1793	45	955	257	2100	8	2537	605	11245	9
Fe	[mg/kg d.b.]	248.9	42.0	895.3	56	274.5	46.2	895.3	44	111.3	60.2	179.1	6	348.5	28.5	1177.5	8
Al	[mg/kg d.b.]	292.2	11.0	1508.4	56	337.2	28.6	1508.4	44	68.0	22.8	103.7	6	211.0	17.6	808.5	8
Mn	[mg/kg d.b.]	43.2	14.0	288.0	15	21.6	15.6	28.1	9	166.6	45.2	288.0	2	36.3	36.3	36.3	1
Cu	[mg/kg d.b.]	8.6	1.1	134.0	24	3.5	1.9	11.4	15	35.6	2.5	134.0	4	4.1	2.5	4.7	5
Zn	[mg/kg d.b.]	19.3	5.8	57.0	14	15.7	8.5	33.8	8	24.6	24.6	24.6	1	10.8	10.8	10.8	1
Co	[mg/kg d.b.]	1.3	0.1	6.4	11	2.1	0.2	6.4	6	0.2	0.2	0.2	1	1.2	1.2	1.2	1
Mo	[mg/kg d.b.]	0.9	0.3	2.3	13	0.9	0.3	2.3	8	0.4	0.4	0.4	1	0.3	0.3	0.3	1
Ni	[mg/kg d.b.]	1.8	0.1	5.8	14	2.2	0.1	5.8	8	2.3	2.3	2.3	1	1.7	1.7	1.7	1
Cr	[mg/kg d.b.]	7.5	0.5	29.5	14	6.8	0.5	16.6	8	4.5	4.5	4.5	1	19.1	0.5	37.8	2
Pb	[mg/kg d.b.]	1.0	0.0	3.1	24	1.0	0.0	3.1	16	1.5	0.1	2.8	3	4.4	0.4	11.6	4
Cd	[mg/kg d.b.]	0.2	0.0	2.7	23	0.3	0.1	2.7	15	0.1	0.1	0.1	3	0.2	0.1	0.2	4
Hg	[mg/kg d.b.]	0.0	0.0	0.0	10	0.0	0.0	0.0	4	0.0	0.0	0.0	1	0.0	0.0	0.0	4

d.b. = dry basis; n/a = no data available; [a] van Loo and Koppejan (2008)[73]; [b] Miles et al. (1995)[74]; [c] Skrifvars et al (1999)[75]; [d] Gilbe et al. (2008)[76]; [e] Erhardsson et al. (2006)[77]; [f] El Saeidy (2004)[78]; [g] Kaufmann (1997)[79]; [h] Obernberger et al. (2006)[80]; [i] Moilanen (2007)[81]; [j] Launhardt et al (2000)[82]; [k] Kaltschmitt et al. (2000)[83]; [l] ECN (2009)[84].

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[75] Skrifvars, B. J., M. Öhman, A. Nordin and M. Hupa (1999). "Predicting bed agglomeration tendencies for biomass fuels fired in FBC boilers: a comparison of three different prediction methods." Energy & fuels 13(2): 359-363.
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[83] Kaltschmitt, M., S. Deimling, B. Jahraus, P. Heinrich, I. Lewandowski, V. Siegle and H. Spliethoff (2000). Leitfaden Bioenergie - Datensammlung. Gülzow, Germany, Fachagentur Nachwachsende Rohstoffe e. V.: 386.
[84] ECN (2009). PHYLLIS - Database for biomass and waste. http://www.ecn.nl/phyllis, Energy Research Centre of the Netherlands.

2.1.5 Summary and outlook

Straw is a resource that is available in large amounts in all four investigated SBA. The largest proportion of that potential originates from cereal production, with winter wheat as the main crop (Figure 24). Poland has the largest absolut potential for straw extraction despite having the lowest share of cereal and oilcrop cultivation of the four regions (Figure 24).

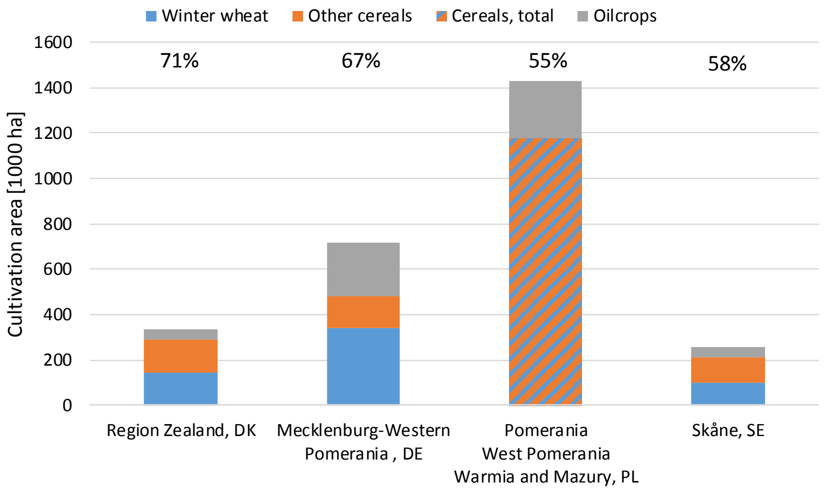

Figure 24. Cultivation area of cereals and oilcrops in the four SBA regions. Numbers above the columns refer to fraction of cereal and oilcrop cultivation area on total arable land.

Technical straw yields per hectare differ substantially between the four SBA regions (Figure 25). Furthermore, the assumptions on what proportion of straw that can be extracted sustainably, between 18-71% (Figure 25).

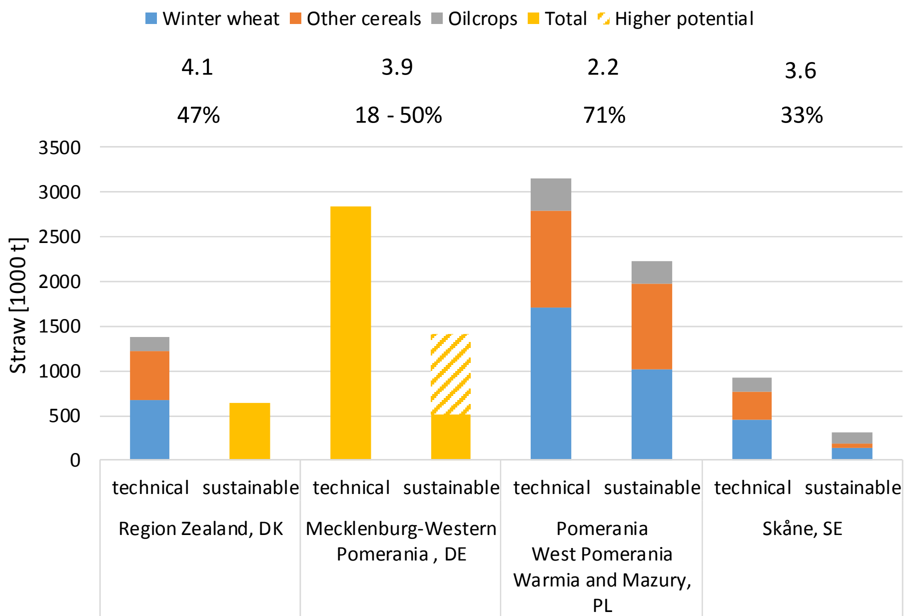

Figure 25. Straw potential (at 15% moisture content) from cereals and oilcrops in the four SBA regions. Numbers above the columns refer to amount of straw [t/ha] (at 15% moisture content) of the technical straw potential and the proportion of the sustainably recoverable straw in reference to the technical straw potential.

Of the four SBA regions investigated in this study, only Region Zealand has developed a large-scale system for utilisation of straw for energy, main as fuel in large-scale combined heat and power (CPH) plants. Region Zealand uses about 35% of it´s straw potential for that purpose, while the corresponding number for Sweden is only 13% (Figure 26). Despite that, Denmark uses less of it´s straw potential compared to Sweden.

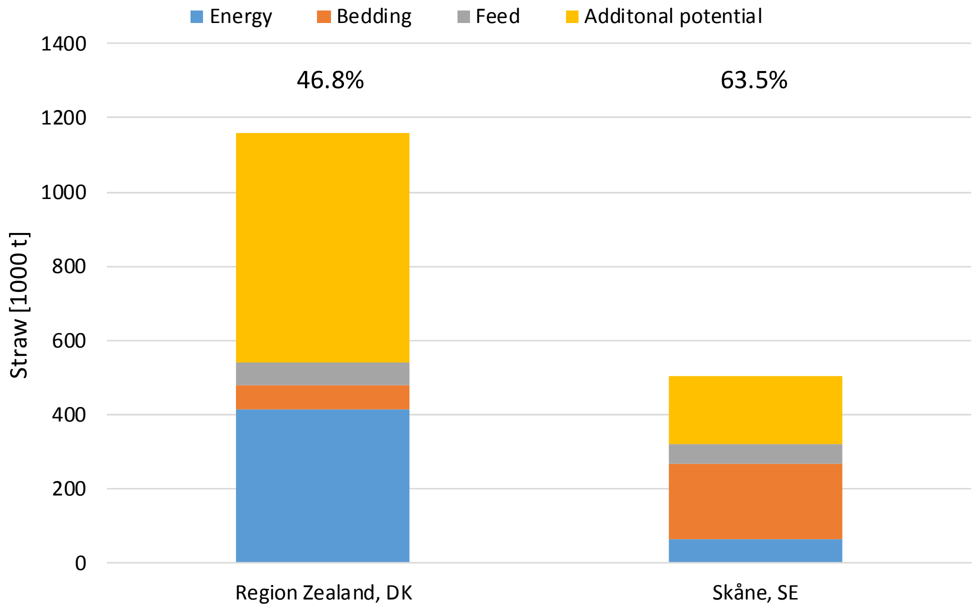

Figure 26. Straw use and potential for the scandinavian SBA regions. Numbers above the columns refer to proportion of straw used [%].

Opportuinities

There are large straw potentials in all investigated SBA regions, and potential to increase the recovery and use of straw on top of the current utilisation. Besides use as solid fuel in heat and power production, straw has been suggested as feedstock for biogas production.
Utilisation of wheat straw as pulp feedstock is currently under upscaling in Sweden[85]. More integrated approaches suggest extraction of valuable wax components (fatty alcohols, alkanes) and paper or ethanol production from the lignocellulosic fraction[86]. Recently, sugars from wheat straw produced at Clariant’s Sunliquid® pre-commercial plant have been tested for production of straw-based isobutene at the Global Bioenergies’ Leuna demo plant[87]. A polymer based on this isobutene is Clariant's new ingredient as a rheology modifier that influences formulation viscosity and achieves specific sensorial and texturizing properties for creams and lotions[88].

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[85] Ringstrom, A. (2019). Essity to try making pulp from wheat straw to stem rising costs. Sustainable business, Reuters.
[86] Clark, J. H., V. Budarin, F. E. I. Deswarte, J. J. E. Hardy, F. M. Kerton, A. J. Hunt, R. Luque, D. J. Macquarrie, K. Milkowski, A. Rodriguez, O. Samuel, S. J. Tavener, R. J. White and A. J. Wilson (2006). Green chemistry and the biorefinery: a partnership for a sustainable future. Green Chemistry 8(10): 853-860.
[87] Global Bioenergies (2019). First production of isobutene from wheat straw at demo scale. Evry, France, https://www.global-bioenergies.com/first-production-of-isobutene-from-wheat-straw-at-demo-scale
[88] Bouwens, T. (2019). Clariant and global bioenergies unveil development of new bio-based cosmetics polymer for more natural formulations. https://www.clariant.com/en/Corporate/News/2018/01/Clariant-and-Global-Bioenergies-unveil-development-of-new-biobased-cosmetics-polymer-for-more-natura, Clariant.

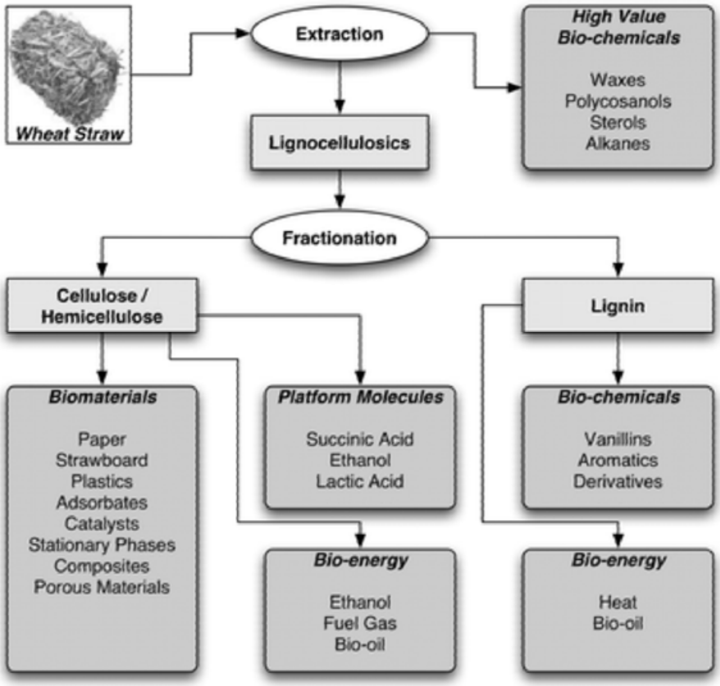

Figure 27. Wheat straw refinery and potential products[86].

A similar concept has been suggested also for oilcrop straw, with the focus on rapeseed straw (Figure 28). Potential products include nanocellulose products, xylan and ligning with product recovery higher than 50% of the original biomass[89].

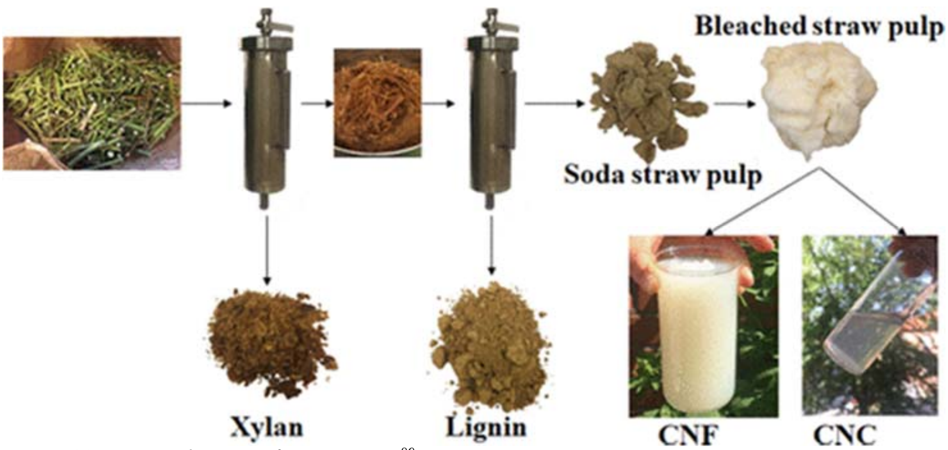

Figure 28. Rapeseed straw refinery concept[89].

Beside biorefinery approaches, straw is used for example as the main feedstock for the production of mushroom substrate, e.g. in Poland and Netherlands, which are Europe´s leading mushroom producting countries.

[89] Svärd, A., R. Moriana, E. Brännvall and U. Edlund (2019). Rapeseed Straw Biorefinery Process. ACS Sustainable Chemistry & Engineering **7**(1): 790-801.

Bottlenecks
Straw recovery is often limited on field level due to concers about the maintenance of soil organic carbon (SOC) levels and – indirectly – soil fertility. However, alternative cropping systems with a more prominent cultivation of intermediate crops could help main SOC levels without straw retainment and therefore increase the amount of sustainably recoverable straw[90].

Despite similar straw potentials in Denmark and Sweden, Denmark recovers about 12 times more straw, that is a.o. used for energy purposes[91]. Differences between the countries include the lack of support programmes specific for straw as an energy resource and the higher competition from wood fuels in Sweden.

Recovery is not a technical issue, suitable technology to produce e.g. large straw bales for transportation, is readily available in all SBA regions investigated. Instead, it is rather an economic and logistics problem of organising the feedstock transport to the receiving industry, where a.o. straw density in the landscape plays a vital role for transportation costs. In that respect, Denmark has an advantage with an almost double as high straw density in the landscape compared to Skåne[91].

In conclusion, ambitious support programmes are needed to make straw available as a feedstock in larger quantaties in Skåne. Of the other SBA regions, Mecklenburg-Western Pomerania has similarily high straw densities as Sweden and Denmark[92], while straw yields is Poland are substantially lower.

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[90] Prade, T., L. Björnsson, M. Lantz and S. Ahlgren (2017). Can domestic production of iLUC-free feedstock from arable land supply Sweden's future demand for biofuels? Journal of Land Use Science 12(6): 407-441.
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2.2 Residues from the wood production value chain

2.2.1 Regional resources in Denmark

Assessed by Mark Booker Nielsen and Tyge Kjær, Roskilde University, Denmark

The potential of the cascade principle to prioritize optimal use of forest biomass to ensure job creation, rural development and reduction of climate effects is emphasizes in EU Forest Strategy. The cascading principle shound ensure that wood is used in following order of priorities: wood-based products, extending their service life, re-use, recycling, bio-energy and disposal[93].

The forest area in the Region Zealand has increased with 25% since 1990. Today the forest area of Region Zealand is 99,709 ha with beech, oak and spruce being the dominating tree species accounting for approximately 50 percent of the total forest area covering the region. Forests covers 13 percent of the total land area in the region coming close to the national average of 14.5 percent (624,782 ha)[94, 95]. Even though this is far less that in surrounding countries in the South Baltic regions the forest area is well distributed across the landscape with many small forests and windbreakers along the fields[96].

Denmark each year consumes around 18 million m^3 of wood. Around 8.5 million m^3 are utilized for energy production, 4-5 million m^3 in utilized in the wood industry and 4-5 million m^3 utilized for paper production. The total Danish forest production of wood is 3.5 million m^3 and another 3 million m^3 derived from other Danish sources e.g. recycling. This leaves around 11-12 million m^3 which are imported for consumption[97,98,99].

Products along the value chain and utilization today

The yearly gross increment is around 1,096,609 tonnes and the net increment of wood not removed is 657,722 tonnes. The removed wood is utilized for either materials or energy utilization. When it comes to the utilization of wood for energy most of the removed is used in regional CHP plants in the form of wood chips. A large sum of wood pellets is also imported to the region mostly for in individual heating in household, most of these wood pellets are imported to Denmark from Estonia (22%), Latvia (24%), Sweden (15%) and Russia (11%)[100]. Finally, energy recovery from wood and paper residues/waste accounts for a total of 171,351 tonnes per year.

There is no paper industry in the region and only three industrial size wood manufacturing company together with several minor SMEs. The three industrial size companies are: F. Junckers that produces flooring, Hvalsø SavværkA/S and Aggersvold Savværk A/S. The residues from these companies are today use for enegy production, but have the potential of being utilized in added value productions. In previous years there used to be more activity in forest product industry, but it has been declining in reason decades, resulting in an increasing net increment of the wood biomass.

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[93] EU COMM, 2013, A new EU Forest Strategy: for forests and the forest-based sector
[94] Statistics Denmark, SKOV11 (2018), http://www.statistikbanken.dk/SKOV11
[95] Skove og plantager 2015, KU
[96] Træer og buske i landskabet, 2007 Danmarks Naturfredningsforening,
[97] Dansk skovbrugs mulige bidrag til øget træproduktion og imødegåelse af klimaforandringer 2010-2100, 2013, KU
[98] Muligheder for bæredygtig udvidelse af dansk produceret vedmasse 2010-2100, 2013, KU
[99] Forest production, 2015, Food and Agricultural Organization of the United Nations
[100] Det danske træpillemarked 2016, EA

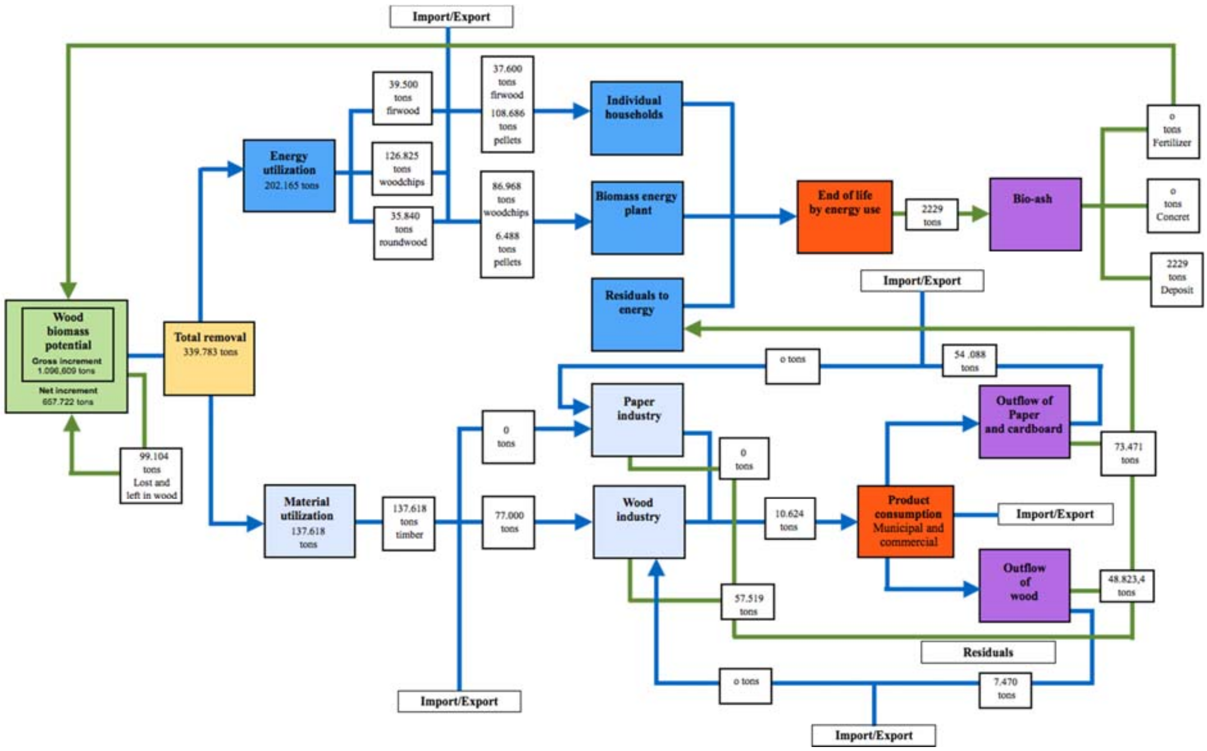

Figure 29. Wood material flow in Region Zealand. The numbers are associated with some uncertainty. Preparation by RUC for this report based on mapping[101].

[101] CASCADES 'Study on the optimised cascading use of wood', 2016, Vis M., U. Mantau, B. Allen

Quantification of feedstock, products and residues

Primary production

Table 24. Forest area [ha] in Region Zealand[102]

Forest area	**1990**	**2000**	**2009**	**2011**	**2013**	**2015**
Total forest area, ha:	75,137	78,148	87,168	93,527	98,950	99,709
Index, 100 =1990	100.0	104.0	116.0	124.5	131.7	132.7
Broad leaves trees, total in ha:	45,899	49,634	61,477	67,390	71,118	70,451
Index, 100 =1990	100.0	108.1	133.9	146.8	154.9	153.5
Softwood trees, total in ha:	24,424	25,484	23,081	23,681	24,479	24,388
Index, 100 =1990	100.0	104.3	94.5	97.0	100.2	99.9
Supporting areas	4,041	2,173	941	621	915	1,423
Forest covered area, total in ha	71,097	75,975	86,228	92,906	98,035	98,287

Table 25. Cultivation area for dominant species [ha] in Region Zealand [102]

Hard wood (dominant species)	**1990**	**2000**	**2009**	**2011**	**2013**	**2015**
Beech	25,369	25,222	22,296	25,358	27,883	27,290
Oak	9,057	11,145	10,633	12,063	12,850	13,365
Maple	3,388	3,784	7,073	8,175	9,267	9,333
Birch	0	0	4,564	3,739	3,557	4,840
Other beech trees species	8,085	9,483	16,911	18,055	17,561	15,623
Beech trees in total	**45,899**	**49,634**	**61,477**	**67,390**	**71,118**	**70,451**
Soft wood (dominant species)						
Norway spruce	14,229	12,617	9,412	9,667	10,760	10,366
Nordmann fir	2,586	5,017	5,049	5,392	4,867	5,103
Other softwood species	7,609	7,850	8,620	8,622	8,852	8,919
Soft wood in total	**24,424**	**25,484**	**23,081**	**23,681**	**24,479**	**24,388**

[102] Statistics Denmark, SKOV11 (2018), http://www.statistikbanken.dk/SKOV11

Table 26. Annual increment and removals of all wood [1000 solid m^3/a] in Region Zealand [103]

	2012	2013	2014	2015	2016
Net increment	1,084	1,275	1,250	1066	677
Total removals	688	760	815	726	786
Harvest	578	552	599	566	638
Windthrow	2	2	4	7	9
Dead	43	51	68	85	101
Missing	66	155	144	68	37
Gross increment	1,823	2,035	2,065	1793	1,463

Table 27. Annual increment and removals of all wood [m^3/ha/a] in Region Zealand[103]

	2012	2013	2014	2015	2016
Net increment	4.2	5.2	6.0	4.5	4
Total removals	8.3	8.9	9.4	8.3	8.4
Harvest	7.0	6.5	6.9	6.4	6.9
Windthrow	0	0.0	0.0	7	0.1
Dead	0.5	0.6	0.8	1	1.1
Missing	0.8	1.8	1.7	0.8	0.4
Gross increment	12.5	14.2	15.4	12.2	12.5

[103] Skove og plantager 2012-2016

Removal and utilization

Table 28. Tree harvest and utilization in Region Zealand [1000 m^3/a] [104]

	2012	2013	2014	2015	2016
Harvest in total	**524.9**	**584.9**	**575.5**	**572.1**	**448.6**
Material utilization	**225.2**	**240.5**	**306.1**	**305.9**	**233.8**
Energy utilization	**299.8**	**344.4**	**269.4**	**266.3**	**214.8**
Firewood in total	129.9	145.9	101.9	88	65.3
Woodchips	139.9	171.1	124.5	133.5	111.4
Roundwood for energy	30	27.4	43	44.8	38.1
Beech wood in total	**287**	**354.3**	**283.7**	**319.2**	**230.9**
Beech wood - Material utilization total	**79.7**	**80**	**90.1**	**125.4**	**91.9**
Beech wood – Wood panels and timber for sawmills	61.1	62	66.4	89.2	53.4
Beech wood - Timber for industry	13.1	14.4	21.4	29.3	33.3
Beech wood - Other material utilization	5.5	3.5	2.3	6.9	5.1
Beech wood- Energy utilization	**207.3**	**274.3**	**193.6**	**193.8**	**138.9**
Beech wood - firewood	123.7	143.5	99.2	85.2	63.9
Beech wood - woodchips	77.5	120.2	85.1	95.1	60.3
Beech wood - Timber for energy	6.1	10.6	9.3	13.5	14.7
Soft wood in total	**237.9**	**230.6**	**291.8**	**252.8**	**217.7**
Soft wood - Material utilization total	**145.5**	**160.5**	**216**	**180.5**	**141.9**
Soft wood – Wood rafts	4.2	7	9.4	8.1	11.7
Soft wood – Short lumber	70.9	81.4	115.6	94.4	81.1
Soft wood – Timber for industry	67.1	66.2	82.6	69.4	45.9
Soft wood – Other material utilization	3.3	5.9	8.4	8.5	3.2
Soft wood - Energy utilization	**92.4**	**70.1**	**75.8**	**72.4**	**75.9**
Soft wood - firewood	6.2	2.4	2.7	2.8	1.4
Soft wood - woodchips	62.3	50.9	39.4	38.3	51.1
Soft wood - Timber for energy	23.9	16.8	33.7	31.3	23.4

104 Statistics Denmark, SKOV55 (2018), http://www.statistikbanken.dk/SKOV55

Consumption of wood

Table 29. Consumption of wood for energy and materials in Region Zealand [t WW].

	Local harvest[105]	**Consumption[106]**	**Consumption mainly based on local supply**	**Import**	**Export**	**Standard calorific value[107]**
Energy production						
Firewood	39,500	37,600	37,600	0	1900	450 kg/m^3 4.1 kWh/kg[108]
Woodchips	126,825	86,968	88,968	0	39,857	9.3 GJ/ton 950 kg/m^3 [109]
Wood pellets – individual heating (Incl. production)	0	108,686	0	108,686	0	17.5 GJ/ton
Wood pellets – district heating (Incl. production)[110]	0	6,488	0	6,488	0	17.5 GJ/ton
Roundwood for energy	35,840	0	0	0	35,840	800 kg/m^3 [13]
Residues/waste recovery from product consumption	128,168	128,168	128,168	0	0	14.7 GJ/ton
Total	**321,362**	**321,339**	**208,165**	**115,174**	**77,597**	
Industry	**Local harvest**	**Consumption for production**	**Consumption mainly based on local supply**	**Import**	**Export**	**Standard calorific value**
Paper and cardboard industry	0	0[15]	0	?	0	
Wood industry	137,618[13]	77,000[19]	77,000[111]	?	60,618	Broadleaves wood: 0.56 tonnes/m^3. Conifers wood: 0.38 tonnes/m^3
Total	**137,618**	**77,000**	**77,000**	**?**	**60,618**	
Products for consumption	**Local production**	**Consumption**	**Consumption mainly based on local production**	**Import**	**Export**	**Standard calorific value**
Paper products	0	70,718[20]	0	70,718[112]	0	
Wood products	10,624[19]	38,741[20]	0	38,741[20]	0	
Total	**10,624[16]**	**109,459**	**0**	**109,459**	**0**	

[105] Statistics Denmark, SKOV55 (2018), http://www.statistikbanken.dk/SKOV55
[106] Energiproducenttællingen, Energistyrelsen
[107] Standardfaktorer for brændværdier og CO2-emissioner, 2017, Energistyrelsen
[108] Boligopvarmning ved brændefyring, ENS, 2012 (s.23)
[109] Markedet for træflis, Hededanmark
[110] Statistics Denmark, NYGB44 (2018), http://www.statistikbanken.dk/BYGB44
[111] F. junckers, grønne regnskaber. Consumption from SME's not accounted for
[112] Estimation – Consumption is the same size as the annual waste potential

Waste and residues

Table 30. Waste and residues [t] in Region Zealand

Tonnes	Bio-ash waste[113]	Recycling- Use as fertiliser on agricultural land	Recycling- Filling material in concrete	Deposit[114]
From energy production				
Firewood	188	0	0	188
Woodchips	869.6	0	0	869.6
Wood pellets – individual heating (incl. production)	543.4	0	0	543.4
Wood pellets – district heating (incl. production)	32.24	0	0	543.4
Roundwood for energy	0	0	0	0
Residues/waste recovery from product consumption	595.5	0	0	595.5
Total	**2229.4**	**0**	**0**	**2229.4**

Table 31. Commercial waste in Region Zealand [115, 116]

	Waste/ residues	Recycling	Energy recovery	Deposit
Wood	14,941	7,470	7,470	0
Paper	12,855	9512	3,342	0
Cardboard	51,458	9777	41,681	0
Wood from building and construction waste	2,026	0	2,026	0
Wood packing	586	0	586	0
Total	**81,866**	**19,290**	**55,106**	**0**

Table 32. Municipal waste in Region Zealand [117]

	Waste	Recycling	Energy recovery	Deposit
Wood	38,741	0	38,741	0
Paper[118]	60,449	39,291	21,157	0
Cardboard and carton[119]	10,269	2,978	7,291	0
Total	**109,459**	**42,269**	**67,189**	0

[113] Bio-ash 0.5 kg/tonne from wood and 1 kg/tonne from wood chips.
[114] Estimation – a small amount might be used as fertiliser
[115] Affaldsdata (R013), Mst,.Average DK recycling of paper (74%), cardboard (19%) and wood (50%)
[116] Affaldsdata (R020), Mst
[117] Henrik Wejdling, 2014. Affaldplus waste potential data
[118] 65% paper recycling of waste potential- based on average recycling in Affaldplus municipalities.
[119] 29% cardboard recycling of waste potential - based on average recycling in Affaldplus municipalities.

Table 33. Industrial wood residues in Region Zealand [t WW/a] [120]

	Waste/ residues	Recycling	Energy recovery	Deposit
Wood residues/by-products	57,519	0	57,519	0
Total	**57,519**	**0**	**57,519**	**0**

Table 34. Characterization of hard wood

Parameter	Unit	Broadleaves	Soft wood
Dry matter (DM) content[121]	[%]	0-50%	0-50%
Net calorific value[121]	[kWh/kg]	19.2	19.0
Hemicellulose content[122]	[%]	up to 35 %	10–15 %
Cellulose content[122]	[%]	41–48 %	46–55 %
Lignin content[122]	[%]	19–28 %	24–33 %
Ash	[% of DM]	0.3	0.3

[120] F.Junckers, grønne regnskaber – residues from SME's not accounted for.
[121] Wood fuel handbook, Food and Agricultural Organization of the United Nations
[122] Chemical composition of wood, Project InoBio

Material flow

Table 35. Current material flow in Region Zealand (2015)

		Current
Step 1 – Wood biomass potential		
Land use[123]	ha	99,709
Total removal	m^3	**726,000**
Harvest	m^3	572,100
Windthrow	m^3	7,000
Dead	m^3	85,000
Missing	m^3	68,000
Gross increment	$\mathbf{m^3}$	**1,793,000**
Net increment	$\mathbf{m^3}$	**1,066,000**
Step 2 – Removal from forests		
Wood removed for energy utilization, total	**t DM**	**202,165**
Firewood	t DM	37,600
Woodchips	t DM	126,825
Round for energy	t DM	39,500
Wood removed for material utilization, total	t DM	**137,618**
Total biomass	**t DM**	**339,783**
Step 3- Removal from forests (%)		
Wood removed for energy utilization, total	**%**	**60%**
Firewood	**%**	11%
Woodchips	**%**	37.4%
Timber	**%**	11.6%
Wood removed for material utilization, total	**%**	**40**
Total biomass	**%**	**100%**
Step 4 - Wood use and residues/waste		
Use 1: Wood consumption, total (inflow)	**t DM**	**321,339**
Wood pellets -Individual households[124]	t DM	108,686
Wood pellets - energy plant	t DM	6,488
Firewood	t DM	37,600
Woodchips	t DM	88,968
Energy from waste/residues	t DM	128,168
Import	t DM	115,174
Export	t DM	77,597
Waste after energy use (Outflow)		
Bio-ash, total	**t DM**	2,229
Fertilizers	t DM	0
Concrete filling material	t DM	0

[123] Statistics Denmark, SKOV11 (2018), http://www.statistikbanken.dk/SKOV11
[124] Energiproducenttælling 2015

Deposit (Outside Denmark)	t DM	2,229
Use 2: Wood consumption, total (Inflow)	**t WW**	77,000
Paper industry	**t WW**	0
Residuals	t WW	0
Wood industry [125]	t DM	77,000
Wood products	t DM	57,519
Residuals	t DM	10,624
Export	t DM	60,618
Import	t DM	?
Product consumption, total (Outflow) [126]		
Wood waste recycling	**t DM**	7,470
Wood waste energy recovery	t DM	48,823
Paper waste recycling	t DM	54,088
Paper waste energy recovery	t DM	73,471

[125] F.Junckers, Grønne regnskaber. Estimation minimum. SME's not included.
[126] Commercial and municipal waste

2.2.2 Regional resources in Germany

Assessed by Moritz Westkämper, Agency for Renewable Resources, Germany

The following report describes the latest development of forest production and forest situation in MWP[127].

A large area of the region of MWP is covered by forests. The latest numbers show that 558.000 ha account for forest area of a total of 2.321.100 ha. More precisely, this number accounts for 4.9 % of the forest area of Germany, which accounts for 11.4 million ha. Other numbers show that 24.1 % of the area of MWP is covered by forest. The German average is 32 %. Within the years of 2002 to 2012 the forest area grew by 5.300 ha.
Overall the number of deciduous trees is growing. The pine tree dominates with dominates with 37.6 % of all trees. 21 % in MWP accounts for of ALN[128]. MWP is the only region in Germany which reaches these high numbers. It has to be mentioned that a lot of deciduous trees are under the umbrella of older coniferous trees, i.e. the number of deciduous trees will grow in the future. Figure 30 shows the distribution of tree species.

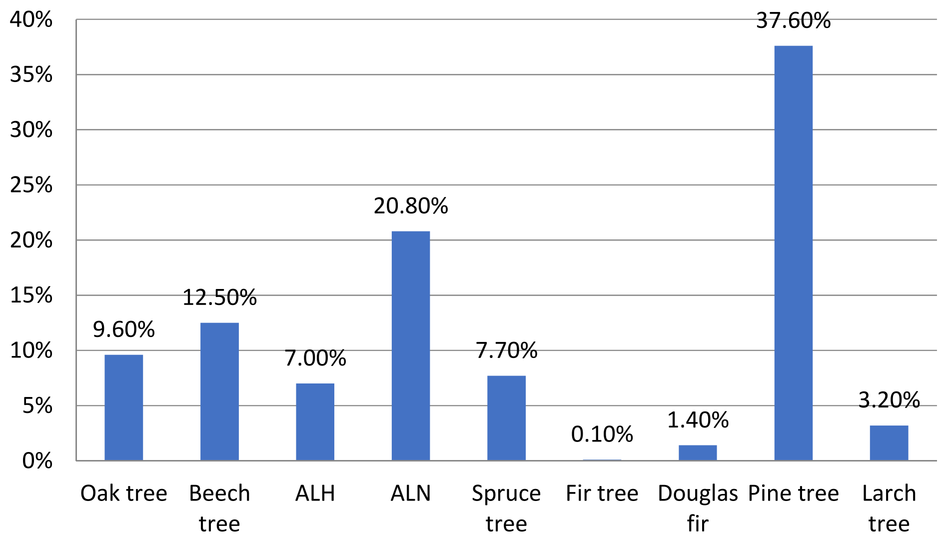

Figure 30. Distribution of tree species[129]. ALN = other deciduous trees with a short life, ALH = other deciduous trees with a long life.

Obviously, the pine tree dominates with 37.6 % (Figure 30). The high number of ALN is worth to mention as well. These high numbers are only visible in MWP (especially alders and birches are represented). Oak trees, beech trees and spruce trees are the other main tree species, where each accounts for nearly 10 %.

Moreover, the average age of a forest in MWP is getting older. The average age in 2012, compared to 2002, grew from 66 years to 72 years.

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[127] MWP = Mecklenburg-Western Pomerania
[128] ALN - other deciduous trees with a short life
[129] Own figure based on Faktensammlung zur Dritten Bundeswaldinventur (BWI 3) für Mecklenburg-Vorpommern. Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz. 2012.

Table 36. Average age of trees in Mecklenburg-Western Pomerania[130]

Oak tree	Beech tree	ALH[131]	ALN	Spruce	Fir tree	Douglas fir	Pine tree	Larch tree	All sorts of trees
01	99	75	57	55	34	46	71	49	72

Sustainable use of wood in Mecklenburg-Western Pomerania

The forests in MWP serve a sustainable and therefore useful function. The wood stock[132] in the forests of the region accounts for 167 million m³ (88 million m³ coniferous trees, 79 million m³ deciduous trees).

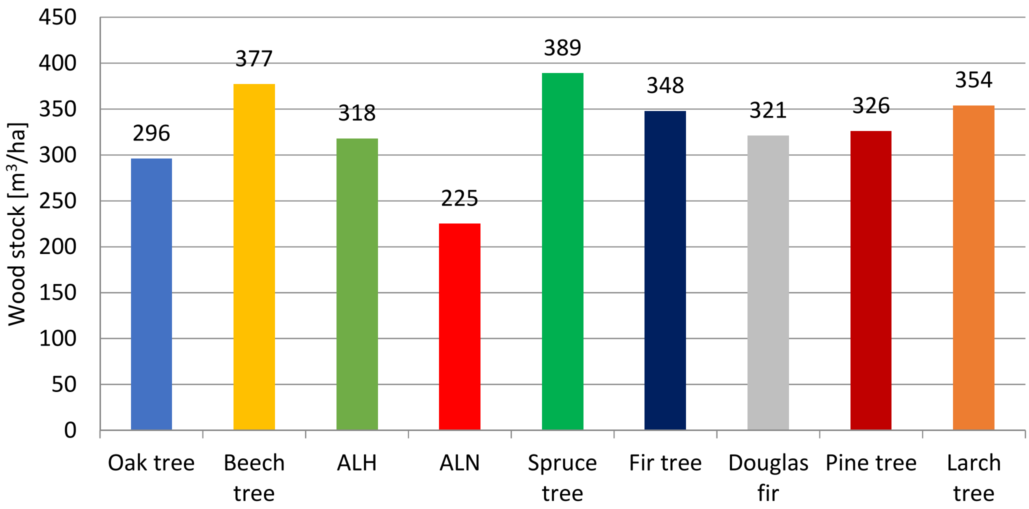

Figure 31. Wood stock [m³/ha] of different tree species in Mecklenburg-Western Pomerania [130]

Regarding the highest wood stock it is visible that spruce trees and beech trees account for the highest number with 389 m³/ha and 377 m³/ha respectively.

Growth of wood stock

In MWP the wood stock growths yearly of about 5.5 million m³. In average, i.e. the growth is around 10.5 m³/ha (average in Germany 11.2 m³/ha). Worth to mention is the wood stock growth of coniferous fir tree, which accounts for 25.4 m³/ha annually and the Douglas fir, which accounts for 17.1 m³/ha. In comparison, the deciduous oak tree accounts for just 8.08 m³/ha.

[130] Faktensammlung zur Dritten Bundeswaldinventur (BWI 3) für Mecklenburg-Vorpommern. Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz. 2012.

[131] ALH - other deciduous trees with a long life

[132] Wood stock is defined by wood with a diameter of 7 cm or higher.

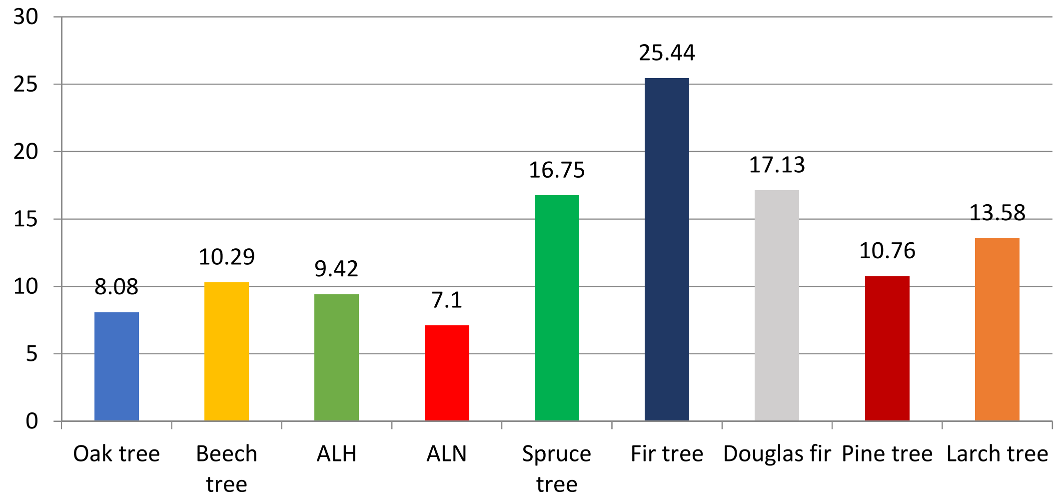

Figure 32. Tree species and their annual wood stock growth [m³/ha/a] [133]

The use of wood in Mecklenburg-Western Pomerania

Annually, around 3.1 million m³ wood are used from the forests in MWP, i.e. 6.0 m³/ha annually. As a result, 57 % of the annual wood growths are used actively. The left 43 % of the wood is left in the forests for environmental reasons (protection forests, forest dead fall) or serve the purpose of wood stock enrichment in young commercial forests.

<u>Forest without use of purpose</u>

There are several areas of forest in MWP without use of purpose. Right now, the respective area accounts for 52,000 ha (9.9 %). 35,000 ha (6.9 %) are National Parks and Conservation Areas, where no use is permitted. The National Biodiversity Strategy and Action Plan (NBSAP)[134] demands that until 2020 5 % of the forest area in Germany is left to the natural development (i.e. no usage at all). With 6.9 % MWP achieved this number already.

In comparison to the German average the forest area in MWP, which is not used or not expected, is relatively high. 17.3 % of the whole forest area is not used. The German average accounts for 8.6 %.

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[133] Faktensammlung zur Dritten Bundeswaldinventur (BWI 3) für Mecklenburg-Vorpommern. Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz. 2012. p. 5.

[134] https://www.bfn.de/en/activities/biodiversity/national-biodiversity-strategy.html

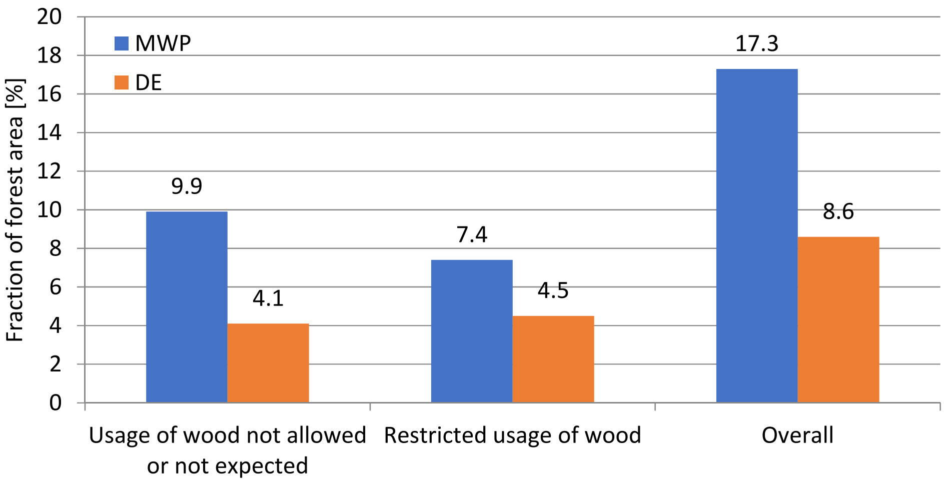

Figure 33. Comparison of forest areas without use or purpose in MWP and Germany[135]

Forest dead fall

In order to ensure a vital environment within forest different parameters play a crucial role (forest dead fall, bugs, mushrooms). In MWP in 2012 every hectare had 16.9 m³ of dead forest fall. That accounts for a growths of 1 m³/ha since 2002. It is planned, as previously mentioned, to leave 5 % of forest area to natural forest development.

Energetic and material use of wood in Germany

In the following the energetic and material use of wood in Germany is described. Data on specific regions are very rare or not accessible yet. Therefore, it is only possible to mention overall data. In Germany the use of wood is divided into energetic and material use and recycling.

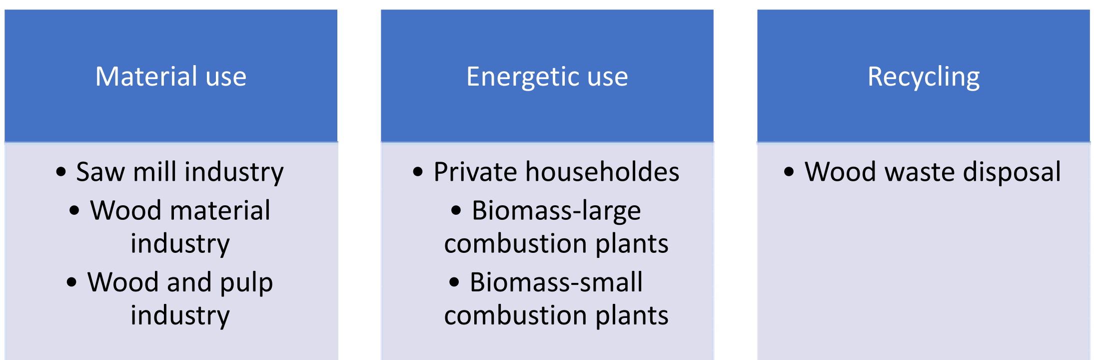

Figure 34. Energetic and material use of wood in Germany[136].

[135] Faktensammlung zur Dritten Bundeswaldinventur (BWI 3) für Mecklenburg-Vorpommern. Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz. 2012. p. 6.

[136] Rohstoffmonitoring Holz. Daten und Botschaften. Fachagentur Nachwachsende Rohstoffe. 1. Edition 2018. p. 2.

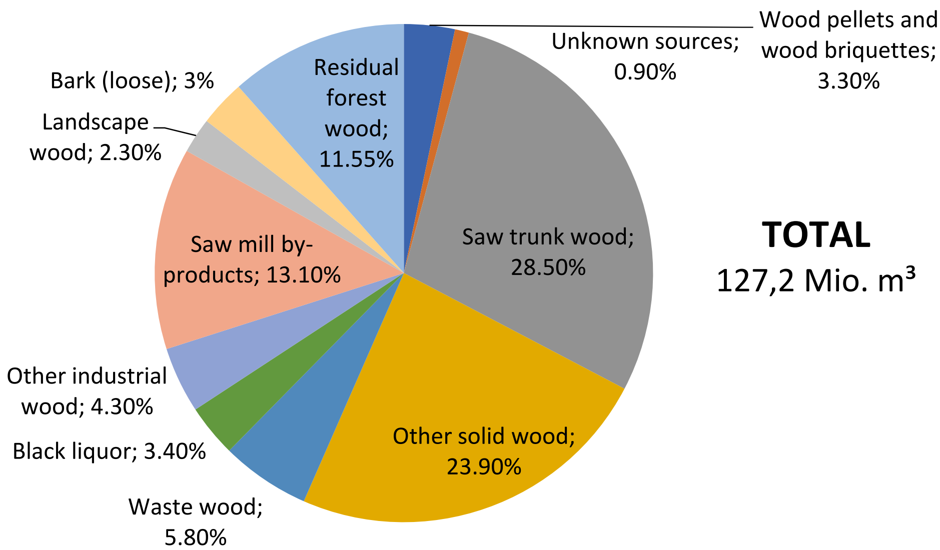

Figure 35. Source of the used wood raw-materials in Germany[137]*.*

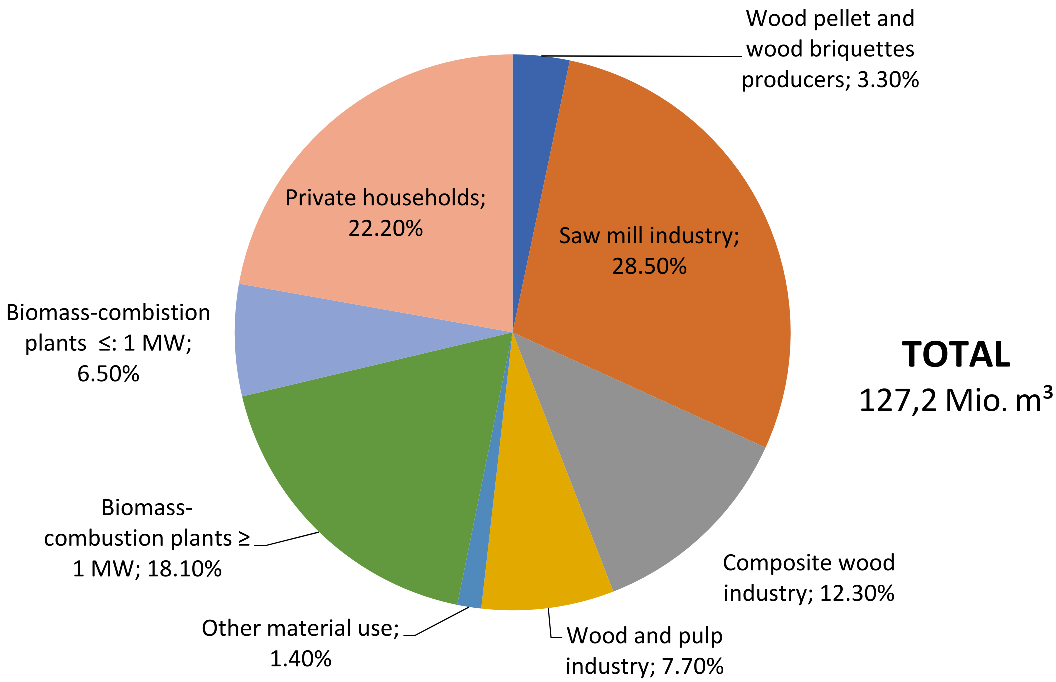

Figure 36. Application wood raw-materials in Germany[137]*.*

[137] Rohstoffmonitoring Holz. Daten und Botschaften. Fachagentur Nachwachsende Rohstoffe. 1. Edition 2018. p. 3.

Development of cutting volume of wood[138]

The development of the cutting volume of coniferous and deciduous wood in Germany decreased from 36.0 million stere[139] in 2015 in comparison to 37.3 million stere in 2010. This is caused by the decrease of the cutting of coniferous wood. The cutting of deciduous wood stayed nearly the same. Nonetheless, the cutting of coniferous wood is clearly higher. The decrease of coniferous wood cuttings did not cause a rise of deciduous wood cuttings.

Table 37 Development of cutting volume of wood in Germany[138]

	2010 [million stere]	[%]	2015 [million stere]	[%]	Change		
					[million stere]	[%]	Points
Coniferous trees	34,985	93.9	33,664	93.5	-1.321	-3.8	-0.3
Deciduous trees	2,289	6.1	2,333	6.5	+0.45	+2.0	+0.3
TOTAL	37,274	100.0	35,997	100.0	-1.276	-3.4	+0.0

138 Rohstoffmonitoring Holz. Sägeindustrie. Einschnitt- und Produktionvolumen. Döring, Przemko et al. Universität Hamburg. March 2017.

139 The stere is a unit of volume in the original metric system equal to 1 m³ of stacked wood.

2.2.3 Regional resources in Poland

Assessed by Dariusz Mikielewicz, Rafał Andrzejczyk, Paweł Dąbrowski & Jan Wajs, Gdańsk University of Technology, Poland

Biomass production sectors (agriculture, forestry and fisheries) and the sectors entirely based on raw materials of biological origin (food industry, production of beverage, tobacco industry, wood and paper industry) are also very important segments of the Polish economy. Their share in the gross value added of the Polish economy in the years 2009-2013 was about 7.5%, while in terms of employment it was about 17.5%.

Table 38. Land structure in Polish South Baltic Area

Land	Pomeranian Region [140]		West Pomeranian Region [141]		Warmia and Mazury Region [142]	
	[1000 ha]		[1000 ha]		[1000 ha]	
Agriculture	759.9	41.5%	837.1	36.6%	994.6	41.1%
Forestry	683.4	37.4%	813.8	35.5%	753.3	31.2%
Fallow land	4.9	0.3%	13.1	0.6%	7.1	0.3%
Urbanized	97.2	5.3%	101.1	4.4%	93.1	3.9%
Other	283.9	15.5%	524.1	22.9%	569.2	23.5%
Total	**1,829.3**	**100%**	**2,289.2**	**100%**	**2,417.3**	**100%**

The condition of forests in Poland is subject to an annual assessment by state authorities. As part of this assessment, the State Forests - by virtue of the Act of 28 September 1991 on forests (Journal of Laws of 2017, item 788) - was obliged to prepare an annual report on the state of forests.
The forest cover of Poland, amounting to around 40% at the end of the 18th century (at that time), decreased to 20.8% in 1945. Deforestation and accompanying impoverishment of the species structure of tree stands caused a decrease in biodiversity in forests and impoverishment of the landscape, soil erosion and disruption of the country's water balance. Reversion of this process took place in the years 1945-1970, when as a result of afforestation 933,5000 ha, the forest cover of Poland increased to 27.0%. The average annual size of afforestation was then 35,900 ha, and in the peak period 1961-1965 - over 55,000 ha.

Currently, the area of forests in Poland is 9,242,000 ha (according to GUS - state on 31.12.2017), which corresponds to a forest cover of 29.6%. The highest forest cover (49.3%) is characteristic for Lubuskie Voivodeship, the lowest (21.5%) - Łódź Province. The area of Polish forests, including land associated with forest management, as at 31/12/2017 amounted to 9,447,000 ha.

The forest cover calculated according to the international standard in 2017 was 30.9% and was lower than the European average of 32.8% (including the forests of the Russian Federation - 44.7%) (Figure 39). Forest area per one inhabitant of Poland (0.24 ha) is one of the lowest in Europe.

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[140] Statistical Yearbook Pomorskie Voivodship 2016, Statistical office in Gdańsk
[141] Statistical Yearobook Zachodniopomorskie Voivodship 2016, Statistical office in Szczecin
[142] Statistical Yearbook Warminsko-Mazurskie Voivodship 2016, Statistical office in Olsztyn

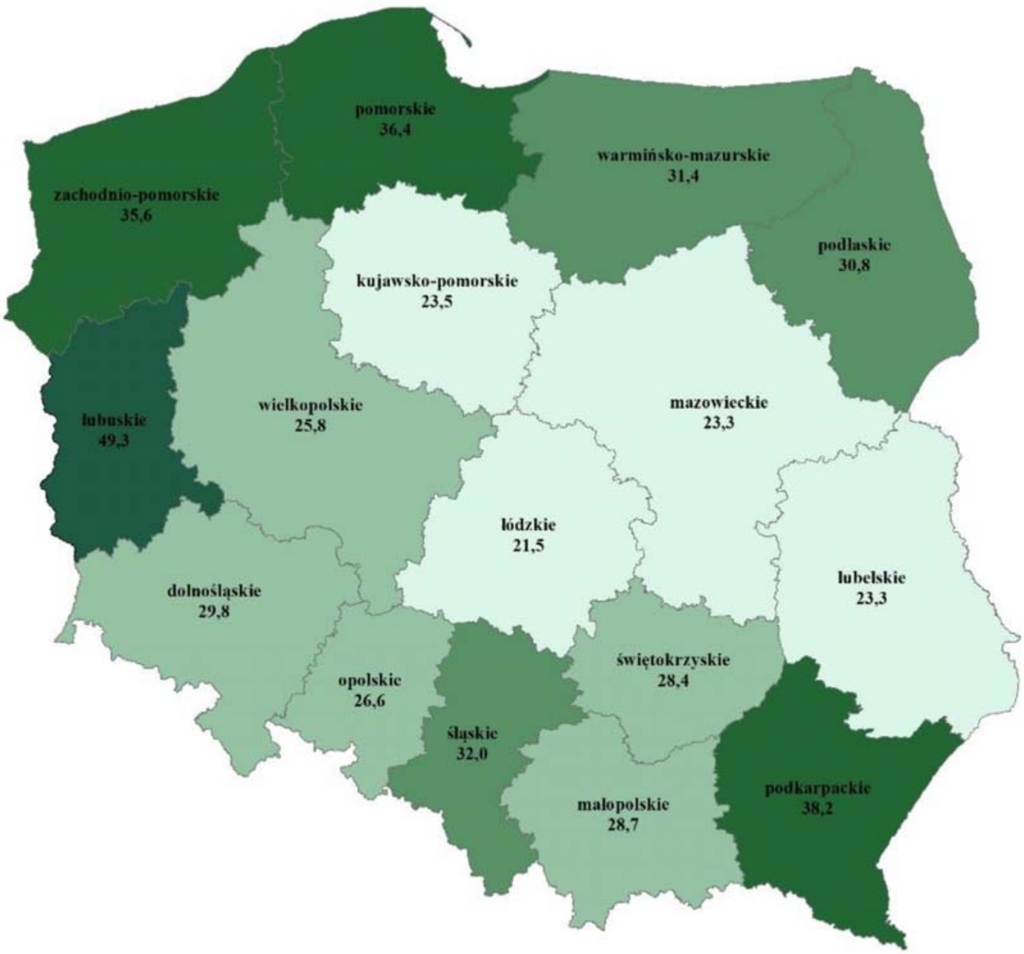

Figure 37. Forest cover in Poland by Regions (GUS) [143]

[143] Forests in Poland in 2017, Information Centre of State Forests, 2017

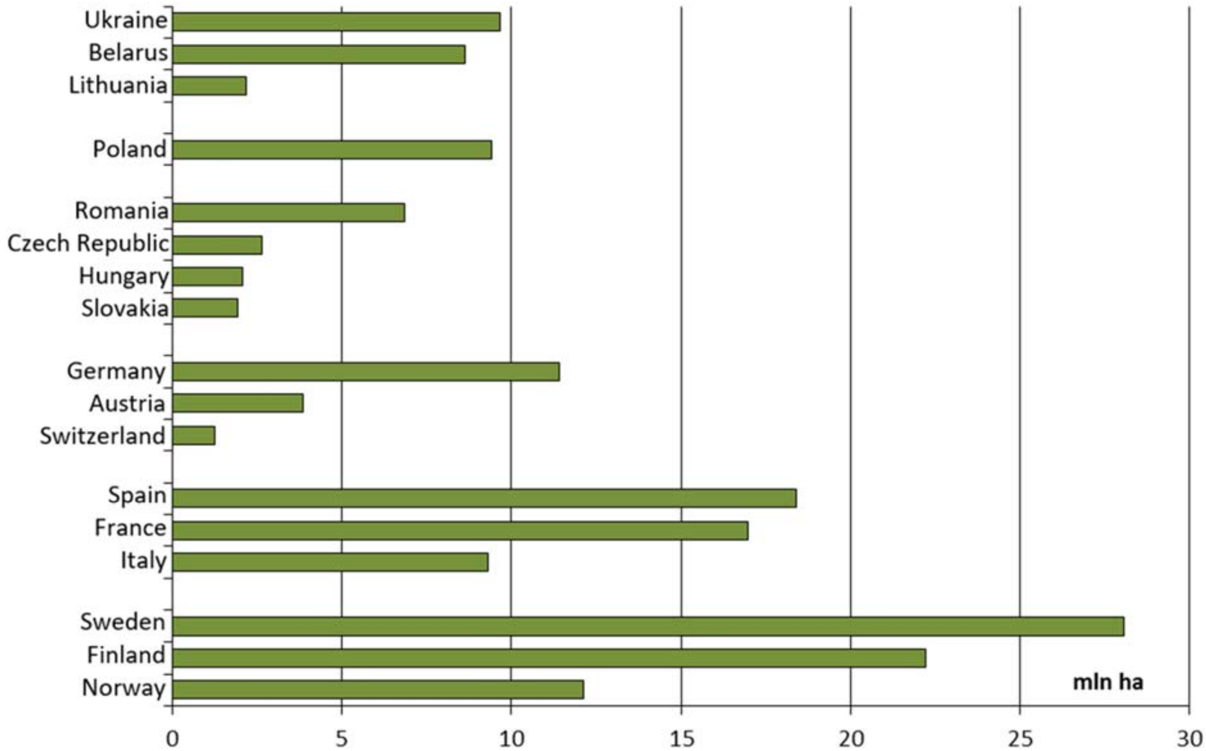

Figure 38. Total forest area (SoEF 2015) [144]

[144] Forests in Poland in 2017, Information Centre of State Forests, 2017

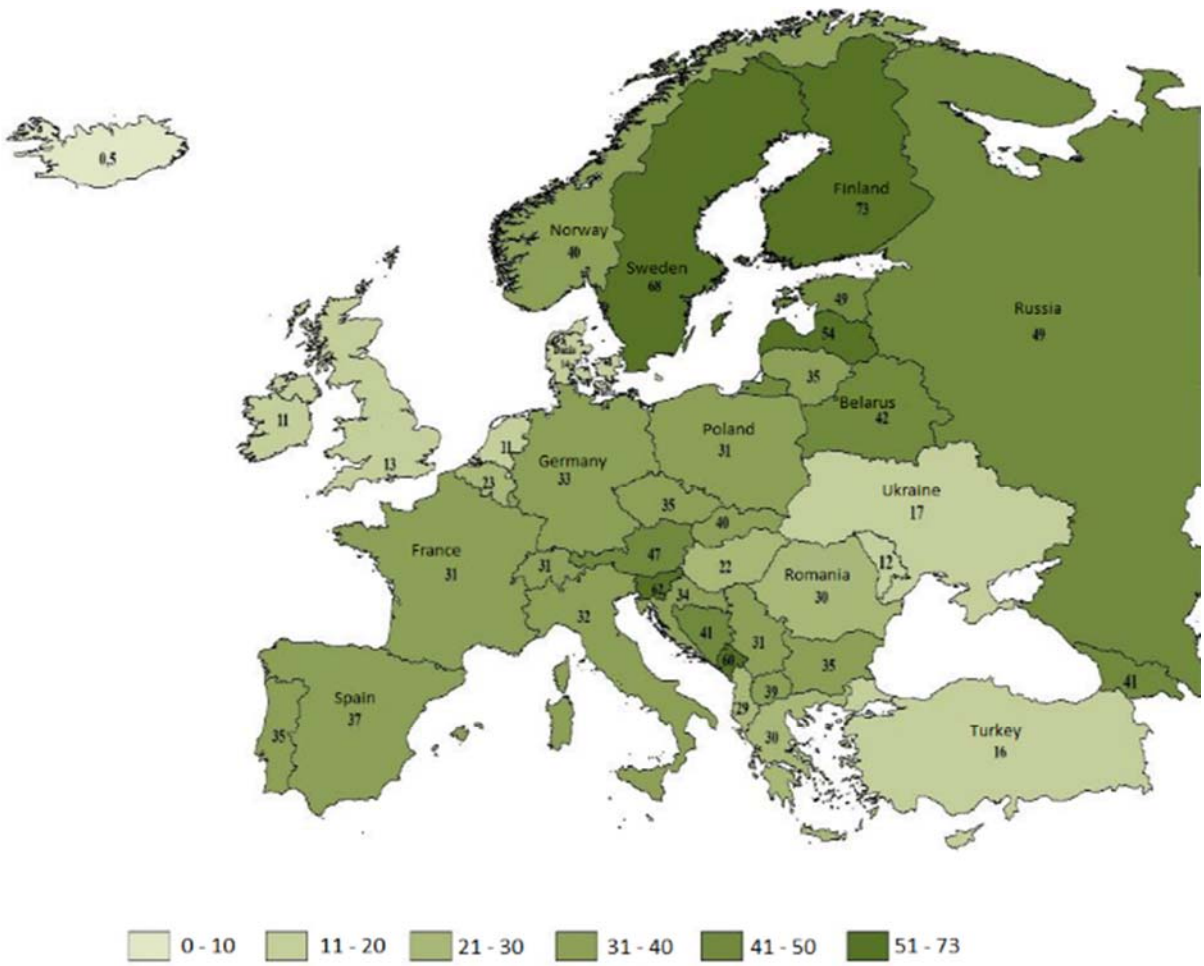

Figure 39. Forest cover of analysed countries (SoEF 2015)[143]

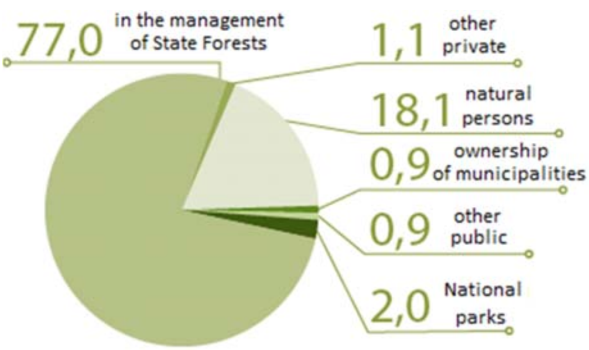

Figure 40. Structure of forest ownership in Poland (GUS)[143]

In the ownership structure of forests in Poland, dominate the public forests - 80.7%, including forests remaining on the board of the State Forest Economy State Forests - 76.9% (Figure 40). In the years 1990-2017, the share of ownership of private forests increased by 2.3 percentage points to the current 19.3%. Adequately (from 83.0% to 80.7%) the share of public property forests decreased.

Table 39. Forest area by species structure of tree stands and voivodships[143]

Region	Selected species of trees in % of forest area in 2017									
	pine	spruce	fir	beech	oak	horn-beam	birch	alder	aspen	poplar
Pomerania	68.4	3.5	0	9.9	4.7	0.8	7	2.9	0.3	0
Warmia and Mazury	47.8	12	–	3.7	8.9	1.6	12.4	9.6	0.9	–
Western Pomerania	58.8	5.3	–	8.8	7.2	0.6	9.5	6.3	0.5	0.1
Total Poland	**58**	**6.2**	**3.1**	**5.9**	**7.7**	**1.6**	**7.3**	**5.7**	**0.8**	**0.1**

Coniferous species dominate 68.4% of the forest area in Poland (Table 39). Pine, which according to WISL occupies 58% of the forest area of all forms of ownership, 60.2% of land in PGL LP and 54.9% in private forests, found in Poland the most favorable climatic and habitat conditions in its Eurasian range, thanks to which it managed to create many valuable ecotypes (e.g. Taborska or Augustinian pine). High preference for coniferous species was also due to their preference, from the 19th century, by the wood industry.

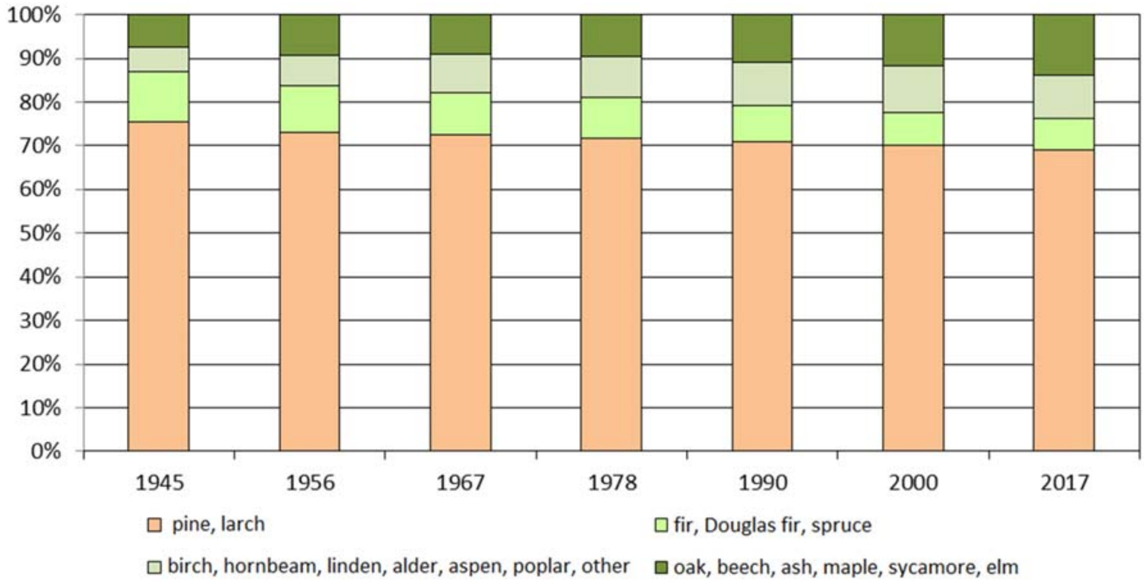

Figure 41. Structure of the surface share of species prevailing in forests managed by State Forests in 1945-2017 [145]

Age structure

In the age structure of the forest, tree stands of III and IV age class dominate, occurring at 24.5% and 19.6%, respectively. The third age class dominates in the forests of most forms of ownership, and in private forests its share is 32.4%. Forest stands over 100 years with KO, KDO and BP occupy 13.2% of the area in PGL Lasy Państwowe, and 3.6% in private forests. The share of non-forested area in private forests is 5.5% at 2/7% in PGL LP.

Renewal of the forest (without grasses and the introduction of the second floor) in 2017 was carried out on the area of 53,754 ha of land of all property categories (Figure 15), of which 6738 ha (12.5%) were natural renewals. The area of renewals in 2017 was about 2,300 ha smaller compared

[145] Bureau for Forest Management and Geodesy, Central Statistical Office, state on 1 January 2017

to 2016. Renovation works were carried out on the area corresponding to 0.58% of the total forest area (from 0.32% in the Małopolskie voivodship to 0.91% in the Opolskie Voivodeship). According to GUS data, the area of forests in Poland from 1990 to 2017 increased by 548,000 ha.

Increasing the area of forests occurs as a result of afforestation of non-forest land used for agriculture or for wasteland. The increase in forest area is also related to the reclassification of other lands covered with forest vegetation - since 2001, the area of afforestation resulting from natural succession has been shown in public statistics.

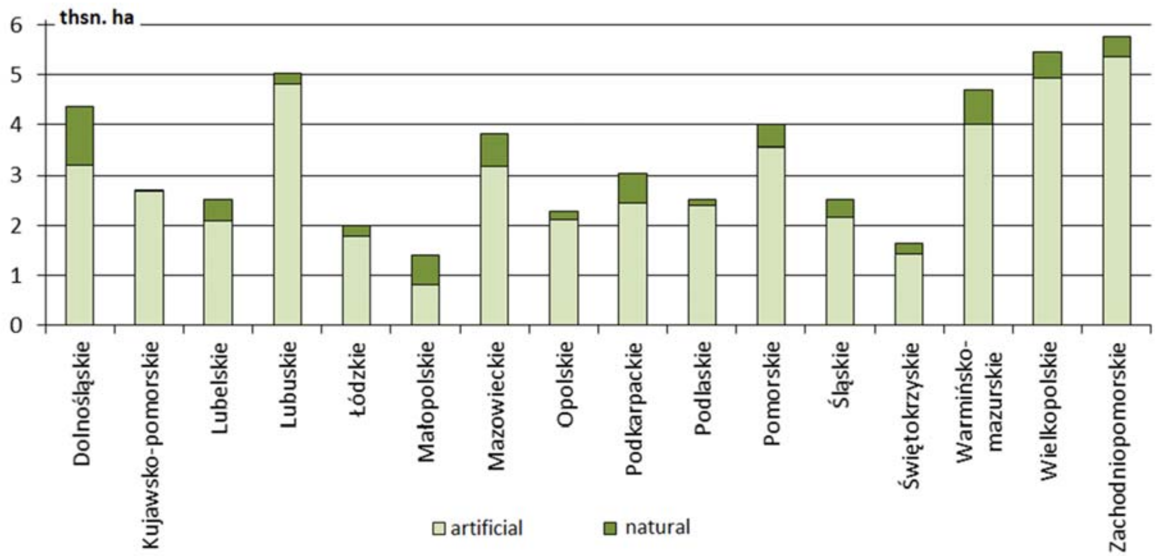

Figure 42. Forest renewals in 2017 by voivodships[146]

In Poland, currently about 1.5 million solid cubic metres of logs for energy (620,000 m^3 coniferous wood and 818,000 m^3 of deciduous wood) and 1.0 million cubic metres of small-size wood are obtained, i.e. together 2.5 million cubic metres[147]. According to estimates of the State Forests, the possibility of obtaining timber amounts to 2 Mm^3 per year, and from 2020 it will be possible to obtain 4 million cubic metres.

It is assumed that 1 solid cubic metre of wood is about 243 liters of heating oil and 1 kg of dry wood corresponds to the energy of 4.4 kWh. The wood consists of: cellulose, hemicellulose and lignin. Cellulose ($C_6H_{10}O_5$) is the basic component of the plant substance and is about 40-60% in wood. In deciduous wood, cellulose is less than coniferous, namely: 43-47% leafy, 53-54% coniferous. Hemicellulose occurs in wood in an amount of about 15-20%, and the amount of lignin ($C_{10}H_{18}O_9$) is 18-30%. Calorific values of individual components are indicative: hemicellulose - 16.2 MJ / kg, lignin - 28.8 MJ / kg, cellulose - 17.3 MJ / kg and resins - 36 MJ / kg.

The basic elements that are part of the wood are; coal (49.5%), oxygen (43.8%), hydrogen (6.0%), nitrogen (0.2%). The differences in the composition between different tree species are insignificant.

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[146] Bureau for Forest Management and Geodesy, Central Statistical Office, state on 1 January 2017

[147] Waldau A.J., Monforti-Ferrario F., Banja M., Arantegui R. L., Renewable Energy Snapshots 2013, Report EUR 26006 EN, EU 2013

The global production of wood pellets in 2010 was around 14 million tonnes [148]. In absolute terms, the largest energy production from biomass is recorded in Germany (37.65 TWh in 2011), Sweden (13 TWh) and Great Britain (12.5 TWh). These three countries represent a share in electricity production at the level of 47% in EU countries. In the case of Sweden and Finland, the main producer of biomass is the wood industry.
Rising prices of conventional fuels cause replacement of it with the granules. The raw material for the production of granules is wood waste. The most popular wastes for the production of granules are sawdust and shavings. You can also produce granules from bark, chips and straw. Then it contains more ash. Granulated boilers can be used wherever replacement coal-fired boilers are planned.
Germany and Sweden are currently the largest producers of granules in Europe and the second after Canada in the world. The use of pellets in the European Union increased from 3.8 million tonnes in 2005 to 9.8 million tonnes in 2010. Double pellet consumption is expected to be doubled to around 24 million tonnes by 2020, of which 11 million tonnes will come from imports. These figures show that there is the greatest demand for this product in Europe. Consumption of pellets in Sweden in 2008 amounted to about 1.85 million tonnes, of which 1.4 million tonnes came from domestic production [9]. The compensating import takes place mainly from the Baltic republics, Finland and Russia. The granulate burns primarily in large and medium-scale boiler rooms (above 1 MW). The aim in the nearest future is to implement biomass boilers for small household boilers (10-15 kW). There is a wide range of granulated combustion equipment on the European market.

Products along the value chain and utilization today

The total biomass of trees is twice as large as the production of usable wood, so it can be concluded that the most important source of biomass as renewable energy in Poland is straw and wood waste. The calorific value of biomass products against conventional fuels is: yellow straw 14.3 MJ/kg, gray straw 15.2 MJ/kg, wood waste 13 MJ/kg, while hard coal on average 25 MJ/kg and natural gas 48 MJ/kg. The calorific value of wood depends on its moisture content. Dry wood is 18 MJ/kg, and at 30% humidity, this value decreases to about 13 MJ/kg.

Wood moisture content

An important problem in the biomass combustion process is its humidity, which affects both the costs of the installation, the type of technology used as well as its acquisition and transport. Therefore, it is required to reduce the humidity from 50% to about 15% [149].

[148] Verhoest Ch., Ryckmans Y., Industrial Wood Pellets Report, Laborelec, 2012.
[149] Wisz J., Matwiejew A., Biomass- laboratory measurements in the view of combustion, Energetyka, September 2005 (in Polish).

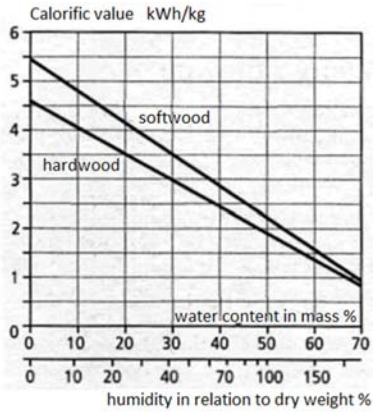

Figure 43. Relation of lower calorific value on moisture content with respect to wood dry mass and the wood with moisture [150] (1 kWh=3.6 MJ).

Physicochemical characterization of biomass

Biomass has a similar qualitative chemical composition to the coal composition. However, there are significant quantitative differences of individual elements. The results of testing various types of biomass in the dry state are presented in Table 40. The calorific value is one of the basic physicochemical parameters of solid biofuels. It ranges from 6-8 MJ / kg for wet biomass (50-60%), up to 15-17 MJ / kg for dry biomass (10-20%) up to 19 MJ / kg for completely dried biomass [9]. The calorific value depends on the biomass moisture and decreases with its increase. For this reason, some types of biomass must be dried to obtain the desired combustion parameters and a specific fuel energy value [9]. An important element of the biomass characteristics is the analysis of the chemical composition of ash [9]. When burning pure biomass, small quantities (0.5-12.5%) are created, with a small amount of harmful substances.

Ash can be used as a fertilizer, and its higher amounts are evidence of biomass pollution. The chemical composition of ash from different types of biomass differs significantly, differing from the composition of ash for lignite. The content of oxides (silicon, calcium and potassium) in the ash is affected by the temperature of the incineration of the sample, which is why it is important that the test methods are uniform. For different samples of the same type, there are also differences in the chemical composition of the ash. These differences are important for the adaptation of biomass burning boilers. Therefore, it is necessary to systematically examine the biomass used, especially when changing its type or supplier. The high content of easily fusible alkali metal oxides causes that the ash melting temperatures are reduced, which may also cause deposits on the boiler heating surfaces [9].

Table 40. Composition of basic elements and calorific value for various biomass species [11]

Parameter	Unit	Oak, aspen	Birch	Pine	Spruce
C	%	50.0	49.3	50.5	49.6
H	%	6.0	6.3	6.0	6.4
O + H	%	44.0	44.3	44.0	44.0
Heating value	kJ/kg	18,380	18,670	19,090	18,630

[150] http://agroenergetyka.pl/?a=article&id=146

The content of volatile parts
Volatile parts are components of biomass that arise during degassing of fuel. The content of volatile components in wood-based fuels is very high and amounts to 80-85%. The highest amount of volatile products is evolved at 20 - 300°C. Thanks to the flying parts, wood can be ignited. Due to the large number of volatile parts, combustion of wood and wood-based fuels requires a special design of the combustion chamber.

Ash content
Ash content in clean wood is 0.5 - 4%, it is a very small amount. Compared to coal, it is twice as low. Thanks for such a low ash content, the dust emission is reduced. However, if the wood is contaminated with, for example, sand or earth, the ash value may even be up to 10%. Wood ash does not melt into the slag because its melting point is 1,300 – 1,400°C, and the temperature in the smoke chamber does not usually exceed 1,200°C. Ash content increases when firewood is protected with wood preservatives.

Moisture content
Immediately after cutting, the wood moisture content is over 35%, but it can be much higher. Wood in a condition known as air-dry (dry in the open air) has a humidity of 8 - 13%. Moisture in wood reduces its heating value, and therefore is a ballast. The calorific value of freshly cut wood (φ = 50%) is approximately 8.4 MJ / kg. Therefore, it is important to burn eg pellets so that it is stored in a dry place. Wood has hygroscopic properties, i.e. absorbs moisture from the environment or gives it to the environment.

Characteristics of various forms of wood
Wood as a fuel occurs in many forms: chopped wood, chips, sawdust and chips, pellets, bark.

Piece wood (chipping)
It is the most commonly used wood fuel. During combustion, during the drying stage, the wood loses all excess moisture, contained in the microspheres of the pulp, and the remaining moisture is in equilibrium with the surrounding moist air. This type of wood immediately after cutting has 60% moisture. To estimate the water content, you can use (Table 42).

Sawdust and shavings
These are waste materials from sawmills and wood processing plants. The moisture content depends on the type of wood from which they are obtained and varies within 6-10% of the dry matter. They contain little dirt and ash. They are one of the cheapest fuels.

Wood bark
It is obtained from trees by debarking. It is very moist (moisture 55-60% of the total weight) and contaminated with sand and soil.

Wood chips
It is shredded wood about 1 cm thick and 2-5 cm long. They come from undercutting spruces, from cutting pine, they are also produced from energy crops (eg energy willow). Moisture content in the supplied chips depends on the method of obtaining them. In freshly chopped wood chips it amounts

to 50-60% of their mass, and after drying 35-45% of their mass[151]. The advantages of using chips: low energy expenditure (1-3% of energy contained in the furnace), they are cheaper than other forms of wood, chipping improves combustion efficiency and allows the use of various wood waste.

Pellets

Pellets are an environmentally friendly fuel and at the same time easy to transport, store and distribute. They are characterized by low moisture content (8-12%), ashes (0.5%) and substances harmful to the environment and high calorific value (16.5-17.5 MJ / kg) [28]. They arise by pressing the material under high pressure. They are an environmentally friendly source of energy. Their combustion does not cause additional emissions of carbon dioxide, their production contributes to reducing the problem of waste management, and the ash obtained in the combustion process can be used as a fertilizer.
Table 41 presents the results of biomass analysis as a potential fuel, Table 42 presents the calorific value of different types of biomass depending on humidity, and in Table 43 the chemical composition of ash of some types of biomass.

Table 41. Results of biomass analysis as a fuel (Energopomiar Laboratory in 1997 2005) [9]

Fuel type	Total moisture [%[	Ash [%]	Heating value* [kJ/kg]	Heating value** [kJ/kg]	Sulfur [%]	Nitrogen [%]	Chlorine [%]	Fluorine [%]
Wood briquettes	7.6	3.7	16,755	18,428	0.08	0.12	0.091	-
Pellets	7.7	1.8	16,880	18,670	0.1	0.12	-	-
Sawdust	39.1-47.3	1.3	5,267	19,346	0.05-0.20	-	-	-
Wood bark	38.4-48.1	3.9-14.7	7,947-11,796	17,588-20,674	0.06-0.07	0.28-0.33	0.02	-
Wood dust	3.8-6.4	2.4-17.1	15,212-19,148	15,161-20,109	0.12-0.21	-	-	0.001-0.003
Wood chips	42.4	0.5	8,957	18,496	0.03	0.06	-	-

*working condition; **dry condition

Table 42. Calorific value of different types of biomass depending on humidity [152]

Biomass type	Humidity	Heating value in wet condition	Heating value in dry condition
	[%]	[MJ/kg]	[MJ/kg]
Wood dust	3.8-6.4	15.2-19.1	15.2-20.1
Sawdust	39.1-47.3	5.3	19.3
Willow chips	40-55	8.7-11.6	16.5
Pellets	3.6-12	16.5-17.3	17.8-19,6
Wood briquettes	3.8-14.1	15.2-19.7	16.9-20.4

[151] Rybak W., Spalanie i współspalanie biopaliw stałych, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2006.
[152] Niedziółka I., Zuchniarz A., Energy analysis of selected types of biomass of vegetable origin, http://www.pan-ol.lublin.pl/wydawnictwa/Motrol8a/Niedziolka.pdf

Table 43 Chemical composition of ash of some types of biomass [12]

Chemical compounds	Wood bark	Wood chips	Pine sawdust	Willow	Biomass
SiO_2	37.3-70.6	19.5-34.9	88.3	20.7	7.2
Fe_2O_3	2.33-4.79	2.45-24.9	1.44	2.28	1.09
Al_2O_3	2.56-2.82	4.16-9.6	1.68	3.84	0.84
Mn_3O_4	0.26-2.1	0.67-2.44	0.21	0.12	0.06
TiO_2	0.11-0.19	0.25-0.57	0.11	0.16	0.08
CaO	15.8-38.2	17.9-37.5	3.61	48.6	40.2
MgO	0.84-2.04	3.01-6.52	0.73	4.29	2.8
SO_3	0.88-3.11	1.96-13.8	0.6	3.44	18.6
P_2O_5	0.88-1.72	2.87-7.08	0.67	6.44	5.05
Na_2O	0.27-0.33	0.40-1.96	0.24	0.63	1.95
K_2O	0.78-1.21	2.40-11.70	2.21	9.29	21.0
BaO	0.07-0.19	0.11-0.41	0.04	0.10	0.05
SrO	0.05-0.09	0.08-0.14	0.01	0.11	0.10

Table 44 Average wood moisture during natural drying [11]

Drying time [months]	Humidity [%]
0	60
3	40
6	35
9	30
12	25
18	18
24	15

The annual wood harvesting in Poland is around 42,000,000 m^3 and annual wood growth is twice that amount, so about 84,000,000 m^3 of wood. The removed wood is utilized for either materials or energy utilization. The annual demand of wood is still about 5,000,000 m^3 bigger than harvesting. In 2016 Poland exported 8,636,152 tonnes of wood and articles of wood in which about 94% to the European Union[153].

There are two large paper industry companies in the region and a few industrial size wood manufacturing company, and several minor SME's. The paper companies are International Paper Kwidzyn SA and Mondi Świecie as well as industrial size companies are: Wójcik that produces furnitures, Wiele. The activity in forest product industry has be increasing recently, resulting in being the leading Polish industry for international cooperation.

[153] Forestry 2017; Central Statistical Office, Warsaw 2017

Quantification of feedstock, products and residues

Table 45. Tree removal and utilization [1000 m^3] by assortments [Forestry 2017; Central Statistical Office, Warsaw 2017]

	2012	*2013*	*2014*	*2015*	*2016*
T O T A L	**37045**	**37946**	**39742**	**40247**	**40901**
TIMBER	**34978**	**35796**	**37661**	**38327**	**39129**
1.Coniferous	26042	26792	28533	29078	30078
1a.large-size general purpose wood	11672	12032	13017	13091	13502
1b.large-size special wood	75	80	92	98	87
1c.medium-size log wood	449	413	388	312	269
1d.medium-size wood for industrial uses	12212	12614	13341	13843	14553
1e.fuelwood	1634	1654	1695	1733	1666
2.Non-coniferous	8936	9004	9128	9249	9052
2a.large-size general purpose wood	2646	2589	2636	2562	2512
2b.large-size special wood	181	191	195	211	206
2c.medium-size wood for industrial uses	4317	4427	4463	4570	4468
2d.fuelwood	1791	1797	1833	1906	1866
SLASH	**2067**	**2148**	**2079**	**1920**	**1771**
1.Slash for industrial uses	448	456	424	408	382
2.Slash for fuel	1619	1693	1655	1512	1389
STUMP WOOD	**0.1**	**1.6**	**2.2**	**0.3**	**–**

Table 46. Consumption of wood in the products industry and the pulp and paper industry[154]

Products	**2010**	**2013**	**2014**	**2015**	**2016**
Total sawnwood [dam^3]	5,461	6,480	6,528	7,330	7,478
Coniferous sawnwood [dam^3]	4,532	5,315	5,458	6,036	6,240
Broadleaved sawnwood [dam^3]	929	1,165	1,070	1,294	1,238
Fibreboards [1000 m^2]	347,016	195,369	125,547	213,952	146,677
Hard fibreboards [1000 m^2]	167,424	159,700	77,074	131,119	79,490
Particle boards [1000 m^3]	4,353	5,170	5,564	5,442	5,870
Paper and paperboard [1000 t]	4,575	5,174	5,510	5,642	5,903
Woodpulp [1000 t]	1,299	1,391	1,434	1,318	1,378

[154] Forestry 2017; Central Statistical Office, Warsaw 2017

Table 47. Consumption of wood products industry and pulp and paper industry by Voivodships[155]

Voivodship	***Sawnwood***		***Fibreboards***		***Particle board***	***Paper and paperboard***
	total	***of which coniferous***	***total***	***of which hard***		
	[1000 m^3]		***[1000 m^2]***		***[m^3]***	***[t]***
Dolnośląskie	256.2	204.7	2,614.5	1,171.8	213,037	508,393
Kujawsko-pomorskie	331.8	252.5	1,500.8	509.2	140,544	874,159
Lubelskie	189.6	141.8	11,461.2	884.4	225,677	269,777
Lubuskie	555.8	521.9	43,819.5	38,205.2	627,929	267,426
Łódzkie	212.3	147.9	1,822.9	1,088.6	159,180	316,463
Małopolskie	952.6	852.9	809.6	159.9	116,189	399,486
Mazowieckie	382.0	299.5	11,759.0	6,489.3	459,088	1,143,254
Opolskie	89.6	64.8	4,339.2	4,006.1	105,467	152,997
Podkarpackie	277.5	170.0	3,635.8	827.3	262,839	116,969
Podlaskie	242.7	203.7	6,631.0	15.7	42,439	77,969
Pomorskie	455.8	370.0	4,329.2	2,491.2	254,020	107,982
Śląskie	403.6	356.8	6,848.8	3,526.6	199,833	204,567
Świętokrzyskie	196.1	188.4	114.3	21.8	84,223	56,662
Warmińsko-mazurskie	593.8	458.3	8,048.4	1,810.2	771,687	89,415
Wielkopolskie	1,344.3	1,111.2	14,018.4	7,234.9	1,093,306	1,171,887
Zachodniopomorskie	994.1	895.5	24,924.2	11,048.2	1,114,304	145,524
POLAND TOTAL	**7,477.8**	**6,239.9**	**146,676.8**	**79,490.4**	**5,869,762**	**5,902,930**

Table 48 Characterization of wood[156]

Parameter	**Unit**	**Spruce**	**Beech**	**Pine**
Net calorific value	[kJ/kg]	20,427	17,771	20,932
Hemicellulose content	[%]	26-35	23-29	27
Cellulose content	[%]	42	38	42
Lignin content	[%]	28	24	26

Table 49 Current material flow based on Wiele Wood facotry (2018)

Step 1 - forest		
Trunk (Log)	[t DM]	129,545,454.50
Roots	[t DM]	4,090,909.09
Branches+foliage	[t DM]	2,727,272.73
Total wood biomass	[t DM]	136,363,636.40

[155] Forestry 2017; Central Statistical Office, Warsaw 2017
[156] http://web.nchu.edu.tw/pweb/users/taiwanfir/lesson/10726.pdf – accessed 23/10/18; https://akela.mendelu.cz/~xcepl/inobio /nove/Wood_anatomy/WAEF-02-chemical_composition.pdf – accessed 23/10/18

Step 2- wood harvest		
Wood harvested	[%]	55
Trunk (Log)	[%]	100
Branches+foliage	[%]	0
Roots	[%]	0
Wood harvested	[t DM]	75,000,000
Trunk (Log)	[t DM]	71,250,000
Branches+foliage	[t DM]	0
Roots	[t DM]	0

Step 3 - wood production		
Wood incoming (Trunk)	[t DM]	75,000,000
Log	[%]	95
Products		
Elevation boards	[t DM]	21,375,000
Wooden pegs	[t DM]	10,687,500
Glued structural elements	[t DM]	7,125,000
Wood pellets	[t DM]	17,812,500
Garden products	[t DM]	14,250,000
Bark	[t DM]	3,750,000
Evaporated water	[t DM]	

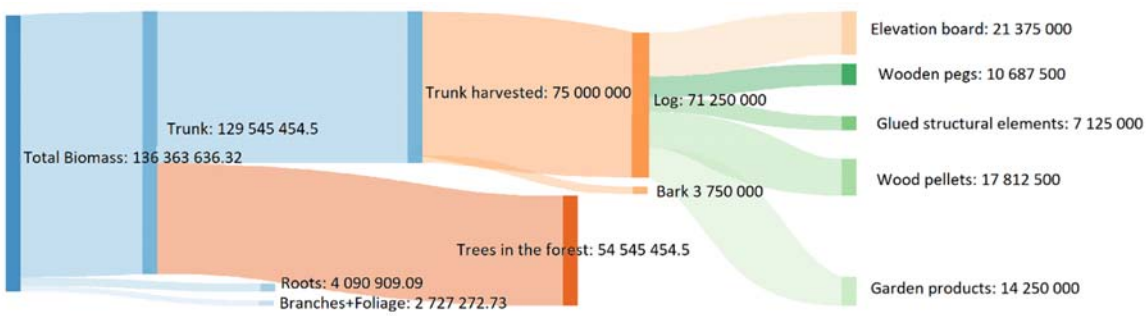

Figure 44. Sankey diagram of biomass flow chain in Wiele wood factory

2.2.4 Regional resources in Sweden

Assessed by Johanna Lund and Anna Ekman Nilsson, RISE Research Institutes of Sweden

The life cycle of forest production includes various measures such as soil preparation, planting, clearing, thinning, cleaning of ditches, fertilization and final harvesting. The measures are linked to different stages of the forest's age. Soil preparation, planting, cleaning of ditches and clearing takes place in the forest's youth and aims to build a new, well-stocked forest area. In the middle ages of the forest, thinning and fertilizers are often carried out with the aim of steering and increasing the growth of the finest trees that will grow into timber trees and become planks in the future. When the forest has reached the appropriate harvesting age, it is time to harvest and then re-start with soil preparation and planting of new plants[157]. Generally, a forest owner wants as much saw timber as possible as it currently provides the best economic return. Therefore, most forest owners manage their forests to develop good saw timber.

The cycle time of the forest depends on how well it grows, but for at least 45 years. More common, however, is to harvest at about 80 years of age. Within the Swedish forestry industry, the productive forest land is defined as the forest land that produces 1 m^3sk per hectare and year. m^3sk is an abbreviation for "forest cubic meter" which is the wood volume of a tree or forest, including bark but excluding branches and roots. When the tree is harvested it is no longer measured in m3sk but in "solid cubic meter" (m^3f). The stem represents 69% of the biomass of a pine tree, 16% of tops and branches and 15% of stubble and roots[158]. Corresponding numbers for a spruce tree are 59% stem, 27% tops and branches and 14% stubble and roots.

Tops and branches are residues from the harvest that are left in the forest if only the stem wood is harvested. Most of the harvest residues are collected after the final harvest, but also at the thinning. Two methods are mainly used for the management of the tops and branches in Sweden. One where the tops and branches is dried in harvest piles on the cutting area and is forwarded together at a later stage. In the other alternative the tops and branches are forwarded directly to the edge of the road immediately after the harvesting, where the material is stored in log piles[159]. Whatever method, the purpose of the handling of the tops and branches is that the material should dry and lose the needles before the next step in the process - decomposition[160]. Stubbles from windthrows are generally not allowed to be included in the tops and branches due to contaminations.
The Swedish forest is by 50% owned by private forest owners, while forest companies (SCA, Holmen, Bergvik Skog et al) owns about 25% and the public (Sveaskog, Swedish Church, municipalities) owns the remaining 25%[161].

Forest industry

Forest industry is mainly the pulp and paper industry and the wood processing industry (sawn timber and other wood products). Other industries such as refining of wood-based products and

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[157] Bergvikskog, 2018. www.bergvikskog.se
[158] Petterson, M. 2007: Grenar och toppar nya möjligheter för skogsägare. Illustratör Gunilla Guldbrand. Guldbrand & Guldbrand. Nya tryckeri city i Umeå AB, 2007.
[159] Lehtikangas, P., 1999. Lagringshandbok för trädbränslen. Andra upplagan. Institutionen för virkeslära, Sveriges lantbruksuniversitet, Uppsala
[160] Nilsson, B., Blom, Å., Thörnqvist, T. 2013: The influence of two different handling methods on the moisture content and composition of logging residues. Biomass And Bioenergy, 2013, 52, 34–42.
[161] Skogssverige, 2018. www.skogssverige.se

trade with wood-based products are also included in the forest industry sector[162]. The latter branches of the forest industry are, however, not included in this report since they produce minor amounts of by-products or waste that could be potential raw materials in a bioeconomy.
The forest industry is very important for the Swedish economy. It is estimated that the forest industry is responsible for about 10% of Swedish GDP and 10% of total exports[162]. In some regions the forest industry is the dominating industry but in Skåne the forest sector is relatively small.
The forest industry receives the raw material from the forest. In Sweden a total of 71.3 million m^3 (m^3 fub=solid cubic meters under cortex) wood was utilised by the forest industry in 2017. Of this 36.3 million m^3 fub were used for production of sawn wood products and 35.3 million m^3 fub were used as pulp wood. Also 9.9 million m^3 of wood chips from sawmills are used in the production of pulp and paper[162]. The Swedish forest industry value chain is depicted in Figure 45.

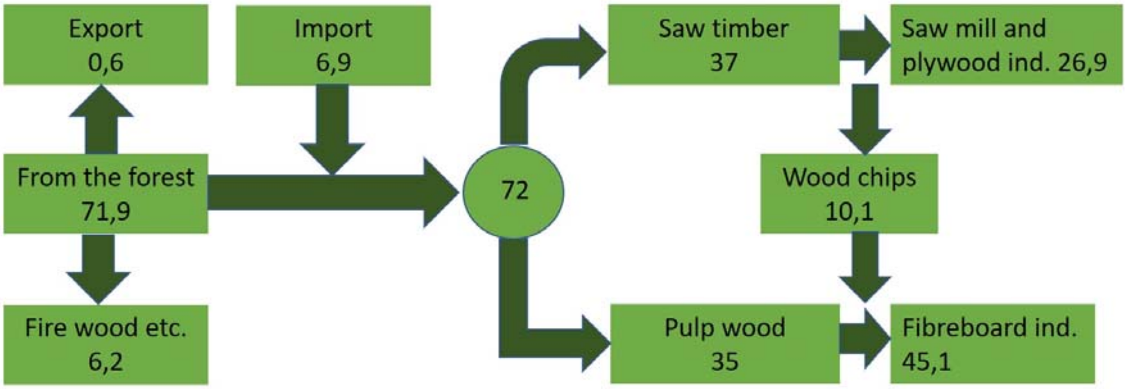

Figure 45. Material flow in Swedish forest industry 2016 (Skogsindustrierna, 2018). Numbers given are in million cubic metres under cortex.

Products along the value chain and utilization today

Forest production
The southwestern part of the Skåne region has almost no forest at all. The spruce has a natural spread only in the northern parts of Skåne, while deciduous forest (beech, oak, etc.) dominates the other parts of the landscape.

Spruce – The yellow-white spruce wood is relatively soft and can be used for many different purposes. It is mainly used for pulp and as construction wood. The long and slim fibers make the spruce wood suitable as a raw material for paper. The spruce usually produces timber of good quality. Spruce is one of the most common woods in the production of sawn timber. Spruce is one of Sweden’s most important export raw materials.

Pine – Pine wood is firmer and harder than spruce wood and is very durable, especially the core. It is mainly used as construction wood, furniture wood, floor wood, craft pulp and to produce chemicals.

Beech – The wood, which is light, hard, sturdy with straight fibers, produces furniture, parquet, toys and glass sticks.
Quantification of feedstock, products and residues

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[162] Skogsindustrierna, 2018. www.skogsindustrierna.se

Saw mills

Approximately half of the wood that is produced in Swedish forests is processed in saw mills. In a saw mill logs are converted to deal and board of a variety of sizes and dimensions. There are two major saw mills in Skåne, Vida HN AB in Hästveda and ATA Timber Widsköfle AB in Everöd. There are also some smaller producers of refined wood products. However, their production of by-products and residues is not large enough to be of significance for the raw material potential in Skåne. In Widtsköfle approximately 75,000 m^3 of sawn products of spruce and pine are produced annually and in Hästveda the production is approximately 180,000 m^3 sawn spruce products. The process flow in a saw mill is depicted in Figure 46.

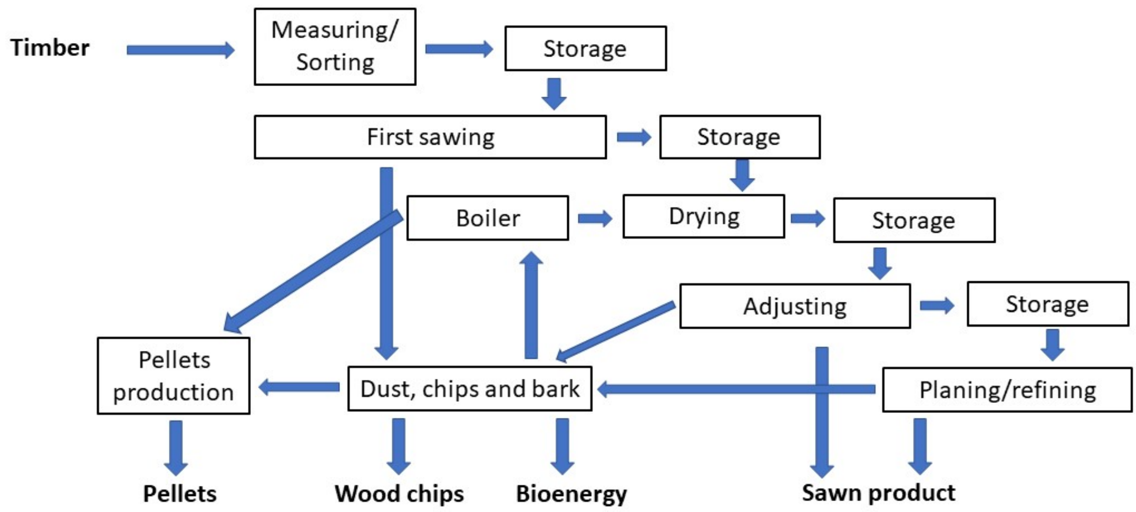

Figure 46. Process flow in a saw mill. Adapted from Naturvårdsverket, 2010[163].

The wood is first debarked, then the dimensions are measured to optimise the sawing so that as much products as possible can be obtained and the amount of by-product is minimized. In addition to sawing, refining of sawn products by, for example, planing is also done in some mills. Wood and by-products that are stored need to be watered to avoid damage to the wood and to reduce the risk of fire (in case of by-products such as saw dust). Final products, however, need to be dry and drying is the most energy demanding process in saw mills. Often by-products such as bark are used for internal heat generation in the saw mill[163].

Pulp and Paper Industry

There is one pulp and paper mill in Skåne, Nymölla mill, owned by Stora Enso. In this mill pulp is produced by the sulphite process. The paper produced is fine paper which is used for printing and copying. In addition to the pulp produced in Nymölla, paper is also produced from pulp produced in other mills. The capacity of the Nymölla mill is 350,000 tonnes of pulp and 560,000 tonnes of paper. In 2016 the production of pulp was 319,000 tonnes and the production of paper was 436,000 tonnes. The production has been relatively stable for the last ten years, varying between 280,000

[163] Naturvårdsverket, 2010. Sågverk Fakta om branschen och dess miljöpåverkan. Branschfakta Sågverk Utgåva 1. Stockholm.

tonnes of pulp in 2008 and 340,000 tonnes in 2007 and 2012 and the paper production between 400,000 tonnes in 2007 and 450,000 tonnes in 2012[164].

The process in Nymölla is depicted in Figure 47. In Nymölla, pulp is produced by a chemical pulping process, the sulphite process. The sulphite process has become less common in the last years due to the more difficult recovery of cooking chemicals compared to the sulphate (or kraft) process. The advantage of the sulphite process is that it gives paper of higher whiteness which is desired in certain applications such as tissue and fine paper (Nymölla miljöredovisning, 2016).

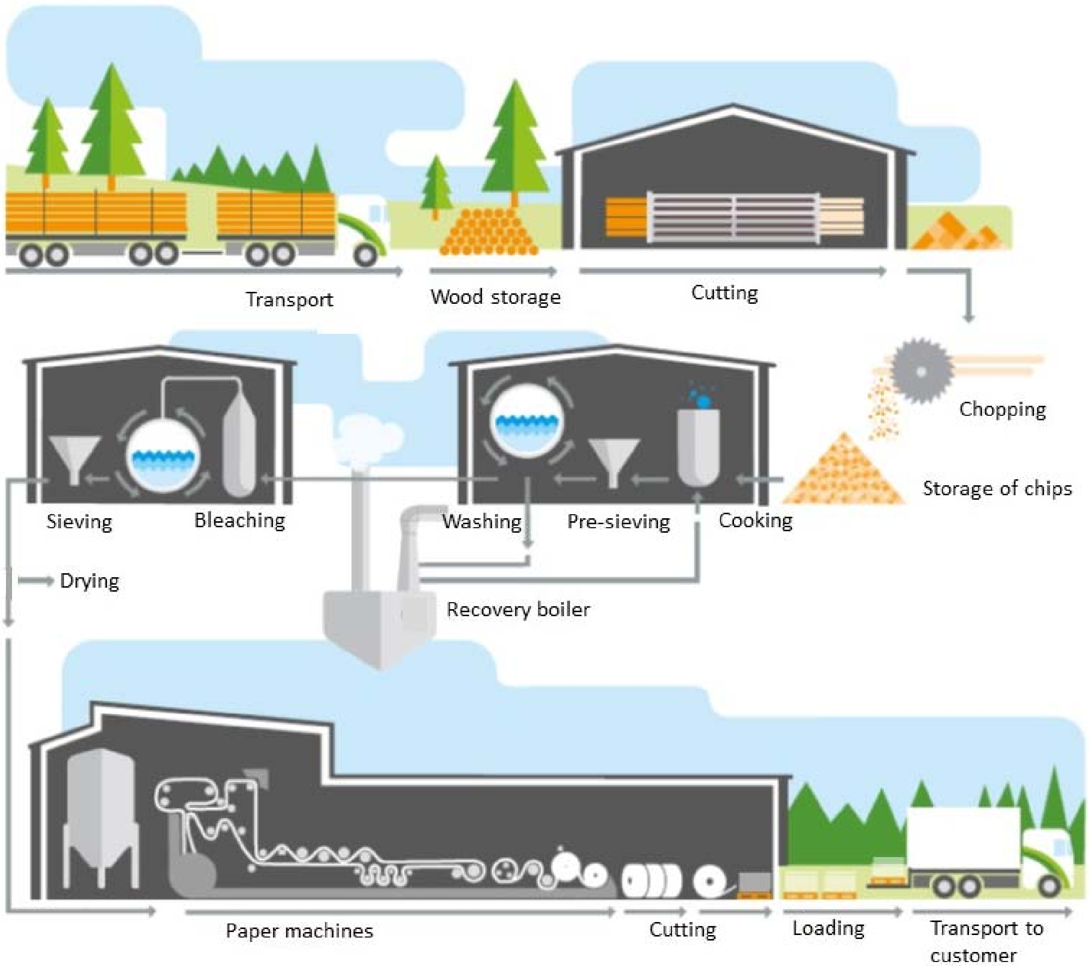

Figure 47. Process flow in Nymölla[165]

In Nymölla, the raw material that enters the mill is pine, spruce, beech, aspen and birch. Most of the material is roundwood but a large share is wood chips from saw mills. The wood is chopped to chips and stored for approximately six weeks to reduce the amount of resin and extractives. After storing the wood is cooked in a solution of chemicals at temperatures of 140-160 $^{\circ}$C and pressure of 500-700 kPa. The cooking is done in batches of approximately 8 hours. The cooking is done to dissolve the cellulose fibres from the lignin. The cooking solution is prepared by dissolving sulphur

[164] Stora Enso, 2016. Miljöredovisning 2016 Nymölla Bruk.
[165] Nymölla miljöredovisning, 2017

dioxide (SO_2) in an alkaline solution based Mg^{2+} (magnesium bi sulphite) because this gives the easiest recovery of cooking chemicals. The lignin together with other substances in the wood are dissolved in the cooking liquid. The pulp is sieved and washed the liquid removed is called thin liquor. The thin liquor is evaporated to thick liquor and the thick liquor is thereafter burned in a boiler. The remaining cooking chemicals are recovered and reused. About 95% of cooking chemicals can be recovered and reused[166].

After washing and sieving, the pulp is bleached. The bleaching process is Totally Chlorine Free (TCF) and instead O_2, NaOH and H_2O_2 together with EDTA are used. After bleaching, the pulp is sieved a last time. The pulp is pumped to the paper machines for production of fine paper. Paper is also produced from pulp bought from other mills.

The energy from combustion of the thick liquor is recovered and used in the process. In addition to this, the mill has an incinerator for solid fuels (bark, branches, residues from pulping, wood chips and sludge from waste water treatment) combined with some fuel oil and LPG. Internal energy generation in the mill covers all heat used and part of the electricity. Combined pulp and paper production are advantageous in terms of energy efficiency because excess energy generated in pulp production can be used for production of paper[167]. Excess heat is delivered as district heat to nearby municipalities Bromölla and Sölvesborg[168].

Primary production

The area of forest land in Skåne was according to the Swedish Forestry Act, 2013-2017, 429,000 hectares and the area of other wooded area was 4,000 hectares. In Skåne around 60% of the forest is coniferous and around 40% is deciduous forest[169]. In Sweden in total the deciduous trees accounts for about 18% of the total wood stock in Swedish forest. The mean annual increment of different tree species (growth of felled trees included) in Skåne, 2012-2016, was 108,800 tonnes WW[170] for pine, 604,800 tonnes WW[1] for spruce, 137,600 tonnes WW for birch, 44,800 tonnes WW for oak, 118,400 tonnes WW for beech and 105,600 tonnes WW for other broadleaved trees[169]. The total mean annual increment of all different tree species in Skåne, 2012-2016, was 1,120,000 tonnes WW.

The gross annual felling of productive forest in Skåne was 2,755,000 m^3sk on average 2014-2016[171]. Recalculated to tonnes the gross felling was 881,600 tonnes WW. There is no available statistics on the gross felling for the different tree species in Skåne[171]. The forest that is harvested in Sweden was mainly used for sawn timber (about 46%), and for pulpwood (about 42%) and the rest goes to energy wood and specialty assortment such as poles[171].

Saw mills

The raw material in saw mills is spruce logs. In Skåne it is estimated that 330,000 m^3 fub (264,000 ton WW) are used as raw material in Hästveda[172] and 139,000[173] m^3 fub (111,200 ton WW) in

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166 Stora Enso, 2016. Miljöredovisning 2016 Nymölla Bruk.
167 Jonsson, J., Kristofersson, J. & Samuelsson, C., 2011. Energikartläggning av integrerat massa- och pappersbruk. Linnéuniversitetet, Växsjö.
168 Stora Enso, 2017. Miljöredovisning 2017 Nymölla Bruk.
169 Skogsstyrelsen, 2018. www.skogsstyrelsen.se
170 45% water content
171 Skogsstyrelsen, 2017. Bruttoavverkning 2016. Sveriges Officiella Statistik. Statistiska meddelanden JO0312 SM 1701
172 Vida, 2018. www.vida.se/sv/vida-wood/vidas-sagverk/hastveda/
173 75,000 m^3 products are produced and the same utilization as in Hästveda is assumed

Widtsköfle[174]. In Hästveda the material is taken within 60 km from the saw mill which includes Skåne but also neighbouring regions. According to information given by Vida HN AB in Hästveda approximately 64% of the log is turned into wood products, 14% is saw dust and bark and 22% is wood chips used in pulp production[174]. However, this is not quite according to the figures they present for the production that rather 54% is turned into sawn products, 180,000 m^3 of 330,000 m^3 [175].

<u>Pulp and Paper Industry</u>
The raw material for the Nymölla mill is round wood, mainly pine, spruce, beech, aspen and birch. Wood chips from saw mills are also used as raw material in the production. In 2017 the total amount of wood used in Nymölla was 1.403 million m^3 fub. Of this 1.074 million m^3 were softwood (including 0.452 million m^3 fub woodchips from saw mills) and 0.329 million m^3 fub were hardwood. Approximately 90% of the pulp wood was of Swedish origin and 10% was imported, mainly from Germany and Poland[176].
The outtake of water from the river Skräbeån was 1 m^3 per second in 2017.
All heat and 40% of the electricity consumed in the mill is produced on site. The fuels used are 94% biofuels, the largest share is processing residues and other internally available biofuels. The remaining 6% come from fuel oil and LPG. In total, 1950 GWh fuels were used in 2017, 1650 GWh of the fuels were internal biofuels. Total electricity consumption in 2017 was 473 GWh and of this, 189 GWh were produced on site[176].

By-products/residues
The harvested area with tops and branches were 4,949 hectares and 47 hectares with stumps in Skåne in 2013. The amount of tops and branches removed were 216,000 tonnes WW[177] in final felling and 99,520 tonnes WW in thinning in an average for three years 2011-2013. This gives a total harvest of 315,520 tonnes WW. Conversion tables for tops and branches from Bioenergiportalen[178] were used in the calculations. The amount of stumps for Skåne is lacking.
At least around one fifth of the tops and branches needs to be left in the forest for environmental reasons[179]. The Swedish Forest Agency recommends that 20% of the harvest residues, as well as most of the needles, should be left on the cutting area. It is usually stated that the share of needled in the roots and branches is 20-30%. Tops and branches are mainly combusted in heat and power plants today.

The residual biomass fractions from forest land are mainly roots and branches today, but in the future, stubs may also be of greater interest. Stumps represent a potential for solid biofuel. In Finland, this resource is used to a greater extent. Stubble harvest causes a reduced need for soil preparation, but stumps require 1-2 years of storage before they are dry enough to burn. The nutrient balance in the forest is less affected by stubble rupture than by removal of tops and branches.

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[174] Ata, 2018. www.ata.nu/anlaggningar/widtskofle/
[175] Vida, 2018. www.vida.se/sv/vida-wood/vidas-sagverk/hastveda/
[176] Stora Enso, 2017. Miljöredovisning 2017 Nymölla Bruk.
[177] 40% moisture content
[178] Bioenergiportalen, 2018. www.bioenergiportalen.se
[179] Skogsstyrelsen, 2018. www.skogsstyrelsen.se

Saw mills

There are three saw mills in Skåne. The main by-products in the saw mill industry are saw dust, wood chips and bark. Saw dust is used for production of pellets, wood chips are used in the pulp and paper industry and bark is mainly used for internal energy generation. There is a variation in the energy content of by-products mainly due to variations in moisture content. In a saw mill energy is mainly used for drying the wood. In addition to sawing, refining of sawn products by, for example, planning is also done in some mills which causes an additional production of wood chips[180].

In addition to by-products generated from the production of sawn timber, leach water from the watering of stored timber can contain valuable compounds, mainly P and N. When wood is dried, a condensate that could contain high concentrations of TOC. The possibilities for taking care of these condensates are still poorly investigated[180].

Pulp and Paper Industry

Processing residues are mainly cooking liquors, bark and wood residues. Today these are all burned for internal energy generation and recovery of chemicals. The spent cooking liquor contains approximately 99% of the added cooking chemicals as well as all lignin and hemicelluloses from the wood raw material. Spent cooking liquor provides 75% of the fuels used in Nymölla[181]. In addition to lignin which provides most of the energy, the sulphite spent liquor contains significant amounts of sugars, mainly originating from the hemicelluloses, and this liquor can be fermented to ethanol. There is a potential to use these sugars for fermentation processes to produce, for example, ethanol[182].

In the process, a large amount of waste water is produced. This is treated at several steps both by ultrafiltration and by biological treatment before the water is released to the recipient and the concentrated sludge is incinerated. However, the waste water still has a considerable amount of organic material both in the form of COD and suspended solids. A biogas plant for the waste water is planned and significant funding for the investment was received from the Swedish government in the end of 2017 through Klimatklivet. Liquid biogas for transport on land and sea will be produced.

Nymölla delivers district heating to Bromölla and Sölvesborg municipalities. In 2016 the total delivery of district heat was 103 GWh. At the Nymölla site a manufacturer of PCC fillers is also situated. PCC is precipitated Calcium Carbonate and the in the process for production of PCC the CO_2 in flue gases from Nymölla is used. This exact amount of CO_2 that is utilised is not specified but the use is larger than the amount of flue gases produced from fossil fuels. Thus, emissions of fossil CO_2 are counted as zero and emissions of bio-based CO_2 were 745,583 tonnes in 2016[183]. Some of the PCC produced is also used in the process at the mill[181].

Characterization of feedstock, products and residues in value chain

Main components of wood are cellulose, hemicellulose, lignin and extractives. Wood is not a homogeneous material; the chemical structure varies between the stem and cortex as well as between root and top. In general, the hemicellulose content of deciduous trees is a little bit higher than for coniferous trees. The lignin content, on the other hand, is usually much lower in deciduous trees. In birch, hemicellulose consists essentially of xylose units. Hemicellulose from conifers is

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[180] Naturvårdsverket, 2010. Sågverk Fakta om branschen och dess miljöpåverkan. Branschfakta Sågverk Utgåva 1. Stockholm.

[181] Jonsson, J., Kristofersson, J. & Samuelsson, C., 2011. Energikartläggning av integrerat massa- och pappersbruk. Linnéuniversitetet, Växsjö.

[182] Helle, S., Murray, A., Lam, J., Cameron, D. & Duff, S. 2004. Xylose fermentation by genetically modified Saccharomyces cerevisiae 259ST in spent sulfite liquor. Bioresource Technology 92 (2004) 163–171.

[183] Stora Enso, 2017. Miljöredovisning 2017 Nymölla Bruk.

more heterogeneous and contains several different sugars and currently has no major commercial use partly because there are no large quantities available.

Table 50. Characterization of stem wood for different wood species

Parameter	Unit	Pine	Spruce	Beech	Oak	Birch
Moisture content[184]	[%]	45-60	40-60	40-45	40-45	35-50
N content, stem and cortex[185]	[g/kg]	0.86	1.1			
P content, stem and cortex[185]	[g/kg]	0.085	0.11			
K content, stem and cortex[185]	[g/kg]	0.47	0.61			
Hemicellulose content[186]	[% of DM];	27	27			32
Cellulose content[186]	[% of DM];	41	43			41
Lignin content[186]	[%]	28	28			22
Ash content[184]	[%]	0.4	0.6			0.4

The moisture content of newly harvested forest residues (tops and branches) is usually between 50 and 55%. The moisture content drops rapidly in the spring and summer regardless if the harvesting residues are stored in piles or in log piles. With higher humidity and rainfall in autumn and winter there will be a rapid increase in the water content in the dry harvest residues. The covered log piles generally has 10% higher water content compared to the uncovered log piles and water content is more homogenous in the material[184].

[184] Lehtikangas, P., 1999. Lagringshandbok för trädbränslen. Andra upplagan. Institutionen för virkeslära, Sveriges Lantbruksuniversitet, Uppsala
[185] Hellsten, S., Akselsson, C., Olsson, B., Belyazid, S., Zetterberg, T. 2009: Effekter av skogsbränsleuttag på markförsurning, näringsbalanser och tillväxt – Uppskalning baserat på experimentella data och modellberäkningar som grund för kartläggning av behov av askåterföring. Rapport B1798. IVL Svenska Miljöinstitutet AB
[186] Eskilsson, S. & Hartler, N. 1973. Whole tree pulping. Part 2. Sulphate cooking. Svensk papperstidning nr 2:63-70.

Table 51. Characterization of tops, branches, tops and branches and stumps for different wood species

Parameter	Unit	Tops		Branches		Tops and branches		Stumps	
		Pine	Spruce	Pine	Spruce	Pine	Spruce	Pine	Spruce
Dry matter content[187]	[%]					40			
N content[185]	[g/kg]			3.6	4.5			1.4	1.7
P content[185]	[g/kg]			0.41	0.58			0.18	0.22
K content[185]	[g/kg]			1.7	1.6			0.52	0.66
Hemicellulose	[%]			32	30				
Cellulose content[186]	[%]			32	29				
Lignin content[186]	[%]			31	37				

As a rule of thumb about 50% of the dry matter content in the wood comes out as pulp. The pulp consists almost entirely of cellulose. Approximately 10% of the dry matter content is bark and the remaining 40% comes out in the cooking liquor. In the sulphite process, the lignin in the cooking liquor is in the form of lignosulphonates. Lignosulphonates can be used as starting material in the production of dispergents and for surface active compounds and adhesives in for example paint[188].

Table 52. Elemental composition of spent cooking liquor at sulphite mill189.

Element	% of DM
Carbon	46.3
Hydrogen	5.1
Sulphur	6.1
Magnesium	3.2
Oxygen, nitrogen etc.	39.3

Saw dust and wood chips from saw mills have not undergone any chemical treatment and the chemical composition of the material is therefore the same as for the wood entering the saw mill.

[187] Skogsstyrelsen, 2018. www.skogsstyrelsen.se
[188] Staffas, L., Hansen, K., Sidvall, A. & Munthe, J. 2015. Råvaruströmmar från skogen – tillgång och samband. IVL-rapport NR C 116. Stockholm.
[189] Jonsson, J., Kristofersson, J. & Samuelsson, C., 2011. Energikartläggning av integrerat massa- och pappersbruk. Linnéuniversitetet, Växsjö.

Table 53. Input data mass balance pulp industry

Pulp and Paper industry		**2016**	**2017**
Incoming wood (soft wood)	[tonnes][1] 40% moist.	818 625	777 500
Incoming wood (hard wood)	[tonnes][1] 40% moist.	392 750	411 125
Incoming wood chips (soft wood)	[tonnes][1, 2] 40% moist.	243 200	226 050
Pulp produced	[tonnes][4]	319 000	350 000
Paper produced	[tonnes][4]	436 000	560 000
Bark produced	[tonnes] 40% moist.	121 138[3]	
Fuels consumed (incl. internal residues)	[GWh]	2000	1950
Energy delivered as district heat	[GWh]	103	97
Waste water (COD)	[tonnes]	11 650	12145
Waste water (suspended solids)	[tonnes]	448	461
Ashes	[tonnes]	n/a	4000

[1] Assuming 1 m^3 fub equals 1.25 ton[190]
[2] Assuming 1 m^3 fub wood chips equals 0.4 m^3 fub wood
[3] Assuming 10% of wood intake according to Staffas et al.[191]
[4] DM content not specified

Table 54. Input data mass balance saw mills

Saw mills	**Unit**	**Amounts**
Incoming spruce wood	[tonnes][1]	586,000[1]
Sawn products	[tonnes][1]	318,750[2]
Saw dust incl. bark	[tonnes][1]	104,000
Wood chips	[tonnes][1]	163,000[3]

[1] Assumed that 54% of incoming wood is turned into sawn products as interpreted from Vida[192]
[2] Number presented by companies
[3] Based on a relation of wood chips/saw dust of 1.57:1

[190] Bioenergiportalen, 2018. www.bioenergiportalen.se
[191] Staffas, L., Hansen, K., Sidvall, A. & Munthe, J. 2015. Råvaruströmmar från skogen – tillgång och samband. IVL-rapport NR C 116. Stockholm
[192] Vida, 2018. www.vida.se/sv/vida-wood/vidas-sagverk/hastveda/

2.2.5 Summary and outlook

Of the four SBA regions, Poland has a considerably larger area under forest, about 4 times larger compared with the area in Mecklenburg-Western Pomerania, 5 times larger than in Skåne and 24 times larger than in Region Zealand (Figure 48). Denmark has comparably small forest area in absolut terms and as proportion of the total land area (Figure 48). Compared to the 70% of area under forest in the whole of Sweden, Skåne has only about 40% of its area covered with forest.

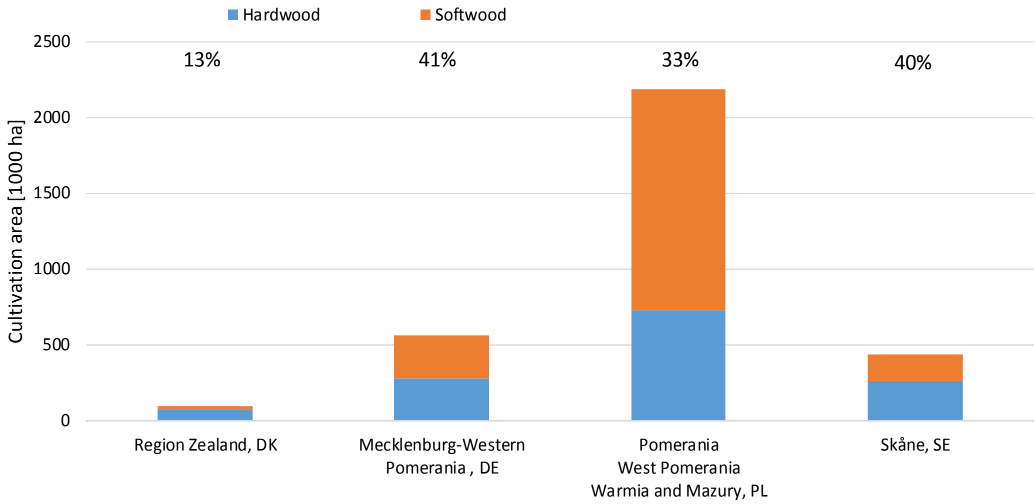

Figure 48. Forest area for hardwood and softwood in the four SBA regions. Numbers above the columns refer to share of forestry area on total land area.

While Denmark is extracting almost 90% of its relatively small wood production, Mecklenburg-Western Pomeranina could almost double its wood extraction (Figure 49). The Polish SBA regions respresent the in absolute terms largest potential for wood extraction, which could be expanded considerably as well. These data are based purely on increment data and have not been assessed for if extraction can be carried out sustainably.

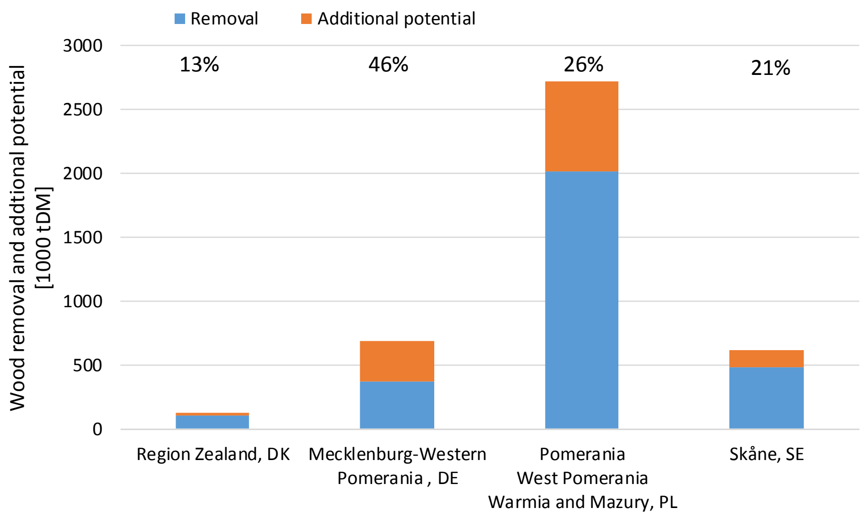

Figure 49. Wood removal for material anad energy purposes and additional potential in the four SBA regions. Numbers above the columns refer to the proportion of unused biomass potential.

Opportunities

The forest and wood-processing industry has long since been a sector characterised by highly efficient large-scale biorefineries. Due to a high energy demand in the facilties, by-products have often been used for heat and power generation. However, in light of decrease demand for paper and an increasing bioeconomy, the sector is inventing itself again and research has focused on a large variety of speciality products from wood, such as packaging materials, textiles, vehicle fuels, insultation, cosmetic, plastic films, nanocellulose and materials for batteries[193,194].

Wood fuels made from residues of the timber extraction ans well as residues from the sulfat cooking processes are current the largest by-products. Furthermore, tall oil from pulp production is already refined for green chemicals and biofuels[195]. The main conversion technologies applied to these new products include extract, bioconversion, fasification, pyrolysis and separation processes (Figure 50).

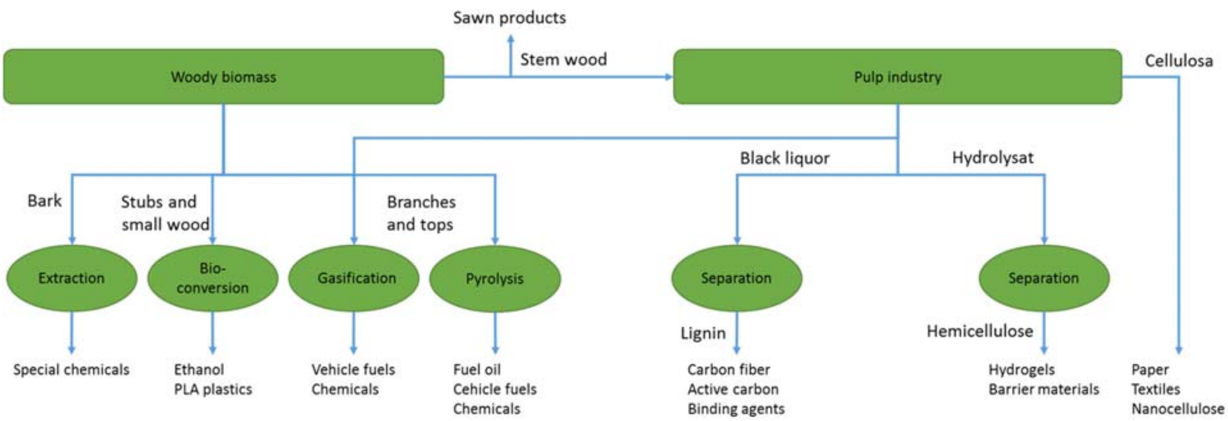

Figure 50. Schematic overview of the main development paths for new products from forestry and pulp industry[195].

Newly designed processes aim at producing e.g. speciality chemicals such as succinic acid, cellulosic ethanol, 1,3-propanediol, 1,4-butanediol, bio-isobutene, ethylene, polypropylene and farnesene[196]. The list of suggested bio-based products has been extended of the last decade and continues to expand (Table 55)[197].

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[193] http://www.svenskaskogen.nu/?gclid=Cj0KCQjwhPfkBRD0ARIsAAcYycH-pzsEnjSb9R6yDbi8gfo1hbgT-x7oAf2-BD4oMRtjCvPwWys_JR0aAnw-EALw_wcB#material

[194] https://bioeconomy.se/

[195] Backlund, B. and M. Nordström (2014). Nya produkter från skogsråvara - En översikt av läget 2014 Stockholm, Sweden, Innventia & Skogsforsk: 67.

[196] Chandel, A. K., V. K. Garlapati, A. K. Singh, F. A. F. Antunes and S. S. da Silva (2018). The path forward for lignocellulose biorefineries: Bottlenecks, solutions, and perspective on commercialization. Bioresource Technology 264: 370-381.

[197] U.S. Department of Energy, 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. In: Perlack, R.D., Stokes, B.J. (Eds.), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN.

Table 55. Potential bio-based products/chemicals selected by US Department of Energy (USDOE) from lignocellulose biorefinery platform[197]. Table reproduced from Chandel et al, 2011[196].

Potential bio-based products/ chemicals selected by USDOE in 2004	Top platform chemicals based on green chemistry by USDOE in 2010
• 1, 4 Succinic, fumaric and malic acids • 2, 5 Furan dicarboxylic acid • 3-Hydroxy propionic acid • Aspartic acid • Glutaric acid • Glutamic acid • Itaconic acid • Levulinic acid • 3-Hydroxybutyrolactone • Glycerol • Sorbitol	• Ethanol • Furans (furfural, 5-hydroxymethylfurfural, 2, 5-FDCA) • Glycerol and its derivatives (propanediol, glycerol carbonate, epichlorohydrin) • Hydrocarbons (isoprenes, etc) • Lactic acid • Succinic acid/Aldehyde/3-hydroxy • Propionic acid • Levulinic acid • Sorbitol • Xylitol

Bottlenecks

Despite considerable value creation potential, commercialisation of biorefineries as described above is often technically and economically difficult due to high capital and operating costs as well as difficulties in the feedstock supply, technical process immaturity and challenges in scale-up[196].

On the supply side, feedstock logistics for residues from primary wood production and collection of waste wood are pointed out as economic bottleneck for large-scale biorefineries, where the need for a large collection area increases transport distances considerably[198]. Also, seasonal availability impacts the supply chain with challenges for the logistics system. Alternative uses of waste wood, e.g. for energy purposes, further decrease profitability and may lead to unstable supply[199].

In addition to platform and speciality chemicals, fiber-based materials facilitating technical advance in the fields of e.g. bioengineering and flexible electronics, are suggested as new products for the bioeconomy[200].

In conclusion, biorefineries using lignocellulosic feedstock from the forestry and pulp sector have a wide range of potential speciality products for the bioeconomy. To overcome the technical and economic challenges that these large-scale refineries face, economic incentives and policies changes have been suggested, but the complexity of the biorefinery systems requires highly specific solutions[201].

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[198] Zhang, F., D. M. Johnson and J. Wang (2015). Life-Cycle Energy and GHG Emissions of Forest Biomass Harvest and Transport for Biofuel Production in Michigan. Energies 8(4): 3258-3271.

[199] Garcia, C. A. and G. Hora (2017). "State-of-the-art of waste wood supply chain in Germany and selected European countries." Waste Management 70: 189-197.

[200] Zhu, H., W. Luo, P. N. Ciesielski, Z. Fang, J. Y. Zhu, G. Henriksson, M. E. Himmel and L. Hu (2016). Wood-Derived Materials for Green Electronics, Biological Devices, and Energy Applications. Chemical Reviews 116(16): 9305-9374.

[201] Purkus, A., N. Hagemann, N. Bedtke and E. Gawel (2018). Towards a sustainable innovation system for the German wood-based bioeconomy: Implications for policy design. Journal of Cleaner Production 172: 3955-3968.

2.3 Residues from the sugar value chain

2.3.1 Regional resources in Denmark

Assessed by Mark Booker Nielsen and Tyge Kjær, Roskilde University, Denmark

The only two sugar factories in Denmark are located in Nakskov and Nykøbing Falster in the southern part of Region Zealand on the islands of Lolland and Falster.
The two factories yearly handle around 2.6 million tonnes of sugar beets with soil and produce around 400,000 of white sugar and feed, energy and fertilizer by-products. The EU sugar quota system was abolished in September 2017 after nearly 50 years and the EU sugar market liberalised creating entirely new condition in the value chain. The liberalisation of the sugar market has resulted in increased stocks and declining prices from over 700 euro per tonne in 2013 in to under 375 euro per tonne in the spring of 2018[202].

The contract price including subsidies that the sugar beet farmers are payed for the sugar beets they deliver to Nordic Sugar has also been declining for several years even though a guaranteed minimum price has been ensured by the EU sugar quota system until 2017. This has increased the need for optimizing the production process and enhancing the contribution margin per/ha for the farmers and contribution margin for per tonne sugar beets going input to the factory for Nordic Sugar. To try to ensure this Nordic Sugar in the campaign of 2017 took over the transport of sugar beets to the factories from the farmers with some starting difficulties and criticism by the sugar beet farmers[203].

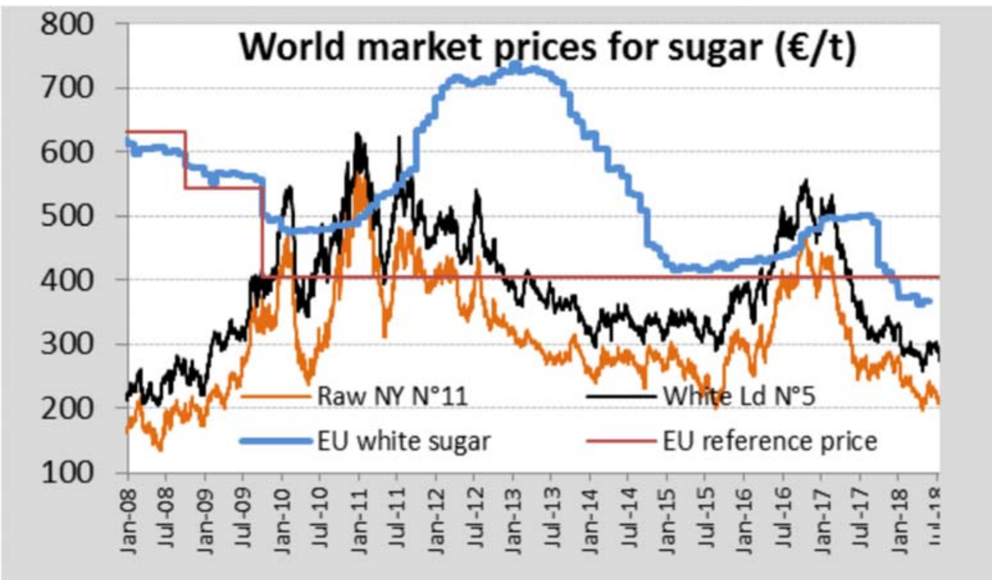

Figure 51. World market prices for sugar (€/t) [202]

Products and by-Products along the value chain and utilization today
The sugar beet production has been declining for several decades in Region Zealand. In 2016 2,630,150 tonnes of sugar beets with soil was delivered to the two sugar factories by 1,124 farmers. The two factories together produced 400,200 tonnes of sugar and a wide range of by-products. A

[202] DG AGRI Dashboard 2018: sugar
[203] Sukkeroe nyt marts 2018

key interest for the factories is distributing as much HP-pulp (28% DM) as possible for direct consumption because the production of sugar pellets (90% DM) is very energy intensive. For the last years the distribution of HP-pulp has been declining by almost 50%, probably due to lower prices on alternative feed products. Today a minimum of 160,000 tonnes DM sugar beet tops are left on field in Region Zealand even though harvest is possible e.g. with a Thyragod harvester[204]. Solely in Guldborgsund and Lolland municipality around 123,000 tonnes DM is left on the fields encompassing an unutilized potential for innovation within the bioeconomy in Region Zealand.

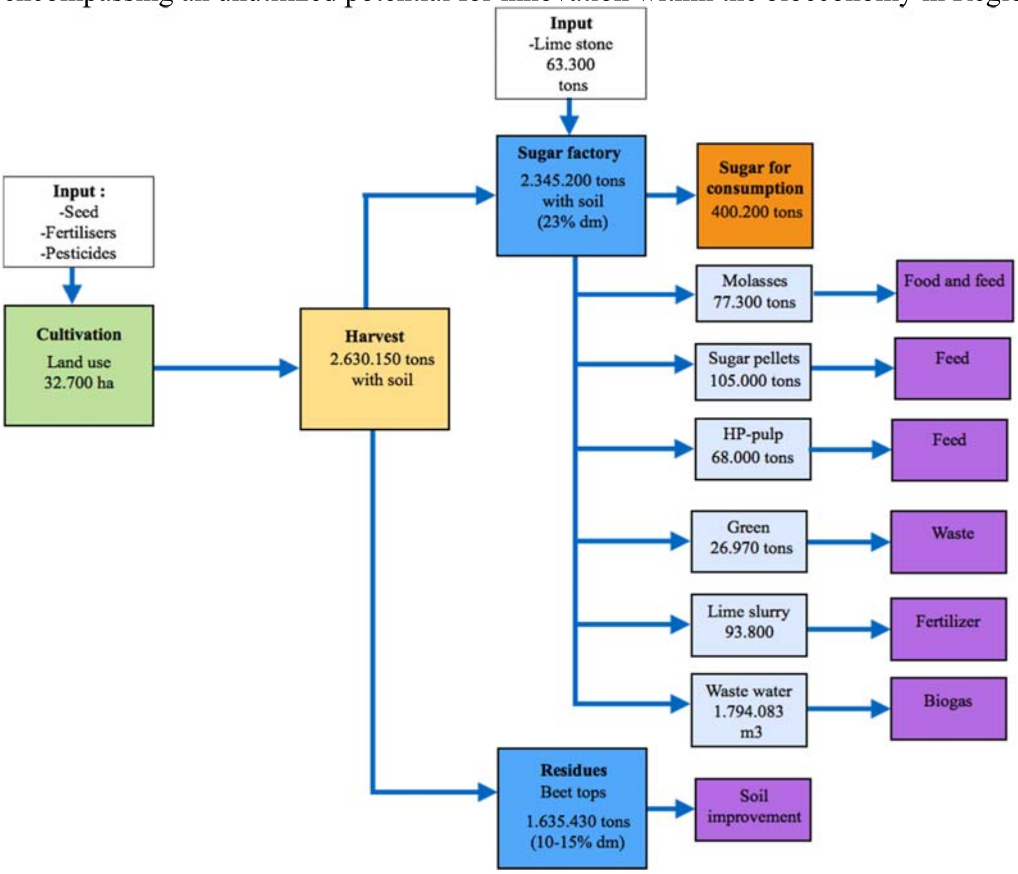

Figure 52. Material flow through the sugar production value chain in Region Zealand. Preparation by RUC for this report based on mapping.

[204] http://www.thyregod.com/

Quantification of feedstock, products and residues

Table 56. Quantification of feedstock, products and residues in Region Zealand

	Unit	2012	2013	2014	2015	2016
Land use Region Zealand[205]	[ha]	40,600	37,800	35,500	24,800	32,700
Average production	[tonnes/ha]	68.2	69.0	82.6	67	71.6
Sugar beet production	[tonnes]	2,771,220	2,594,266	2,933,437	1,769,071	2,345,207
Number of sugar beet farmers[205]	[-]	1,401	1,325	1,265	1,183	1,124

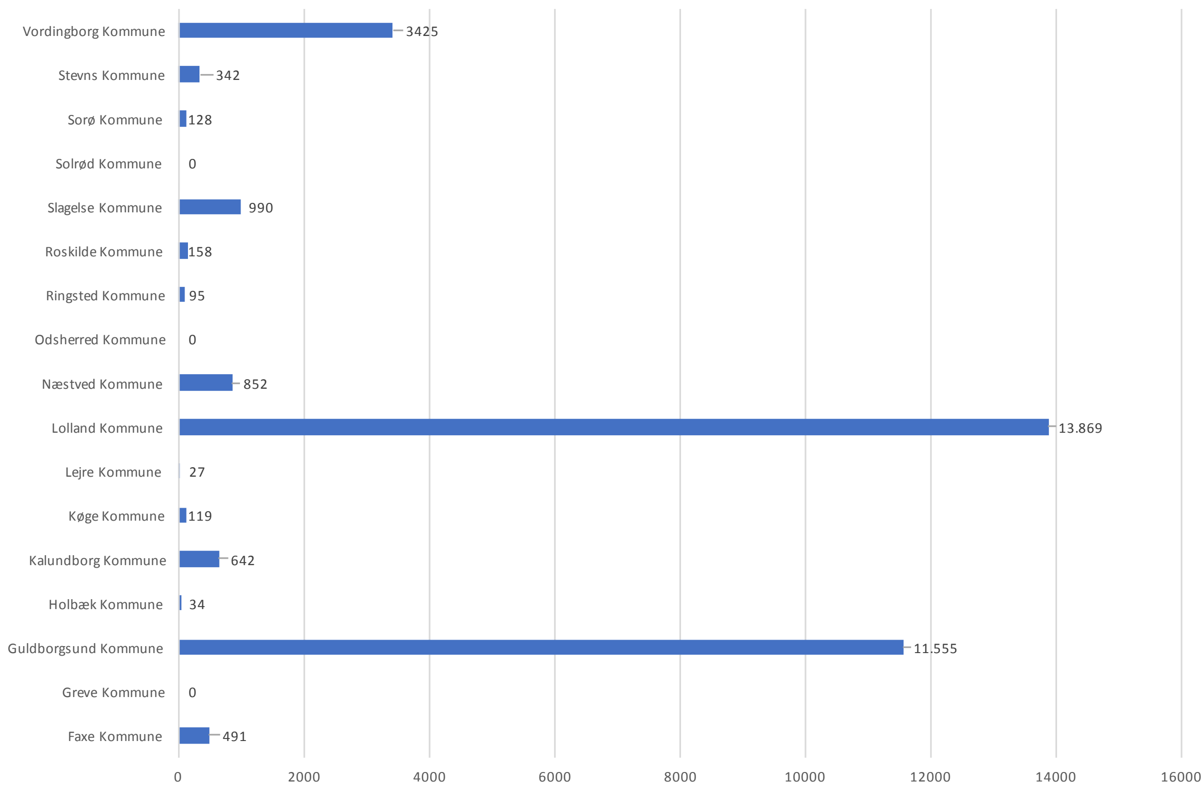

Figure 53. Land use for sugar production in the municipalities in Region Zealand 2016. Prepared by RUC for this report.

[205] Danske Sukkerroedyrkere 2013-2017

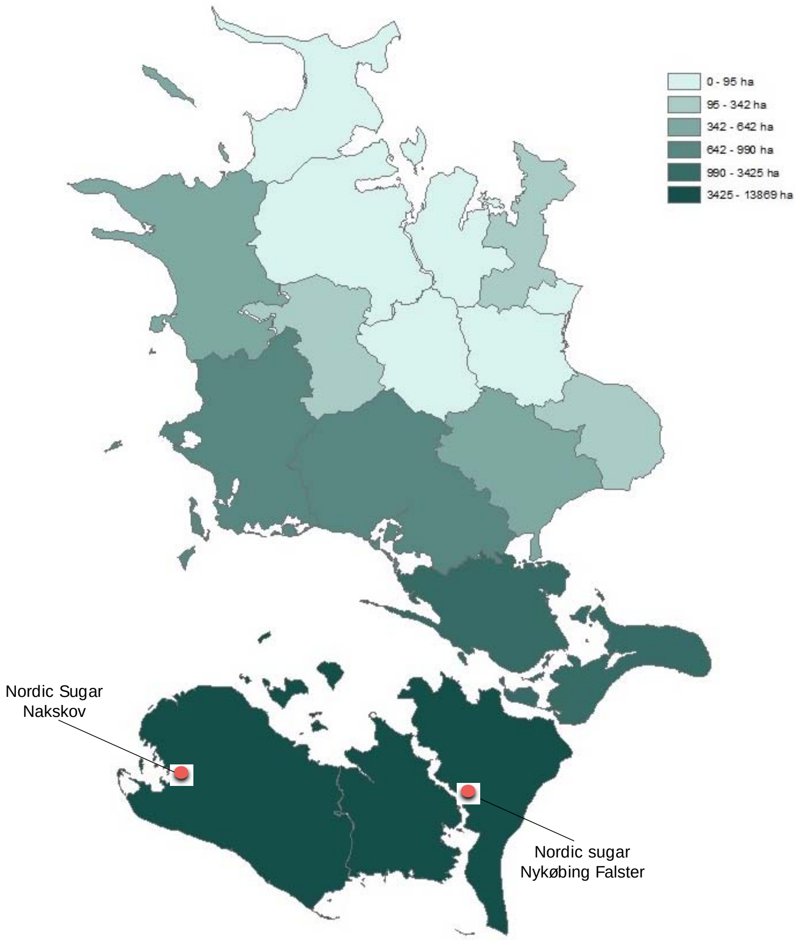

Figure 54. Distribution of land use for cultivation of sugar beets in Region Zealand. Most of the cultivation takes place in the Southern part of the region near the two sugar production factories. Preparation by RUC for this report based on mapping

By-products and residues

Table 57. Annual amounts of residues and by-products from the sugar factory in Nykøbing Sjælland and Nakskov (m = measured, c = calculated).

	Unit	Data type	2012	2013	2014	2015	2016
Nykøbing							
Land use	[ha]	m	21,200	19,400	18,500	13,000	17,100
Clean sugar beets	[t]	m	1,452,877	1,402,432	1,563,156	944,450	1,196,661
Produced white Sugar	[t]	m	249,751	249,299	269,351	165,424	204,810
Delivered pol sugar	[t]	m	261,221	258,389	255,718	171,535	213,673
Total pulp	[t DM]	m	72,392	66,760	74,443	47,478	58,937
Pulp for HP-pulp	[t DM]	m	-	38,073	36,230	14,060	18,052
Pulp for sugar pellet	[t DM]	m	-	28,687	38,213	33,418	40,885
HP-pulp	[t]	m	-	140,870	132,000	93,835	68,000
Sugar beet pellets	[t]	c	0	31,900	42,493	37,161	45,464
Molasses	[t]	c	47,945	46,280	51,584	31,167	39,490
Nakskov							
Land use	[ha]	m	19,400	18,200	17,000	11,800	15,600
Clean sugar beets	[t]	m	1,318,343	1,191,833	1,370,281	824,621	1,148,546
Produced white Sugar	[t]	m	225,616	212,661	220,732	145,477	195,474
Delivered pol sugar	[t]	m	239,961	222,387	234,607	152,437	205,206
Total pulp	[t DM]	m	64,368	56,056	64,904	40,397	53,887
Pulp for sugar pellet	[t DM]	m	64,368	56,056	64,904	40,397	53,887
Sugar beet pellets (89.9 DM)	[t]	c	71,577	62,334	72,173	44,921	59,922
Molasses	[t]	c	43,505	39,330	45,219	27,212	37,902
Pulp for sugar pellets	[%]	m	-	69	74	72	84
Pulp for HP-pulp	[%]	m	-	31	26	28	16

Input and output

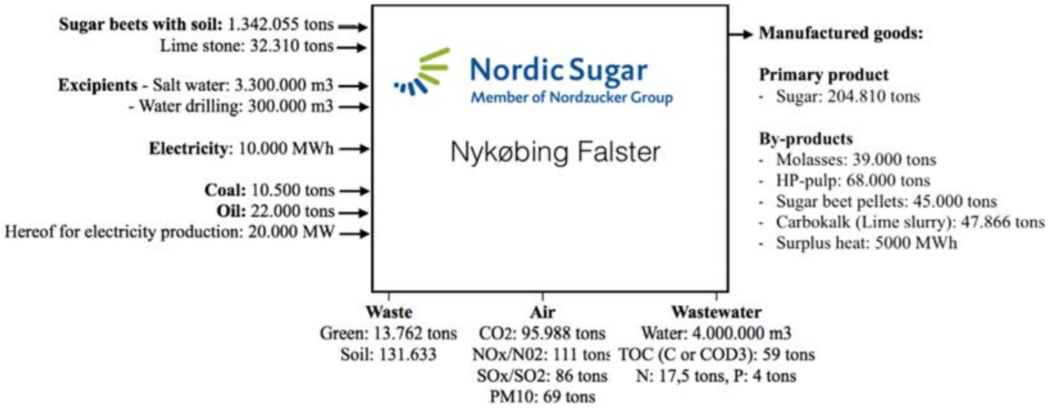

Figure 55. Input/output of the sugar factory in Nykøbing Falster[206]

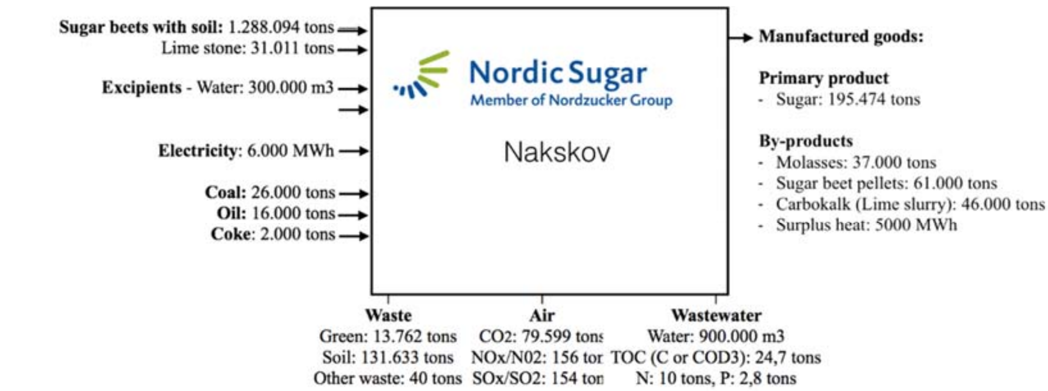

Figure 56. Input/output of the sugar factory in Nakskov[206]

[206] Grønne regnskaber 2009/2010: https://miljoeoplysninger.mst.dk/

Characterization of sugar residues

Table 58. Characterization of sugar residues.

Parameter	Unit	Sugar beets	Sugar beet pulp	HP Pulp	Molasses	Sugar beet tops
Dry matter content[207,208,209]	[%]	22	11.5-12	27	74	10-15
Dry matter that can be	[%VS of TS]	85				95
Volatile solids loading[210]	[% of VS]	90				80
Biogas potential[210]	[m^3]	324				357
Biogas production[210]	[m^3 CH_4/t]	34				78
N content[207210,207]	[% of DM]	1.28	1.68	1.66	2.08	
N content[211]	[kg/t]	1.8				3.79
P content[207]	[g/kg DM]	1.7	0.9	0.8	0.4	
P content[211]	[kg/t]	0.2				0.25
K content[207]	[g/kg DM]	21	5.6	10	28	
K content[211]	[kg/t]					
Protein content[207]	[% of DM]	8	10.5	10.4	13	
Hemicellulose content[212,213]	[g/kg DM]	221	42		-	
Pectin[213]	[% of DM]		435			
Cellulose content[212,213]	[g/kg DM]	272	185		195	
Lignin content[212,213]	[g/kg DM]	18.5			35	
Starch[212]	[g/kg DM]	18			0	
Sucrose[212]	[g/kg DM]	160-265			27	
Sugar[207,214]	[% of DM]	69.4	61.8	2	60	
Ash[207]	[% of DM]	8	6.2	7.2	12.7	10

Material flow for sugar beet production

Table 59. Material flow for sugar beet production at Nordic Sugar in Region Zealand 2016. M=Measured values based on data from Nordic sugar. C=calculated values based in data about the input/input of the different steps of the sugar manufacturing process.

	Unit	Data type	Nybøbing	Nakskov	Total
Cultivation					
Land use (71.6 tonnes sugar beet/ha)[215]	ha	m	17,100	15,600	32,709
Harvest					
Sugar beet potential total	[t WW]	c	1,425,504	1,368,188	2,793,693
DM in beet tops (5 tonnes DM/ha)[214]	[t DM]	c	83,449	80,094	163,543
Beet tops (10-15%)[214]	[t WW]	c	834,492	800,939	1,635,430
Harvested sugar beets[215,216,217]	[t WW]	c	1,342,055	1,288,094	2,630,150

[207] Landbrugsinfo - Fodermiddeltabel
[208] SEGES Fodermiddeltabel 2017
[209] Roer tilbage i dansk landbrug - potentiale i ny kombination af foder og bioenergi
[210] Omregningskoficent Protein = N*6,25
[211] NIRAS biogasdata
[212] Danmarks potentiale for afgrødebaseret biobrændstofproduktion i år 2020, DTU RISØ
[213] Bonnin et al, 2002. Characterisation of pectin subunits released by an optimum combination of enzymes. Carbohydrate Research, 337, 1687-1696.
[214] Birkemose et al, 2013. Biomasse til biogasanlæg i Danmark
[215] Danske Sukkerroedyrkere – Sukkerstatistik 2017
[216] Grønne regnskaber 09/10
[217] John P. Jensen, Nordic Sugar - Technology and Innovation, 2017. Sukkerfabrik som bioraffinaderi – produkter og sidestrømme samt ideer til værdiforøgelse

Sugar production					
Step 1 - Beet washer					
Input sugar beets to factory[215,216,217]	[t WW]	c	1,342,055	1,288,094	2,630,150
Soil and stones (12% total)[216]	[t WW]	c	131,633	126,340	257,973
Green (1.15% of total) (20% DM)[217]	[t WW]	c	13,762	13,208	26,970
Output clean beets[215]	[t WW]	m	1,196,661	1,148,546	2,345,207
Step 2- Slicing machine					
Input clean beets[215]	[t WW]	m	1,196,661	1,148,546	2,345,207
DM in sugar beets (23.5% DM)[216,218,209]	[t DM]	c	281,215	269,908	551,124
Water in sugar beets[216,218,209]	[t WW]	c	915,446	878,638	1,794,083
Output cossettes[215]	[t WW]	m	1,196,661	1,148,546	2,345,207
Step 3- Extraction					
Input sugar beets[217]	[t WW]	c	1,196,661	1,148,546	2,345,207
Output exhausted cossettes (40% of total)[217]	[t WW]	c	478,664	459,418	938,083
Output diffusion juice (115% of total)[217]	[t WW]	c	1,376,160	1,320,828	2,696,988
Step 4 - Press					
Input DM cossettes/pulp (12% DM)[208,207,217]	[t WW]	c	478,664	459,418	938,083
Input DM in pulp (12 % DM cossettes)[217,207,208]	[t DM]	c	57,440	55,130	112,570
Output pressed pulp total (27% DM)[219]	[t WW]	c	212,527	196,815	409,342
Output to HP-pulp (27% DM)[215,207,219]	[t WW]	c	66,641	0	66,641
Output DM in pulp use for HP-pulp[215,207,219]	[t DM]	c	18,011	0	18,011
Output for drying	[t DM]	c	145,886	196,815	342,700
Step 5 - Drying					
Input pressed pulp (28% DM)[220]	[t WW]	c	145,886	196,815	
Output sugar beet pellets (89.9% DM)[208,221]	[t WW]	c	45,441	61,305	106,746
Step 6 - Juice purification					
Input diffusion juice[217]	[t WW]	c	1,376,160	1,320,828	2,696,988
Input lime stone (2.7% of total)[216,217]	[t WW]	c	32,310	31,011	63,321
Input sinters (0.5% of total)[217]	[t WW]	c	5,983	5,743	11,726
Output lime slurry (4% of total)[217]	[t WW]	c	47,866	45,942	93,808
Output thin juice (120% of total)[217]	[t WW]	c	1,435,993	1,378,255	2,814,248
Step 7 - Evaporation					
Input thin juice[217]	[t WW]	c	1,435,993	1,378,255	2,814,248
Output thick juice (25% of total)[217]	[t WW]	c	299,165	287,137	586,302
Step 8 - Crystallisation					
Input thick juice[217,215]	[t WW]	c	299,165	287,137	586,302
Output molasses (3.3% of total)[217,215]	[t WW]	c	39,490	37,902	77,392
Output pol sugar (Pol sugar 17.9%)[215]	[t WW]	c	214,202	205,590	419,792
Output white sugar (17% sugar)[215]	[t WW]	c	203,432	195,253	398,685
Step 9 - Sugar drying					
Input white sugar[217]	[t WW]	c	203,432	195,253	398,685
Output white sugar[217]	[t WW]	c	203,432	195,253	398,685
Step 10 - Sugar storing					
Produced white sugar[217]	[t WW]	c	203,432	195,253	398,685

[218] VFL Oversigt over landsforsøgene 2017
[219] http://www.nordicsugar.dk/foder/kvaeg/hp-pulpr/
[220] Miljøstyrelsen, 2013. Godkendelse til opstilling og drift af damptørrer
[221] http://www.nordicsugar.dk/foder/kvaeg/pulpetterrkosetterr/

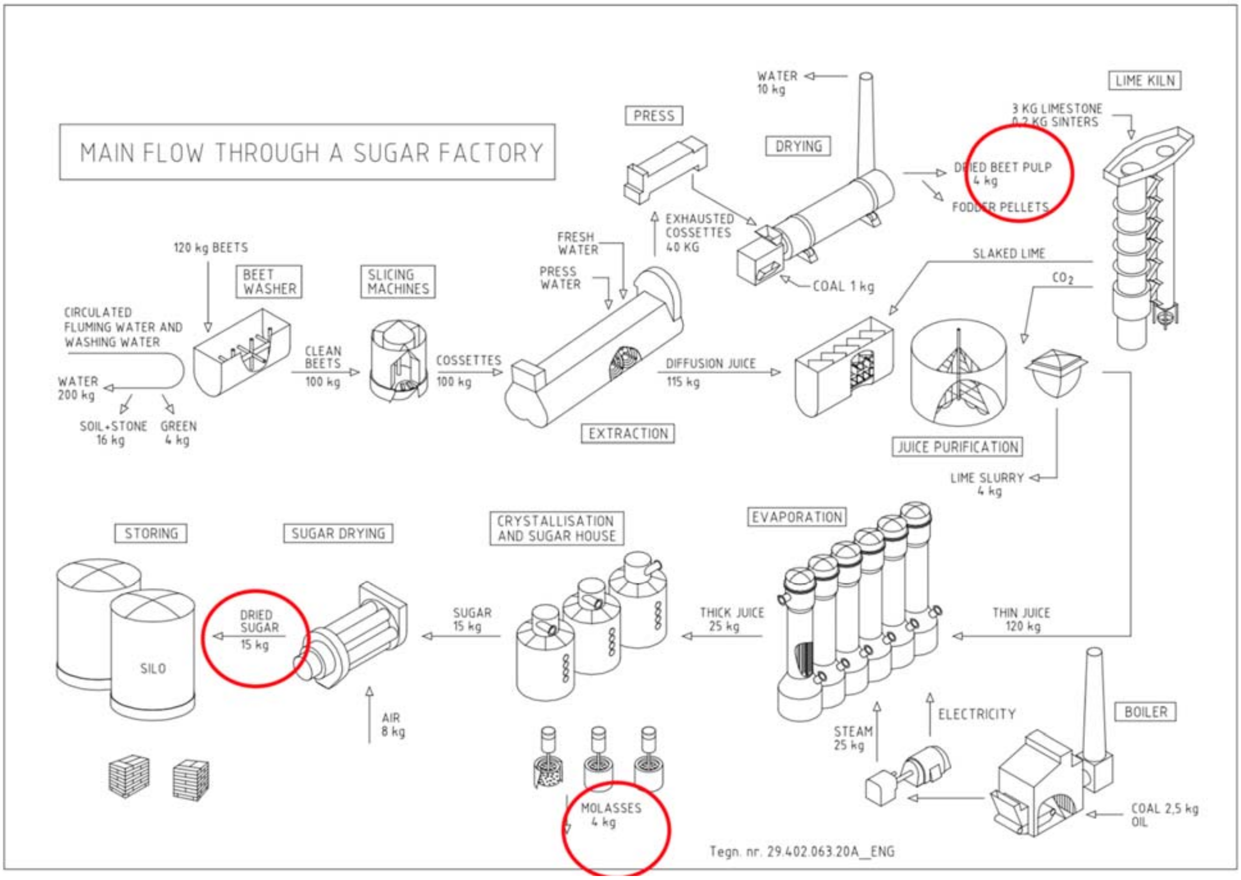

Figure 57. Main flow through a sugar factory [222]

[222] John P. Jensen, Nordic Sugar - Technology and Innovation, 2017. Sukkerfabrik som bioraffinaderi – produkter og sidestrømme samt ideer til værdiforøgelse

2.3.2 Regional resources in Germany

Assessed by Max Mittenzwei and Daniel Schiller, University of Greifswald, Germany

The hub of Mecklenburg-Western Pomerania's sugar industry is Suiker Unie GmbH & Co. KG in Anklam. As it is the only sugar factory in the region, it works as the pivotal point of the sugar value chain. It was founded in 1883 and has achieved more than 130 years of experience. In 2009, the Anklam sugar factory was acquired by the Dutch group Royal Cosun U. A. and has since then been known as Suiker Unie GmbH & Co. KG. In 2018 the factory had 180 core employees, 30 campaign forces and 24 trainees. The abolition of the current quota for the marketing of food sugar within and outside the EU at the end of 2017 favoured increased market competition while at the same time aimed at making sugar production itself "greener". The following years will show, how this will affect the sugar market in the long term.

The first step of the value chain is the cultivation of sugar beets. Sugar beets are being cultivated by 346 farmers on an area of 20.100 ha, which equals to around 8% of the arable land area in Mecklenburg-Western Pomerania (MWP). The seeds are sourced exclusively from the factory. Beet cultivation is carried out in accordance with the guidelines of Integrated Pest Management (IPS) and is 100% certified in accordance with the Biofuel Sustainability Ordinance. After the cultivation, the beets are harvested by the farmers. Before loading, an automatic sampler draws a quality sample which is analysed for admixtures such as soil, stones and cabbage, as well as sugar content and other value-determining ingredients. The results are used to control production and flow into the payment of the beets. The settlement is based on the market price for the various products. In addition, the company guarantees a minimum price. All beets are pre-cleaned in the field using modern loading equipment in order to keep soil and other admixtures to a minimum. Only transport companies certified for the transport of food and animal feed are used for the delivery of the beets to the factory. Inside the factory the sugar beets are processed in nine processing steps, before the sugar is stored in sugar silos. The sugar is then either transported to clients or marketed for consumers.

Products along the value chain and utilization today

Various by-products are produced along the value chain. Only 60-70% of the beets are processed to sugar in the factory, the other 30-40% are used as a feedstock for the production of bio-ethanol. All of the residues of the factory are used in some form. The beet pulp and tails are processed into animal feed, chips and other residual and waste materials. Further residues are fermented into raw biogas in the biogas plant throughout the year, which is used as a power source for the factory and fed directly into the natural gas grid as green energy via a plant of edis Netz AG. The waste materials from sugar production itself are processed to bio-ethanol on a basis of the fermentation of fresh or stored thick juice at a rate of 220 m³ per day. The CO_2 from the fermentation process is collected and can be used to produce carbonated drinks. Further, waste material from fermentation and biogas production can also be seen as a potential for future usage of biocomposites or products from pyrolysis. Furthermore, wastewater is purified in a biological water treatment system. This generates sewage gas, which is fed into the gas network together with the waste gas. Moreover, the used limestone acts as a basis for the production of Betacal-lime fertilizer. In the sense of a biorefinery, sugar beet is thus almost 100% re-used at the factory.

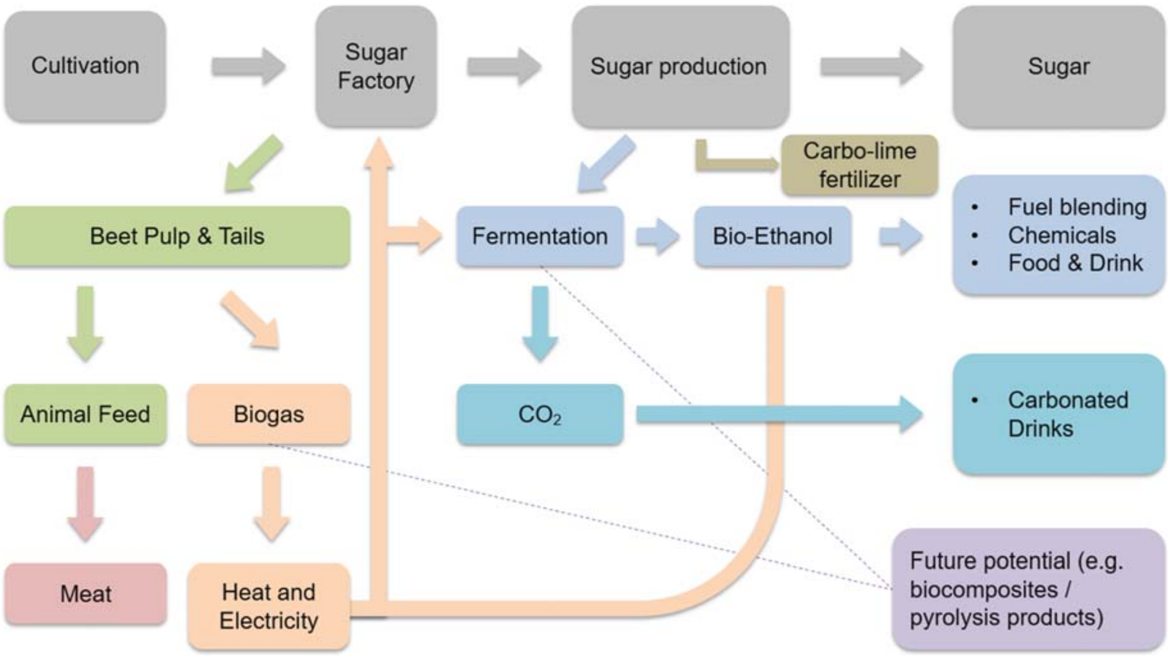

Figure 58 - Qualitative sugar value chain for Suiker Unie GmbH & Co. KG (own figure)

Quantification of feedstock, products and residues

Table 60. Primary production of sugar beet from 2013-2017 (based on LFA MV 2013-2017)

Parameter	Unit	2013	2014	2015	2016	2017	2018
Area	[ha]	-	-	-	19.300	-	20.100
Farms	[-]	388	382	382	385	345	346
Sugar yield	[t/ha]	11.9	14.3	11.8	13.1	13	13.86
Raw Sugar beet yield	[t WW/ha]	65.8	84.5	65.9	70.6	74.6	77.0
Raw Sugar beet yield	[t WW]	~1,400,000	1,520,000	~1,300,000	1,432,000	1,412,859	1.3 – 1.4 mill.
Beet processing	[t/day]	11,526	9,806	11,620	11,500	12,000	12,000

Suiker Unie GmbH & Co. KG only processes sugar beets from Mecklenburg-Western Pomerania. The factory is currently working on increasing beet processing to 15,750 tonnes per day. At the same time, despite the increase in production, no more energy is to be used than in the 2013/2014 beet campaign. Furthermore, beet acreage has developed dynamically since 2006 and is expected to continue to grow gradually, with 23,000 ha expected in 2024. The sugar yield has more than doubled since 1991 as a result of various modernization measures.

By-products and residues

As the usage of by-products is shown and explained above, Table 61 gives a quantitative overview:

Table 61. By-Products (SUIKER UNIE Gmbh & Co. KG 2018)

By-Products	Unit	2018	Usage
Bioethanol	[m³]	70,000	power source / fed into grid
Biomethane	[Nm³]	12,000,000	power source / fed into grid
Dry Chip Pellets	[t DM]	30,000	animal feed, source for Bio-Methane
Press Chips	[t DM]	90,000	animal feed
Betacal-Lime Fertilizer	[t DM]	50,000	fertilizer for own farmers / sold to customers

The bioethanol produced at the site is added to the fossil fuel as a renewable fuel. Biomethane is used on the heating market and also as a fuel. Both products are certified according to the legal requirements for sustainability and meet the legal requirements for greenhouse gas reduction from 2017. Bioethanol and biomethane are both certified according to the legal requirements for sustainability and meet the legal requirements for greenhouse gas reduction from 2017.

Characterization of feedstock, products and residues

Table 62. Content of sugar beets (per kg DM)[223]

Parameter	Unit	Sugar Beet
Dry matter content	[%]	23
Ash	[g/kg]	80
Protein content	[g/kg]	80
nXP	[g/kg]	142
UDP	[%]	20
Lysin	[g/kg]	3.3
Methionine	[g/kg]	0.2
NEL	[MJ/kg]	7.46
ME	[MJ/kg]	11.8
Sugar	[g/kg]	647
Raw fibre	[g/kg]	85
Ca content	[g/kg]	2.3
P content	[g/kg]	1.5
Na content	[g/kg]	1.0
K content	[g/kg]	8.0

[223] Bayrische Landesanstalt für Landwirtschaft 2014, p. 54-60

Mass balance

Table 63. Sugar factory mass balance[224]

Step 1 – cultivation		
Total sugarbeet biomass	[t DM]	1.3 – 1.4 mill.
Step 2 – beet harvest		
Step 3 – sugar production		
Beets incoming	[t DM]	1.3 – 1.4 mill.
Products		
White sugar	[t DM]	100,000
Molasses	[t DM]	25,000
Vinasses	[t DM]	19,000
Dry chip pellets	[t DM]	30,000
Press chips	[t DM]	90,000
Carbo-lime fertilizer	[t DM]	50,000
Bio-Ethanol	[m³]	70,000
Biomethane	[Nm³]	12,000,000

[224] SUIKER UNIE GmbH & Co. KG, 2018

2.3.3 Regional resources in Poland

Assessed by Dariusz Mikielewicz, Rafał Andrzejczyk, Paweł Dąbrowski & Jan Wajs, Gdańsk University of Technology, Poland

Almost entire sugar beet production goes for production of sugar. Sugar beets are cultivated by around 34,000 farmers. In 2016 the beet area covered 202,000 ha. There are in Poland four players on the sugar market with one only Polish company. These are:

- Krajowa Spółka Cukrowa (National Sugar Company) – share 39.1%
- Nordzucker Polska SA – 9.4%
- Pfeifer and Langen - 26.4%
- Südzucker Polska SA– 25%

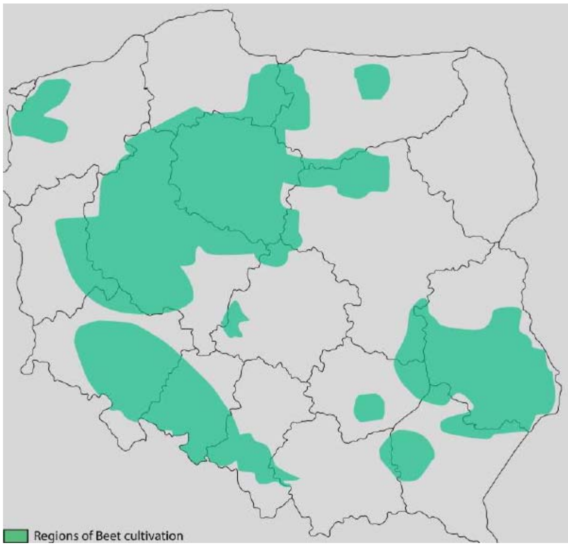

Figure 59. Regions of sugar beets cultivation in Poland [225]

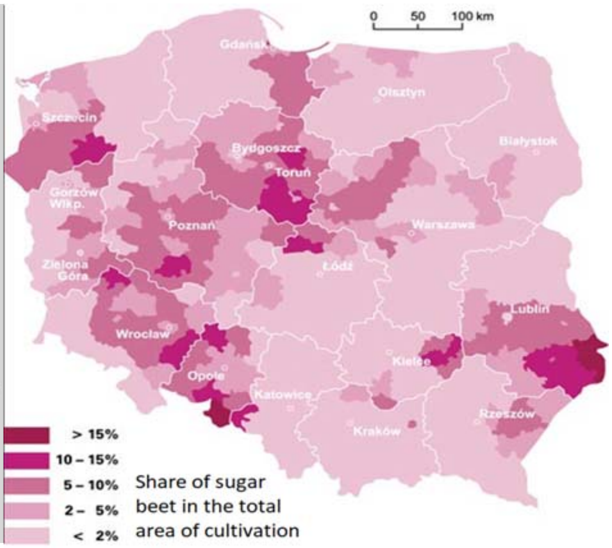

Figure 60. Share of sugar beet of total cultivation area[226]

Similarly as in other European countries in Poland all sugar is produced from sugar beets. The sugar beet seeds are planted in the spring and harvested in September to November. A beet harvester collects the beets in field, after the harvest the beets are stored in a pile in the edge of the field before being transported to the sugar industry. The beet tops are left in the field. The farmer is responsible for preparing the best quality beet roots to the sugar factory, hence he has to perform the washing of the beets. At the company site the beets are weighted. Transports of the beets to the company is at the expense of the farmer. Beets are washed and separated from soil, stones, and other admixtures. The soil management presents a huge problem for the company. Then, clean beets are cleared from their tails. Beet tails are used in a different process. Beets without tails are cut into small stripes, known as cossette. Cossette is about 80% of the mass delivered to factory (raw sugar beets). After adding water in the 1:1 ratio the raw sugar beet juice is released by diffusion. In this process, called the juice extraction, the beet pulp is obtained. Raw juice is subjected to the filtration process where the result is the thin juice (Raw juice -> 92.5% Thin Juice + 7.5% carbonation lime),

[225] Rafał Strachota, Potential of sugar beet cultivation in Poland by Association of Sugar Beet Growers in Poland, V Baltic Biogas Forum Gdańsk, 16-17 June 2016.

[226] https://sites.google.com/site/uprawaburakacukrowegowpolsce/

while carbonation lime is a by-product. Thin juice is then boiled to evaporate water and thick juice is obtained. The white sugar is dried, cooled and transported to silos, where it is stored. A diversity of products is produced in the sugar industry; including sugar products, feed products (molasses, beet pulp), sugar factory lime, stones, beet soil and water, see Fig. 1. Some products made in the factory are recirculated into the system as biogas, steam and water. As an example, the biogas produced at the site is combusted and the heat is utilized in the process.
In Pomeranian Region there is only one sugar refinery, Malbork, and one sugar factory, Malbork, both owned by National Sugar Company. A refinery is an industry where the primary feedstock is raw sugar from sugar factories.

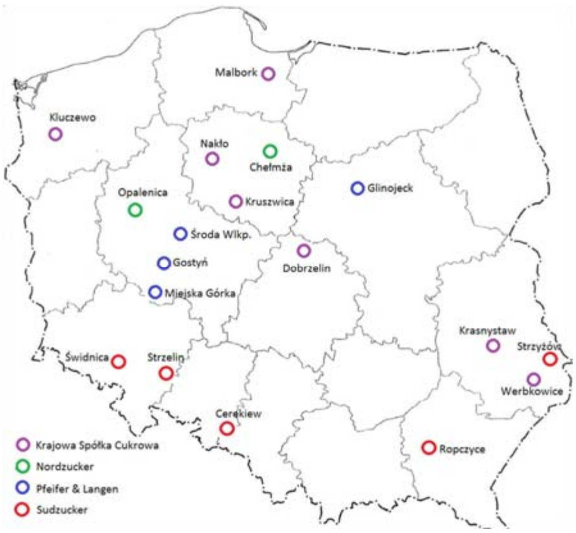

Figure 61. Locations of sugar plants in Poland in respect to regions[227]

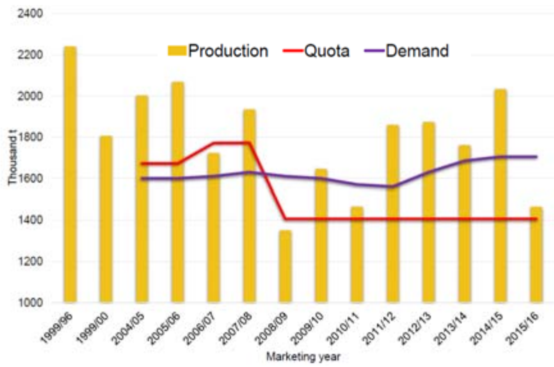

Figure 62. Sugar production and consumption in Poland[227]

The present production of sugar remains same as twenty years ago despite the fact that the beet area cultivation area reduced by about 2.5 times.

[227] https://docplayer.pl/8896250-Rynek-cukru-stan-i-perspektywy.html

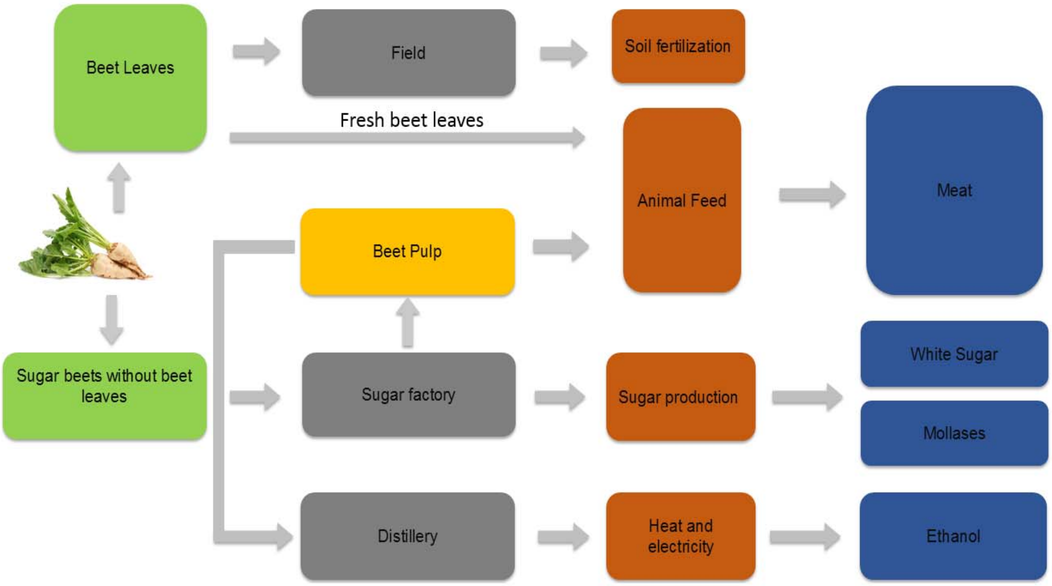

Figure 63. Sugar production – step by step

Malbork Sugar Company is seeing its potential problems and are aware of the fact that it should be more involved in research projects leading to the improvement of their disposed waste. Hopefully the present activities in the BioBIGG project will be picked up by the company authorities and partially considered as interesting in the management of the available nutrients.

Products along the value chain and utilization today

The primary feedstock in Malbork sugar factory are sugar beets. The sugar beet can only be cultivated in the entire Poland, and in the Pomeranian Region mainly in the southern and eastern parts of the region.

The root of the beet contains 75% water, around 16-18% sugar, 5% fibre and about 0.5% of ash[228]. The exact sugar content can vary depending on the cultivar and on the growing conditions. End products from Malbork (previously qualified as waste), include: pulp[229], animal feed, rootlets and beet chips - sold for fodder, molasses[230] (used in the fermentation industry), defecosaturating lime[231] (used in the fertilization of agricultural fields).

Malbork is one of the other six sugar-producing facilities in the National Sugar Company. Krajowa Spółka Cukrowa summarized the results of the sugar campaign 2017/2018. In all seven sugar factories, the company raised a total of over 6 million tonnes of sugar beets. In total, it produced over 900,000 tonnes of white sugar. The highest average sugar beet yield was obtained in Kruszwica sugar factory - 73 tonnes/ha. Yields of over 70 tonnes per ha have also been reached by the Dobrzelin and Nakło Sugar Factories. In 2017, sugar beets were grown on the area of approx. 96,000 ha, by about 15,800 farmers.

[228] National Sugar Company, 2018
[229] Registered under PN-85 / R-64808
[230] Registered under PN-76 / R-64772
[231] Registered under PN-93 / C-87007/02; defecosational lime is waste plant mass and solid sludges from cleaning and washing beets are subjected to processes recovery of R3 and R11

Quantification of feedstock, products and residues

The cultivation area of sugar beets in West Pomeranian Region in 2016 was 10,000 hectares, in Pomeranian Region – 9,500 ha and in Warmia and Mazury – 2,700 ha. Sugar beet yields are constantly increasing. In 1996 the average beet yield was 35 t/ha, whereas in 2004 it amounted to 45 t/ha. In the last five years the average is 62 t/ha. In 1996 the average sugar yield was 4.2 t/ha, whereas in 2004 it amounted to 7 t/ha. In the last five years the average is 9.5 t/ha. The corresponding trends are presented in Fig. 3 and Fig. 4.

During 10 years the number of growers decreased by more than half, to 34,000. In 1996 the cultivated area for the beets was 450,000 ha, whereas in 2004 that was 280,000 ha. The last five years average is 187,000 ha. In 1996 the average area of beet per farm was 1.8 ha, in 2004 – 3.6 ha, the last five years average is 5.3 ha.

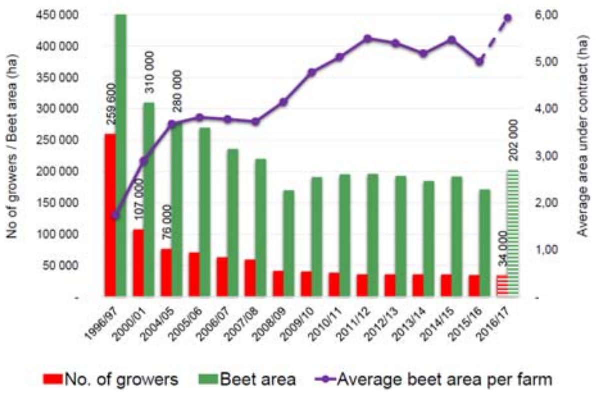

Figure 64. Sugar beets cultivation area and the number of sugar farmers in Poland[232]

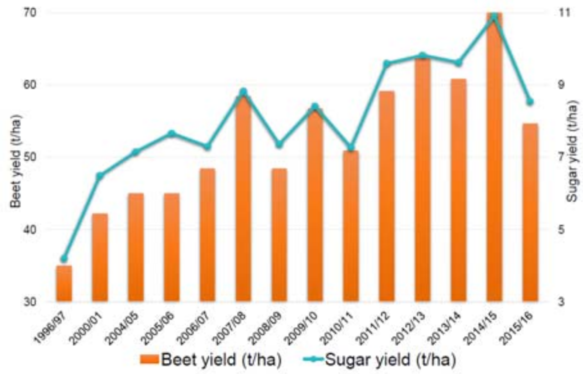

Figure 65. Beet yields and sugar yields in Poland[232]

[232] https://kzpbc.com.pl/wykresy,22,pl.html

Table 64. Cultivation area of sugar beets [1000 ha] in different regions in Poland and in total[233,234,235,236]

Region	2013	2014	2015	2016	2013-2016
Pomerania	10.3	9.2	9.2	9.3	9.5
Warmia and Mazury	2.7	3.1	2.1	2.8	2.7
Western Pomerania	9.4	11.3	9.4	9.8	10.0
Total Poland	**193.8**	**197.8**	**180.2**	**203.6**	**193.9**

Table 65. Sugar beet yield [1000 t WW][226,228,233,234]

Region	2013	2014	2015	2016	2013-2016
Pomerania	596.9	610.9	522.7	689.2	604.9
Warmia and Mazury	170.4	171.5	117.0	166.2	156.2
Western Pomerania	593.9	818	546.3	779.5	684.4
Total Poland	**11234.3**	**13488.8**	**9364.5**	**13523.7**	**11902.8**

Table 66. Sugar beet yield [1000 t DM][233,234,235,236]

Region	2013	2014	2015	2016	2013-2016
Pomerania	149.2	152.7	130.7	172.3	151.2
Warmia and Mazury	42.6	42.9	29.3	41.6	39.1
Western Pomerania	148.5	204.5	136.6	194.9	171.1
Total Poland	**2808.58**	**3372.20**	**2341.13**	**3380.93**	**2975.7**

There are some regions in Poland that are specializing in sugar beet cultivation. As can be seen in Figure 1 western and central Poland have largest share of sugar beet in the total are of cultivation. It corresponds with Figure 2, where locations of sugar plants in Poland in respect to regions are shown. Those regions that have big share of sugar beet, have also their own sugar plants.

By-products and residues along the chain

All biomass residues from the Malbork refinery are utilized today, Table 67. Molassed sugar beet pellets are used as feed material in the feed industry and as feed for feeding ruminants, horses, sheep and pigs. When fed to horses, the pellets must be soaked first. It can also be used as a silage agent. Molassed sugar beet pellets are manufactured during the beet campaign. The manufactured product is available throughout the year. The molassed sugar beet pellets consist of approx. 90% dried beet fibres and about 10% molasses.

Molasses is used as animal feed for ruminants, horses and pigs. It is also a good binder for pelleting and binds dust. Molasses is also used as a silage agent and as a substrate in biotechnological production. Molasses is produced during the beet campaign. The product is available throughout the year.

Beet pulp is partly used as a substrate in an alcohol production, e.g. as an additive in Mełno Distillery together with bread leftovers, onion peels.

233 Statistics Poland, Agriculture Department; Agriculture in 2017
234 Statistical Yearbook Pomorskie Voivodship 2016, Statistical office in Gdańsk
235 Statistical Yearobook Zachodniopomorskie Voivodship 2016, Statistical office in Szczecin
236 Statistical Yearbook Warminsko-Mazurskie Voivodship 2016, Statistical office in Olsztyn

Table 67. Yearly production in Malbork[237]

Products	Produced amount [t/a]
Sugar	78,445
Molasses	18,996
Molassed sugar beet pellets HP-Pulp	468,477

Today most of the sugar beet tops is left in the field and are ploughed into the soil. Sugar beet tops have high water content at harvest, which makes them difficult to preserve as silage. It is therefore an advantage to use sugar beet tops as fresh material, for example as substrate (feedstock) used for for biogas production. This feedstock is mainly available at harvest in September to November.

Characterization of feedstock, products and residues

One residue feedstock from the sugar industry that were investigated in this section on the characteristics was Molasses.

Table 68. Characterization of molasses from the Malbork Sugar Factory[238]

Parameter	Unit	Molasses
Moisture content	[%]	75
N content	[%]	0.2
P content	[%]	0.05
K content	[%]	0.3
Hemicellulose content Cellulose content	[%] [%]	2.3
Ash content	[%]	0.6

By weight molasses consists of 75% moisture, 2.3% cellulose and hemicellulose, 0.2% nitrogen, 0.05% Phosphor, and 0.6% of ash.

Mass balance

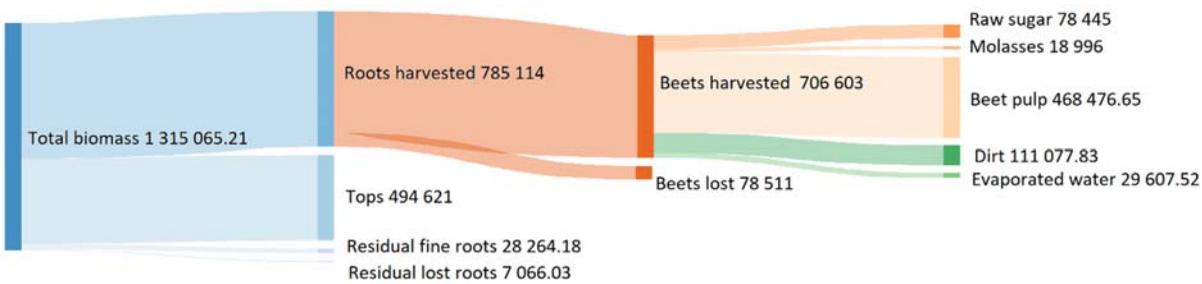

Figure 66. Sankey diagram of biomass flow chain in Malbork Sugar Factory

[237] Malbork Sugar factory data and own calculations
[238] Jan Dobrzycki „Chemical fundamentals of sugar technology" WNT; 1984

Table 69. Feedstock, products and residues in the Malbork sugar factory[239,240]

Step 1 - field		
Roots harvested	[t WW]	785,114
Tops, total	[t WW]	494,621
Residual fine roots	[t WW]	28,264.18
Residual roots (losses)	[t WW]	7,066.03
Total sugar beet biomass	[t WW]	1,315,065.21
Step 2- beet harvest		
Beets harvested	[%]	90
Beets lost	[%]	10
Tops, harvested	[%]	0
Roots harvested	[t WW]	706,603
Tops, harvested	[t WW]	0
Residual fine roots	[t WW]	28,264.08
Residual roots (losses)	[t WW]	7,066.03
Residual tops (losses)	[t WW]	0
Step 3 - sugar production		
Beets incoming	[t WW]	706,603
Dirt	[%]	15.64
Products		
Raw sugar	[t WW]	78,445
Molasses	[t WW]	18,996
Molassed sugar beet pellets	[t WW]	468,476.65
HP-Pulp	[t WW]	
Dirt	[t WW]	111,077.83
Evaporated water	[t WW]	29,607.52

[239] Report from sugar beet campaign http://www.zpbcmk.pl/index.php
[240] Yield losses during harvesting of different types of sugar beets; http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.baztech-article-BAR0-0040-0032/c/httpir_ptir_orgartykulypl100ir1002101pl.pdf

2.3.4 Regional resources in Sweden

Assessed by Johanna Lund, RISE Research Institutes of Sweden

The sugar production starts in the field. In Sweden, all sugar is produced from sugar beets. The sugar beet seeds are planted in the spring and harvested in September to November. A beet harvester collects the beets in field, after the harvest the beets are stored in a pile in the edge of the field before being transported to the sugar industry. The sugar industry receives the sugar beets from the farmers and the beets are weighted on reception at the sugar plant. The sugar plant pays for the transports, by truck and tractor. After that, the beets are washed, and stones and soil are being removed. Then the beets are sliced into pieces in the size of French fries. The sliced beets are then transported to the extraction tower where the hot water extracts the sugar from the beets and you get a thin raw juice. When the sugar is extracted from the strips, they are further processed and used as animal feed. The thin juice is then purified in a step where hydrated lime and carbon dioxide is added and binds substances that are not sugar. The liquid is the filtrated and a thin juice that contains around 16% sugar remains and goes into the evaporation where the water is steamed away in several steps. What remains is a thick juice with a sugar content of just above 70%. The thick juice is further concentrated and when it is concentrated enough sugar crystals begin to form. The pulp is then pumped to the centrifuges where the brown syrup is thrown away from the white sugar crystals, which remain in the centrifuge. What remains after the centrifugation is a viscous syrup like product, molasses, which are used for animal feed. The white sugar is dried, cooled and transported to silos, where it is stored. A diversity of products is produced in the sugar industry; including sugar products, feed products (molasses, beet pulp), sugar factory lime, stones, beet soil and water, see Figure 67. Some products made in the factory are recirculated into the system as biogas, steam and water. As an example, the biogas produced at the site is combusted and the heat is utilized in the process.

All cultivation of sugar beets in Sweden is contracted by Nordic Sugar which is the only sugar producing company in Sweden. In Sweden most of the sugar beets are grown in Skåne. There is one sugar refinery, Arlöv, and one sugar factory, Örtofta, in Sweden, both owned by Nordic Sugar. A refinery is an industry where the primary feedstock is raw sugar from sugar factories.

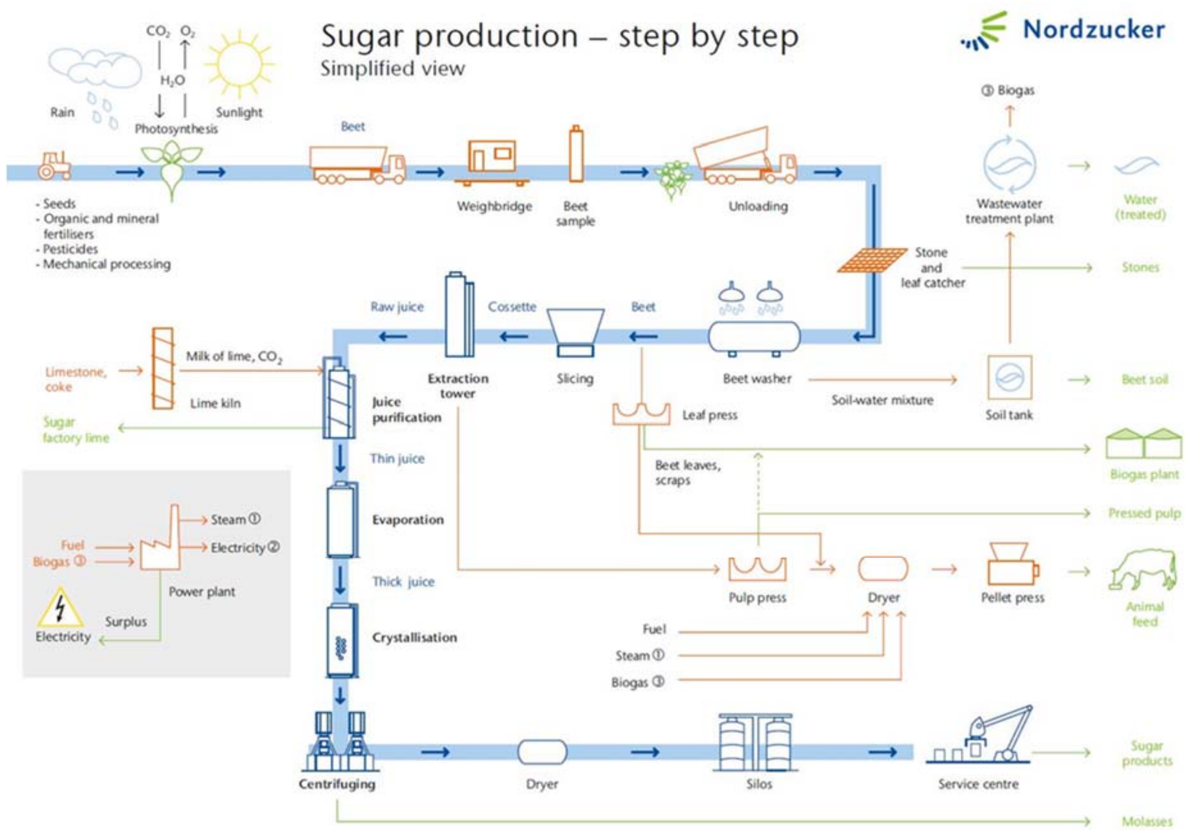

Figure 67. Sugar production – step by step[241]

Nordic Sugar has become more and more involved in research projects the last couple of years, also in the Swedish organization. A lot of the research projects they are involved in is into biobased products and processes, and the aim of the involvement from Nordic Sugar is to find a value chain improvement. They are involved in projects regarding biocommodities for bioplastic products. They are also involved in a project that will develop a value chain based on side streams from the sugar industry to produce key basic chemicals.

Just before the production season for sugar or just after the season there is a possibility to utilize some parts of the factory for storage or some other type of production. Some parts of the production line are only adapted to the large flow of biomass, but some parts of the production line there are several smaller machines instead of one large.

Products along the value chain and utilization today

The primary feedstock in Örtofta sugar factory are sugar beets. The sugar beet can only be cultivated in the southern parts of Sweden and around 85% of the Swedish sugar beet is grown in Skåne. In Sweden, the yield is about 45 tonnes of beet and just over 30 tonnes of beet tops per hectare. The root of the beet contains 75% water, around 16-18% sugar, and 5% fiber[241]. The exact sugar content can vary depending on the cultivar and on the growing conditions. End products from Örtofta are sugar, molasses, molassed sugar beet pellets and HP-pulp. Örtofta is one of the largest and most efficient sugar-producing facilities in northern Europe. The yearly production of sugar at

[241] Nordzucker. 2018. www.nordzucker.de

Örtofta is 382 000 tonnes/year[242]. Around 2 million tonnes of sugar beets are processed at Örtofta sugar factory each season. All cultivation of sugar beets in Sweden is contracted by Nordic Sugar. About 50% of the white refined sugar manufactured is sold on the consumer market, the rest is sold to the food industry[242]. The consumption of sugar in Sweden of sugar is around 60,000 tonnes per year and of syrup 2,000 tonnes per year (average for 2010, 2013, 2014 and 2015[243]).

In Arlöv many different special products are manufactured for a wide range of applications, mainly for the food industry. Some examples of special products are vanilla sugar, icing sugar, syrup, cube sugar, liquid sugar and nib sugar. They produce various sugar solutions which are developed in close cooperation with the customers and are delivered to daily basis to customers all over Sweden.

Quantification of feedstock, products and residues

The average area of sugar beets in Skåne 2013-2017 was 29,055 hectares, Table 70. In 2015 the area with sugar beets was 19,465 hectares in total in Sweden, a large decrease compared to 2014 with 34,401 hectares. The decrease in sugar beet area followed the same trend in Skåne. A global surplus of sugar, combined with the new industry agreement, led to the reduction of sugar beet in 2015. In 2016 the area with sugar beets was almost back to normal again with 30,714 hectares. The standard harvest for sugar beets 2017 in Skåne was 66,324 kg/ha, 63,081 kg/ha in Blekinge and 63,349 kg/ha in Halland[244].

Table 70. Area sugar beets in hectares in different regions in Sweden and in total[245]

Region	Area sugar beets in hectares					
	2013	2014	2015	2016	2017	2013-2017
Skåne	34,555	32,854	18,644	29,403	29,817	29,055
Blekinge	692	585	287	438	422	485
Halland	831	811	402	703	755	700
Other regions	172	151	132	170	187	162
Total Sweden	36,250	34,401	19,465	30,714	31,182	30,402

The total calculated sugar beet yield in wet weight in Skåne is 1,927,017 tonnes WW and 481,754 tonnes DM on average 2013-2017, Table 71 and Table 72. The calculated dry matter content was 25%. On average for total of Sweden the total yield was 2,012,765 tonnes WW and 503,191 tonnes DM.

[242] Nordic Sugar. 2018. www.nordicsugar.se
[243] Jordbruksverket, 2016. Jordbruksverkets sockerstatistik. Statistik från Jordbruksverket. Statistikrapport 2016:02.
[244] Jordbruksverket & SCB, 2018. Normskördar för skördeområden, län och riket 2017. JO 15 SM 1701.
[245] Jordbruksverket, 2013-2017. Jordbruksmarkens användning 2013. JO 10 SM 1302. 1402, 1601, 1701, 1703

Table 71. Sugar beet yield [t WW]

Region	Sugar beet yield					
	2013	2014	2015	2016	2017	2013-2017
Skåne	2,291,826	2,179,009	1,236,545	1,950,125	1,977,583	1,927,017
Blekinge	43,652	36,902	18,104	27,629	26,620	30,582
Halland	52,643	51,376	25,466	44,534	47,828	44,370
Other regions	11,435	10,038	8,775	11,302	12,432	10,796
Total Sweden	2,399,555	2,277,326	1,288,891	2,033,590	2,064,463	2,012,765

Table 72. Sugar beet yield [t DM]

Region	Sugar beet yield					
	2013	2014	2015	2016	2017	2013-2017
Skåne	572,956	544,752	309,136	487,531	494,396	481,754
Blekinge	10,913	9,226	4,526	6,907	6,655	7,645
Halland	13,161	12,844	6,367	11,134	11,957	11,092
Other regions	2,859	2,510	2,194	2,825	3,108	2,699
Total Sweden	599,889	569,331	322,223	508,397	516,116	503,191

Skåne can be divided into three agricultural areas, Figure 68.

Figure 68. Different agricultural regions in Skåne, black=southern plains, grey=central districts and white=woodlands

The crop distribution varies between the three different areas, Figure 3. The southern plains have more cereals, oil seed crops and sugar beets than the other areas. The central district has also large areas of cereals and sugar beets, but more area of pasture, potatoes and maize compared to the other areas. The woodlands have much smaller areas of cereals and sugar beets, but large areas of pastures.

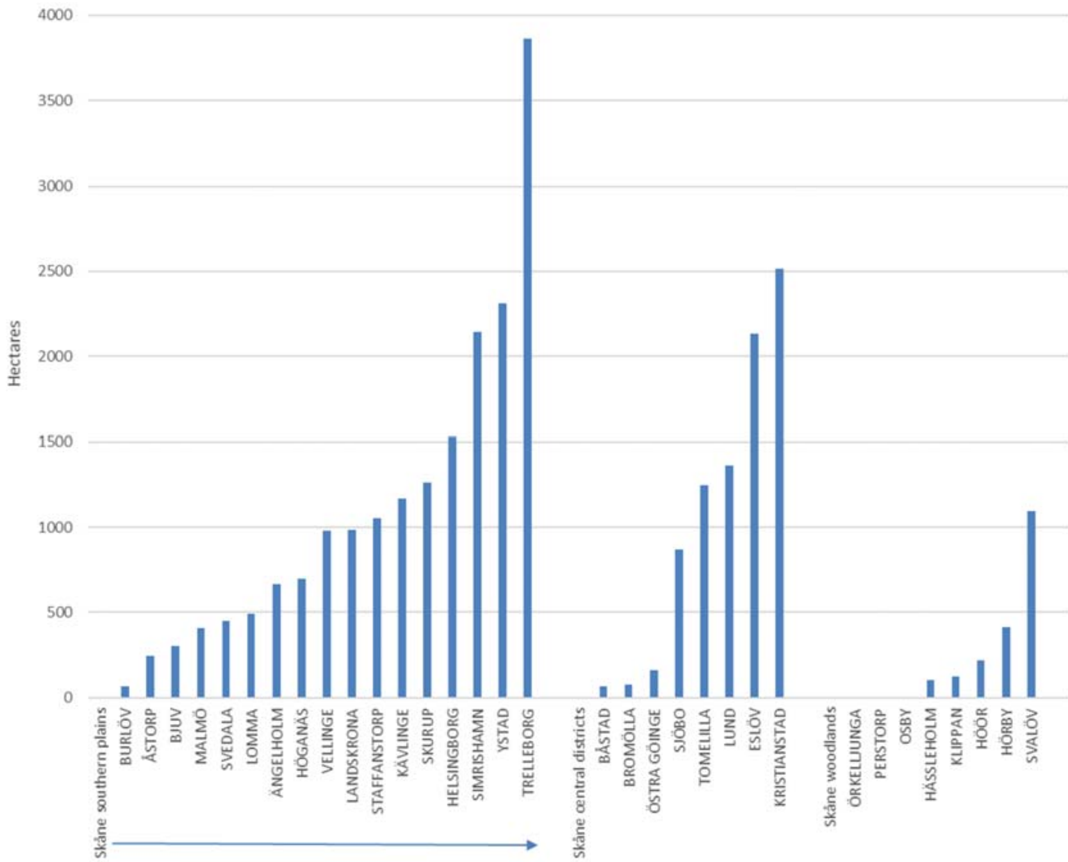

Figure 69. Area of sugar beets for different regions and municipalities in Skåne in hectares.

By-products/residues along the chain and end products
All biomass residues from the Arlöv and Örtofta refinery factories are utilized today, Table 73 and Table 74. Nordic Sugar doesn’t want to use the word biomass residues; since they are all utilized today they see the residues as co-products. Molassed sugar beet pellets are used as feed material in the feed industry and as feed for feeding ruminants, horses, sheep and pigs. When fed to horses, the pellets must be soaked first. It can also be used as a silage agent. Molassed sugar beet pellets are manufactured during the beet campaign. The manufactured product is available throughout the year. The molassed sugar beet pellets consist of approx. 90% dried beet fibres and about 10% molasses. HP Pulp is primarily used as feed for ruminants and is an excellent complement to home-grown silage and grain. HP Pulp must be ensiled before use. All manufacturing and sales of HP Pulp is done during the beet campaign.

Molasses is used as feed material and as an individual feed for ruminants, horses and pigs. It is also a good binder for pelleting and binds dust. Molasses is also used as a silage agent and as a substrate in biotechnological production. Molasses is produced during the beet campaign. The product is available throughout the year.

Table 73. Production [t/a] in Örtofta[246]

Products	Amount produced in Örtofta
Sugar	382,000[a]
Molasses	58,000
Molassed sugar beet pellets (Betfor®)	74,000
HP-Pulp (HP-Massa®)	69,000

[a] Of which a part is delivered to Arlöv

Table 74. Production [t/a] in Arlöv[246]

Products	Amount produced in Arlöv
Sugar solution	146,000
Syrup	31,000
Cube sugar	7,800
Special products	11,000
Fractional sugar	23,000
Molasses	250

The average yield for sugar beet tops in Sweden is around 2.5 tonnes dry matter per hectare[247]. Today most of the sugar beet tops is left in the field and are ploughed into the soil. Sugar beet tops have high water content at harvest, which makes them difficult to preserve as silage. It is therefore an advantage to use sugar beet tops as fresh material, for example as substrate (feedstock used for production of biogas) for biogas production. The material is mainly available at harvest in September to November.

Characterization of feedstock, products and residues

The four residue feedstocks from the sugar industry that was investigated in this section on the characteristics was molassed sugar beet pellets, HP Pulp, Molasses and Beet top, Table 75.

Table 75. Characterization of feedstock, products and residues in sugar industry value chain[248]

Parameter	Unit	Molassed sugar beet pellets	HP Pulp	Molasses	Beet top
Dry matter content	[%]	91	27	75	12.7
N content	[%]				
N content	[kg/t WW]				3.56
P content	[%]	0.1	0.1	0.02	
P content	[kg/t WW]				0.36
K content	[%]	0.8		3.4	
K content	[kg/t WW]				3.78
Protein content	[%]	8.6	10.8	9.8	22.8[249]
Hemicellulose	[%]	17			
Cellulose content	[%]	14			
Lignin content	[%]	1			
Ash content	[g/kg]			8.2	

[246] Nordic Sugar. 2018. www.nordicsugar.se
[247] Jordbruksverket, 2017. Kalkyler för energigrödor 2017. Fastbränsle, biogas, spannmål och raps.
[248] www.nordicsugar.se
[249] http://edepot.wur.nl/409816, protein content on dry matter basis

By weight sugar beet pulp consists of 22 % cellulose, 32% hemicellulose, 27% pectin, 9% minerals, 7% proteins, 2% lignin and 2 % fat, Table 76 and Table 77. The sugars that mainly build up the polysaccharides in the beet pulp are glucose (C_6), arabinos (C_5), uronic acids (C_6) and small amounts of rhamnose (C_6) and galactose (C_6) and xylose (C_5) traces.

Table 76. Comparison of available monosaccharide compositions of sugar beet pulp (SBP) material

Components	**% by weight of sugar beet pulp dry matter**		
	Micard et al. (1996)[250]	**Bonnin et al. (2002)[251]**	**Fadel et al. (2000)[252]**
Rhamnose	2.4	2.31	2.00
Fructose	0.2		0.15
Arabinose	20.9	18.14	18.51
Xylose	1.7	1.46	3.02
Mannose	1.1	1.24	1.51
Galactose	5.1	4.5	6.26
Glucose	21.1	19.99	22.85
Galacturonic acid	21.1	18.4	21.02
Methanol	1.8		
Acetic Acid	3.9		
Ferulic acid	0.8		
Diferulic acid	0.04		
Protein	11.3		7.42
Ash	3.6		
Total content	73.6	66.2	75.4

Table 77. Categorization and composition in % of dry matter weight of sugar beet pulp based on data from different literature sources

Polysaccharides	**% by weight of sugar beet pulp dry matter**		
	Micard et al. (1996)[250]	**Bonnin et al. (2002)[251]**	**Fadel et al. (2000)[252]**
Cellulose	19.7	18.5	20.9
Hemicellulose	4.2	4.2	6.7
Glucomannans	2.2	2.5	3.0
Xyloglucans	0.5	0.4	0.9
Xylans	0.7	0.6	1.3
Heteroxylans	0.8	0.7	1.4
Pectins	49.7	43.5	47.9
Homogalacturonan	13.9	11.5	15.2
RGI:Backbone:	8.7 (3.7+5.0)	8.4 (3.5+4.8)	7.3 (3.1+4.2)
Side chains	25.5	22.2	24
RGII	1.7	1.4	0.9
Total	74	66	75

[250] Micard, V., Renard, C. M. G. C. & Thibault, J.-F. 1996. Enzymic saccharification of sugar-beet pulp. Enzyme Microb. Technol., 19, 162-170.
[251] Bonnin, E., Dolo, E., Le Goff, A. and Thibault, J-F. 2002. Characterisation of pectin subunits released by an optimum combination of enzymes. Carbohydrate Research, 337, 1687-1696.
[252] Fadel, J.G., DePeters, E.J., & Arosemena, A. 2000. Composition and digestibility of beet pulp with and without molasses and dried using three methods. Animal Feed Science and Technology, 85, 121-129.

Mass balance

Figure 70. Sankey diagram over the mass balance of sugar beet biomass production [t DM/a] in Skåne.

Table 78. Mass balance of sugar production in Skåne.

Step 1		
Roots harvested	[t DM]	460156
Tops, total	[t DM]	115991
Residual fine roots	[t DM]	4602
Residual roots (losses)	[t DM]	21748
Total sugarbeet biomass	**[t DM]**	**602497**
Step 2- beet harvest		
Beets harvested	[%]	95
Beets lost	[%]	5
Tops, harvested	[%]	1
Roots harvested	[t DM]	460156
Tops, harvested	[t DM]	1160
Residual fine roots	[t DM]	4602
Residual roots (losses)	[t DM]	21748
Residual tops (losses)	[t DM]	114831
Step 3 - sugar production		
Beets incoming	[t DM]	460156
Dirt	[%]	5
Products		
Raw sugar	[t DM]	382000
Molasses	[t DM]	58
Molassed sugar beet pellets (Betfor®)	[t DM]	74
HP-Pulp (HP-Massa®)	[t DM]	69
Dirt	[t DM]	23008
Evaporated water	[t DM]	54947

2.3.5 Summary and outlook

The cultivation area of sugarbeets in the investigated SBA regions varies between 20,000-34,000 hectares (Figure 71). In Poland, with a larger area of arable land, only around 1% of arable land is cultivated with sugarbeets, while Denmak and Sweden use approx. 7% of their arable land for sugar production.

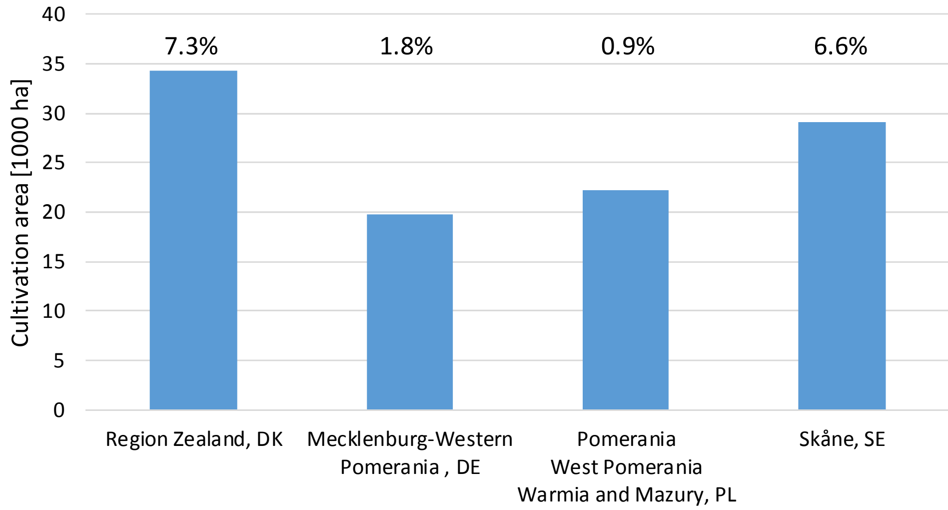

Figure 71. Cultivation area of sugarbeets in the four SBA regions. Numbers above the columns refer to the fraction of sugarbeet cultivation area on total arable land.

The amounts of sugarbeet tops available from the sugar value chain in the SBA regions varied between 73,000-171,000 tonnes dry matter annually (Figure 72). The differences are due to the unequal size in cultivation area between regions, but also due to the much lower (assumed) yield of sugarbeet tops per hectare, which are only half in Sweden compare to Denmark and Poland (Figure 72).

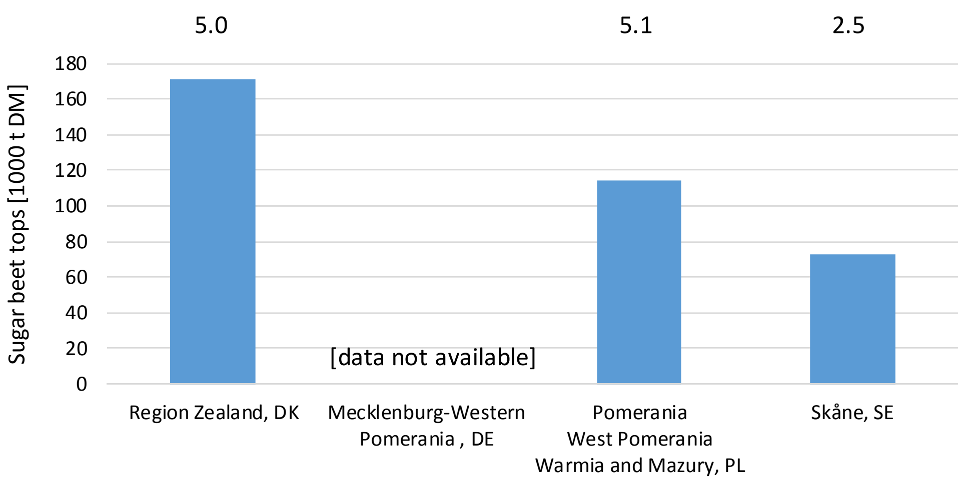

Figure 72. Amount of sugar beet tops [1000 t DM] in the four SBA regions. Numbers above the columns refer to the sugarbeet top dry matter yield per hectare [t DM/ha].

Other residual streams from the sugar value chain are pellets, molasses and pulp, which are present in the same relative proportions in all four SBA regions (Figure 73).

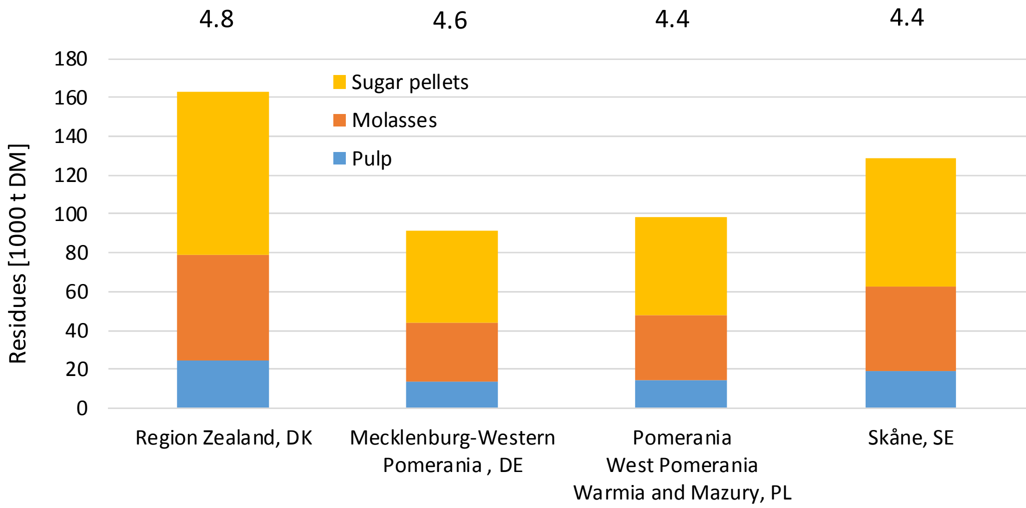

Figure 73. Amount of residues from sugar production [1000 t DM] in the four SBA regions. Numbers above the columns refer to the amount of residue per hectare of sugarbeet cultivation [t DM/ha].

Opportunities

The first by-product in the sugar value chain are the sugarbeet leaves or tops, which were historically used as animal feed but which are typically left in the field today and incorporated into the soils as green fertilisation. Besides energy applications such as feedstock for biogas production[253], sugarbeet tops have been suggested – due to protein contents >25% – for protein extraction for use as food or feed[254]. Due to higher potential revenues from protein extraction compared to use as biogas substrate[255], a combined protein extraction and residue digestion could outweigh the high feedstock supply costs[253].

Other residues include sugar pellets and molasses and pulp which can be combined to formulate attractive animal feed products. Alternative uses of residual pulp and molasses include use as feedstock for ethanol and hydrogen production through fermentation[256,257], however, it is unclear if this presents a more economic sustainable use[258]. Residual sugar beet pulp may contain pectin substances[259] that have do not have gel-forming capabilities as pectins extracted from citrus peel

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[253] Kreuger, E., T. Prade, L. Björnsson, M. Lantz, I. Bohn, S.-E. Svensson, A. Lindkvist and T. Hörndahl (2014). Biogas från skånsk betblast - Potential, teknik & ekonomi. Lund, Sweden, Environmental and Energy Systems Studies, Lund University: 61.

[254] Kiskini, A. (2017). Sugar beet leaves: from biorefinery to techno-functionality. Includes bibliographical references. - With summary in English, Wageningen University.

[255] Johansson, E., T. Prade, I. Angelidaki, S.-E. Svensson, W. R. Newson, I. B. Gunnarsson and H. P. Hovmalm (2015). "Economically Viable Components from Jerusalem Artichoke (Helianthus tuberosus L.) in a Biorefinery Concept." International Journal of Molecular Sciences 16(4): 8997-9016.

[256] Berlowska, J., K. Pielech-Przybylska, M. Balcerek, W. Cieciura, S. Borowski and D. Kregiel (2017). Integrated Bioethanol Fermentation/Anaerobic Digestion for Valorization of Sugar Beet Pulp. Energies 10(9): 1255.

[257] Lay, C.-H., J.-H. Wu, C.-L. Hsiao, J.-J. Chang, C.-C. Chen and C.-Y. Lin (2010). Biohydrogen production from soluble condensed molasses fermentation using anaerobic fermentation. International Journal of Hydrogen Energy 35(24): 13445-13451.

[258] Hamley-Bennett, C., G. J. Lye and D. J. Leak (2016). Selective fractionation of Sugar Beet Pulp for release of fermentation and chemical feedstocks; optimisation of thermo-chemical pre-treatment. Bioresource Technology 209: 259-264.

[259] Rombouts, F. M. and J.-F. Thibault (1986). Feruloylated pectic substances from sugar-beet pulp. Carbohydrate Research 154(1): 177-187.

and apple pomace, but rather have interesting emulsifying properties[260]. Furthermore, phenolic substances were extracted from sugar beet pulp and subsequent fermetantion of the residues for production of succinic acid has been proposed[261].

Bottlenecks

In order to collect the sugarbeet tops in the field, add-on technology for the beeet harvesters is available, but not common. A functional chain for harvesting of tops also needs to be integrated with beet harvest, where some methods may cause additional costs due to decrease in harvesting capacity for the sugarbeets[253]. Sugarbeet tops also have a fertilising effect that needs to be compensated for when removing the tops from the field. Sugarbeet tops usually contain only low dry matter contents (around 13%), which makes transport expensive. As a consequence, in-field fractionation units for DM recovery have been suggested.

For the residual by-products of sugar refineries, the extraction of pectins and other valuable components could be interesting and profitable, but require development of stable and cost-effective biotechnological processes[261,262].

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[260] Chen, H.-m., X. Fu and Z.-g. Luo (2016). Effect of molecular structure on emulsifying properties of sugar beet pulp pectin. Food Hydrocolloids 54: 99-106.

[261] Alexandri, M., R. Schneider, H. Papapostolou, D. Ladakis, A. Koutinas and J. Venus (2019). Restructuring the Conventional Sugar Beet Industry into a Novel Biorefinery: Fractionation and Bioconversion of Sugar Beet Pulp into Succinic Acid and Value-Added Coproducts. ACS Sustainable Chemistry & Engineering 7(7): 6569-6579.

[262] Almohammed, F., M. Koubaa, A. Khelfa, M. Nakaya, H. Mhemdi and E. Vorobiev (2017). Pectin recovery from sugar beet pulp enhanced by high-voltage electrical discharges. Food and Bioproducts Processing 103: 95-103.

2.4 Residues from the food value chains

2.4.1 Regional resources in Denmark

Assessed by Mark Booker Nielsen and Tyge Kjær, Roskilde University, Denmark

Large amount of food processing residues, by-products and organic waste and municipal organic waste is generated the entire EU and offers a vast unutilized innovation potential within the bioeconomy. Denmark has long standing tradition of continuously developing and optimising the 'traditional' bioeconomic agri-food value chains and position of strength to seize these new business opportunities[263]. Region Zealand is no exception. In the following assessment we will map materials flow of main product and side streams through the food processing value chains in Region Zealand. The assessment will focus on the following value chains and include a mapping of municipal organic waste:

Grain production value chain

- Milling industry
- Malting and brewing industry

Livestock value chain

- Slaughterhouse
- Dairies

Fruit value chain

- Pectin industry

Municipal organic waste

- Organic waste

Milling industry

There are two milling companies in Denmark operating in Denmark. The company Lantmännen Cerealia located in Esbjerg and Valsemøllen A/S located in Vejle and Køge. The flour mill is Køge owned by Valsemøllen is the only mill in Region Zealand.

Table 79. Production of winter and spring wheat [1000 t] for milling in Region Zealand[264,265]

Crop	2012	2013	2014	2015	2016
Winter wheat –Milling	86.3	95.2	113.7	78.7	83.8
Spring wheat – Milling	3	1.5	2.6	3	2.4
Total	89.3	96.7	116.3	81.7	86.2

263 Denmark as growth hub for a sustainable bioeconomy, Danish Bioeconomy Panel (2014)
264 Statistics Denmark, HALM1 (2018), http://www.statistikbanken.dk/HALM1
265 Jordbrugsanalyser.dk

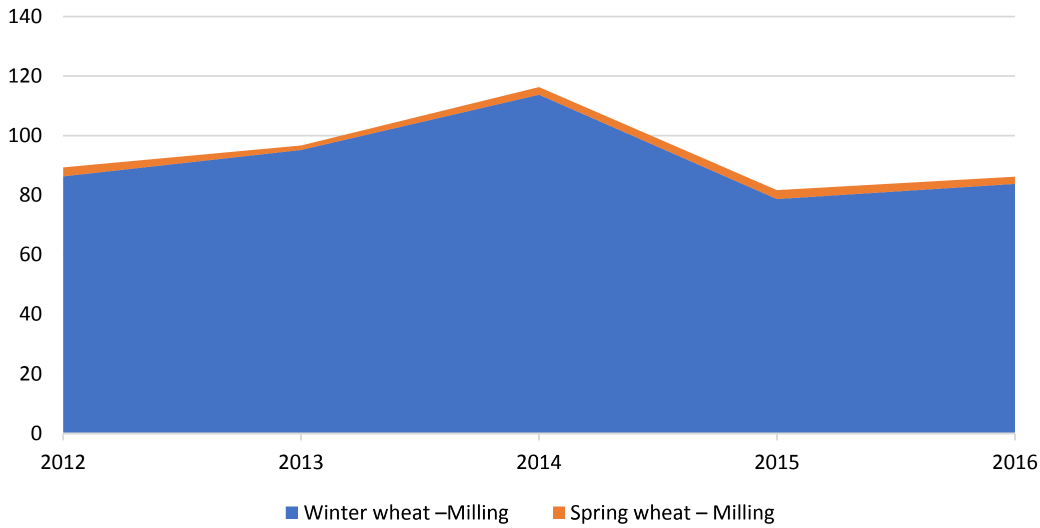

Figure 74. Production of winter and spring wheat [1000 t] for milling in Region Zealand [266,267]

[266] Statistics Denmark, HALM1 (2018), http://www.statistikbanken.dk/HALM1
[267] Jordbrugsanalyser.dk

Current products and residues along the value chain

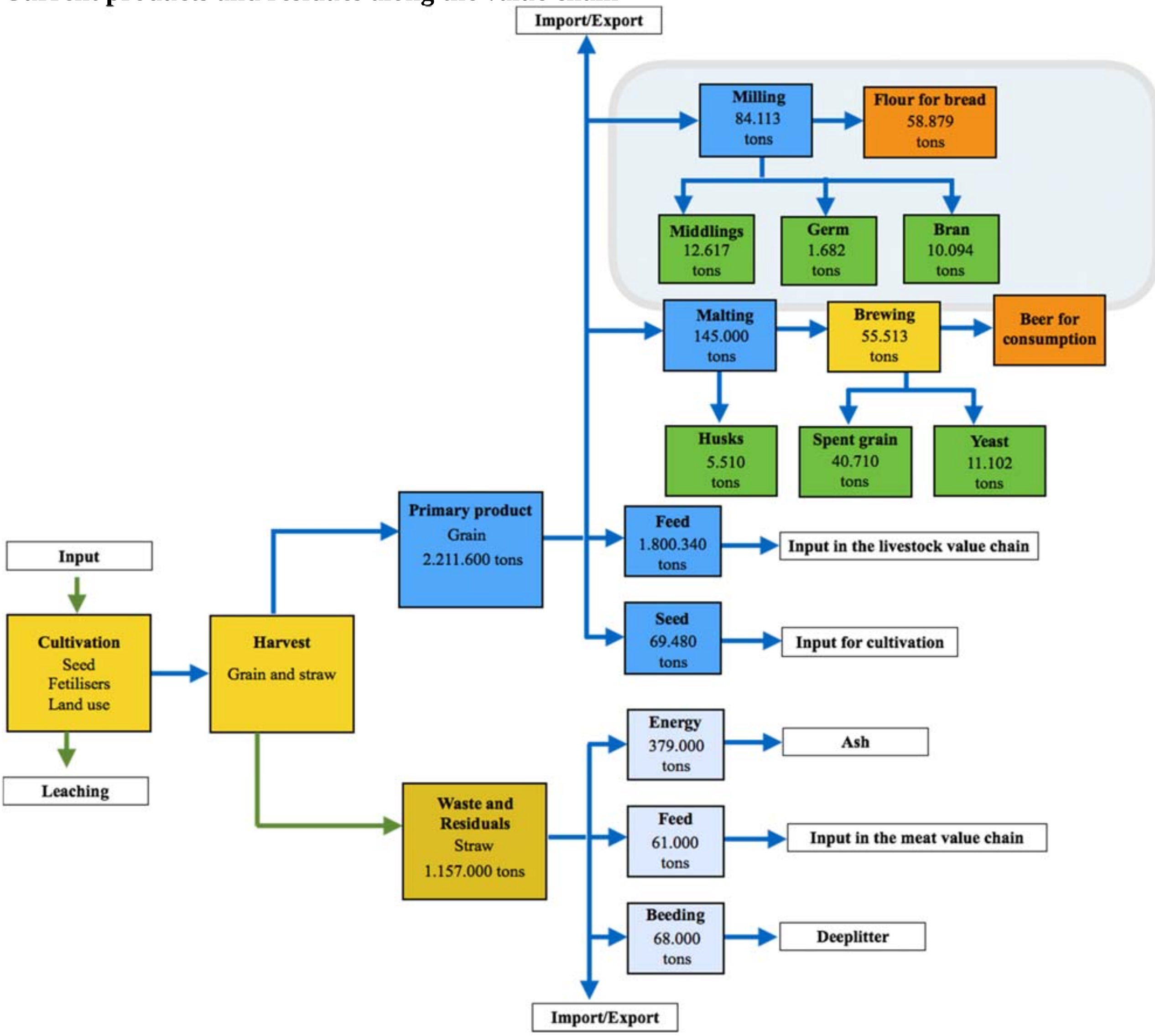

Figure 75. Material flow through the grain production value chain in Region Zealand with focus on the milling industry 2016

Quantification of residues and by-products

Table 80. Quantification of residues and by-products in Region Zealand 2016

Input	Amount [t WW/a]	Share [%]	Used as
Total wheat for production of flour	84,113	100	
By-products / residues			
Middlings	12,617	15	Feed
Wheat germ	1,682	2	Feed
Wheat feed meals	841	1	Feed
Wheat bran	10,094	12	Feed/food
Output			
Wheat flour	58,879	70	Food

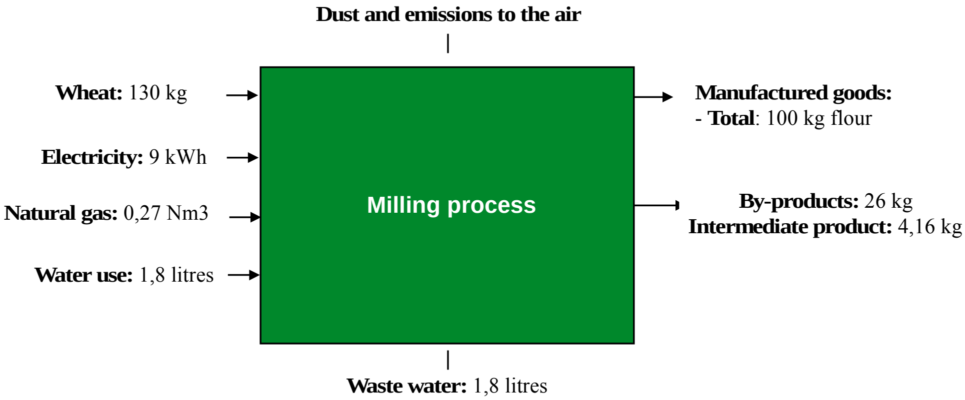

Figure 76. Input/output analysis of typical flour milling factories in Denmark[268]

Malting and brewing industry

The malting and brewing industry is part of the grain value chain in the region. Large amounts of residues are generated from the malting and brewing industry. In Region Zealand there are located two large breweries Royal Unibrew and Harboes Brewery as well as about 25 small and medium size breweries. Furthermore, the regional brewery industry also includes one of Denmark's two malting companies called Viking Malt that was up until 2016 owned by Carlsberg and called Danish Malting Group.

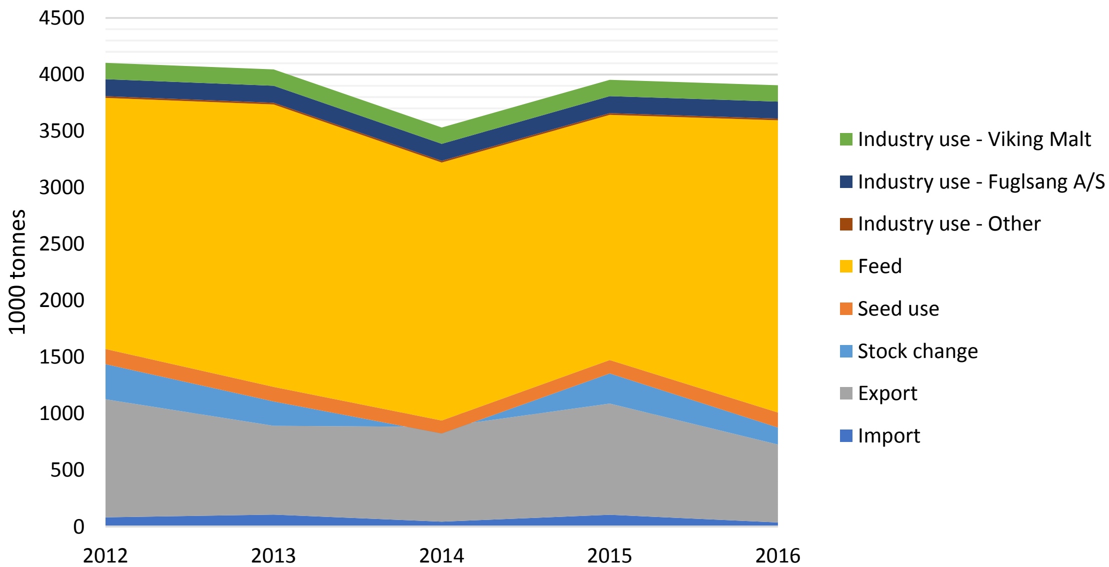

Figure 77. Barley production in Denmark[269, 270]

[268] LCI data for the calculation tool Feedprint for greenhouse gas emissions of feed production and utilization Dry Milling Industry, Wageningen University and Research Centre (2012)
[269] Statistics Denmark, HST77 (2018), http://www.statistikbanken.dk/HST77
[270] https://miljoeoplysninger.mst.dk/

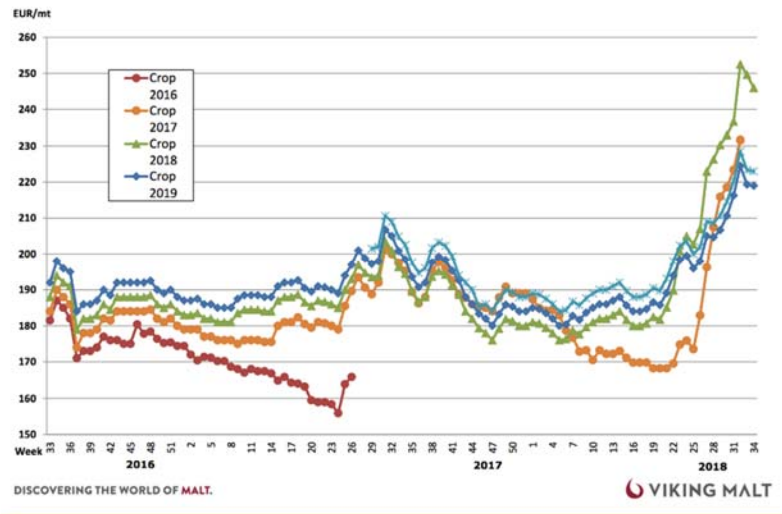

Figure 78. Malting barley prices. Basis FOB Swedish/Danish Port[271]

[271] https://www.vikingmalt.com/how-we-do-it/barley-reports/

Current products and residues along the value chain

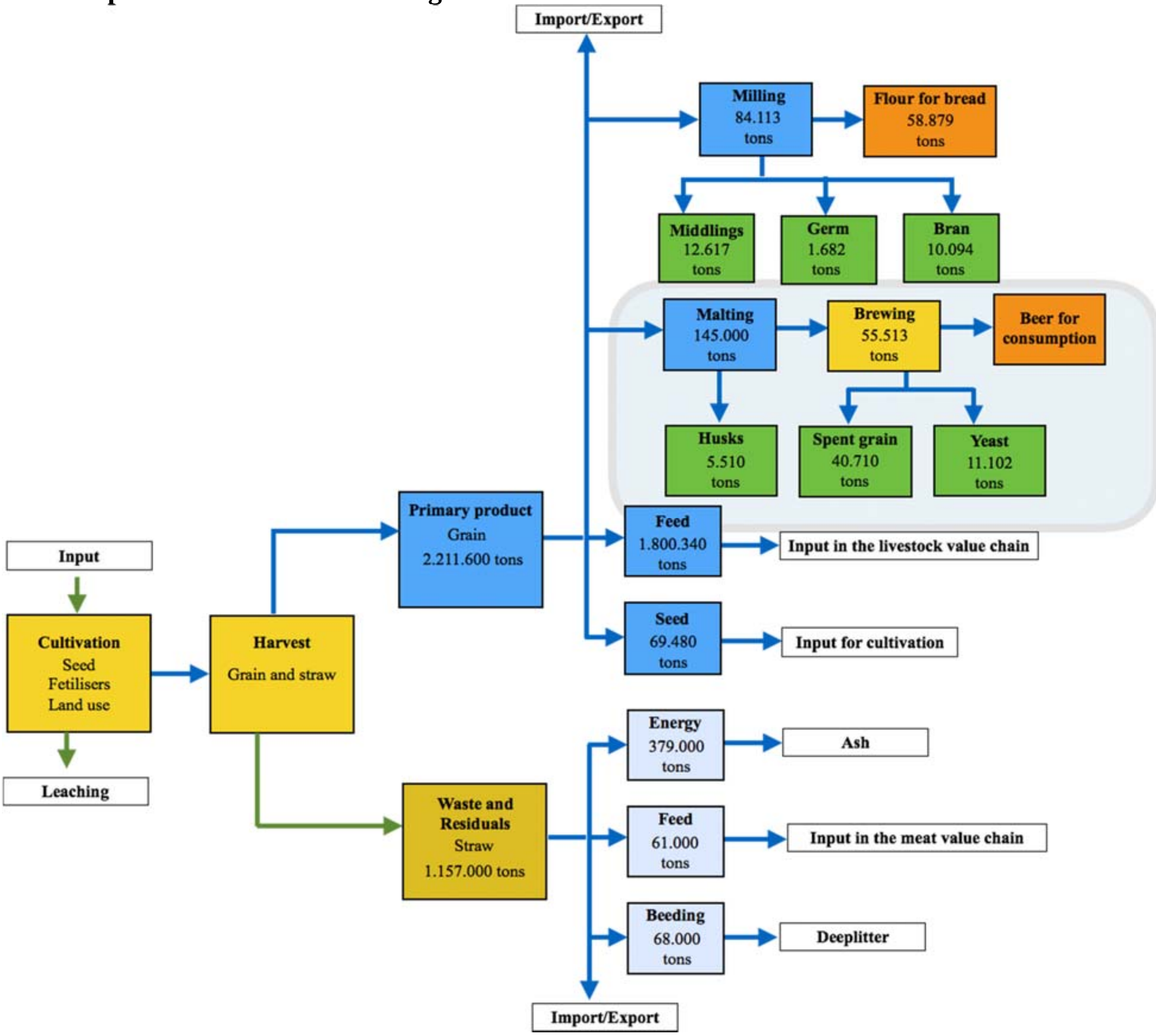

Figure 79. Material flow through the grain production value chain in Region Zealand with focus on the brewing industry.

Quantification of residues and by-products in Region Zealand

Step 1: Malting[272]

Table 81. Quantification of residues and by-products from the malting industry in Region Zealand

Input	Amount [t WW/a]	Used as
Total malt barley	145,000	
By-products / residues		
Green malt sprout	1,160	Feed
Malt husk	4,350	Feed
Barley Husk	1,450	Feed
Total output		
Total malt production	118,000	

Step 2: Brewing[273]

Table 82. Quantification of residues and by-products from the brewery industry in Region Zealand

Input	Amount [t WW/a]	Used as
Total malt	55,513	
By-products / residues		
Spent grain	40,710	Feed
Yeast	11,102	Feed
Total output		
Total production of beer (hl)	3,700,925	Food

[272] Mst, Grønne regnskaber 09/10 – Danish Malting Group
[273] Mst, Grønne regnskaber 09/10 Haboes and Royal Unibrew/Faxe Brewery

Input/output analysis of typical malteries and breweries in Denmark

Step 1: Malting[274]

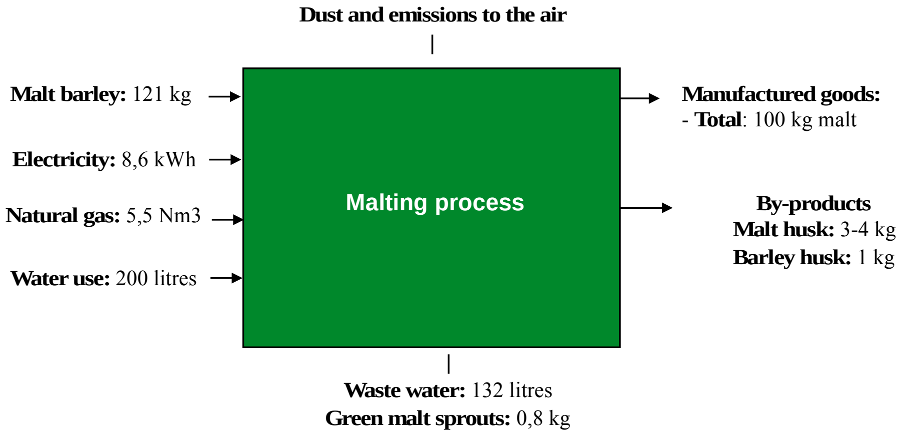

Figure 80. Input/output analysis of typical malting factory in Denmark[274]

Step 2: Brewing[275,276]

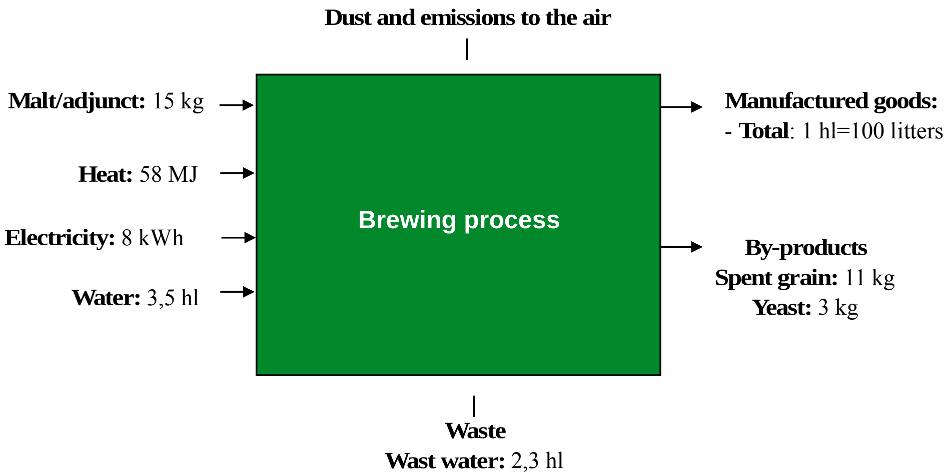

Figure 81. Input/output analysis of typical brewery in Denmark[275,276]

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[274] Mst, Grønne regnskaber 09/10 – Danish Malting Group
[275] Mst, Grønne regnskaber 09/10 Haboes and Royal Unibrew/Faxe Brewery
[276] Presentation: Nile Brewery Ltd. In-plant Water CP-assesment, Danbrew (2007)

Slaughterhouse industry[277]

The pig production in Region Zealand is relatively small compared with other regions in Denmark with a total of 1,369,279 pigs and sows in 2016 accounting to approximately 10 percent of the total Danish pig production[278].

The pigs produced in the region are feed by regional cultivated crops but also e.g. soya beans meal and corn imported from countries like Argentina, Brazil and Ukraine[279].

The pig farms in Region Zealand yearly produce approximately 2.3 million tonnes of manure that utilized as fertilizer on the fields. Approximately 130,000 tonnes is utilized as feedstock in biogas plant for anaerobic digestion – the digestate is subsequently utilized as an improved fertilizer product.

There is one industrial size slaughterhouse in the region owned by Danish Crown located in Ringsted Municipality. The slaughterhouse annually receives around 2.7 million pigs that is processes into meat products. No pigs are imported into Denmark from other EU countries due risk of disease, but pigs are imported from other regions[280].

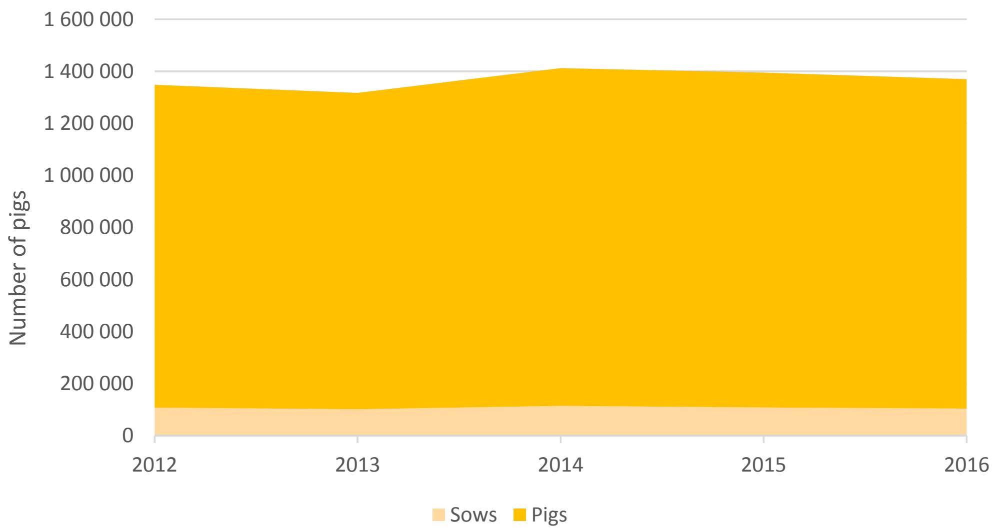

Figure 82. Pig production in Region Zealand

[277] Statistics Denmark, HDYR07 (2016), http://www.statistikbanken.dk/HDYR07
[278] Statistics Denmark, KOMB07 (2016), http://www.statistikbanken.dk/KOMB07
[279] Miljømæssige konsekvenser ved den danske import af majs og soja til svinefoderproduktionen, KU (2014)
[280] Danmark statistik - Svineproduktion under forandring (2018)

Current products and residues along the value chain

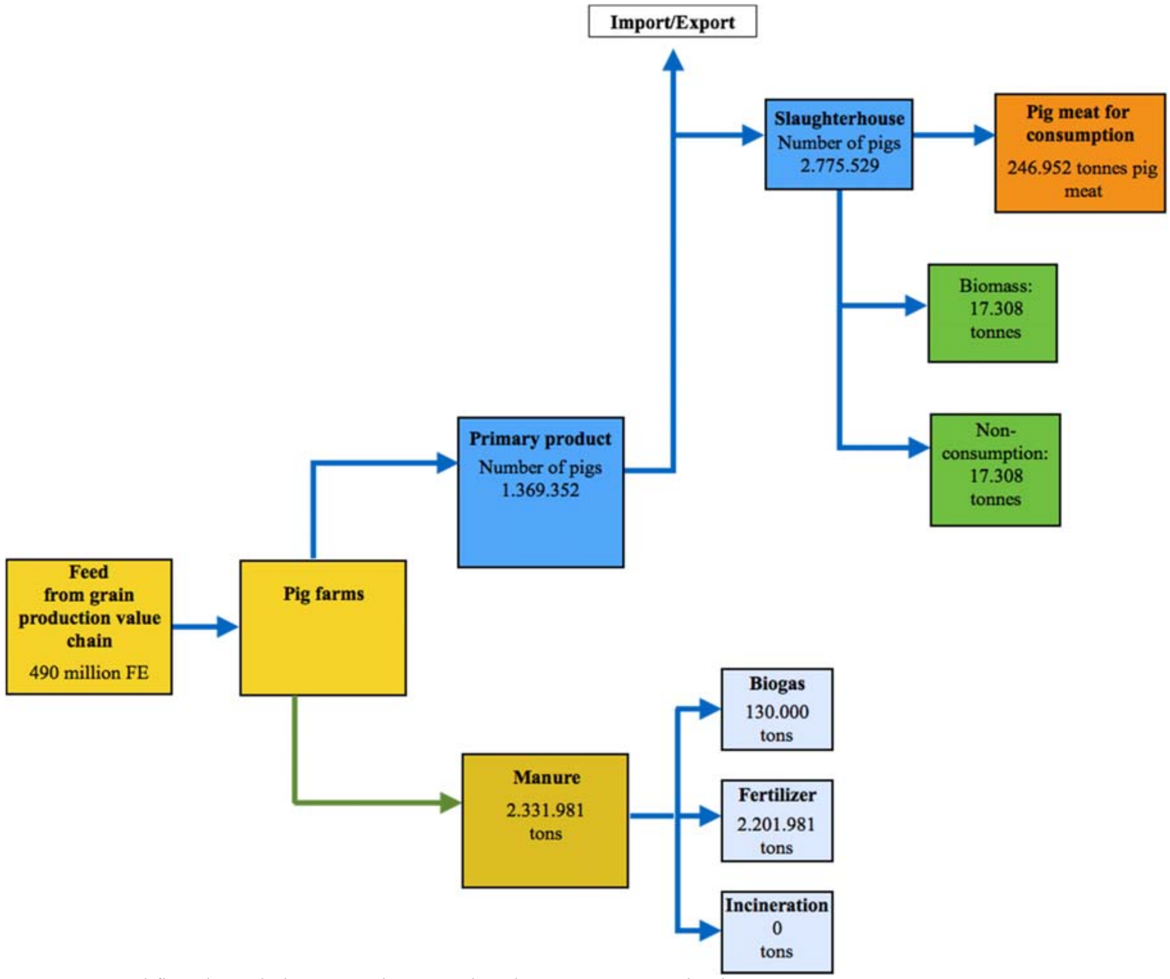

Figure 83. Material flow through the pig production value chain in Region Zealand.

Quantification of residues and by-products in Region Zealand

Table 83. Quantification of pig production in Region Zealand 2012 [t/a] [281]

Production	Amount	Used as
Pigs [-]	1,369,352	Raw material
By-products / residues/waste		
Manure [t/a]	2,331,981	Fertilizer/biogas

Table 84. Quantification of residues and by-products from the pig industry in Region Zealand 2011/2012

	Amount	Used as
Total input		
Pigs to slaughterhouse [-]	2,775,529	Food
Pigs to slaughterhouse [t/a]	305,000	Food
By-products / residues/waste		
Manure – Stomach/colon content [t/a]	17,308	Biogas/fertilizer
Non-consumption animal by-products [t/a]	22,616	Biogas/fertilizer
Total output		
Total amount of pig meat [t/a]	246,952	Food
Total amount of pig blood [t/a]	6,862	Food

Input/output analysis of typical slaughterhouse in Denmark

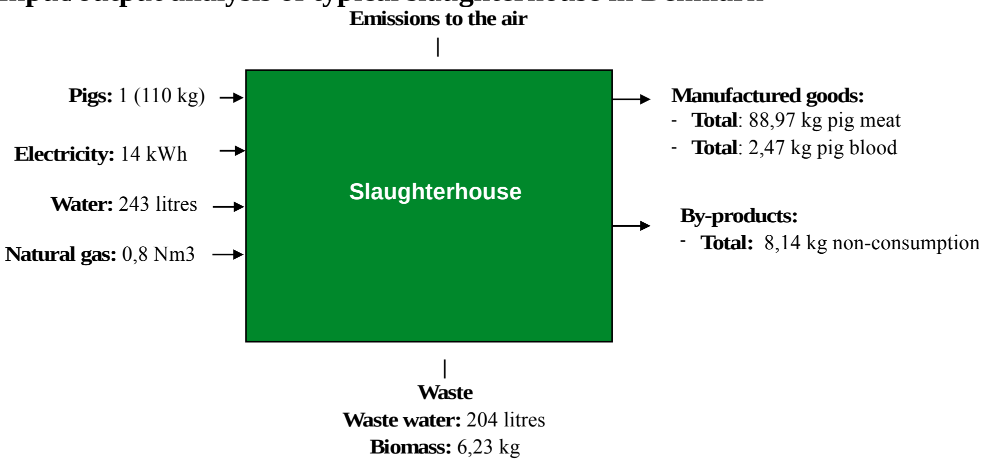

Figure 84. Input/output analysis of typical slaughterhouse in Denmark from 1 pig[281]

[281] Mst, Grønne regnskaber 11/12 – Danish Crown Ringsted

Dairy industry[282]

The dairy industry is relatively small in Region Zealand compared with other region in Denmark. region has 81,614 cattle a number that has been very stable the last couple of years[283]. The only industrial size dairy in the region is owned by Arla Food and located in Slagelse.

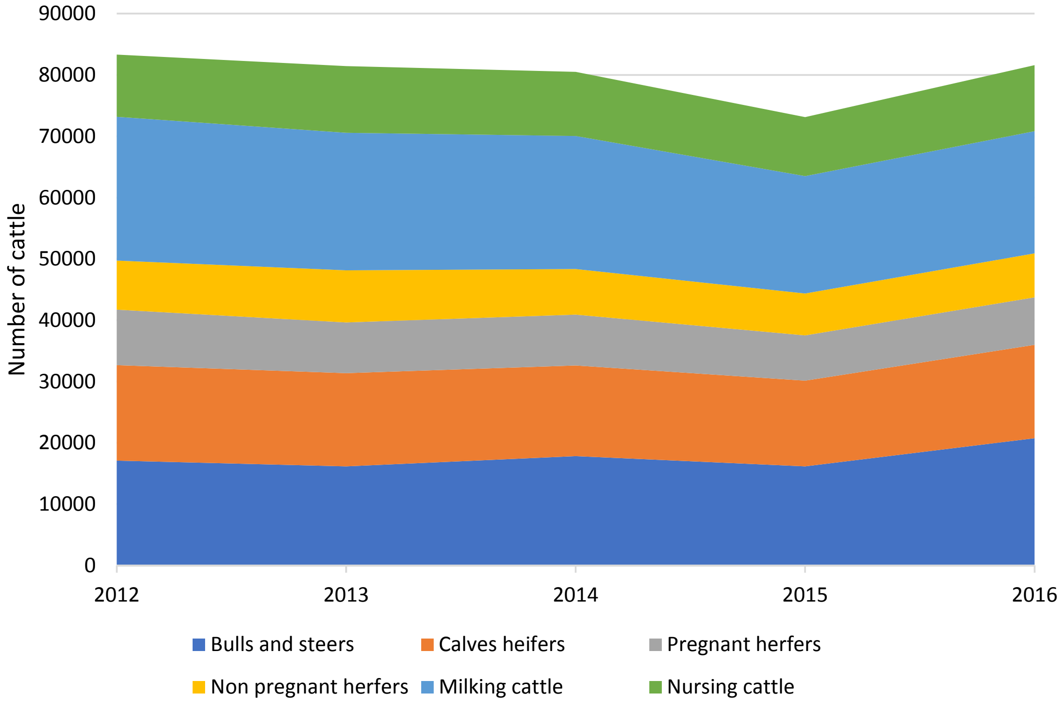

Figure 85. Cattle production in Region Zealand[282,283]

[282] Statistics Denmark, HDYR07 (2016), http://www.statistikbanken.dk/HDYR07
[283] Statistics Denmark, KOMB07 (2016), http://www.statistikbanken.dk/ KOMB07

Current products and residues along the value chain

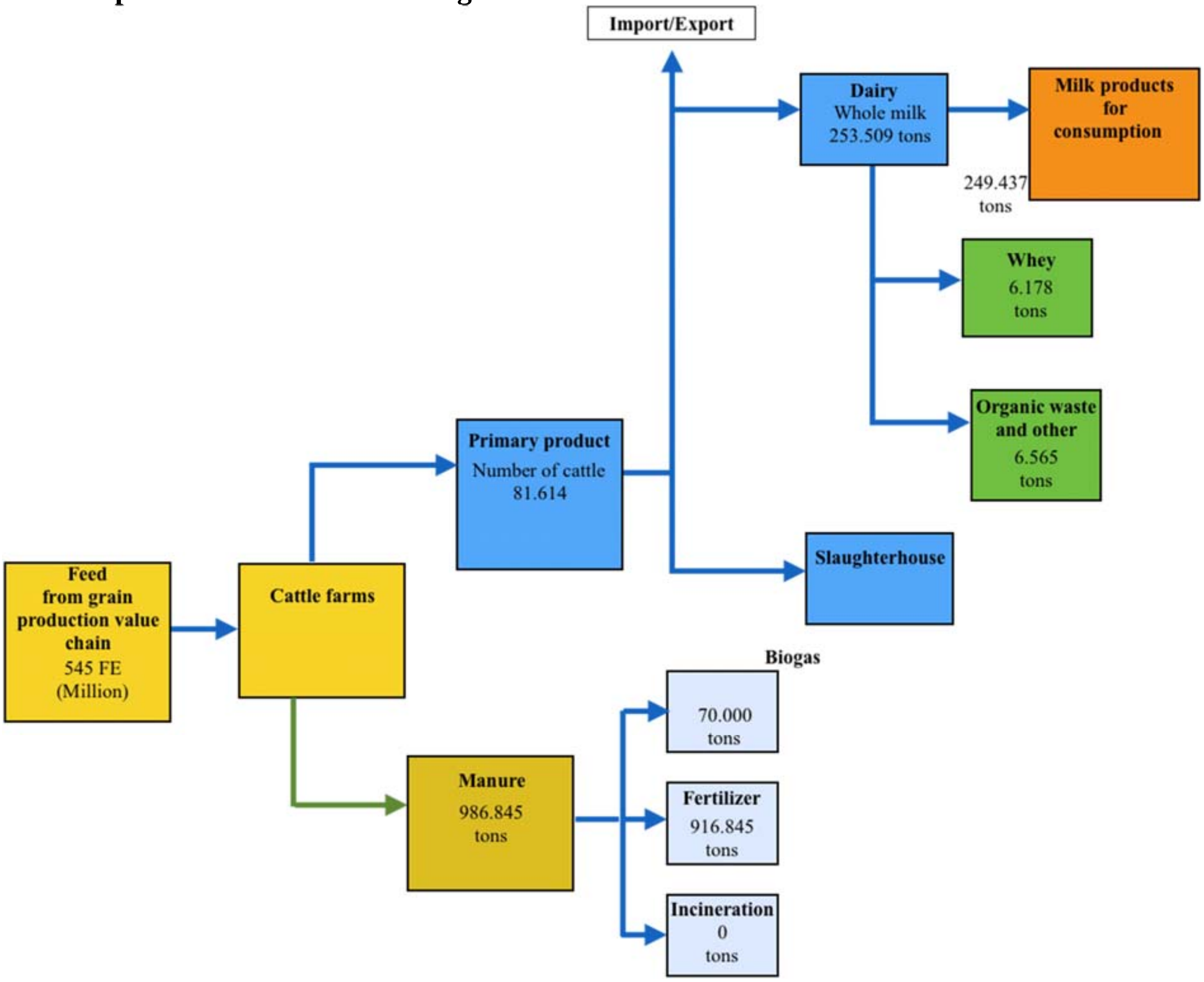

Figure 86. Material flow through the cattle production value chain in Region Zealand 2011/2012

Quantification of residues and by-products in Region Zealand

Table 85. Quantification of residues and by-products from the dairy industry in Region Zealand 2009-2010

	Amount [t WW/a]	Used as
Total input		
Whole milk	253,509	Raw material
Jam	1,080	Raw material
Other	477	Raw material
By-products / residues/waste		
Whey	6,178	Biogas/fertilizer
Organic waste	1,713	Biogas/fertilizer
Other	4,852	Biogas/fertilizer
Total output		
Milk products	192,318	Food
Butter	193	
Whole milk	48,974	Food
Cream	7,952	Food

Input/output analysis of typical dairy in Denmark[284]

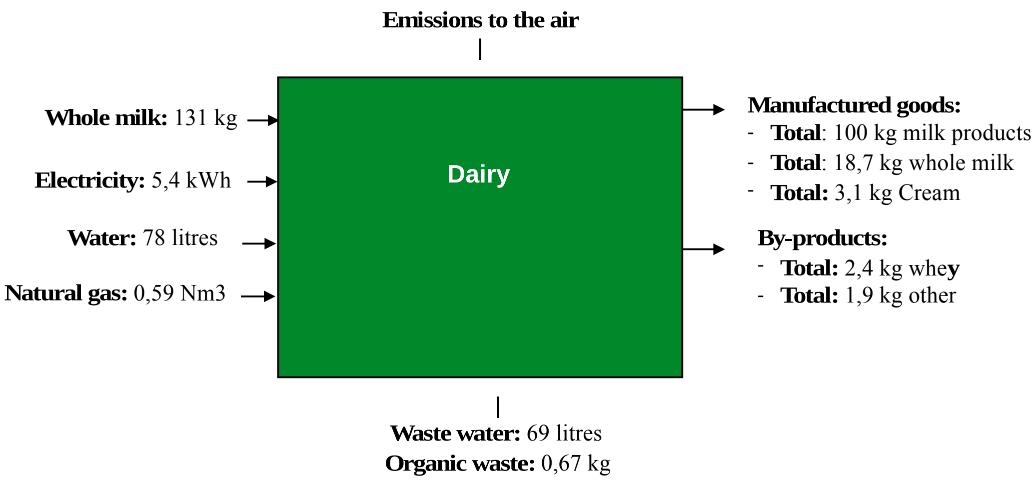

Figure 87. Quantification of residues and by-products from the cattle industry in Region Zealand

[284] Mst, Grønne regnskaber 09/11 – Arla Food Slagelse

Pectin industry

One of the world's biggest pectin factories is located in Region Zealand. The pectin factory in Lille Skensved is owned by CP Kelco a part of the C.M. Hubber Cooperation. The factory in Skensved was started in 1948 and today is the factory with the biggest pectin production in the world. The pectin produces have several applications including improving texture and stability in food products and pharmaceutical and personal care applications[285].

The production of pectin is based on dried lemon peels that are imported from South & Central America and Southern Europe. The dried peels are a residue from the production of juice and lemon oil. The factory in Lille Skensved receives around 140,000 tonnes of dried lemon peels per year that is utilised to produce an estimated 32,000 tonnes of pectin. The main residue from the production process is the utilized peel. The peel residues were previously used as cattle feed, but because of a decreasing demand the peel residues are today use as feedstock at Solrød Biogas.

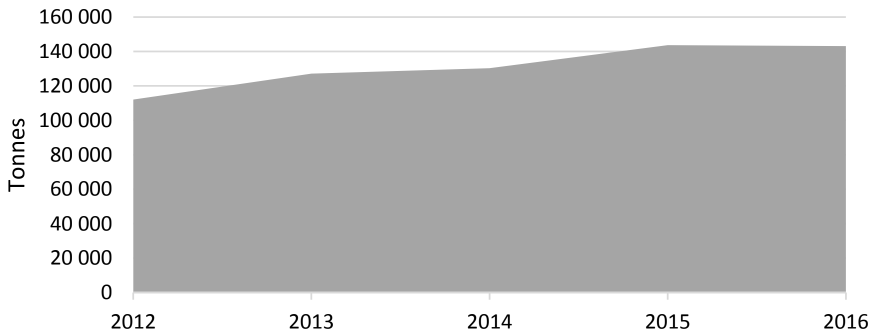

Figure 88. Imported dried lemon peels in Region Zealand[286]

Current products and residues along the value chain[287]

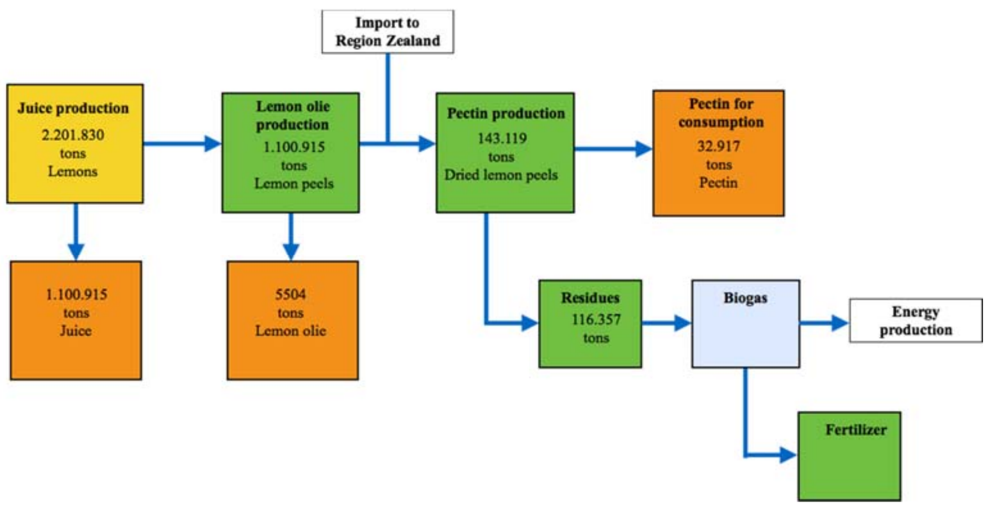

Figure 89. Material flow through the pectin production industry in Region Zealand 2016

[285] Ciriminna, Rosaria et al (2016): Pectin Production and Global Market
[286] CSR rapport 2016 produced by CP Kelco
[287] Presentation by Jan Staunstrup (2019): Citrus pectin market and world market

Quantification of residues and by-products in Region Zealand

Table 86. Residues and by-products from pectin production in Region Zealand 2016[288]

	Amount [t WW/a]	Used as
Total input	143,119	
Dried peels		Raw material
By-products / residues/waste		
Residues from pectin production	116,357	Biogas/fertilizer
Total output		
Pectin	32,917	Food ingredient

Input/output analysis of typical slaughterhouse in Denmark[289,288]

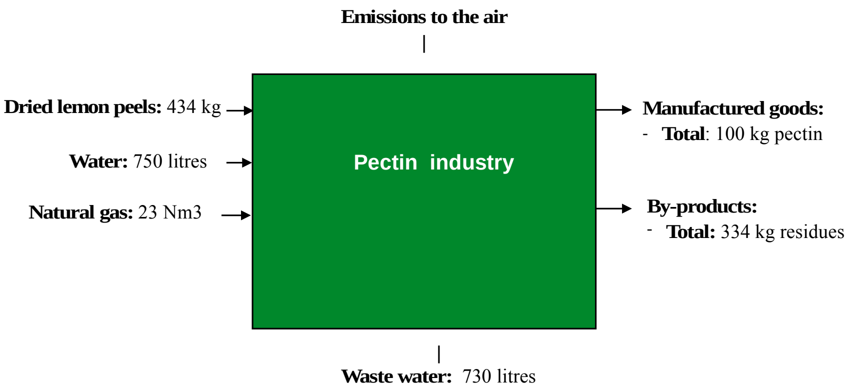

Figure 90. Quantification of residues and by-products from the pectin industry in Region Zealand

Municipal organic waste

There are three main utilities handling the treatment of organic household waste from municipalities in Region Zealand. Based on of the studies of the average amount collected from apartment building and houses combined with studies of the amount of reject it has been estimated that there in collection potential is approximately 51,820 tonnes in the region.

[288] CSR rapport 2016 produced by CP Kelco

[289] Mst, Grønne regnskaber 09/11 – CP Kelco

Table 87. Municipal organic waste[290]

	Population	Households	Total potential[a] [t WW/a]	Collection potential[b] [t WW/a]
ARGO municipalities				
Greve	49,518	20,660	4,382	2,893
Holbæk[c]	69,972	30,710	6,491	4,276
Kalundborg[c]	48,660	21,886	4,814	3,251
Køge	59,868	25,555	5,339	3,490
Lejre	27,317	10,277	2,376	1,653
Odsherred[c]	32,816	14,263	3,194	2,180
Roskilde[c]	86,207	38,503	7,733	4,922
Solrød	21,788	8,915	1,911	1,270
Stevns	22,260	9,263	2,115	1,460
Total for ARGO	**418,406**	**180,032**	**38,355**	**25,395**
Affaldplus municipalities				
Faxe[c]	35,614	15,758	3,504	2,382
Næstved[c]	82,342	37,953	8,037	5,301
Ringsted[c]	34,031	14,964	3,059	1,970
Slagelse[c]	78,140	36,727	7,456	4,781
Sorø[c]	29,543	13,103	2,893	1,959
Vordingborg[c]	45,806	21,875	4,694	3,122
Total for A+[c]	**305,476**	**140,380**	**29,643**	**19,515**
REFA municipalities				
Guldborgsund	60,979	29,739	6,416	4,282
Lolland	42,638	18,094	3,925	2,628
Total for REFA	**103,617**	**47,833**	**10,341**	**6,910**
Total Region Zealand	827,499	368,245	78,339	51,820

[a] Total amount of organic waste estimated to be found in municipal waste[291]
[b] The amount expected to be collected based on previous experience with source separation in Denmark[291]. 10-15% of the collected potential will likely be reject before being pulped.
[c] Municipalities that separate organic household waste. There are no measured numbers yet as almost all of started the source separation in 2017 and 2018 due to the EU waste directive 2008.

[290] Kildesorteret husholdningsaffald på biogasanlæg, 2017, RUC based on data from Danish Environmental Agency
[291] Information from AffaldPlus

2.4.2 Regional resources in Germany

Assessed by Beate Cuypers, University of Greifswald, Germany

In the European Union, food waste was defined as "any food substance, raw or cooked, which is discarded, or intended or required to be discarded"[292].

Food waste is divided into *solid urban waste* (= municipal waste) and *industrial waste. Solid urban waste* ("Siedlungsabfall") covers household waste, household waste-like industrial waste, bulky waste, street waste, market waste, compostable waste from the biological waste bin, garden and park waste, and waste from the separate collection of paper, cardboard, cardboard, glass, plastics, wood and electronic parts.

Specifically, household waste consists of residual waste, garden and bio-waste, paper-cardboard and packaging, glass, textiles as well as metals. Household waste-like industrial waste (commercial waste) includes waste generated in small businesses, public authorities, schools, etc. and, like household waste, is sorted, collected and disposed.

The household and commercial food waste is collected separately in designated bio-waste bins as well as in residual (general) waste bins. The disposal of waste from private households in Mecklenburg-Western Pomerania is the task of counties and urban municipalities.

Industrial waste includes the waste produced by industrial activity, which means any material that is rendered useless during a manufacturing process. Industrial food waste is a complex field and we concentrated on the main food waste producers besides retail:

- slaughterhouses
- flour mills
- dairies
- starch producing firms
- bakeries
- fruit and vegetable processing firms
- breweries
- fishing industry

In 2015, 5.0 million tonnes of waste were generated in Mecklenburg-Western Pomerania and delivered to the waste disposal. 80% of the waste is from the own state, almost 17% came from the other federal states and another 3% of the waste came from abroad.

Food and kitchen waste from private households is collected in the bio-bin, if available, and/or the normal waste bin. The following food waste is allowed for the bio bin:

- bread and pastry leftovers
- fish leftovers and bones
- vegetable waste
- cheese residues, including natural bark
- bones
- nutshells
- leftovers (uncooked, cooked, spoiled)
- feathers
- eggshells
- meat and sausage remains
- salad waste
- coffee filter bags, coffee grounds
- milk product residues
- fruit remains
- teabags, tea residues
- hair

Basically all food waste can be disposed in the bio-bin. Unfortunately, not every municipality uses bio-bins, a lot of food waste is disposed via the residual bin. Therefore, an analyzation of the urban waste is necessary.

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[292] Wikipedia, 2018

Municipal organic waste
With the Closed Substance Cycle Waste Management Act ("Kreislaufwirtschaftsgesetz KrWG"), Germany is implementing the EU waste framework directive ("Abfallrahmenrichtlinie") into national law. Since January 1, 2015, § 11 (1) KrWG requires waste producers and public waste management authorities to collect bio waste separately. This applies to garden, park and landscaping waste as well as food and kitchen waste. Since then, private households must also be able to dispose of organic waste separately from residual waste and yellow waste bins, preferably through the organic waste bin close to the household. The respective federal state is responsible for monitoring the implementation of the law. Despite this law, the separate collection is not implemented at all or only inadequately in numerous districts and cities. Especially in Mecklenburg-Western Pomerania the implementation is very poor.

Since its implementation in 2005, the bio-bin has only been established on the island of Rügen, in Stralsund and in the former rural district Nordvorpommern[293]. There are no bio-bins in the areas Pasewalk, Tutow, Usedom, Greifswald, Anklam. Reasons are the increasing costs and the low acceptance of the inhabitants in that region. Besides self-composting some parts of the food waste, the waste is quantitatively disposed into the residual waste bin. As a result, only 27 kg bio waste per inhabitant in MV is collected separately. Due to massive differences in the local waste-management it is better to look at the data from all regions in MV: Whereas Vorpommern-Greifswald has no possibility to separately dispose food-waste, in Schwerin and Vorpommern-Rügen the amount of bio-waste per capita per year (79 and 77 kg per capita and year, respectively) is much higher than the average in Germany (59 kg per capita and year) (see Figure 91).

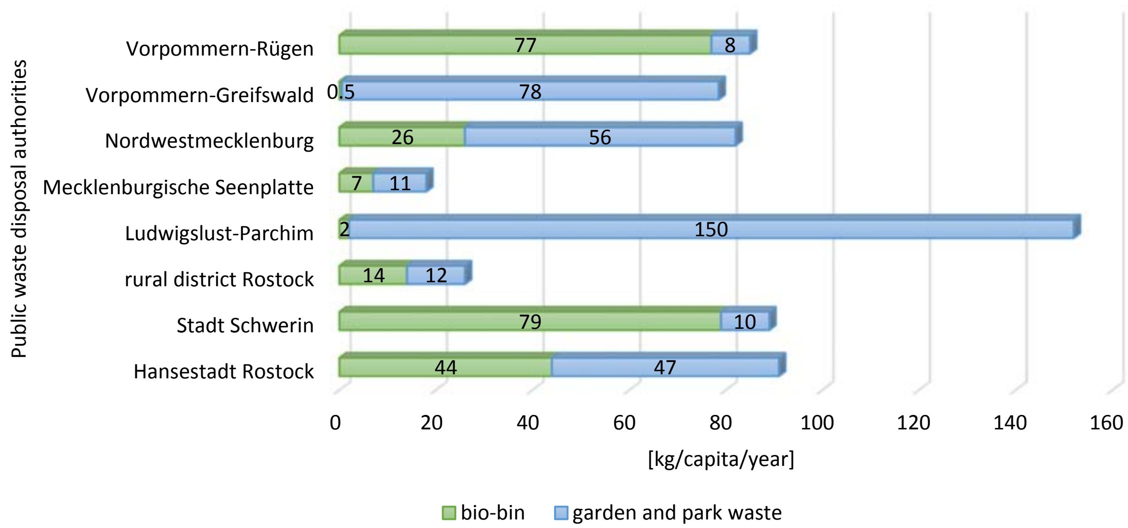

Figure 91. Biowaste in Mecklenburg-Western Pomerania 2016[294]

[293] Ostsee Zeitung, 2015
[294] Daten zur Abfallwirtschaft 2016; Schriftenreihe des Landesamtes für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern 2017, Heft 4

Table 88. Biowaste [kg/capita/a] in Mecklenburg-Western Pomerania 2016[295]

Region	**Total waste [kg/capita/a]**	**Separately collected organic waste from the bio bin [kg/capita/a]**
Mecklenburg-Western Pomerania	435	27
Germany	462	59

27 kg per capita equals to 43,500 tonnes waste from the bio-bins per year in MV. Furthermore, food waste from households in MV is mainly disposed into the residual bin. Similar amounts will be self-composted and a small part is reused for the keeping of small domestic animals (see figure 2).

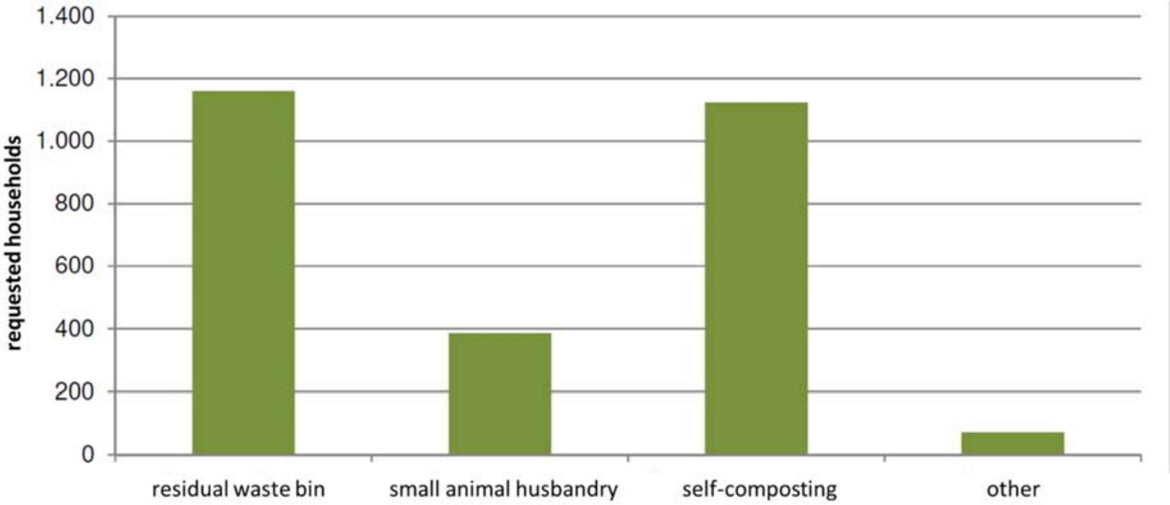

Figure 92. Disposal routes of kitchen waste according to a questionnaire assessment[296]

In comparison of Eastern Germany to overall Germany, a disproportionate amount of food waste is used as animal feed (11.5%; average in Germany is 6.2%). Almost every 8th bin of avoidable food waste is used as animal feed. Obviously, these waste quantities inhabit also food, which in households without animals would possibly still be used by the persons themselves. One reason for that might be that in the East the most recyclable food is thrown away due to shelf life problems. Optically unappetizing or "old" foods are probably used more quickly for animal feed than thrown away[297].

As an example: In Greifswald, urban waste is transferred in containers and afterwards compacted at a local plant. After shipping it in pressed-waste-containers to Stralsund, it is fractionated at a plant, while the bio waste is treated in one of a total of 17 composting plants in MV. In these plants impurities are getting sorted out, the residual waste is composted and at the end given to the farmers.

Commercial kitchen waste is not in the responsibility of the public waste disposal authority, since there is no obligation to offer waste. Accordingly, disposal of this waste via the bio-waste bin is not

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[295] Own table based on: Statistikportal 2017; ; Statistische Ämter des Bundes und der Länder; Umweltökonomische Gesamtrechnungen der Länder (https://www.statistikportal.de/de/ugrdl/ergebnisse/abfall/hha#5735)
[295] Source: Bioabfallstudie MWP, p.76
[296] Source: Bioabfallstudie MWP, p.76
[297] GfK SE, 2017, p. 29

permitted[298]. Commercial kitchen waste is disposed by special waste disposal companies (e.g. “Refood”), who can be commissioned by the kitchens. In contrast to the urban waste, commercial kitchen waste should be collected separately to nearly 100%.

Products along the value chain and utilization today

Food waste that gets into the bio- or the residual bin is composted, fermented or applied to biomass heating plants. In Germany, about 5.05 million tonnes of food waste are released yearly into the municipal waste collection system (70% residual waste and 30% bio-bin). This corresponds to an amount of approx. 62 kg per capita per year. However, this amount corresponds only a part of the food waste disposal chain, as there are other available routes, e.g. home composting, feeding to pets or disposing it into the sewers.

All together, we have 5.8-7.54 million tonnes per year of food waste in Germany. 3.14 million tonnes per year or 38.4 kg/capita/a of food waste is avoidable and 1.2 million tonnes per year or 14.7 kg/capita/a is partially avoidable food waste.

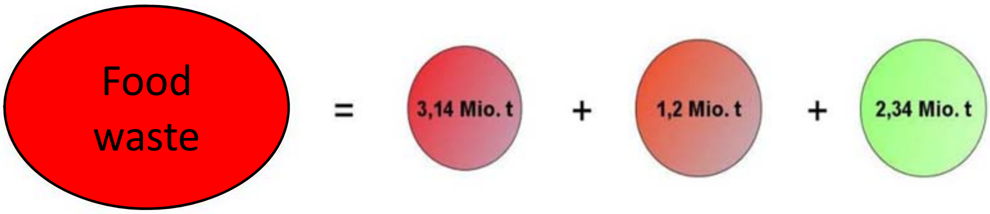

Figure 93. Discarded food waste: Avoidable: 3.14 million t (red colour), partially (facultatively) avoidable: 1.2 million t and unavoidable: 2.34 million t (green colour) food waste[299]

According to the waste balances 2010, 81,916 tonnes bio waste for recycling, which includes bio waste from the organic waste bin as well as garden and park waste from public facilities and private households, was collected separately. This corresponds to a population-specific volume of 50 kilograms per capita per year. Proportionally, the bio waste mass is composed as follows:

- 29,612 tonnes bio waste comes from the bio-bin or the bio-bag (2018: 43,459 tonnes in MV)
- 5,424 tonnes garden and park waste from public facilities
- 46,880 tonnes garden and park waste from private households

Table 89 shows the development of organic waste in Germany and MV.

Table 89. Development of collected organic waste in Germany and MV[300]

Bundesland	2014		2015		2016	
	[1000 t]	[kg/capita/a]	[1000 t]	[kg/capita/a]	[1000 t]	[kg/capita/a]
Germany	9,832	121	9,666	118	10,183	123
Mecklenburg-V.	107.3	67	103.5	64	120.1	75

[298] Bioabfallstudie MWP aktualisiert, page 17
[299] Ermittlung der weggeworfenen Lebensmittelmengen und Vorschläge zur Verminderung der Wegwerfrate bei Lebensmitteln in Deutschland, 2012
[300] Own table based on Statistisches Bundesamt, Fachserie 19, Reihe1, Umwelt, Abfallentsorgung

Typically, the waste from bio bins can be disposed in three different ways. The biological waste recycling is basically subdivided into composting (aerobic) and fermentation (anaerobic). As wood is the main source for thermal processes, these will be neglected for household food waste (see figure 3).

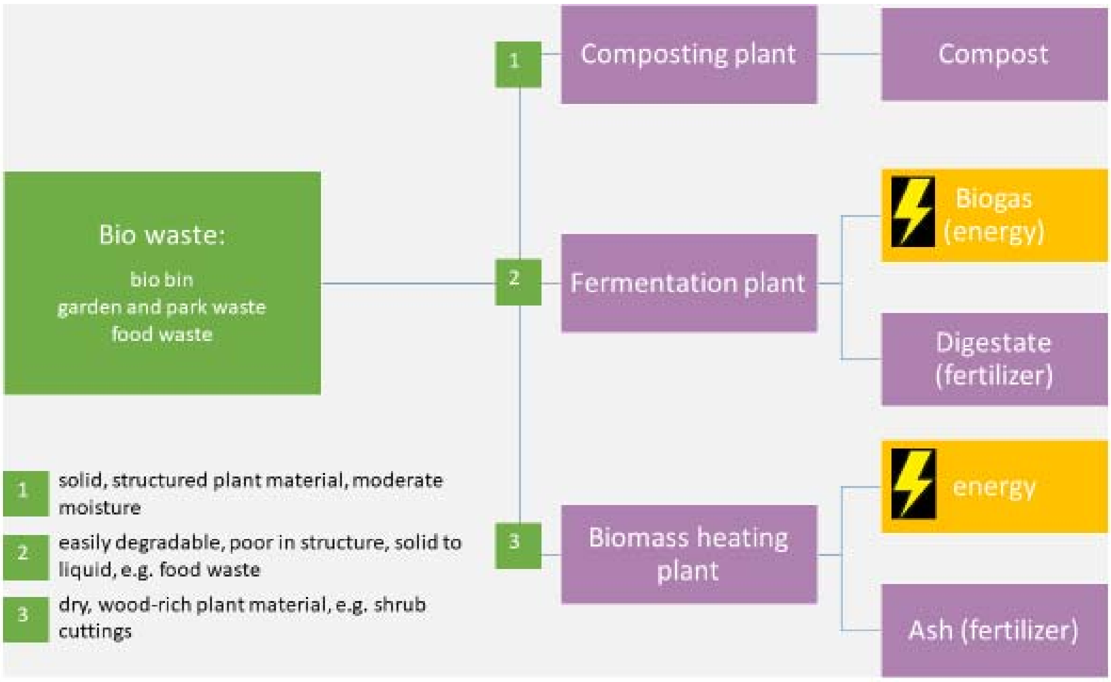

Figure 94. Utilisation of bio-bin waste[301]

Situation in MV

Composting plants

In 2010, 47 composting plants in MV were announced, 41 were active (33 in 2016).[302]
132,159 tonnes of bio waste were treated as input in total in these composting plants in 2010 – the main part came from the own state.

Table 90. Input-/output streams [t/a], average plant size of composting plants in MV in 2010[303]

Total Input	Input	Bio Waste Origin of MV	Output	Total Output	Average Plant
159,907	132,159	102,320	68,722	87,753	10,244

[301] Adapted from: https://www.umweltbundesamt.de/daten/ressourcen-abfall/verwertung-entsorgung-ausgewaehlter-abfallarten/bioabfaelle#textpart-6
[302] LUNG MWP, 2016
[303] Bioabfallstudie MWP, p. 39; own analysis

Fermentation Plants

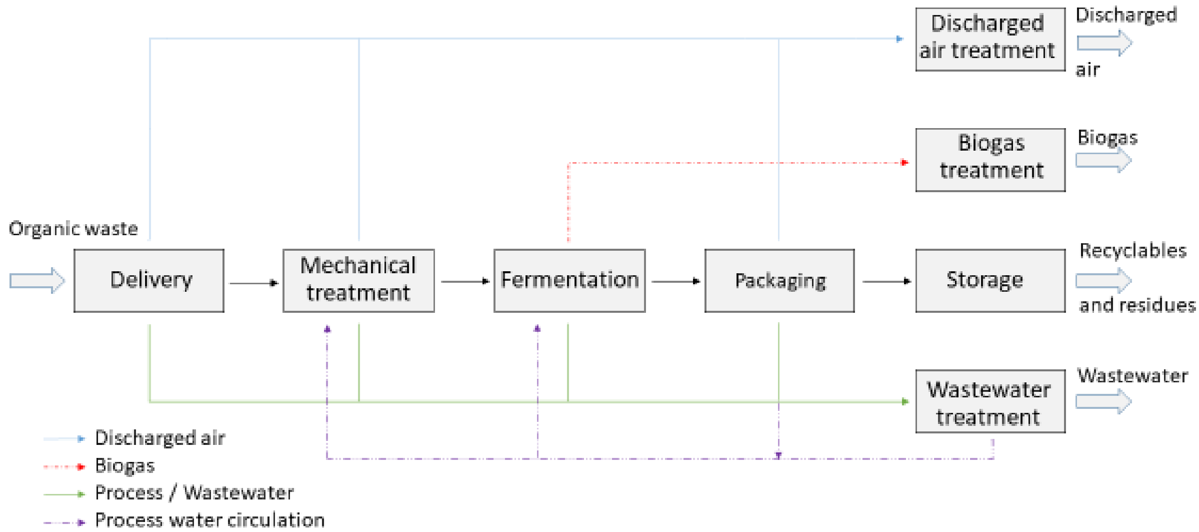

Figure 95. Schematic procedure of fermentation plants for the treatment of bio-and green waste as well as residual waste[304]

In 2010, bio waste was fermented in a total of 10 fermentation plants (8 in 2016), however, no fermentation plant in MV recycled bio waste from bio-bins. It is exclusively industrial bio waste, food waste and other bio waste usually used in combination with manure that gets fermented (see Table 91). As a result, wet fermentation processes take place usually in the mesophilic temperature range. Almost all bio waste fermentation plants are operated as one stage plants.

Table 91. Input-/output streams, average capacity of digestion plants in MV[305]

Total Input	Food and kitchen waste			Total Output	Average Plant
	Input	Origin of MV	Output		
363,526	11,561	9,844	323,041	41,625	363,526
Total Input	**Other organic commercial waste**			**Total Output**	**Average Plant**
	Input	**Origin of MV**	**Output**		
363,526	159,277	83,642	323,041	41,625	363,526

Self-composting

We can relate to some analysis on sorting of domestic waste in special rural districts, which is reported in their waste management concepts. Biogenic residues are predestined for single or multiple recycling routes, depending on their material composition. Possible recycling routes are composting, fermentation, co-digestion and thermal utilization (including combustion and pyrolysis).

However, fermentation residues can be composted afterwards, so both methods are not mutually exclusive, but can build up on each other. In a next step, the digestate can be composted and can positively influence the process as well as the end product.

[304]Adapted from: Anlagen zur Erzeugung von Bioenergie p. 650; Peter Weiland, Klaus Fricke, Christof Heußner, Axel Hüttner, Thomas Turk (https://link.springer.com/content/pdf/10.1007%2F978-3-642-24895-5_8.pdf)

[305] Bioabfallstudie MWP, p. 40; own analysis

Urban waste
The Ostmecklenburgisch-Vorpommersche Verwertungs- und Deponie GmbH is the municipal waste disposal company of the counties Mecklenburgische Seenplatte, Vorpommern-Greifswald and Vorpommern-Rügen, located in Rosenow near Brandenburg. The storage site has a capacity of 2 million m³ for untreated waste and 2 million m³ for pre-treated waste. Since 01.06.2005 the deposit of untreated waste in Germany is no longer allowed. Therefore, a mechanical-biological waste treatment plant was built on the site of the waste disposal site Rosenow in 2004/2005. Additionally to Rosenow, locations in Stralsund, Demmin, Neustrelitz, Jatznick and Stern fulfill a similar function.
The waste treatment as well as the waste management plant guarantees the environmentally sound and economical disposal of residual waste for 750,000 inhabitants on an area of 12,580 km^2 in Mecklenburg-Western Pomerania.

Table 92. Waste disposal site Rosenow[306]

Total area of the disposal Rosenow	244 ha
from that disposal and operating area	92 ha
from that compensation areas for nature conservation	152 ha
Total term	25-30 Years
Total volume	2 Mio t/a
Storage	160,000 t/a
Number of employees	48

Industrial food waste
In Germany, manufacturers are legally obligated to separate certain waste segments by the "Trade, Commerce and Industry Regulation Act". For industrial food waste, there are about 200-300 companies that take over the disposal of the gastronomy and food industry (restaurants, retailer, hotels). One of the bigger waste management companies is "ReFood", which has 1,000 employees, more than 450 vehicles and 18 branch offices. The company processes food and food residues, frying fats, vegetable edible fats and fat separator contents. ReFood exchanges the food waste containers as required in a flexible disposal cycle and recycles the organic residues to environmentally friendly energy (see Figure 96) in whole Germany.

ReFood operates two locations in MV:
Malchin, its catchment area is MV up to the axis Wismar – Schwerin, parts of Sachsen-Anhalt and Brandenburg. Kogel-Ludwigslust, which covers the remaining part of western MV, Schleswig-Holstein and the city of Hamburg

The head office is in Selm. Because of active competition between the existing disposal companies, data is all in-house and will not be released. Beneath the qualitative processing of the food waste there is no possibility of calculating the amount of food waste in MV.

[306] Own table based on OVVD https://www.ovvd.de/unternehmen/ovvd/aufgaben

On the basis of these findings, we can assume the following value chain:

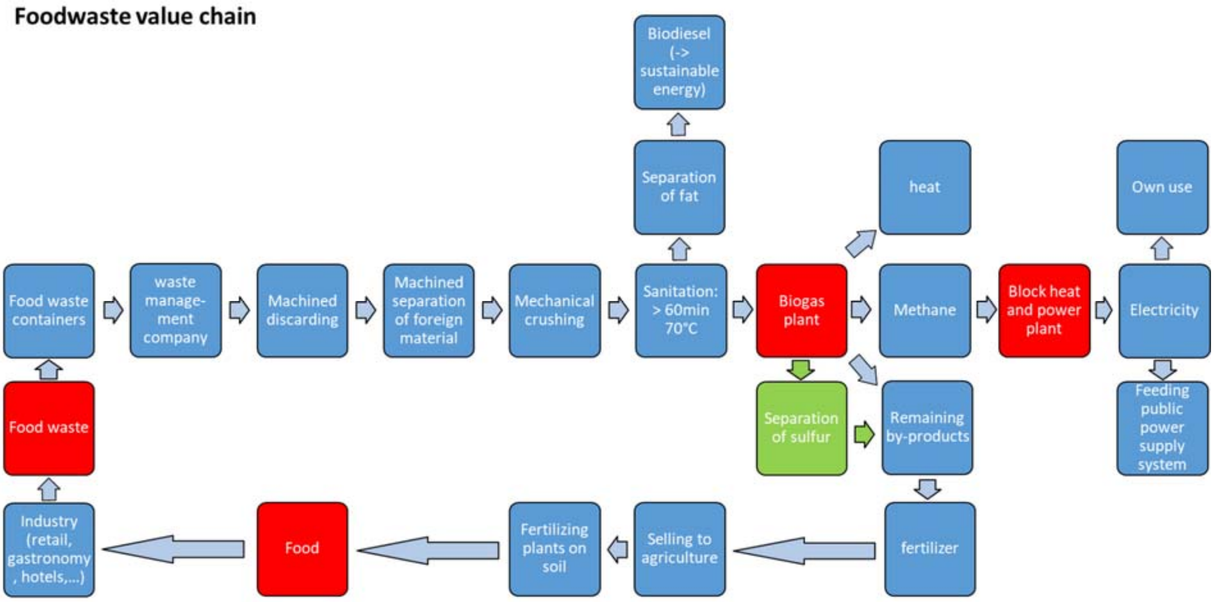

Figure 96. Foodwaste value chain[307]

Quantification of feedstock, products and residues

In Germany, the amount of food waste includes between 11 million t (Kranert et al., 2012) and 18 Million t (Noleppa and Cartsburg 2015) yearly from agriculture, industry, commerce, major consumers and private households. The food industry and major consumers, such as restaurants and canteens, each account for 17 percent of food waste (1.9 million tonnes), about five percent derives from trade (550,000 tonnes). In Germany actual statistical data comes from “Statistische Ämter der Länder”, “Statistisches Bundesamt D Stasis” and „Abfallwirtschaftsplan 2015“. Unfortunately, at best, the data show household food waste and organic waste, but not the part of the food waste in it.

Only limited recent literature concerning the composition of food waste in MV is available[308]. So, the following data are mainly from 2010 (Bioabfallstudie MV aktualisiert) and, if possible, supplemented with more actual data.

[307] ReFood, own layout
[308] Statistisches Amt MV, Abfallentsorgung MV 2014

Food and kitchen waste from households

For a rough calculation of the amount of food waste in household waste and the bio-bin, we can use the following data for MV:

Table 93. Waste potentials as fractions of food, kitchen and garden waste in residual and bio waste in MV[309]

Type of waste	Proportion						Total		
	Garden waste			Food and kitchen waste					
	[%]	[t]	[kg/person/a	[%]	[t]	[kg/person/a	[%]	[t]	[kg/person/a
Non-recyclabl	7.4	23,085	14	34.3	107,000	65	41.7	130,085	79
Bio-	62.	18,50	11	4.6	1,368	1	67.	19,875	12

The evaluation of residual waste sorting shows that there are still around 41.7% of bio waste potentials included. Related to the amount of household waste in MV from 2010 (311,954 tonnes) this gives a mass of approx. 130,000 tonnes of biogenic substances in residual waste. That corresponds to a specific amount of 79.0 kg per capita and year. The percentage by weight of food and kitchen waste (based on 34.3%) is 107,000 tonnes. This means that on average, each inhabitant in MV annually throw away 65 kg of food[310]. In 2015, the amount of organic waste was 64 kg capita and year.[311]

Concerning the composition of the bio-bin, data from autumn 2010 show a variation of 2.2-10.9%[312] of food waste and data from 2009 show a fraction of 3-4%[313], respectively. Assuming an average of 4.62%, a total of 1,368 tonnes food waste gets thrown into the bio-bin (see Table 93)[314].

In 2016, 335,571 tonnes of urban waste was collected in MV. Presuming the same part of food waste than in 2010, this would mean a total amount of 106,466 tonnes food waste in the urban waste.

In 2010, a total of 41,940 tonnes separately collected organic waste, which contained food and kitchen waste from households, was treated in composting plants[315]. In 2016, 120,145 tonnes organic waste in MV were treated, 56,686 tonnes gardening and park waste + 43,459 (36%) from the bio bin[316]. 18,115 tonnes was from the own state, 14,024 tonnes from foreign federal states. For the remaining mass of 9,801 tonnes, the area of origin could not be determined due to missing information in the operator reports.

Composition of avoidable food waste

The composition of food waste in MV is not known. We have data from a survey from 2011, where 200 private households in Germany were asked about the composition of their food waste[317].

[309] Bioabfallstudie MWP, p.67
[310] Bioabfallstudie MWP, p. 69
[311] Statistische Ämter der Länder – Abfallwirtschaft, UGRdL , 2017
[312] Höfs, 2011
[313] Kern et. al, 2009
[314] Bioabfallstudie MWP, p. 65
[315] LUNG MWP, Daten zur Abfallwirtschft 2016
[316] Abfallentsorgung 2016; Table 23.2.2
[317] TheConsumerView GmbH, 2011

A new survey on food waste in households in Germany shows that fresh fruit and vegetables are equally classified as the most discarded foods, at around 17% each (see Figure 97)[318]. The second place is taken by cooked/prepared products with 16%, followed by bread and bakery products with around 14%, beverages with almost 11%, dairy products with more than 9%, prepared, frozen products/preserves of meat and vegetables with around 7%, others with just over 5% and fresh meat, sausages and fresh fish with around 4%.

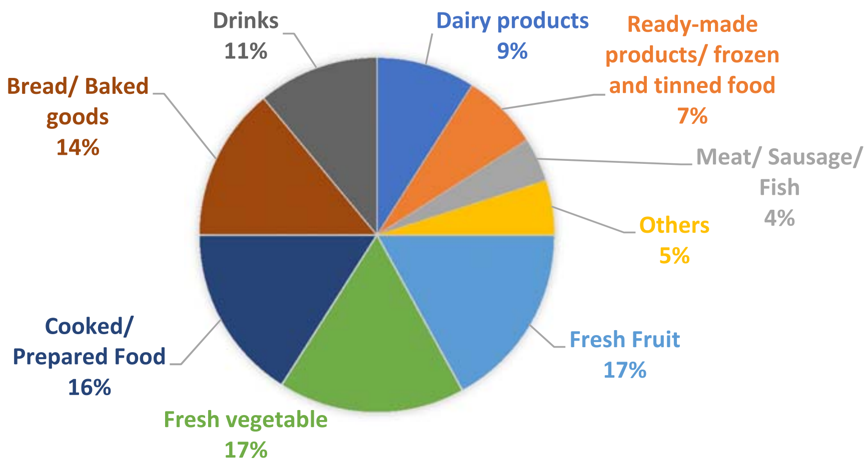

Figure 97. Composition of avoidable food waste by product group[319]

Assuming that this composition of food waste is representative also for MV, we can assume the following amount of food waste in our region in 2016:

Table 94. Calculation of the composition of food waste in MV[320]

Component	2011*		2017**	
	[%]	[t]	[%]	[t]
Fruits	48	51,104	17	18,099
Vegetables			17	18,099
Self-prepared meals and convenience food	15	15,969	16	17,035
Pastries	14	14,904	14	14,905
Drinks			11	11,711
Meat and fish	11	11,711	4	4,259
Milk products	11	11,711	9	9,582
Ready-made products, frozen and tinned food			7	7,453
Other			5	5,323
Food waste in total	100	106,466	100	106,466

There are different possibilities to dispose the food waste. In Germany, one third is disposed in the bio-bin and the residual waste, followed by the waste water channel with a share of 14%, the own compost with 9% and the use as animal feed with 6%. Approximately 3 % is allocated to other

[318] Schmidt et al., 2018
[319] Own presentation with data of the BMEL, 2017
[320] http://huehn.org/taste_the_waste/daten/15-09-2011/results_save_food_study_germany.pdf
Schmidt_Schneider_Claupein_LebensmittelablleinprivatenHaushalteninDeutschland_2018_04

disposal channels. The disposal channels are chosen by households according to the product groups. Bio-bins and compost are primarily used for the disposal of fresh fruit and vegetables. A large proportion of liquid food and dairy products is disposed in the toilet or drain. Above all, bread and bakery products as well as cooked/prepared food is used as animal feed. Comparatively similar amounts of almost all product groups are disposed in the residual waste.[321]

Kern et al. (2010) calculated that only 40% of the food waste can be disposed into the bio bin. Therefore, the theoretical bio-bin potential is 81,708 tonnes.

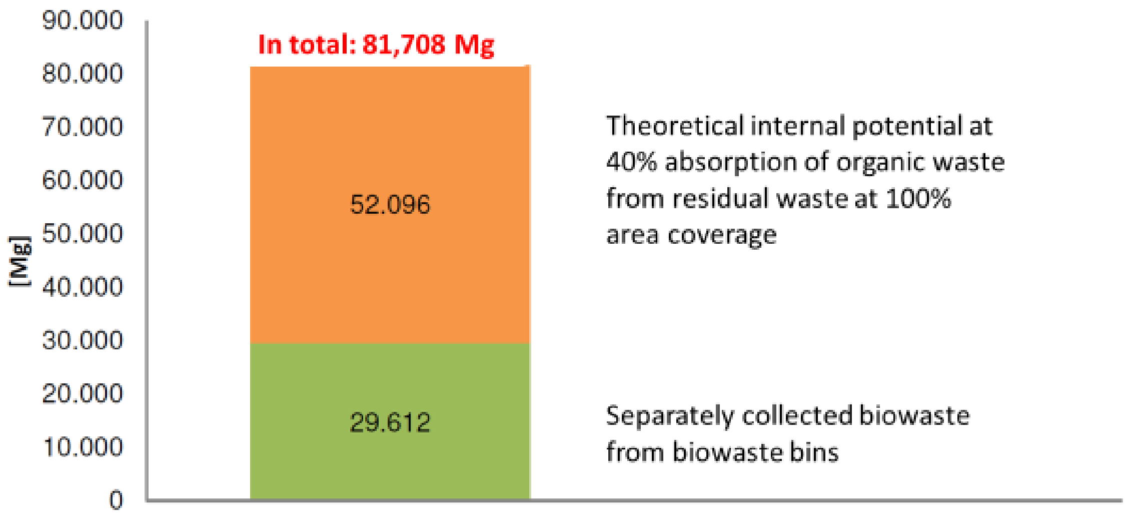

Figure 98. Overview available and theoretically available bio waste container potential[322]

Furthermore, according to the city of Rostock, a 25% reduction of the biogenic content in the residual waste could be achieved by providing bio-bins and containers for garden waste.

Table 95. Food waste removal in Mecklenburg-Western Pomerania[323]

	Total waste volume	Waste facility							Recovery rate	Recycling rate
		Disposal operations				Recovery operations				
		Total	Deposit	Thermical removal	Treatment to disposal	Total	Energetic recovery	material recovery		
	[1000 t]								[%]	
waste collection	14,147	3,859	-	3,068	791	10,288	7,845	2,443	73	17
Street-sweeping/ Garden waste/ Park waste	986	215	99	42	83	779	53	717	78	73

A large proportion of bio waste from composting and fermentation plants will be utilized in the agricultural sector, in gardening and landscaping as well as in the private sector on soils. Composts are characterized by soil structure improving components (organic substance) with comparatively low nutrient contents. The portion of each nutrient vary depending on the starting

[321] Schmidt et al., 2018
[322] Bioabfallstudie MWP
[323] https://www.destatis.de/DE/Publikationen/StatistischesJahrbuch/Umwelt.pdf?__blob=publicationFile, S. 13

material. In Mecklenburg-Western Pomerania in 2013, bio waste from 37 composting plants was recycled.[324]
The recycling routes of the bio waste compost produced in the country will be evaluated on the basis of the statistical data of plant operators. Accordingly, an essential part of the in MV generated compost is used in the small consumer sector and landscaping. In addition, non-deductible amounts are used in agriculture and forestry (including horticulture) (see figure 7). There is no further subdivision in the statistical data collection. In this respect, the significance of the amount of compost in terms of quantities applied in Mecklenburg-Western Pomerania on the soil is severely restricted. In recent years, released compost quantities had a decreasing trend. In 2012, about 67,000 tonnes of compost were recycled.

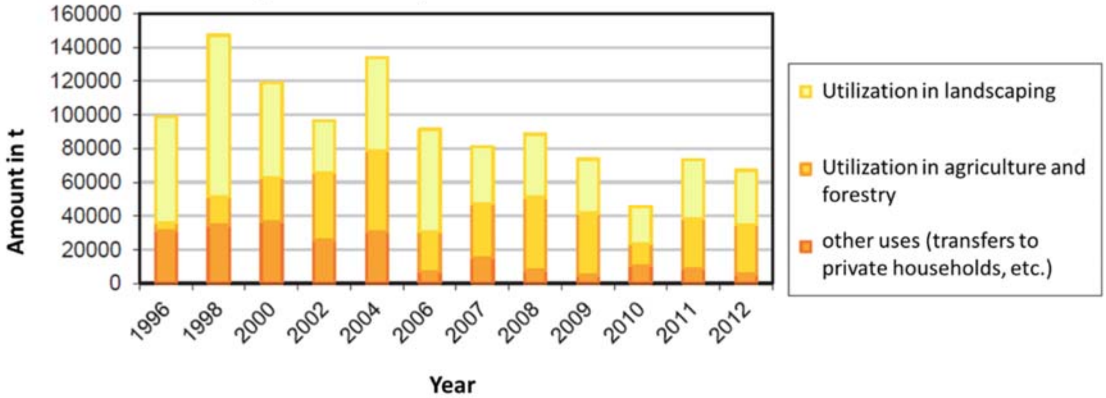

Figure 99. Ways of utilization of composts from compost plants in MV[325]

With the increase in biogas plants operated in Mecklenburg-Western Pomerania, the amount of fermentation residues increases. At the beginning of 2014, 251 biogas plants were operated in MV (according to the 4th BImSchV). In these Biogas plants, mainly animal farm fertilizers (manure, solid manure, poultry feces) and renewable raw materials of agricultural land (cereals, grass, maize) are processed. In 2014, eight biogas plants that use bio waste were located in MV.
Information on the quantities of biogas plants, which process bio waste and animal by-products, were registered within the scope of the reporting obligations under the biological waste ordinance ("Bioabfallverordnung") by the State Offices of Agriculture and Environment and the competent agricultural Authority (LFB).
According to operator information from 2012, around 339,000 t of fermentation residues have been completely disposed of for utilization in agriculture in these biogas plants in MV.[326]

Food and kitchen waste from commerce
In 2015, 928,000 tonnes kitchen- and canteen-waste and 60,000 tonnes market waste for consumption or processing of unsuitable substances (including superimposed foods) was generated in Germany[327].

In MV, the mass of input from food and kitchen waste from industry in 2010 was in total 12,171 tonnes. 10,352 tonnes were from the own state, 1.716 tonnes came from foreign federal states. 103

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[324] LUNG, 2013
[325] Bodenschutzprogramm MWP Teil 2 – Bewertung und Ziele; January 2017
[326] LUNG, 2015
[327] https://www.destatis.de/DE/Publikationen/StatistischesJahrbuch/Umwelt.pdf?__blob=publicationFile, S. 13

tonnes were with no indications of source. Furthermore, organic waste accumulates in commerce, which also contributes to bio waste and partly contains food waste. The advent of this treated other organic commercial waste / commercial bio waste (“sonstiger organischer Gewerbeabfall/gewerblicher Bioabfall”) in 2010 was in total 165,463 tonnes. Of these, 89.338 tonnes came from their own and 76.325 tonnes from other sources outside the federal state.

Slaughterhouse waste
In MV, 40 slaughterhouses with the following amounts of slaughtering can be found:

Table 96. Commercial slaughterings and meat production in MV[328]

slaughtered animals [1,000]						amount of slaughter [1,000 t]					
total	cattle	calves	pigs	sheep	horses	**total**	cattle	calves	pigs	sheep	horses
489	129	7	341	12	0	**70**	37	1	32	0	0

In 2016, 489,000 animals (cattle, calves, pigs, sheep and goats) with a total weight of 70,000 tonnes were slaughtered commercially in MV. Home slaughtering of 7.031 animals with 730 tonnes[329] takes only a minor part of the total amount (70,706 tonnes)[330]. For whole Germany, from 64,254 million animals nearly all were accepted for slaughtering. 187,817 animals (0.3 %) were later selected out as not wholesome food[331]. Furthermore, 93,766 tonnes slaughtered poultry was produced in 2010 (no updated data available) in slaughterhouses with a monthly capacity of at least 2,000 animals[332]. Altogether, 164,213 tonnes of animals were slaughtered in 2016 (data on poultry: 2010).
There are no data about the amount of slaughtered animals (neither amount nor weight) which could be used for food. General calculations about animal by-products (animal residues which are not suitable for human consumption bristles, fats, bones, offal, stomach and intestinal contents and much more), can be calculated depending on the type of animal.

Table 97. Animal by-products in MV in 2016 (own calculation from data of the cited literature)

	Total	Cattle	Pigs	Poultry
Slaughtered animals [t]	164,213	37,743	32,704	93,766
Waste [%]	30	34	42	25
Waste [t]	50,010	12,833	13,736	23,442

Subtractions of the waste from the total amount of slaughtered animals results in 114,203 tonnes of meat which was produced in 2016 in MV in slaughterhouses.

For other industrial food waste we can get no information from the waste producers. Two main reasons can be given: First, the companies are underlying a stringent data protection law and

[328] Statistisches Bundesamt, Statistisches Jahrbuch 2017, page 502
[329] StatA MWP, Statistisches Jahrbuch 2017, page 485
[330] StatA MWP, Statistischer Bericht C303 2016 00, page 7
[331] Calculation from https://www.destatis.de/DE/Publikationen/StatistischesJahrbuch/StatistischesJahrbuch 2017.pdf?__blob=publicationFile, page 503
[332] StatA MWP, Statistischer Bericht C303 2016 00, page 8

secondly all industrial fields are underlying a massive trade rivalry. Making their data transparent will reduce their competitiveness.

Mass balance

Unfortunately, there is no specific data available for MV. Instead, figure 8 shows a Sankey diagram of food and food waste streams determined from statistical surveys.

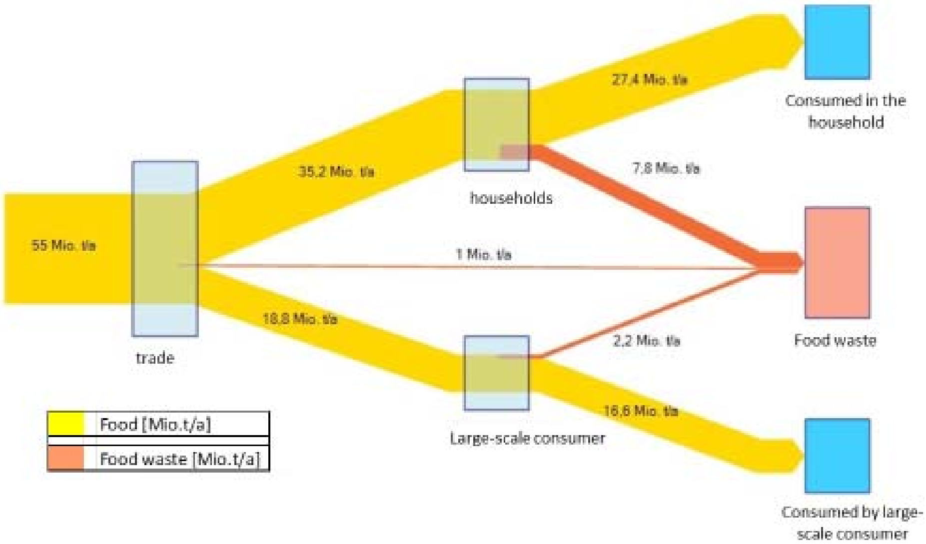

Figure 100. Sankey-diagram from food- and food-waste-streams[333]

[333] https://www.zugutfuerdietonne.de/fileadmin/_migrated/content_uploads/Studie_Langfassung_01.pdf, page 225

2.4.3 Regional resources in Poland

Assessed by Dariusz Mikielewicz, Rafał Andrzejczyk, Paweł Dąbrowski and Jan Wajs, Gdańsk University of Technology, Poland

Information presented below is primarily coming from the statistical office data, as well as regional authorities. Due to the decentralised occurrence of industrial food residues, collecting data on residual materials streams is a time-consuming work that unfortunately is further impeded by the reluctance of many companies to share information on their residues. The report is a thorough inventory of residues from the main food industries. In this assessment, we included residues from the following industries:

- Flour mills and bakeries
- Fruit and vegetable processing
- Dairies
- Slaughterhouses and meat processing factories
- Fishing industry and other aquatic biomass
- Breweries
- Ethanol industry
- Household food residues
- Manure

Flour mills and bakeries

There are six flour mills in Pomeranian Region:

- Pomorskie Młyny Tadeusz Rybak, 83-020 Cedry Wielkie; Mickiewicza 8, 83-020 Cedry Wielkie
- Gdańskie Młyny sp. z o.o., ul. Na Ostrowiu 1, 80-873 Gdańsk, woj. Pomorskie
- "Gardejski Młyn" PPUH Leszek Zaremba, ul. Młyńska 22, 82-520 Gardeja, woj. Pomorskie
- Nagórski Władysław Młyn Usługowo-Handlowy, ul. Kleszczewska 15, 83-250 Skarszewy, woj. Pomorskie
- Starba Andrzej Mańczak Adam Sp.j. Młyn Gospodarczy, ul. Wojska Polskiego 42, 83-000 Pruszcz Gdański, woj. Pomorskie
- Suchowiecki Eugeniusz Młyn, ul. Młynarska 6, 77-310 Debrzno, woj. pomorskie

First two mills produce cereal-based flour for industrial food production and end-consumer use, while the remaining ones are the small local mills producing the flour in response to the market requirements. Crop production in three considered regions in 2016 is presented in Table 98.

Table 98. Cultivated area [ha] for different crop products in Polish South Baltic Area in 2016

	West Pomeranian region[334]	Pomeranian region[335]	Warmia and Mazury region[336]
Total wheat	164,111	598,626	150,888
Rye	51,966	51,386	27,031
Total barley	46,280	32,837	32,131
Oats	21,122	24,634	19,010
Triticale	69,724	77,878	85,995
Cereal mixed	7,099	34,994	37,150
Potatoes	11,661	17,693	9,355
Sugar beets	9,448	9,211	2,060
Feed	43,073	52,021	102,816
Oilseeds	115,699	79,345	77,735
Vegetables	2,873	7,335	3,052
Tree fruit	11,044	2,857	4,346
Fruit bushes and berry fruit	6,007	2,861	4,773
Total cultivated area	**560,107**	**991,678**	**556,342**

In Pomeranian Region there are over 300 small to medium size bakeries. It is not allowed by law to utilize the unsold bread returned from the stores and rejected bread, biscuits and dough from the bakery for any purposes such as yeast production. Such waste can for example be utilised in ethanol production factories, such as Mełno. Waste produced by bakeries in Poland in years 2016-2017 amounts to 2,741 tonnes per year[337]

Table 99. Sown area [ha] in Pomeranian Region[335]

Crops	2005	2010	2015	2016
Cereals	414,407	405,421	392,104	388,227
Basic cereals	347,175	342,216	340,470	332,252
Wheat	132,758	135,647	153,735	151,765
Rye	73,089	56,183	51,386	48,824
Barley	50,900	43,324	32,837	48,945
Oats	31,113	36,620	24,634	28,076
Triticale	59,315	70,444	77,878	54,642
Mixed cereals	53,981	49,575	34,994	38,922
Buckwheat, millet and other cereals	7,285	9,587	8,303	10,285
Maize for grain	5,966	4,042	8,336	6,768

[334] Statistical Yearbook Zachodniopomorskie Voivodship 2016, Statistical office in Szczecin
[335] Statistical Yearbook Pomorskie Voivodship 2016, Statistical office in Gdańsk
[336] Statistical Yearbook Warminsko-Mazurskie Voivodship 2016, Statistical office in Olsztyn
[337] https://mojetesco.pl/spolecznosci/walka-marnowaniem-zywnosci/dane-dotyczace-marnowania-zywnosci-polsce/

Table 100. Crop products [t] in Pomeranian Region[338]

Crops	2005	2010	2015	2016
Cereals	1,411,222	1,489,560	1,651,593	1,530,651
Basic cereals	1,240,452	1,318,493	1,495,053	1,353,785
Wheat	607,295	645,667	850,744	745,041
Rye	157,065	162,320	158,452	144,953
Barley	172,135	158,609	120,702	179,072
Oats	83,724	103,687	74,718	89,499
Triticale	220,233	248,211	290,437	195,220
Mixed cereals	144,017	145,603	104,752	120,152

Table 101. Sown area [ha] in West Pomeranian Region[339]

Crops	2005	2010	2015	2016
Cereals	522,776	425,226	381,565	400,046
Basic cereals	473,741	394,119	353,203	372,108
Wheat	203,705	166,762	164,111	166,352
Rye	88,895	69,403	51,966	61,122
Barley	83,110	60,471	46,280	57,720
Oats	39,405	39,469	21,122	24,981
Triticale	58,626	58,014	69,724	61,933
Mixed cereals	32,645	14,678	7,099	6,976
Buckwheat, millet and other cereals	8,007	11,665	12,863	13,873
Maize for grain	8,382	4,765	8,399	7,089

Table 102. Crop production [t] in West Pomeranian Region[339]

Crops	2005	2010	2015	2016
Cereals	1,755,090	1,861,031	1,817,660	1,718,925
Basic cereals	1,650,683	1,771,728	1,735,066	1,630,462
Wheat	805,343	90,8210	943,030	805,530
Rye	258,067	233,487	211,275	221,457
Barley	274,148	257,661	210,713	238,561
Oats	123,484	133,714	71,012	90,737
Triticale	189,640	238,657	299,035	274,177
Mixed cereals	64,775	48,528	23,621	22,728

[338] Statistical Yearbook of the Pomorskie Voivodeship 2017 – Statisticial Office in Gdańsk
[339] Statistical Yearbook of the Zachodnio-pomorskie Voivodeship 2017 – Statisticial Office in Szczecin

Table 103. Sown area [ha] in Warmia and Mazury Region[340]

Crops	2005	2010	2015	2016
Cereals	443,814	429,017	369,639	407,872
Basic cereals	335,596	347,394	315,055	345,625
Wheat	136,232	143,663	150,888	157,726
Rye	33,341	39,578	27,031	34,190
Barley	53,855	44,732	32,131	48,897
Oats	23,673	29,916	19,010	24,716
Triticale	88,495	89,504	85,995	80,096
Mixed cereals	95,702	64,285	37,150	42,285
Buckwheat, millet and other cereals	6,033	8,369	5,011	8,915
Maize for grain	6,485	8,969	12,422	11,047

Table 104. Production [tonnes] in Warmia and Mazury Region[340]

Crops	2005	2010	2015	2016
Cereals	1,497,058	1,760,218	1,461,328	1,521,121
Basic cereals	1,237,651	1,448,023	1,293,839	1,312,251
Wheat	571,765.5	703,792.4	741,110.7	664,059.6
Rye	121,668.8	137,744.4	79,201.9	95,269.1
Barley	164,861.8	200,571.8	100,919.5	161,270.8
Oats	70,614.5	78,323.1	52,241	75,430.4
Triticale	308,740.2	327,591.3	320,365.7	316,221.2
Mixed cereals	221,624	268,591.1	103,754.8	129,533.7

Table 105. Production [1000 t] of major food industry products in Poland[341]

Specification	2005	2010	2013	2015	2016
Wheat flour	2,487.9	2,230.2	2,229.6	2,297.3	2,367.7
Rye flour	244.6	200.9	220.6	244.6	250.2
Fresh bread	1,548.7	1,669.9	1,689.2	1,587.8	1,589.4
Baker's yeast	74.2	79.1	85.4	73.5	71.3

According to the survey carried out by bakery industry it was estimated that the turnover of fresh bakery producers was about 10.6 billion PLN (1€=4PLN) in 2010. In that the following share is seen:

- Micro companies (1-9 people): 4.0 billion PLN
- Small companies (10-49 people): 5.2 billion PLN
- Medium companies (50-249 people): 2.8 billion PLN
- Large companies (more than 249 people): 0.8 billion PLN

The whole production of bread and rolls in Poland is about 4 million tonnes (2010) and a little more than a half of the above quantity is produced by micro bakeries employing less than 9 people (2.3 million tonnes). That shows the structure of bread production in the region. Average monthly per capita consumption of bread, cakes and cookies in kg in households is presented in Table 106.

[340] Statistical Yearbook of the Warmińsko-Mazurskie Voivodeship 2017 – Statisticial Office in Olsztyn
[341] Statistical yearbook of agriculture 2017 - Central Statistical Office - Warsaw

Table 106. Average monthly per capita consumption of bread, cakes and cookies in kg in households in Poland[342]

Products	2005	2006	2007	2008	2009
Mixed bread	4.58	4.24	3.97	3.81	3.65
Wheat bread	1.05	1.05	1.04	1.01	0.96
Rye bread	0.27	0.27	0.28	0.25	0.24
Bread (total)	5.90	5.56	5.29	5.07	4.85
Cakes and cookies	0.59	0.62	0.62	0.65	0.65

Today the consumption of bread and rolls in households is equal to 166 g per day per capita (60 kg per year, per person). The bread consumption shows a decreasing tendency in households (from 2003: 2 kg of bread less every year per person). According to calculations the real consumption of bread and rolls in Poland is equal to 230 g per day and by person (80 kg per year, per person)[343]

Fruit and vegetable processing

Poland is one of the biggest producers of fruit and vegetables in the European Union. Poland accounts for 11% of the EU fruit production and for 9% of the EU vegetables production. In terms of agricultural area devoted to fruit and vegetables production Poland ranks third in the EU, only after Spain and Italy. Growing area in Poland stands for 10% of EU fruit area and for 11% of EU vegetables area. Polish production ranks first as regards soft fruit, apples, mushrooms, onions, cabbage and carrots. Poland is also a leader regarding the production of many processed fruit and vegetables (mainly apple juice, frozen soft fruit and frozen vegetables) and one of the leaders as far as exports of fresh and processed fruit and vegetables are concerned.[344]

The fruit production has significantly increased during the last decade (Table 107). This concerns especially the biggest export hit, namely apples and soft fruit. It is worth recalling in this context that Poland is the leading world exporter of apple juice concentrate. Considerable increase has been also observed in indoor cultivations of tomatoes and mushrooms (in contrast to outdoor cultivations for which the total production decreased between 2003 and 2015, see Table 107).

[342] Statistical yearbook of agriculture 2017 - Central Statistical Office - Warsaw

[343] Henryk Piesiewicz, Andrzej Szydłowski, Status and development opportunities of the bread baking branch in Poland, UIB – Congress, 12-16, September 2010, POZNAŃ, POLAND

[344] Jan Fałkowski and Aleksandra Chlebicka (2018), *Fruit and vegetables producer organisations – some insights on their functioning based on data from Poland*, European Commission, Joint Research Centre, doi:10.2760/758545

Table 107. Production of fruit and vegetables in Poland in 2003-2015 [1000 t] [345]

Sector	2003	2005	2007	2009	2011	2013	2015	2015/2003
Total fruit	3,304	2,992	1,694	3,646	3,415	4,128	4,099	1.24
Fruit form trees	2,877	2,425	1,267	3,103	2,887	3,526	3,581	1.24
Apples	2,428	2,075	1,040	2,626	2,493	3,085	3,168	1.3
Soft fruits	431	497	427	543	528	603	518	1.2
Total vegetables	5,091	5,458	5,709	5,601	5,575	4,986	4,795	0.94
Ground vegetables	4,420	4,785	4,987	4,810	4,803	4,004	3,792	0.85
Cabbage	1,237	1,320	1,325	1,276	1,231	975	874	0.7
Carrot	835	929	938	913	887	743	677	0.81
Onion	678	714	753	708	677	551	548	0.81
Glass-house vegetables	671	673	722	791	772	982	1,002	1.49
Mushrooms	165	190	205	220	260	295	315	1.9

Table 108. Production of major food products[345]

Specification	2005	2010	2013	2015	2016
Fruit and vegetable juices [1000 hl]	8601.1	7342.1	8058.5	9451.7	9707.9
Frozen vegetables [1000 t]	436.2	528.6	636.4	610.4	706.3
Canned vegetables [1000 t]	148.0	260.2	236.3	305.2	286.2
Jams from fruit, excluding citrus [1000 t]	80.8	55.5	55.5	47.4	42.7

At the end of 2015, 305 entities grouping fruit and vegetables growers were registered in Poland. Among those there were 195 producer organisations (64% of all the entities) and 110 (36% of all entities) producer groups. Producer groups (PGs) are legal bodies formed by farmers who wish to acquire the status of recognised producer organisations (POs). The number of producer organisations (groups) has been constantly growing over the last decade and this was visible especially between 2009 and 2012 when 60% of the currently registered entities were formed. Over time some organisations (groups) stopped their activity. In total, in the period 2004-2015, this happened to 35 groups and organisations from fruit and vegetables sector.

Generally speaking the production of potatoes, sugar beets and rape and turnip rape shows an increasing trend since 2010, whereas the production of all vegetables shows a negative trend in all considered regions. Significant increase can be noticed in fruit production.

Table 109. Production [t] of major vegetables in Pomeranian Region[346]

Crops	2005	2010	2015	2016
Potatoes	597,152	513,452	460,573	579,274
Sugar beets	484,086	508,105	522,738	689,180
Rape and turnip rape	159,514	167,475	225,157	183,306
Meadow hay	372,402	416,443	512,024	479,623

[345] Statistical yearbook of agriculture 2016 - Central Statistical Office - Warsaw
[346] Statistical Yearbook Pomorskie Voivodship 2017, Statistical office in Gdańsk

Table 110. Production [t] of major vegetables in Pomeranian Region[347]

Crops	2006-2010	2010	2015	2016
T O T A L	163,729	142,896	112,225	119,631
Cabbages	37,643	32,414	22,233	24,279
Cauliflowers	7,375	2,768	2,405	2,429
Onions	7,599	5,131	4,304	4,933
Carrots	43,511	35,610	28,455	28,744
Beetroots	13,626	8,830	5,593	6,024
Cucumbers	8,004	6,983	4,608	5,619
Tomatoes	1,300	990	735	776
Others	44,671	50,170	43,892	46,827
T O T A L	17,126	13,047	19,535	22,744
Apples	14,143	11,186	17,731	20,641
Pears	1,011	670	436	533
Plums	990	606	490	552
Cherries	748	408	545	643
Sweet	196	144	254	303
Others	38	33	79	72

Table 111. Production [t] of major vegetables in Warmia and Mazury Region[348]

Crops	2006-2010	2010	2015	2016
Sugar beets	176,105.0	175,167.0	117,007.5	166,157.5
Rape and turnip rape	146,475.9	143,830.1	194,054.8	128,987.0
Meadow hay	809,135.2	1,082,592.8	1,144,831.3	1,168,447.3

[347] Statistical Yearbook Pomorskie Voivodship 2017, Statistical office in Gdańsk
[348] Statistical Yearbook Warminsko-Mazurskie Voivodship 2017, Statistical office in Olsztyn

Table 112. Production [t] of major vegetables in Warmia and Mazury Region[349]

Crops	2006-2010	2010	2015	2016
T O T A L	87,403.4	80,056.4	53,273.5	68,914.6
Cabbages	26,491.1	25,821.4	16,413.2	18,364.3
Cauliflowers	4,095.8	3,158.9	1,805.8	2,575.9
Onions	2,469.4	1647.8	670.0	668.0
Carrots	35,826.0	31,664.0	16,800.2	27,683.0
Beetroots	3,049.8	3,673.0	1,520.7	1,516.2
Cucumbers	2,638.6	2,810.2	1,626.5	1,842.4
Tomatoes	858.4	929.1	241.9	514.3
Others	11,974.4	10,352.0	14,195.2	15,750.6
T O T A L	15,756.4	16,995.3	18,026.0	14,821.7
Apples	11,590.2	13,055.8	13,855.8	11,254.7
Pears	567.1	803.9	975.1	808.0
Plums	1,429.2	1,297.4	963.0	793.9
Cherries	1,879.2	1,393.3	1,731.0	1,505.5
Sweet cherries	219.4	314.7	454.7	440.8
Others	71.3	130.2	46.4	18.8

Table 113. Production [t] of major vegetables in West Pomeranian Region[350]

Crops	2006-2010	2010	2015	2016
Potatoes	474,791	351,671	357,188	501,651
Sugar beets	462,441	555,601	546,339	779,522
Rape and turnip rape	281,633	299,937	341,187	240,877
Meadow hay	361,311	427,565	564,290	530,991

Table 114. Production [t] of major vegetables in West Pomeranian Region[350]

Crops	2006-2010	2010	2015	2016
T O T A L	105,827	83,721	69,782	79,332
Cabbages	40,105	32,630	22,530	25,580
Cauliflowers	2,790	2,213	1,844	2,131
Onions	8,007	3,967	6,104	7,011
Carrots	22,299	18,805	17,534	19,927
Beetroots	10,055	8,769	8,745	9,487
Cucumbers	4,656	3,382	3,861	4,448
Tomatoes	1,359	1,026	401	1,070
Others	16,556	12,929	8,765	9,678
T O T A L	16,874	18,094	34,025	38,997
Apples	12,493	15,972	30,439	34,641
Pears	1,159	542	590	575
Plums	954	379	573	632
Cherries	993	434	764	792
Sweet	1,062	684	1,498	1,173
Others	213	84	161	1,186

[349] Statistical Yearbook Warminsko-Mazurskie Voivodship 2017, Statistical office in Olsztyn
[350] Statistical Yearbook Zachodniopomorskie Voivodship 2017, Statistical office in Szczecin

Dairies

Poland is the fourth largest milk producer in the EU-28. In 2017, the raw milk output in Poland will be upwards to 13,800 million tonnes, a five-percent increase over 2016. In 2017, 86 percent of milk will be delivered to the dairy industry. The remaining 14 % will be consumed on-farm or sold at the local level.

At the beginning of 2017, cow inventories showed 2,130 million head and were almost same as in 2016 level. The average 2016 yield per cow was 6,037 kilograms, a five-percent increase over 2015.

In the first eight months of 2017, milk deliveries in Poland increased by 4.5 percent over the same period in 2016. The production increase stems from higher milk prices and ample feed supplies. In August 2016, average farm-gate prices for milk were €33 per 100 kilograms of milk, a 30-percent increase over August 2016.[351]

Table 115. Milk production in Pomeranian Region[352]

2003	2005	2010	2015	2016	Specification
191.5	310.2	286.2	350.4	354.3	Million litres
	39.8	38.1	46.1	48.9	Per 100 ha agricultural land in 1000 litres
	4,037	4,096	4,992	5,268	Average annual quantity of milk per cow in litres

Table 116. Milk production in Warmia and Mazury Region[353]

2003	2005	2010	2015	2016	Specification
536.3	811.1	922.3	959.6	1016.5	Million litres
	81.2	92.1	96.5	99.4	Per 100 ha agricultural land in 1000 litres
	4,305	4,549	5,013	5,444	Average annual quantity of milk per cow in litres

Table 117. Milk production in West Pomeranian Region[354]

2003	2005	2010	2015	2016	Specification
129.8	No data	174.3	172.1	147.1	Million litres
	No data	19.2	20.6	17.3	Per 100 ha agricultural land in 1000 litres
	No data	4,575	4,676	3,831	Average annual quantity of milk per cow in litres

Table 118. Milk and related production in Poland[355]

Specification	2005	2010	2013	2015	2016
Processed liquid milk [mill L]	2,294.0	2,742.1	3,025.1	3,198.3	3,268.8
Standardized cream [1000 Hl]	2,605.2	2,319.0	2,145.5	2,143.8	2,087.7
Milk and cream powder [1000 t]	193.4	123.9	153.8	207.7	206.6
Butter and dairy spreads [1000 t]	179.5	173.9	170.1	191.4	204.1
Cheese and curd [1000 t]	605.8	731.1	820.9	833.4	871.3

[351] GAIN Report 11/3/2017
[352] Statistical Yearbook Pomorskie Voivodship 2017, Statistical office in Gdańsk
[353] Statistical Yearbook Warminsko-Mazurskie Voivodship 2017, Statistical office in Olsztyn
[354] Statistical Yearbook Zachodniopomorskie Voivodship 2017, Statistical office in Szczecin
[355] Statistical yearbook of agriculture 2017 - Central Statistical Office - Warsaw

In Pomeranian Region, there are five dairy production facilities located in Nowy Dwór Gdański, Gdańsk, Kartuzy, Chojnice and Perlino. At one of the facilities, even fruit beverages are produced and residues from these processes are included in Table 120. A total of about 11,239 tonnes of residues are produced annually in Pomerania.

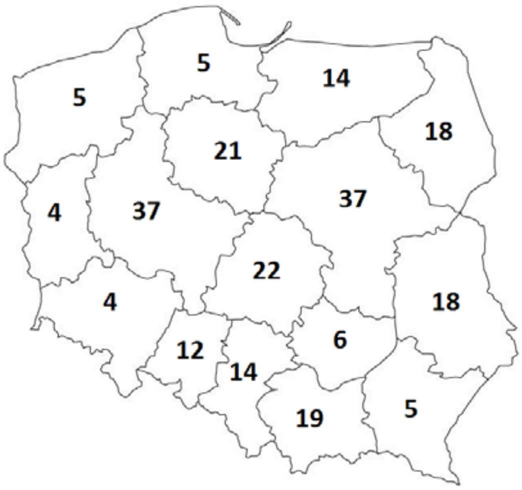

Figure 101. Dairy processing plants in Poland in 2015[356]

Table 119. Milk production [1000 L] in Pomerania, West Pomerania and Warmia and Mazury, Poland[357]

Region	Milk production
Pomerania	354,308
West Pomerania	147,142
Warmia and Mazury	1,016,456
Poland	12,867,000

Table 120. Biodegradable wastes [t] from dairy processing plants in Pomerania region[358]

Company name	Annual wastes production
Spółdzielnia Mleczarska Spomlek, Chojnice	670
Okręgowa Spółdzielnia Mleczarska w Kartuzach	588.6
Maluta - Okręgowa Spółdzielnia Mleczarska w Nowym Dworze Gdańskim	6,737.7
Zakład Mleczarski "Śnieżka", Perlino (gm. Gniewino)	2,878.7
Spółdzielnia Mleczarska Polmlek-Maćkowy, Gdańsk	364.3
Total	11,239.3

According to researchers in Poland, two-thirds of milk and milk products were withdrawn from sales before their *used-by* date.

[356] Maria Zuba-Ciszewska, The Role Of Dairy Cooperatives In Reducing Waste Of Dairy Products In The Lubelskie Voivodeship, Journal of Agribusiness and Rural Development, 1(47) 2018, 97–105
[357] CENTRAL STATISTICAL OFFICE, Signal preparation, Physical sizes of animal production in 2016, Warsaw, 08/09/2017.
[358] Prepared on the basis of selected data from the list of waste holders according to their activities with the list of waste, Department of Environment and Agriculture, Marshal's Office in Gdańsk.

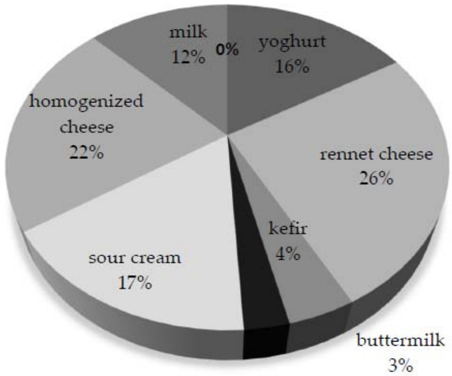

Figure 102. The percentage structure of the wasted milk and milk products[359]

According to the Food Wastes in Poland (2016-2017)[360] report the dairy industry generated 1,218.32 tonnes of waste.

Slaughterhouses and meat processing factories

The largest livestock populations are in Mazowieckie and Wielkopolskie voivodships. The leading regions for swine production are Wielkopolskie, Kujawsko-Pomorskie and Lódzkie, while the leading ones for cattle are Wielkopolskie, Mazowieckie and Podlaskie.

Table 121. Production [1000 t] of meat industry products in Poland[361]

Specification	2005	2010	2013	2015	2016
Slaughter products: cattle and calves	185.6	218.7	214.4	214.7	204.1
Slaughter products: pigs	1,031.0	928.8	1,185.8	1,221.6	1,281.8
Animal fats, rendered, edible	63.5	89.5	89.9	112.2	121.2
Poultry meat	1,237.2	1585.6	2042.3	2,382.7	2,797.2
Cured meat products	755.8	729.4	767.3	774.8	849.5

Table 122. Production [1000 t] of animals for slaughter in Pomerania[362]

Specification	2005	2010	2015	2016
Meat (including fats and pluck)	*98.9*	*217.5*	*292.7*	*308.8*
Meat and fats of which:	**94.8**	**207.5**	**279.2**	**295.0**
Beef	5.1	13.2	15.3	13.4
Veal	0.3	0.2	0.1	0.1
Pork	75.8	134.5	168.2	186.5
Mutton	0.2	0.2	0.1	0.1
Horseflesh	0.0	0.0	0.0	0.0
Poultry	12.3	58.3	93.5	92.8
Goat and rabbit	1.1	1.1	2.0	2.1
Pluck	**4.1**	**10.0**	**13.5**	**13.8**

[359] Beata Bilska *, Małgorzata Piecek and Danuta Kołozyn-Krajewska, A Multifaceted Evaluation of Food Waste in a Polish Supermarket—Case Study, Sustainability 2018, 10, 3175; doi:10.3390/su10093175
[360] https://mojetesco.pl/spolecznosci/walka-marnowaniem-zywnosci/dane-dotyczace-marnowania-zywnosci-polsce/
[361] Statistical Yearbook of Agriculture 2017 - Central Statistical Office - Warsaw
[362] Statistical Yearbook Pomorskie Voivodship 2017, Statistical office in Gdańsk

Table 123. Production [1000 t] of animals for slaughter in Warmia and Mazury[363]

Specification	2005	2010	2015	2016
Meat (including fats and pluck)	*226.7*	*263.8*	*302.3*	*312.8*
Meat and fats of which:	**214.7**	**249.9**	**285.9**	**296**
Beef	16.5	15.4	23.7	21.3
Veal	2	1	0.5	0.3
Pork	88.5	88.4	92.6	93.4
Mutton	0.1	0.1	0.1	0.1
Horseflesh	0	0.2	0.1	0.1
Poultry	106.4	143.7	166.3	178.2
Goat and rabbit	1.3	1.3	2.6	2.7
Pluck	**12**	**13.9**	**16.4**	**16.8**

Table 124. Production [1000 t] of animals for slaughter in West Pomerania[364]

Specification	2005	2010	2015	2016
Meat (including fats and pluck)	-	185.6	173.6	172.6
Meat and fats of which:	**-**	**164.3**	**164.6**	**163.8**
Beef	-	5.6	5.2	5.1
Veal	-	0.4	0.2	0.2
Pork	-	62.2	39.3	40
Mutton	-	0	0	0
Horseflesh		0	0	0
Poultry	-	92.7	116	114.4
Goat and rabbit	-	3.4	3.8	4.1
Pluck	**-**	8.5	8.9	8.8

Table 125. Egg production in Polish SBA regions[363,364,365]

Region	2005	2010	2015	2016	Specification
Pomeranian Region'	447.3	311.5	235.8	293.4	Egg production [million]
	241	205	174	209	Average annual number of eggs per laying hen [-]
West Pomeranian Region	-	411.1	284.8	320.4	Egg production [million]
	-	232	206	246	Average annual number of eggs per laying hen [-]
Warmia and Mazury	149	157.2	269	240.7	Egg production [million]
	185	199	223	232	Average annual number of eggs per laying hen in units

In Pomeranian Region there are four larger facilities that process animals for food and/or slaughterhouse residues, e.g. for production of animal feed and gelatine. These are located in Człuchów Powiat. Apart from that reported here are additional 16 smaller dedicated facilities for that purpose. For the processing of animal by-products, EU regulations have to be complied with in order to avoid spreading of diseases like BSE and food and mouth disease. Animal residues are grouped into three categories of which categories 2 and 3 can be used for composting, biogas

363 Statistical Yearbook Warmińsko-Mazurskie Voivodship 2017, Statistical office in Olsztyn
364 Statistical Yearbook Zachodniopomorskie Voivodship 2017, Statistical office in Szczecin
365 Statistical Yearbook Pomorskie Voivodship 2017, Statistical office in Gdańsk

production or e.g. production of chemicals[366]. Category 1 residues are considered specified risk material, which needs to be combusted (850°C – 2 s, or 1100°C – 0.2 s), in exceptional cases used for feeding of scavenger birds, as fuel (processed or unprocessed), medicine, cosmetics production. Category 2 materials include among other manure and rejected animal materials, which need to be sanitised by a thermal treatment. Can be used as organic fertilisers, soil enhancers, for composting and fermentation (after pressure sterilization), special feeding of animals (fur animals, zoo, circus, homeless, bite). Finally it can be used as fuel (processed or unprocessed), and for medicine and cosmetics production.
Category 3 includes animal residues that are not part of categories 1 and 2, e.g. waste from the food industry and food returned from the stores. Also, these materials need to be sanitised.
The total amount of residues amounted in Poland to about 2 million tonnes[367]. There are special processing plants for management of waste. In first category there are 11 such units in Poland, and none in Pomeranian, West Pomeranian as well as Warmia and Mazury Regions. In second category there are 5 such units in Poland, and none in Pomeranian, West Pomeranian as well as Warmia and Mazury Regions. In the third category there are 92 such units in Poland, with 9 units in Pomeranian, 1 in West Pomeranian as well as 3 in Warmia and Mazury Regions.

Table 126. Amount of biodegradable waste [t] in Pomeranian Region from meat related industry, 2013[368]

No.	Meat Factory	Biodegradable waste	County
1.	Zakłady Mięsne "Skiba", Chojnice	783.0	chojnicki
2.	Zakład Przetwórstwa Mięsnego Sp. J., Konarzyny	73.8	chojnicki
3.	Poldanor S.A. - Ferma Trzody w Płaszczycy (gm. Przechlewo)	21,304.8	człuchowski
4.	Poldanor S.A. - Ferma Trzody w Pawłówku (gm. Przechlewo)	19,217.1	człuchowski
5.	Przedsiębiorstwo Wielobranżowe "A.S.G", Człuchów	159.6	człuchowski
6.	Westpol-Teeuwissen Pharma Sp. z o.o. Rzeczenica	4,041.1	człuchowski
7.	Prime Food Sp. z o.o., Przechlewo	4,904.1	człuchowski
8.	Westpol-Teeuwissen Pharma Sp. z o.o. Chojnice	2,333.2	człuchowski
9.	Zakłady Mięsne Nowak Sp. z o.o. Kolbudy	288.7	gdański
10.	Vector Food, Wyczechowo (gm. Somonino)	487.0	kartuski
11.	Lis Przetwórstwo Mięsne, Sierakowice	372.1	kartuski
12.	Nazar Produkcja Kebabu, Leźno (gm. Żukowo)	308.9	kartuski
13.	Obojan Sp. z o.o. Stężyca	84.8	kartuski
14.	Firma F.H.U. "Rafalex" Wilcze Błota (gm. Stara Kiszewa)	893.7	kościerski
15.	Gospodarstwo Rolne Ryszard Woźniak, Papiernia (gm. Lipusz)	232.3	kościerski
16.	Wytwórnia Wędlin Zbigniew Zabrocki, Górki Wybudowanie (gm. Karsin)	132.6	kościerski
17.	Rzeźnia, Masarnia, Sprzedaż Mięsa i Wędlin, Sp. Jawna, Ryjewo	215.7	kwidzyński
18.	Zakład Przetwórstwa Mięsnego, Sp.J. Kwidzyn	121.0	kwidzyński
19.	Przeds. Prod. Zwierzęcej "Przybkowo" Sp. z o.o. Ferma Stanisławka,	242.6	wejherowski
20.	Masarnia Dominik Sp. J., Godętowo (gm. Łęczyce)	78.8	wejherowski
21.	Wytwórnia Wędlin, Rumia	68.3	wejherowski
TOTAL		56,343.2	

366 Rozporządzenie Parlamentu Europejskiego i Rady (WE) nr 1069/2009 z dnia 21 października 2009 r.
367 Krzysztof Bednarczyk, Biuro Pasz, Farmacji i Utylizacji, Główny Inspektorat Weterynarii, Uboczne produkty pochodzenia zwierzęcego, 1 March 2018
368 https://pbpr.pomorskie.eu/documents/294485/599352/Za%C5%82%C4%85cznik+9.+Najwi%C4%99ksi+wytw%C3%B3rcy+odpad%C3%B3w+biodegradowalnych+z+przemys%C5%82u+rolno-spo%C5%BCywczego+.pdf/7a3d2aee-b6e6-43d2-8462-df96cae0dcd8

Table 127. Amount of biodegradable waste [t] in Pomeranian Region from poultry related industry, 2013[369]

No.	Poultry Factory	Biodegradable waste	County
1.	Ubojnia Drobiu, Pomysk Wielki	960.6	bytowski
2.	Ferma Drobiu Sekura, Buchowo (gm. Debrzno)	923.2	człuchowski
3.	Przedsiębiorstwo Wielobranżowe, Przechlewo	152.5	człuchowski
4.	JDA Produkcja działy Specjalne S.C. Suchy Dąb	353.2	gdański
5.	Mielewczyk Spółka Jawna, Dzierżążno (gm. Kartuzy)	5,928.4	kartuski
6.	Rzeźnia Drobiu, Niestępowo (gm. Żukowo)	5,623.0	kartuski
7.	Ubojnia Drobiu Gosz Sp. z o.o. Sierakowice	2,486.0	kartuski
8.	Ubojnia Drobiu "Drobful", Przodkowo	375.3	kartuski
9.	Ubojnia Drobiu, Miszewko (gm. Żukowo)	312.6	kartuski
10.	P.H.U - Ubojnia Drobiu "Hubart", Bruskowo Wielkie	243.3	słupski
11.	(gm. Słupsk)	1,276.4	starogardzki
12.	Sms Food Industries Poland Sp. z o.o. Starogard Gdański	1,440.3	tczewski
TOTAL		20,074.8	

Meat production has been extensively increasing over the period 2005-2016 in Poland. A total increase of about 70% and in case of poultry over 100% can be observed. Egg production has varied according to regions, but in Pomeranian Regions it has decreased by 37% during 2005-2016[370]

Fishing industry and other aquatic biomass

Residues from the fishery industry in Pomeranian and West Pomeranian Regions occur either on-board fishing ships or in fish processing plants. A large proportion of fish is cleaned already on the ships and residues are discarded directly into the sea. Atlantic cod are gutted on the ships, while the head is removed first in the processing facility. Flatfish are usually cleaned on the ship. In Pomeranian Region, there are three large fish processing facilities and several smaller ones. All residues from Atlantic herring and cod processing are milled and frozen for use as animal feed, amounting to just over 18,000 tonnes per year.

Since 1980, catches of marine fish have been systematically decreasing. In 1985, they amounted to 652,000 tonnes, in 1990 – 430,000 tonnes, and in 2000 – 200,000 tonnes. After 2010, the amount of fishing for aquatic organisms is at a similar level and in 2015 amounted to 187,000 tonnes[371,372]. Factors affecting the fish economy are the availability of raw material, fleet and industry potential as well as the administration and organization of the fish market.

The most frequently caught fish by Polish fishermen in 2015 included: sprats, herring, horse mackerel and cod. They accounted for over 85% of the catch mass. Fish are most often processed. The largest share in the market for fish products is canned food, marinades and fish preserves, which produce more than 150,000 tonnes per year. There are currently 68 business entities operating in Poland processing and preserving fish and marine invertebrates. The value of sold

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[369] https://pbpr.pomorskie.eu/documents/294485/599352/Za%C5%82%C4%85cznik+9.+Najwi%C4%99ksi+wytw%C3%B3rcy+odpad%C3%B3w+biodegradowalnych+z+przemys%C5%82u+rolno-spo%C5%BCywczego+.pdf/7a3d2aee-b6e6-43d2-8462-df96cae0dcd8

[370] Central Statistical Office - Warsaw

[371] GUS: Rocznik Statystyczny Gospodarki Morskiej 2010. Zakład Wydawnictw Statystycznych, Warszawa 2010.

[372] GUS: Rocznik Statystyczny Gospodarki Morskiej 2016. Zakład Wydawnictw Statystycznych, Warszawa 2016.

production of these products in 2015 was 8.9 billion PLN, which accounted for 0.9% of the value of all industrial products and 5.4% of the value of food products.
In 2008, imports of fresh salmon to Poland, gutted with heads, intended for processing, amounted to over 75,000 tonnes, of which about 40,000 tonnes were allocated for export products. [373] When processing such raw material for smoked products, mainly sliced fillets without skin, waste raw materials: heads, spines, fins, skins and other, together constitute, according to estimates from fish processing plants, about 45% of processed raw material. Over the years in Poland over 33,000 tonnes of salmon waste are produced, of which over 1,600 tonnes are raw and smoked skins. Quantitative assessment and characterization of salmon waste materials showed that the percentage share of these raw materials in relation to the weight of gutted fish head is: 12% heads, 11% spine, 5% skin. Wastes from salmon processing, particularly of the skin, can be a good raw material for the production of innovative high value-added market products, such as, for example, fish oil with specific properties, as well as collagen and gelatine[374].

Table 128. Amount of biodegradable waste in Pomeranian Region from fish related industry, 2013[375]

No.	Fish Factory	Biodegradable waste	County
1.	Wylęgarnia Ryb "Dąbie", Dąbie (gm. Bytów)	63.3	bytowski
2.	Dro - Ryb Sp. z o.o. Chojnice	906.0	chojnicki
3.	EvraFish Sp. z o.o. Brusy	102.0	chojnicki
4.	Zakład Hodowli Pstrąga w Zaporze Mylof Sp. z o.o., Zapora gm.	61.0	chojnicki
5.	Wytwórnia Mączki Rybnej w Dobrzyniu	561.6	człuchowski
6.	(gm. Przechlewo)	688.6	kościerski
7.	Sprzedaż Hurt Detal Przetwórstwo Ryb "Ryby" Sp. J.,	248.0	kwidzyński
8.	PPH-Man Henryka, Kaniczki (gm. Sadlinki)	73.5	lęborski
9.	Laurin Seafood Sp. z o.o. Lębork	2,536.5	pucki
10.	Zakład Produkcyjny Polinord w Kartoszynie, Kartoszyno (gm.	680.5	pucki
11.	Jantar Ltd" Sp. z o.o. Zdrada (gm. Puck)	646.9	pucki
12.	Laguna Sp. J., Łebcz (gm. Puck)	612.1	pucki
13.	Nord Capital Sp. z o.o. Rekowo Górne (gm. Puck)	237.6	pucki
14.	Przedsiębiorstwo Rybne "Helon", Leśniewo (gm. Puck)	228.9	pucki
15.	Orfa Co., Władysławowo	220.5	pucki
16.	Firma Wielobranżowa "Natmar", Połczyno(Puck)	95.3	pucki
17.	Morpol S.A. Duninowo (gm. Ustka)	5,144.5	słupski
18.	Przetwórstwo Rybne "Łosoś" Sp. z o.o. Włynkówko (gm. Słupsk)	3,540.8	słupski
19.	Fario Sp. J., Żochowo (gm. Potęgowo)	664.9	słupski
20.	Koral S.A. Tczew	87.3	tczewski
21.	King Oscar Sp. z o.o. Strzebielinko (gm. Gniewino)	566.8	wejherowski
22.	TPR Sp. z o.o. Strzebielinko (gm. Gniewino)	201.3	wejherowski
TOTAL		18,167.9	

[373] Hryszko K., Seremak-Bulge J., Kuzebski E., Pieńkowska B., Rakowski M., Szostak S., Drożdż J.: Rynek ryb. Stan i perspektywy. Wyd. IERiGŻ-PIB, 13, 28-30.
[374] GUS: Rocznik Statystyczny Przemysłu 2016. Zakład Wydawnictw Statystycznych, Warszawa 2016.
[375] https://pbpr.pomorskie.eu/documents/294485/599352/Za%C5%82%C4%85cznik+9.+Najwi%C4%99ksi+wytw%C3%B3rcy+odpad%C3%B3w+biodegradowalnych+z+przemys%C5%82u+rolno-spo%C5%BCywczego+.pdf/7a3d2aee-b6e6-43d2-8462-df96cae0dcd8

Breweries

There are no large-scale breweries in Pomeranian Region. The biggest one, Amber Brewery, produces approximately 200,000 hl of beer. For its production it uses about 3,000 tonnes of barley, few tonnes of hops and about 3,000 tonnes of malt. According the acquired communication with the brewery all waste is managed. The pulp is collected and sold for fodder (about 2,000 tonnes per year), spent yeast is collected and sold to a specialist company that processes it into feed additives (annually over 200 tonnes), spent diatomaceous earth is collected, composted and is an additive to natural fertilizers for the soil (about 30 tonnes), waste labels are collected and transferred to a specialized company for management (over 20 tonnes per year), waste paper, foil and aluminum are collected and transferred for reprocessing (20-40 tonnes per year). The survey carried out by the authorities of Pomeranian Region indicated the total waste in the amount of 340.8 tonnes.

Additionally, there are about 10 microbreweries, typically with low production ranging between 25,000 and 100,000 litres per year. Typical residues from breweries include brewer´s spent grain (BSG), which composes the major fraction of the residues as well as residues of hop, wort and yeast. The typical range of residue production is about 5-25 tonnes per year. Assuming an average of 10 tonnes of brewing residues per microbrewery, the total amount of residues would be around 100 tonnes annually. The residues are either used as animal feed (either on the own farm or sold/donated to other organisations) or biogas substrate.

Table 129. Production of brewery industry products in Poland[376]

Specification	2005	2010	2013	2015	2016
Beer from malt [million hl]	31.6	36.8	40.0	40.9	41.4
Malt [1000 t]	314.7	336.7	361.2	404.1	400.8

Table 130. Amount of biodegradable waste [t] in Pomeranian Region from breweries, 2013[377]

No.	Brewing Factory	Biodegradable waste	County
1.	Browar Amber Sp. z o.o. Spółka Komandytowa, Bielkówko (gm. Kolbudy)	340,8	gdański
TOTAL		340,8	

Potato industry

In the area of the southern Baltic Sea, there are several companies involved in the processing of potatoes, including Alex-Pol, Farm Frites and Jantar. The idea of the maximum use of bio-waste produced during potato processing is carried out by Farm Frites Poland SA with the plant located in Lębork (Pomorskie Voivodeship). The company deals in the production of potato products, and the plant located in Poland annually processes about 220,000 tonnes of potatoes. By 2020, the factory intends to recycle all post-production waste generated in the plant, and thus not to export any production waste to the local landfill.

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[376] Statistical yearbook of agriculture 2017 - Central Statistical Office - Warsaw

[377] https://pbpr.pomorskie.eu/documents/294485/599352/Za%C5%82%C4%85cznik+9.+Najwi%C4%99ksi+wytw%C3%B3rcy+odpad%C3%B3w+biodegradowalnych+z+przemys%C5%82u+rolno-spo%C5%BCywczego+.pdf/7a3d2aee-b6e6-43d2-8462-df96cae0dcd8

The leading supplier of raw material for the aforementioned factory is Farm Frites 2 Sp. z o. o. from Damnica. At present, the farm has an area of about 3,500 ha (including leased land), grows annually 950 ha of potatoes in a four-year cycle of crop rotation, interchangeably with cereals (wheat, barley, rye), rapeseed, grass and maize. The farms employ 63 people permanently and about 50 people for a definite period. The average yield on the farm is about 47 tonnes of potatoes per hectare. Already at this stage of production, natural waste, in the form of residues on harvested crops, is used for personal use, serving soil fertilization and its protection against erosion. The amount of potatoes produced by the farm Farm Frites Poland Two is not sufficient to cover the entire demand of the factory in Lębork, which is why it is additionally contracted around 5,000 ha, in the area from the western Polish border to Żuławy. For the needs of early varieties, a small area is also contracted near Poznań and Kalisz. Therefore, the company cooperates with more than 70 farmers. Farm Frites Poland S.A. in Lębork invests in solutions that reduce water, gas and electricity consumption. It has its own two-stage sewage pre-treatment plant equipped with an anaerobic installation, which reduces pollution in process waters with 90% efficiency. The produced biogas after purification is burned in a cogeneration unit, which simultaneously produces electricity and heat. After pre-treatment, all sewage is discharged to the Municipal Sewage Treatment Plant in Lębork. In 2016 it was 574,000 m^3, a 6.4% increase from 2014. The increased demand for water for production purposes translates directly into increased amounts of sewage discharged into the municipal sewage treatment plant. In 2016, Farm Frites Poland S.A. in Lębork, produced 2,588 MWh of electricity, which was fully used to cover the needs of the factory. Own electricity accounted for 8.2% of total electricity demand. By 2020, the company intends to increase the share of energy from renewable sources in total energy consumption to a minimum of 10%.
The waste recycling rate in the company is increasing - in 2013 it exceeded 96%, while in 2016 over 99.5% of all waste produced in the factory was recycled. Packaging waste, such as cardboard or foil, is separated and forwarded for recycling. Potato starch, obtained during production of frites, is transported to the local distillery and the potato alcohol is made from it – about 2,200 tonnes annualy. Rest of wastes generated during process (such as earth, mud, stones and potato peelings, crumbs and other remains from frites production, except the frying oil) is processed in a biogas plant, resulting in electricity and heat as well as organic fertilizer. The company undertakes cooperation with the Biogas Power Plant in Darżyno (Nadmorskie Wiatrowe Wiatrowe Darżyno sp. o.o.), providing 70 tonnes of organic waste per day.

Table 131. Cultivated area [ha] for potatoes in Pomeranian Region, 2017

	West Pomeranian region[378]	**Pomeranian region**[379]	**Warmia and Mazury region**[380]
Potatoes	**11,661**	**17,693**	**9,355**
Total cultivated area	560,107	991,678	556,342

Table 132. Production of potato starch [1000 t] in Poland in the period 2005-2016, 2017[381]

Product	**2005**	**2010**	**2013**	**2015**	**2016**
Potato starch	111.7	76.9	112.3	138.3	194.8

[378] Statistical Yearobook Zachodniopomorskie Voivodship 2016, Statistical office in Szczecin
[379] Statistical Yearbook Pomorskie Voivodship 2016, Statistical office in Gdańsk
[380] Statistical Yearbook Warminsko-Mazurskie Voivodship 2016, Statistical office in Olsztyn
[381] Statistical yearbook of agriculture 2017 - Central Statistical Office - Warsaw

Table 133. Potato production in the SBA regions in Poland, 2017[381]

Region	2005	2010	2015	2016
Pomerania	597,152	513,452	460,573	579,274
Warmia and Mazury	245,398.9	248,490.1	179,719.1	216,599.0
West Pomerania	474,791	351,671	357,188	501,651

Ethanol industry

Table 134. Production [million l] of destillary industry products in Poland, 2017[382]

Specification	2005	2010	2013	2015	2016
Vodka (in terms of 100%)	79.0	107.0	115.7	96.1	97.7
Rectified spirit (100% ethyl alcohol)	152.8	135.9	146.5	132.4	123.0

Distillery Sobieski is a part of the international Belvedere Group, which accounts for about 22% of the Polish market. The company purchases agricultural distillate made usually from cereal, or raw spirit, from local and certified distilleries. The distilled spirit of the highest quality is used for the preparation of liqueurs and spirits vodka and flavoured spirit drinks, such as herbal, fruit and bitter. In addition to agricultural ethyl alcohol and demineralized water, the produced beverages include natural aromas and flavour additives, sugar syrup and caramel. From the on-site distillation, reject alcohol containing alcohols heavier and lighter than ethanol are collected and sold as raw materials for other production systems and have an economic value to the company. Carried out survey of the company resulted in the conclusion that the company is not producing any waste.
Mełno ethanol production site is the one which was investigated by us in the frame of the project. This is the first step in the production of raw spirit. There are 5 other such plants in the Pomeranian Region. There is a strong commercial competition of ethanol producers to find the potential customers. Actually the Sobieski Distillery is not the first choice customers, as higher prices are paid by the companies producing so called car cosmetics. The input to the process is based primarily on unused biomass such as bakery, fruits, and vegetables leftovers from bakeries, hypermarkets, fruit and vegetable processing factories and factories that produce e.g. pizza bases. This biomass is a solid one and has to be milled, mashed, weaken and heated up before the fermentation process. Much effort is therefore dedicated to the processes of cutting, grinding and temperature rising of the biomass. Thus the excellent idea is to connect the distillery with the biogas plant, which is actually the case in the considered site. The wastes from fermentation process go to biogas plant while biogas is combusted to meet the energy demand of fermentation process. The remainders from the fermentation process is the stillage which is rich in fibres and proteins and it is used as fertilisers in the local agriculture.

[382] Statistical yearbook of agriculture 2017 - Central Statistical Office - Warsaw

Table 135. Amount of biodegradable waste [t] in Pomeranian Region from distillery industry, 2013[383]

No.	Distillery Factory	Biodegradable waste	County
1.	Przeds. Prod. Handlowe Gorzelnia Rolnicza S.C. Jeziorki	8,241.9	chojnicki
2.	Gorzelnia Domisław, Kijno (gm. Czarne)	4,479.0	człuchowski
3.	Gorzelnia Rolnicza w Gwieździnie (gm. Rzeczenica)	2,600.0	człuchowski
4.	Mix S.A. - Zakład w Kwidzynie	562.0	kwidzyński
5.	Gorzelnia rolnicza, Podole Wielkie (gm. Główczyce)	24,160.0	słupski
TOTAL		40 042.9	

Household food residues

Collection of food waste from households is part of the EU goal of reducing the amounts of organic residues ending up in dumps and other household waste.

Poland is obliged to fulfil obligations resulting from EU directives, i.e. to achieve appropriate levels of limiting the mass of municipal biodegradable waste sent to storage (by 16 July 2020 - not more than 35%), as well as recycling levels, preparation for re-use and recovery by other methods of paper, metals, plastics, glass (until December 31, 2020 - 50%), as well as non-hazardous construction and demolition waste (until December 31, 2020 - 70%).

In Gdańsk, the segregation of household waste into organic and another waste started only from 1 January 2014 and is at its infancy. Collection of food residues from households, restaurants, large kitchens and shops and an energy recovery from 40% of these collected residues was decided on in 2012 with the aim to reach this goal by the end of 2018.

The definitions of catering and communal waste and the method of their disposal are regulated by two legal codes:

- The Act of 14 December 2012 on waste (Journal of Laws of 2013, item 21)
- Regulation (EC) No 1069/2009 of 21 October 2009 defining sanitary rules for animal by-products not intended for human consumption.

According to the Act, waste produced in the home kitchen is not considered different from waste produced in mass catering facilities. Theoretically, these facilities should sign a waste disposal contract and, according to the contract, collect rubbish in a container, however there is a catch about waste of animal origin (meat, milk, yogurt, meats and even honey). Garbage from gastronomy can be thrown into a garbage container (as municipal waste), provided that there is no hazardous waste in them. According to the regulation 1069/2009 (definition included in the regulation) catering waste is all food waste, including used cooking oil coming from restaurants, catering facilities and kitchens, including collective and home kitchens (theoretically the same as the law says).

In addition, the regulation states that catering wastes are also considred withdrawals (e.g. expired or not responding to health quality). Food of animal origin is a Category 3 material and therefore these products needs to be disposed of in a special way in order to avoid the risks to human and animal health (hazardous waste).

If the meat, yogurt, milk, and eggs are spoiled or expire, then we have already made up the third category waste. Also post-consumer waste (what the customer did not eat, and contained the animal

[383] https://pbpr.pomorskie.eu/documents/294485/599352/Za%C5%82%C4%85cznik+9.+Najwi%C4%99ksi+wytw%C3%B3rcy+odpad%C3%B3w+biodegradowalnych+z+przemys%C5%82u+rolno-spo%C5%BCywczego+.pdf/7a3d2aee-b6e6-43d2-8462-df96cae0dcd8

product) is considered hazardous waste. The regulation states that such waste should be, among others, burned, introduced into the soil as a fertilizer, or it may form a feed for fur animals (fox farms) or pet food (dogs, cats). According to the regulation of catering waste (i.e. the general ones), farm animals (pigs, cows, chickens, goats) must not be fed. It's about the food chain and the fact that what an animal feeds has an impact on our health as a consumer.

Biodegradable waste from industry and biomass processing
Waste classification due to their origin, type and impact on the environment is included in the Polish catalogue of waste. Depending on the source of waste, it is divided into 20 categories. Table 134 presents the mass of biodegradable waste (other than municipal waste) from the following categories: 02 - waste from agriculture, horticulture, hydroponics, fishery, forestry, hunting and food processing; 03 - wastes from wood processing and the production of panels and furniture, pulp, paper and cardboard; 19 - waste from installations and devices used for waste management, sewage treatment plants and treatment of drinking water and water for industrial purposes.

Table 136. Mass of biodegradable waste [t] other than municipal from group 02, 03 and 19 produced in the Pomerania voivodship in 2014-2016 as at 31 December of a given year[384]

Waste source	Type of waste	2014	2015	2016
Waste from agriculture, horticulture, hydroponics, forestry, hunting and fishing	Animal tissue	737.5	506.0	695.1
	Plant mass	208.5	33.6	1,091.8
	Animal droppings	1,391.2	975.9	16.6
	Waste from forestry	3.2	2.7	-
	Waste from hydroponic cultivation	-	-	-
Waste from the preparation and processing of food products of animal origin	Waste from washing and preparation of raw material	133.1	140.6	162.8
	Animal tissue	22,444.5	10,578.4	7,928.2
	Raw materials and products unsuitable for consumption and processing	8,497.8	9,081.3	6,026.5
	Sludge from factory sewage treatment plants	20,242.0	27,797.6	30,888.1
	Waste from the production of fishmeal	-	-	366.0
Waste from the preparation, processing of food products and waste of plant origin, including waste from fruits, vegetables, cereal products, edible oils, cocoa, coffee, tea and tobacco processing, yeast and the production of yeast extracts, molasses preparation and fermentation	Sludge from washing, cleaning, peeling, centrifuging and separation of raw material	6,747.4	8,689.4	11,717.7
	Raw materials and products unsuitable for consumption and processing	1,391.8	1,112.4	838.6
	Sludge from factory sewage treatment plants	20,743.2	27,525.8	23,320.8
	Pomace, sludge and other waste from the processing of plant products	53,910.1	58,618.2	68,963.7
	Waste from the production of plant feed	55.3	46.8	33.9
	Tobacco waste	-	-	0.1
Waste from the sugar industry	Sludge from factory sewage treatment plants	-	-	-
	Sugar beet pulp	-	-	-

[384] Report on the implementation of the Waste Management Plan for the Pomorskie Voivodeship 2018 for the years 2014-2016, Office of the Marshal of the Pomeranian Voivodeship, Department of Environment and Agriculture

Waste source	Type of waste	2014	2015	2016
Waste from the dairy industry	Raw materials and products unsuitable for consumption and processing	142.6	126.3	58.4
	Sludge from factory sewage treatment plants	38.0	653.3	96.9
	Waste whey	16,885.2	11,953.7	11,670.6
Waste from the bakery and confectionery industry	Raw materials and products unsuitable for consumption and processing	171.6	111.2	33.3
	Sludge from factory sewage treatment plants	84.0	108.0	51.0
	Food fats unsuitable for use	46.3	48.2	39.2
Waste from the production of alcoholic and non-alcoholic beverages (excluding coffee, tea and cocoa)	Waste from washing, cleaning and mechanical comminution of raw materials	100.0	50.0	50.0
	Waste from the distillation of spirits	9.6	3.0	3.0
	Raw materials and products unsuitable for consumption and processing	32.8	-	-
	Sludge from factory sewage treatment plants	-	-	-
	Pomace, sediment and post-fermentation residues, decoctions	33,730.5	24,764.5	42,246.2
Waste from wood processing and the production of panels and furniture	Bark and cork waste	20,606.7	6,587.0	14,494.3
	Sawdust, shavings, cuttings, wood, particle board and veneer	227,801.3	100,321.0	79,404.7
	Sludge from factory sewage treatment plants	57.2	50.7	74.2
Waste from the production and processing of cellulose fiber, paper and cardboard	Bark and wood waste	264,576.1	261,805.0	285,137.0
	Sludge from cellulose production using the sulfite method (including green liquor sediments)	8,528.4	7,385.4	7,193.6
	Sludge from de-inking of wastepaper	33,642.6	33,953.6	34,727.2
	Mechanically separated rejects from the processing of wastepaper and cardboard	6,014.4	4,701.8	5,846.8
	Waste from sorting paper and cardboard intended for recycling	12,939.4	14,733.4	14,615.8
	Fiber waste, sludge from fibers, fillers and coatings derived from mechanical separation	30,404.0	25,318.7	26,246.3
	Sludge from factory sewage treatment plants	54,995.5	55,552.1	51,463.9
Waste from anaerobic waste decomposition	Fermented waste from anaerobic decomposition of municipal waste	-	-	-
	Fermented waste from anaerobic digestion of animal and plant waste	52,707.2	61,600.0	6,750.0
Waste from sewage treatment plants (not included in other groups)	Waste caught by screening	4,905.8	5,420.0	5,191.6
	The content of sand separators	3,388.7	4,001.8	3,985.3
	Fats and oil mixtures from oil/water separation	2,280.4	2,325.2	2,845.9

Waste source	Type of waste	2014	2015	2016
	containing only edible oils and fats			
	Sludge from biological treatment of industrial wastewater	386.7	680.0	3,734.9
Waste from the treatment of drinking water and water for industrial purposes	Solid waste from pre-filtration and screening	233.2	318.6	287.2
	Sediments from water clarification	59.7	125.3	83.7
Waste from mechanical waste treatment (e.g. manual processing, sorting, crushing, granulating)	Paper and cardboard	8,157.1	6,658.3	6,560.3
	Wood	3,036.5	3,956.4	4,798.6
	Textile	46.1	275.6	947.5
	Other waste (including mixed substances and objects) from mechanical treatment of waste	496,284.8	518,185.0	564,956.0
TOTAL		1,418,798.0	1,296,881.8	1,325,643.3

Table 137. Amount [1000 t] of not edible biodegradable waste from the agri-food industry, agriculture, forestry, and food products in the Pomeranian Voivodeship in 2013[385]

Product	Amount
Poultry	22,036.2
Fish	18,416.9
Meat	61,631.5
Ethanol	39,821.7
Dairy	11,470.2
Fruits/Vegetables	72,119.9
Sugar	6,076.7

Municipal waste

In 2017, 11,696,700 tonnes of municipal waste were collected in Poland (an increase of 2.7% compared to 2016). There was an average of 312 kg of collected municipal waste per inhabitant of Poland. In comparison with 2016, the amount of municipal waste generated per inhabitant increased by 9 kg. Municipal household waste collected in 2017 (9,971,200 tonnes) accounted for the majority (83.3%) of municipal waste generated. The amount of this waste increased by 4.3% compared to the previous year. From the municipal waste collected or received in 2017, 6,770,900 tonnes were destined for recovery (about 56.6% of the amount of municipal waste generated). Of that, about 3,990,000 tonnes of municipal waste were destined for recycling (26.7% of the amount of municipal waste generated). About 848,000 tonnes of municipal waste (7.1% of the amount of municipal waste generated) were directed to biological processing (composting or fermentation) processes. Almost 2,734,200 tonnes of municipal waste (about 22.8% of municipal waste generated) were designated for thermal transformation with energy recovery. A total of 5,197,800 tonnes were directed to neutralization processes, of which 4,999,700 tonnes (41.8% of municipal waste generated) was designated for landfilling, and 198,100 tonnes (1.7% of municipal waste generated) for disposal by thermal transformation without energy recovery[386]

[385] https://pbpr.pomorskie.eu/documents/294485/599352/Za%C5%82%C4%85cznik+9.+Najwi%C4%99ksi+wytw%C3%B3rcy+odpad%C3%B3w+biodegradowalnych+z+przemys%C5%82u+rolno-spo%C5%BCywczego+.pdf/7a3d2aee-b6e6-43d2-8462-df96cae0dcd8
[386] Municipal waste and maintenance of cleanliness and order in municipalities in 2017 - Central Statistical Office

Table 138. Municipal waste collected by fractions and voivodships in 2016[387]

Voivoidships	Total		Mixed	Collected separately								
				total	paper and cardboard	glass	plastics	metals	textiles	hazardous	bulky	biode-gradable
	[1000 t]	[kg/capita]	[1000 t]									
POLAND	11,654.3	303.3	8,712.1	2,942.3	254.1	447.3	304.2	24.3	1.6	1.1	338.0	822.9
Pomorskie	761.2	329.3	579.9	181.3	16.7	25.7	22.2	0.2	0.5	—	15.7	75.4
Warmińsko-mazurskie	434.4	302.1	361.1	73.4	7.9	11.5	10.9	0.2	—	—	7.6	20.9
Zachodniopomorskie	606.1	354.7	486.1	120.0	14.7	20.7	8.9	0.4	0.1	—	19.8	36.4

[387] Environment 2017 - Central Statistical Office - Warsaw

2.4.4 Regional resources in Sweden

Assessed by Thomas Prade, Swedish University of Agricultural Sciences

Residues and by-products along the food processing industry and food waste from households have a large potential as feedstocks for bioeconomy, but are subject to large variations in terms of feedstock purity and composition. Residues occur at different stages of the food production chain, from crop residue in the field during primary production to residues from extraction, refining and other industrial processes. While specific field residues (straw, sugar beet leaves) are presented separately (0; 2.3.4), the industrial residues were assessed here.

Due to the decentralised occurrence of industrial food residues, collecting data on residual materials streams is a time-consuming work that unfortunately is further impeded by the reluctance of many companies to share information on their residues. A full update has unfortunately proven impractical in this project. However, in order to be able to present a realistic picture of the amount of residues occurring in the sectors investigated, we chose to estimate the residue potential relying on an earlier publication on residue potentials from these value chains in the Öresund region[388]. The report is a thorough inventory of residues from the main food industries. Although the report is seven years old as the present report is produced, the composition of the current food industry residues and wastes was assumed to be similar, and therefore the results in the report were considered still valid. This assumption was supported by the assessment of agricultural production statistics for Sweden and Skåne in particular as presented for each sector below.

In this assessment, we included residues from the following industries:

- Flour mills and bakeries
- Fruit and vegetable processing
- Dairies
- Slaughterhouses and meat processing factories
- Fishing industry and other aquatic biomass
- Breweries
- Starch industry
- Ethanol industry
- Household food residues
- Manure

Flour mills and bakeries

There are two flour mills in Skåne, Skånemöllan and Lilla Harrie Valskvarn. Skånemöllan produces cereal-based flour for industrial food production and end-consumer use, while Lilla Harrie Valskvarn is part of the Pågen bakery and provides this bakery with flour.

In Skåne, Pågen is the only industrial-sized bakery located in Malmö where bread, biscuits and muffins are produced[388]. The required yeast is produced on-site using unsold bread returned from the stores and rejected bread, biscuits and dough from the bakery.

[388] Engdahl, K., Tufvesson, L., Tufvesson, P. 2011. Bioraffinaderi Öresund - potentialstudie för produktion av kemikalier och bränsle. Environmental and Energy System Studies, Lund University.

The total amount of residues from this food industry sector were about 11,000 tonnes in 2011 (Table 139).

Table 139. Residual streams and by-products from bakeries/flour mills in Skåne, reproduced from Engdahl et al.[388]

Products	**Amount (2011) [t WW]**	**Used as**
Total production, flour and animal feed products	1,300,000	
By-products / residues		
Rejected and returned bread	8,400	Substrate for yeast production, pig feed
Rejected dough	1,000	Substrate for yeast production
Cereal screenings, husks	1,300	Combustion, biogas production

The primary production area of the main agricultural crops has been very stable over the past 10 years (Figure 103).

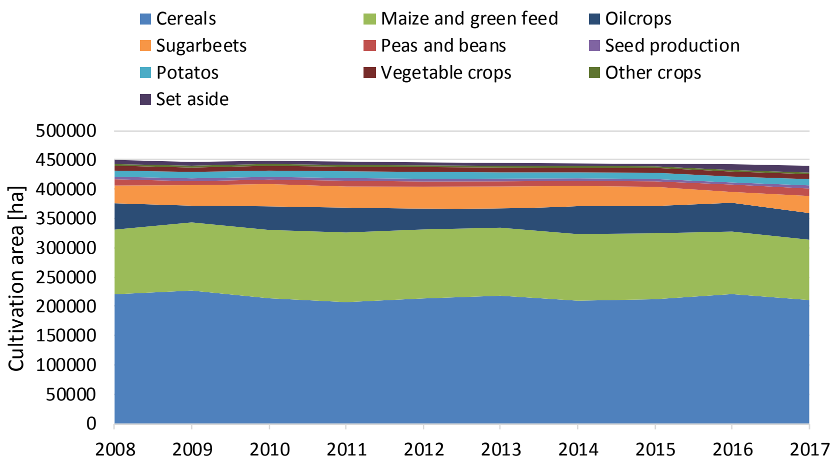

Figure 103. Cultivation area of the main crop groups grown in Skåne 2008-2017 based on official statistics[389].

The resulting primary production from these cultivation areas was relatively stable during 2008-2017 (Figure 104), except for sugarbeets for which production varied probably due to the abolishment of sugar quotas in 2017[390].

[389] SBA. 2018. Åkerarealens användning efter kommun och gröda, hektar. År 1981-2017, (Ed.) Swedish Board of Agriculture. Jönköping, Sweden.
[390] SBA. 2017. EU:s marknadsreglering för socker, Swedish Board of Agriculture. Jönköping, Sweden.

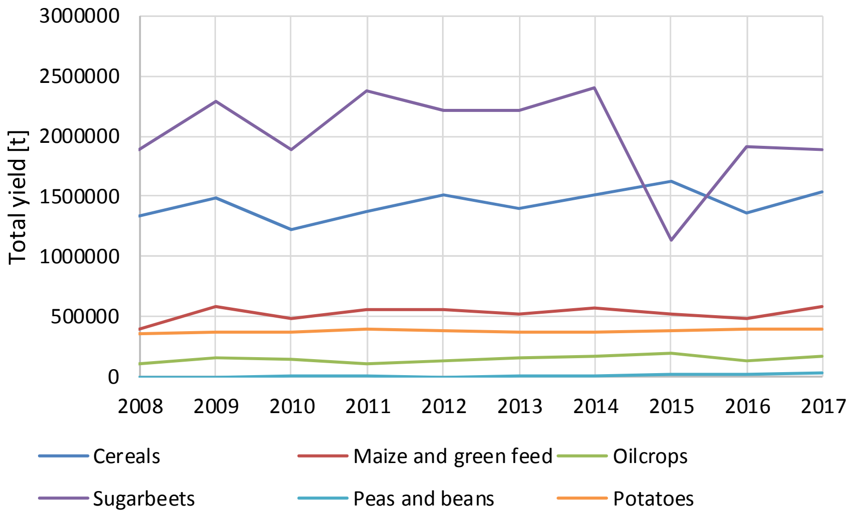

Figure 104. Total crop yields 2008-2018 in Skåne based on official statistics[391].

While total flour and hulled grains consumption has been relatively stable with the 1960´s, flour products have increase steadily since then (Figure 105). However, since 2010 increase in consumption of these products has slowed considerably and only increased by 1.6% from the period 2010-2012 to the period 2014-2016.

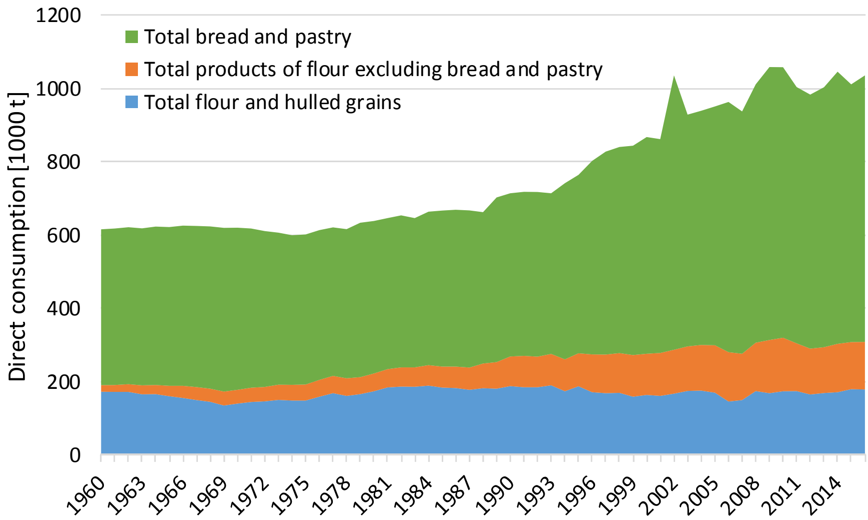

Figure 105. Consumption of flour and flour-based products in Sweden[392].

Fruit and vegetable processing

In Skåne, there are seven larger facilities where vegetables (mostly root crops) are processed. Typical residues include vegetable residues and peels, and in one case even frying oil from processing to semi-finished and fully finished food products. In 2011, these facilities produced about 42,000 tonnes of organic residues (Table 140). One of the larger food processing companies is Orkla Foods which has implemented a stringent sustainability policy to actively work with

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[391] SBA. 2018. Skördar efter län och gröda år 1965-2017, Swedish Board of Agriculture. Jönköping, Sweden.
[392] SBA. 2017. Livsmedelskonsumtion och näringsinnehåll - Uppgifter till och med 2016. Swedish Board of Agriculture.

reducing the amount of organic residues according to EU regulations. Two of the seven larger food processing facilities belong to Orkla Foods, the larger of which produces 16,400 tonnes organic residues from processing potatoes and other vegetables, as well as meat. Assuming a similarly large production today compared to in 2011 (compare Figure 104), this represent about 40% of the organic food residues occurring at processing plants in Skåne. In this facility, about 3,000-4,000 tonnes per year of potato peel and second-rate red beet are produced which are currently used as animal feed. Since these fractions can be kept separated from other organic residues, the company is looking for new ways of using these fractions as resources in food production[393].

Furthermore, there is one facility in Skåne producing juice, wine and cider, which has by-products from the fermentation processes for wine and cider. Organic residues from this facility contain fruit peel and seeds and other fruit residues.

Table 140. Residual streams and by-products from fruit and vegetable processing in Skåne, reproduced from Engdahl et al[394].

Products	**Amount (2011) [t WW]**	**Used as**
Total production, vegetables	240,000	
Fruit juices, wines and cider	43,000	
By-products / residues		
Peel, starch and potato residues	5,600	Fertiliser, wastewater treatment
Residues from vegetable processing, food waste, apple residues and onion peel	31,000	Fertiliser, animal feed, biogas production
Sludge	1,600	Fertiliser, biogas production
Fat separation sludge	2,400	Biogas production
Frying oil	90	
Fermentation residues	1,100	Soil improving products

For horticultural crops, production increased by 26% between 2008 and 2014 and has been relatively stable since (Figure 106).

[393] Lundahl, L. 2018. Amount of wastes and organic residues at Orkla Foods Sverige, pers. communication to T. Prade.
[394] Engdahl, K., Tufvesson, L., Tufvesson, P. 2011. Bioraffinaderi Öresund - potentialstudie för produktion av kemikalier och bränsle. Environmental and Energy System Studies, Lund University.

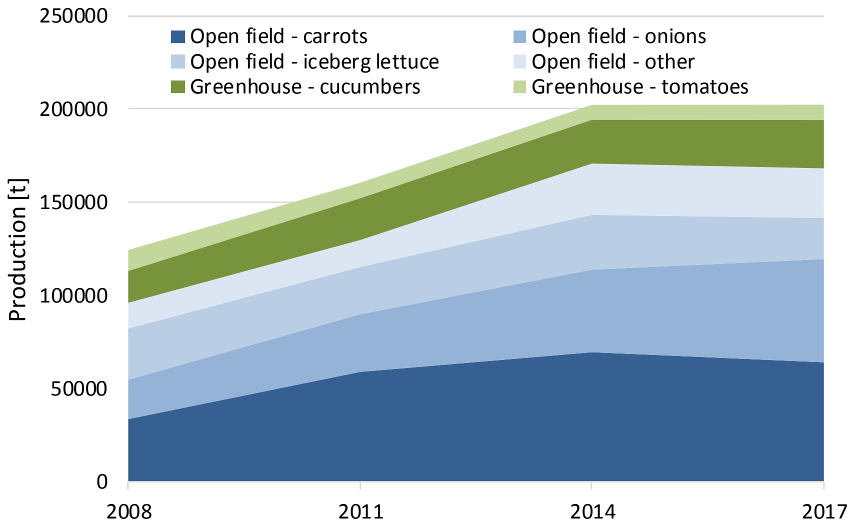

Figure 106. Open field and greenhouse production of horticultural crops 2008-2017 in Skåne based on official statistics[395-396].

Direct consumption of root vegetables and other vegetables has been increasing steadily since the 1960´s, with an increase of approx. 7.1% from the period 2010-2012 to the period 2014-2016 (Figure 107).

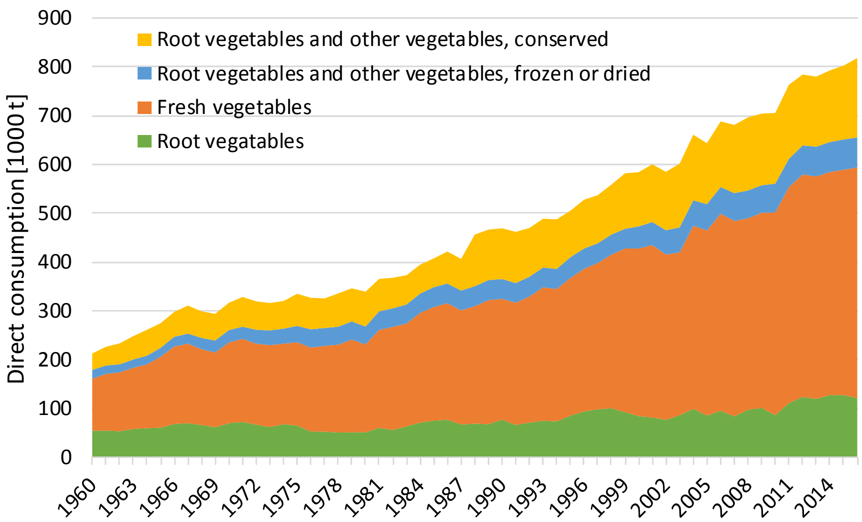

Figure 107. Direct consumption of root vegetables and other vegetables[397].

Direct consumption of potatoes and potato products has had a negative trend since the 1960´s, but increased by 5.3% from the period 2010-2012 to the period 2014-2016 (Figure 108).

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[395] SBA. 2018. Köksväxter i växthus. Antal företag, växthusyta, skördad mängd. År 1999, 2002-2017. Län/riket, Swedish Board of Agriculture. Jönköping, Sweden.
[396] SBA. 2018. Köksväxter på friland. Antal företag, areal, skördad mängd. År 1999, 2002-2017. Län/riket, Swedish Board of Agriculture. Jönköping, Sweden.
[397] SBA. 2017. Livsmedelskonsumtion och näringsinnehåll - Uppgifter till och med 2016. Swedish Board of Agriculture.

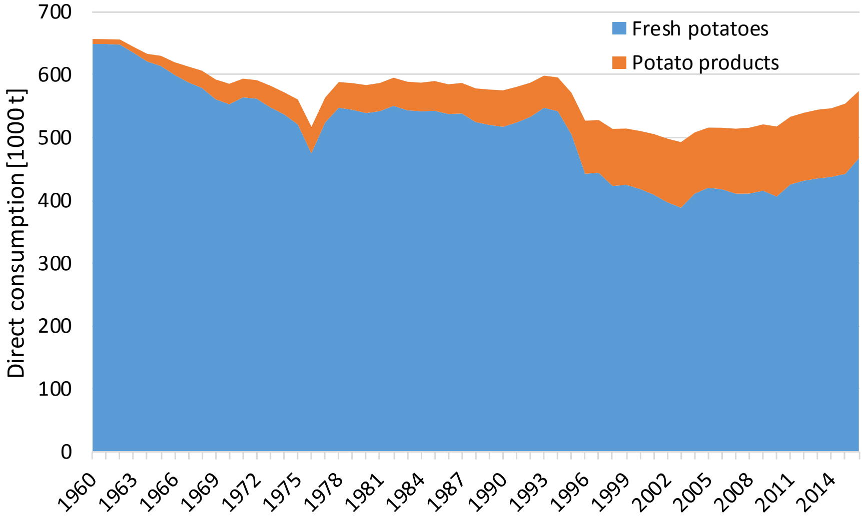

Figure 108. Direct consumption of fresh potatoes and potato products[397].

Direct consumption of fresh fruit and fruit products has increased steadily since the 1960´s, and increased by 7.2% from the period 2010-2012 to the period 2014-2016 (Figure 109).

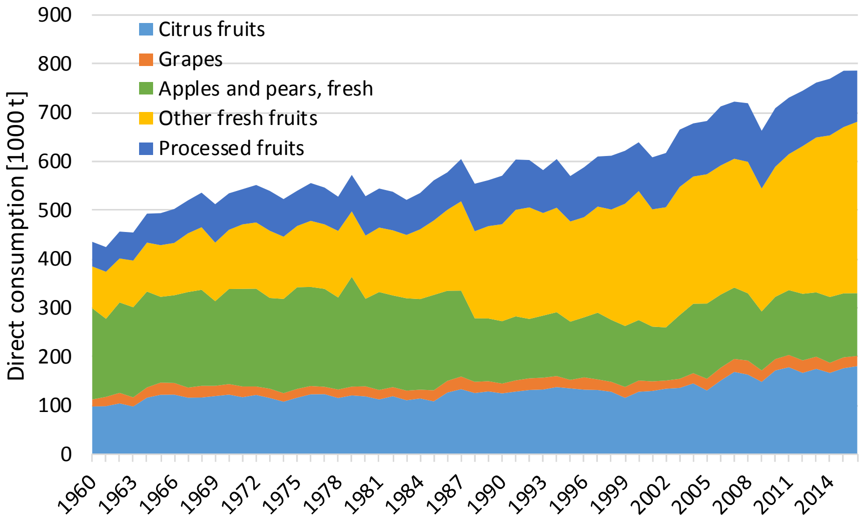

Figure 109. Direct consumption of fresh fruits and fruit products[398].

Dairies

In Skåne, there are five dairy production facilities located in Malmö, Kristianstad, Helsingborg, Dalby and Tomelilla. At one of the facilities, even fruit beverages are produced and residues from these processes are included in Table 141. A total of about 74,000 tonnes of residues are produced annually in Skåne and the Öresund region of Denmark.

[398] SBA. 2017. Livsmedelskonsumtion och näringsinnehåll - Uppgifter till och med 2016. Swedish Board of Agriculture.

Whey is a by-product from cheese production and usually contains a large fraction of proteins. Whey is processed to be used as animal feed or biogas production[399], but has also be used to produce milk replacements for infants or as food additive. Milk residues and fat sludge are often used for biogas production due to their high energy content. Dairies have expressed their ambition to decrease the production of these milk residues as far as they can be avoided[399]. Arla, a leading dairy in Europe, announced recently the investment of over 3 mill. Euros in an innovation centre to process whey as a food ingredient, with a second innovation centre facility inaugurated last year already[400].

Table 141. Residual streams and by-products from dairy facilities in Skåne, reproduced from Engdahl et al[401].

Products	**Amount (2011) [t WW]**	**Used as**
Total production, dairy products[a]	500,000	
By-products / residues		
Whey[b]	44,800	Pig feed, biogas production, milk replacement, food additive
Milk residues	16,000	Pig feed, biogas production
Fat separation sludge	490	Biogas production
Fatty acids	1,600	Food ingredient
Combined residues	5,300	Pig feed

[a] By-products from one dairy in Denmark were subtracted from the numbers in Engdahl *et al*[401].
[b] By-products from one dairy in Denmark were subtracted from the numbers in Engdahl *et al*[401].

Dairy production has been slightly decreasing in Sweden since 2011 (Figure 110). However, since most of the dairy production is located outside Skåne, this is assumed to have had no effect on the overall amount of residues and wastes from dairy production in Skåne. From the period 2010-2012 to the period 2014-2016, the number of milk cows in Sweden and Skåne has been decreasing by 1.3 and 4.8%, respectively, while the corresponding amount of milk used as raw material in dairy production has been increasing by 0.5%[402].

[399] Linné, M., Ekstrandh, A., Englesson, R., Persson, E., Björnsson, L., Lantz, M. 2008. Den svenska biogaspotentialen från inhemska restprodukter. Swedish Waste Management, Swedish Biogas Association, Swedish Gas Association, The Swedish Water & Wastewater Association.
[400] Schönning, O. 2018. Arla ska vaska guld ur vasslen. in: ATL, LRF media. Stockholm.
[401] Engdahl, K., Tufvesson, L., Tufvesson, P. 2011. Bioraffinaderi Öresund - potentialstudie för produktion av kemikalier och bränsle. Environmental and Energy System Studies, Lund University.
[402] SBA. 2018c. Mejeriproduktion. År 1995-2017, Swedish Board of Agriculture. Jönköping, Sweden.

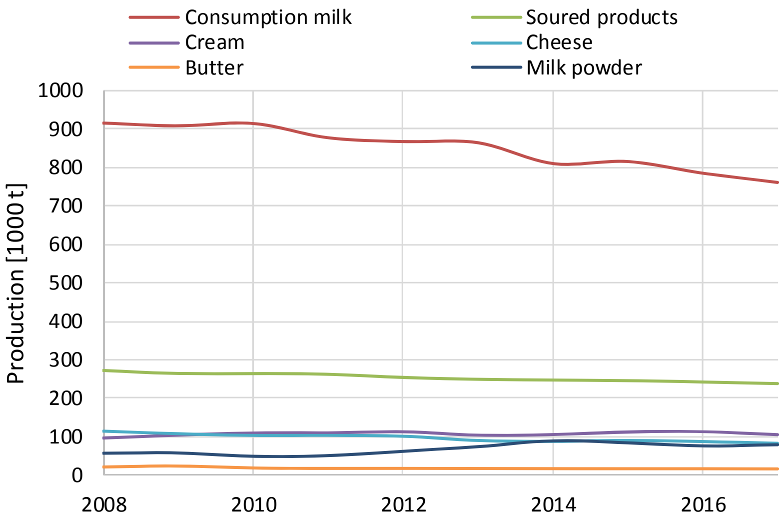

Figure 110. Dairy production 2008-2017 in Sweden based on official statistics[402].

During 2010 to 2017 the share of milk cows in Skåne in the total number of Swedish milk cows has been varying between 11.2 and 11.8% and – assuming an even milk productivity –milk production in Skåne has been varying between 320,000 and 335,000 tonnes/a.

Slaughterhouses and meat processing factories
In Skåne there are six larger facilities that process animals for food and/or slaughterhouse residues, e.g. for production of animal feed and gelatine. For the processing of animal by-products (ABP), EU regulations have to be complied with in order to avoid spreading of diseases like BSE and food and mouth disease[403]. Animal by-products are grouped into three categories of which categories 2 and 3 can be used for composting, biogas production or e.g. production of chemicals. Category 1 residues are considered specified risk material, which also includes material from international transports, and which needs to be combusted. Category 2 materials include among others manure and rejected animal materials, which require sanitissation by a thermal treatment. Category 3 includes animal residues that are not part of categories 1 and 2, e.g. waste from the food industry and food returned from the stores. Also, these materials need to be sanitised[404]. The total amount of residues amounted to about 45,000 tonnes annually in Skåne and the Öresund region in Denmark, with sludge, blood spill and intestine content as the major contributor (Table 142).

Table 142. Residual streams and by-products from slaughterhouse facilities in Skåne, reproduced from Engdahl et al[405].

By-products	Amount (2011) [t WW]	Used as
Category 3	3,700	Biogas production
Sludge, blood spill, stomach and intestine content[a]	37,000	Biogas production, fertiliser
Intestine package	2,500	Biogas production
Rejected products and raw materials	220	
Fat separation sludge	1,300	

[a] Includes also by-products from one slaughterhouse in Denmark.

403 Regulation No 1069/2009 laying down health rules as regards animal by-products and derived products not intended for human consumption. European Commission. Brussels, Belgium.
404 Regulation No 852/2004 on the hygiene of foodstuffs. European Commission. Brussels, Belgium.
405 Engdahl, K., Tufvesson, L., Tufvesson, P. 2011. Bioraffinaderi Öresund - potentialstudie för produktion av kemikalier och bränsle. Environmental and Energy System Studies, Lund University.

Meat production has been relatively stable over the period 2008-2017 in Sweden, a total increase of 1.2% (Figure 111). However, pig production has decreased 11% while poultry production has increased 33% in the same period. Egg production has increased by 26% during 2008-2017[406].

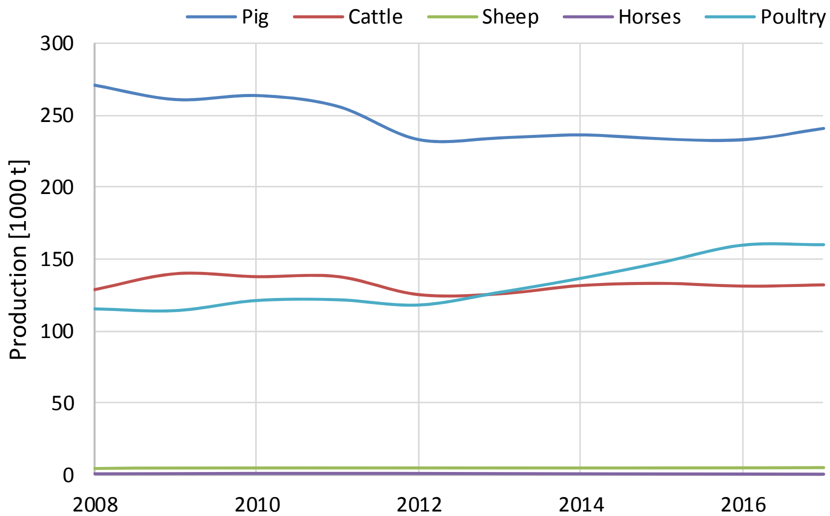

Figure 111. Amounts of slaughtered animals for meat production 2008-2017 in Skåne based on official statistics[407-408].

Fishing industry and other aquatic biomass

Residues from the fishery industry in Skåne occur either on-board fishing ships or in fish processing plants. A large proportion of fish is cleaned already on the ships and residues are discarded directly into the sea[409]. Atlantic cod are gutted on the ships, while the head is removed first in the processing facility. Flatfish are usually cleaned on the ship. In Skåne, there are three fish processing facilities under the roof of one company. All residues from Atlantic herring and cod processing are milled and frozen for use as animal feed, amounting to 3,000-4,000 tonnes per year.

Based on official statistics for fish caught and landed to the whole of Sweden, the amount of residues from processing the fish on-board the vessels was calculated using species-specific conversion factors[410]. During 2014-2018 on average 163,000 tonnes of fish for human consumption were caught and landed annually (Figure 112). This corresponds to 84% of the total catch, the remaining 13% represent fish used as bait and for production of fish meal and oil and represents also non-fish species. Atlantic herring and European sprat represent 94% of the fish to be processed as food. Since processing of these fish species exclusively happens on land, the residues (representing 97% of all residues from food fish processing) will become available only at fish processing plants. Fish landed to the Swedish south coast (Skåne and Blekinge) amounted to approx. 18,000 tonnes annually during 2014-2018.

Residues that occur during on-board processing and which potentially can be landed in Skåne and Blekinge county amount therefore to approx. 600 tonnes wet weight annually, representing ca 60% of the on-board residues occurring for fish landed in the whole of Sweden. These residues (~42%

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[406] SBA. 2018d. Partihandelns invägning av ägg. År 1995-2017, Swedish Board of Agriculture. Jönköping, Sweden.
[407] SBA. 2018f. Slakt av fjäderfä vid slakteri. År 1995-2017, Swedish Board of Agriculture. Jönköping, Sweden.
[408] SBA. 2018g. Slakt av större husdjur vid slakteri. År 1995-2017, Swedish Board of Agriculture. Jönköping, Sweden.
[409] Bucefalos. 2014. Biogaspotential från akvatiska substrat i Skåne - delrapport 1 - Alger på stränder och fiskrens. Region Skåne.
[410] Ericsson, J. 2018. Swedish sea-fisheries during 2017. Statistics Sweden.

dry matter content) have been shown to be rich in fat (28.9%) and protein (10.6%) and further contain about 1.3% carbohydrates and 1.0% minerals[411].These residues used to be discarded at sea. However, a landing obligation agreed upon in 2013 in the European Union, aims at reducing by-catches and improving data on actual catches as a driver for higher fishing selectivity and better planning[412]. When implemented (as planned for in the period 2015-2019), this will likely increase the amounts of fish screenings and residues available at land.

For the residues occurring at fish processing plants, considerations for import and export of fish (including from aquaculture) have to be considered. In 2011-2013, residues from fish processing in Sweden amounted to approx. 63,000 tonnes wet weight annually[413]. For 2011, the amount of residues in Skåne were estimated to 4,300 tonnes fish screenings and 1,600 tonnes fat-rich sludge. The amount of fish landed in Sweden has increased by ca 10% from the period 2011-2013 until the period 2014-2018, while the share of fish landed at the Swedish south coast decreased by ca 50% in the same comparison. The amount of fish screenings and fat-rich sludge produced in Skåne is therefore likely about 45% smaller assuming no change in contribution from different fish species to the total catch.

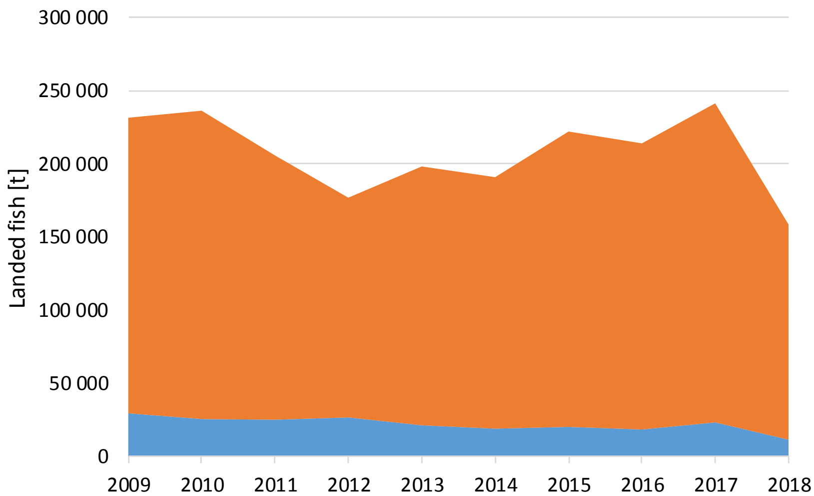

Figure 112. Fish landed in Sweden (orange) and at the Swedish south coast (blue) based on official statistics[414]

Besides residues from the fishing industry and the fish processing industry, aquatic resources in Skåne include algae and seagrass. Due to an increasing problem of eutrophication along Skånes coastal waters, macro algae (green, red and brown algae) and seagrass are abundant along the coast and are continuously washed upon the beaches, constituting a problem for the tourist industry. Many municipalities remove this biomass and put in on pile close the beach. Biogas use of this biomass has been suggest[415].

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[411] Carlsson, M., Uldal, M. 2009. Substrathandbok för biogasproduktion. Swedish Gas Centre.
[412] EP. 2013. Regulation (EU) No 1380/2013, (Ed.) European Parliament and of the Council, Vol. 1380/2013. Brussels, Belgium.
[413] Bergman, K. 2015. Co-products in the Swedish Seafood Processing Industry - Quantification and present uses. Department of Biological and Environmental Sciences, University of Gothenburg
[414] HVM. (2018). "Fångststatistik för yrkesfisket." Retrieved 28 Aug 2018, from https://www.havochvatten.se/hav/samordning--fakta/data--statistik/fangststatistik-yrkesfisket.html.
[415] Bucefalos. 2014. Biogaspotential från akvatiska substrat i Skåne - delrapport 1 - Alger på stränder och fiskrens. Region Skåne.

A survey from 2014 in the same study revealed a potential of about 64-83,000 tonnes wet weight, depending on if the aquatic biomass is collecting even in nature conservation areas or not, at a density of approx. 375 kg/m^2. The amount of biomass on the beach ranged between 0 and 2,600 tonnes wet weight per kilometre of beach with an average of approx. 600 t/km. The biogas potential of the total biomass was estimated to be 18.6 GWh/a.

Table 143. Products as well as residual streams and by-products from fishery and fish processing facilities in Skåne and Blekinge as wells as other aquatic biomass in Skåne. Numbers for fish screenings and sludge reproduced from Engdahl et al.

Products	**Amount [t WW]**	**Used as**
Total production, processed fish	18,000	
By-products		
Fish screenings	3,000-4,000[a]	Animal feed
Fat-rich sludge	900[a]	Biogas production
Additional fish residues	600	Currently discarded at sea
Algae and seagrass	64,000-83,000	Currently not collected

[a] From processing plants in Skåne.

Breweries

There are no large-scale breweries in Skåne, however, there are more than 30 microbreweries, typically with low production ranging between 25,000 and 250,000 litres per year. Typical residues from breweries include brewer´s spent grain (BSG), which composes the major fraction of the residues as well as residues of hop, wort and yeast. The typical range of residue production is about 5-80 tonnes per year. Assuming an average of 30 tonnes of brewing residues per microbrewery, the total amount of residues would be around 1000 tonnes annually. The residues are either used as animal feed (either on the own farm or sold/donated to other organisations) or biogas substrate. Many microbreweries avoid registration as animal feed producer, primarily due to costs and barriers such as hygienic requirements for feed storage. Some of the breweries that are registered feed producers have difficulties to find recipients, probably due to the low animal density in Skåne. Especially the minor fractions are often discarded in the drain.

Table 144. Residual streams and by-products from microbreweries in Skåne.

Products	**Amount (2018) [t WW]**	**Used as**
Total production, produced beer	Approx. 33,000,000 litres	
By-products		
Brewer´s spent grain	1,000	Animal feed, biogas substrate, compost

Starch industry

There are two companies processing potatoes, maize and tapioca for starch production in Skåne, Lyckby Starch and Avebe Stadex. Lyckaby has one processing facility for starch potatoes in Skåne that together with three other starch-producing facilities in the neighbouring county Blekinge processes potatoes for starch production. The company buys most of the about 300,000 tonnes of starch potatoes produced annually in Sweden, i.e. in the counties of Skåne, Blekinge and Kalmar. About 75%, or 220,000 tonnes of the starch potatoes in are processed in the facility in Skåne. Both food starch (40,000 tonnes/a) and industrial starch products (33,000 tonnes/a) are produced (Table 145).

During processing of the potatoes, about 70% of the potatoes mass is collected as potato fruit juice, which is used to extract proteins for animal feed. 100,000 tonnes of fruit juice (with a dry matter content of 3%) from about 150,000 tonnes potatoes are concentrated to 37% dry matter content and sold as certified-organic fertilizer. The 90,000 tonnes of evaporated water are condensed and reused in the process. About 2% of the potato mass is cellulose extracted as pulp, of which about 1/3 can be extracted as fibres for use as food ingredient. Avebe Stadex produces about 26,000 tonnes of food grade starch derivatives annually, using potatoes, maize and tapioca roots as feedstocks.

Table 145. Main products and by-products from the starch industry in Skåne and Blekinge.

Products	Amount[t WW]	Used as
Total production, food starch	76,000	
Total production, industrial starch	33,000	
By-products		
Fibers	1,000[a]	Food ingredient
Protein	2,600[a]	Animal feed
Concentrated potato juice	9,000[a]	Organic fertiliser

[a] Data for Lyckeby starch only.

The area and total yield of starch potatoes cultivation in Skåne have been increasing from the period 2010-2012 to the period 2014-2016 by 3.7 and 14.8%, respectively, during 2008-2017, Figure 113, suggesting a potential increase of residues and by-products from starch production in Skåne.

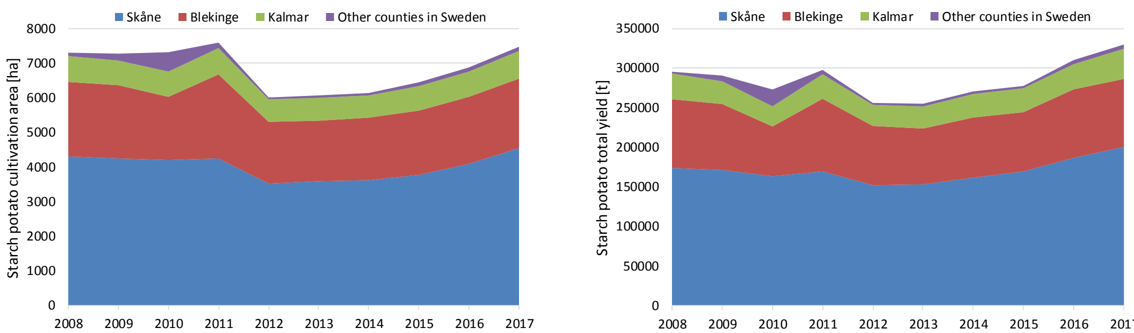

Figure 113. Cultivation area (left) and total yield (right) of starch potatoes in the counties of Skåne, Blekinge, Kalmar and Sweden in total 2008-2018 based on official statistics[416]

Ethanol industry

Absolut Vodka produces ca. 100 million litres of alcoholic beverages (45 million litre pure ethanol) annually in Skåne, most of which is exported globally. The production uses typically 110,000-115,000 tonnes of winter wheat grains[417]. Production of each litre of vodka results in 4 litres of stillage with a DM content of 8-9%[417], which makes stillage the main by-product. Since wheat is used for the process, the stillage is rich in fibres and proteins and it is used as animal feed in the production of approx. 250,000 pigs and 40,000 cows annually. From the distillation, reject alcohol containing alcohols heavier and lighter than ethanol are collected and used as carbon course for biotechnological processes. Both by-products therefore contribute as raw materials for other production systems and have an economic value to the company.

[416] SBA. 2017. Totalskörd och hektarskörd efter region, gröda och år 1965-2017, Swedish Board of Agriculture. Jönköping, Sweden.
[417] Olsson, T. (2018). Restprodukter Absolut. Personal communication to T. Prade. Åhus, Sweden, The Absolut Company AB.

Table 146. Main products and by-products from the ethanol industry in Skåne 2017.

Products	**Amount [t WW]**	**Used as**
Total production, alcoholic beverages	94,000	
By-products		
Stillage	370,000	Animal feed
Reject alcohol	700-800	Carbon source in microbiological processes

Household food residues

Collection of food waste from households is part of the EU goal of reducing the amounts of organic residues ending up in dumps and other household waste. In Sweden, a national goal of 50% collection of food residues from households, restaurants, large kitchens and shops and an energy recovery from 40% of these collected residues was decided on in 2012 with the aim to reach this goal by the end of 2018. In 2016, 86% of the households in Skåne had separate collection of household food waste, while in Blekinge, Kronoberg and Kalmar the corresponding shares were 78, 41 and 65%, respectively[418].

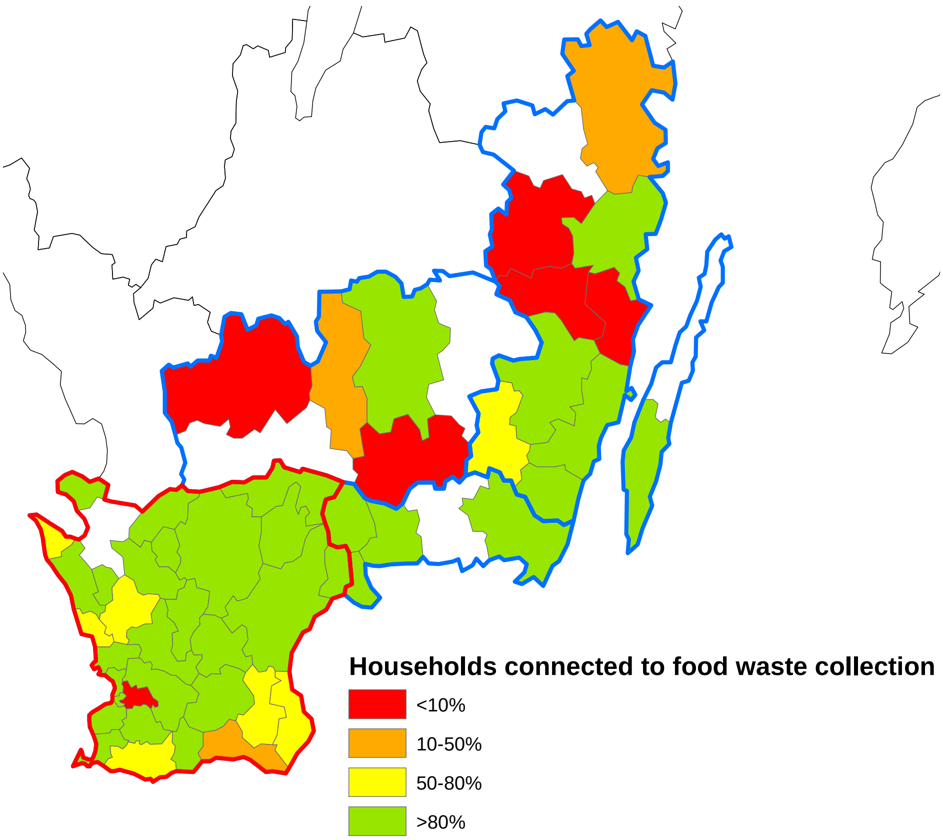

Figure 114. Households connected to food waste collection in municipalities in Skåne (red) and in the other Swedish SBA regions (blue). White colour within the SBA regions denotes missing data. Data adopted from Westin (2017)[418].

[418] Westin, J. 2017. Hushållsavfall i siffror - kommun och länsstatistik 2016. Avfall Sverige.

In the SBA regions in Sweden, Blekinge leads the collection of food waste with 60 kg/person, followed by Skåne (50 kg/person), Kronoberg (30 kg/person) and Kalmar (26 kg/person)[418]. It is up to each municipality to implement these regulations by building systems for collection of organic materials, a work which was progressed varying degree in different municipalities of Skåne. Waste collection in Skåne is organised by a total of nine different companies serving between 1-14 municipalities and between 12,700 and 750,000 people (Figure 115).

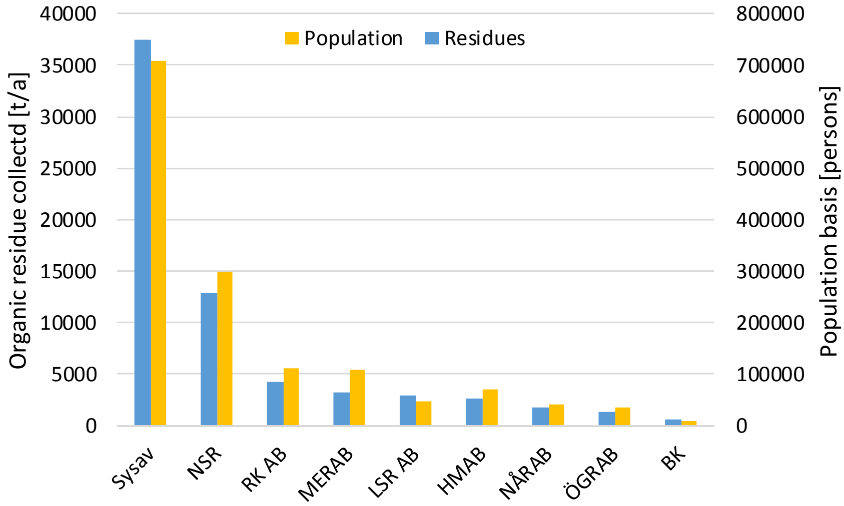

Figure 115. Collection of organic residues [t/a] and corresponding population basis [persons] for the nine waste handling companies in Skåne.

All nine companies deliver the household food waste to biogas plants at different sizes using different digestion processes. That way, both energy and plant nutrients are recovered and recycled to agriculture. In Skåne, 95% of the collected household food waste are treated in a biogas process assuring a high degree of energy and plant nutrient recovery (Figure 116).

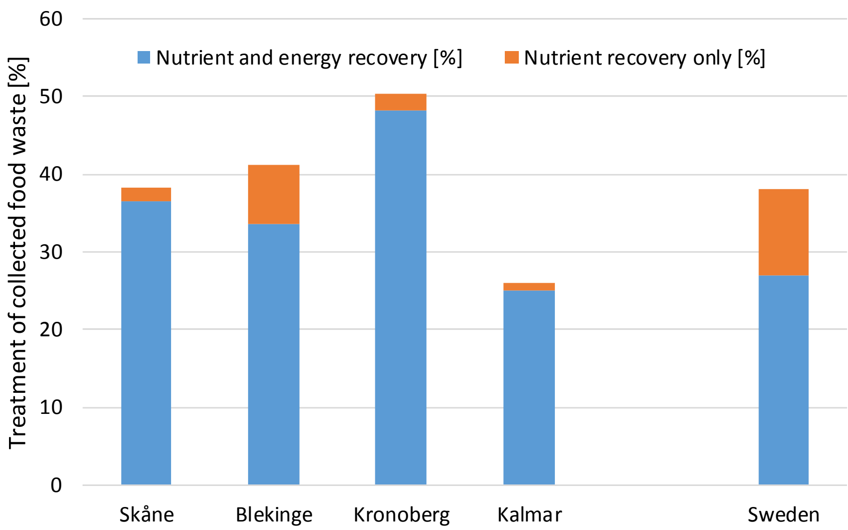

Figure 116. Treatment of collected household food waste in the SBA region and Sweden as a total. Data adopted from Westin (2017)[418].

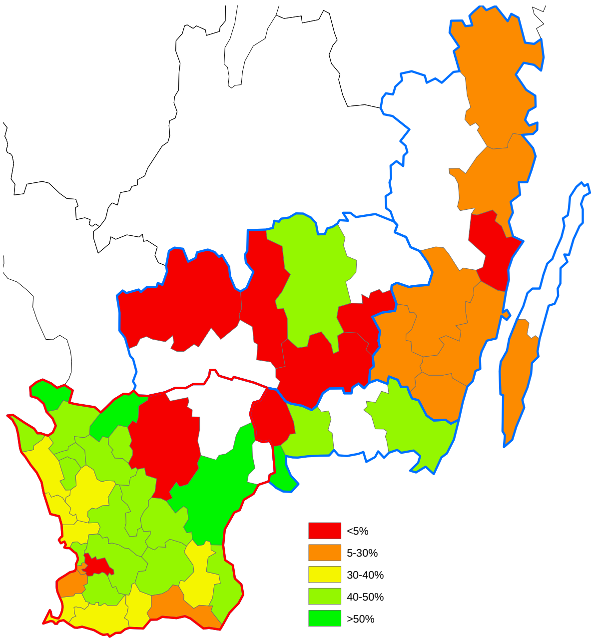

Figure 117. Nutrient and energy recovery in Skåne (red) and the other Swedish SBA regions (blue) in 2016. White colour within the SBA regions denotes missing data. Data adopted from Westin (2017)[418].

Industrial collection of food and restaurant residues

Besides separation of food residues in the household residual streams, food residues are collected from food stores, large kitchens and restaurants (Figure 118).

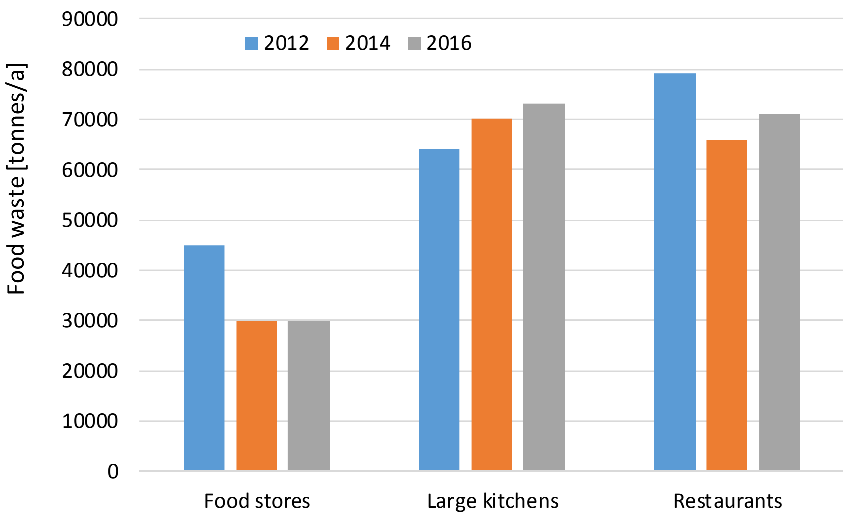

Figure 118. Food waste collected from food shops, large kitchens and restaurants in Sweden[419].

[419] Westöö, A.-K., Jensen, C. 2018. Matavfall i Sverige - Uppkomst och behandling 2016. Swedish Environmental Protection Agency.

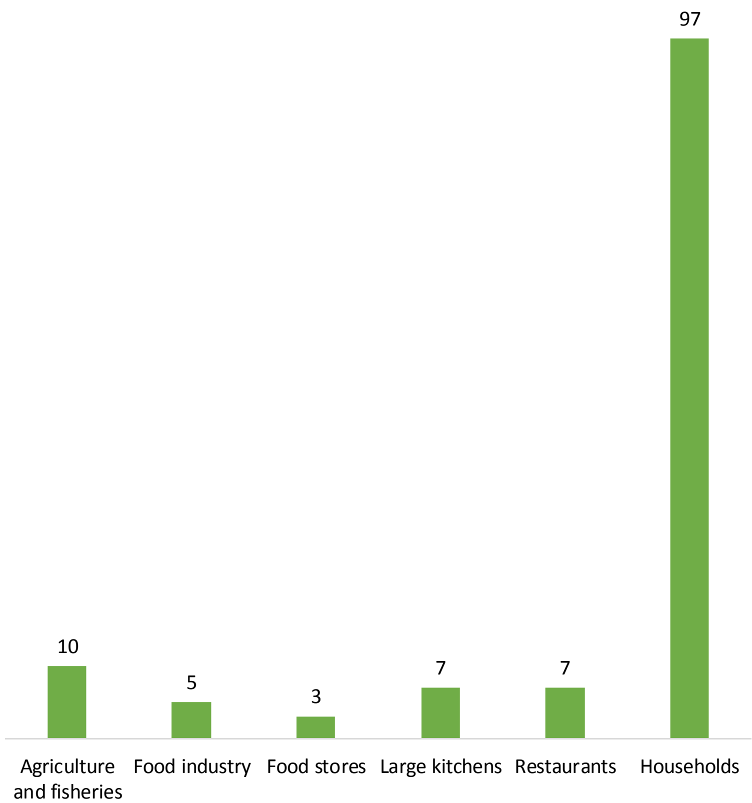

Figure 119. Food waste collected [kg/capita] for different sources[420]

Manure

The total amount of manure and slurry in Skåne 2016 was about 400,000 tonnes dry matter (Figure 120) corresponding to 4.69 million tonnes wet weight, reflecting the dominating management as slurry. From the period 2007-2010 to the period 2013-2016, manure production in Skåne has deceased with 2.3% in total.

The potential of manure from animal husbandry has been evaluated earlier as a feedstock for biogas production. For Skåne, an energy potential of 450 GWh/a based on manure was estimated in 2011, of which about half originated from slurry and half from solid manure[421].

[420] Food waste in Sweden 2016

[421] Björnsson, L., Lantz, M., Murto, M., Davidsson, Å. 2011. Biogaspotential i Skåne. Länsstyrelsen i Skåne län.

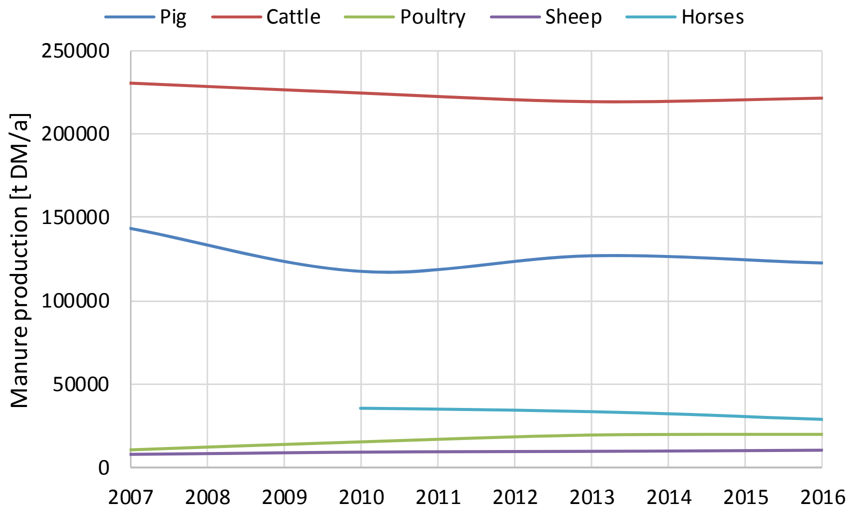

Figure 120. Amount of slurry and manure dry matter (DM) in Skåne 2007-2016 based on number of animals, amounts of manure typical for different animals and characteristics of manure for different manure management systems[422, 423].

422 SJV. 2011. Föreskrifter om ändring i Statens jordbruksverksföreskrifter och allmänna råd (SJVFS 2004:62) om miljöhänsyn i jordbruket vad avser växtnäring. Swedish Board of Agriculture.
423 SJV. 2017. Husdjur efter kommun och djurslag 1981-2016 JO0103G6, Swedish Board of Agriculture. Jönköping, Sweden.

2.4.5 Summary and outlook

There are large amounts of residues available from the food industry and the from household food waste collection. We present a comparison for four larger fractions of these residues.

Considerable amounts of animal waste from slaughterhouses are available in all SBA regions (Figure 121). Alothough data do not include the regions West Pomerania and Warmia and Mazury in Poland, the amount of residues in Poland are highest among the four SBA regions.

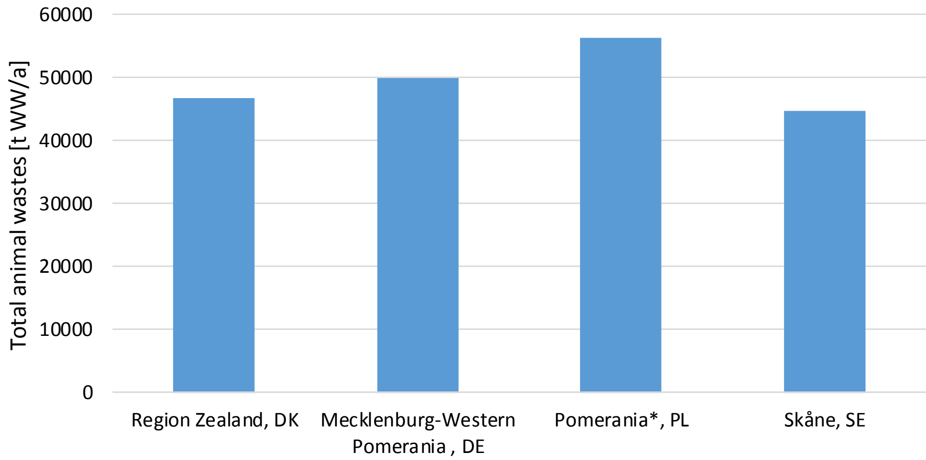

*Figure 121. Total animal wastes in the four SBA regions. * Data for regions West Pomerania and Warmia and Mazury, Poland, is missing.*

Due to a very high milk production and low fraction of by-products, Skåne show a considerably higher potential, around 70,000 tonnes wet weight per year, compared to the other SBA regions (Figure 122). The Polish SBA regions still have a large potential of residues from dairies, around 50,000 tonnes wet weight per year. Whey represents the major proportion of the residues.

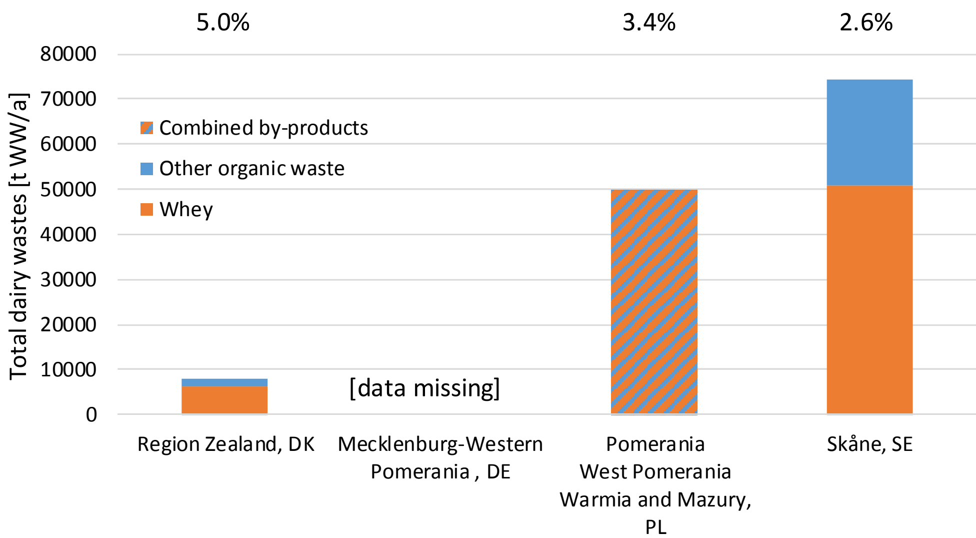

*Figure 122. Dairy residues in the four SBA regions. Numbers above the columns refer to proportion of residues relative to total milk production. * Data for Mecklenburg-Western Pomerania is missing.*

In terms of brewery by-products, substantial amounts are available from two large breweries and one malting company in the Danish SBA region (Figure 123), which amount to circa 58,000 tonnes per year. In the German SBA region, fiver smaller breweries co-produce approx. 25,000 tonnes per year of residues. In comparison in the Swedish and Polish SBA regions, only microbreweries exist that produce residues. Almost all residues from both large-scale and micro breweries are used as animal feed or as a feedstock in biogas production. Of the Danish by-products, about 70% are spent grain, 20% are yeast residues and 10% are husks.

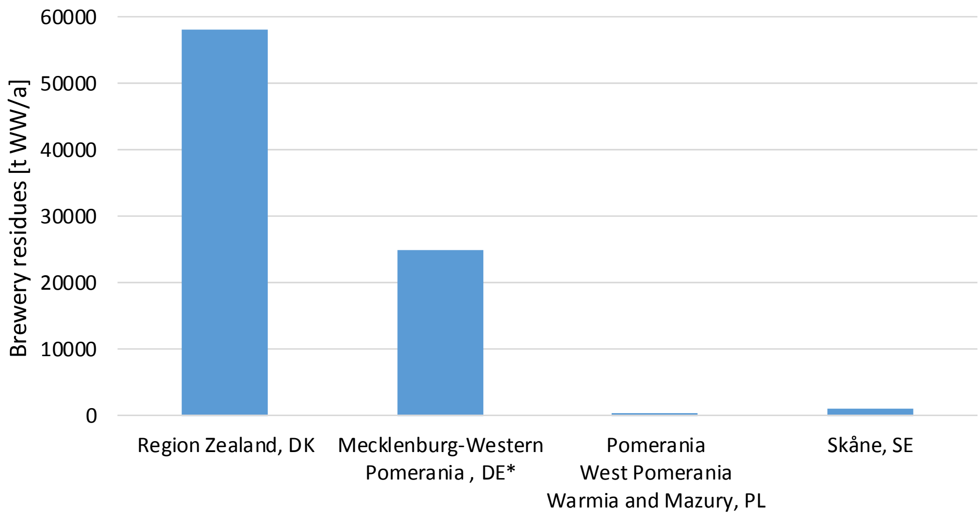

*Figure 123. Brewery residues in the four SBA regions. * Data for Mecklenburg-Western Pomerania was calculated on the basis of 1.59 million hectolitre beer production[424] and amass fraction of 15.7% of residues on total beer production similar to Danish production data.*

Another large fraction of by-products and residues is household food waste as separated from household waste. The food waste potentials vary between 50,000-110,000 tonnes per year of food waste in the four SBA regions (Figure 124). Also, the share of how much of the potential that is collected varies strongly between 39% in Mecklenburg-Western Pomerania and 86% in Skåne.

[424] http://www.ostsee-zeitung.de/Nachrichten/MV-aktuell/Brauereien-in-MV-verkaufen-mehr-Bier-gegen-den-Trend

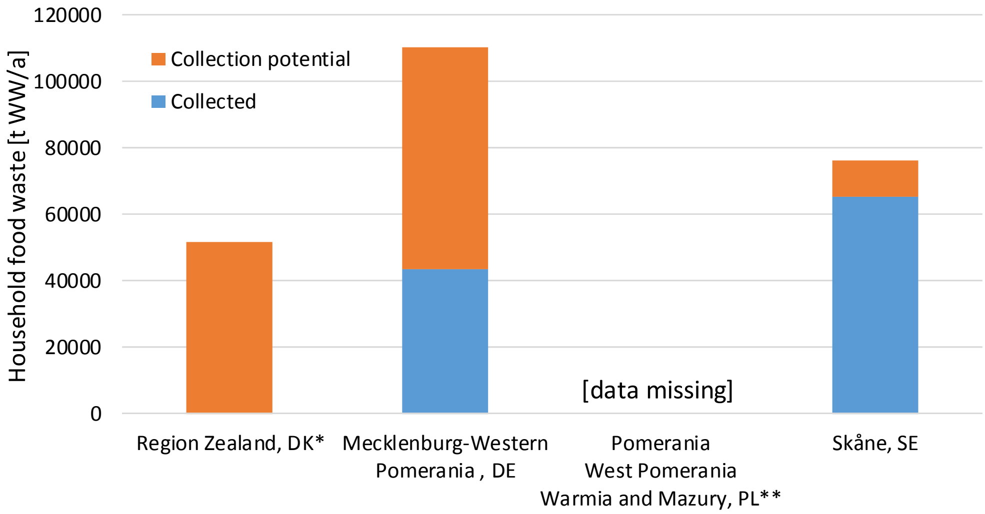

*Figure 124. Collection potential and collected amounts of household food residues in the four SBA regions. * Data for collected amounts missing for Region Zealand. ** Data for the Polish SBA regions is missing.*

Opportunities

Animal waste

Sludge, blood spill and intestine content are the fraction of animal wastes occurring in slaughterhouses. These residues are termed waste as part of the EU regulations that aim to avoid spreading of diseases like BSE and food and mouth disease from animal by-products. Animal residues are grouped into three categories of which Category 1 residues are considered specified risk materials (SRM), which also includes material from international transports, and which need to be combusted. Category 2 materials include among others manure and rejected animal materials, which require sanitissation by a thermal treatment. Category 3 includes animal residues that are not part of categories 1 and 2, e.g. waste from the food industry and food returned from the stores.

Due to the recent emergence of bovine spongiform encephalopathy (BSE), most of the traditional uses of rendered animal meals such as blood meal, meat and bone meal (MBM) as animal feed, pet food or fertilizer were eliminated with significant economic losses for the entire sector[425]. Residues within Categories 2 and 3 can be used for composting, biogas production or e.g. production of chemicals, but need to be sanitised.

Hydrolysis of keratins from animal hair and wool, horns, claws, hooves, feathers and scales representing animals groups of mammals, birds, fish, reptiles, and amphibians, could be used for production of nitrogenous fertilizer and animal feed) and its fermentation broth could be useful in leather industry and textile industry[426].

Animal manure and fecal sludge have been suggested as feed for insect production, where e.g. fly larvae are used to treat the organic residues and the harvested larvae could be used as animal feed or

[425] Mekonnen, T., P. Mussone and D. Bressler (2016). Valorization of rendering industry wastes and co-products for industrial chemicals, materials and energy: review. Critical Reviews in Biotechnology 36(1): 120-131.
[426] Kumawat, T. K., A. Sharma, V. Sharma and S. Chandra (2018). Keratin Waste: The Biodegradable Polymers.

for production of secondary products (biodiesel, biologically active substances)[427]. Also protein extraction from these materials has been suggested almost 40 years ago[428].
But also specified risk materials (Category 1) could be used for innovative products, such as development of an environmentally friendly protein-based plywood adhesive with an improved water resistance property[429]. Even other protein-based products have been suggested, including o bio-based plastics, flocculants and surfactants and fire fighting foams[425]. The fat fraction could be valorized into products and co-products that are utilizable in the biodiesel and oliochemical industries[425].

Dairy residues

Dairy wastes, generally, have suspended solids and organic matter, high content of nitrogen and phosphorous and the presence of oil and greases. Furthermore, they can contain residues of the cleaning products used in utensils and equipment cleaning[430]. Dairy residues include mainly whey protein, milk residues and fat sludge. For the milk residue, dairies have expressed their ambition to decrease the amount of residues as far as they can be avoided[399]. Milk residues and fat sludge are often used for biogas production due to their high energy content. However, fermentation of these residues for the production of neutracuetical and supplements has been suggested. In the fermentation step, microbial-driven release of functional ingredients is desired and the harvested products as expected to have e.g. antioxidant, antimicrobial, immunostimulatory, antidiabetic, anticancer, antihypertensive, anticoagulant, calcium-binding, hypocholesterolemic and appetite suppression effects[431].

Whey, a by-product from cheese production, is rich in proteins. The residual product can be fractionalised into lactose, whey proteins as whey protein concentrate, lactalbumin and lactoglobulin[432], which are products commercialized in the food and pharmaceutical industries. Arla, a leading dairy in Europe, announced recently the investment of over 3 million Euros in an innovation centre to process whey as a food ingredient, with a second innovation centre facility inaugurated last year already[433].

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[427] Čičková, H., G. L. Newton, R. C. Lacy and M. Kozánek (2015). The use of fly larvae for organic waste treatment. Waste Management 35: 68-80.
[428] Cooper, R. N. and C. F. Denmead (1979). Chemical Treatment of Slaughterhouse Wastes with Protein Recovery. Journal (Water Pollution Control Federation) 51(5): 1017-1023.
[429] Adhikari, B. B., V. Kislitsin, P. Appadu, M. Chae, P. Choi and D. C. Bressler (2018). Development of hydrolysed protein-based plywood adhesive from slaughterhouse waste: effect of chemical modification of hydrolysed protein on moisture resistance of formulated adhesives. RSC Advances 8(6): 2996-3008.
[430] Ahmad, T., R. M. Aadil, H. Ahmed, U. u. Rahman, B. C. V. Soares, S. L. Q. Souza, T. C. Pimentel, H. Scudino, J. T. Guimarães, E. A. Esmerino, M. Q. Freitas, R. B. Almada, S. M. R. Vendramel, M. C. Silva and A. G. Cruz (2019). Treatment and utilization of dairy industrial waste: A review. Trends in Food Science & Technology 88: 361-372.
[431] Patel, S. and S. Shukla (2017). Chapter 30 - Fermentation of Food Wastes for Generation of Nutraceuticals and Supplements. Fermented Foods in Health and Disease Prevention. J. Frias, C. Martinez-Villaluenga and E. Peñas. Boston, Academic Press: 707-734.
[432] Pescuma, M., E. M. Hébert, F. Mozzi and G. Font de Valdez (2008). Whey fermentation by thermophilic lactic acid bacteria: Evolution of carbohydrates and protein content. Food Microbiology 25(3): 442-451.
[433] Schönning, O. 2018. Arla ska vaska guld ur vasslen. in: ATL, LRF media. Stockholm.

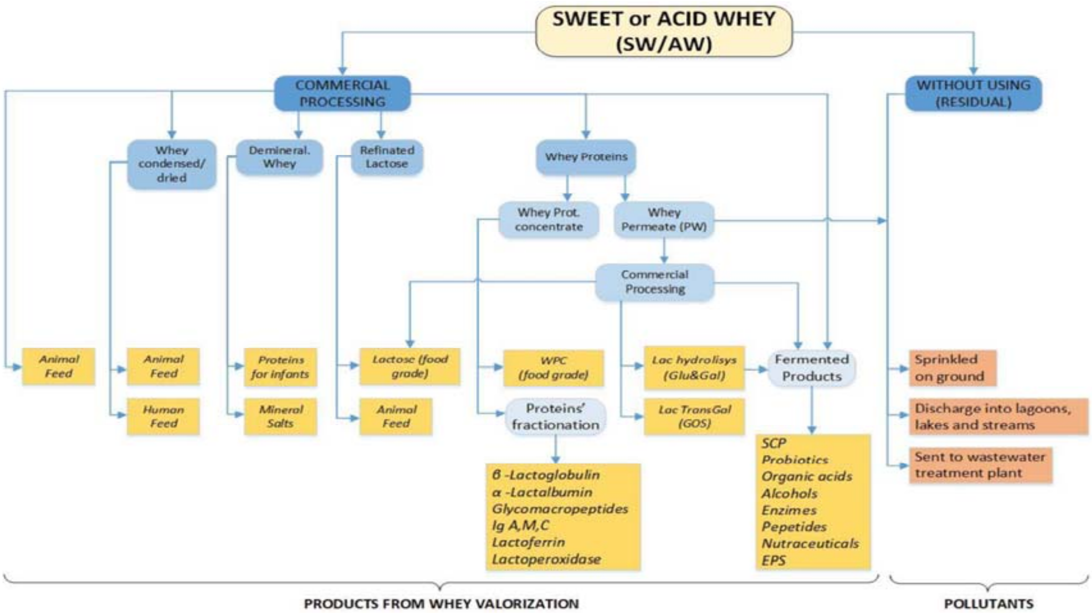

Figure 125. Potential uses of milk whey[434]

Whey and its protein concentrate are used as ingredients in the food industry mainly due to their foaming and emulsifying properties[435]. Furthermore, whey proteins provide a way to fortify foods, increasing the nutritional quality of cheese, dairy desserts and bakery products[435]. Production of beverages through lactic fermentations, providing desirable sensory profiles, has been pointed out as an option to add value to whey[436]. For instance, a whey-based kefir beverage with strong bacterial inhibitory properties that also contains potentially probiotic microorganisms has been demonstrated[437]. Other fermentation-based products using whey as sustainable substrate include e.g. biofuels such as ethanol and butanol, single cell protein, organic acids such as lactic acid, propionic acid and succinic acid, enzymes, bioactive peptides as nutrional supplements, polysaccharides such as xanthan gum, exopolysaccharides (EPS), biosurfectants such as sophorolipids as well as polyhydroxyalkanoates (PHA), e.g. polyhydroxybutyrates (PHB)[333].

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[434] Pais Chanfrau, J., J. Núñez Pérez, M. Lara Fiallos, L. Rivera Intriago, V. Abril Porras, M. Cuaran Guerrero and L. Trujillo Toledo (2017). Milk Whey- From a Problematic Byproduct to a Source of Valuable Products for Health and Industry: An Overview from Biotechnology. La Prensa Medica Argentina 103(4): 1-11.
[435] Ji, T. and Z. U. Haque (2003). Cheddar whey processing and source: I. Effect on composition and functional properties of whey protein concentrates. International Journal of Food Science & Technology 38(4): 453-461.
[436] Sinha, R., C. Radha, J. Prakash and P. Kaul (2007). "Whey protein hydrolysate: Functional properties, nutritional quality and utilization in beverage formulation." Food Chemistry 101(4): 1484-1491.
[437] Londero, A., R. Quinta, A. G. Abraham, R. Sereno, G. D. Antoni and G. L. Garrote (2011). Inhibitory Activity of Cheese Whey Fermented with Kefir Grains. Journal of Food Protection 74(1): 94-100.

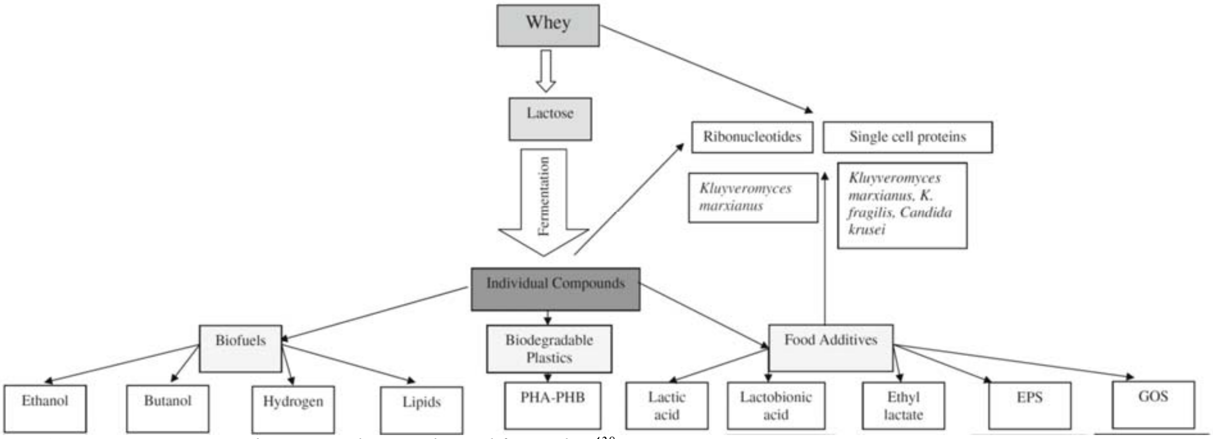

Figure 126. Fermentation products using lactose derived from whey[438].

But also non-food application of whey components have been suggested, e.g., safe paper glue based on whey protein isolate and sucrose[439]. Another example are nanofibrils derived from whey protein, which can be used in edible films and coatings (EFCs). These materials provide functions such as preventing weight loss, reducing lipid oxidation, providing microbial stability to foods, protecting antimicrobial compounds against adverse reactions (such as oxidation or hydrolysis), andpreserving functional foods during processing and storage[440].
Also for the by-product of whey protein isolate formation, i.e. the whey permeate, uses have been suggested. The permate has a high content of lactate and production of unicellular microbial protein for animal feed, the production of organic acids, alcohols, and the production of probiotics and different prebiotic substances are possible uses[434].

Brewery residues
Typical residues from breweries include brewer´s spent grain (BSG), which composes the major fraction of the residues as well as residues of hop, wort and yeast. BSG consists of the barley grain husks obtained as solid residue after the production of wort and is rich in fibre and protein. Typically, the residues are either used as animal feed (either on the own farm or sold/donated to other organisations) or as feedstock for biogas or ethanol production.

There are some BSG components of interest for potential health benefits. These include dietary fibres (e.g. arabinoxylan, β-glucans, lignin), phenolic components (e.g. hydroxycinnamic acid, ferulic acid and p-coumaric acid) and the protein fraction (~15–25% w/w) with a high content of the essential amino acid lysine (~30% of the total protein content), in comparison to other cereal products[441].

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438 Pescuma, M., G. F. de Valdez and F. Mozzi (2015). Whey-derived valuable products obtained by microbial fermentation. Applied Microbiology and Biotechnology 99(15): 6183-6196.
439 Wang, G. and M. Guo (2014). Property and storage stability of whey protein-sucrose based safe paper glue. Journal of Applied Polymer Science 131(1).
440 Feng, Z., L. Li, Q. Wang, G. Wu, C. Liu, B. Jiang and J. Xu (2019). Effect of Antioxidant and Antimicrobial Coating based on Whey Protein Nanofibrils with TiO_2 Nanotubes on the Quality and Shelf Life of Chilled Meat. International Journal of Molecular Sciences 20(5): 1184.
441 Lynch, K. M., E. J. Steffen and E. K. Arendt (2016). Brewers' spent grain: a review with an emphasis on food and health. Journal of the Institute of Brewing 122(4): 553-568.

Based on high cotent of these components, BSG has been utilised in the manufacture of bakery products such as bread, biscuits, cookies, muffins, cakes, waffles, pancakes, tortillas, snacks, doughnuts and brownies[442]. For manufacturing these types of products, BSG is dried and in many cases is milled to allow application in food products[442].

BSG is rich in cellulose and hemicellulosepolysaccharides, which are added value compounds with many industrial applications and which can be extracted using several chemical processes such as acid and hydrothermal hydrolysis[442]. Xylose and arabinose are the most common sugar present in the hemicellulose fraction of BSG, which can be extracted after chemical hydrolysis. Acid hydrolysis can be used prior to extraction of lignins from BSG, which are valuable components for the production of dispersant,emulsificant and chelant agents, activated charcoal, polymers,adhesives and fertilizers, among others[442]. The ferulic and p-coumaric acids, extractable by means of chemical treatment, have been reported to have antioxidant properties and have important industrial applications in food, cosmetic and pharmaceutical areas[442]. The BSG fiber are also of interest for the pulp and paper industry (e.g. for production of paper towels, business cards and coasters) and as absorbant materials (e.g. for heavy metal removal)[442]. Fermentative use of the spent grain as growth medium has been suggested but also as less chemical-intensive methosd for extraction of the valuable compounds.

Household and industrial food waste

Collection of food waste from households is part of the EU goal of reducing the amounts of organic residues ending up in dumps and other household waste fractions. The amount of food waste available to innovative uses depends on several steps (Figure 127).

Figure 127. EU priorities for the handling of organic wastes.

Highest priority has the prevention of food waste, which of course influences the amount of food waste that can be collected. Most of the food waste in e.g. Sweden is treated so that nutrients are recycled and energy is recovered. The most efficient technology here is to digest the food waste in a biogas plant to recover methane gas as fuel and using the nutrient-rich digestate as a fertiliser in agriculture. From a sustainability point of view, anaerobic digestion and incineration with energy recovery are the best options to treat food waste[443]. Beside fermentative processes, thermal

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442 Mussatto, S. I. (2014). "Brewer's spent grain: a valuable feedstock for industrial applications." Journal of the Science of Food and Agriculture 94(7): 1264-1275.

443 Eriksson, M., I. Strid and P.-A. Hansson (2015). Carbon footprint of food waste management options in the waste hierarchy – a Swedish case study. Journal of Cleaner Production 93: 115-125.

treatments of household biowaste such as torrefaction and carbonization that produce carbon-rich solid biofuels have been suggested[444].

Innovative uses of collected food waste fall under the category re-use. The recovery of nutritional, functional, and textural properties from the food supply chain waste will be an important driver. For example, new food industry additives could be derived from protease inhibitors (appetite suppressants) from potato peels or essential oils, flavonoids, and pectin from citrus waste or other bioactive compounds including polyphenols, carotenoids, vitamins, antioxidants, flavonoids, and fibers extracted from vegetable and fruits waste[445]. Other valuable compounds in food wastes include chemicals (enzymes, organic acids, glycerol, animal feed, among others), materials (bioplastics, biopolymers, nanoparticles, fibers) or fuels (such as methane, hydrogen, biodiesel, ethanol)[446]. Due to its high water content and its nutrient and energy content, food waste has been suggested as substrate for fermentation processes. Here, food wastes can be used as potential feedstock in biological processes for the generation of various biobased products along with its remediation. Enabling bioprocesses for foowd waste valorisation include acidogenesis, methanogenesis, solventogenesis, photosynthesis, oleaginous process, bio-electro-genesis, etc., that yield various products like biofuels, platform chemicals, bioelectricity, biomaterial, bio-fertilizers, animal feed[447].

[444] Vakalis, S., A. Sotiropoulos, K. Moustakas, D. Malamis, K. Vekkos and M. Baratieri (2017). Thermochemical valorization and characterization of household biowaste. Journal of Environmental Management 203: 648-654.
[445] Coma, M. and A. Chatzifragkou (2019). Chemicals from Food Supply Chain By-Products and Waste Streams. Molecules 24(5): 978.
[446] Capson-Tojo, G., M. Rouez, M. Crest, J.-P. Steyer, J.-P. Delgenès and R. Escudié (2016). Food waste valorization via anaerobic processes: a review. Reviews in Environmental Science and Bio/Technology 15(3): 499-547.
[447] Dahiya, S., A. N. Kumar, J. Shanthi Sravan, S. Chatterjee, O. Sarkar and S. V. Mohan (2018). Food waste biorefinery: Sustainable strategy for circular bioeconomy. Bioresource Technology 248: 2-12.

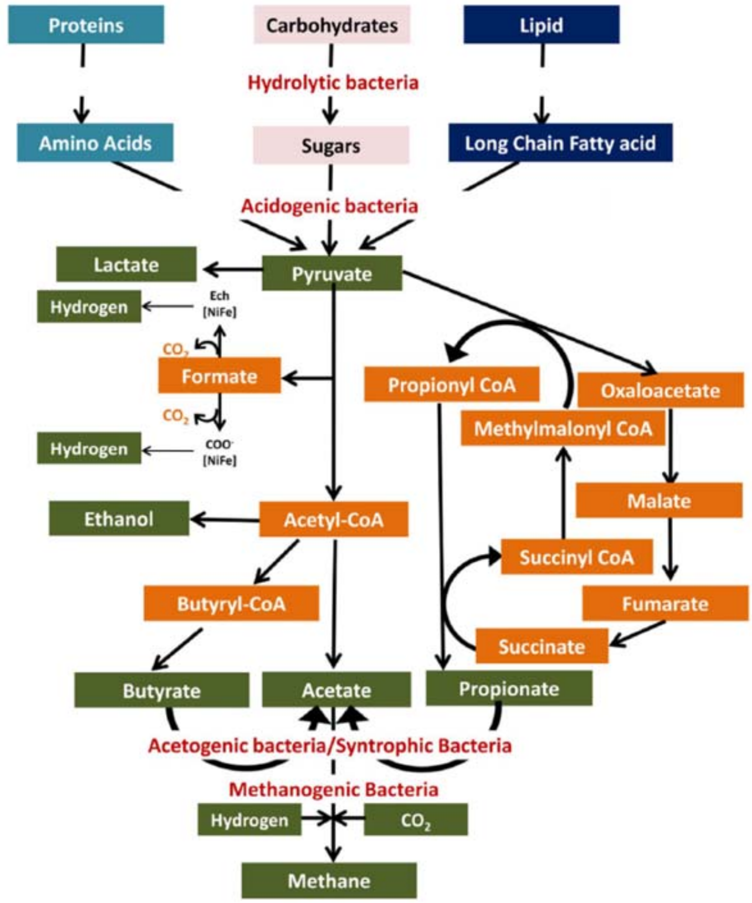

Figure 128 Schematic pathway of anaerobic fermentationfor biobased products generation[447]

The conversion of this waste into volatile acids can be paired with bioenergy production, including hydrogen and/or biogas (Figure 129). For this purpose, food waste refinery concepts have been presented, that may use mixes of industrial food wastes to produce energy carriers (hydrogen, methane, heat and power) and hydrogen fermentation by-products which could be recovered as valuable bioresources such as volatile acids (including lactic, acetic, and propionic acids), bioplastics, compost and activated sludge[448]. But also direct extraction from industrial food waste streams could be applied, e.g. recovery of carotenoids from fruit and vegetable wastes by supercritical fluid extraction[445].

[448] Sen, B., J. Aravind, P. Kanmani and C.-H. Lay (2016). State of the art and future concept of food waste fermentation to bioenergy. Renewable and Sustainable Energy Reviews 53: 547-557.

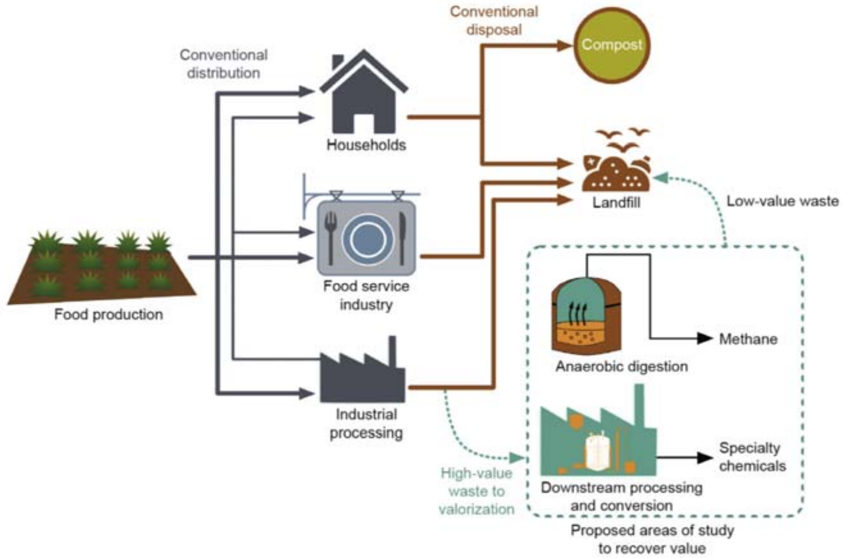

Figure 129. Simplified flow diagram of food from production to disposal[449].

Bottlenecks

Animal waste

Bottlenecks for the production of fly larvae on feedstock from slaughterhouses on an industrial scale are have been identified as technological aspects of scaling-up the production capacity, insufficient knowledge of fly biology necessary to produce large amounts of eggs, and current legislation. Especially technological innovations are considered key measures to remove barriers and could greatly improve performance of the biodegradation facilities and decrease production costs[427].

For the speciality products suggested above, employment of a biorefinery approach valorizing all ingredients and co-products of the animal processing industry waste including protein, fat, and ash is suggest[425]. However, the heterogeneity of the residues´ compositions are a challenge for implementation[425].

Dairy residues

For commercial purposes, most speciality products must compete with pendants of petrochemical origin in cost and production capacity to meet high-volume commodity applications. In some cases, as in low-volume specialty markets, such as cosmetics and healthcare, high production costs can be tolerated. In contrast, for low-cost applications, inexpensive feedstocks, such as whey, will be required for sophorolipids to be economically competitive[430].

Brewery residues

Brewer´s spent grain (BSG) represents an inexpensive material for the natural fortification (through increasing fibre and protein content) of food products. However, application of BSG to products at low levels (<15%) has been suggested to avoid alterations in the flavour, texture and colour of the final product[442].

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[449] RedCorn, R., S. Fatemi and A. S. Engelberth (2018). Comparing End-Use Potential for Industrial Food-Waste Sources. Engineering 4(3): 371-380.

For use as feedstock or substrate for fermentative processes, implementation of the valorisation of BSG has been slow with no production facilities on an industrial scale[442]. Due to high energy requirement for drying the BSG, use as cattle feed continues to be the main application. The high water content of BSG also means that transport results in a high cost. Combustion of BSG at the brewery has been an alternative option.

Household and industrial food waste

The high variability of the household food waste characteristics is a problem for designing robust processes for the fermentative use of these residuals. Geographical origin, the type of collection source and the season of the collection all had a significant impact on the residue compostion[450]. For biogas processes, the high carbohydrate contents and the low pH are constituting an inhibition risk for the digestion process[450]. Limitations, particularly in terms of the biodegradability and inhibition of substrates, given the presence of substances with antimicrobial actions such as D-limonene may result in low methane yields and low economic performance of the process[445]. Application of thermal conversion pathways are contrained due to the high water content and the molecular structure of biowaste[451].

Biorefinery concepts could be a core element for the exploitation of biomass/waste towards the manufacture of marketable intermediates and end-products for human consumption, however, the influence of the state of the feedstock (e.g., spoilage level) on the quality and quantity of the extracted materials must be assessed[452].

[450] Fisgativa, H., A. Tremier and P. Dabert (2016). Characterizing the variability of food waste quality: A need for efficient valorisation through anaerobic digestion. Waste Management 50: 264-274.
[451] Vakalis, S., A. Sotiropoulos, K. Moustakas, D. Malamis, K. Vekkos and M. Baratieri (2017). Thermochemical valorization and characterization of household biowaste. Journal of Environmental Management 203: 648-654.
[452] Coma, M. and A. Chatzifragkou (2019). Chemicals from Food Supply Chain By-Products and Waste Streams. Molecules 24(5): 978.

3. Additional feedstocks

3.1 Regional resources in Sweden

Assessed by Thomas Prade, Swedish University of Agricultural Sciences (SLU)

Besides the residues that occur in the above presented sections, additional primary feedstocks from agriculture can be made available. For Sweden an earlier study presented a methodology for categorising virgin primary feedstocks that do not compete with food and feed production and that have a low risk for indirect land use change (ILUC) effects to occur[453]. Four categories of agricultural feedstocks were suggested (Table 147).

Table 147. Categories of iLUC-free feedstock investigated in the assessment adopted from Prade et al (2017) [453].

Category	**Feedstock**	**Potential feedstocks**
1	Agricultural residues	• Straw • Sugar beet and potato tops • Excess grass ley silage
2	Crops produced on previously unused arable land	• Grass leys on abandoned arable land • Grass leys on set aside arable land
3	Additional crops from arable land	• Intermediate crops • Crops from ecological focus areas
4	Additional biomass from arable land via intensification	• Grass leys from intensified production

The main feedstocks from category 1 were presented in the sections 2.1-2.4.

3.1.1 Crops produced on previously unused arable land

The second category includes grass leys grown on arable land currently not used for production, such as on abandoned and set-aside arable land. Abandoned land was defined as land that has been cultivated before, is not currently occupied and could be cultivated again[454]. Set-aside land is only temporarily taken out of production, e.g. for weed treatment, green manuring or as a biodiversity measure.

Approximately 88,000 ha of land is currently marked as abandoned[454] and was estimated to have the potential to produce approx. 18,000 t DM per year in Skåne in the form of grass leys cultivated at low intensity (e.g. unfertilised grass-clover leys) to produce one cut[453]. Skåne has about 50% of the potential for grass leys on abandoned arable land and Kalmar, Blekinge and Kronoberg county contribute with 21, 9 and 19%, respectively (Figure 130).

[453] Prade, T., Björnsson, L., Lantz, M., Ahlgren, S. 2017. Can domestic production of iLUC-free feedstock from arable land supply Sweden's future demand for biofuels? Journal of Land Use Science, 12(6), 407-441.

[454] Olofsson, J. and P. Börjesson (2016). Nedlagd åkermark för biomassaproduktion - kartläggning och potentialuppskattning. Gothenburg, Sweden, f3 - The Swedish Knowledge Centre for Renewable Transportation Fuels and Foundation: 60.

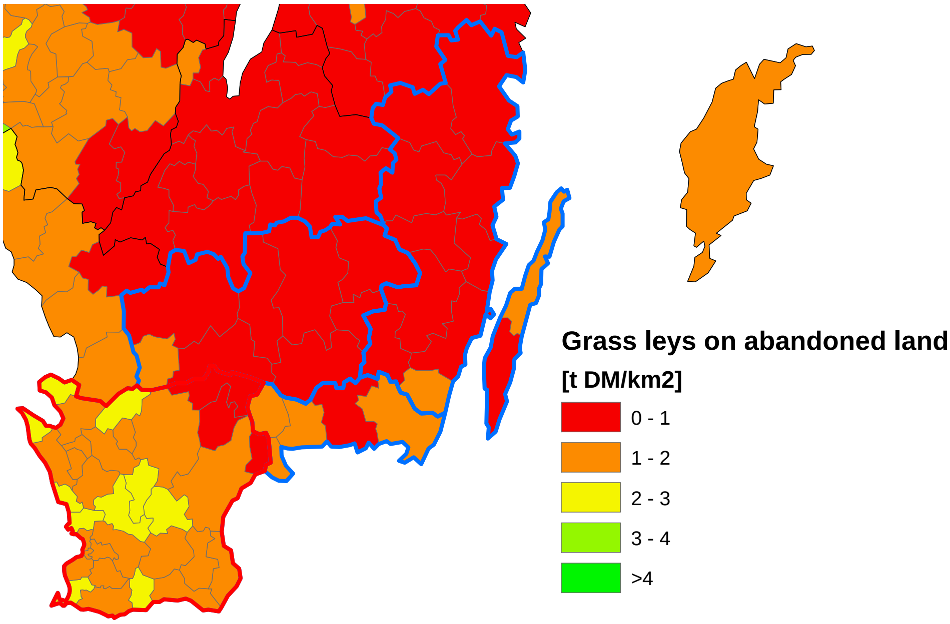

Figure 130. Intensity of grass ley biomass potential on abandoned land in Skåne (red border) and the other Swedish SBA regions (blue border) based on Pradeet al. (2017) [453].

The area of set-aside land was estimated to be around 150,000 hectares and to be able to produce 23,000 t DM per year in Skåne[453]. Skåne has 64% of the biomass potential from grass leys on set-aside arable land, while Kalmar, Blekinge and Kronoberg county contribute with 26, 10 and 8%, respectively (Figure 131).

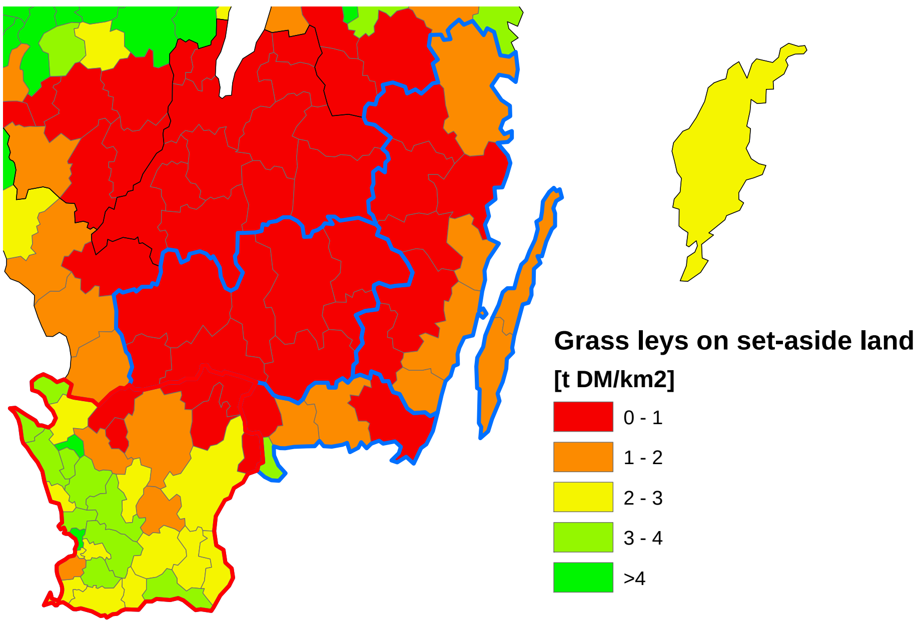

Figure 131. Intensity of grass ley biomass potential on set-aside land in Skåne (red border) and the other Swedish SBA regions (blue border) based on Prade et al. (2017) [453].

3.1.2 Additional crops from arable land

Category 3 crops were defined as crops grown on arable land that do not compete with other food and feed production. This includes crops grown in between main crops, so-called intermediate crops (ICs) and ecological focus areas (EFA) crops.

Intermediate crops and EFA crops

Intermediate crops currently grown as catch-crops are very important for reducing residual mineral N in the soil, especially after vegetable crops (e.g. green peas, new potatoes, lettuce), which have a short growing season and leave large amounts of crop residues with a high N content[455].

The potential to produce ICs was estimated to approx. 140,000 tonnes dry matter per year (Figure 132), assuming that they were cultivated as summer IC, i.e. sown after an early harvested crop and harvested in late autumn[453]. The study estimated the potential cultivated area was estimated from the cultivated area of early food potatoes, peas for processing and cereals including winter rye, winter barley, spring barley and winter wheat. IC biomass yield was simulated and varied between 3.7 and 4.1 t DM/ha in Skåne. Skåne holds ca 90% of the total IC biomass potential in the Swedish SBA regions.

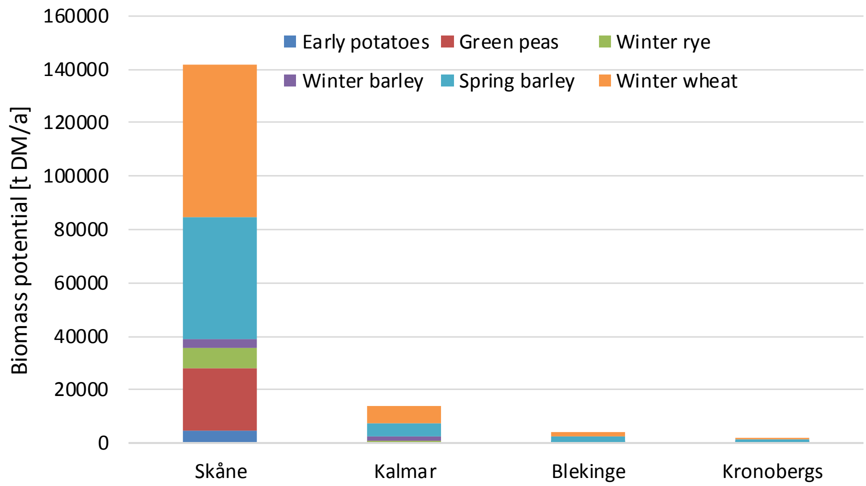

Figure 132. Biomass potential for intermediate crops depending on pre-crop in the Swedish SBA regions.

The biomass is located mostly in the highly agricultural municipalities in Skåne (Figure 133).

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[455] Neumann, A., Torstensson, G., Aronsson, H. 2011. Losses of nitrogen and phosphorus via the drainage system from organic crop rotations with and without livestock on a clay soil in southwest Sweden. Organic Agriculture, 1(4), 217-229.

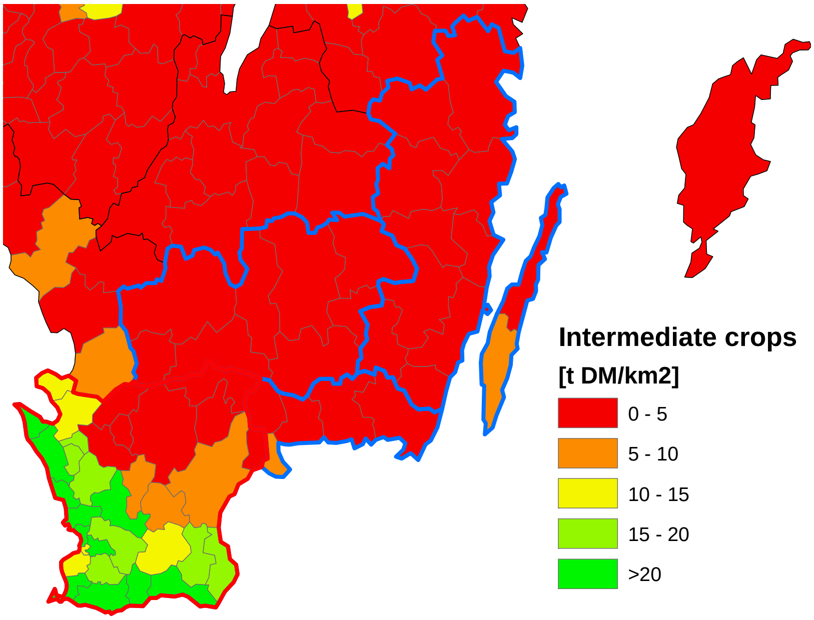

Figure 133. Intermediate crop biomass potential intensity in Skåne (red border) and the other Swedish SBA regions (blue border) based on Prade et al. (2017) [453].

Crops grown on Ecological Focus Areas as required as greening measures by the EU common agricultural policy (CAP) are a second source of biomass in this category. Farmers in Sweden located within defined areas in southern Sweden are required to mark out at least 5% (7.1% for N-fixing plants) of their arable land as EFAs. Besides fallow land, buffer strips and field margins, crops including catch crops, green covers and nitrogen-fixing crops may be cultivated. The study reported a EFA crop biomass potential of approx. 120,000 tonnes dry matter per year in Skåne assuming EFA crop yield varying between 3.8 and 4.0 t DM/ha[453]. Skåne holds ca. 80% of the total EFA crop biomass potential in the Swedish SBA regions (Figure 134).

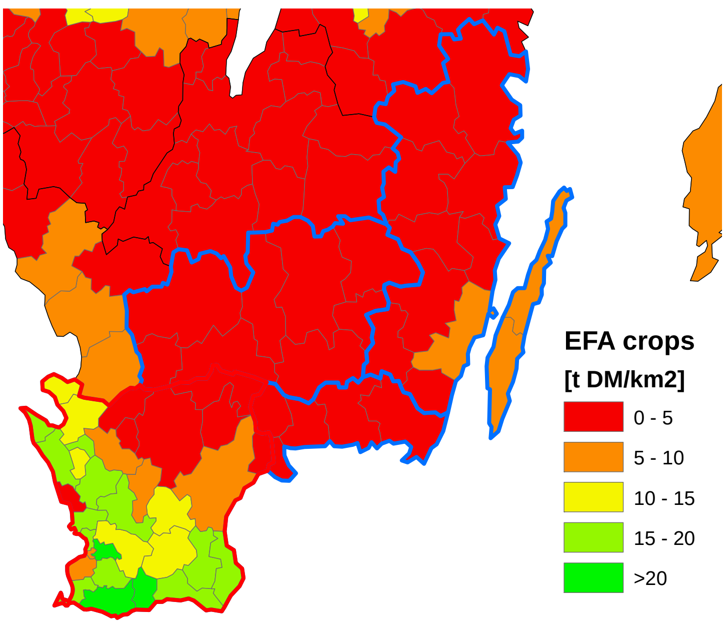

Figure 134. Crop biomass potential intensity for ecological focus areas (EFA) in Skåne (red border) and the other Swedish SBA regions (blue border) based on Prade et al.(2017) [453].

Grass leys

Category 4 crops were assumed to originate from intensification of current production of ley crops. Grass ley forage crops, are often grown at intensities well below potential biomass yield and depending on location, one to three additional cuts could be taken[456], corresponding to an average 30% grass ley yield increase as a base assumption[453].

The biomass potential was estimated to be approx. 170,000 tonnes dry matter in Skåne. That corresponds to 48% of the total grass ley potential from intensification in the Swedish SBA regions, where Kalmar, Blekinge and Kronoberg contribute with 30, 7 and 15%, respectively (Figure 135).

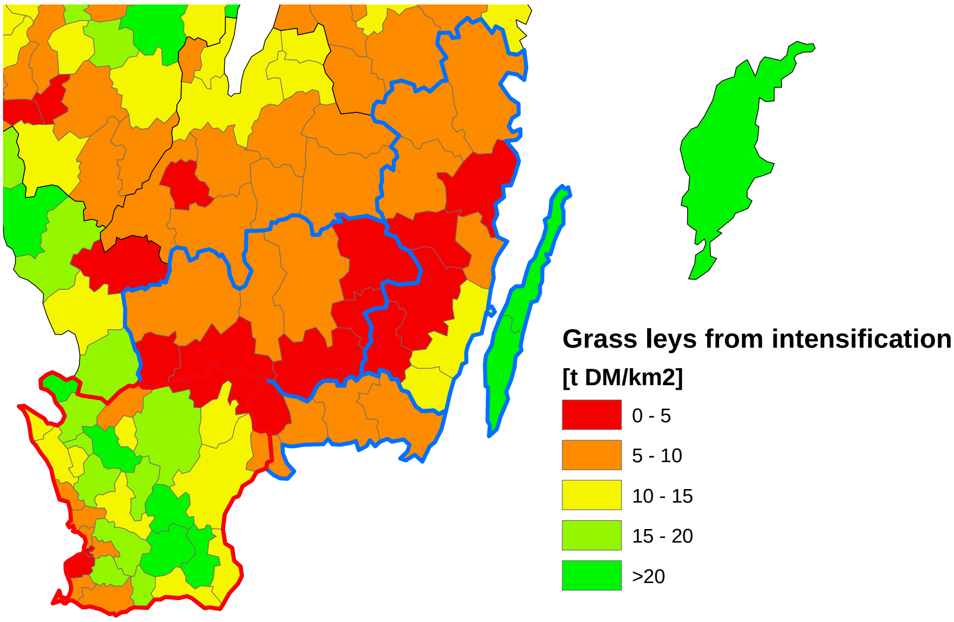

Figure 135. Grass ley biomass potential intensity from a 30% yield intensification in Skåne (red border) and the other Swedish SBA regions (blue border) based on Prade et al. (2017)[457].

[456] Gunnarsson, C., Ahlström, A., Ljungberg, D., Prade, T., Rosenqvist, H., Svensson, S.-E. 2017. Fresh and ensiled crops - a new way to organize year-round substrate supply for a biogas plant. F3 Centre.

[457] Prade, T., Björnsson, L., Lantz, M., Ahlgren, S. 2017. Can domestic production of iLUC-free feedstock from arable land supply Sweden's future demand for biofuels? Journal of Land Use Science, 12(6), 407-441.

3.1.3 Summary and outlook

Additonal feedstocks from agricultural origin (Categories 2-4) could contribute with roughly 470,000 tonnes dry matter per year, or 1.25 times the amount of biomass as the existing agricultural residues such as straw and sugarbeet tops (Figure 136).

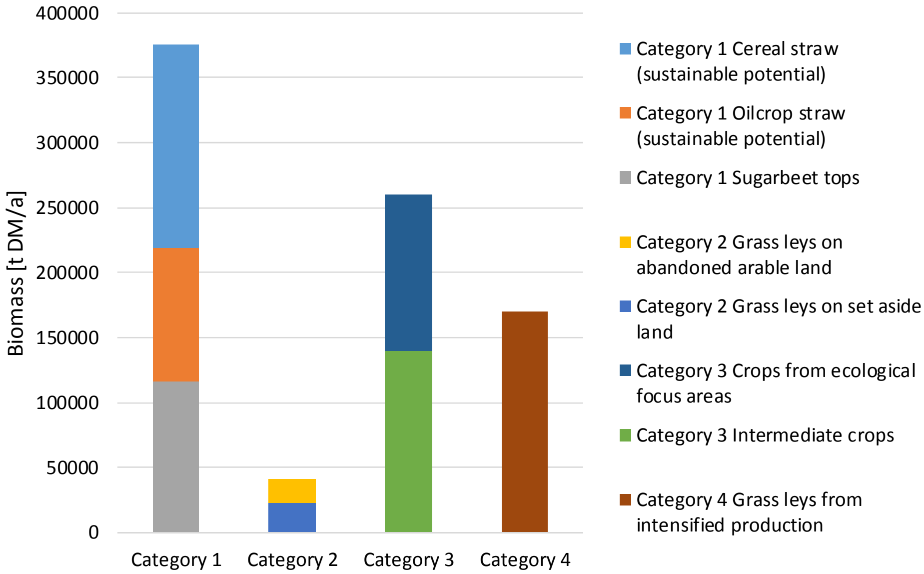

Figure 136. Potential sustainable biomass from agricultural origin in Skåne.

Protein content of these addional feedstocks is over 50,000 tonnes dry matter per year, or about 1.3 times the amount of biomass as the existing agricultural residues (Figure 137).

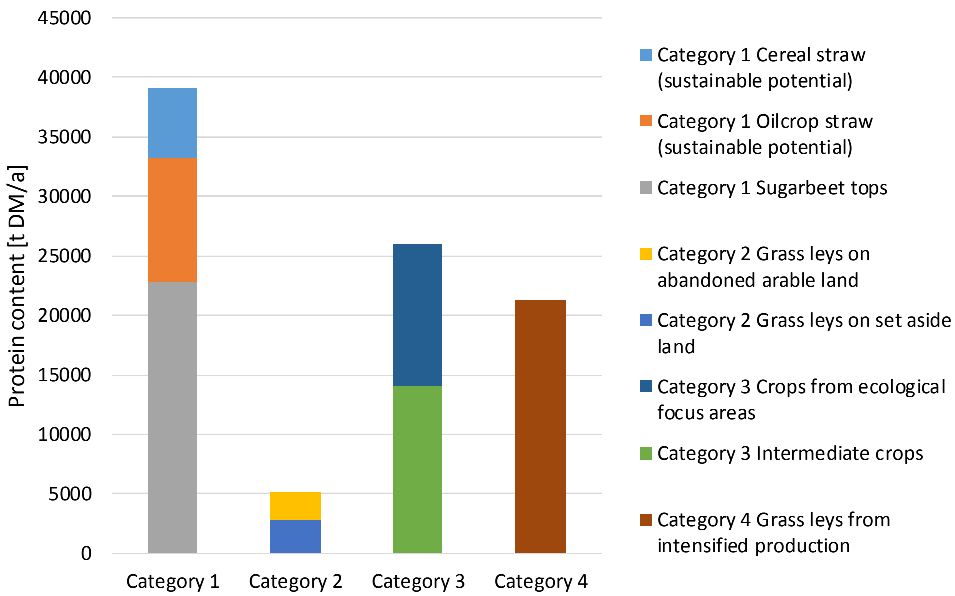

Figure 137. Potential protein biomass from agricultural origin in Skåne[458].

[458] Estimated based on average nitrogen content and a protein factor of 6.25.

Opportunities
Shifting protein production from animal to plant proteins is regarded as a more sustainable way of nutrient supply in terms of food and feed, but their production should be based on inedible biomass by humans (e.g. grassland for feeding ruminants)[459]. Existing agricultural residues and additionally grown sustainable feedstocks represent a large feedstock base of approx. 850,000 tonnes dry matter per year, and a protein content of approx. 90,000 tonnes dry matter per year in Skåne alone. Similar approaches can be taken in the other SBA regions and could therefore form a new basis of income to agricultural businesses.

A large variety of plant species of intermediate crops can be grown with different biomass yields, different plant development rates and different content of proteins and other valuable compounds. This, however, also presents an opportunity to adjust the cropping systems to fit the needs of the utilisation processes on hand.

For ley crops and straw, technology for collection and distribution of the feedstocks is mature and widely available, which could support large-scale implementation. For straw, policy development has been shown to be an effective measure to implement large-scale utilisation in Denmark[460].

Bottlenecks
Calcuculating the protein feedstock gives only a rudimentary picture of what is possible to implement. Extractability of crude and functional proteins has been shown to vary considerably and needs to be investigated for each feedstock.

Plant proteins still face many bottlenecks in terms of availability of technology, e.g. solubility, foaming and emulsifying properties, and in the nutritional and sensory quality of the finished product (e.g. "green" taste)[459]. Lipoxygenases or saponins are pointed out as the generators of "off-flavors". Genetics and formulations, possibly combinations of these, have been highlighted as measures for improvement[459]. Consumer behavior and acceptability remains the final bottleneck for developing new protein sources[459].

Similar to residues from the value chains discussed above, the variability of the biomass composition and quality may impose critical process limitations, but quality standards for the feedstock are missing and need to be defined and implemented. Standardisation of feedstocks will enable process and product standardisation and allow to reduce processing costs.

Cost for collection and supply of existing residues such as sugar beet tops and sustainably grown intermediate crops may turn out to be high, both in reference to the high water content of the feedstock and the low concentration in the landscape. On the other hand, intermediate crops have been shown to have many positive effects such as weed competition, contribution to soil organic carbon as well as nitrogen fixation or accumulation, which – if accounted for – could pay for part of the extablishing costs.

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[459] Chardigny, J.-M. and S. Walrand (2016). Plant protein for food: opportunities and bottlenecks. OCL Oilseeds and fats crops and lipids 23(4).
[460] Bentsen, N. S., D. Nilsson and S. Larsen (2018). Agricultural residues for energy - A case study on the influence of resource availability, economy and policy on the use of straw for energy in Denmark and Sweden. Biomass and Bioenergy 108: 278-288.

4. Summary & conclusions

The types of residues with the highest amount of residues available for innovative products in the bioeconomy originate from the agriculture (straw), forestry (wood production residues) and food industry (sugar production residues) (Figure 138). Straw represents the highest single overall feedstock potential in all SBA regions. Poland has especially high amounts of straw and woody feedstock available. In comparison, the potential of additional sustainable feedstocks as presented for the Swedish SBA region is in the same size as the potential for straw, but with more interesting properties for extraction of valuable coumpounds such as proteins for food and feed.

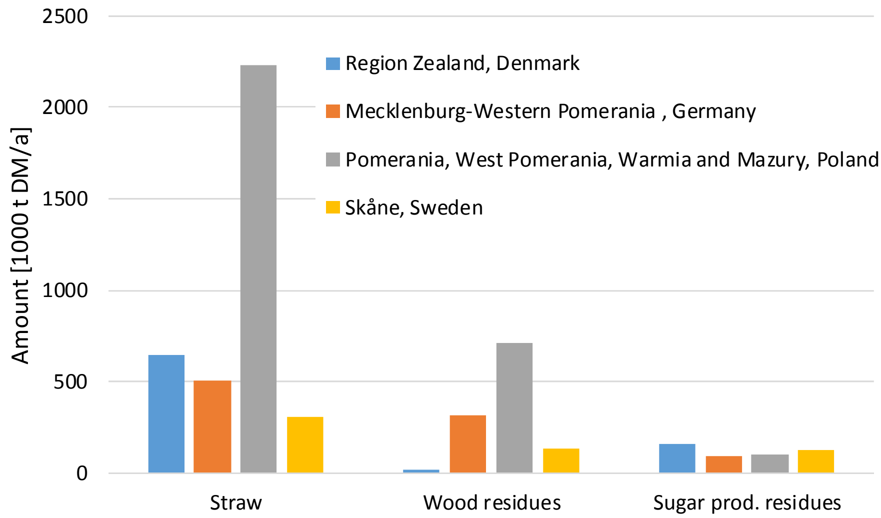

Figure 138. Amounts [1000 t DM/a] of residues available in the three largest sectors in the four SBA regions.

Other sectors generating large amounts of residues are private homes (household food waste), the meat industry, the dairy industry and breweries (Figure 139).

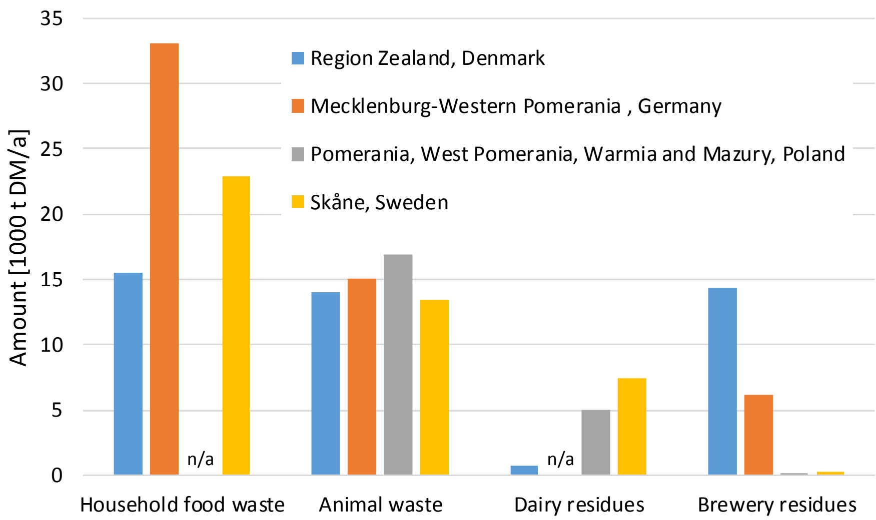

Figure 139. Amounts [1000 t DM/a] of residues available in four sectors in the four SBA regions.

Housefold food waste and animal by-products dominate the feedstock base in most regions. Animal by-products (ABP) are subject to restrictive regulations for use and disposal. Still, use of residues for extraction of peptides or gelatines for use as food ingredients have been developed commercially. Household food waste which may also contain animal-based residues such as bones, meat and blood are a very interesting feedstock with many potential utilisation pathways, but utilisation also requires sanitisation by a thermal treatment.

For processes and product value chains where bulk feedstocks are required, straw and woody residues are readiliy available, both in terms of volume and technology readiness. However, large-scale use of residues might not be feasible and in terms of priorisation of residues and feedstocks, waste valorisation should focus on food products with the potential to replace production of goods and services, rather than on food products that occur in large quantities or have a high carbon footprint.

Residual by-products, residues and wastes are often favourable in terms of climate and carbon footprint and other sustainability indicators, since utilisation of them contributes to an improved resource efficiency. However, despite being considered for free or low in purchasing cost, these feedstocks are often expensive in the extraction or transportation stage, due to low biomass concentrations in the field, bulkiness in transport or high water contents.

For many of the green or food industry residues, studies have shown that higly valuable compounds can be extracted or produced by means of fermentation. Energy recovery is an option either directly or after extraction or use for the production of secondary products (and by-products). Here, use as a biogas substrate is applied to many of the food industry residues already since these feedstocks are rich in nutrients, carbon and energy, and the resulting residue is valuable as organic fertilizer, replacing mineral fertilisers.

Additional sustainably produced feedstocks from agriculture may be available in large quantities as well and have the advantage that quality can be controlled and adjusted to the process needs. The feedstocks presented in this report are considered sustainable in the sense that competition with food and feed production is minimised. For evaluating the overall sustainability of products based on these feedstock, case-specific assessment should be carried out, e.g. in the form of LCA studies.