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WOOD RESOURCE BALANCES – CIRCULAR ECONOMY AND CASCADING

20 years of Wood Resource Monitoring

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CHARTER FOR WOOD 2.0 CLIMATE VALUES RESOURCES

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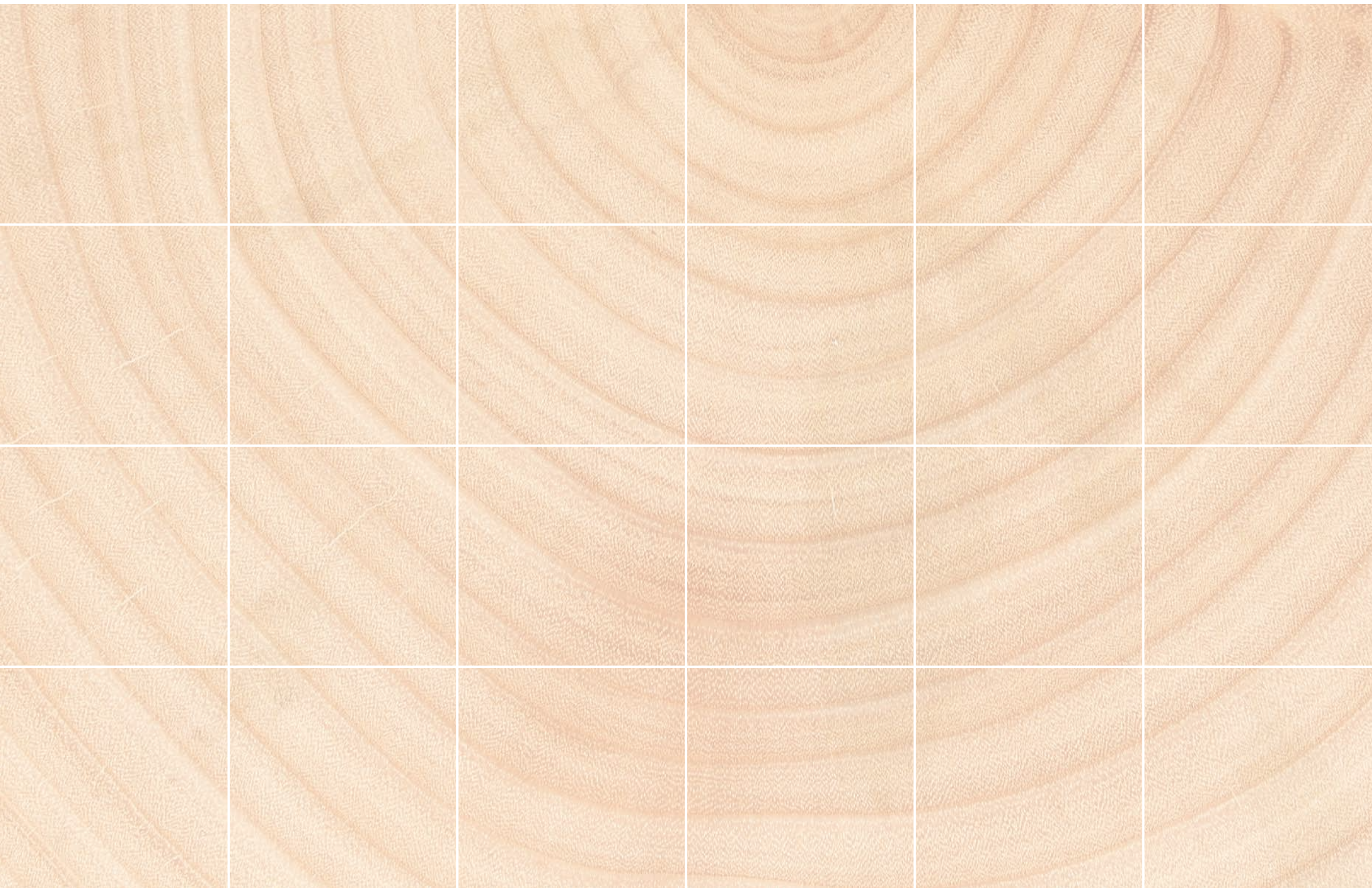
WOOD RESOURCE BALANCES – CIRCULAR ECONOMY AND CASCADING

20 years of Wood Resource Monitoring



FOREWORD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Dear Reader,
With the publication Wood Resource Balances – Circular Economy and Cascading, you have a comprehensive collection of data in your hands. This provides you with detailed information on the material flows of wood raw material and consistent data on the development and structure of the wood market in Germany.

The reliably prepared database is the result of the scientific project "Systemic Wood Resource Monitoring", funded by the Federal Ministry of Food and Agriculture (BMEL) from 2018 to 2022. The project was carried out by INFRO – Raw materials information systems and the Institute of International Forestry and Forest Economics at the Thünen Institute (TI).

The market analyses of all relevant sectors of wood processing and use provide important data from sawmills to the wood-based materials and pulp industries as well as on the quantity and use of waste wood and the use of wood for energy. In this publication, INFRO Managing Director and University Professor Dr Udo Mantau has compiled these market analyses into the German wood resource balance. The basis for the wood resource balance was prepared by the previous project "Wood Resource Monitoring", on which INFRO and TI had been working together with the University of Hamburg since 2015.

This was preceded in the 1990s by studies by Professor Mantau and the Sawmill By-products Working Group. Studies on raw material proportions in the material use of wood and on data bases for the use of wood as an energy source were performed, from which the current data collection and reporting gradually developed.

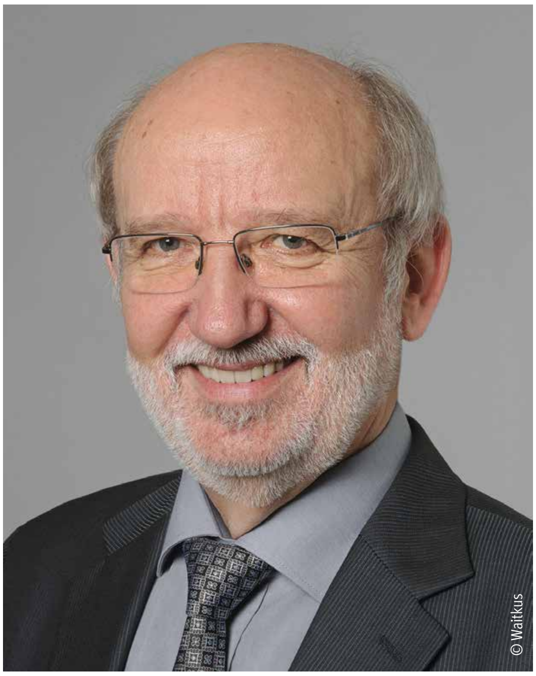
In the meantime, the data from the wood resource monitoring has been incorporated into planning and reports at various levels – for example in the overall forest accounts, the national energy statistics and the accounting of fellings in the course of the use-side estimation of wood removals and fellings. International bodies such as the FAO also refer to data from resource monitoring.

I would therefore like to take this opportunity to thank the intellectual father of resource monitoring, Professor Udo Mantau, for his more than twenty years of dedicated efforts in this field. Due to this resource monitoring achieved so far, we are currently in a much better position to assess challenges and opportunities based on data.

In this regard, I wish you an insightful read.

Dr Andreas Schütte
Managing Director, Agency for Renewable Resources (FNR)

PREFACE



The chair of the Bioeconomy Council, Michael Böcher, posed the question of an ideal consultative process in the 6/22 issue of “Forschung & Lehre”. In the Luhmannian sense, politics is based on power, while science is about truth. The classic linear model, according to which science finds an answer to a political question, cannot overcome the fundamental discrepancy between the two. Rather, it would be more effective if a reciprocal relationship between questions and answers were to emerge.

Wood Resource Monitoring originated around the year 2000 in the Sawmill By-products Working Group. The demand for wood energy was growing into a relevant competitor for the wood feedstock. Questions arose to which neither available data nor existing models could provide an answer.

“One is no experience without the activity of questioning.” “The actual essence of the idea is perhaps not so much that the solution occurs to one, as to a riddle, but that the question occurs to one, which pushes forward into the open and thereby makes the answer possible.” (H. G. Gadamer; Truth and Method. 2010. P 368, 372).

I was lucky enough to be asked questions in the Sawmill By-products Working Group that only gained importance in research and politics years later. At the same time, the study results influenced the questions of the working group participants, so that we were constantly pushing each other forward. The main aim was to provide data on wood volumes and their composition. The general understanding is that data are the fodder for models from which knowledge is derived. This is a serious underestimation of the knowledge-generating effect of data. “Perception is not only the source of knowledge, but it is knowledge itself.” (A. Schopenhauer). Only the acquisition of new data for previously unknown phenomena made it possible to rethink the interrelationships of the timber market. This eventually led to the development of Wood Resource Balances and macro-economic Wood Flow Analyses.

Accounting is the third innovative force, alongside questions and data. With Wood Resource Balances, contradictions arise between the various data sources and structural concepts. These are indications of previous inaccurate perceptions (data) and concepts (models). The Wood Resource Balancing model has expanded the structural knowledge of wood markets in many ways by making the material flows between the markets transparent and new markets have emerged or differentiated. In doing so, they did not stand on their own, but had to constantly integrate themselves anew into a complex circular flow model.

I am grateful for the questions, the inspiration of the data and the contradictions in their structural interaction, which always lead to new questions …

Professor Dr Udo Mantau
INFRO e. K. – Raw materials information systems

CONTENT

1 KEY MESSAGES

1.1 Sources and uses

RECOURCE MONITORING PROCEDURE

A basic idea of Wood Resource Monitoring is to record the wood feedstock via the wood use. The statistics on felling at the forest road say little or nothing about where the wood is used. Similarly, the statistics on the production of goods do not contain any information on the raw material composition. Thus, it is difficult, if not impossible, to obtain data along the material flow for a circular economy model. However, a manufacturer of a product can provide information on the forest wood, residual or recycled wood used. With the information on the raw material composition of the wood users, the raw material flows can be traced back from the product to the feedstock.

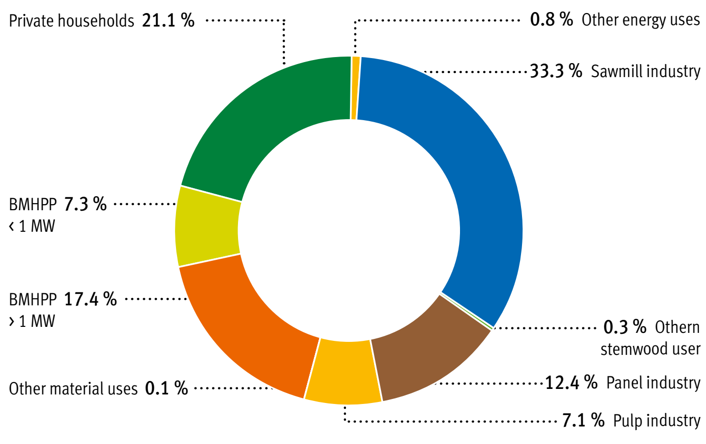
This is the essential difference between the calculation of macroeconomic material flows and the calculation of material flows of a production process. In a factory, the flow of goods from the purchase (input) to the product (output) can be traced exactly. In a national economy, on the other hand, no data is available. Therefore, the data flow in economic material flow analyses is the reverse of the material flow. For this reason, additional data collection is required for such calculations, as has been done in the Wood Resource Monitoring for about twenty years. Material compositions at various levels create the prerequisite for measuring and modelling the circular economy.

Finally, there are areas of use that are not recorded in the statistics, such as splitwood use in private households. It is therefore logical to start in this presentation with the wood use sectors, from which, in the opposite direction to the material flow, raw materials and feedstocks result.

USER

The sawmill industry is the most important user of wood with 33.3 % (Figure 1.1). It plays an important role in the mobilisation of wood, as it processes logs with a higher value and can thus pay corresponding wood prices. The share of other log users (plywood, veneer, sleepers) has continuously decreased to 0.3 %, but this sector still plays an important role in high-grade timber sales.

Figure 1.1: Shares of wood use by user groups in % (2020)



Source: Mantau, Infro 2022

In addition to roundwood from final felling and thinning, wood use in the wood-based panels and pulp industry also includes waste and recycled wood. This applies to an even greater extent to biomass combustion plants, which use waste wood especially in larger plants. Private households, on the other hand, use splitwood to a greater extent and increasingly pellets. Energy wood products (e.g. pellets) do not appear in the figure because they are an intermediate product. They are later fed into the combustion process.

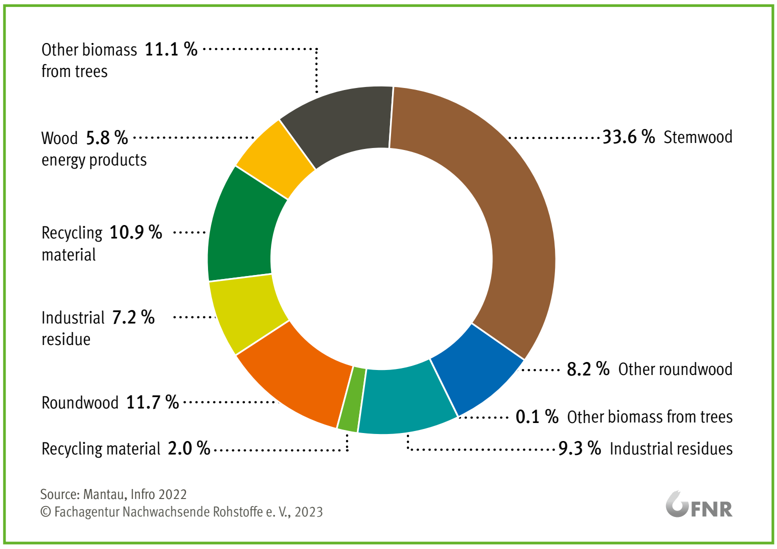
In recent years, energy wood products have become increasingly important. For communication reasons, they were initially included in the Wood Resource Balance. However, this ultimately represents double counting. When sawdust is converted into pellets, it is not already burned. To avoid this double counting, there is no getting around another intermediate step in the balancing. However, this also offers the possibility of clarifying another aspect of wood use with the conversion of feedstocks into traded raw materials.

In 2020, 52.8 million m³ of roundwood (rough wood) was used for material purposes and 14.7 million m³ for energy purposes. In relation to all raw materials, 41.9 % of roundwood was used for materials and 11.7 % for energy in 2020 (Figure 1.2).

DEFINITION WOOD IN THE ROUGH

The term "wood in the rough" comes from forest inventories. Since not every seedling can be recorded, the statistical cut-off or limit of wood in the rough at 7 cm DBH with bark. DBH stands for diameter at breast height, which corresponds to a distance from the forest ground of 1.3 metres.

Figure 1.2: Shares of raw material use by user groups in % (2020)



ENERGY WOOD PRODUCTS

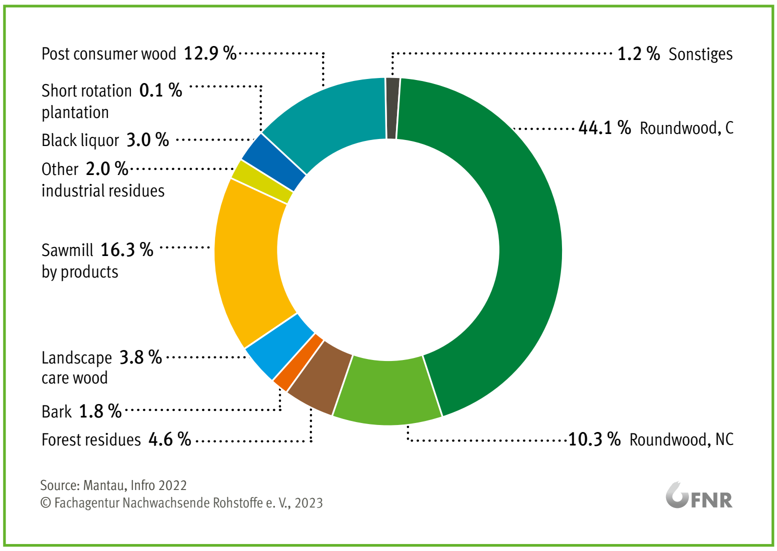
Energy wood products (pellets, briquettes, wood chips) now account for 7.3 million m³ or 5.8 % of all raw materials used for wood applications. This again illustrates the extent of possible double counting and the need for this intermediate step. Residual and recycling material corresponds to 11.3 % of all raw materials in material use and 18.1 % in energy use. Tree biomass except roundwood includes forest residues, landscape care wood, short rotation wood and bark. They are of very little importance in the material sector (0.1 %). The situation is different in the use of wood for energy. In the energy sector, other biomass includes, in addition to the aforementioned, other wood feedstocks that are not defined in more detail. In total, this group accounts for 11.1 % of the wood raw materials.

In order to determine the raw material volume as a whole, the raw material input of the energy wood products is distributed among the raw material segments used for this purpose. Therefore, it mainly increases the share of sawmill by-products (16.3 %. Figure 1.3).

SOURCES

Almost half (44.1 %) of the wood feedstock used is softwood roundwood or other softwood in the rough, i.e. softwood with a diameter of more than seven centimetres. Corresponding hardwood accounts for 10.3 %. Thus, 54.4 % of the feedstock used is roundwood (wood in the rough), which is the comparative value for the calculated annual renewable wood availability. Wood below the limit of wood in the rough (‹ 7 cm) is considered forest residues (4.6 %). A large part of it is attributed to firewood. The latter also applies to landscape care wood (3.8 %), which includes garden wood. Other significant shares are accounted for by sawmill by-products (16.3 %) and reused wood from the disposal system (waste wood) and direct uses in households (12.9 %).

Figure 1.3: Utilisation of wood feedstock by user groups in % (2020)



So far, mainly percentage shares have been presented. This is due to the fact that wood is used in many products (sawn timber, chemical pulp) with different quantities and units of measurement (m³, t_{od}), which would make a comparative overview impossible. The solid wood equivalent (m^3_{swe}) was developed as a universal comparative measure.

DEFINITION SOLID WOOD EQUIVALENT

The abbreviation "m^3_{swe}" stands for solid wood equivalent. The abbreviation follows the English term (solid wood equivalent). It is always used when units of a wood use are calculated back to their raw material input.

Since the use of raw materials is an important objective of Wood Resource Monitoring, the unit of measurement represents the transfer of wood between two areas of use in the form of a fictitious, converted, average forest wood cubic metre used. This makes clear the imputed difference between a statistically reported m³ (e. g. m³ felling) and a wood cubic metre that has been converted back from products (sawn timber) (m^3_{swe}). The solid wood equivalent goes back to the development of the Wood Resource Balances (MANTAU 2004, 2010) and enables complex comparisons to be made between a wide range of products along the entire wood value-added chain and to calculate back to their wood raw material content. Similarly used raw wood equivalents (m^3_r) are identical at the first processing stage. However, they have the disadvantage that they overestimate the raw material use at several processing stages, as they fully count residual and recycled wood as wood input in each case and do not clearly separate the raw material types. For example, a table may contain 0.1 m³ of wood, but if the tabletop consists of a particleboard and only the frame is made of solid wood, only 0.06 m³ of sawn wood (primary wood) may have been used for it. The abbreviation m^3_f is already used in Scandinavia for solid cubic metres (fastkubikmeter). To avoid any confusion, the English abbreviation (swe) is also retained in German. It is also internationally established, as it has been adopted by the UNECE/FAO.[1]

1.2 Development of the areas of use

MATERIAL AND ENERGY USE OF WOOD

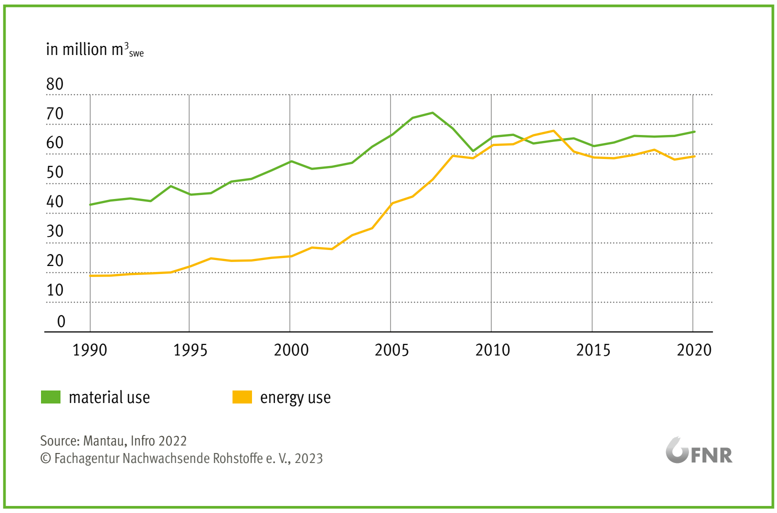
In the period between 1990 and 2000, the material use of wood is growing. The use of wood for energy is characterised by stable use in fireplaces of private households and the traditional use of process heat in wood industry plants.

In the period from 2001 to 2014, the developments differ. A weak construction market development initially causes material demand to stagnate, but then it picks up enormously as a result of strong domestic growth. In the course of globalisation, exports are also growing. The financial crisis brings the upswing to an abrupt end.

Energy use is characterised by the promotion of renewable energies, waste avoidance (waste wood) and sharply rising oil prices (2005 to 2010). During this time, it grows to become a serious competitor of material use and even surpasses it for a short time. Subsequently, material demand remains on a moderate growth course, while energy demand falls back slightly.

1 *FAO/UNECE (2019): Forest proucts conversion factors*

Figure 1.4: Development of material and energy use of wood

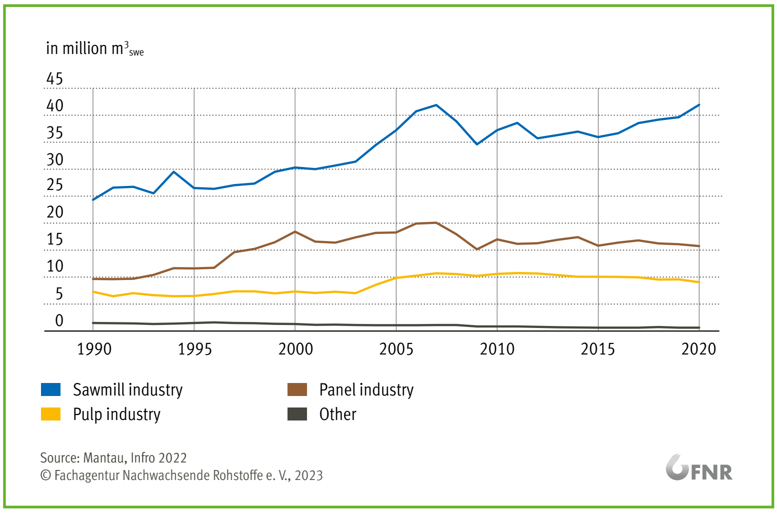


The main drivers of energy demand are subsidy impulses and rising energy prices. Their influence decreases significantly around 2010. However, the demand habits had become established and so demand remained at a high level. Experience from the years 2003 to 2008 shows that this does not necessarily have to remain the case when energy prices rise sharply like in 2022.

MATERIAL USE

Material use is dominated by the sawmill industry. It has benefited from the construction boom in the last decade, while the wood-based panels and pulp industries show a stable to slightly declining trend. Other uses include other log consumers (veneer, plywood, sleepers) as well as new bio-based products such as WPC and chemical feedstocks. While the other stemwood consumers have steadily lost importance in Germany, new bio-based products have a very promising perspective. However, their quantitative importance is still low or statistically not yet tangible. Contrary to earlier presentations, the quantities of mulchers were not included in this group (see section 3.3).

Figure 1.5: Development of material wood use

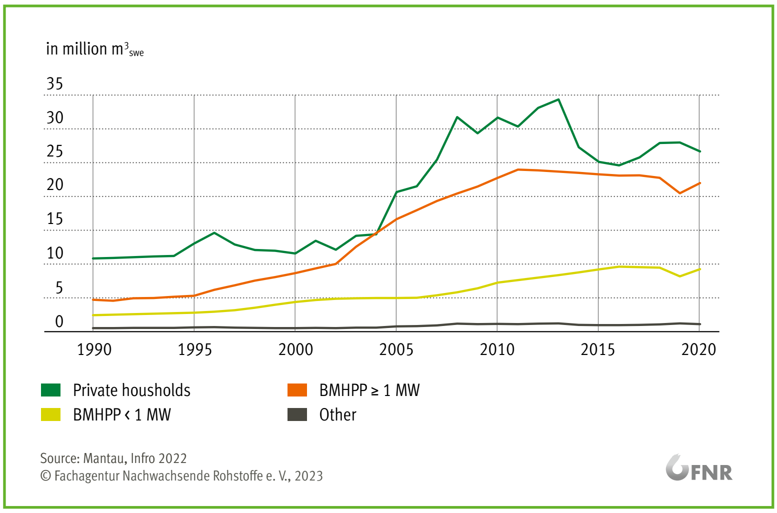


The largest wood energy users are private households. In recent years, the share of forest wood decreased and the use of energy wood products increased.

BIOMASS COMBUSTION PLANTS

The development of biomass combustion plants is not driven by the economy, but by subsidy measures and the capacities that have been built up. The subsidies have recently benefited the small plants more. The dry year 2019 coincided with a survey year, so the setback became apparent. In general, consumption follows capacity development. Other uses include the short period of an experimental plant for biofuel (Choren) as well as the amount of wood briquettes not attributable to private households but reported by the Federal Statistical Office (cf. chapter 2.11).

Figure 1.6: Development of wood use for energy

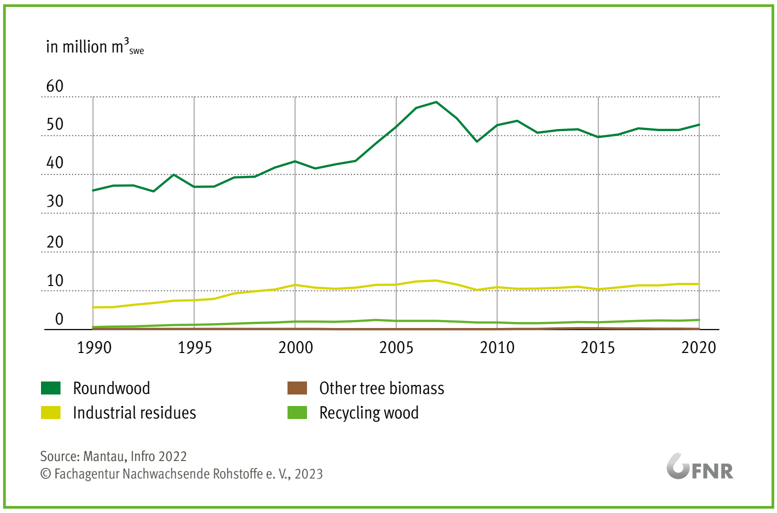


1.3 Wood raw material input according to uses

RAW MATERIAL INPUT IN THE MATERIAL USES

The raw material input in the material uses is dominated by the use of roundwood (logs and other wood in the rough). On average over the last ten years, this accounted for 76.7 % of the raw material input. Only the use of wood residues is still of considerable importance in terms of volume (16.4 %). Other tree wood (0.4 %; landscape care wood, short rotation plantation wood, forest residues, bark) is more of a marginal phenomenon. The use of recycled wood (3.0 %) is of great importance for the circular economy. In material uses, it occurs almost only in particleboard.

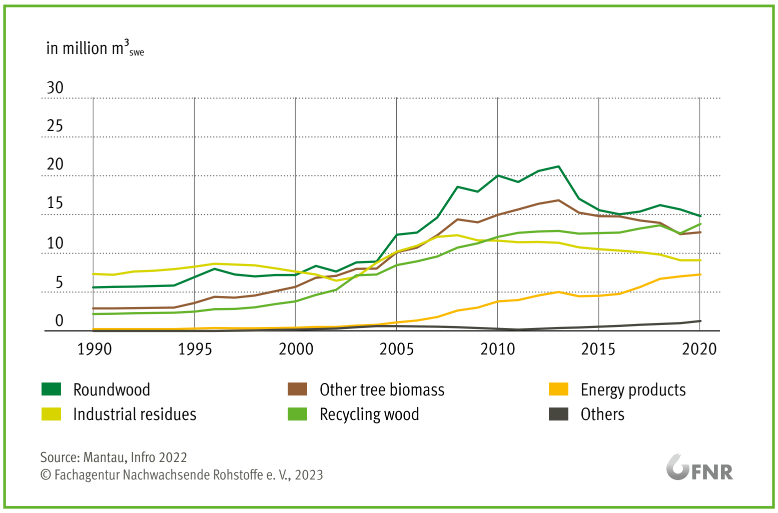
Figure 1.7: Development of wood use for material uses



USE OF WOOD FOR ENERGY

In the use of wood for energy, the use of raw materials is much more widely spread. The volume axis has been reduced to half. On average over the last ten years, the share of wood in the rough was 27.9 %, other tree wood 24.0 %, direct use of industrial wood residues 17.0 %, recycled wood 21.0 % and energy wood products 8.8 %. For other 1.1 % of the wood feedstocks, a specification was not possible.

Figure 1.8: Utilisation of wood raw materials for energy uses



The differences in the use of wood for materials and energy show that the competition between the two cannot be assessed in general terms of "wood use" but must be considered in a very differentiated manner for individual product ranges. Not all product ranges are mutually substitutable. Rather, large parts of the energy use (e. g. waste wood, LPM) cannot be used as materials, or only to a limited extent. In addition, the different qualities used in the respective assortments (e. g. roundwood) should also have to be included, which is not possible within the framework of Wood Resource Monitoring.

1.4 Softwood and hardwood use

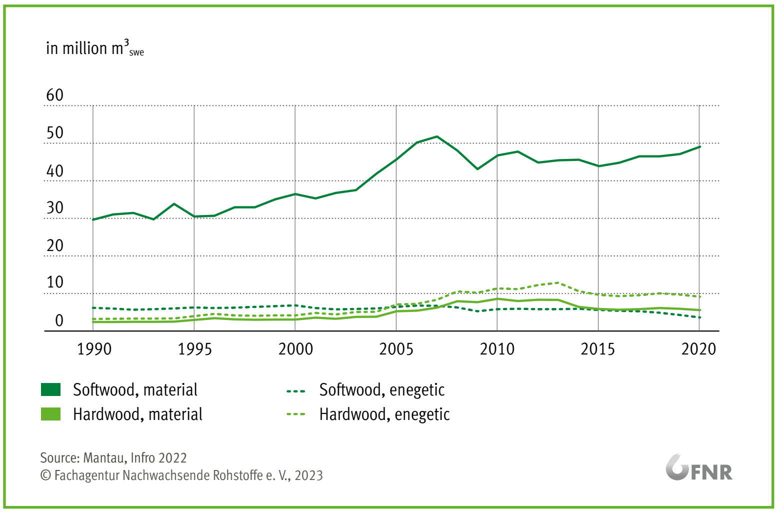
IMPORTANCE OF THE BASIC WOOD TYPES

Softwood dominates by far in material uses. This is mainly a result of the demand in the construction and packaging industries. However, even in the furniture industry, which has a greater affinity for hardwood, softwood and hardwood are used in equal measure, taking into account the residual materials.

On average over the last ten years, 67.5 % softwood was used for material and 7.6 % for energy. Hardwood accounted for about a quarter of the wood used. At 15.2 %, energy use is significantly more important than material use (9.6 %).

The conversion of forests towards hardwood has many justified silvicultural reasons. Given the needs of the population and the environmental benefits of wood as a material, its use should be considered in the search for sustainable concepts.

Figure 1.9:
Material and energy use by soft- and hardwood



1.5 Cascade use

CASCADING USE OF WOOD

"Cascade use is the efficient use of raw materials by using residual and recycled materials to expand the available biomass for material use in a given system." (Vis et al. 2016).

When the EU Commission wanted to investigate the effects of cascade use in the context of the circular economy in 2014, only one empirical study was available. This was the Wood Flow Analysis (Mantau 2012). Based on this, the Wood Flow Analysis was further developed to calculate cascade factors (Mantau, Blanke 2016). In the bioeconomy project (Bringezu 2020), the approach was calculated continuously for Germany for the period 2000 to 2015 (Mantau, Blanke 2016). **With the redesign of wood resource accounting in this report, cascade factors are currently possible for the period 1990 to 2020 for all sectors of wood resource accounting.**

DEFINITION OF THE CASCADE FACTOR AND SECONDARY INPUT RATE

The cascade factor and the secondary input rate describe the same phenomenon in two different ways. The cascade factor expresses how often primary wood has been used by multiple utilisation of secondary material (waste and recycled wood) has been used (e. g. 2.0). The secondary input rate expresses the proportion of the secondary material (e. g. 50 %).

DIFFERENT PREMISES FOR THE REALISATION OF CASCADE USES

The Table 1.1 shows the use of tree wood (primary wood) and secondary wood feedstock (residual and recycled wood). The secondary input rate expresses how large the share of secondary material used is. The sawmill industry uses only primary wood. However, it produces a large proportion of wood residues that enable cascading uses in the other wood uses. The wood-based panel industry uses two-thirds residual and recycled wood. In the case of pulp, a distinction is made between primary and secondary (recovered paper) produced pulp. Due to the high use of recovered paper in Germany, the latter makes a big difference. Without secondary pulp, the secondary input rate of material use is 21.3 %. If recovered paper is included, it is 52.7 %.

Table 1.1: Cascade use of wood utilisation

Wood utilisation 2020 – Germany	Wood utilisation	Wood from trees	Secondary sources	Secondary input rate
	in million m^3_{swe}	in million m^3_{swe}	in million m^3_{swe}	in %
Lumber	42.1	42.1	0.0	0.0
Panels	16.0	5.5	10.5	65.6
Pulp	9.0	5.2	3.8	41.9
Material use I	**67.1**	**52.8**	**14.3**	**21.3**
Used paper	44.5	0.0	44.5	100.0
Material use II	**111.7**	**52.8**	**58.9**	**52.7**
Wood energy products	7.0	1.1	5.9	84.9
BMHPP ≥ 1MW	20.7	1.8	19.0	91.4
BMHPP < 1 MW	7.3	2.4	4.9	67.5
Private households	21.2	15.3	6.0	28.1
Wood energy use	57.3	20.7	36.6	63.9
Total	**169.0**	**73.5**	**95.5**	**56.5**

CASCADING USE OF ENERGY WOOD

For energy use, BMA ≥ 1 MW have the highest secondary input rate (91.4 %) due to the high use of waste wood, followed by energy wood products with 84.9 %. Households have a relatively low secondary input rate (28.1 %) due to high log consumption.

In this example, the secondary input rate of the energy users was only used for their directly used wood feedstock, i.e. calculated without energy wood products. Such determinations are not true or false, but expedient or inexpedient. Here it follows the purposes of making energy wood producers visible and attributing the secondary input rate to the first receiving hand. This also shows that the calculation of the secondary input rate depends on the composition of the product groups, or the deposited model structure. For example, in these calculations, forest residues were attributed to the wood residues and not to the primary biomass, based on the basic idea of the circular economy. More details on this and detailed calculations in section 3.2.

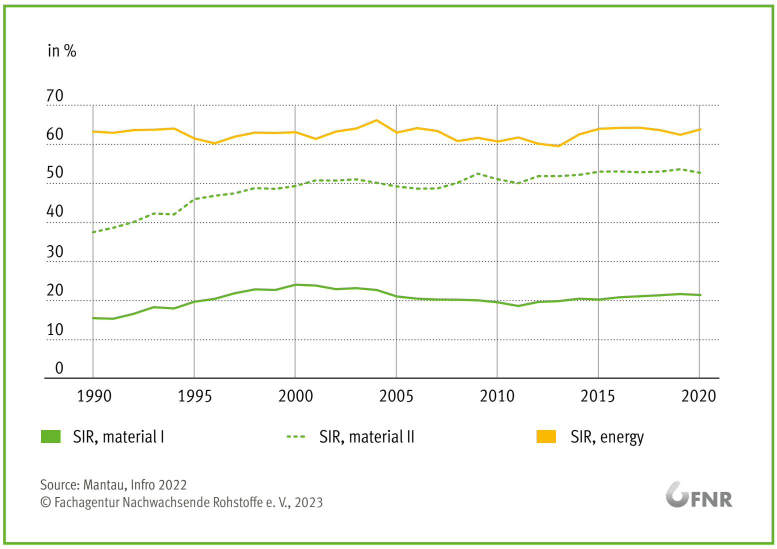
TEMPORAL DEVELOPMENT OF CASCADING USE

Since the underlying circular economy model is backed up with data for the period from 1990 to 2020, changes in developments can also be shown. The secondary input rate of energy use fluctuates relatively stably around 62.8 % (Figure 1.10). Material use II (with recovered paper) increases strongly until 2000 and then grows moderately. Material use I even falls back after the year 2000. The background to this development is the strong increase in demand for construction timber, which has strengthened the influence of the sawmill industry.

CAUSES OF CASCADE UTILISATION

This points to an interesting aspect of cascade use. Changes in economic secondary input rates do not necessarily indicate a change in the use of secondary raw materials in the technical sense. They can be a consequence of different developments in the sectors (change in capacity) but can also be the result of more efficient raw material use. Mantau/Blanke (2016) have also pointed out that in order to optimise a circular economy system, it is not individual rates that are important, but the system as a whole (provision and utilisation) that must be taken into account. For example, the sawmill industry only has a secondary input rate of "0", but without the residual materials it produces, the secondary use of many other wood uses would not be possible.

Figure 1.10: Secondary input rates (SIR) of wood utilisation in %



Overall, the material use of wood shows a secondary input rate of 52.7 %, which means a cascade factor of 2.12. This means that from one cubic metre of primary wood, more than two cubic metres (swe) of wood products are produced by using residues and recycled materials.

The secondary input rate of energy use is higher at 63.9 %, but it is not followed by any other use. Energy wood use is end use. The high secondary input rate is mainly a consequence of the use of waste wood in large combustion plants and the use of wood residues in energy wood products.

2 WOOD USE

2.1 Preliminary remark

Adjustment of Wood Resource Balancing

METHODOLOGICAL EXTENSIONS TO WOOD RESOURCE BALANCING

There were several methodological changes to the last cycle of Wood Resource Balancing[2] Intermediate products (e. g. pellets) were not included in the feedstocks but in an additional accounting step as raw materials between raw materials and uses. This avoids double counting (cf. section 2.11).

The treatment of the bark was changed in order to avoid inconsistencies in the calculation process (cf. section 3.3). The use of bark outside the Wood Resource Balance (mulchers) is no longer included in the overall balance, but only the bark used in the listed sectors of wood use. However, the bark chapter presents the uses of bark in more detail than before.

Furthermore, the Wood Resource Balancing was restructured in order to provide more accurate data for forest wood modelling. The differentiation for this goes beyond the structure presented here.

The Wood Resource Balancing method was merged with the modelling of the Wood Flow Analysis to form a consistent unit. While there were previously “Partial Wood Resource Balances” for individual feedstocks, it has now become possible to present “Input-Output Balances” for the production process in the use sectors.

Foreign trade in wood was so far implicitly included in the calculations. It was not presented for reasons of simplification. For this purpose, forms of presentation were found that now link Wood Resource Balancing with sectoral considerations (production, export, import) (market sectors).

This has resulted in a system of balances that can be used to illustrate the different aspects of complex market structures. All presentations are made for the year 2020, but they are available in full for the period 1990 to 2020 via a dashboard and are presented in 10-year steps in the appendix. Where structural aspects from surveys are presented, they refer to the survey year.

Why Wood Resource Balances and now more of them? The first Wood Resource Balance (Mantau 2004) was developed primarily for the clear presentation of the more complex timber market structures at the beginning of the millennium. Methodologically, however, it also provides support for data verification and data generation. Through balancing, contradictions in the data become apparent and, as a data system becomes more complete, data gaps can be more easily identified. The first Wood Resource Balances also unconsciously created the preconditions for later circular economy models. For in a cycle – as in a balance sheet – every flow must have a beginning and an end, i. e. an entry and an counter entry.

2 *Mantau U. et al. (2018) Wood Resource Monitoring, Ed. FNR –. Report numbers 955, 956, 957*

DEFINITION OF BALANCE SHEET TYPES

Balance sheet types and their function

Wood Resource Balance: This is the original form of Wood Resource Balancing and compares all raw material sectors with all use sectors. It takes into account the raw material mix in the sectors of use and calculates back to the raw material input.

Partial Wood Resource Balances: They close an information gap in the Wood Resource Balance, which does not show in which sectors an individual feedstock is used. This makes it possible to show specifically in which uses e.g. forest wood or waste wood is used.

Input-Output Balances: They balance the production process according to input and output quantities and are broader in scope than Wood Resource Balancing. Thus, the bark is included as an input volume to the full extent of the harvested solid cubic metres of roundwood. It becomes part of the uses (input) or is recorded as a loss or marketable bark supply (residue) on the output side. In Wood Resource Balancing, only the bark processed in the product is included. They thus represent the entire material flow.

Market sectors: The production from the input-output balance establishes the link to the usual market view with production, stock, import and export and calculated consumption. This creates the bridge from Wood Resource Balancing (output product) to the end product sectors (e. g. construction, furniture, packaging, paper), which, however, are not in the scope of this publication.

Terms used in Wood Resource Balancing

In addition to the keyword glossary, the uses, context and justification of important wooden terms will be addressed first. This follows Wittgenstein's understanding of language, whereby a sentence can be understood not only from its words and grammar, but also from what is said before and after, as well as the environment in which it is said.

Tree wood: The term includes all wood feedstock from primary production. It was introduced because tree wood can be represented as a combined material flow in the material flow analysis. It consists of roundwood, landscape care wood and wood from short-rotation plantations.

The term **roundwood** is used synonymously with **wood in the rough** (wood over 7 cm diameter at breast height, BHD). For non-specialist readers, it should be noted that the term wood in the rough is of particular importance because forest inventories record wood up to the limit of wood in the rough. This results in the stock and increment of forest wood. Both are important variables for comparing forest increment and wood utilisation.

In the biological sense, forest **residues are** also predominantly tree wood. For material flow analysis or cascade utilisation, however, forest residues are **primarily wood residues**. One can also speak of primary wood residues in addition to **secondary wood residues**. Secondary residues (less abstractly: **industrial residues**) include sawmill by-products, other industrial residues and black liquor. Wood residues (e. g. sawdust) are unavoidably produced in a production process (sawmill) that is directed towards another production target (sawn timber).

In the context of Wood Resource Balancing, the formation of group terms serves the purpose of clarity. The term **tree biomass** includes forest residues and bark in addition to tree wood.

Recycled materials were already in use (construction, furniture, newspaper). They are wood feedstocks (waste wood, waste paper) that, after collection and, if necessary, processing, are returned to material or energy uses as recycling materials.

Feedstocks and **raw materials**: Feedstocks refer to the natural or otherwise occurring material with no specific allocation in use. Raw materials are feedstocks that have been allocated in some way. This differentiation was triggered by energy wood products. Pellets, for example, are an energy product. However, they are only put to energy use in a household. To avoid double counting, the category of wood raw materials (e. g. pellets) was introduced between wood feedstock (e. g. sawmill by-products) and wood uses. In the case of sawmill by-products, there is physically not the slightest difference between the feedstock produced and the raw material used as sawmill by-product in a mill. In the context of the Wood Resource Balancing revision, the necessity (energy wood products) was used to increase the information value by assigning all feedstocks (waste wood, black liquor) to the use groups (tree wood, residues, recycling material) separate for material and energy use (cf. sec. 4).

Logs in the sense of Wood Resource Balancing does not refer to the sorting of wood at the forest road (felling statistics), but to the use of wood in certain sectors. Logs include all roundwood that is processed in sawmills and "other log processing industries" (e. g. plywood). At the same time, the term builds a bridge to forest wood modelling. Logs are predominantly attributed to forestry end-use.

Other roundwood is wood in the rough that is not used in the aforementioned industries. It can be used for material (mechanical pulp) or energy (splitwood) purposes. It can be obtained from thinning or final felling, but is always roundwood in the sense of wood in the rough (> 7 cm BHD). If surveys show that wood with a diameter of less than 7 cm is also used in material production (e. g. particleboard), it should be classified as forest residues.

2.2 Sawing industry

STRUCTURE OF THE SAWMILL INDUSTRY

The sawmill industry is characterised by a very broadly diversified company size structure. It includes small village sawmills that produce for regional needs as well as large industrial plants that supply the world market. Smaller sawmills can exist economically in discontinuous operation, depending on demand or in connection with other income sources (agriculture). They contribute to the regional economy. In order to survive supra-regionally or internationally, cost structures are needed that are more likely to be achieved with large units (economies of scale). The total number of sawmills has been declining for years. Medium-sized sawmills are disproportionately affected by this. The following table shows the distribution of sawnwood producers by cutting size class for the year of the last survey (2018).

The distribution of the cutting volume by cutting size classes is the mirror image of the corresponding distribution of the number of plants.

Table 2.1: Number of sawmill plants and cutting by cutting size class

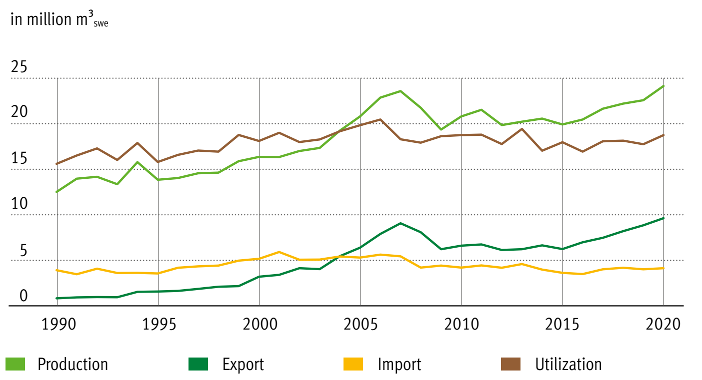
2018	Sawmill industry		Cutting volume	
Cutting size class	Number	%	million m^3	%
1–999 m^3	828	47.0	0.262	0.7
1,000–4,999 m^3	447	25.4	1.087	2.8
5,000–19,999 m^3	288	16.3	2.755	7.0
20,000–99,999 m^3	130	7.4	4.902	12.5
100,000–499,999 m^3	52	3.0	11.557	29.5
500,000 m^3 and more	17	1.0	18.583	47.5
Total	1,761	100.0	39.147	100.0

Source: Döring, P.; Gieseking, L.; Mantau, U. 2020: Sawing Industry 2018

Development of softwood lumber production

The development of production is completely different in the sawing industry for softwood lumber than for hardwood lumber. Until the beginning of the 1990s, the softwood lumber industry was a small to medium-sized industry. Then several supportive framework conditions arrived. Unification and the subsequent building boom (1989–1995) led to high demand in the new federal states. Since the prefabricated house industry, which is primarily timber construction, was able to supply the demand even without local craftsmen, timber construction had competitive advantages. Tragic events for the forestry industry, such as the major storm events (Vivian/Wibke, 1989/1990) led to favourable purchasing conditions for the timber industry. With the development in the New Federal States, new sawmill enterprises were promoted. With increasing investment opportunities, the sawmill industry also developed products such as structural timber (KVH, BSH), which opened up further applications in the building sector (hall girders). With the Renewable Energy Act (EEG), the demand for sawmill by-products increased, turning what was once a problem into an attractive and easily marketable feedstock. The sawmill industry expanded its forward integration with its own pellet plants, biomass power plants and pre-products for the construction industry. Thus, larger production plants were formed, which could more easily tap export markets. The house building boom in the US and the US import restrictions on Canadian lumber gave a strong boost to the already existing export activities. As the chart shows, demand partly collapsed again with the financial crisis, but the structural change in the softwood lumber industry was complete and maintained at a much higher level. Lumber production is currently receiving growth impulses again due to international demand and higher preferences for climate-friendly construction.

Figure 2.1: Development of the market sectors of softwood lumber



Source: Federal Statistical Office, production and foreign trade statistics and own calculations
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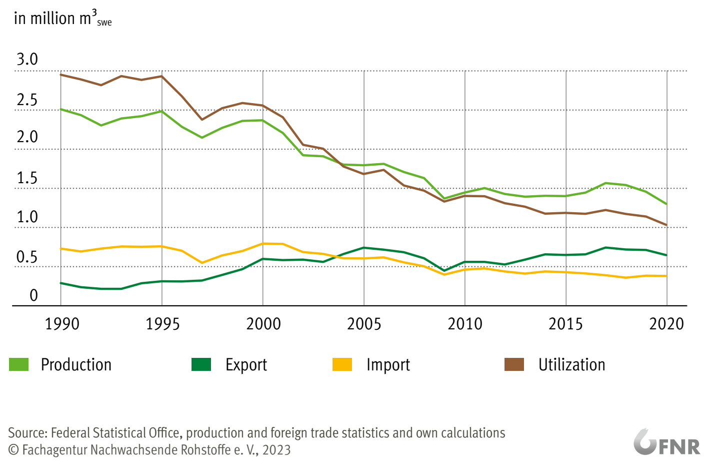
Development of hardwood lumber production

The development of the market for hardwood lumber is quite different. The production and consumption of hardwood lumber are declining during the entire period under consideration. In foreign trade, exports are growing faster than imports, which means that domestic use is declining even more than production.

It does not fit at all into a time when deciduous trees are becoming more and more important for mixed forest stands. The reasons are manifold and can only be partially discussed here. In the construction sector, hardwood is mainly used for interior applications (e. g. stairs, parquet). For the more material-intensive area of construction, from roof trusses to prefabricated houses, softwood is used almost exclusively. Even every house built of stone has a roof truss made of softwood. It is lighter, easier to work with and usually cheaper. Last but not least, the graded shape of softwood has processing advantages over hardwood, which splits into numerous branches after a short stem section. This is nice to look at, but difficult to process. The lighter, softwood is also dominant in the packaging sector (pallets). In the furniture sector, on the other hand, solid hardwood has larger shares, but if add wood-based panels (e. g. particleboard) are added, more softwood is used than hardwood even in the furniture sector. This is partly a knock-on effect, as particleboard uses large proportions of sawmill by-products and waste wood, which is largely softwood.

The economic causes have already been partly addressed. The main reason for the restrained use of hardwood is its more complex processing. Hardwood is heavier, harder and more varied in shape. This makes automated processing more difficult. Thus, hardwood is often exported as logs or sawn timber to countries with lower labour costs and returns as parquet friezes or plywood.

Figure 2.2: Development of the market sectors of hardwood lumber



SUBSTITUTION OF SOFTWOOD PRODUCTS

It should not go unmentioned that there are numerous research efforts and developments to facilitate the uses of hardwood. “Construction beech” is one example that has already reached market maturity. This is statistically reflected in other product categories. Nevertheless, the substitution of softwood products with hardwood products is one of the greatest challenges of future wood use.

The sawmill industry plays an important role in this because it buys the main product of forestry in the form of logs. This leads to the question of the volume of wood used in the sawmill industry.

REPORTING THRESHOLDS

As for other sectors, there is a reporting threshold in the official statistics for plants subject to reporting requirements. It was raised from 5,000 m³ of cutting in 2007 (production statistics) and 2009 (wood processing statistics) to plants with at least ten employees, depending on the economic focus. Thus, the official statistics do not show the full production volume. Another possible reason for under-reporting is the integration of further processing in the sawmill industry (planed wood, boards). This may mean that sawn timber that is processed internally is not always reported as rough timber in the statistics. For the use of raw materials in the sawmill industry, but also for determining the amount of residues, it is important to know the entire production. A very detailed analysis of these effects was carried out by Przemko Döring (2020).

Raw material use in the sawmill industry

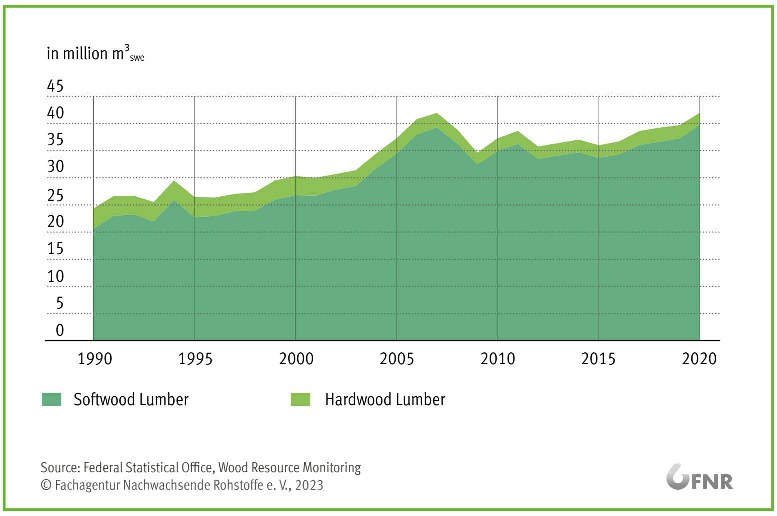
The calculation of total lumber production starts with an extrapolation of the sawnwood production not recorded in the official statistics. For the years 2002, 2005, 2010, 2015 and 2018, coverage rates of the production statistics were determined separately for softwood and hardwood. According to this, the coverage rate for rough timber from softwood increased from 77 % to 80 % between the years 2002 and 2018, while that for rough timber from hardwood tended to decrease from just under 40 % to 34 %. The lower collection rate is also due to the greater importance of smaller sawmills in the hardwood sector.

Subsequently, yield factors (logs used to sawn timber produced) are used to calculate back to the required stemwood. The values between the survey years are interpolated using the development of the production statistics. The example shows that both sources are necessary to obtain a picture that is close to realistic circumstances. The Federal Statistical Office provides continuous time series, while the Wood Resource Monitoring supplements the production volume in survey years and determines the composition of the raw materials.

STEMWOOD PROCESSING IN THE SAWMILL INDUSTRY

The following figure shows the use of stemwood in the sawmill industry. In 1990, the share of softwood was 84.6 % and that of hardwood cut was still 15.4 %. Since softwood log use expanded strongly while hardwood log use tended to decline slightly, the hardwood share decreased to 5.2 %, which is equivalent to saying that 94.8 % of the cutting in 2020 was softwood. The cause of this clear disproportion to the silvicultural objectives is the demand from consumers in the construction, packaging, furniture and paper sectors, who are probably not even aware of the consequence.

Figure 2.3: Development of stemwood input in the sawmill industry



Sectors of the process and the market

Supplementing the previous graphs, the following input-output balance and the link to the market sectors via production gives a market overview in figures. The left part shows the production process in the form of calculated solid wood equivalents (m^3_{swe}). The sawmill industry uses only stemwood (tree wood). Compared to many other wood products, it does not use residual and recycled wood. Instead, it is a major supplier of residual materials in the form of sawmill by-products, which are used, for example, in particleboard production or for pellets. On the output side, the product appears first, followed by residues, losses and if relevant compression or expansion.

Table 2.2: Input-output balance and market sectors of the sawmill industry (2020)

Process in million m^3_{swe}				in million m^3	
Input		Output		Market	
Softwood lumber industry					
Tree Wood	39.840	Product	24.143	Production	24.143
Bark	5.020	Residue	19.221	Export	9.691
Residue	0.000	Losses	1.496	Import	5.177
Recycling	0.000			Change i. St.	−0.088
Input	**44.859**	**Output**	**44.859**	**Domestic use**	**19.717**
Hardwood lumber industry					
Tree Wood	2.168	Product	1.308	Production	1.308
Bark	0.236	Residue	1.027	Export	0.656
Residue	0.000	Losses	0.070	Import	0.390
Recycling	0.000			Change i. St.	0.002
Input	**2.405**	**Output**	**2.405**	**Domestic use**	**1.040**
Lumber industry, total					
Tree Wood	42.008	Product	25.450	Production	25.450
Bark	5.256	Residue	20.247	Export	10.347
Residue	0.000	Losses	1.566	Import	5.567
Recycling	0.000			Change i. St.	−0.085
Input	**47.264**	**Output**	**47.264**	**Domestic use**	**20.756**

Sources: Wood Resource Monitoring, Federal Statistical Office

Bark is good packaging when transporting roundwood. It is removed before cutting and used for energy or other purposes (mulch). To calculate back to the tree bark, one assumes surcharges on the debarked wood of 12.6 % for softwood and 10.9 % for hardwood.[3] However, the calculated bark of the standing log in the forest does not arrive completely in the sawing process. Losses during harvesting, transport or bending at the woodyard reduce the bark availability. According to the ITOC study, a loss of 29.8 % was assumed, regardless of where this loss occurs between the standing tree in the forest and the processing stage in the sawmill. In the process accounting, the bark is fully included in calculated form and appears on the output side as residual material (potential supply) and loss.

COMBINING MATERIAL FLOW AND MARKET ANALYSIS

The aim of this revision of the Wood Resource Monitoring is to combine the methods of Wood Resource Balancing, Wood Material Flow Analysis and Market Analysis in terms of data technology. The latter is done with the following table as an example for the year 2020. The right side of the table shows the sectors of the sawn timber market. The calculated uses result from the production after deducting exports and adding imports. The sawnwood market is presented in cubic metres of sawnwood and shows a positive foreign trade balance. When the stock is reduced, or put to use, the use increases accordingly. Therefore, the change in stock, in relation to the use, carries a negative sign in the stock build-up.

On the statistical sources

The basis for determining the raw material shares or re-estimating quantities is the Wood Resource Monitoring with the reports shown (List at the end of the chapter). For the presentation of sectoral development (production, foreign trade) and interpolations, the GENESIS database of the Federal Statistical Office was used from 2002. Earlier data are based on the corresponding specialised series or compilations of the ZMP market balances. Data on stockpiling are taken from the BMEL Timber Market Reports. The classifications change over time or individual data are not reported and have to be re-estimated. Product groups may have to be recompiled. Thus, for the presentation of continuous series over long periods of time, numerous calculations are required due to systematic changes. Their presentation would go beyond the scope of this publication, so the abbreviated form "Wood Resource Monitoring, Federal Statistical Office" is used.

3 *Mantau et al. (2016)*

Own calculations are included in almost all graphs and tables. The reference "own calculation" is omitted. Further references can be found in the bibliography.

Deviations in the column totals

In the case of extrapolations, it can happen that partial quantities of plants are used. This can lead to rounding in the summary, so that the sum of a column can deviate slightly.

The phenomenon also occurs when statistical data sources are combined into larger units (millions). Sum deviations also occur when percentages are rounded.

Since the cases mentioned are correct roundings, they are also presented in this way. The alternative would be a manipulative intervention which, in the case of complex systems (dashboard), would also destroy the algorithm.

2.3 Pulp industry

STRUCTURE OF THE PULP INDUSTRY

Compared to the sawmill industry, the industrial structure of the wood and pulp industry is rather clear as a result of the necessary plant size. The number of plants in 2019 was 14 and the production capacity was 2.713 million tonnes. For this purpose, a wood raw material volume of 9.508 million m^3_{swe} was processed. The high volume (m^3) in relation to the mass (t) is a consequence of the fibre extraction process, which produces residual material (black liquor) in addition to chemical pulp in roughly equal amounts. This requires 2.483 m^3_{swe} per tonne for the production of mechanically extracted mechanical pulp and 4.703 m^3_{swe} for chemically extracted chemical pulp.

Table 2.3: Number and capacity of pulp industry

2019	Pulp industry		Capacity	
Industry structure	**Number**	**%**	**Mio. t**	**%**
Mechanical pulp	8	56.3	1.078	39.7
Chemical pulp (sulfit)	4	29.6	0.620	22,9
Chemical pulp (sulfat)	2	14.1	1.015	37.4
Total	**14**	**100.0**	**2.713**	**100.0**

Source: Gieseking, L.; Döring, P.; Mantau, U. (2020)

In an international context, Germany is a "dwarf" in pulp production, but a "giant" in paper production. Based on FAO statistics, the production of the pulp industry in Germany was ranked 4th in Europe and 15th in the world in 2020. The paper industry, on the other hand, ranked 1st in Europe and still 5th in the world. How can the contradiction be explained in a few words?

PRODUCTION CONSTRAINTS

For a long time, sulphate pulp production was associated with considerable emissions to water and air. Thus, it was not possible in densely populated Germany due to environmental regulations and concentrated instead on Scandinavia and America. However, sulphate pulp is an important raw material for most paper products, partly because of its strength. Since production in Germany was limited to the manufacture of sulphite pulp and mechanical pulp, its growth in size remained limited. In the meantime, sulphate pulp plants have also been encapsulated so well that they can be operated largely without air and water emissions. Around 2004, two sulphate pulp mills were also built in Germany. But at that time, the German paper industry had long since established itself as a recycling industry. This was consequent, because Germany, with its large population, has a high volume of waste paper.

Development of the pulp industry

Until 2010, production for mechanical pulp was largely stable. After that, capacity declines by a third and production falls by almost half.

PAPER PRODUCTION FROM RECYCLED PAPER

In the pulp sector, the development is somewhat different. As already mentioned, domestic production is rather low compared to the uses and accounts for about a quarter of the uses. The capacity build-up around the year 2004 is not as clearly visible in the figure as in wood use. Domestic uses are very much dominated by imports, but Germany is also a notable exporter of chemical pulp. Both mechanical pulp and chemical pulp (sulphite) show a tendency to decline from 2010 onwards. This is probably a consequence of improved recycling technologies, which have in the meantime increased the share of waste paper in paper production to about 75 %. Overall, the development of the wood and pulp industry in Germany is rather slightly declining.

Figure 2.4: Development of the mechanical pulp market sectors

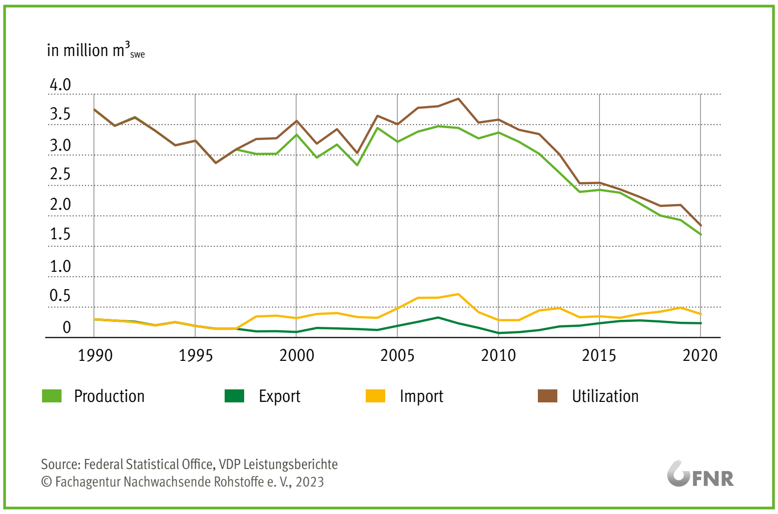
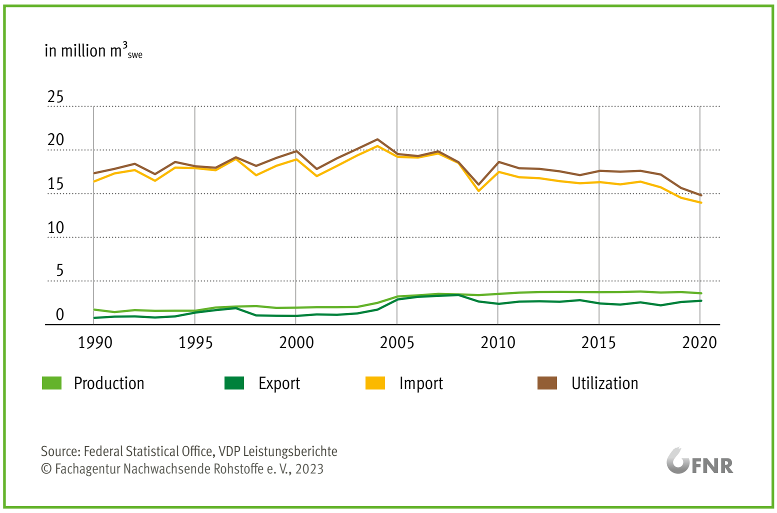


Figure 2.5: Development of the chemical pulp market sectors



Raw material use in the pulp industry

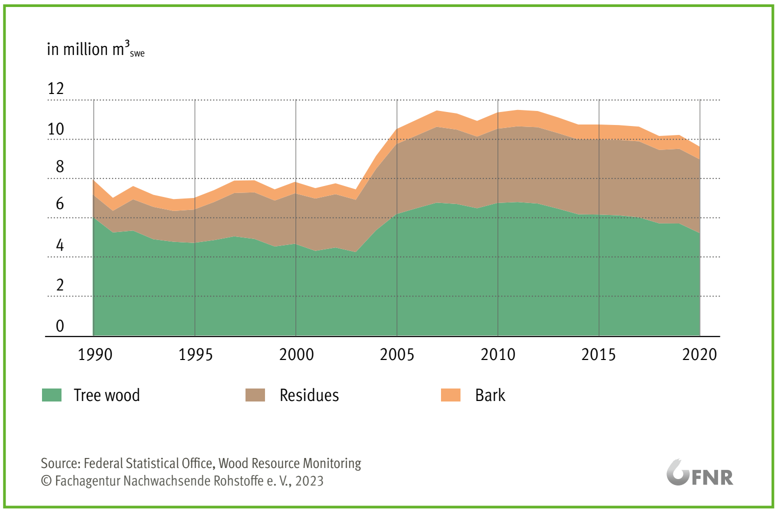
The presentation of wood use in the pulp industry is done for mechanical and chemical pulp together. The development illustrated above can also be seen in the use of raw materials. After an increase in capacity around the year 2004, the use of wood initially remains constant and tends to decline from around the year 2010. At the same time, the use of wood residues has increased.

The bark shown is not processed in the product. It is included as a calculated input (tree bark) and flows out in the material flow on the output side as bark loss and potential market supply (residual material). This includes an internal energy use. This would be accounted for in the biomass combustion plants.

BLACK LIQUOR

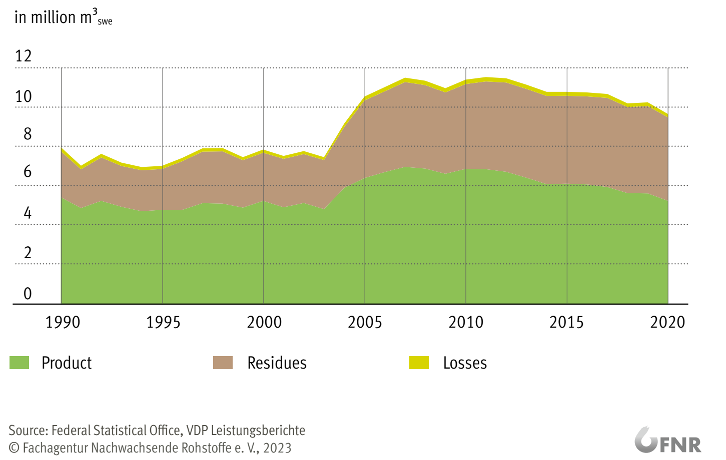
Just as the sawmill industry provides about 40 % of the roundwood used as wood residues for other production processes, chemical pulp production produces about half of the wood used as waste liquor (black liquor). In this case, the term “residual material” would be more appropriate, but that would only lead to another term with no gain in knowledge. It is clear from the figure that their share has increased with the larger share of chemical pulp.

Figure 2.6: Development of raw wood input in the pulp industry



Currently, black liquor is used in the pulp industry for energy in large combustion plants. However, it is also potentially a feedstock for biorefineries.

Figure 2.7: Development of output flows in the pulp industry



Input-output balance and market sectors

SECONDARY PULP (WASTE PAPER)

The data on the production process have already been largely discussed. The outflows result predominantly from the calculated bark losses. The following market balance shows the high foreign trade activity for chemical pulp. The background to this was discussed at the beginning. It should also be noted that secondary pulp (waste paper) is not included in the calculations. At 44.5 million m^3_{swe}, the overall balance for chemical pulp would be dominated by the use of recycling material.

Table 2.4: Input-Output-balance and market sectors of pulp industry (2020)

Process in million m^3_{swe}				in million m^3_{swe}	
Input		Output		Market	
Mechanical pulp industry					
Tree Wood	1.367	Product	1.687	Production	1.687
Bark	0.172	Residue	0.121	Export	0.227
Residue	0.320	Losses	0.051	Import	0.377
Recycling	0.000			Change i. St.	0.000
Input	**1.859**	**Output**	**1.859**	**Domestic use**	**1.838**
Chemical pulp industry					
Tree Wood	3.851	Product	3.547	Production	3.547
Bark	0.475	Residue	4.103	Export	2.695
Residue	3.443	Losses	0.119	Import	13.907
Recycling	0.000			Change i. St.	0.000
Input	**7.769**	**Output**	**7.769**	**Domestic use**	**14.759**
Pulp industry					
Tree Wood	5.219	Product	5.234	Production	5.234
Bark	0.647	Residue	4.224	Export	2.922
Residue	3.763	Losses	0.170	Import	14.285
Recycling	0.000			Change i. St.	0.000
Input	**9.628**	**Output**	**9.628**	**Domestic use**	**16.597**

Source: Wood Resource Monitoring, Federal Statistical Office, VDP Leistungsberichte

2.4 Wood-based panel industry

Structure of the wood-based panel industry

The wood-based panel industry includes particleboard, OSB, fiberboard (MDF, HDF) and lightweight panels (LDF, insulation board).

In principle and from a technological point of view, veneer and plywood also belong to wood-based panels, since wood-based panels include products that are assembled from intermediate products (fibres, veneers) into a semi-finished product (fiberboard, plywood).

From the point of view of Wood Resource Monitoring, it would seem appropriate to add veneers and plywood to a group for which, similar to sawnwood, mainly more valuable logs are used.

There were 22 production sites in the wood-based panel industry in Germany in 2020. Due to integrated sites with several production lines, the number of operating sites was 29.

Table 2.5: Number of operating sites and capacity of the wood-based panel industry (2020)

2020	Panel industry		Capacity	
Industry structure	**Number**	**%**	**Mio. m³**	**%**
Particle board	12	41.4	5.778	46.8
OSB	3	10.3	1.297	10.5
Fibreboard	11	37.9	3.972	32.2
Insulation baord	3	10.3	1.290	10.5
Total	**29**	**100.0**	**12.337**	**100.0**

Source: Gieseking, L.; Döring, P.; Mantau, U. (2020)

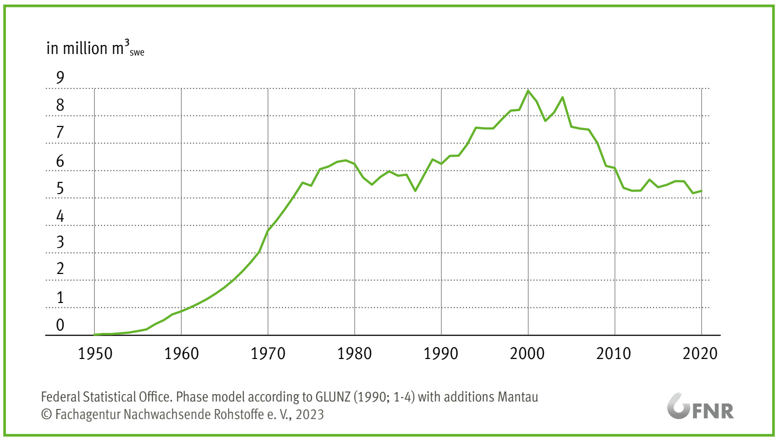
Development of the wood-based panel industry

Before describing the development of the wood-based panel industry as in other sections, the particleboard will be highlighted here in a longer overview. It represents German industrial history like hardly any other product and at the same time it is a good example for the marketing concept of the product life cycle.

PARTICLE BOARD

In the reconstruction phase after World War II, production starts sluggishly at first. The product has not yet reached its full maturity and the markets are not developed or there is a lack of purchasing power. These things change in the expansion phase between 1960 and 1970. The product increasingly meets the requirements for use and the demand for furnishings is huge. A standardised material at a favourable price fits exactly into this period of “kidney tables”. In the following decade, the expansion continues in terms of volume, but the price competition between the companies grows seriously. Only those who can reduce costs can continue to hold their own. During this period, the best way to do this is to grow in size (economics of scale). Thus, although the number of factories is almost halved, their production capacity increases significantly because the production of the individual factories grows more strongly. In addition to the internal dynamics in the industry, there is also a slowdown in economic development in the 1980s. Under the circumstances, it is hardly possible to earn money with a largely homogeneous, comparable product. Particleboard plants diversify through forward integration, pre-produce furniture parts or become active in trade fair construction. Like many other industries, unification leads to a strong upswing in the 1990s. The great demand for new construction is mainly met by prefabricated houses, in which particleboard is also used. Eastern enlargement leads to the establishment of production facilities in Eastern European countries. For another decade, the production level can be largely maintained, as globalisation has a stabilising effect on exports. With the financial crisis, however, production collapses significantly and falls back to the production level of the 1980s.

Figure 2.8:
Particle board development represents industry developments

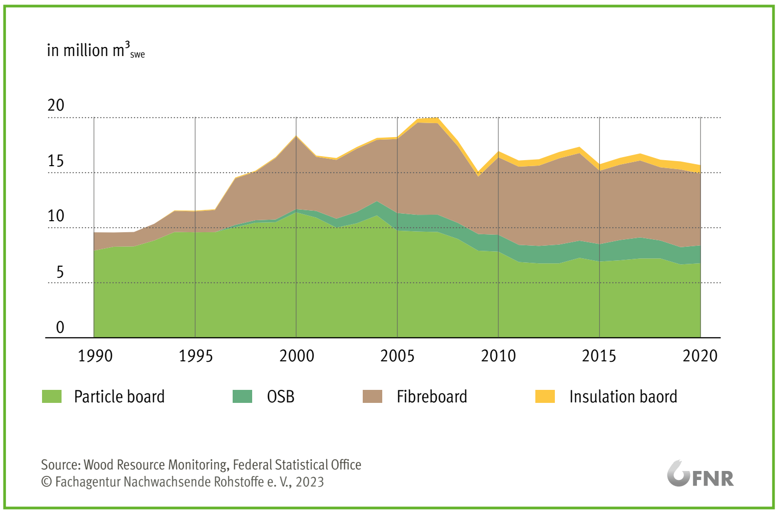


FIBREBOARD

In addition to this internal product dynamic, the development of other type of panels also plays a role. For example, fibreboard is becoming a competitor to particleboard in the furniture sector and OSB is taking over market share of particleboard in the construction sector.

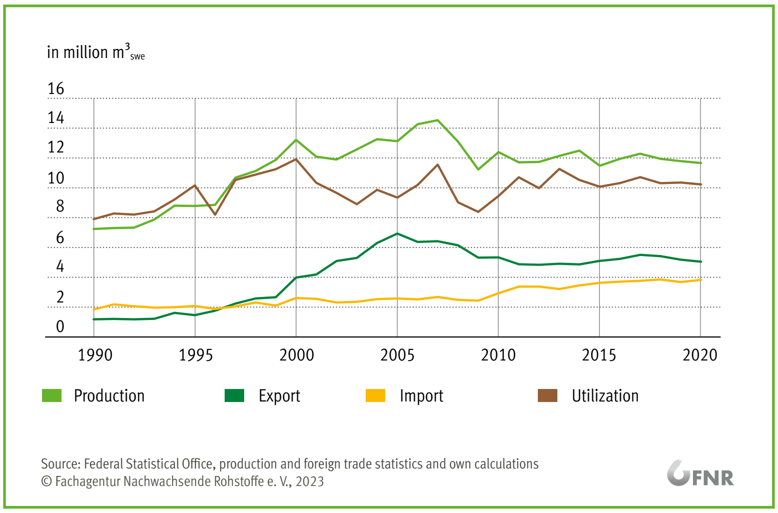
The following graph shows the development of the wood-based panel industry according to the uses of raw materials. The upswing up to 2010 is very much characterised by the market penetration of fiberboards. After overcoming the financial crisis, wood use remains above a level of 15 million m^3_{swe} wood raw material. In addition to the development of production capacities for OSB boards, fibre insulation boards have also gained in importance in recent years.

Figure 2.9:
Market development of panel industry by type of panels



After summarising the production and foreign trade data for all types of panels, the sectors of the wood-based panel industry develops as shown in Figure 2.10. The development is presented in cubic metres of panels. Wood-based panels have very different densities and thus different proportions of wood. Production has exceeded domestic uses by about 1.5 million m³ in the last ten years. After overcoming the financial crisis, production, exports and imports are largely stable. The figure shows a clear upswing in exports between 1995 and 2005. In the last decade, more than ten million cubic metres of panels were used per year in Germany.

Figure 2.10: Development of the market sectors for wood-based panels



The following figure shows the result of the survey on raw materials in the wood-based panel industry in 2020. It is an example of the primary statistical surveys that have to be carried out for all sectors of wood use in order to determine the raw material flow quantitatively by different raw materials. The proportions can fluctuate significantly between survey years. This shows the necessity of repeating such surveys. On average, they took place every three years in the Wood Resource Monitoring.

DIFFERENCES IN THE USE OF RAW MATERIALS

The particleboard has a very diverse structure and is so far the only material product that takes up a larger amount of recycling material (waste wood; 36.2 %). OSB board predominantly processes material with a long coherent fibre structure (planing chips) obtained from roundwood. In previous surveys, this was exclusively softwood. In the current survey, smaller quantities of hardwood and sawmill by-products were added. The majority of the fiberboards use sawmill by-products. The wood-based panels industry thus processes a total of 32.6 % tree wood, 50.4 % wood residues, 15.7 % recycling material and 1.3 % bark.

Figure 2.11: Raw material input in the production of wood-based panels in % (2020)

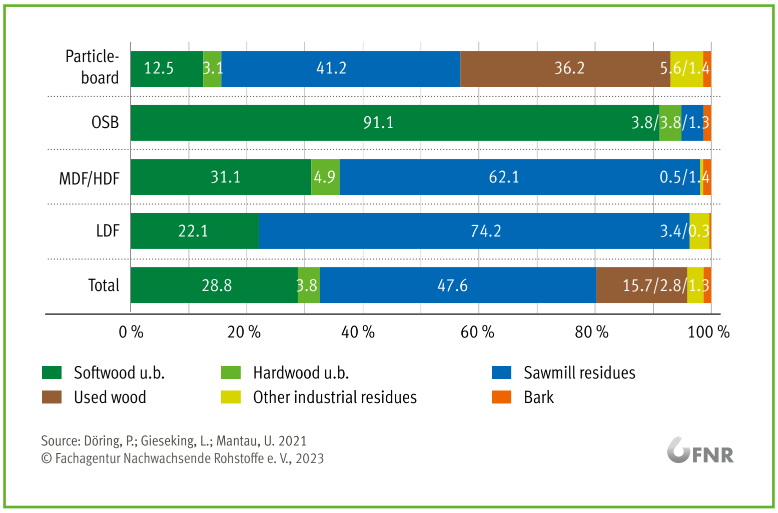
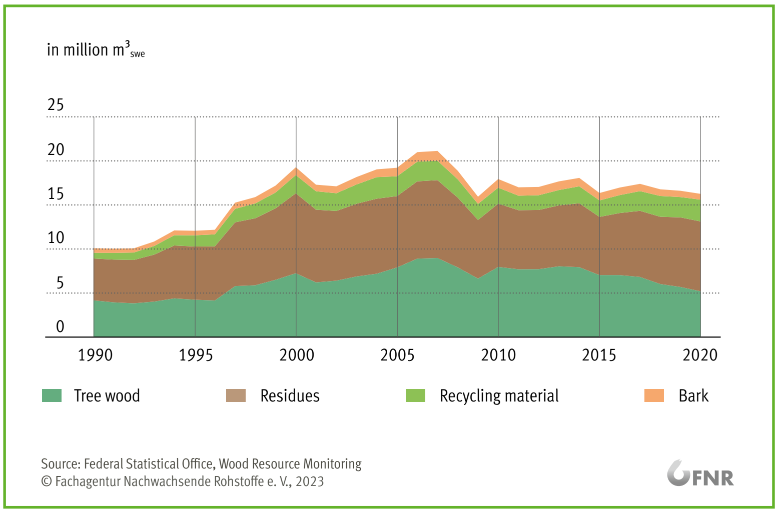


Figure 2.12: Development of raw material use in the wood-based panel industry



Input-output balance and market sectors

The presentation of the input-output balances with the market sectors is on the one hand a supplement to the previous market presentations. On the other hand, quantitative orders of magnitude are also to be presented in data form at this point, in addition to the graphics. However, they are also another control instrument for the analysis, as one can flexibly call up the years 1990 to 2020 via a dashboard and thus become aware of inconsistencies. Balance sheets also serve as a good control tool in market research. Only the reference to "official data" alone is not sufficient for consistent calculations. In the context of a cycle analysis, they must also be internally consistent.

Figure 2.13: Development of the input-output sectors in the panel industry

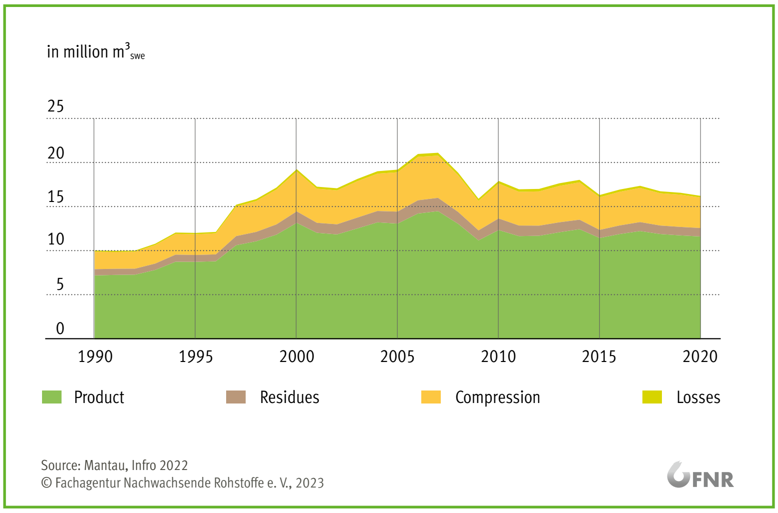


Table 2.6:
Input-output balance and market sectors of the panel industry (2020)

Process in million m^3_{swe}				in million m^3_{swe}	
Input		Output		Market	
Particleboard					
Tree Wood	1.013	Product	5.259	Production	5.259
Bark	0.144	Residue	0.349	Export	1.680
Residue	3.253	Losses	0.034	Import	1.968
Recycling	2.475	Compres-sion	1.243		
Input	**6.885**	**Output**	**6.885**	**Domestic use**	**5.547**
OSB					
Tree Wood	1.642	Product	1.263	Production	1.263
Bark	0.207	Residue	0.206	Export	0.511
Residue	0.000	Losses	0.062	Import	0.856
Recycling	0.000	Compres-sion	0.318		
Input	**1.849**	**Output**	**1.849**	**Domestic use**	**1.608**
MDF/HDF					
Tree Wood	2.345	Product	3.832	Production	3.832
Bark	0.290	Residue	0.353	Export	2.612
Residue	4.078	Losses	0.086	Import	0.702
Recycling	0.000	Compres-sion	2.441		
Input	**6.713**	**Output**	**6.713**	**Domestic use**	**1.921**
LDF					
Tree Wood	0.171	Product	1.290	Production	1.290
Bark	0.022	Residue	0.044	Export	0.236
Residue	0.601	Losses	0.006	Import	0.297
Recycling	0.000	Compres-sion	−0.547		
Input	**0.793**	**Output**	**0.793**	**Domestic use**	**1.350**
Total					
Tree Wood	5.171	Product	11.644	Production	11.644
Bark	0.662	Residue	0.952	Export	5.040
Residue	7.932	Losses	0.189	Import	3.823
Recycling	2.475	Compres-sion	3.456	Change i. St.	0.216
Input	**16.240**	**Output**	**16.240**	**Domestic use**	**10.210**

Source: Mantau, Infro 2022

2.5 Other log users

Other wood uses are divided into two groups. “Other stemwood users” include veneer and plywood industries as well as sleeper manufacturers.

Veneer industry

STEMWOOD PROCESSING IN THE VENEER INDUSTRY

A major challenge in the study of the veneer industry is the delimitation of the plants that are attributed to it. More details on this can be found in the study from Gieseking/Mantau 2020. In Germany, a total of 343,676 m³ of veneer was produced in 2019. For the entire production, 632,735 m³ of roundwood were processed. However, with a volume of 266,398 m³, a large part of the production was used by companies for internal further processing (e. g. plywood). This corresponded to a share of 77.5 %. This share can be assigned to rotary cut veneers overall. However, since only manufacturers of classic veneers, i. e. face veneer, bottom veneer and cross-band veneer, were to be examined for the actual evaluation, these companies were not considered further in the further survey. Thus, the basic population of the German veneer industry finally included 19 companies. These comprised a production volume of 77,278 m³. A total of 142,980 m³ of roundwood was processed for this purpose. This corresponds to a narrow definition of the veneer industry. In the process, 0.9 % softwood, 97.9 % hardwood and 1.2 % tropical wood were used.

Table 2.7: Stemwood used in the veneer industry by type of veneer in m³

2020	Production	
Industry structure	**in m³**	**%**
Decorative veneers	77,278	22.5
Veneers for plywood	58,298	17.0
Other veneer manufacturers	208,100	60.6
Total	**343,676**	**100.0**

Source: Gieseking, L.; Mantau, U. 2020: Furnierindustrie 2019

Plywood industry

The market definition of the plywood industry is no less problematic than that of the veneer industry (Gieseking/Karstedt/Mantau, 2020). For demarcation purposes, a locked gluing (crosswise) and at least one veneer layer were assumed.

After an elaborate selection process, 13 plywood companies were identified in 2019 that met the criteria and produced domestically. They produced 104,867 m³ of plywood in 2019. For this purpose, 184,208 m³ of stemwood and 21,655 m³ of semi-finished products were processed.

STEMWOOD PROCESSING IN THE PLYWOOD INDUSTRY

Plywood-producing plants can also use intermediate products and purchase these or stemwood from abroad. For the research question of Wood Resource Monitoring, the quantity procured domestically is of interest. 89 % of plywood production is made from stemwood. It should be noted that the feedstocks and semi-finished products can come from own production and from purchases. 11 % of the production is made exclusively from purchased semi-finished goods.

Roundwood imports were very low at 1,050 m³. Of the volume used domestically, 54.6 % was softwood and 45.4 % hardwood. Softwood is used more in the inner layers.

Table 2.8: Roundwood use in the plywood industry in m^3_{swe}

2020	Quantity	
Roundwood input	**in m³**	**%**
Softwood	100,600	54.6
Hardwood	83,608	45.4
Total	**184,208**	**100.0**

Source: Gieseking, L.; Mantau, U. 2020: Furnierindustrie 2019

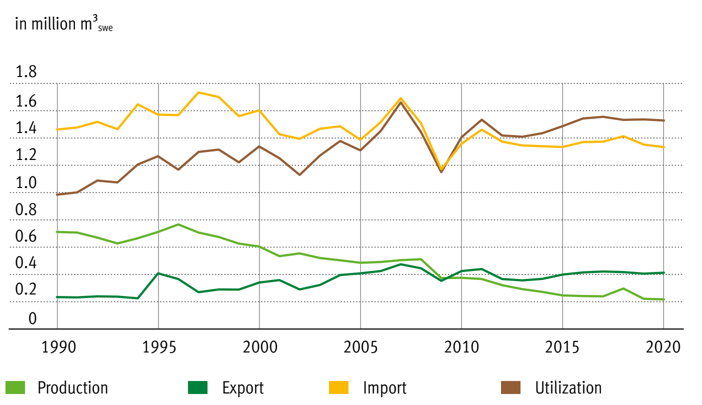
The group of other stemwood uses is open for further additions. In addition to veneer and plywood, railway sleepers were also included, which are listed in the 2020 statistics with 32,000 m³.

Development of the other stemwood processing industries

The uses of the stemwood processing industries are mainly characterised by plywood. Although Germany only produces about 0.1 million m³ of plywood, about 1.2 million m³ are still used. Consequently, the vast majority is covered by imports. Since Germany is traditionally established in the plywood business, it has remained a trading hub, so that larger quantities of plywood are also exported.

Plywood and veneer have a similar problem to hardwood lumber. There is a lack of competitive processing capacity. This leaves the industry with only specialised niche markets. Mass-produced goods are cheaper to import. In the case of railway sleepers, the decline in volume is due to substitution by concrete sleepers. Wooden sleepers are probably only needed as replacements for existing tracks or in special applications.

Figure 2.14: Development of the market sectors of the stemwood processing industry

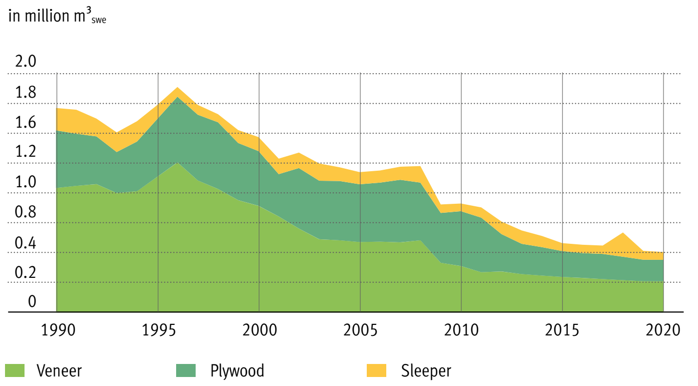


Source: Federal Statistical Office, production and foreign trade statistics and own calculations

Raw material use in the other stemwood processing industry

The veneer and plywood market underwent two waves of internationalisation. The first occurred as early as the 1970s, when large quantities of tropical timber from overseas were still being processed. As part of the development policy goals of the exporting countries, their policy was to bring back value-added processes. Importing countries followed the cheaper labour costs and relocated their production to countries in the tropics.

Figure 2.15: Development of stemwood use in other stemwood processing industries



Source: Wood Resource Monitoring, Federal Statistical Office

The second wave of internationalisation is clearly visible (Figure 2.15). Although wood species from northern latitudes have long dominated the use of wood, production costs continued to be a driver that caused large parts of production to migrate to Eastern Europe.

Input-output balance and market sectors

There is still potential for development in this group. For example, integrated production processes in particular are a recording problem. This applies to other veneer producers (wood cutlery) or to construction products that are not produced from primary products (construction beech). In contrast, glulam produced from sawn timber, for example, is recorded in the raw timber use.

The two examples show that for completeness, areas outside the semi-finished goods markets must also be considered in the future. Their importance could become greater than the markets considered here.

Table 2.9: Input-output balance and market sectors of other stemwood processing industries (2020)

Process in million m^3_{swe}				in million m^3_{swe}	
Input		Output		Market	
Veneer					
Tree Wood	0.143	Product	0.077	Production	0.077
Bark	0.016	Residue	0.077	Export	0.058
Residue	0.000	Losses	0.005	Import	0.082
Recycling	0.000	Compres-sion	0.000		
Input	**0.159**	**Output**	**0.159**	**Dom. use**	**0.101**
Plywood					
Tree Wood	0.210	Product	0.105	Production	0.105
Bark	0.025	Residue	0.122	Export	0.351
Residue	0.000	Losses	0.007	Import	1.446
Recycling	0.000	Compres-sion	0.000		
Input	**0.235**	**Output**	**0.235**	**Dom. use**	**1.199**
Sleeper					
Tree Wood	0.052	Product	0.032	Production	0.032
Bark	0.006	Residue	0.024	Export	0.000
Residue	0.000	Losses	0.002	Import	0.000
Recycling	0.000	Compres-sion	0.000		
Input	**0.058**	**Output**	**0.058**	**Dom. use**	**0.032**
Industries processing logs					
Tree Wood	0.405	Product	0.214	Production	0.214
Bark	0.046	Residue	0.223	Export	0.410
Residue	0.000	Losses	0.014	Import	1.528
Recycling	0.000	Compres-sion	0.000		
Input	**0.451**	**Output**	**0.451**	**Dom. use**	**1.332**

Source: Mantau, Infro 2022

Comparing the study on the wood-based panel industry and the wood and pulp industry with the studies on the veneer and plywood industry, the amount of work was roughly the same. However, the volume relevance is disproportionately higher in the former.

Thus, one can reduce the frequency of surveys in less relevant markets. Official statistics, however, face the same problems and can contain major data problems, as a comparison of different sources on veneer and plywood has shown (Gieseking/Karstedt/Mantau; 2020). The structures of such markets, which are far more complex than the simple understanding of supply and demand, can only be learned through intensive research for data.

2.6 Other wood processing industries

PRODUCTS CONSIDERED

The division of the other industries into "other stemwood processing" and "other wood processing" industries is done with the purpose of a more precise matching to the forest wood modelling. The group of "other wood-processing industries" currently consists of WPC and basic chemicals. The group could thus also be called "new bio-based products", but it should initially remain open to a broader product spectrum. What most of the new or relatively new product groups have in common is that no official data is available and only few data on their market volume.

WPC: Wood Polymer Composites (wood-polymer materials)

WPCs were first used as decking boards, but now also cover other areas of use such as façade cladding. Their wood content varies between 30 % and 80 %. In Germany, it is rather above average. For the calculations, 50 % wood and 50 % plastics were assumed. Accordingly, half a tonne of wood would be used to produce one tonne of WPC, which corresponds to a volume of about one cubic metre of wood.

The Nova Institute (2009) estimated a production volume of 12,000 to 15,000 t of WPC for 2007/08. Current research of our own revealed seven verifiable producers for the period 2020/21 who, according to telephone information or internet research, produced between 114,000 and 126,900 t of WPC. A production volume of 114,000 t was assumed for 2020. In order to form a closed data series, linear interpolation was used due to a lack of further data. Only sawmill by-products were used as raw materials.

Wood as a chemical raw material

The production of chemical pulp by the sulphate or sulphite process is also a chemical production process. This section deals with processes for the production of chemical base materials. So far, such processes are only known as experimental plants in Germany. A low current wood use of 4,000 m^3 can be assumed. Sawmill by-products were assumed as the raw material used. However, when processing on a large industrial scale, roundwood is also likely to be used increasingly – as in the pulp industry.

Estimates within the Biorefineries Roadmap assume a demand of around 450,000 tonnes of beech chips for a synthesis gas biorefinery such as Leuna, i.e. about one million cubic metres of hardwood. Basically, this category is a placeholder in Wood Resource Monitoring for future developments. In particular, this area cannot be disregarded when forming use scenarios of future developments.

GROWTH EXPECTATIONS

The potential of this product group is enormous. Renewable bio-monoethylene glycols (BioMEG) serve as a base material for the production of PET bottles, packaging materials, polyester textiles and refrigerants. Renewable bio-monopropylene glycols (BioMPG) can be used for detergents, de-icing agents, perfumes and cosmetics. The examples of the Borregard biorefinery plant in Norway or Lenzkirch in Austria (viscose) show that the possibilities of using wood in these areas have also been technologically possible for a long time. Moreover, as a substitute for oil-based chemical feedstocks, biodegradable plastics and their development are desirable for achieving ecological goals.

The question of timber availability is not explored in detail in this report. As the 4th Federal Forest Inventory will be completed in 2022 and results are expected in 2023/24, this would be speculative or soon outdated. The closer desirable wood uses come to the limits of an exhaustible resource, the more important fine-tuning with empirically supported data on wood use (Wood Resource Monitoring) and wood availability (Federal Forest Inventories) becomes.

2.7 Large combustion plants (CHO 1 and more MW)

Structure of large combustion plants

In the survey year 2019, 409 wood combustion plants with a combustion heat output (CHO) of 1 MW or more were identified. Several boilers located at one site or plants belonging to one and the same company are combined into one plant (Döring/Weimar/Mantau, 2021).

The Table 2.10 shows the number of plants and the wood consumption separately by CHO classes. In total, wood consumption in 2019 was 11.0 million tonnes. Other biomass that may also be used in 2019, such as black liquor, is not included in this list. The data on black liquor is determined via the pulp industry survey and allocated to the large combustion plants over 1 MW in the accounting.

In the Table 2.10 the number of plants is followed by the average CHO in MW and the wood use in the respective size class. 33.2 % of the total wood use is accounted for by 72 plants (17.6 %) in the size class 20 to under 50 MW.

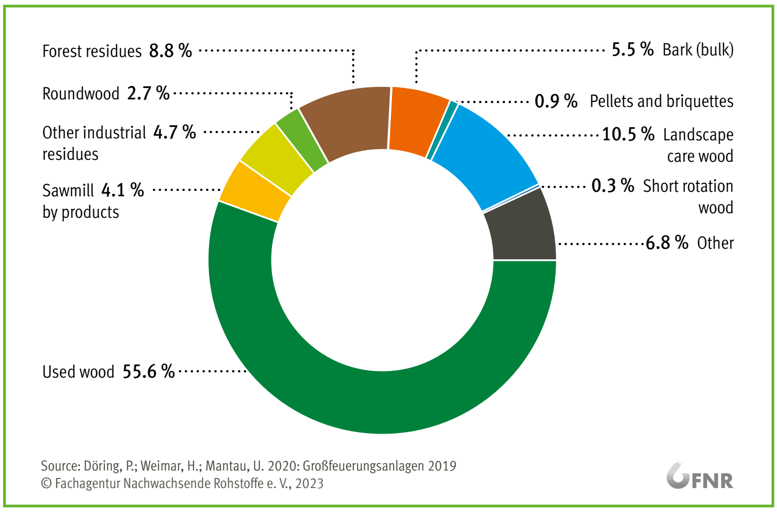
Table 2.10: Number of plants and wood consumption separately by CHO classes

	BMHPP > 1 MW		Ø CHO	Wood use	
CHO-classes in kW	Number	in %	MW	1.000 t	in %
1,000–4,999	188	46.0	2.4	490	4.4
5,000–9,999	50	12.2	7.0	384	3.5
10,000–19,999	60	14.7	14.8	1,365	12.4
20,000–49,999	72	17.6	32.0	3,648	33.2
50,000–99,999	30	7.3	64.0	3,332	30.3
100,000 and more	9	2.2	175.9	1,787	16.2
Total	**409**	**100.0**	**18.3**	**11,005**	**100.0**

Source: Döring, P.; Weimar, H.; Mantau, U., U. 2020: Großfeuerungsanlagen 2019

Waste wood had the largest share of the wood assortments with a consumption volume of 6.1 million t (55.6 %). The assortments of sawmill by-products (0.5 millionvt) and other industrial residual wood (0.5 million t) as by-products of the woodworking and processing industries together had a share of 8.8 %. Forest residues were also relatively important with 1.0 million t or 8.8 %. The consumption of landscape care wood and loose bark, with shares of 10.5 % and 5.5 %, amounted to 1.2 million t and 0.6 million t respectively. Industrial wood (forest debris) had a share of 2.7 % with 0.3 million t. “Other” (6.8 %) included wood resources that could not be defined more precisely, such as screening residues or wood chips of undetermined origin.

Figure 2.16: Shares of wood assortments used in wood consumption in % (2019)



Development of large combustion plants

CONVERSION INTO TARGET UNITS

One of the basic principles of Wood Resource Monitoring is to ask respondents about the unit of measurement in which they think and act (several, if necessary). In this way, the respondent's experiential knowledge is captured congruently. The conversion into the target unit is done afterwards. For biomass plants, the unit of measurement used is the tonne in air-dry condition (t_{ad}). Due to the different water content, a conversion is first made into oven dry (absolutely dry) tonnes (t_{od}) and then into solid wood equivalents (m^3_{swe}). The recorded quantity of 11.0 million t_{ad} corresponded to 7.9 million t_{od} or 16.5 million m^3_{swe}. The different significance of the water content can be seen in the fact that the percentage distribution of the raw material composition changes with the unit of measurement.

Table 2.11: Conversion of recorded t_{ad} into m^3_{swe}

Wood assortment	1.000 t_{ad}	%	1.000 t_{od}	%	1.000 m^3_{swe}	%
Used wood	6,124	55.6	4,924	62.7	10,650	64.4
Sawmill by products	457	4.1	281	3.6	598	3.6
Other industrial residues	515	4.7	427	5.4	908	5.5
Roundwood	296	2.7	188	2.4	362	2.2
Forest residues	969	8.8	547	7.0	1,051	6.4
Bark (bulk)	610	5.5	316	4.0	659	4.0
Pellets and briquettes	100	0.9	90	1.1	191	1.2
Landscape care wood	1,156	10.5	626	8.0	1,239	7.5
Short rotation wood	33	0.3	29	0.4	56	0.3
Other	746	6.8	425	5.4	817	4.9
Total	**11,006**	**100.0**	**7,851**	**100.0**	**16,529**	**100.0**

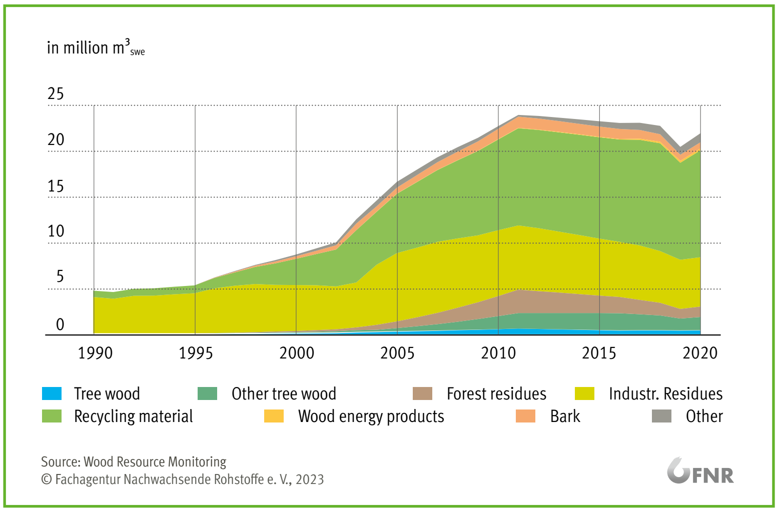
Source: Döring, P.; Weimar, H.; Mantau, U., U. 2020: Großfeuerungsanlagen 2019

Development of raw material use in large combustion plants

In the first period of representation, large combustion plants occurred mainly in the pulp industry and in the traditional wood industry. Biomass has always been used for energy in the wood industry. With the Act on the Sale of Electricity to the Grid (EEG) and the Renewable Energy Act (25.02.2000), there was a revival in the use of wood for energy. Fuel demand increased significantly from 2003 onwards, and the capacity build-up continued until 2011. The EEG subsidy for a newly constructed plant was granted for 20 years. The moderate decline can possibly be explained by the fact that plants built early on are already running out of subsidies or, in the case of older plants, repair services no longer pay off by the end of the subsidy period and the plant was shut down. This is also supported by the decline in the number of plants (−18.8 %) in the 2019 study.

The relatively uniform trend between the survey years can be explained by the linear interpolation of the data. This is supported by the fact that the plants usually run at full capacity, as production is independent of market movements. The survey year 2019 was an exception. 2019 was a particularly dry year in which the wood used also had a lower water content. A lower water content results in a higher calorific value and thus reduces the amount of wood required for the same output. In heat-producing plants, the higher outdoor temperature may have led to a lower demand. This is indicated by the strong decrease in plants with less than 10 MW. Smaller plants tend to produce heat, large plants tend to produce electricity. The same effect was also observed in 2019 for plants below 1 MW.

Figure 2.17: Development of raw material use in large combustion plants



The presentation of the input-output balance is shown coherently for all uses of wood energy in the following section.

2.8 Small combustion plants (CHO up to 1 MW)

Structure of small combustion plants

The separation of biomass combustion plants, also referred to as biomass plants in the following, has technical reasons. While the number of large combustion plants allows for a survey of all plants in principle, this is impossible and also not necessary with approx. 45,000 small combustion plants/heatings. However, a random sample fails due to the lack of address material for a random selection. Even obtaining these addresses for the survey is a challenge. This is also the case in many other areas of Wood Resource Monitoring and is only described here as an example. More details on the methodology can be found in the study Döring/Weimar/Mantau (2021), which is summarised here.

To determine the total number of installations, there are registration registers. Until the study in 2016, the population was compiled using the CHO based on lists from the chimney sweep crafts itself. Until the study for 2019, the Central Guild Association (ZIV) compiled its own statistics according to nominal heat output (NHO), so it seemed sensible to switch to the official source. The NHO was converted into CHO with an efficiency of 90 %.

The ZIV also provided data for previous years. This resulted in a new population for 2016 as well as a changed distribution of the installations among the classes. The population for 2016 now consisted of 44,867 installations compared to the number of 36,572 installations used for the calculations in the previous study. Such breaks are a fundamental problem, but are a reality of data collection in otherwise unknown market areas. Statistical error calculations only make sense if they are random phenomena. In order to build confidence in cases of this kind, the only way is to present the procedure in detail and to deal transparently with the solution used for problems that arise. For this reason, the Wood Resource Monitoring studies contain detailed descriptions of the procedure, but no calculations of the random error. Its application only makes sense if the prerequisite of random errors is given. Statistical offices also rarely report random errors in their surveys.

DETERMINATION OF THE POPULATION

In order to determine the population, the systems that could be assigned to private households were excluded from the total number of systems in the respective CHO classes from 16 kW. For this purpose, the MAP subsidy data was used up to a NHO of 100 kW. According to this, the share of non-households in the 16–50 kW capacity range was 2.9 %, in the 51–100 kW capacity range it was 29.1 % (Biomass Atlas). In the output range 101 kW and above, it was assumed that only non-household installations were involved. The following table shows the population of plants in the NHO output range 16–900 kW derived on this basis. The presentation is supplemented by a conversion to CHO classes. According to this, the calculated parent population is 43,029 plants with a calculated wood consumption of 6.2 million t_{ad}.

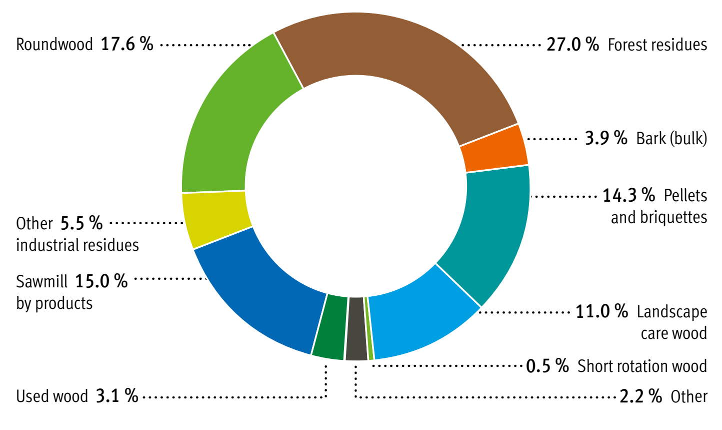
Table 2.12: Number of plants and wood consumption separately by nominal NHO and combustion heat output (CHO) classes (2019)

NHO	CHO	BMHPP < 1 MW		Wood use	
in kW	in kW	Number	in %	1,000 t	in %
16–100	18–111	23,515	54.6	1,200	19.3
101–500	112–556	17,637	41.0	3,206	51.4
601–900	557–999	1,877	4.4	1,826	29.3
Total		43,029	100.0	6,232	100.0

Source: Assumptions and own calculations according to ZIV 2020 and Biomass Atlas

A comparison between the composition of raw materials in large combustion plants (Figure 2.16) and in small combustion plants (Figure 2.18) shows clear differences in the uses of the raw materials. While the energy use of waste wood plays a dominant role in large combustion plants, it hardly occurs in small combustion plants. In contrast, forest residues (27.0 %), wood in the rough (17.6 %), sawmill by-products (15.0 %), and pellets/briquettes (14.3 %) are significantly more important.

Figure 2.18: Shares of wood assortments used in BMA < 1 MW in % (2019)



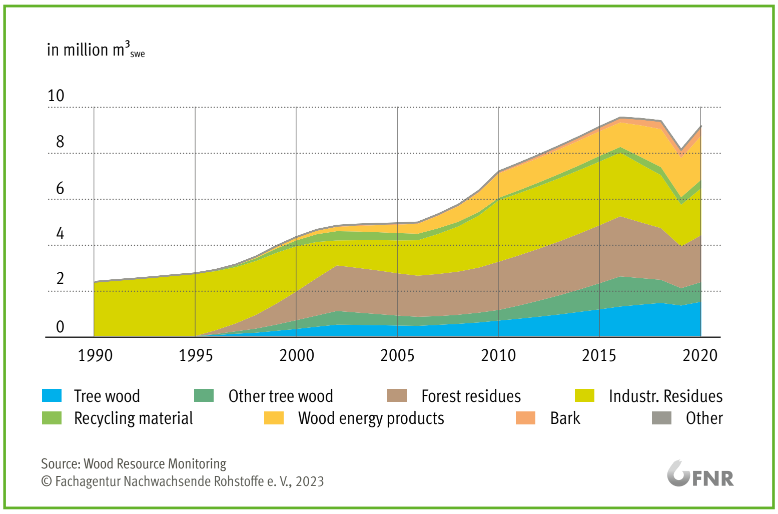
Source: Döring, P.; Weimar, H.; Mantau, U., 2020: Small combustion plants 2019

For more detailed explanations on the background of the conversion and updating of the data, please refer to the previous section and the study on small combustion plants (Döring/Weimar/Mantau 2021).

Development of raw material use in small combustion plants

Small-scale combustion plants are mainly used in municipalities and commercial plants. They differ on the one hand from small private systems in private households and on the other hand from large systems with a CHO of 1 MW or more. Originally, they were most likely to be found in small woodworking businesses. They were equipped with the accumulating industrial wood residues for heat generation. With the EEG, a change will take place from 2020. Municipalities are also forest owners and are likely to have operated heat-generating plants with forest residues. The share of industrial residual wood remains largely constant. With the introduction of a bonus for renewable feedstocks (NAWARO 2012), the share of roundwood is growing. Energy wood products are steadily gaining in importance from the year 2000 onwards.

Figure 2.19: Development of raw wood use in small combustion plants



At this point, the input side of the balances is presented for all users of wood energy. A market presentation is not possible, as imports and exports cannot be attributed to the users. An overview of foreign trade is given in section 2.12. On the output side of the process balance, there is mainly combustion and losses in the form of ash and allocated bark losses between forest and plant.

The differences in the use of raw materials to generate heat and energy have already been addressed in part. Here they are presented comparatively for the year 2020.

There are clear focal points. While recycling material (53.4 %) and residues (29.9 %) dominate in large combustion plants, the distribution of small combustion plants is broader: residues (44.7 %), tree wood (25.7 %) and energy wood products (20.9 %). For private households, it is mainly splitwood (57.2 %), followed by energy wood products (19.3 %).

Table 2.13: Comparison of raw materials used in wood energy and heat production (2020)

Process in million m^3_{swe}					
BMHPP > 1 MW			**BMHPP < 1 MW**		
Tree Wood	1.781	8.1 %	Tree Wood	2.362	25.7 %
Bark	0.668	3.0 %	Bark	0.417	4.5 %
Residue	6.565	29.9 %	Residue	4.112	44.7 %
Recycling	11.732	53.4 %	Recycling	0.376	4.1 %
E-products	0.211	1.0 %	E-products	1.922	20.9 %
Other	0.996	4.5 %	Other	0.000	0.0 %
Input	**21.953**	**100 %**	**Input**	**9.190**	**100 %**
Private households			**Total**		
Tree Wood	15.258	57.2 %	Tree Wood	19.400	33.6 %
Bark	1.025	3.8 %	Bark	2.111	3.7 %
Residue	3.302	12.4 %	Residue	13.980	24.2 %
Recycling	1.630	6.1 %	Recycling	13.738	23.8 %
E-products	5.133	19.3 %	E-products	7.266	12.6 %
Other	0.310	1.2 %	Other	1.305	2.3 %
Input	**26.658**	**100 %**	**Input**	**57.800**	**100 %**

Source: Mantau, Infro 2022

2.9 Private households

Structure of private households

While biomass installations are largely unknown populations, the population of households in Germany is well documented by the Federal Statistical Office.

SEGMENTATION BY GROUP OF RESIDENTS

At the beginning of the century, there was no reliable data on the use of wood in private households. The first two surveys were conducted on our own initiative as part of studies on the use of wood and building products in the remodelling market. Since in the building sector owner-occupiers play a significant role, whereas in a rented dwelling both landlords and tenants make expenditures, the segmentation was carried out according to occupant groups. This approach also proved to be useful for extrapolating the use of energy wood in private households and has been retained to date (Thünen 2022). The survey results of the 2018 study are presented here. The update includes the study for the year 2020.

For the present study on the year 2018, 10,102 households were surveyed about their firewood consumption via a mail panel. Only questionnaires that could be clearly assigned to one of the extrapolation groups were evaluated. Furthermore, a weighting factor was used to increase representativeness, whereby underrepresented subjects were weighted more heavily and vice versa.

Table 2.14: Sample and parent population of the survey in private households (2018)

	Sample		Basic population	
	Number	%	Number in 1,000	%
Households	**7,981**	**100.0**	**36,966**	**100.0**
without central heating	7,810	97.9	35,880	97.1
in one and two family homes	3,465	43.2	16,694	45.2
inhabited by owner	2,704	33.7	12,800	34.6
inhabited by tenant	761	9.6	3,894	10.5
in three and more family homes	4,345	54.7	19,186	51.9
inhabited by owner	921	11.4	3,245	8.8
inhabited by tenant	3,424	43.3	15,942	43.1
with central heating, mainly wood	171	2.1	1,086	2.9

Source: Döring, P.; Glasenapp, S.; Mantau, U. 2020

Table 2.15 illustrates the great importance of one and two family homes. 85.8 % of firewood consumers are in this group. The share in apartment buildings is correspondingly low. This again illustrates theimportance of the extrapolation approach according to occupant groups, which has proven itself for building products. Fireplaces and central heating systems are also building products.

The number of households using firewood in 2018 was 6.6 million, or 17.9 % of all households. Among owners of one and two family homes, the share of firewood users is particularly high at 39.3 %. In apartment buildings, significantly more wood heaters are found in owner-occupied flats.

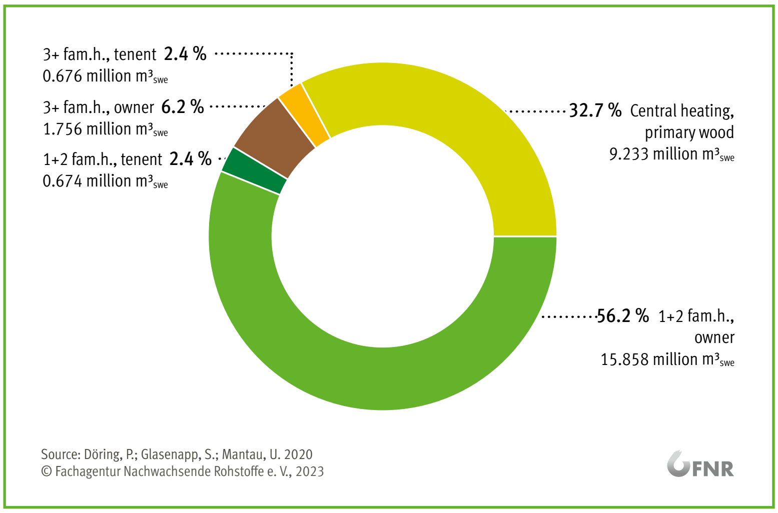
Table 2.15: Firewood users by resident group (2018)

	Fire wood user		House-holds (hh)	Fire wood user
	Number in million	in %	Number in million	% of hh
Households	**6.625**	**100.0**	**36.966**	**17.9**
without central heating	6.625	100.0	36.966	17.9
in one and two family homes	5.685	85.8	17.535	32.4
inhabited by owner	5.347	80.7	13.609	39.3
inhabited by tenant	0.338	5.1	3.926	8.6
in three and more family homes	0.940	14.2	19.431	4.8
inhabited by owner	0.678	10.2	3.447	19.7
inhabited by tenant	0.262	4.0	15.984	1.6

Source: Döring, P.; Glasenapp, S.; Mantau, U. 2020

The distribution of wood use shows that traditionally the owners of one and two family homes with individual heating systems represent the most important group of firewood users (56.2 %). Increasingly, the use of wood in central heating systems is gaining in importance and attracts large shares of use (32.7 %).

Figure 2.20: Firewood use by occupant group (2018)



WOOD ASSORTMENTS

As expected, splitwood from the forest forms the largest share of the wood assortments used (64.5 %). It is of great importance that surveys differentiate the origin of splitwood. Although splitwood comes mainly from the forest, it also comes from garden wood (8.3 %) and from wood from landscape care activities (1.4 %) and is processed into splitwood. This quantity would otherwise be counted as forest wood and thus the forest wood use would be overstated.

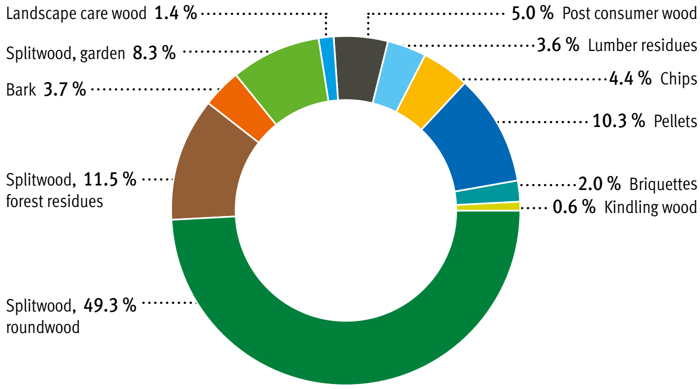
It should also be noted that the 18.2 million m³ of wood in the rough is divided into 76.4 % splitwood, 17.8 % branches (< 7 cm; forest residues) and 5.7 % splitwood bark. Thus, 13.9 million m³ and not 18.2 million m³ are to be compared with the harvested wood from forests in solid wood equivalents.

Wood feedstocks that have undergone further processing or treatment account for an increasing share (16.8 %) of wood uses (wood pellets 10.3 %, wood briquettes 4.4 %, wood chips 2.0 %, kindling wood 0.6 %).

The splitwood stocks of private households amounted to 52.7 million cubic metres in 2018. This corresponded to about 2.6 times the annual consumption of splitwood.

In terms of splitwood from the forest, households consumed 60.8 % hardwood and 39.2 % softwood in 2018.

Figure 2.21: Shares of wood assortments used (2018)



Source: Döring, P.; Glasenapp, S.; Mantau, U. 2020

Further evaluations according to characteristics (without "no information") revealed:

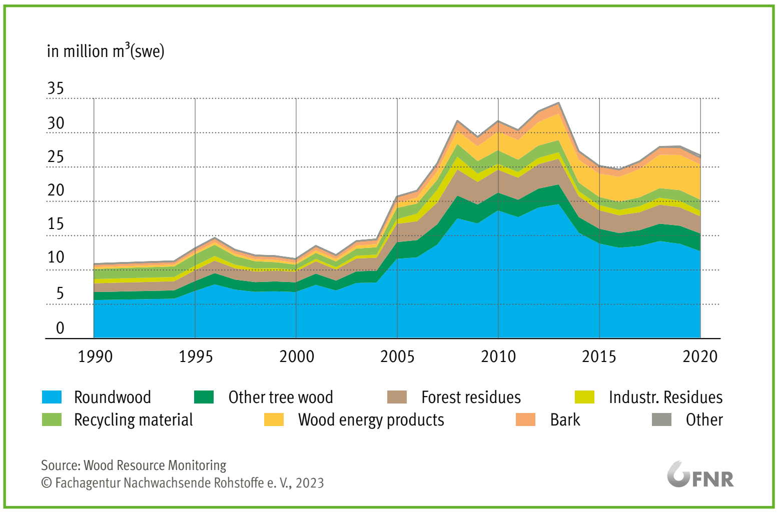
- 32.3 % of firewood consumers live in inner cities and suburbs and 67.2 % live near or far from the city.
- Towns with up to 20,000 inhabitants account for 68.0 % of firewood users.
- According to the life cycle model, "older families" account for 45.1 % of firewood users.
- For one third of the firewood users, the household net income is above € 3,000.
- 45.6 % of firewood users are older than 50 years.
- White-collar workers account for 54.1 % of firewood users.
- Forest owners account for 11.0 % of firewood users and 21.3 % of firewood use.

Development of the use of raw materials in private households

The development is characterised by three development phases. Until the mid-1990s, annual uses increased only slowly (+0.9 %). Only reunification led to a jump in levels (+36.5 %). In this phase, traditional firewood use dominated. From the year 2000 onwards, significantly higher rates of increase emerged. These were a consequence of the emerging subsidy measures and sharply rising energy prices. The dramatic oil price increases from 2005 onwards led to a corresponding revival in the use of firewood. The energy and wood markets merged during this period.

Between 2009 and 2013, the uses grow more slowly and are also characterised by cold winters (e. g. 2010). With the 2014 study, there was a decline for the first time. Wood use was 28.3 million m³ and remains at a significantly lower level thereafter. Rather warm weather lowers the uses of single-fuel heating systems (splitwood). Energy wood products, especially pellets, continue to rise with the growing number of central heating systems. It will be interesting to see how the energy price increases of 2022 will affect demand. As supplementary heating systems in particular will react to this, the use of splitwood is likely to increase significantly again after it had given up market share to energy wood products.

Figure 2.22: Development of raw material use in private households



2.10 Other energy use of wood

Structure of other energy wood use

One can hardly speak of a "structure" in this area. It is more of a catch-all. The title remains for systematic reasons. As with material uses, there are a multitude of niches in which energy uses can take place. The model structure is designed so that an unlimited number of Wood Resource Balances for niche applications can be aggregated into one group.

Biofuels (Biomass to Liquid, BtL)

With the promotion of renewable energies, energy policy objectives aimed at the use of renewable feedstocks for the transport sector as well. Agricultural plants are mainly used for this purpose. Trials with wood were undertaken in Germany by "Sun-Diesel" in Choren. In the meantime, the trials have been discontinued. Currently, no consumption quantities are known in this area. In the first years of the construction of the plant in Choren, five plants with a capacity of 500,000 litres of biofuel each were under discussion. This would have meant an additional wood use of about 12.5 million m^3_{swe}. The example shows that this area can definitely gain importance and is therefore retained as an open position. Furthermore, the concept of Wood Resource Balancing is not limited to Germany and may well gain importance in other countries.

Unknown uses of wood briquettes

Wood briquettes did not appear in the statistics until 2018. They are an interesting example of the treatment of largely unknown markets in Wood Resource Monitoring. The only source that systematically reported the uses of wood briquettes was the Wood Resource Monitoring in its studies on energy wood use in private households (Mantau 2004; Mantau/Sörgel 2006; Hick/Mantau 2008; Mantau 2012; Döring/Glasenapp/Mantau 2016; Döring/Glasenapp/Mantau 2020; Jochem/Glasenapp/Weimer 2022). However, these were always only the uses in private households. The household study for 2018 showed 0.564 million m^3_{swe} for wood briquettes and the study for 2020 0.690 million m^3_{swe}. After conversion, this corresponded to 0.361 million t_{ad} wood briquettes.

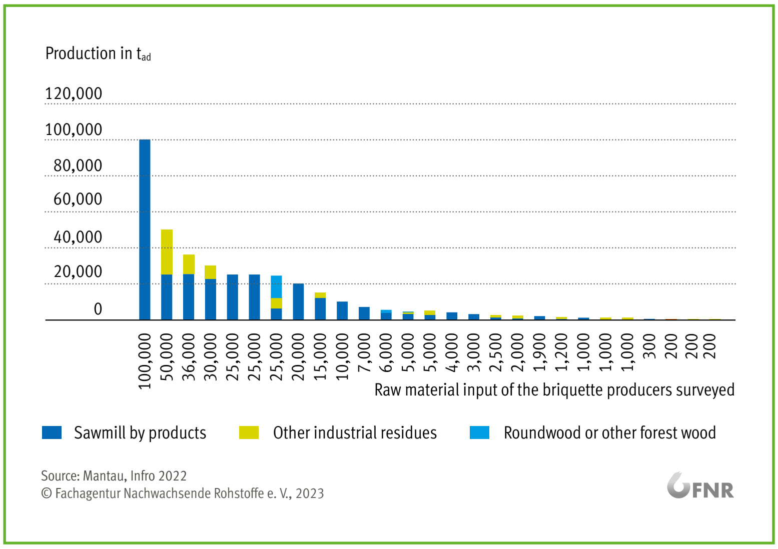
With the new system of production statistics, the Federal Statistical Office reported for the first time in 2020 on wood briquettes as of 2019 (GP19-162915003; briquettes, logs compressed from sawdust and similar). At 0.841 million t_{ad}, this corresponded to 1.605 million m^3_{swe} and was a little-noticed sensation. However, data gaps and data contradictions are not a problem, but an opportunity to learn something new.

Research revealed that numerous wood briquette presses for throughputs between 410 and 1,050 kg per hour have been sold in recent years (www.briquetting.com/briquette-presses/wood-briquette-machine). The number appeared so large and is unsecured, so it is not documented here. Inclusion in the production statistics provides a reliable basis for the production volume. However, it is already apparent that the total volume is rather larger, as small and medium-sized craft enterprises also press for their own use or direct sales. They are likely to be below the statistical cut-off.

Moreover, there seems to be an extraordinary dynamic in the market, as the volume of 0.841 million t_{ad} stated by the Federal Statistical Office in 2020 increased by one third in 2021 (1.272 million t_{ad} or 2.429 million m^3_{swe}). However, the year 2021 is outside the time frame considered here.

With the adoption of the data from the Federal Statistical Office as the given production volume, it remains unclear which raw materials are used for this. A spontaneous internet search and subsequent telephone survey of 27 briquette producers with 0.377 million t_{ad} production volume revealed the following input of wood raw materials in the plants surveyed. In Figure 2.23 the individual results of the survey are shown in order to disclose the data basis.

Figure 2.23: Raw material input of the briquette producers surveyed (2022)



In total, 79.5 % were sawmill by-products, 16.5 % other industrial waste wood and 4.0 % forest wood. The proportionate use of hardwood could not be stated by all plants for the respective assortments. According to the available data, it amounted to 1.8 % for sawmill by-products, 7.5 % for other industrial waste wood and 8.0 % for forest wood. In the sum of all individual data, it was 3.0 %.

CALCULATION OF WOOD BRIQUETTES

Finally, the question arises as to how the existing knowledge can be incorporated into Wood Resource Monitoring. This first requires a continuous data series, which is a challenge in view of the breaks and the relevant quantity, or requires the courage to fill in the gaps.

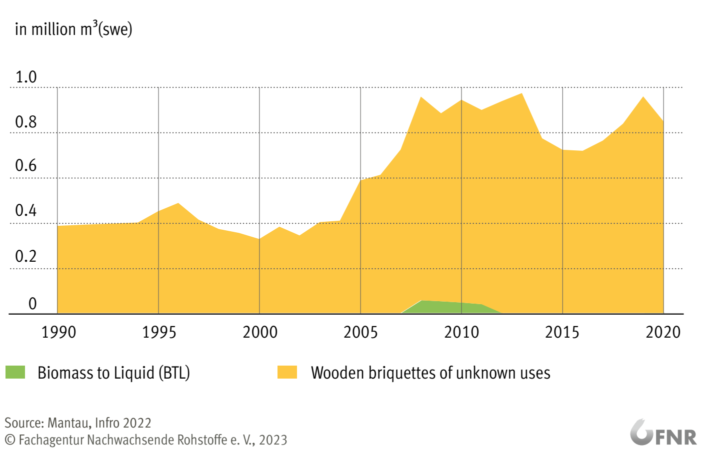
The statistically reported figure for the year 2020 is 2.3 times the amount empirically collected in private households by then, and a high number of unreported cases cannot be ruled out. Therefore, it would be a clear underestimation of the uses if one were to work retrospectively solely with the determined quantities in private households. Thus, the quantity for 2020 (0.841 million t_{ad}) was interpolated backwards using the rate of change in the development of briquette use in private households.

The data series thus obtained flows into the energy wood products sector as briquette production, while the previous data series on briquette use in private households remains unchanged. The remaining quantity is attributed to the use of this section of other energy wood uses.

Based on the comments of several participants in the research, it is reasonable to assume that large parts of these quantities are produced and used or sold in craft enterprises. This remains to be clarified by further surveys (e. g. small combustion plants).

Apart from the short-term BtL production, the development of this sector for wood briquettes is a residual calculation and task for the future. Its advantage is that the quantity is included in the Wood Resource Balancing calculation system and the research question has been worked out.

Figure 2.24: Development of raw material use in other energy wood uses



2.11 Energy wood products

Structure of the market for energy wood products

Energy wood products in this section include pellets, wood briquettes and charcoal. Domestic production is relevant for Wood Resource Balancing. Foreign trade in energy wood is dealt with in the following section.

Pellets

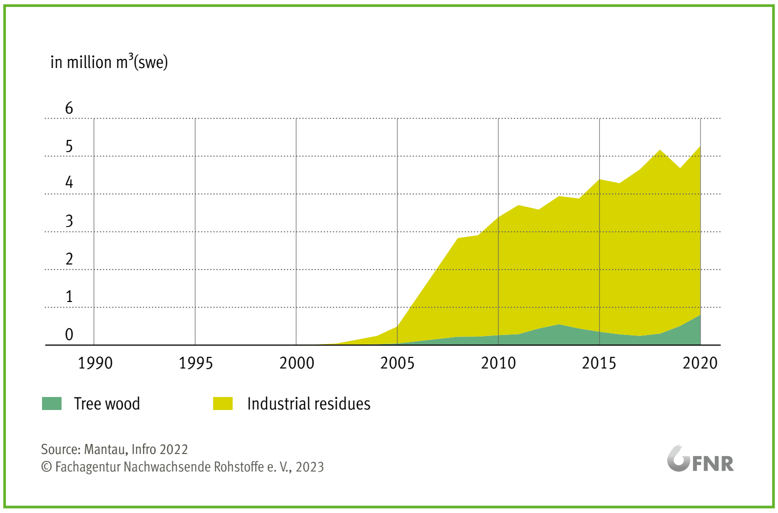
Pellets are a relatively young product. The beginnings of production were presented in the study Mantau et al. (2006). It forms the basis for quantifying the early phase of market development.

As the market grows in importance, the German Energy Wood and Pellet Association (DEPV) reports from surveys of member companies. Since 2009, the Federal Statistical Office has also reported on production and foreign trade. The data are largely consistent. The surveys of member companies show somewhat greater fluctuation than those of the Federal Office. On average, the difference between 2011 and 2020 was less than one percent. In individual years it can be up to fifteen percent. For these calculations, the data from the Federal Statistical Office was used to ensure comparability with foreign trade.

The trading unit of pellets is tonne in air-dry condition, which is assumed to be approx. 10 % water content for pellets. A conversion figure of 1.00 tonnes of pellets as well as wood briquettes to 1.91 m^3_{swe} is assumed.

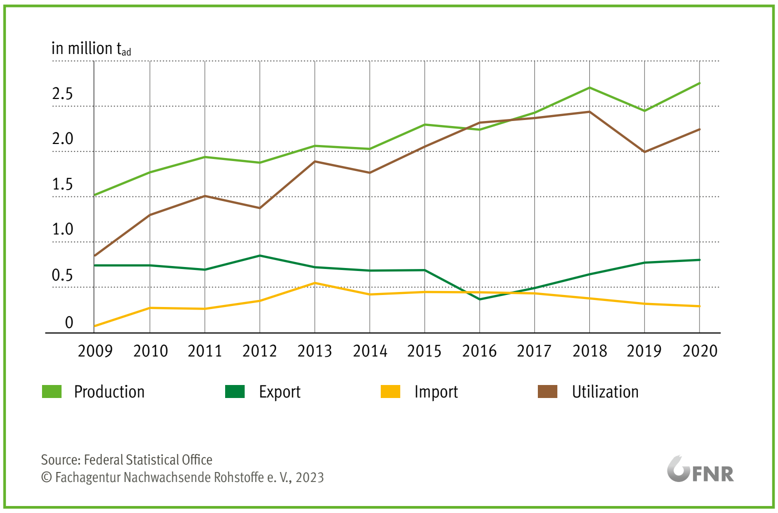
The shares of raw material use in the period 2012 to 2020 are based on data from the DEPV. Previously, according to research, a fixed distribution of 92.3 % sawmill by-products, 7.2 % softwood logs and 1.7 % hardwood logs was assumed.

Figure 2.25: Development of raw material use in the pellet industry



From the production survey of 2009 onwards, the market for pellets can be presented with consistent data series. The Figure 2.26 shows a continuously increasing pellet production. The heat and drought year 2019 is also making itself felt in this segment with declining uses. It also shows how exports are used as an outlet for domestic surpluses.

Figure 2.26: Development of the market for pellets

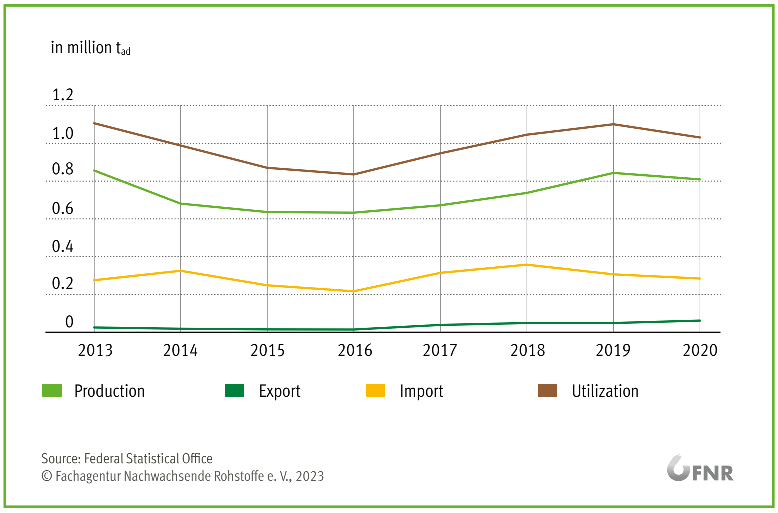


Wood briquettes

The derivation of the data for wood briquettes was discussed in detail in section 2.10 in detail.

Production data (briquettes, logs compressed from sawdust and similar; GP19-162915003) were only reported from 2019 and derived retrospectively (see Section 2.10). Data in foreign trade on "Wood waste, sawdust and wood scrap pressed" had been available for some time, but with very different commodity codes and not clearly distinguished from waste wood. Thus, the development is subject to the assumptions made.

Figure 2.27: Development of market sectors for wood briquettes



As a result of the existing, reliable empirical bases, two aspects nevertheless clearly emerge. The market is significantly larger than previously assumed and it is very strongly characterised by imports. The uses are unclear, as already mentioned. If wood briquettes with waste wood content are also imported, which would be possible according to the statistical system, it is also conceivable that they could be used for co-firing in industrial plants.

Charcoal

When one thinks of charcoal, one does not necessarily think of wood energy use in private households or of production in Germany. Charcoal production is associated with fine dust emissions and has only been operated in Germany with a special permit for plants with a historical background.

According to our own research, of 10 documented plants in Germany, 5 plants produced less than 100 t per year. 3 plants were in the range of 100 to 400 tonnes and 2 plants over 1,000 tonnes. Most of the charcoal used in Germany is imported.

According to the WWF study "Barbecue charcoal 2020 – An EU market analysis", imported charcoal mostly comes from dubious sources in Eastern Europe or from tropical areas, causing deforestation there and contributing to global warming.

In the study Hennenberg et al. (12/2022) by the Federal Environment Agency, the foreign trade in energy wood was examined in detail (Mantau). In the period 2010 to 2020, an annual average of 70,439 tonnes came from Poland, 32,677 from Paraguay and 19,811 from Nigeria (p. 215), to name just the three most important supplier countries.

Thus, the question also arises for Wood Resource Monitoring whether there can be relevant production in Germany or whether it will remain with historical small-scale plants and the quantities will be imported from abroad.

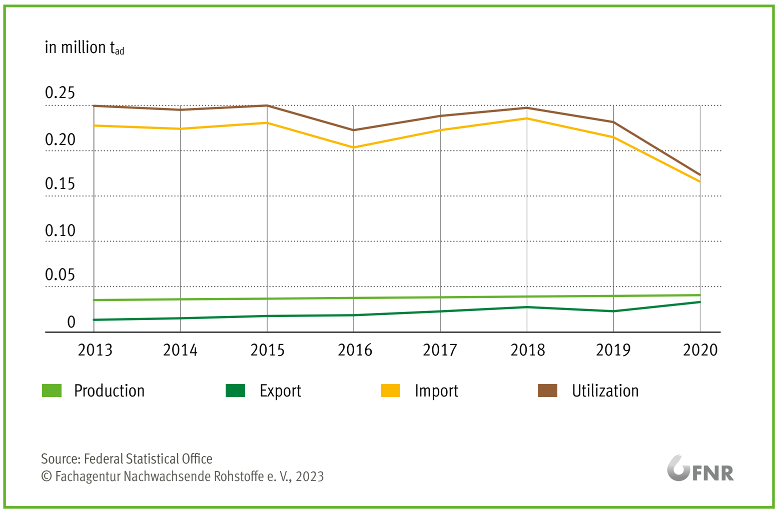
Current research of our own brought interesting findings in this regard. The company proFagus GmbH stated that they work according to DIN EN ISO 9001 and produce charcoal in closed processes. Thanks to the high process temperature in the retort, acids and tars are burnt or extracted and further processed (distilled). They do not seep into the ground, as is common in the charcoal pile and pollack process. Production was a good 30,000 tonnes. Three tonnes of untreated beech wood are processed into one tonne of barbecue charcoal and two tonnes of by-products (acids, tars). This corresponds to a conversion factor of 4.5 m^3 of beech wood per tonne of charcoal. Internationally, it is more likely to be 6.0 m^3/tonne.

Under these conditions, the market for charcoal could also develop into a relevant domestic production. According to the research mentioned above, the production volume in Germany is currently 40,000 tonnes of charcoal. On average, a conversion factor of 5 m^3_{swe} per tonne of charcoal was assumed.

The raw material used is mainly beech wood. In 2020, 200,000 m^3_{swe} was used in production. The raw material used for imports (6 m^3_{swe} per t) amounted to just under one million m^3_{swe}. In the years before, it was around 1.3 million m^3_{swe}.

The latter is a consequence of the year 2020, when many a garden party may have been cancelled due to the Corona pandemic. Imports fell from around 220,000 t in previous years to 165,000 t in 2020.

Figure 2.28: Development of the market for charcoal



For Wood Resource Monitoring, the market could be of increasing interest. If there is greater awareness of the problems of imported goods and domestic companies can offer an environmentally friendly alternative in relevant quantities, the importance of domestic production will most likely grow.

2.12 Foreign trade in fuelwood

BALANCE OF TRADE

The statements in this section are based on a foreign trade analysis by the author in the UBA study on the current use and promotion of wood energy (Hennenberg et al. 2022). Deviations result from the meanwhile updated household survey by Thünen (2022) and minor actualisations in waste wood imports. The conclusions remain unchanged.

In Germany, a total of 20.629 million t of wood energy products were used in 2020 (excluding charcoal). Domestic production was at about the same level (20.489 million t). However, this does not mean that no foreign trade took place. Imports of 2.571 million tonnes were offset by exports of 2.441 million tonnes. The balance amounted to –0.131 million t. For wood pellets, Germany was a net exporter in 2020 with half a million tonnes. For other wood energy products, the foreign trade balance was negative.

Table 2.16:
Importance of foreign trade for wood energy use in Germany by product range in million t_{ad} (2020)

in million t	Production	Export	Import	Balance (Ex-Im)	Domestic use
Firewood*	8.902	0.190	0.206	−0.015	8.918
Wooden pellets	2.755	0.801	0.289	0.511	2.243
Wooden briquettes	0.806	0.050	0.259	−0.209	1.015
Used Wood	8.035	1.399	1.817	−0.418	8.453
Total	**20.498**	**2.441**	**2.571**	**−0.131**	**20,629**
Charcoal	0.040	0.032	0.165	−0.133	0.173

* under bark
Source: after Hennenberg et al. (2022)

Looking at the product ranges and sectors according to their share of domestic use, Germany has a balanced trade balance overall. 99.4 % of domestic use is covered by domestic production. Larger deficits occur in wood briquettes and charcoal.

Table 2.17:
Importance of foreign trade for wood energy use in Germany by product range in % of domestic use in 2020

in % 2020	Produktion	Export	Import	Balance (Ex-Im)	Domestic use
Firewood*	99.8	2.1	2.3	−0.2	100.0
Wooden pellets	122.8	35.7	12.9	22.8	100.0
Wooden briquettes	79.4	4.9	25.5	−20.6	100.0
Used Wood	95.1	16.6	21.5	−4.9	100.0
Total	**99.4**	**11.8**	**12.5**	**−0.6**	**100.0**
Charcoal	23.1	18.2	95.1	−76.9	100.0

* under bark
Source: after Hennenberg et al. (2022)

In the following, the dimensions of input and output flows and market sectors are presented to illustrate their orders of magnitude.

Of the total input stream, pellets account for 75.4 %, wood briquettes for 21.8 % and charcoal for 2.8 %. The residue is a consequence of the calculated bark occurrence and the loss corresponds to the calculated bark loss. No bark is assumed for charcoal. The losses correspond to the acids and tars. These could also be seen as residues, but since they leave the balance area in Wood Resource Balancing, they fall under losses. Theoretically, losses could also be separated into physical losses and out of balance.

Table 2.18: Input-output balance and market sectors of energy wood products (2020)

Process in million m^3_{swe}				in million t_{ad}	
Input		**Output**		**Market**	
Pellets					
Tree Wood	0.794	Product	2.755	Production	2.755
Bark	0.100	Residue	0.070	Export	0.801
Residue	4.467	Losses	0.030	Import	0.289
Recycling	0.000	Compres-sion	2.507	Change i. St.	0.000
Input	**5.361**	**Output**	**5.361**	**Domestic use**	**2.243**
Briquettes					
Tree Wood	0.061	Product	0.806	Production	0.806
Bark	0.008	Residue	0.005	Export	0.058
Residue	1.478	Losses	0.002	Import	0.281
Recycling	0.000	Compres-sion	0.733	Change i. St.	0.000
Input	**1.547**	**Output**	**1.547**	**Domestic use**	**1.029**
Charcoal					
Tree Wood	0.200	Product	0.040	Production	0.040
Bark	0.000	Residue	0.000	Export	0.032
Residue	0.000	Losses	0.160	Import	0.165
Recycling	0.000	Compres-sion	0.000	Change i. St.	0.000
Input	**0.200**	**Output**	**0.200**	**Domestic use**	**0.173**
Total					
Tree Wood	1.056	Product	3.601	Production	3.601
Bark	0.107	Residue	0.075	Export	0.891
Residue	5.945	Losses	0.192	Import	0.735
Recycling	0.000	Compres-sion	3.240		
Input	**7.108**	**Output**	**7.108**	**Domestic use**	**3.445**

Source: Mantau, Infro 2022

This concludes the description and analysis of the sectors of use. In accordance with the concept of Wood Resource Balancing, the reports of the wood sources result from the use of raw materials in the use sectors.

The following studies have been produced so far as part of the Wood Resource Monitoring (1999–2021) (available at www.infro.eu):

Sawmill industry	**Mantau, U.; Sörgel, C. (2003):** Standorte der Holzwirtschaft. Sägeindustrie. Hamburg.
	Sörgel, C.; Mantau, U.; Weimar, H. (2006): Standorte der Holzwirtschaft. Aufkommen von Sägenebenprodukten und Hobelspänen. Hamburg.
	Döring, P.; Mantau, U. (2010): Standorte der Holzwirtschaft. Sägeindustrie – Einschnitt und Sägenebenprodukte 2010. Hamburg.
	Döring, P.; Glasenapp, S.; Mantau, U. (2017): Sägeindustrie 2015. Einschnitt- und Produktionsvolumen. Hamburg.
	Döring, P.; Gieseking, L.; Mantau, U. (2020): Sägeindustrie 2018. Einschnitt- und Produktionsvolumen. Hamburg.
Pulp industry	**Mantau, U.; Sörgel, C. (2003):** Standorte der Holzwirtschaft. Sägeindustrie. Hamburg.
	Mantau, U.; et al. (1999): Standorte der Holzwirtschaft. Sägeindustrie, Zellstoff- und Holzschliffindustrie, Holzwerkstoffindustrie, Altholzexporte nach Italien. Hamburg.
	Mantau, U.; Weimar, H.; Wierling, R. (2002): Standorte der Holzwirtschaft. Holzwerkstoffindustrie, Holzschliff- und Zellstoffindustrie, Sägeindustrie, Außenhandelsstatistik. Hamburg.
	Mantau, U.; Sörgel, C. (2004): Standorte der Holzwirtschaft. Holzwerkstoffindustrie, Holzschliff- und Zellstoffindustrie, Sägeindustrie. Hamburg.
	Sörgel, C.; Mantau, U. (2006): Standorte der Holzwirtschaft. Holz- und Zellstoffindustrie 2005. Hamburg.
	Döring, P.; Glasenapp, S.; Mantau, U. (2017): Holz- und Zellstoffindustrie 2015. Entwicklung der Produktionskapazität und Holzrohstoffnutzung. Hamburg.
	Gieseking, L.; Döring, P.; Mantau, U. (2020): Holz- und Zellstoffindustrie 2019 – Entwicklung der Produktionskapazität und Faserrohstoffnutzung. Teilbericht im Projekt Rohstoffmonitoring Holz. Hamburg 2020.
Wood-based panel industry	**Mantau, U., et al. (1999):** Standorte der Holzwirtschaft. Sägeindustrie, Zellstoff- und Holzschliffindustrie, Holzwerkstoffindustrie, Altholzexporte nach Italien. Hamburg.
	Mantau, U.; Weimar, H.; Wierling, R. (2002): Standorte der Holzwirtschaft. Holzwerkstoffindustrie, Holzschliff- und Zellstoffindustrie, Sägeindustrie, Außenhandelsstatistik. Hamburg.
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Energy wood products	**Mantau, U.; Sörgel, C.; Weimar, H.; Langenberg, G. (2006):** Aktuelle Entwicklungen und Perspektiven des Pelletmarktes. Hamburg 2006, 100 S.

3 WOOD SOURCES

3.1 Roundwood (wood in the rough)

SOURCES AND USES

The uses of roundwood are reported according to logs and other roundwood. A distinction can be made between softwood and hardwood for both areas. A separate presentation of stemwood and other roundwood is possible, but would unnecessarily inflate the balance. In the Wood Resource Balancing concept, the terms stemwood and other roundwood are differentiated according to their uses. Logs correspond to the sum of the sawmill industry and other log use. All other areas correspond to other roundwood. In the summary roundwood balance, the uses are listed individually anyway. If a differentiation contains additional information, it is included in the text.

SOFTWOOD ROUNDWOOD

The users are listed on the right-hand side of the partial Wood Resource Balance for coniferous roundwood. In total, 55.6 million m^3_{swe} of softwood roundwood were used. Of this, 39.1 million m^3_{swe} (71.8 %) was logs and 15.7 million m^3_{swe} (28.2 %) was other roundwood. Coniferous roundwood is used 88.5 % for material and 11.5 % for energy. The largest material user is the sawmill industry (71.6 %) and the largest energy user are private households (8.6 %).

Table 3.1: Partial Wood Resource Balance for softwood logs

PARTIALLY WOOD RESOURCE BALANCE FOR ROUNDWOOD, C					
Sources 2020	**million m^3_{swe}**	**in %**	**million m^3_{swe}**	**in %**	**Uses 2020**
Roundwood, C			39.8	71.6	Saw mill industry
Domestic use	55.6	100.0	4.7	8.4	Panel industry
– Import	4.2	7.6	4.6	8.3	Pulp industry
+ Export	12.1	21.8	0.1	0.2	Other stemwood use
+ Δ Stock, industry	−0.1	−0.1	0.0	0.0	Other mat. wood use
= Total use	**63.5**	**114.1**	**49.2**	**88.5**	**Material wood use**
			0.8	1.5	Energy product manufacturer
			0.2	0.3	BMHPP ≥ 1 MW
			0.6	1.2	BMHPP < 1 MW
			4.8	8.6	Private households
			0.0	0.1	Other energy use
			6.4	**11.5**	**Wood energy use**
Domestic use	**55.6**	**100.0**	**55.6**	**100.0**	**Total**

Source: Mantau, Infro 2022

The left side of the balance is based on the calculated domestic use and additionally takes into account foreign trade and, as far as available, the change in stock. If the stock is reduced (–), wood that is not taken from the forest enters the market. If the stock is built up (+), roundwood is stored not used. Due to high calamities (beetle wood), 12.4 million m^3 of softwood logs were exported in 2020. 4.1 million m^3 were imported. They go into use or can also be re-exported in part. Foreign trade data is not a back-calculation. Thus "(swe)" is in brackets because the column contains recorded as well as recalculated cubic metres.

In 2020, 55.6 million m^3_{swe} of softwood logs were used domestically by the wood-using sectors. Foreign trade activities increased the volume of wood removed from the forest to 63.5 million $m^3_{(swe)}$.

The comparison of the partial Wood Resource Balances for softwood and hardwood logs provides interesting information about the usage habits.

HARDWOOD ROUNDWOOD

In total, 12.7 million m^3_{swe} of hardwood roundwood were used. Of this, 2.5 million m^3_{swe} (19.7 %) was logs and 10.2 million m^3_{swe} (80.3 %) was other roundwood. The ratio is almost the opposite for softwood roundwood. This can be explained on the one hand by the growth habit of hardwood, which has significantly fewer stem parts (availability), and on the other hand by the greater processing effort (costs) and the utilisation disadvantages (consumer preferences) in most areas of use. These circumstances strongly influence the type of use.

Hardwood logs are used 28.1 % for material and 71.9 % for energy. The largest material user is the sawmill industry (17.0 %) and the largest energy user is private households (62.0 %).

Table 3.2: Partial Wood Resource Balance for hardwood logs

PARTIALLY WOOD RESOURCE BALANCE FOR ROUNDWOOD, NC					
Sources 2020	**million m^3_{swe}**	**in %**	**million m^3_{swe}**	**in %**	**Uses 2020**
Roundwood, NC			2.2	17.0	Saw mill industry
Domestic use	12.7	100.0	0.5	4.1	Panel industry
– Import	0.4	3.1	0.6	4.8	Pulp industry
+ Export	1.2	9.1	0.3	2.3	Other stemwood use
+ Δ Stock, industry	−0.2	−1.4	0.0	0.0	Other mat. wood use
= Total use	13.3	104.6	3.6	28.1	Material wood use
			0.0	0.0	Energy product manufacturer
			0.2	1.6	BMHPP ≥ 1 MW
			0.9	6.7	BMHPP < 1 MW
			7.9	62.0	Private households
			0.2	1.6	Other energy use
			9.2	71.9	Wood energy use
Domestic use	**12.7**	**100.0**	**12.7**	**100.0**	**Total**

Source: Mantau, Infro 2022

There are no particularities in foreign trade, which is also due to the fact that hardwood was not affected by the bark beetle attack. In 2020, 1.2 million m³ of hardwood logs were exported and 0.4 million m³ imported.

In 2020, 12.7 million m^3_{swe} of hardwood logs were used domestically by the wood-using sectors. Foreign trade activities increased the required wood supply from the forest to 13.3 million $m^3_{(swe)}$.

SUMMARY OF ROUNDWOOD (WOOD IN THE ROUGH)

Finally, the areas can be combined into a roundwood balance. In 2020, 68.4 million m^3_{swe} was used for domestic uses in Germany. Taking foreign trade into account, the total sources for domestic and foreign use increased to 76.8 million $m^3_{(swe)}$. 77.2 % of domestic uses are for materials. 22.8 % is used for energy. Private households in particular (18.5 %) use roundwood for energy. The distinction between roundwood and splitwood is not important for the objective of Wood Resource Balancing. The decisive factor is that it is wood in the rough. Branches are counted as forest residues. Splitwood from gardens is accounted for in the balance as landscape care wood.

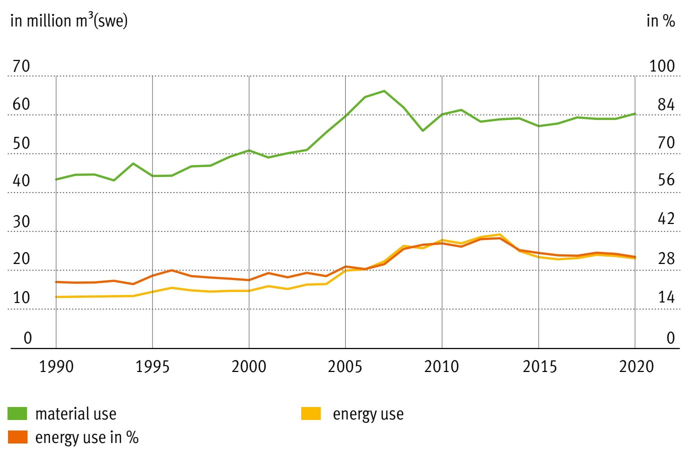
Table 3.3: Partial Wood Resource Balance for Roundwood (wood in the rough)

PARTIALLY WOOD RESOURCE BALANCE FOR ROUNDWOOD (WOOD IN THE ROUGH)					
Sources 2020	**million m^3_{swe}**	**in %**	**million m^3_{swe}**	**in %**	**Uses 2020**
Roundwood, total			42.0	61.4	Saw mill industry
Domestic use	68.4	100.0	5.2	7.6	Panel industry
– Import	4.6	6.8	5.2	7.6	Pulp industry
+ Export	13.3	19.5	0.4	0.6	Other stemwood use
+ Δ Stock, industry	−0.3	−0.4	0.0	0.0	Other mat. wood use
= Total use	76.8	112.3	52.8	77.2	Material wood use
			0.8	1.2	Energy product manufacturer
			0.4	0.5	BMHPP ≥ 1 MW
			1.5	2.2	BMHPP < 1 MW
			12.7	18.5	Private households
			0.2	0.3	Other energy use
			15.6	22.8	Wood energy use
Domestic use	**68.4**	**100.0**	**68.4**	**100.0**	**Total**

Source: Mantau, Infro 2022

In addition to the clear presentation of wood market relationships, the aim of Wood Resource Balancing from the beginning was to calculate back to the felling volume. In 2004, it was thus possible to prove that felling in Germany was underestimated by 24.4 % in the statistics (Mantau 2004, p. 22). In the meantime, the back-calculation of felling is part of the official statistical reporting (Thünen, Einschlagsrückrechnung, 2020).

Figure 3.1: Development of the material and energy use of roundwood and share of energy use



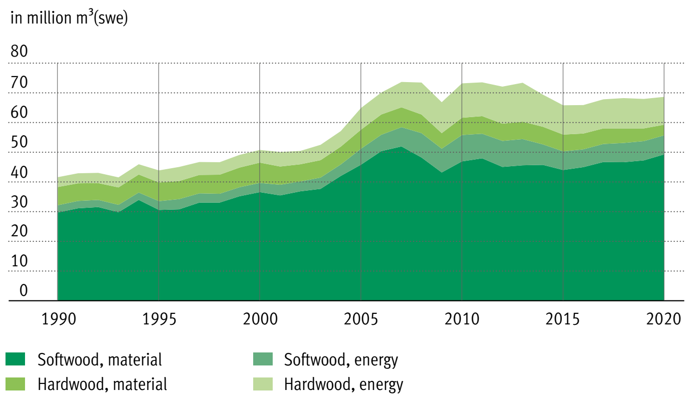
Source: Mantau, Infro 2022

DEVELOPMENT OF ROUNDWOOD UTILISATION

The Figure 3.1 shows the development over time of material and energy use of roundwood. After the energy use in private households had reached its peak in 2013, its share fell back below 20 %.

The Figure 3.2 shows the development of the total material and energy wood use according to wood species groups. As will be shown in comparison with other wood raw materials, the suppliers of roundwood in particular reacted flexibly to the increasing demand. Within roundwood, it was primarily the material sources of softwood that enabled the expansion. With the strong growth in energy demand around the year 2000, the use of hardwood roundwood also increased. Its material sources, on the other hand, continued to decline along with its uses.

Figure 3.2: Development of roundwood use by wood species



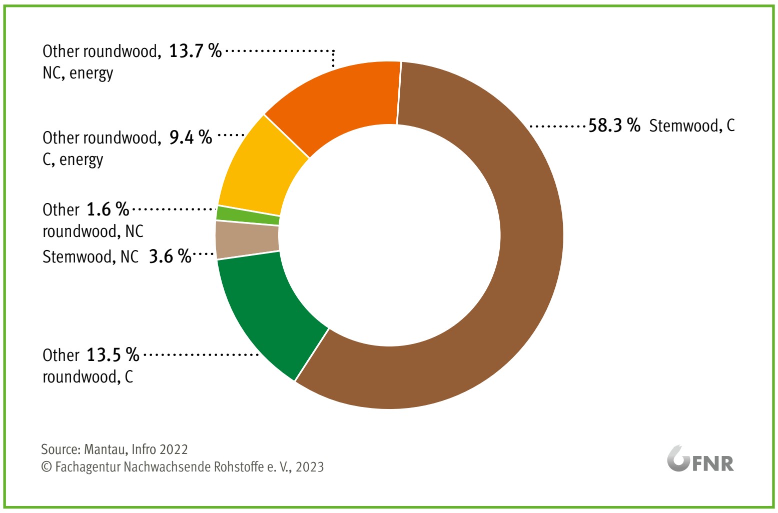
Source: Mantau, Infro 2022

The Figure 3.3 additionally differentiates between logs (uses in sawmills and other log processing industries) and other roundwood for the year 2020.

Of the 77.0 % share of roundwood used as a material, 93.2 % is softwood and 6.8 % is hardwood. Of the 23.0 % share of roundwood used for energy, 40.7 % is softwood and 59.3 % is hardwood.

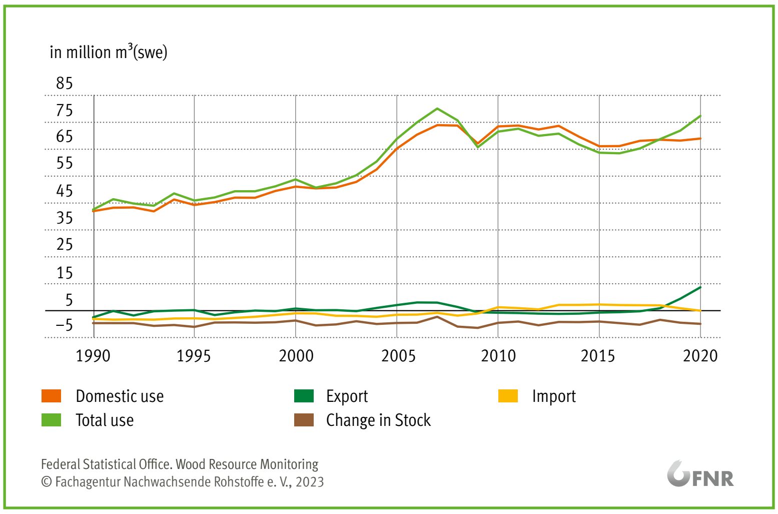
Stemwood use is of great importance for wood mobilisation because it is an important prerequisite for harvesting forest wood in total to cover costs. Of the roundwood used, 61.8 % are stemwood and 38.2 % is other roundwood. The stemwood (logs) used in 2020 were 94.2 % softwood and 5.8 % hardwood.

Figure 3.3: Roundwood shares in the uses



The following graphs show the market sectors for roundwood as a whole. Domestic volume is defined as the sum of all use sectors. In the total volume, imports are subtracted and exports and changes in stock are added. This corresponds to the right-hand side of the partial Wood Resource Balance (Table 3.3).

Figure 3.4: Development of roundwood market sectors



The year 2020 differs from the previous years in terms of softwood log exports. In 2021, softwood log exports will remain at a high level of 10.7 million m³ after 12.1 million m³ in 2020. Domestic use increased moderately, so that one can speak of a largely stable development of domestic use since 2010.

No particular fluctuations in foreign trade are discernible on the hardwood roundwood market in 2020. Exports exceeded imports in most years. Domestic use continues to lose importance despite the already low level. This could soon change due to rising energy prices and the associated purchase of roundwood. There are currently no signs of any change in the material use of wood.

Figure 3.5: Development of the market sectors of softwood roundwood

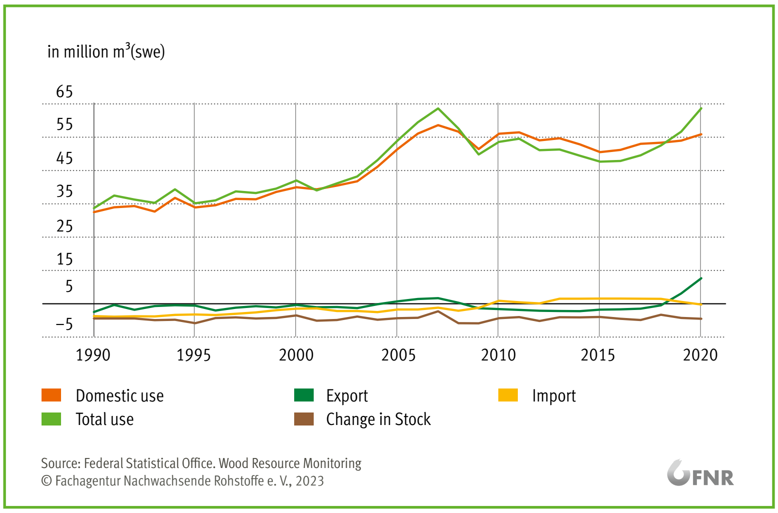
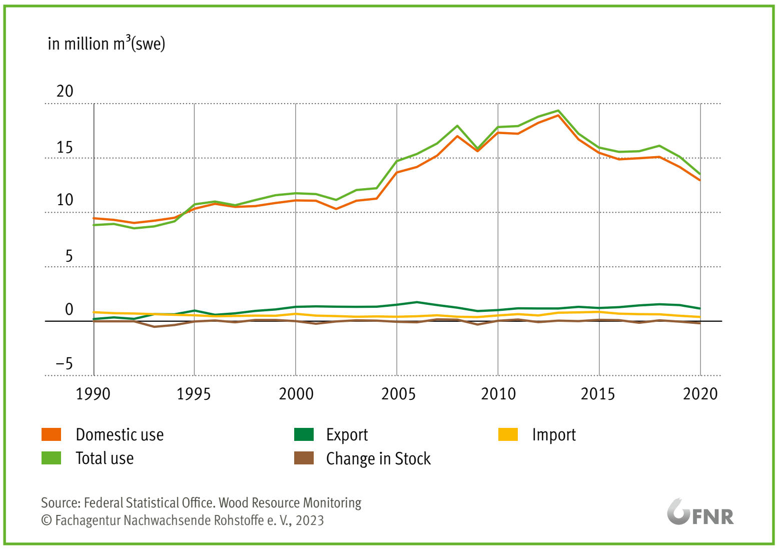


Figure 3.6: Development of the market sectors of hardwood roundwood



3.2 Forest residues

DISTINCTION FROM ROUNDWOOD

Forest residues, as distinct from wood in the rough, are wood less than 7 cm in diameter. However, the assortment cannot be defined so clearly. Together with crowns, branches and twigs, a part of the needles is always removed. Leaves have already fallen off during the harvesting season in autumn and winter. The bark of wood below the limit of wood in the rough is not calculated separately, but is included in the tonnage. When preparing splitwood, wood chips or the unprocessed delivery of forest residues, unused wood in the rough may also be included. Unused wood in the rough can be low-grade wood in the rough, cuttings that occur during value-added sorting or ordinary wood in the rough that was not transported away for logistical reasons. Thus, it cannot always be clearly determined in the sorting process, and overlaps cannot be ruled out in the survey on uses either.

In the material sector, the use of roundwood in the rough results in the input of small quantities in particleboard production. Due to the nature of the forest residues, they are almost completely used for energy.

Table 3.4: Partial Wood Resource Balance for forest residues

PARTIALLY WOOD RESOURCE BALANCE FOR FOREST RESIDUES					
Sources 2020	**million m^3_{swe}**	**in %**	**million m^3_{swe}**	**in %**	**Uses 2020**
forest residues			0.0	0.0	Saw mill industry
Domestic use	5.8	100.0	0.1	0.9	Panel industry
– Import	0.0	0.0	0.0	0.0	Pulp industry
+ Export	0.0	0.0	0.0	0.0	Other stemwood use
+ Δ Stock, industry	0.0	0.0	0.0	0.0	Other mat. wood use
= Total use	5.8	100.0	**0.1**	**0.9**	**Material wood use**
			0.0	0.0	Energy product manufacturer
			1.2	20.2	BMHPP ≥ 1 MW
			2.1	35.8	BMHPP ‹ 1 MW
			2.5	43.2	Private households
			0.0	0.0	Other energy use
			5.7	**99.1**	**Wood energy use**
Domestic use	**5.8**	**100.0**	**5.8**	**100.0**	**Total**

Source: Mantau, Infro 2022

In the case of households, forest residues accrue with the use of splitwood, in that they also include branches and twigs. Forest residues are processed as a by-product for biomass combustion plants as part of the timber harvesting process.

In addition to the high proportion of uses for energy, the Figure 3.7 shows the development of forest residual wood use. As expected, it is coupled to the increasing use of wood for energy.

The Figure 3.8 also shows the overall development and differentiates according to user groups. For private households, branches and twigs are part of splitwood use. The use in biomass combustion plants increases with the capacity build-up and then falls back again.

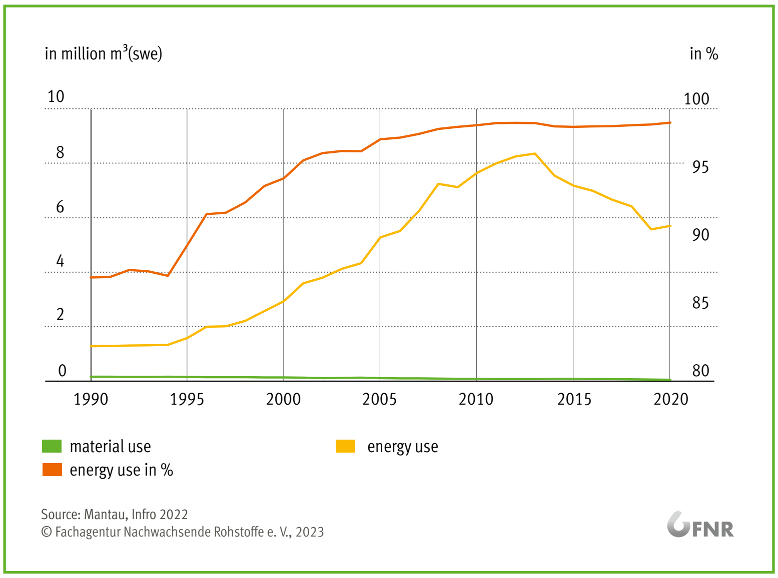


Figure 3.7: Development of the material and energy use of wood from forest residues and share of energy use

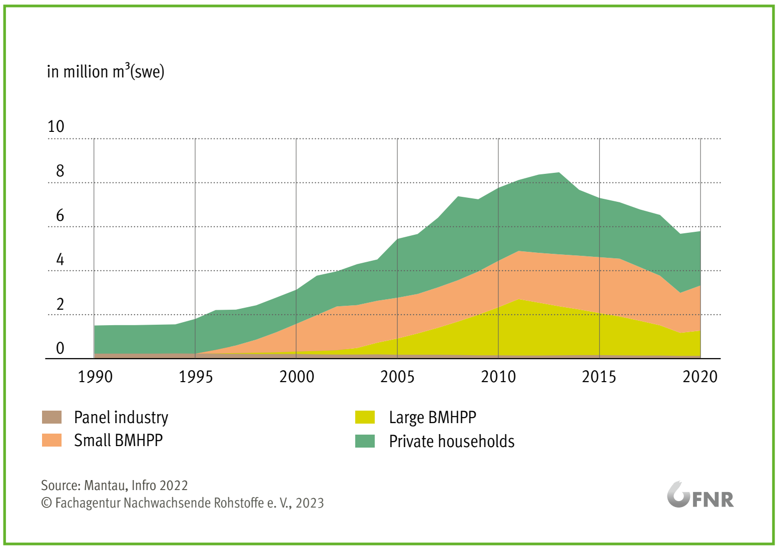


Figure 3.8: Development of the uses of forest residues

3.3 Bark

COMPLEX BARK UTILISATION

Bark can drive a modeller of circular flows into madness. Imagine a movie with four star roles, all played by the same actor in the same outfit. Only the language is different.

The amount of bark on the standing tree is different from the amount that arrives at the factory gate. In processing, it can flow into the product attached to the trunk or additionally be purchased as loose bark. The accounting of bark in the cycle process has been completely reorganised. The aim was to make the information about this feedstock more transparent and comprehensive and less prone to errors in the accounting process.

If only the bark used is considered, it seems too low to the forestry-informed reader. Significantly higher values also come from forest growth models.

The gross input of bark is calculated as a mark-up on the roundwood used. According to the ITOC model (Mantau et al. 2016), this is 12.6 % for softwood and 10.9 % for hardwood. Theoretically, there is already a difference to the bark of the standing tree, because the solid cubic metre of stock (VFm) is not taken into account by the volume of wood remaining in the forest (stumps, felling notches, quality defects). However, since it is a matter of calculating the uses, only the bark on the removed stem (roundwood) is calculated.

Bark is an excellent packaging, but it also takes damage during transport. The ITOC model was developed as part of a COST Action to better align timber supply modelling and timber market research data needs. Transport losses were estimated at 29.4 %. On average, 70.6 % of the gross bark (cubic metre) of a stem reaches the user. The transport losses are attributed to the first receiving hand.

The remaining 70.6 % either go into "production" or are potentially available as market bark (residual material). Production is to be understood in a very broad sense, as the adhering bark is also burnt in energy use. In material use, it only occurs to a small extent in particleboard production.

In energy use, however, the bark can also be purchased. In this case, a wood energy user purchases part of the potential market bark. The use of loose bark occurs in biomass combustion plants. For these users, the bark used consists of bark components on the roundwood used and purchased loose bark.

ADJUSTED BALANCE SHEET STRUCTURE FOR BARK

As a consequence, the partial Wood Resource Balance for bark is somewhat different from that for other raw materials. The first column shows the theoretical bark volume. It is attributed to the user who takes up roundwood. According to this, 78.8 % of bark accrued in combination with material purposes and 21.2 % for energy purposes. According to the bark factors, 8.4 million m^3_{swe} of bark accrued in 2020. It is reduced at the same location by the bark losses of 29.4 % or 2.5 million m^3_{swe}. The uses (mainly incineration) of bark include 2.2 million m^3_{swe}. After deduction of losses, this corresponds to 37.4 % of the bark. 62.6 % or 3.7 million m^3_{swe} remain as potential market volume. The column shows negative signs in the energy sector because bark is purchased there, i.e. part (23.1 %) of the market bark that accumulates in the material uses is already used in the energy user sectors.

Table 3.5: Partial Wood Resource Balance for bark

WOOD RESOURCE BALANCE FOR BARK (CALCULATED POTENTIAL)								
	Sources		Losses		Uses		Potential	
	million m^3_{swe}	in %	million m^3_{swe}	in %	million m^3_{swe}	in %	million m^3_{swe}	in %
Saw mill industry	5.256	62.6	1.566	63.4	0.000	0.0	3.690	99.5
Wood-based panels	0.662	7.9	0.189	7.6	0.105	4.7	0.368	9.9
Mechanical and chemical pulp	0.647	7.7	0.170	6.9	0.000	0.0	0.477	12.9
Other stemwood use	0.046	0.5	0.014	0.6	0.000	0.0	0.032	0.9
Other mat. wood use	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0
Material wood use	**6.611**	**78.8**	**1.939**	**78.5**	**0.105**	**4.7**	**4.568**	**123.1**
Energy product manufacturer	0.107	1.3	0.032	1.3	0.000	0.0	0.075	2.0
BMHPP > 1 MW	0.041	0.5	0.012	0.5	0.668	30.2	−0.639	−17.2
BMHPP < 1 MW	0.175	2.1	0.052	2.1	0.417	18.8	−0.294	−7.9
Private households	1.460	17.4	0.435	17.6	1.025	46.3	0.000	0.0
Other energy use	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0
Wood energy use	**1.784**	**21.2**	**0.532**	**21.5**	**2.111**	**95.3**	**−0.858**	**−23.1**
Total	**8.395**	**100.0**	**2.470**	**100.0**	**2.216**	**100.0**	**3.709**	**100.0**

Source: Mantau, Infro 2022

CHANGES OF BARK OCCURRENCE

This leaves the question of where the 3.7 million m^3_{swe} will remain. The Industrieverband Garten (IVG) e. V. and the Gütegemeinschaft Substrate für Pflanzen e. V. (GGS) represent about 200 manufacturing companies. They estimate that in Germany about "3 million m³ of bark are used annually as a soil conditioner and as a substrate starting material". It is not said what kind of cubic metres are involved. Since the industry deals in bulk, the conversion factor would be 0.33, or 1 million m^3_{swe}. Waste statistics show 0.622 million tonnes of bark waste (input from waste management facilities) for 2019. With a conversion figure of 1.1 t in m^3_{swe}, this would correspond to approx. 0.725 million m^3_{swe}. If both quantities are subtracted from the market potential, there are still approx. two million t of not allocated potential marketable bark. It is unlikely that this is lying around unused somewhere, as the garden associations speak of scarcity in their statement on the draft bill for the amendment of the Biowaste Ordinance (BioAbfV).

This again shows how accounting is a source of new questions that would not even arise without accounting. So what could explain the remaining 2 million m^3_{swe} or 6 million m³ bulk volume?[4]

4 *I would like to thank Mr Bernd Heinrich (KWF) for numerous helpful hints on this question.*

The total volume of 8.4 million m^3_{swe} is calculated using bark factors. The assumed factors are within the usual range[5], so that possible deviations from this value should not play a decisive role.

HIGHER BARK LOSSES

The losses could be higher than 29.4 %. The current calamity situation (bark beetle) would suggest this. On damaged trees, parts of the bark already fall off on the standing tree and the harvesting, bending and transport losses are also higher with loosely adhering bark and can go as far as total loss. If one were to assume a bark loss of 50 %, this would already explain the difference to a large extent, since the areas of use mentioned also tend to be somewhat higher. This is a typical example of the knowledge-creating value of Wood Resource Balancing, as the discrepancy in data shown requires an explanation and, as a consequence, the loss factors are to be adjusted, ideally depending on the amounts of damaged wood.

Another explanation for the low bark availability are changes in forest management. Increased use of debarking harvester heads increases the retention of bark in the forest. An increased use of debarking machines in the forest can also be observed. In the sense of our calculation, this also leads to higher losses.

According to Lühr et al. (2021), woodchips can lose 20 to 30 % of their dry matter through microbiological-chemical processes during longer storage and without prior drying. Even though the magnitude has not been measured for bark, this effect could also play a role.

The amount used for mulch could be higher than indicated by the associations. In any case, no sources are given for the 3 million m³ bulk volume. Furthermore, the figure only concerns the affiliated plants, which according to the associations account for 90 % of the total. Last but not least, there may be uses that have not been considered so far. A certain proportion of direct levies is also conceivable.

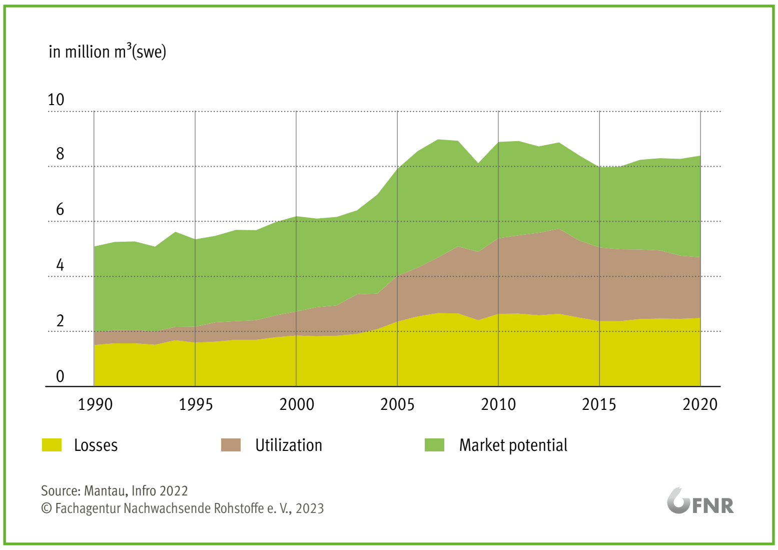
Conversion factors of raw materials with high changing water contents show large fluctuations and empirical findings are rather rare. The used conversion factor of 0.33 in relation to the indicated amount of mulchers is due to an earlier study (Mantau/Weimar 2006) on biomass combustion plants. Thus, the quantity of mulchers used could be higher than assumed here.

5 *FAO/ITTO/UNECE Forest product conversion factors questionnaire, 2018*

With this new approach to accounting for bark, a stable foundation stone for cycle modelling has been found. The reported data offer starting points for further development. Only the recorded bark quantities of 2.2 million m^3_{swe} that go into the uses are included in the Wood Resource Balancing. Thus, the critical aspects relate more to the reported potential market volume, which has no significance for Wood Resource Balancing. Mulchers and others are not included in the balance area (out of balance).

The Figure 3.9 shows the development of bark supply in the cumulative form of its accounting entry. The total volume of bark largely follows the material use of logs. In 2020, 29.4 % – as assumed – fell to bark losses, 26.4 % of the bark goes into uses and 44.2 % is potentially available on the market. By definition, losses fluctuate with sources. The uses primarily follow the energy use. This has declined somewhat in recent years. This increases the residual size or the potential market volume.

Figure 3.9: Development of the accounting entry of the bark supply



3.4 Landscape care wood and SRC

Landscape care wood

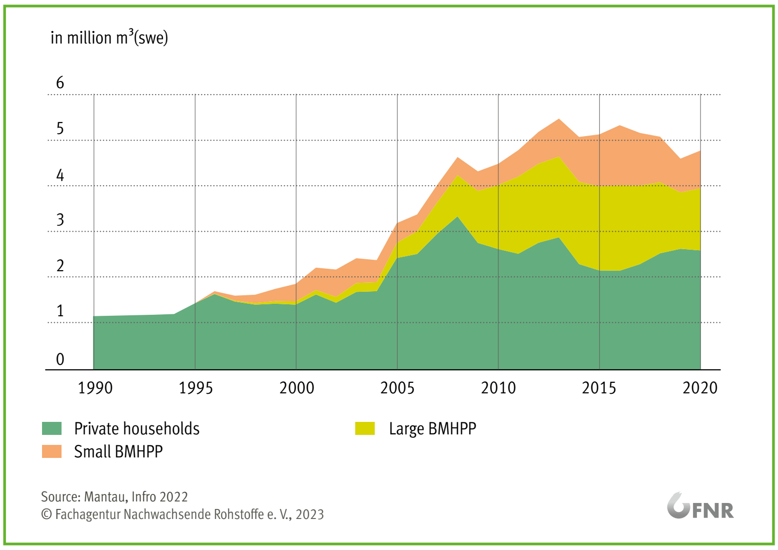
Landscape care material is defined as: grassy, herbaceous and woody organic residues from the maintenance of roadside areas, waterways, nature conservation areas, public recreational areas and cemeteries. It can be divided into green waste (grassy and herbaceous fraction) and landscape care wood (woody fraction). Landscape care material mainly accumulates in municipalities. Usually, garden wood is not included in the Landscape care material category. In this study, the Anglo-Saxon term “wood outside forests” or “urban wood” is assumed, which also includes garden wood. According to the study on the use of firewood in private households, they used the largest quantities of landscape care wood in the form of garden wood.

In 2020, 5.4 million m^3_{swe} of landscape care wood was produced. The amount is measured by the users. The largest share (2.2 million m^3_{swe}) was accounted for by private households in the form of garden wood (40.4 %). This was followed by large combustion plants with 1.9 million m^3_{swe}, which corresponded to a share of 35.1 %. The share of small combustion plants was a quarter (24.6 %) or 1.3 million m^3_{swe}. The sources and uses of landscape care wood can also be presented as a partial Wood Resource Balance. However, since this does not contain more than the previously mentioned data, it is not included. It also follows from the user groups mentioned that landscape care wood is used 100 % for energy.

IMPACT OF ENERGY USE OF WOOD

The development in Figure 3.10 shows traditionally high sources in the context of splitwood use in private households. This has risen sharply with the general increase in energy wood use in private households from 2005 onwards. As the capacity of biomass combustion plants continued to increase, the more readily available waste wood probably reached a limit and alternatives were increasingly used. In the case of small-scale combustion plants, both the NAWARO promotion and the availability of materials in the municipalities and their interest in developing renewable energies are likely to have led to greater use.

Figure 3.10: Sources of landscape care wood by users



Short-rotation plantations (SRP)

The smaller the quantities become, the more difficult it is to record them in surveys. According to Wood Resource Monitoring, 61,000 m^3_{swe} was used in large combustion plants in 2020 and 27,000 m^3_{swe} in small combustion plants.

According to the Federal Statistical Office (Land Use FS 3 R 2.1.2), there were 1,491 plants with short-rotation plantations with an area of 5.727 ha in 2020. Assuming a production output of 10 t fresh mass per hectare and year, this would result in 57,000 t fresh mass or, after conversion (1.07), approx. 61,000 m^3_{swe}. The difference of 27,000 m^3_{swe} can be explained either by over-reporting in Wood Resource Monitoring, under-reporting by the Federal Statistical Office or a higher yield. In the latter case, the yield would have to be 15.4 m^3_{swe} (88,000 m^3_{swe}/5,727 ha), which seems very high. According to Lühr et al. (2021), the area was 6,600 ha, which would put the yield at about 70,000 m^3_{swe}. Another explanation could be a wrongly declared origin of the woodchips used (forest, landscape management, SRC). As mentioned at the beginning, with such small quantities, it is already a success if relevant quantities are recorded in the sample at all.

3.5 Sawmill by-products

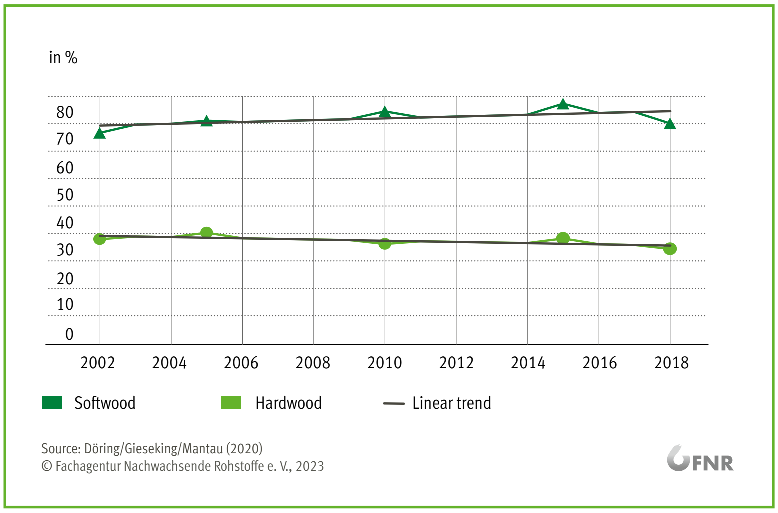
FEEDSTOCK FOR CASCADE USE

Sawmill by-products are a by-product of sawn timber production. Thus, there is a direct correlation to the development of the sawing volume of the sawmill industry. The yield of sawn timber in softwood sawing was 60.6 % in the last sawmill study of 2018. For hardwood sawing, the yield was 62.4 %. According to this, 39.1 million m³ of logs were cut in 2018, of which 23.8 million m³ were rough lumber and 15.4 million m³ were sawmill by-products, cross-cut pieces and other. The yield across all sawmill operations was thus 60.7 %.

As already mentioned in the section 2.2 the production volume for sawn timber is underestimated in the production statistics. On the one hand, this is due to the cut-off threshold, as the production of plants with fewer than 10 employees is not recorded. On the other hand, it is possible that plants that process sawn timber produced in-house only report the quantities of processed products, but not the rough timber.

The coverage ratios (quantity ratio of extrapolation via sawmill surveys to production statistics) of the five survey years (symbols in Figure 3.11) are extrapolated with a trend function for the missing years. The collection rate for sawn softwood was on average 82.0 % and for sawn hardwood only 37.4 %. While the collection rate for softwood increased on average by +0.411 % per year, it decreased by −0.153 % for hardwood. The low collection rate for hardwood lumber in official statistics was due on the one hand to the larger share of sawmills below the cut-off threshold and on the other hand to the fact that very large plants are more active in further processing and report the end products but not the rough timber.

Figure 3.11: Coverage rates of softwood lumber production

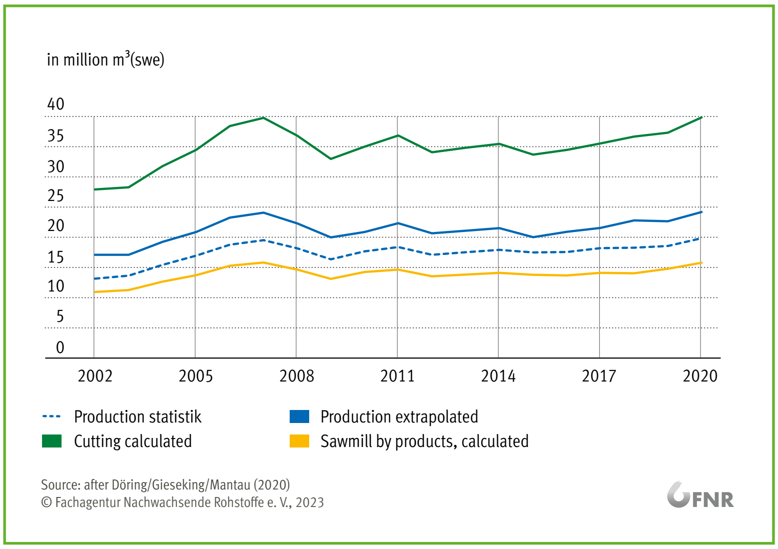


This once again underlines the importance of complete surveys as well as the continuous reporting of the Federal Statistical Office. Only by merging the two is it possible to obtain continuous data that is close to reality. The continuity of official statistics is just as important, since it would not be possible to carry out analyses with different survey years in the various sectors and the resulting missing values.

In order to arrive at realistic values for the sawmill by-products, a similar step is needed to develop the yield. For more detailed information, please refer to the study mentioned. The methodologically interested reader will find a detailed account in Döring (2020).

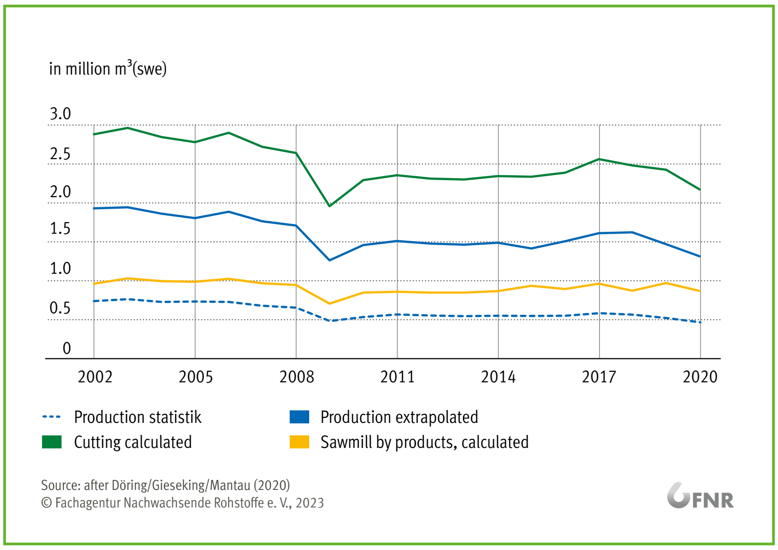
The Figure 3.12 shows in the dashed blue line the production reported in the production statistics. The solid line represents the extrapolated production in million m³. The green line shows the back-calculated softwood log input in million m^3_{swe}. The yellow line is the calculated input of sawmill by-products in million m^3_{swe}. It corresponds to the difference between softwood log input and softwood lumber production. The example demonstrates the procedure for incomplete data and makes it clear by the abbreviation “swe” which data have resulted from a back-calculation of the feedstocks. The brackets around “(swe)” make it clear that different cubic metre ways are shown in the figure.

Figure 3.12: Production statistics for sawn softwood and derived values



The differences between the figures for softwood and hardwood lumber are the 10-fold larger dimension of the axis intercept for softwood, the different development direction and the amount of re-estimation required.

Figure 3.13: Production statistics for hardwood lumber and derived values



However, this only solves one of the data problems for sawmill by-products. The next one arises from the comparison of the quantity used and the sources. As the partial Wood Resource Balance (Table 3.6) shows that 20.5 million m^3_{swe} of sawmill by-products were used in 2020. 55.1 % of this was for material use and 44.9 % for energy use. The largest users were the wood-based panel industry (36.2 %) and the pellet industry (27.7 %).

If the negative foreign trade balance is taken into account, domestic demand rises to 21.8 million m^3_{swe}. The extrapolated quantity of available sawmill by-products is significantly less at 16.6 million m^3_{swe} and thus the balance shows a deficit on the source side of 5.3 million m^3_{swe}.

Calculation errors can be ruled out in this case. It is thus a knowledge gap to which the balance sheet points. The gap probably arises in part from a conceptual vagueness: We often use terms without fully understanding them. This does not even have to be a mistake, but follows the need for communication and thereby also promotes knowledge. The exact terms of the query on the use side would have to be: "sawmill by-products" and "wood chips, sawdust, slabs and splinters as well as shavings from other solid wood processing". Firstly, the respondents are usually not aware of the different sources and secondly, the questionnaire would not be answered any more or less if all the questions were answered so "precisely".

LIMITS OF STATISTICAL RECORDING

This is about something as rustic as Wood Resource Balances, but it is also an insightful epistemological phenomenon. The more precise one is, the less one may recognise. This is not to advocate vagueness, but the appropriate path to clarity here is different from a fully defined problem that overwhelms the respondent. It is one of the basic principles of Wood Resource Monitoring – with exceptions – to limit the scope of the survey to one page. In addition, the respondent is to be picked up in his or her linguistic way of thinking. This also applies if his way of thinking is imprecise, because he would not understand or be able to answer anything more precise and thus would not answer or would answer even more imprecisely. Questionnaire development, however, is another topic. Let us return to the problem of the revenue gap for sawmill by-products.

Table 3.6: Partial Wood Resource Balance for sawmill by-products

PARTIALLY WOOD RESOURCE BALANCE FOR SAWMILL BY-PRODUCTS					
Sources 2020	**million m^3_{swe}**	**in %**	**million m^3_{swe}**	**in %**	**Uses 2020**
Sawmill by-products			0.0	0.0	Saw mill industry
Domestic use	20.5	100.0	7.4	36.2	Panel industry
– Import	0.7	3.2	3.8	18.3	Pulp industry
+ Export	1.9	9.5	0.0	0.0	Other stemwood use
+ Δ Stock, industry	0.0	0.0	0.1	0.6	Other mat. wood use
From Sawmills	16.6	80.6	**11.3**	**55.1**	**Material wood use**
Domestic availability	15.3	74.3	5.7	27.7	Energy product manufacturer
Other sources	5.3	25.7	0.7	3.2	BMHPP ≥ 1 MW
Other uses	0.0	0.0	1.4	6.7	BMHPP < 1 MW
			0.8	4.0	Private households
			0.7	3.3	Other energy use
			9.2	**44.9**	**Wood energy use**
Domestic use	**20.5**	**100.0**	**20.5**	**100.0**	**Total**

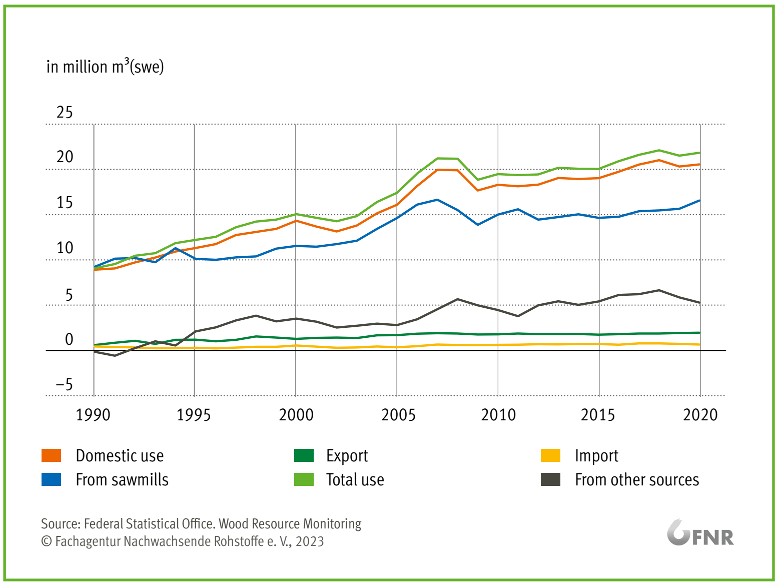
Source: Mantau, Infro 2022

SAWMILL BY-PRODUCTS FROM OTHER SOURCES

The gap could be solved by further surveys, e.g. of craft enterprises and other wood processors. Wood shavings in particular could also be regarded as “sawmill by-products”. In the sense of the definition used, however, they would then fall under other industrial waste wood. In other processing operations, logs are processed into wood chips. This is clear to wood market insider (wood-based panels, chemical pulp, pellets) and is unlikely to cause this ambiguity. However, it is conceivable that intermediaries and processors buy up raw materials and process them into value-added wood chips or mix them with sawmill by-products. In these cases, they would be included on the use side as sawmill by-products, but would not appear on the source side.

Apart from the occurrence of the phenomenon as such, it is interesting to note that the amount of sawmill by-products that do not come from sawmills tends to increase. The presentation is a difference calculation. A difference can have several causes. The difference may have to do with the increasing uses of processed wood materials (e.g. wood chips and shavings). In that case, a growing demand is supplied from sources other than sawmills.

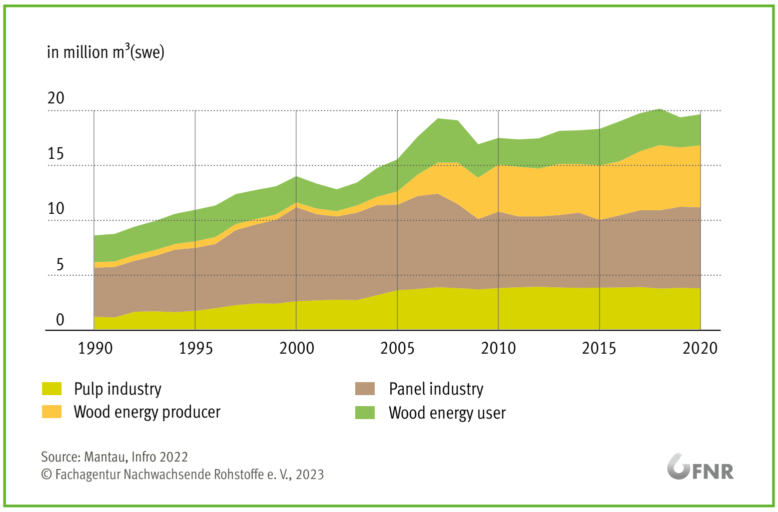
Figure 3.14: Development of the market sectors for sawmill by-products



The sources of sawmill by-products are growing as a by-product of sawn timber production. Within the framework of wood processing or in the form of upstream production processes, there is an increasing use of raw materials that correspond to sawmill by-products.

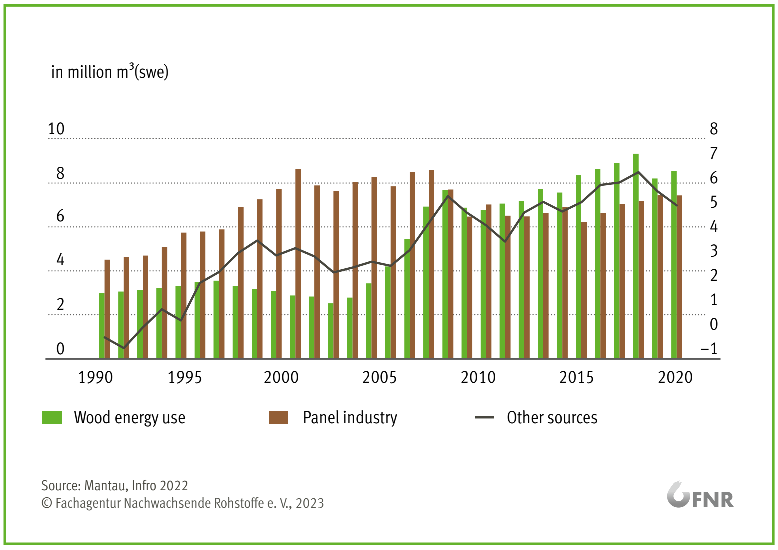
The Figure 3.15 shows the development of the use sectors. The wood-based panel industry and the wood and pulp industry represent the material uses. In wood energy use, sawmill by-products are used directly or as energy wood products (pellets, briquettes).

Figure 3.15: Development of the uses of sawmill by-products according to users



In the Figure 3.16 the line shows the development of the other sources. According to this, it can be assumed that the first increase of other sources was triggered by the strong growth of the wood-based panel industry. From 2005 onwards, strong demand from wood energy users seems to have driven the growth. In any case, Wood Resource Balancing has highlighted a relevant area where information is still needed.

Figure 3.16: Energy wood use and other sources of sawmill by-product sources



3.6 Other industrial residues

A WIDE RANGE OF SECTORS OF ORIGIN

Other industrial residues are produced in a large number of sectors during the processing of wood. These include above all the end product sectors:
- construction Industry
- packaging industry
- furniture industry and furniture craft.

The uses of other industrial residues include the wood-based panel industry, which partly recycles its own waste materials, and above all the users of wood raw materials for energy purposes.

In the year with the highest sources of other industrial residues (2010), the volume used amounted to 5.1 million m^3_{swe}. As the partial Wood Resource Balance shows, the market volume has halved in the meantime (2.5 million m^3_{swe}). Thus, a look at the uses becomes interesting.

Table 3.7: Partial Wood Resource Balance for other industrial residues

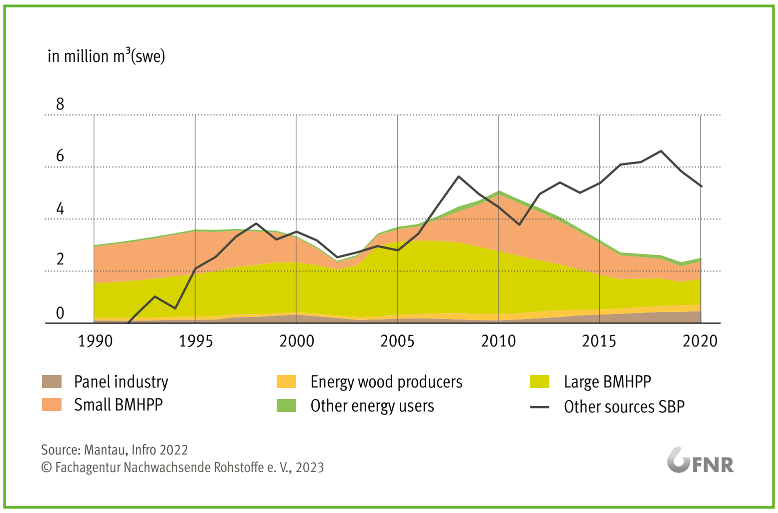
PARTIALLY WOOD RESOURCE BALANCE FOR OTHER INDUSTRIAL RESIDUES					
Sources 2020	**million m^3_{swe}**	**in %**	**million m^3_{swe}**	**in %**	**Uses 2020**
Other industrial residues			0.0	0.0	Saw mill industry
Domestic use	2.5	100.0	0.4	17.6	Panel industry
– Import	0.0	0.0	0.0	0.0	Pulp industry
+ Export	0.0	0.0	0.0	0.0	Other stemwood use
+ Δ Stock, industry	0.0	0.0	0.0	0.0	Other mat. wood use
Domestic use	**2.5**	**100.0**	**0.4**	**17.6**	**Material wood use**
			0.3	10.1	Energy product manufacturer
			1.0	39.8	BMHPP > 1 MW
			0.7	26.9	BMHPP < 1 MW
			0.0	0.0	Private households
			0.1	5.6	Other energy use
			2.1	**82.4**	**Wood energy use**
Domestic use	**2.5**	**100.0**	**2.5**	**100.0**	**Total**

Source: Mantau, Infro 2022

At first glance, the course of other industrial residues seems difficult to comprehend. From the end of the 1990s, there was a dramatic decline in construction demand, which resulted in a lower volume of other industrial residues. In addition, the sharp drop in the use of small combustion plants between 1999 and 2004 takes place at a time of legal changes that may have triggered material shifts. The considerable oil price increases were also accompanied by a mobilisation of residual materials. In addition, other industrial residues have an impact relationship with the waste wood market. If the demand for wood energy is very high, they can be marketed directly. If there are hardly any buyers, quantities are disposed of.

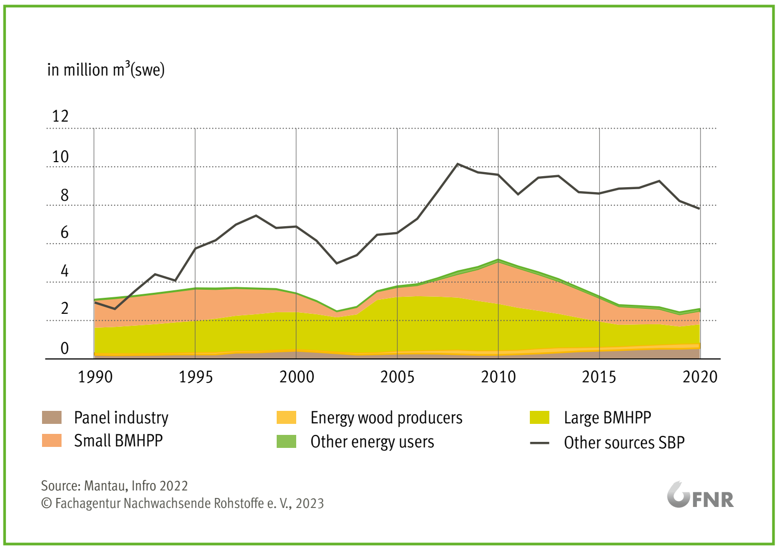
The decline in recent years could also be related to the previously considered development of sawmill by-products from other sources. When wood residues are chipped and offered in the form of wood chips, the user sees them as wood chips, i. e. sawmill by-products.

Figure 3.17: Development of the uses of other industrial residues by user compared to "sawmill by-products" from other sources



As already explained in the section "Sawmill by-products" from other sources, they probably come mainly from further processing, i. e. they are "other industrial waste wood". What would be more logical than to add them to the other industrial waste wood? In that case, the market would be around eight million m³ in recent years, with a slight downward trend.

Figure 3.18: Development of the uses of other industrial residues by user with the addition of "sawmill by-products" from other sources



The problem is that the user often cannot distinguish whether it comes from sawmills or other sources. With the current reporting form, the information needs of Wood Resource Balancing are largely met. A more precise clarification would require considerable data collection, which has to be weighed against the quantitative relevance of further differentiation.

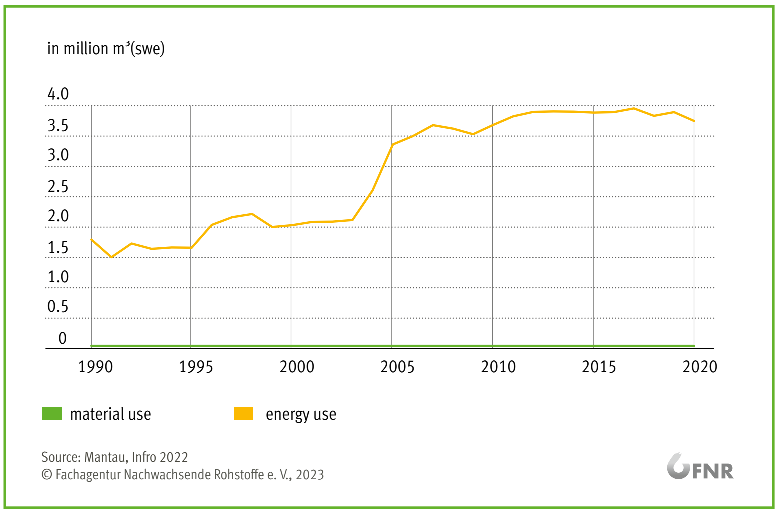
3.7 Black liquor

INTERNAL USE

Black liquor is a by-product of chemical pulp production. It is produced during the separation of lignin and cellulose and is a mixture of lignin, water and the chemicals used for extraction. Black liquor is hardly ever sold on the market, but is used directly in the chemical pulp and paper industry to generate heat and electricity. For example, the largest biomass power plant in Germany (135 MW) is located in a pulp mill.

The development of the sources of black liquor follows the development of the pulp industry. The marked increase in 2004 and 2005 is a consequence of the capacity expansion of the sulphate pulp mills. The decline due to the financial crisis was moderate. The sources of black liquor reached about 4 million m^3_{swe}. It is to be expected that the sideways movement with moderate fluctuations will continue, as the plants are mostly running at full capacity and significant increases are only possible through capacity expansion. There are no signs of this at present.

Figure 3.19: Development of the uses of black liquor



The partial Wood Resource Balance does not provide any additional information in this case. It accumulates as a residual material in the pulp industry and is used for energy in the company's own large-scale combustion plants. However, findings from other countries show that this does not have to remain the case. Black liquor can be used as a feedstock for the extraction of numerous bio-based products in the chemical industry.

3.8 Waste wood

COMPLEX MARKET STRUCTURE

In the waste wood study (Döring/Mantau 2021), the sources and distribution of waste wood were determined exclusively in disposal companies. Waste wood was defined as waste wood in the sense of the Waste Wood Ordinance (see Weimar 2009). The surveyed volume of waste wood includes both domestic quantities and imports that were handled by waste management companies. Other quantities in the form of industrial wood residues, e.g. from the production process of the wood industry, which are used for energy recovery in combustion plants without a diversion via the waste wood disposal companies, are considered industrial waste wood. Used wood that is used in private households, e.g. for energy, is recorded in the household study (Döring, Glasenapp and Mantau 2020). The volume of waste wood in the disposal system includes both the domestic volume and imports that were routed via disposal companies.

The waste wood collected by waste management companies is sold on to users, but also traded between waste wood companies to a considerable extent. As a rule, smaller disposal companies deliver the waste wood to larger ones that have sorting and processing facilities. The trading volume thus contains double counts and does not correspond to the market volume. The market volume results from the trading volume minus sales to other disposal companies.

Table 3.8: Trade and market volume of waste management companies

Distribution, utilization	1,000 t_{ad}	in %
Trading volume	10,270	100.0
Internal utilization	1,498	14.6
Distribution, utilization	8,772	85.4
… to other disposal companies	1,992	22.7
… to other enduser	6,780	77.3
Market volume	**8,278**	**80.6**

Source: Döring/Mantau (2021)

The trading volume was 10.3 million t_{ad}. Less intra-trade of 2.0 million t_{ad}, the market volume was 8.3 million t_{ad}.

Table 3.9:
Number of plants and trade volume by size class

Plant size	Plants		Trading volume	
	Number	%	1,000 t_{ad}	%
‹ 500 t	443	26.3	85	0.8
500–999 t	332	19.7	227	2.2
1,000–2,499 t	294	17.5	442	4.3
2,500–4,999 t	223	13.2	769	7.5
5,000–9,999 t	166	9.9	1,062	10.3
10,000–19,999 t	114	6.8	1,557	15.2
20,000–49,999 t	76	4.5	2,516	24.5
50,000–99,999 t	25	1.5	1,833	17.9
100,000–199,999 t	9	0.5	1,228	12.0
≥ 200,000 t	2	0.1	550	5.4
Total	**1,684**	**100.0**	**10,270**	**100.0**

Source: Döring/Mantau (2021)

SPECIFIC INFLUENCING FACTORS

Survey years are not always “normal” years. The year 2020 was a special year in two respects. An additional address source (Ordinance on Specialised Waste Management Companies, eEFBV) made it possible to process a much larger number of potential waste management companies (5,243 plants) than in previous studies. Since these were predominantly smaller plants, the volume of trade in particular rose sharply. This is possibly one reason for the 1.7 million t increase in market volume since the previous study (2016). On the other hand, according to the BAV, market participants described that although the commercial waste wood sources decreased in the Corona year 2020. However, the sources from private households recorded a significant increase. In the absence of travel and entertainment options, private households increasingly turned to home and garden. This led to long queues in front of the waste management companies.

The Table 3.10 shows that disposal plants with annual sales of less than 10,000 t deliver large shares of waste wood to other disposal companies, while plants with annual sales of more than 10,000 t_{ad} mainly deliver directly to end-users.

The partial Wood Resource Balance for waste wood shows a waste wood use of 16.2 million m^3_{swe} for 2020. Of this, 15.3 % is accounted for by material use and 84.7 % by energy use. The main users are large combustion plants with 72.4 % of the waste wood.

The uses are offset by sources of 13.9 million m^3_{swe} from the waste management companies. Net imports bring 1.1 million m^3_{swe} into the market. They are listed on the use side and are to be added to the sources accordingly. Thus, domestic availability amounts to 16.6 million m^3_{swe}. Since the uses are lower by 0.4 million m^3_{swe}, uses are still to be expected to the extent that are not listed on the uses page. However, this may also be due to inaccuracies in the survey procedures.

Table 3.10: Trade and market volume of waste management companies

Plant size	Trading volume	Intratrade		End user	
	1,000 t_{ad}	1,000 t_{ad}	%	1,000 t_{ad}	%
< 500 t	85	43	52.2	39	47.8
500–999 t	227	114	55.1	93	44.9
1,000–2,499 t	442	205	47.3	229	52.7
2,500–4,999 t	769	352	49.2	363	50.8
5,000–9,999 t	1,062	370	37.0	631	63.0
10,000–19,999 t	1,557	148	10.4	1,270	89.6
20,000–49,999 t	2,516	680	27.3	1,815	72.7
50,000–99,999 t	1,833	41	2.8	1,418	97.2
100,000–199,999 t	1,228	38	4.9	724	95.1
≥ 200,000 t	550	2	1.0	198	99.0
Total	**10,270**	**1,992**	**22.7**	**6,780**	**77.3**

Source: Döring/Mantau (2021)

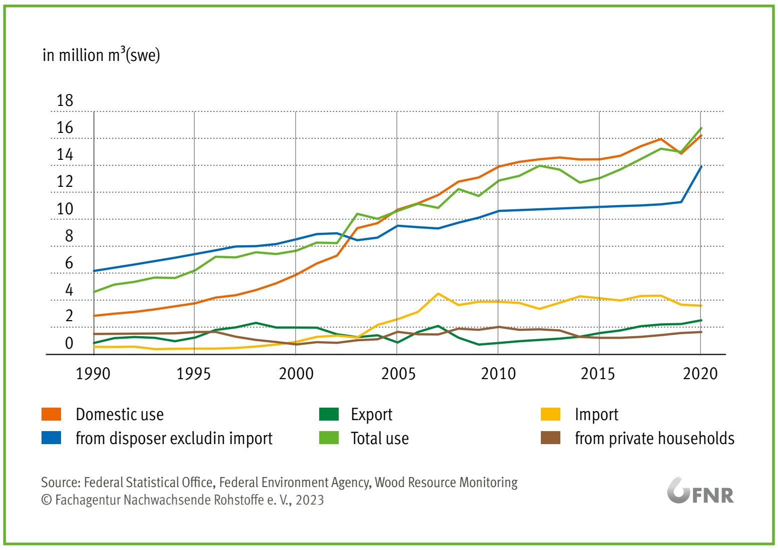
Table 3.11: Partial Wood Resource Balance for waste wood

PARTIALLY WOOD RESOURCE BALANCE FOR WASTE WOOD					
Sources 2020	**million m^3_{swe}**	**in %**	**million m^3_{swe}**	**in %**	**Uses 2020**
Waste wood			0.0	0.0	Saw mill industry
Domestic use	16.2	100.0	2.5	15.3	Panel industry
– Import	3.6	22.2	0.0	0.0	Pulp industry
+ Export	2.5	15.5	0.0	0.0	Other stemwood use
+ Δ Stock, industry	0.0	0.0	0.0	0.0	Other mat. wood use
From disposer	13.9	85.9	**2.5**	**15.3**	**Material wood use**
In households	1.6	10.1	0.0	0.0	Energy product manufacturer
Domestic availability	16.6	102.6	11.7	72.4	BMHPP > 1 MW
Other sources	0.0	0.0	0.4	2.3	BMHPP < 1 MW
Other uses	–0.4	–2.6	1.6	10.1	Private households
			0.0	0.0	Other energy use
			13.7	84.7	**Wood energy use**
Domestic availability	**16.2**	**100.0**	**16.2**	**100.0**	**Total**

Source: Mantau, Infro 2022

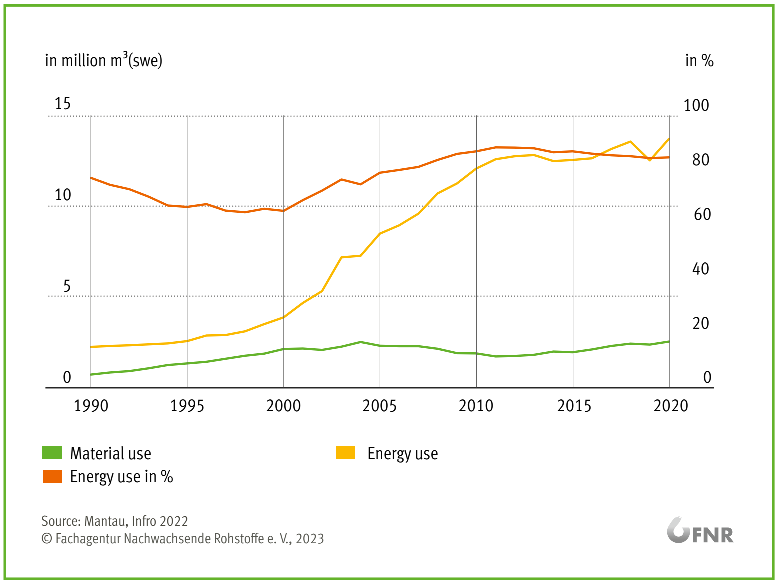
Domestic use is only growing moderately after the construction of the large combustion plants. The volume of waste wood from disposal companies has stagnated since 2010. Imports by disposal companies have been deducted, as they are included in total imports. Towards the end of the period under review, there are special effects. In the case of biomass combustion plants, the dry year 2019 has a lowering effect on use, and in the case of waste wood, the corona year 2020 results in a special increase. Since 2006, domestic use has exceeded domestic production. The surplus in 2020 is therefore rather an exception. In the case of private households, the uses are fed by their own sources.

Figure 3.20: Development of the market sectors of waste wood



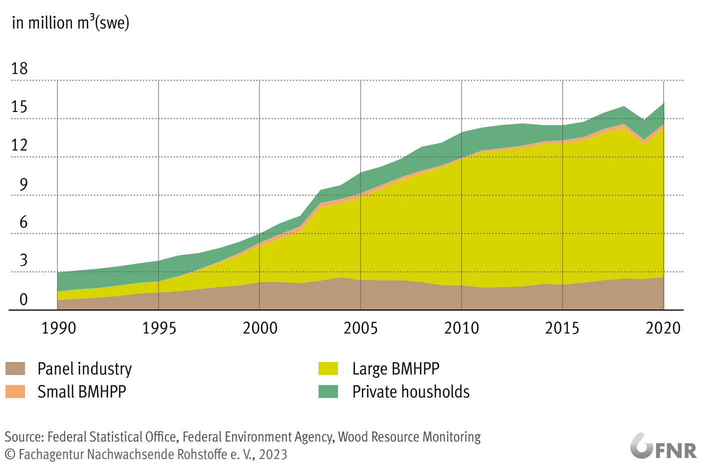
Between 1995 and 2000, the share of material use was approx. 30 % and the share of energy use correspondingly 70 %. With the waste wood legislation, in particular the landfill ban and the development of large-scale combustion plants, the growing sources were mainly accounted for by energy use. In recent years, it has been around 80 %.

Figure 3.21: Development of the material and energy uses of waste wood



Accordingly, the development of the use sectors is also largely characterised by the use of waste wood in large combustion plants. The other sectors are developing relatively stable.

Figure 3.22: Development of waste wood use sectors



The following studies have been produced so far as part of the Wood Resource Monitoring (1999–2021) (available at www.infro.eu):

Waste wood market	**Mantau, U.; Weimar, H. (2003):** Standorte der Holzwirtschaft. Aufkommens- und Vermarktungsstruktur von Altholz. Hamburg.
	Weimar, H.; Mantau, U. (2008): Standorte der Holzwirtschaft. Altholz im Entsorgungsmarkt – Aufkommens- und Vermarktungsstruktur. Hamburg.
	Weimar, H. (2009): Empirische Erhebungen im Holzrohstoffmarkt am Beispiel der neuen Sektoren Altholz und Großfeuerungsanlagen. Lang, Frankfurt am Main.
	Döring, P.; Cords, M.; Mantau, U. (2018): Altholz im Entsorgungsmarkt. Aufkommen und Verwertung 2016. Hamburg.
	Döring, P.; Mantau, U. (2021): Altholz im Entsorgungsmarkt. Aufkommen und Verwertung 2020. Hamburg.

4 WOOD RESOURCE BALANCES AND SUMMARIES

4.1 Preliminary remarks

Work to date

After the methodological foundations for data collection were laid in the first years of Wood Resource Monitoring, the first coherent presentation of the wood market structures was made in 2004 with the "Wood Resource Balance" (Mantau 2007) with the aim of realistically determining the fellings and the availability of other wood feedstocks. In the report "Continous data for Wood Resource Balancing" (Mantau/Sörgel/Weimar 2007), a continuous data basis was created for the period 1987 to 2005 for the first years of Wood Resource Monitoring. Further reports on the developments of the wood market followed in 2009, 2012 and 2019. The present report updates the developments up to 2020. 2020 is also the reference year of this report.

Balance sheet structure and definitions

In the new version of the Wood Resource Balancing (2022), all use sectors were given a uniform structure. The abbreviations follow English terms. The following explanations serve to define and structure the accounting and are presented in formalistic brevity.

The **process volume (PRC)** or the **(input side)** is composed of
- **tree wood (WTR),**
- **wood residues (RES)**,
- **recycled wood (REC)** und
- **processed bark (BRP)**.

WRT or **(Wood Resources from Trees)** is divided into
- **softwood (CRW)**,
- **hardwood (NRW)**,
- **landscape care wood (LCW)** und
- **short rotation wood (SRP)**.

Other tree biomass (OTB) equals tree biomass minus logs or *OTB = RSF + LCW + SRP + BRP*

Residues (RES) are divided into **primary residues (forest residues, RSF)** and **secondary residues (RSI)**. The latter are further differentiated into **sawmill by-products (SBP)**, **other industrial residues (OIR)** and **black liquor (BLI)**. REC is differentiated into **waste wood (PCW)** and **recovered paper (UPP).**

On the output side, there is the **product (PRD)**, the **residues (RSO)**, **compression or expansion (CPN)** and **product losses (PRL).**

To link Wood Resource Balance with sectoral analyses, **exports (EXP)**, **imports (IMP)** and **changes in stocks (STC)** are added to the **product (PRD)**. This results in the **domestic supply** *DSP = PRD – EXP – STC* and the **domestic use** *DUS = PRD – EXP + IMP – STC*.

The bark is included in the calculations as **gross input (GRC)** and is divided into *BRK = BRP + BRL + BRM*

Processed bark (BRP), bark loss (BRL) and **potential market bark (BRM).**

On the **source side**, the respective feedstock is listed for all sectors of use. The sectors of use are combined into groups:

Sawn timber (SCA) = Softwood lumber (SCN) + Hardwood lumber (SCC).

Mechanical pulp (PLP) = mechanical pulp (PLM) + chemical pulp (PLC).

Wood-based panels (PAN) = particleboard (PBB) +OSB (POB) + fiberboard (PFB) + lightweight panels (PLB).

Other log processing industries (OMT) = veneer (VEN) + plywood (PLW) + sleepers (SLP).

Other woodworking industries (OMN) = basic chemicals (CHM) + wood polymer materials (WPC).

Energy product manufacturer (EPM) = pellets (PEL) + wood briquettes (BQT) + charcoal (CHC)

Further subgroups can be assigned to the groups. The summaries serve the clarity of the Wood Resource Balances.

According to the uses, **wood in the rough (RWS)** is divided into **wood in the rough, coniferous (RWC)** and **wood in the rough, non-coniferous (RWN)**, where *RWC = softwood log users (STC) + other softwood roundwood users (IC7) and RWN = hardwood log users (STN) + other hardwood roundwood users (IN7)*.

Where data are available, **export, import and storage** are also calculated for all supply sectors, resulting in **domestic supply** *(DSP = PRD – EXP – STC)* and **domestic use** *(DUS = PRD – EXP + IMP + STC)*.

According to the structure, all uses and sources can be separated into material and energy use.

The following table shows the sectors of sources and uses, which are structured as described above. This is preceded by tables that prepare the system breaks and data gaps of the official statistics and establish the connection to Wood Resource Monitoring. They cannot be standardised to the same extent. Their methodological presentation would go beyond the scope of this publication.

Table 4.1: Sources and use sectors of Wood Resource Balancing

Sources		Material uses		Energy uses	
WRT	Wood Resources from Trees	SWA	SawnWood, All	EPP	Energy Product Producer
CRW	Coniferous RoudWood	SWC	SawnWood, Conifers	PEL	PELlets
NRW	Non-conferous RoundWood	SWN	SawnWood, Non-conifers	BQT	BriQueTtes
LCW	Landscape Care Wood	PLP	PuLP	CHC	Charcoal
SRP	Short Rotation Plantation	PLM	PuLp, Mechanical	ENN	Final energy user
RES	RESidues	PLC	PuLp, Chemical	BMA	BMhpp Above 1 MW
RSF	ReSidues from Forest	PAN	PANel	BMB	BMhpp Below 1 MW
SBP	Sawmill By Products	PPB	Panel, Particle Board	PHH	Private HouseHolds
OIR	Other Industrial Roundwood	POB	Panel, Oriented strand Board	OEU	Other Energy User
BLI	Black LIquor	PFB	Panel, Fibre Board	BTL	Biomass To Liquid
REC	RECicling material	PLB	Panel, Low density Board	OBU	Other Briquette Use
PCW	Post Consumer Wood	OMS	Other Material uses, stemwood		
UPP	Used Paper Products	VEN	VENeer		
BRK	BaRK	PLW	PLyWood		
BRP	BaRk, Processed	SLP	SLeePer		
		OMO	Other Material uses, Other		
		CHM	CHeMical materials		
		WPC	Wood Polymere Composites		

Source: Mantau, Infro 2022

4.2 Wood Resource Balances

The usual view of the Wood Resource Balance compares the sources of wood according to the feedstocks used with the uses by sector (Table 4.2). On the source side are the feedstocks from natural production (tree biomass), industrial residues and recycled materials. On the use side, the material and energy wood use sectors are listed.

DEFINITION OF SOURCES AND USES

Why are the terms **sources** and **uses** applied in the Wood Resource Balance and not supply and demand? Supply and demand are terms from microeconomics with a behavioural theoretical model for companies and households. Wood Resource Balancing works with statistical values generated from survey activities of official statistics and Wood Resource Monitoring and not from behavioural economic models. Sources and uses express the factual data basis more adequately and also distinguish themselves from other economic models as an independent balance-theoretical approach.

Table 4.2: Wood Resource Balance 2020

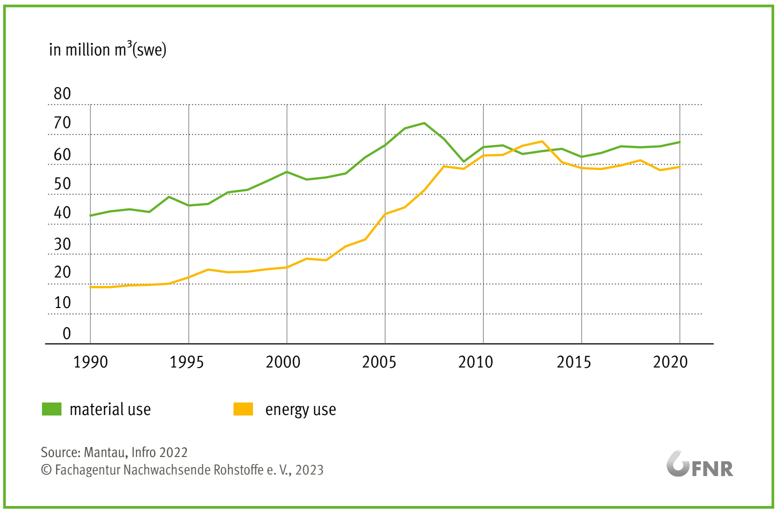
WOOD RESOURCE BALANCE 2020					
Sources 2020	**million m^3_{swe}**	**in %**	**million m^3_{swe}**	**in %**	**Uses 2020**
Roundwood, C	55.6	44.1	42.0	33.3	Sawmill industry
Roundwood, NC	13.0	10.3	0.4	0.3	Othern stemwood user
Forest residues	5.8	4.6	15.7	12.4	Panel industry
Bark	2.2	1.8	9.0	7.1	Pulp industry
Landscape care wood	4.8	3.8	0.1	0.1	Other material uses
Short rotation plantat.	0.1	0.1	**67.2**	**53.3**	**Material uses**
Sawmill by products	20.5	16.3	22.0	17.4	BMHPP > 1 MW
Other industrial residues	2.5	2.0	9.2	7.3	BMHPP < 1 MW
Black liquor	3.7	3.0	26.7	21.2	Private housholds
Post Consumer Wood	16.2	12.9	1.0	0.8	Other energy uses
Other	1.6	1.2	**58.9**	**46.7**	**Energy uses**
Total	**126.0**	**100.0**	**126.0**	**100.0**	**Total**

Source: Mantau, Infro 2022

Of the total wood feedstocks used in 2020, 64.6 % were biomass from primary production and 34.1 % were secondary feedstocks such as industrial wood residues (21.3 %) and waste wood (12.9 %). In this presentation, the raw material input for energy wood products (e. g. pellets) is included in the raw material input (e. g. sawmill by-products).

On the use side, of the 126.0 million m^3_{swe} of wood feedstock, 53.3 % is used for materials and 46.7 % for energy.

Figure 4.1: Development of wood use for materials and energy



As already shown in the section 1.2 and in the individual areas of use, the use of wood for energy experienced a strong revival from about the year 2000 onwards, reaching approximately the level of material use around the year 2010. Since then, the use of wood for energy has declined slightly until 2020 and the use of wood for materials has increased moderately.

The following two figures show the development of the raw material composition according to material and energy use. The material use of wood is dominated by the use of round wood (wood in the rough). Industrial residues, especially sawmill by-products, are also a traditional feedstock for material uses. Recycling material (waste wood) is used in small quantities overall, almost exclusively in particleboard.

The wood feedstocks for energy use have a different composition – not all wood is the same. Roundwood is mainly used in private households. Large combustion plants mainly take up waste wood. Other tree biomass (landscape management, forest residues, bark, SRC) has covered a larger share of the energy wood demand since about 2005. Industrial residues are a relatively stable component of energy use. Energy wood products are becoming increasingly important and are also replacing the uses of roundwood.

Figure 4.2: Uses of wood feedstocks in material use

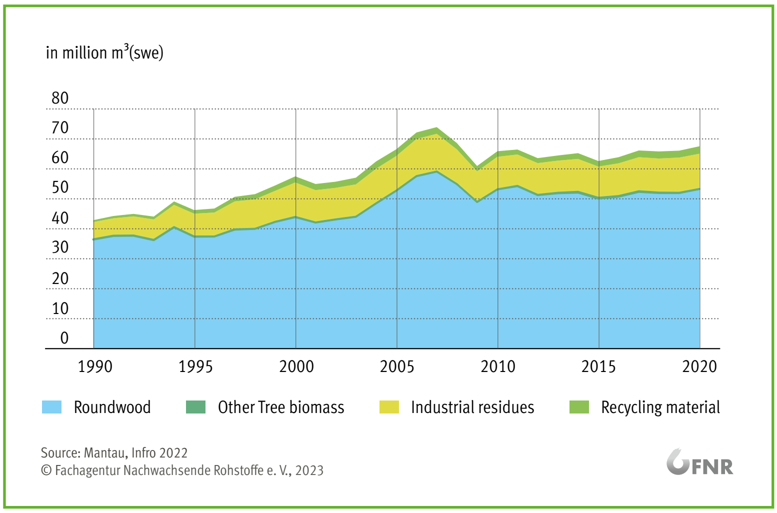
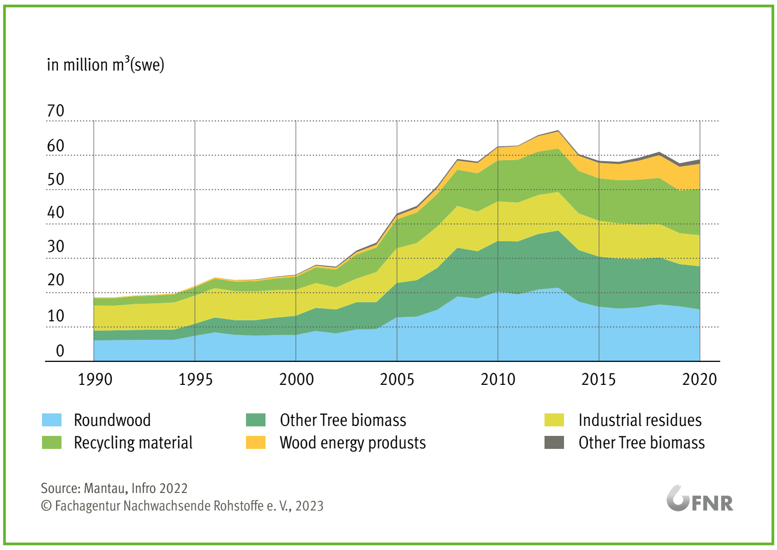


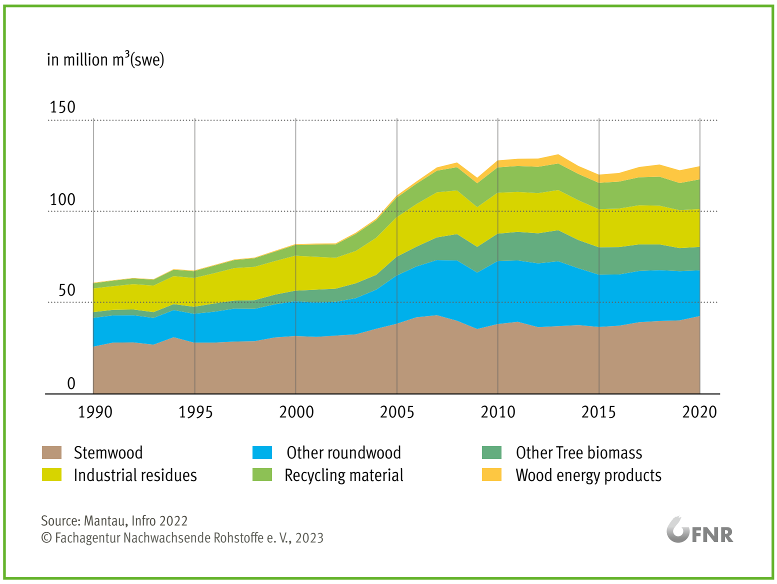
Figure 4.3: Uses of wood feedstock in energy use



The growing importance of energy wood products ultimately provided the impetus to revise the structure of the wood balance sheets. In the balance (Table 4.1), the wood feedstocks used for energy wood products are included on the sources side. In the Figure 4.3 only the direct wood feedstocks are shown and the energy wood products are added as a separate category. This opens up the possibility of combining the wood feedstocks into product categories according to use. The Wood Resource Balance is divided into feedstocks and raw materials on the source side. Raw materials are feedstocks that are assigned to a use. Wood in the rough in the forest becomes roundwood at the user, or in the material use, roundwood is divided again into logs (e. g. sawmill) and other roundwood (e. g. board, chemical pulp). The latter largely corresponds to the term industrial wood used in the felling statistics. Since in the wood feedstock accounting the conversion is made from the use back to the feedstock and into (swe), the classification is not made at the forest road for the expected use, but via the real use.

The following Figure 4.4 shows the development of raw materials in the sum of all uses. After the strong expansion in the first decade of the millennium, the development of wood use was relatively stable. With respect to the last decade, log use increased slightly, while other roundwood was used somewhat less. In addition to a rather stagnating use in material uses, especially splitwood use in private households decreased. The use of wood residues depends on the sources, which in turn follow the production of the wood industry. Without wood processing, there is also no residual wood. The waste wood disposal system in Germany is well developed and the sources are largely used. The production of energy wood products is gaining market share.

Figure 4.4: Total uses of wood feedstock



The following Wood Resource Balances are presented for feedstocks, raw materials and uses. This is done in 10-year steps. On the left side, the wood feedstocks are listed in a differentiated manner. In the middle section, there are groupings according to material and energy uses (raw materials) and finally, on the right side, the users.

This is followed in Table 4.4 a separate presentation according to material and energy wood use and thus opens up a further view of different raw material compositions. These were previously worked out more specifically in the partial Wood Resource Balances of the individual wood feedstocks.

Table 4.3: Wood Resource Balance of all wood uses

WOOD RESOURCE BALANCE 1990–2020								
Raw material	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**	**Uses**	**million m^3_{swe}**	**in %**
Wood Resource Balance 2020								
Roundwood, C	55.6	44.1	Stemwood	42.4	33.6	Sawmill industry	42.0	33.3
Roundwood, NC	13.0	10.3	Other roundwood	10.4	8.2	Other stemwood user	0.4	0.3
Forest residues	5.8	4.6	Other tree biomass	0.2	0.1	Panel industry	15.7	12.4
Bark	2.2	1.8	Industrial residues	11.8	9.3	Pulp industry	9.0	7.1
Landscape care wood	4.8	3.8	Recycling material	2.5	2.0	Other material uses	0.1	0.1
Short rotation plantat.	0.1	0.1				**Material uses**	**67.2**	**53.3**
Sawmill by products	20.5	16.3	Roundwood	14.7	11.7	BMHPP > 1 MW	22.0	17.4
Other industrial residues	2.5	2.0	Industrial residues	9.1	7.2	BMHPP < 1 MW	9.2	7.3
Black liquor	3.7	3.0	Recycling material	13.7	10.9	Private households	26.7	21.2
Post Consumer Wood	16.2	12.9	Wood energy products	7.3	5.8	Other energy uses	1.0	0.8
Other/difference	1.6	1.2	Other biomass	14.0	11.1	**Energy uses**	**58.9**	**46.7**
Total	**126.0**	**100.0**	**Total**	**126.0**	**100.0**	**Total**	**126.0**	**100.0**
Wood Resource Balance 2010								
Roundwood, C	55.8	43.5	Stemwood	38.0	29.6	Sawmill industry	37.3	29.1
Roundwood, NC	17.3	13.5	Other roundwood	14.7	11.5	Other stemwood user	0.7	0.6
Forest residues	7.7	6.0	Other tree biomass	0.1	0.1	Panel industry	17.0	13.2
Bark	2.8	2.2	Industrial residues	10.9	8.5	Pulp industry	10.5	8.2
Landscape care wood	4.5	3.5	Recycling material	1.8	1.4	Other material uses	0.0	0.0
Short rotation plantat.	0.0	0.0				**Material uses**	**65.5**	**51.1**
Sawmill by products	18.3	14.3	Roundwood	20.0	15.6	BMHPP > 1 MW	22.7	17.7
Other industrial residues	5.1	4.0	Industrial residues	11.6	9.1	BMHPP < 1 MW	7.2	5.6
Black liquor	3.7	2.9	Recycling material	12.1	9.4	Private households	31.7	24.7
Post Consumer Wood	13.9	10.8	Wood energy products	3.8	3.0	Other energy uses	1.1	0.9
Other/difference	−0.9	−0.7	Other biomass	15.2	11.9	**Energy uses**	**62.7**	**48.9**
Total	**128.2**	**100.0**	**Total**	**128.2**	**100.0**	**Total**	**128.2**	**100.0**

WOOD RESOURCE BALANCE 1990–2020								
Raw material	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**	**Uses**	**million m^3_{swe}**	**in %**
Wood Resource Balance 2000								
Roundwood, C	39.6	48.3	Stemwood	31.5	38.4	Sawmill industry	30.3	36.9
Roundwood, NC	11.1	13.5	Other roundwood	11.9	14.5	Other stemwood user	1.2	1.4
Forest residues	3.1	3.8	Other tree biomass	0.2	0.2	Panel industry	18.4	22.4
Bark	0.9	1.1	Industrial residues	11.5	14.0	Pulp industry	7.2	8.8
Landscape care wood	1.9	2.3	Recycling material	2.1	2.5	Other material uses	0.0	0.0
Short rotation plantat.	0.0	0.0				**Material uses**	**57.1**	**69.6**
Sawmill by products	14.3	17.5	Roundwood	7.2	8.8	BMHPP > 1 MW	8.6	10.5
Other industrial residues	3.3	4.1	Industrial residues	7.6	9.3	BMHPP < 1 MW	4.3	5.3
Black liquor	2.0	2.5	Recycling material	3.8	4.7	Private households	11.5	14.0
Post Consumer Wood	5.9	7.2	Wood energy products	0.4	0.5	Other energy uses	0.5	0.6
Other/difference	−0.1	−0.1	Other biomass	5.9	7.1	**Energy uses**	**24.9**	**30.4**
Total	**82.1**	**100.0**	**Total**	**82.1**	**100.0**	**Total**	**82.1**	**100.0**
Wood Resource Balance 1990								
Roundwood, C	32.1	52.9	Stemwood	25.7	42.3	Sawmill industry	24.3	40.0
Roundwood, NC	9.5	15.6	Other roundwood	10.2	16.8	Other stemwood user	1.4	2.3
Forest residues	1.4	2.4	Other tree biomass	0.2	0.3	Panel industry	9.6	15.8
Bark	0.5	0.8	Industrial residues	5.7	9.4	Pulp industry	7.2	11.8
Landscape care wood	1.2	1.9	Recycling material	0.6	1.1	Other material uses	0.0	0.0
Short rotation plantat.	0.0	0.0				**Material uses**	**42.4**	**69.9**
Sawmill by products	8.9	14.7	Roundwood	5.6	9.2	BMHPP > 1 MW	4.7	7.7
Other industrial residues	3.0	4.9	Industrial residues	7.3	12.1	BMHPP < 1 MW	2.4	3.9
Black liquor	1.8	2.9	Recycling material	2.2	3.6	Private households	10.8	17.7
Post Consumer Wood	2.8	4.7	Wood energy products	0.3	0.4	Other energy uses	0.5	0.8
Other/difference	−0.5	−0.8	Other biomass	2.9	4.8	**Energy uses**	**18.3**	**30.1**
Total	**60.7**	**100.0**	**Total**	**60.7**	**100.0**	**Total**	**60.7**	**100.0**

Table 4.4: Wood Resource Balances by Material and Energy Uses of Wood

WOOD RESOURCE BALANCE 1990–2020											
Material use of wood						**Energy use of wood**					
Raw material	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**	**Raw material**	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**
Wood Resource Balance 2020											
Round-wood, C	49.2	73.2	Stemwood	42.4	63.1	Round-wood, C	6.4	10.9	Round-wood	14.7	25.1
Round-wood, NC	3.6	5.4	Other roundwood	10.4	15.5	Round-wood, NC	9.4	15.9	Other biomass from trees	12.7	21.6
Forest residues	0.1	0.1	Other tree biomass	0.2	0.2	Forest residues	5.7	9.7	Industrial residues	9.1	15.5
Bark	0.1	0.2	Industrial residues	11.8	17.5	Bark	2.1	3.6	Recycling material	13.7	23.3
Landscape care wood	0.0	0.0	Recycling material	2.5	3.7	Land-scape care wood	4.8	8.2	Wood energy products	7.0	11.9
Short rotation plantat.	0.0	0.0	**Raw products**	**67.2**	**100.0**	Short rotation plantat.	0.1	0.2	Other biomass	1.6	2.7
Sawmill by products	11.3	16.8	Sawmill industry	42.0	62.5	Sawmill by products	9.2	15.7	**Raw products**	**58.9**	**100.0**
Other industrial residues	0.4	0.7	Other stemwood user	0.4	0.6	Other industrial residues	2.1	3.5	BMHPP › 1 MW	22.0	37.3
Black liquor	0.0	0.0	Panel industry	15.7	23.3	Black liquor	3.7	6.4	BMHPP ‹ 1 MW	9.2	15.6
Post Consumer Wood	2.5	3.7	Pulp industry	9.0	13.4	Post Con-sumer Wood	13.7	23.3	Private households	26.7	45.3
			Other material uses	0.1	0.2	**Other/ differ-ence**	1.6		Other energy uses	1.0	1.8
Total	**67.2**	**100.0**	**Uses**	**67.2**	**100.0**	**Total**	**58.9**	**100.0**	**Uses**	**58.9**	**100.0**

WOOD RESOURCE BALANCE 1990–2020											
Material use of wood						**Energy use of wood**					
Raw material	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**	**Raw material**	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**
Wood Resource Balance 2010											
Round-wood, C	46.9	71.5	Stemwood	38.0	58.0	Round-wood, C	8.9	14.2	Round-wood	20.0	31.8
Round-wood, NC	5.8	8.9	Other roundwood	14.7	22.4	Round-wood, NC	11.5	18.4	Other biomass from trees	14.9	23.8
Forest residues	0.1	0.1	Other tree biomass	0.1	0.2	Forest residues	7.6	12.2	Industrial residues	11.6	18.5
Bark	0.0	0.0	Industrial residues	10.9	16.7	Bark	2.8	4.4	Recycling material	12.1	19.3
Landscape care wood	0.0	0.0	Recycling material	1.8	2.8	Land-scape care wood	4.5	7.2	Wood energy products	5.0	8.0
Short rotation plantat.	0.0	0.0	**Raw products**	**65.5**	**100.0**	Short rotation plantat.	0.0	0.0	Other biomass	−0.9	−1.5
Sawmill by products	10.8	16.5	Sawmill industry	37.3	56.9	Sawmill by products	7.5	11.9	**Raw products**	**62.7**	**100.0**
Other industrial residues	0.1	0.1	Other stemwood user	0.7	1.1	Other industrial residues	5.0	8.0	BMHPP > 1 MW	22.7	36.2
Black liquor	0.0	0.0	Panel industry	17.0	25.9	Black liquor	3.7	5.9	BMHPP < 1 MW	7.2	11.5
Post Consumer Wood	1.8	2.8	Pulp industry	10.5	16.1	Post Con-sumer Wood	12.1	19.3	Private households	31.7	50.5
			Other material uses	0.0	0.0	**Other/ differ-ence**	−0.9	−1.5	Other energy uses	1.1	1.8
Total	**65.5**	**100.0**	**Uses**	**65.5**	**100.0**	**Total**	**62.7**	**100.0**	**Uses**	**62.7**	**100.0**

WOOD RESOURCE BALANCE 1990–2020											
Material use of wood						**Energy use of wood**					
Raw material	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**	**Raw material**	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**
Wood Resource Balance 2000											
Round-wood, C	36.5	64.0	Stemwood	31.5	55.1	Round-wood, C	3.1	12.3	Round-wood	7.2	28.9
Round-wood, NC	6.8	12.0	Other roundwood	11.9	20.8	Round-wood, NC	4.3	17.1	Other biomass from trees	5.7	22.7
Forest residues	0.1	0.2	Other tree biomass	0.2	0.3	Forest residues	2.9	11.8	Industrial residues	7.6	30.6
Bark	0.0	0.0	Industrial residues	11.5	20.2	Bark	0.9	3.5	Recycling material	3.8	15.3
Landscape care wood	0.0	0.0	Recycling material	2.1	3.6	Land-scape care wood	1.9	7.5	Wood energy products	0.7	2.7
Short rotation plantat.	0.0	0.0	**Raw products**	**57.1**	**100.0**	Short rotation plantat.	0.0	0.0	Other biomass	−0.1	−0.3
Sawmill by products	11.2	19.6	Sawmill industry	30.3	53.1	Sawmill by products	3.1	12.5	**Raw products**	**24.9**	**100.0**
Other industrial residues	0.3	0.5	Other stemwood user	1.2	2.1	Other industrial residues	3.0	12.1	BMHPP > 1 MW	8.6	34.6
Black liquor	0.0	0.0	Panel industry	18.4	32.2	Black liquor	2.0	8.1	BMHPP < 1 MW	4.3	17.4
Post Consumer Wood	2.1	3.6	Pulp industry	7.2	12.7	Post Con-sumer Wood	3.8	15.3	Private households	11.5	46.2
			Other material uses	0.0	0.0	**Other/ differ-ence**	−0.1	−0.3	Other energy uses	0.5	1.8
Total	**57.1**	**100.0**	**Uses**	**57.1**	**100.0**	**Total**	**24.9**	**100.0**	**Uses**	**24.9**	**100.0**

WOOD RESOURCE BALANCE 1990–2020											
Material use of wood						Energy use of wood					
Raw material	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**	**Raw material**	**million m^3_{swe}**	**in %**	**Raw products**	**million m^3_{swe}**	**in %**
Wood Resource Balance 1990											
Round-wood, C	29.7	70.0	Stemwood	25.7	60.5	Round-wood, C	2.4	13.2	Round-wood	5.6	30.7
Round-wood, NC	6.1	14.5	Other roundwood	10.2	24.0	Round-wood, NC	3.3	18.1	Other biomass from trees	2.9	15.9
Forest residues	0.2	0.4	Other tree biomass	0.2	0.5	Forest residues	1.3	7.0	Industrial residues	7.3	40.1
Bark	0.0	0.1	Industrial residues	5.7	13.5	Bark	0.5	2.5	Recycling material	2.2	11.9
Landscape care wood	0.0	0.0	Recycling material	0.6	1.5	Land-scape care wood	1.2	6.4	Wood energy products	0.7	4.0
Short rotation plantat.	0.0	0.0	**Raw products**	**42.4**	**100.0**	Short rotation plantat.	0.0	0.0	Other biomass	−0.5	−2.6
Sawmill by products	5.6	13.3	Sawmill industry	24.3	57.3	Sawmill by products	3.3	17.9	**Raw products**	**18.3**	**100.0**
Other industrial residues	0.1	0.2	Other stemwood user	1.4	3.2	Other industrial residues	2.9	16.0	BMHPP › 1 MW	4.7	25.6
Black liquor	0.0	0.0	Panel industry	9.6	22.6	Black liquor	1.8	9.7	BMHPP ‹ 1 MW	2.4	13.0
Post Consumer Wood	0.6	1.5	Pulp industry	7.2	16.9	Post Con-sumer Wood	2.2	11.9	Private households	10.8	58.9
			Other material uses	0.0	0.0	**Other/ differ-ence**	−0.5	−2.6	Other energy uses	0.5	2.6
Total	**42.4**	**100.0**	**Uses**	**42.4**	**100.0**	**Total**	**18.3**	**100.0**	**Uses**	**18.3**	**100.0**

4.3 Cascade uses

CLASSIFICATION ISSUES

Cascade uses can be expressed quantitatively as secondary input rate or cascade factor. The secondary input rate expresses how large the proportion of secondary material is. The cascade factor describes the ratio of total material used to primary biomass.

Based on the basic idea of the circular economy, the forest residues were included in the wood residues and not in the primary biomass. The example shows that the calculation of the ratios for cascade use also depends on definitional decisions, which are disclosed here.

The technologically oriented reader should bear in mind that we are dealing here with macroeconomic processes. Unlike the efficiency measurement of a production plant, macroeconomic factors are also influenced by market movements. This and other aspects of cascade utilisation have already been discussed in the section on 1.5 section. The following tables present indicators of cascade utilisation over time.

DEVELOPMENT OF CASCADE USE

The secondary input rate for wood uses as a whole increased from 43.9 % to 56.5 % between 1990 and 2020. Minor shifts can be a consequence of industry developments. For example, if the sawmill industry grows due to high construction demand, it also provides more sawmill by-products, but stemwood use grows more strongly in absolute terms.

There is a tendency to increase the use of secondary wood feedstocks in material use. However, the changes are small because technological conditions preclude any substitution between wood feedstocks.

This is more possible with energy use. Here, substitution is more limited by price differences. Initially, only residual and recycled materials were used in biomass combustion plants. With the expansion of capacities, the use is limited by availability and so primary raw materials were also increasingly used. The secondary input rate is higher for energy use than for material use. This shows that the ratios express a partial aspect of the uses, but are not a general assessment standard for correct or incorrect use. Both uses complement each other to a certain extent. The choice of raw material is a consequence of value and technological suitability for the respective uses.

Table 4.5:
Secondary input rates of wood-based uses

Germany	Secondary input rates of wood-based uses in %						
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Sawmill industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Panel industry	50.3	57.1	57.4	54.3	51.2	54.1	65.6
Pulp industry	16.0	26.5	35.5	36.6	35.9	38.3	41.9
Material use I	**15.5**	**19.7**	**24.1**	**21.1**	**19.6**	**20.2**	**21.3**
Secondary pulp	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Material use II	**37.5**	**46.0**	**49.3**	**49.2**	**51.0**	**53.0**	**52.7**
Wood energy products	84.7	84.3	78.5	86.4	90.4	90.0	84.9
BMHPP ≥ 1 MW	100.0	100.0	98.3	96.5	91.6	90.2	91.4
BMHPP < 1 MW	100.0	100.0	83.6	80.5	81.4	71.4	67.5
Private households	36.5	35.1	27.8	29.9	26.6	26.6	28.1
Energy uses	**63.3**	**61.6**	**63.1**	**63.1**	**60.8**	**64.0**	**63.9**
Wood uses	**43.9**	**49.8**	**52.5**	**53.3**	**54.7**	**57.0**	**56.5**

Source: Mantau, Infro 2022

CASCADE FACTORS

Cascade factors describe the same phenomenon in a different way. A secondary input rate of 50 % corresponds to a cascade factor of 2.0. Two cubic metres of wood use are generated from one cubic metre of primary wood.

If there is little or no primary wood input, the cascade factor tends towards infinity, while the secondary input rate reaches a maximum value of 100 %. In general, it can be said that wood economic utilisation through the use of residual and recycled wood doubles the utilisation possibilities of primary biomass. This is not only a question of utilisation, but also of the supply of secondary material.

Table 4.6: Cascade factors of forestry uses

Germany	Cascade factors of forestry uses						
	1990	1995	2000	2005	2010	2015	2020
Sawmill industry	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Panel industry	2.01	2.33	2.35	2.19	2.05	2.18	2.90
Pulp industry	1.19	1.36	1.55	1.58	1.56	1.62	1.72
Material use I	**1.18**	**1.25**	**1.32**	**1.27**	**1.24**	**1.25**	**1.27**
Secondary pulp	–	–	–	–	–	–	–
Material use II	**1.60**	**1.85**	**1.97**	**1.97**	**2.04**	**2.13**	**2.12**
Wood energy products	6.54	6.37	4.65	7.36	10.47	9.96	6.63
BMHPP ≥ 1 MW	–	–	60.48	28.33	11.94	10.24	11.65
BMHPP < 1 MW	–	–	6.10	5.12	5.37	3.49	3.08
Private households	1.58	1.54	1.38	1.43	1.36	1.36	1.39
Energy uses	**2.73**	**2.60**	**2.71**	**2.71**	**2.55**	**2.78**	**2.77**
Wood uses	**1.78**	**1.99**	**2.10**	**2.14**	**2.21**	**2.32**	**2.30**

Source: Mantau, Infro 2022

4.4 Outlook

INFLUENCE OF WOOD RESOURCE BALANCING ON INTERNATIONAL REPORTING

The explanations of the individual areas have already contained indications at various points as to how the balancing can be expanded in detail. This is an ongoing process that is necessary in exchange with the application in order to maintain the informative function of Wood Resource Balancing.

With the EUwood Study (2010), the Wood-Flow-Analysis (2012) and the Cascade Study (2016), Wood Resource Balancing found its way into international timber market reporting and is now standard in EU Commission reporting through the Joint Research Center in ISPRA (Cazzaniga et al. 2021).

DIRECTION OF THE CALCULATIONS

Wood Resource Balancing is an explicative model for the representation and explanation of market structures and market developments. For a look into the future or the analysis of interdependencies, additional mechanisms of action are to be incorporated. The basic idea of Wood Resource Balancing is that the explicative value of the analysis gains in significance if the data extraction runs in the opposite direction to the value-added chain. This is because a great deal of information can only be obtained by backward calculation.

Market research today is generally faced with the challenge of thinking in cycles. For the analysis of circular economy processes, the recording of the semi-finished product level (e.g. sawn timber, chemical pulp) is not sufficient. Only the integration of the end product markets (e.g. construction, furniture, packaging) makes it possible to close cycles. The paper sector has been an exception so far because it is very homogeneous in terms of data. However, such an approach follows the availability of data and not the research question.

SIGNIFICANCE OF THE END USE SECTORS FOR THE CIRCULAR ECONOMY ANALYSIS

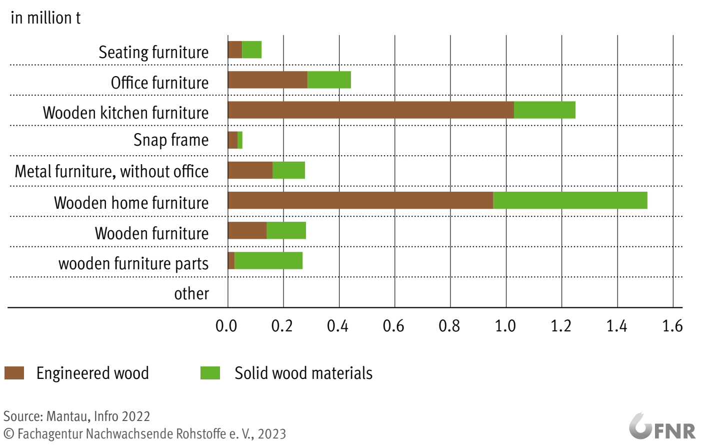
In this cycle of Wood Resource Monitoring, it was possible to conduct a wood use analysis for an end-use market (furniture) using the example of the furniture market. With this study, the author continues his work on determining wood use in end-use sectors, which was started with studies on wood use in the construction sector (Mantau 2013, 2018). This provides an empirical basis for the analysis of the bioeconomy and the circular economy.

The aim of the study was to determine wood use in the furniture sector through empirical survey, structural material flow modelling and extrapolation via production statistics for the German economy (Mantau 2022). End-product sectors are a particular challenge because they are significantly more complex than semi-finished goods markets and the wood content in the products (e. g. wardrobe) is mostly unknown.

1,002 pieces of furniture were evaluated in terms of their materials. The recorded furniture weight was 46,730 kg, of which 71 % was wood and 29 % other materials such as glass, metal or leather. In addition to the furniture weight, a packaging weight of 19.8 % was added, so that the total weight of the recorded material was 55,989 kg.

The extrapolation was made using 60 furniture assortments from the production statistics, which showed 106 million pieces of furniture in 2020. The study determined the wood mass used in furniture (3.6 million t) and wood input for furniture production including offcuts (4.4 million t). A good third of the wood input (34.5 %), measured in mass (furniture weight), is accounted for by solid wood and 65.5 % by wood-based panels.

Figure 4.5: Wood use in the furniture industry by furniture type 2020 in m^3_{swe}

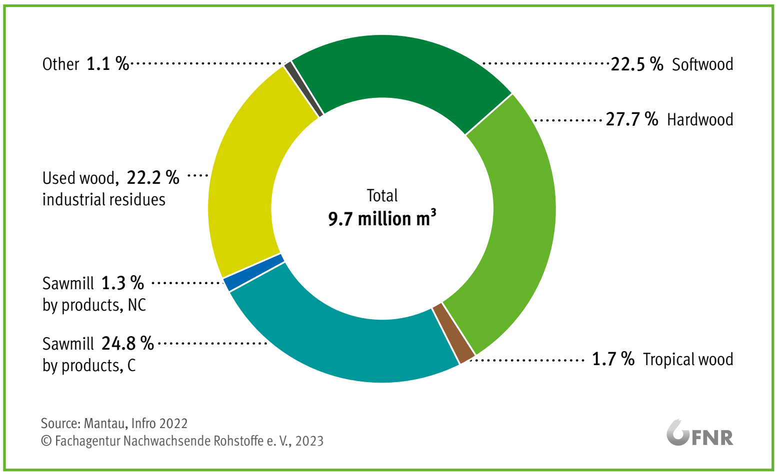


In accordance with the Wood Resource Balancing method, the study makes it possible to calculate back from the piece of furniture to the forest wood. For this purpose, the tonnage of the materials used is converted to the product volume (m^3_{swe}). The solid wood equivalent (m^3_{swe}, solid wood equivalent) corresponds to one cubic metre of solid wood input. The total volume of wood used for furniture production in 2020 was 7.2 million m^3_{swe}. Of this, 31.0 % was solid wood and 69.0 % wood-based panels, measured in volume (swe).

To determine the feedstock input, the raw material composition for wood-based panels must be taken into account. Of this, 29.1 % is accounted for by forest wood, 40.0 % by sawmill by-products and 29.5 % by waste wood. After merging with the results for solid wood, it is possible to show the raw material composition of wood use in the furniture industry as a whole in solid wood equivalents (m^3_{swe}).

The furniture industry uses secondary raw materials, but also produces residual materials (offcuts) itself during furniture production. A total of 9.6 million m^3_{swe} of wood feedstock is used in the furniture industry. Of this, forest wood accounts for 5.0 million m^3_{swe}, sawmill by-products for 2.5 million m^3_{swe}, waste wood and other industrial residues for 2.1 million m^3_{swe}, and miscellaneous for 0.1 million m^3_{swe}. Thus, the secondary input rate in German furniture production was 48.2 % or, in other words, one cubic metre of forest wood input led to 1.93 m³ of wood input in total (cascade factor 1.93).

Figure 4.6: Wood raw material use in the furniture industry



Finally, a Wood Resource Balance can be presented for the use of wood in the furniture industry. For the sake of clarity, assortments were grouped at the semi-finished goods level.

The methodical approach of market analysis via end-product sectors leds to several advantages. It goes beyond the semi-finished goods level. It is only through the end-product markets that information is gained about the product potentials (office furniture, cabinets) for reuse and recycling. The demand modelling is done without direct reference to consumer demand via assumptions on the semi-product level, but via the development of demand of private and industrial consumers. In this way, wood supply modelling could also be controlled on the basis of demand and not on the basis of the harvesting maturity of the trees.

Table 4.7: Wood Resource Balance of the Furniture Industry 2020

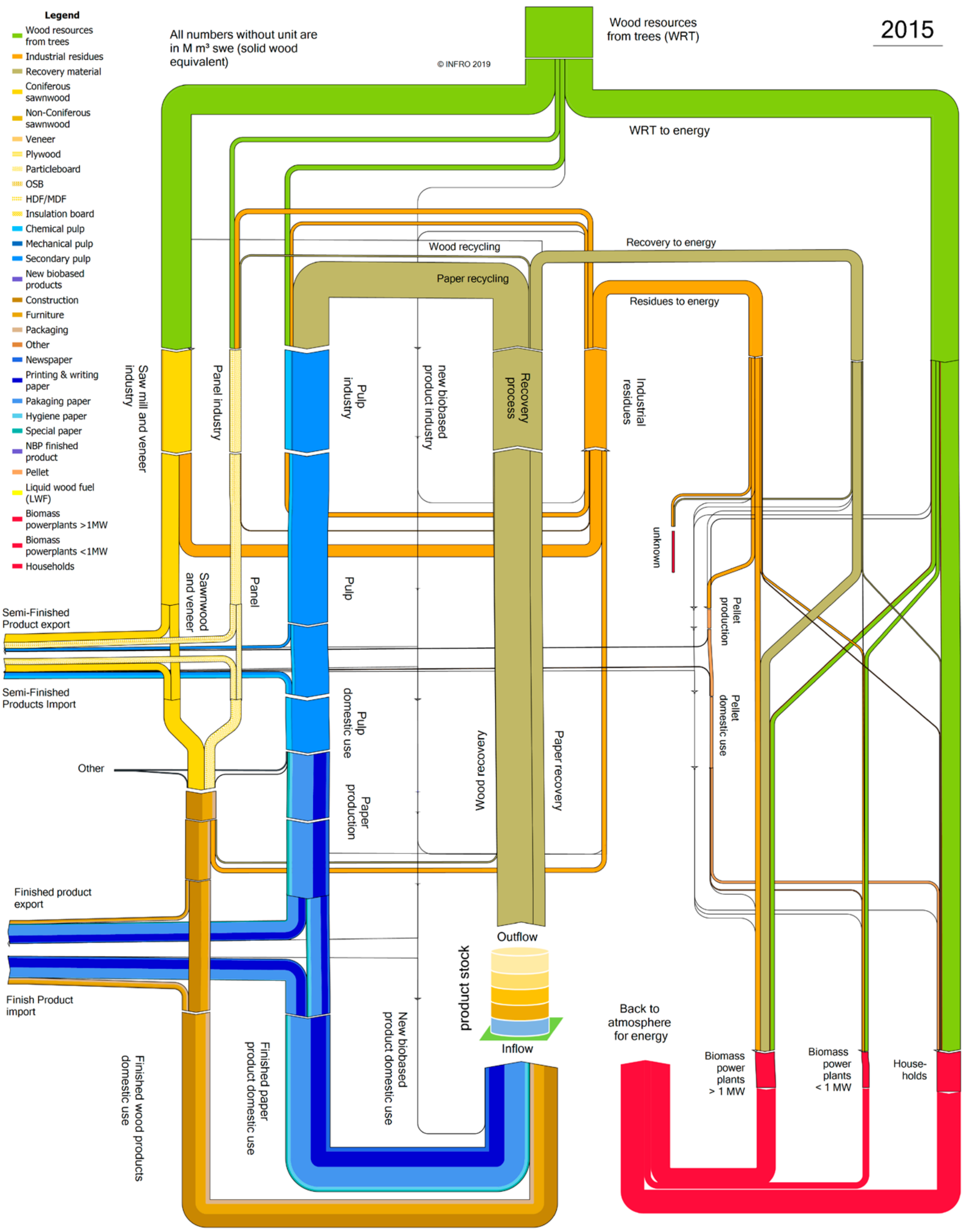
Wood Resource Balance of the Furniture Industry 2020 in million m^3_{swe}					
Raw material	**million m^3_{swe}**	**Semi-finished goods**	**million m^3_{swe}**	**Finished goods**	**million m^3_{swe}**
Roundwood, C	2.150	Softwood	0.852	Seating furniture	0.207
Roundwood, NC	2.645	Hardwood	2.123	Office furniture	0.706
Roundwood, tropical	0.163	Tropical wood	0.163	Wooden kitchen furniture	2.065
Sawmill by products, C	2.373	Plywood panels *)	0.737	Snap frame	0.094
Sawmill by products, NC	0.125	Fiberboard **)	1.104	Metal furni-ture, without office	0.451
Ohter industri-al residues	0.252	Particleboard	4.400	Wooden home furniture	2.456
Wood waste	1.593	Other boards ***)	0.011	Wooden furniture	0.473
Post consumer wood	0.279	Used wood	0.279	Wooden furniture parts	0.404
Other	0.108	Other ****)	0.019	Other	0.337
				Residues of semi-finished products	2.493
Total	**9.687**	**Total**	**9.687**	**Total**	**9.687**

*	*Plywood, multiplex, blockboard, laminated veneer lumber*
**	*Honeycomb panel, MDF, HDF; HPL, WPC*
***	*Rattan, wicker, etc.*
****	*not further defined*

Secondary input rate without others: 48.2 % | Cascade factor without others: 1.930

The major disadvantage of this approach is the complexity of the end-product markets and the resulting need to use extensive positions of existing statistics. However, these only become usable for cycle analyses when they are linked with data on assortments and wood shares. In the age of digitalisation, however, this should not be a fundamental obstacle. Systemic upheavals usually first require more data on open questions and not more mathematics with existing data structures. “Perception is not only the source of knowledge, but it is knowledge itself.” (A. Schopenhauer).

Based on the available empirical surveys, the Wood Flow Analysis was developed and calculated for the years 2000 to 2015. It is based on the results of the Wood Resource Balancing and should suffice here as an outlook on a systemic market model for the analysis of bioeconomy and circular economy.



Quelle: Mantau U. Blanke C.

Figure 4.7: Macroeconomic material flow model for wood in Germany 2015 (basis: m³swe)

The following studies have been produced so far as part of the Wood Resource Monitoring (1999–2021) (available at www.infro.eu):

Wood Resource Balancing	**Mantau, U. (2004):** Holzrohstoffbilanz Deutschland. Bestandsaufnahme 2002. Abschließender Forschungsbericht. Hamburg.
	Mantau, U.; u. M. v. Sörgel, C. (2006): Holzrohstoffbilanz Deutschland. Bestandsaufnahme 2004. Ergebnisbericht. Hamburg.
	Mantau, U.; u. M. v. Sörgel, C. (2006): Holzrohstoffbilanz Deutschland. Bestandsaufnahme 2004. Methodenbericht. Hamburg.
	Mantau, U.; Sörgel, C.; Weimar, H. (2007): Holzrohstoffbilanz Deutschland. Bestandsaufnahme 1987 bis 2005. Dynamisierung. Ergebnisbericht. Hamburg.
	Mantau, U. (2009): Holzrohstoffbilanz Deutschland, Szenarien des Holzaufkommens und der Holzverwendung 2008 bis 2012. Celle.
	Mantau, U. (2012): Holzrohstoffbilanz Deutschland, Entwicklungen und Szenarien des Holzaufkommens und der Holzverwendung 1987 bis 2015. Hamburg.
	Mantau, U. (2019): Holzrohstoffbilanz Deutschland, Entwicklung des Holzaufkommens und der Holzverwendung 1987 bis 2016, FNR FKZ 22015918, 72 S.
	Mantau, U. (2023): Holzrohstoffbilanzierung – Kreislaufwirtschaft und Kaskadennutzung – 20 Jahre Rohstoffmonitoring Holz, FNR FKZ 22019714.

5 APPENDIX

5.1 Conversion factors

The following conversion factors are used in Wood Resource Balancing.

Table 5.1: Applied conversion factors for Wood Resource Balancing

Assortment	registered unit	in t_{od}	in m^3_{swe}	t_{od} in m^3_{swe}	m^3_{swe} in t_{od}
Stemwood	m^3	0.48	1.00	2.083	0.480
Industrial wood (other)	m^3	0.52	1.00	1.923	0.520
Forest residues	m^3	0.52	1.00	1.923	0.520
Sawmill by-products	m^3	0.47	1.00	2.128	0.470
Bark, bulk	B_{CM}	0.18	0.33	1.833	0.545
Bark	m^3	0.36	0.75	2.083	0.480
Other industrial residual wood	m^3	0.47	1.00	2.128	0.470
Waste wood	t_{ad}	0.80	1.73	2.163	0.462
Landscape care wood	t_{od}	1.00	1.98	1.980	0.505
Pellets	t_{ad}	1.20	2.55	2.128	0.470
Wood briquette	t_{ad}	0.90	1.91	2.128	0.470
Average				**2.037**	**0.492**

Source: Mantau U., Sörgel C. (2006)

If a biomass combustion plant processes different assortments and records them in delivered form (air-dry), the question arises as to the water content (WC) of the assortments for converting the oven dry weight. For this purpose, conversion values were determined from various survey results.

Table 5.2: Conversion factors for supplied assortments to biomass combustion plants

Assortment	WC [%]	t_{ad} in t_{od}	t_{od} in t_{ad}	t_{ad} in m^3_{swe}	m^3_{swe} in t_{ad}	m^3_{swe} in t_{od}
Roundwood	36.4	0.64	1.57	1.33	0.754	0.480
Forest residues	43.6	0.564	1.77	1.08	0.922	0.520
Sawmill by-products	38.5	0.61	1.63	1.18	0.846	0.520
Bark	48.1	0.52	1.93	1.10	0.906	0.470
Other industrial residual wood	17.2	0.83	1.21	1.72	0.580	0.480
Waste wood	19.6	0.8036	1.24	1.71	0.585	0.470
Landscape care wood	45.9	0.54	1.85	1.17	0.855	0.462
Energy wood	12.0	0.88	1.14	1.74	0.574	0.505
Other woody biomass	43.1	0.57	1.76	1.21	0.826	0.470
Other biomass	33.8	0.66	1.51			
Pellets	10.0	0.90	1.11	1.78	0.561	0.505
Briquettes	10.0	1.20	0.83	2.55	0.392	0.470

Source: Weimar/Mantau (2006, p. 13)

The following conversion factors were used to determine the ash produced in combustion processes.

Table 5.3: Share of ash in % of m³$_{swe}$

Raw product	in %	Raw product	in %
Softwood	0.7	Black liquor	62.0
Hardwood	0.9	Waste wood	6.0
Landscape c. w.	5.0	Waste paper	2.4
Short rot. plant.	2.5	Bark	3.8
Forest residues	8.0	Briquettes	1.0
Sawmill by products	1.5	Pellets	1.0
Other ind. residues	1.5	Green chips	3.0

Source: Mantau, Infro 2022

5.2 Glossary

Combustion heat output (CHO) Combustion heat output is the heat content of the fuel, related to the lower calorific value, which can be supplied to a combustion plant in continuous operation per unit of time (1. BimSch).

Compression In panel production, wood is compressed (e. g. 1.3 m³ roundwood becomes 1.0 m³ particleboard). In principle, expansion (honeycomb panel) is also possible.

Discontinuous operation Plants that do not produce continuously, e. g. smaller sawmills that cut for irregular demand.

Energy wood products Wood feedstocks that are further processed for energy use (e. g. pellets, briquettes).

Feedstock, wood feedstock A feedstock whose uses are still undetermined (e. g. residues).

Forest residues All forest wood under 7 cm (e. g. branches, tops), but also needles and wood in the rough that is not used for qualitative or other reasons.

Fuelwood, energy wood Wood that is used for energy production.

Hardwood According to the felling statistics, the wood species groups oak (red oak), beech (and other hardwood).

Landscape care wood (LPH) All wood outside the forest that is put to uses. This also includes garden wood used by private households.

Logs Roundwood (wood in the rough) processed in the sawmill industry.

Nominal heat output (NHO; NWL) Nominal heat output is the highest amount of heat per time unit that can be used by the combustion plant in continuous operation (1. BimSch). The NHO was converted into CHO with an efficiency of 90 %.

Other log processing industries	In addition to the sawmill industry, this includes veneer, plywood and sleeper manufacturers, i. e. plants that generally only process wood from final felling. In principle, the boundaries are blurred.
Other roundwood	Roundwood (wood in the rough) not included in the logs.
Outflow	In balancing, mainly the calculated bark loss. It can also be substances that leave the balance area or wood losses in production. The latter have not been included in Wood Resource Balancing so far. Should the need arise, the area can be further subdivided.
Raw material, wood raw material	A feedstock (residue) that is put to a uses (e. g. fuelwood).
Recycled material, recycled wood	Recycled materials were already in use (construction, furniture, newspaper). They are wood feedstocks (waste wood, waste paper) which, after collection and, if necessary, processing, are reused for material or energy purposes.
Roundwood	Is used synonymously with wood in the rough and thus also includes, for example, splitwood obtained from roundwood.
Short-rotation plantations (SRP)	Fast-growing species (e. g. willows) that are harvested on agricultural land after a few years.
Softwood	According to the felling statistics, the wood species groups spruce (spruce, fir, Douglas fir) and pine (pine, larch, strobe).
Solid wood equivalent (m^3_{swe})	Unit of measurement of timber transfer between two uses in the form of a fictitious, converted, average forest timber cubic metre used.
Sources	All areas of wood feedstock that can be put to uses.
Tree biomass	Tree wood, forest residues and bark.
Tree wood	Roundwood, Landscape care material, Short-rotation plantations.
Uses	All areas in which wood is used.
Wood in the rough	Forest wood with a breast height diameter of 7 cm and more.
Wood residues	Wood residues (e. g. sawdust) inevitably arise in a production process (e. g. sawmill) that is directed towards another production target (e. g. sawn timber).

5.3 Source reference

Literature

Wood Resource Monitoring studies are listed in the respective sections, unless they have been explicitly named in the text.

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UBA: notifizierungspflichtige Abfälle. Notifiable waste.

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ZMP: Forst und Holz. Marktbilanz. Zentrale Markt- und Preisberichtstelle GmbH. Bonn, various years up to 2001.

5.4 List of figures

5.5 List of tables

5.6 List of abbreviations

Most abbreviations have been retained according to the German original.

BHD	Breast height diameter (trunk diameter of 7 cm above bark)
BImSchV	Federal Immission Control Ordinance
BioMEG	Renewable bio-monoethylene glycols
BioMPG	Renewable bio-monopropylene glycols
BMA	Biomass combustion plants
BMFA	Biomass combustion plants
BMEL	Federal Ministry of Food and Agriculture
BtL	Biomass to Liquid (fuel production from biomass or biomass liquefaction).
CHO	Combustion heat output (CHO)
EEG	Renewable Energies Act
EFm	Harvest solid cubic metres
Fm	Forestry term for m^3
HDF	High Density fiberboards
HPS	Wood preference scenario
o.R.	Without bark
KUP	Short-rotation plantations
kW	Kilowatt
LDF	Low Density Fibre boards (e. g. insulation boards)
MAP	Market incentive programme
MDF	Medium Density Fibre borads
MW	Megawatt (1,000 kW)
NAWARO	Renewable feedstocks
NHO	Nominal heat output (NWL)
m.R.	With bark
o.R.	Without bark
OSB	Oriented Strand Boards
PET	Polyethylene terephthalate (thermoplastic)
Rm	Room measure for layered timber (1 Rm over bark = 0.8 m^3 over bark or 0.7 m^3 under bark)
SRm	Bulk cubic metre (1 m^3 = 0.4 m^3)
t_{ad}	Tonne in air-dry condition
t_{od}	Tonne in absolutely dry condition, oven dry
Vfm	Solid cubic metre of stock
WC	Water content
WPC	Wood Polymer Composites (decking boards)
ZIV	Central Guild Association

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