Modelling the Material Wood Flow
from Finished Products to Forest Wood

Circular Economy Model for Wood
TRAW (Total Resource Assessment of Wood)

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Version 25th of October 2025

Informationssysteme für Rohstoffe

Joint project:

Forest development as a consequence of changes in wood demand, climate change, natural disturbances and policy requirements – An analysis of the response options of the forestry and wood industry

(Dealing with Impacts on Forests under Changing End-Use Demand, Climate Change, Natural Disturbances and Policy Goals)

Sub-project:

Wood use in sectors of finished products and its effect on the demand for semi-finished products and raw materials, the TRAW model (Total Resource Assessment of Wood). Circular economy model for wood.

Grant recipient:

INFRO e. K. – Raw materials information systems

Funding code: 2220WK32B4 WKF - Forest Climate Fund

Project duration: 1 December 2021 to 31 May 2025

Date of publication: 2025

Cover image: own design using Shutterstock

Citation

Mantau, U. (2025): Modelling the Material Wood Flow from Finished Products to Forest Wood. Circular Economy Model for Wood (TRAW, Total Resource Assessment of Wood). Partial report of the DIFEN project. FNR FKZ 2220WK32B4. 116 pages. 2nd edition. Available online at www.infro.eu

Keywords:

Wood use, circular economy, circular economy model, wood market model, construction, furniture, packaging, paper, other wood uses, wood utilisation coefficients, sensitivities, offcuts, substitution, recycling, wood residues, wood resource balances

Publisher:

INFRO e. K. - Information Services for Resources
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The project on which this report is based was supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Agency for Renewable Resources (FNR) as the BMEL's project management agency for the Renewable Resources funding programme. The responsibility for the content of this publication lies with the author.

Gefördert durch:

Bundesministerium
für Ernährung
und Landwirtschaft

aufgrund eines Beschlusses
des Deutschen Bundestages

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1. Introduction

1.1 Problem definition

From an application-oriented perspective

"Wood, as a renewable raw material, plays a central role on the path to a bio-based and sustainable future. With only limited expandable raw material resources, it is the common goal of the forestry and timber industry to use wood from sustainable forest management efficiently." (FNR 2025) The concept of the circular economy encompasses various aspects, including resource conservation, the substitution of finite resources with renewable feedstocks, and cascade utilisation. As a result, it contributes to supplying the economy and meeting climate targets.

From a model theory perspective

In order to measure and evaluate cycles in a comprehensible manner, data is required that in some cases goes beyond the scope of previous statistical reporting. In this context, the raw material composition of semi-finished and finished products is particularly interesting. This challenge has been solved for wood as a raw material at the raw and semi-finished product level through Wood Resource Monitoring (Mantau 2023, 2023 a). The area of finished products has so far only been researched on a broad empirical basis in the context of the construction (see Mantau, Blanke, Döring 2018) and furniture (see Mantau, Hiller, Gieseking, Blanke 2022) sectors. For an accurate modelling of the circular economy, a broader recording of semi-finished products input in the sectors of finished products is necessary. In this case, "appropriate" means that demand in end-use sectors triggers supply behaviour at the semi-finished and raw material levels in line with economic relationships. The recording of impact processes and the analysis of future developments require the inclusion of the sectors of finished products.

Objective

This paper has the following objectives:

The development of wood use is determined by demand via end-use markets.

Data gaps are filled by studies on individual products and expert estimates.

The expected calculation gap between finished products and semi-finished products is quantified.

A forecasting system is developed to predict future developments in end-use markets that goes far beyond existing estimates based on gross domestic product.

The developments of the end-product markets are quantified using the data structures of the Wood Resource Monitoring. The term "Wood Resource Monitoring" will include the end-product markets.

The concept of wood resource balancing will be retained because quantity flows in the cycle must balance quantitatively, as in a balance sheet. Wood resource balancing at individual nodes is a prerequisite for mapping cycles.

Future forest wood extraction will be derived from demand in sectors of finished products.

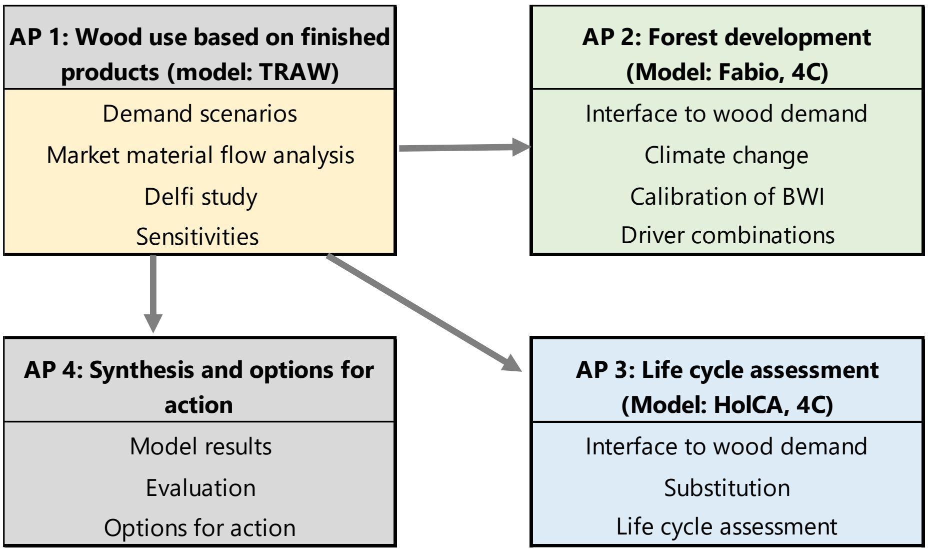
1.2 Classification in the DIFENs project

Contribution to basic research

TRAW (Total Resource Assessment of Wood)

Work package 1 models wood use on the basis of end-demand sectors. This is derived regressively from general framework data that can be derived in the long term. The volume developments for semi-finished products and raw materials are then derived mathematically by applying technical coefficients.

Figure 1-1: Classification within the DIFENs project



Source: DIFENs project application

Derived forest wood demand for Fabio

The demand for forest wood is derived from the development of sectors of finished products. The results are passed on to the forest wood modelling (Fabio, 4C) in the form of logs (use of wood in the rough in sawmills) and other wood in the rough, separated into coniferous and hardwood. The volume of bark and forest residues can be calculated more accurately in the forest wood modelling. The corresponding quantities of forest residues used allow conclusions to be drawn about the extent of forest residue extraction from the forest, but not about the quantities arising from timber harvesting.

Derived wood uses for greenhouse gas accounting (HolCA)

The structure of TRAW makes it possible to process the use of semi-finished products in the sectors of finished products for GHG accounting and to allocate them to their uses with high accuracy. The uses of sawn timber do not arise entirely from the semi-finished goods sector, but result from demand in the construction industry, the furniture industry, the packaging industry and numerous other areas. TRAW allows wood flows and their developments to be assigned to each area of use. In addition, it is possible to model the waste wood market to create a direct comparison of the inflows and outflows of wood products. This approach provides an alternative view to the wood product storage concept.

Sensitivity analyses to quantify options for action

TRAW can be used to analyse the effects of changes in end-use developments on forest wood extraction or recycling flows. The study ran through various scenarios, including a higher share of wooden buildings, a reduction in offcuts, the substitution of softwood with hardwood and the substitution of wood in the rough with waste wood.

Using an adaptation scenario, a simultaneous analysis of the effects of all measures on wood availability (Fabio) was carried out.

1.3 Summary

Framework

Demographic change is leading to a decline in population in Germany, resulting in falling household and employment figures. Economic developments, on the other hand, tend to show stability or growth. Even gross domestic product in real terms overstates the use of raw materials when a society develops from a manufacturing to a service sector. The relative developments of the economic sectors provide a less problematic basis for estimates. As with all future values, it should be noted that they are based on assumptions. The background to the assumptions is explained in detail.

Construction sector

Developments in the construction industry are calculated as a baseline scenario (BAS) based on economic developments and with an increasing share of wooden buildings (wood construction scenario, HBS) as a result of changes in preferences. The share of wooden buildings is increased by around one third (31.9%) of the initial value for each building group. The difference in wood products used will remain limited to 645,000 m^3_{hwe} semi-finished products in 2050. Enclosed into raw materials, the additional quantities used in 2050 will amount to 873,000 m^3_{swe}.The cumulative effect of additional wood use amounts to 9.0 million m^3_{hwe} semi-finished products, which, applying the average ratio to raw materials (1.472) would correspond to 15.5 million m^3_{swe}.

There are several reasons for the limited volume effects. The target value of a one-third increase in the share of wooden buildings will not be achieved immediately but will build up linearly between 2024 and 2050. In the decade between 2020 and 2030, the construction industry will experience an economic downturn. Ultimately, new construction accounted for only one third of wood use in 2023. 63 % was used for renovation and remodelling and 4% for civil engineering. The share of new construction will continue to decline until 2050.

In addition to the increase in the share of wooden buildings, economic developments will also lead to an increase in the use of wood. This will amount to a total of 14.7 % or 3.5 million m^3_{swe}. Of this, 11.4 % will be attributable to economic developments, particularly in remodelling, and 3.3 % to the change in the share of wooden buildings in new construction.

Three quarters of uses in the construction sector are accounted for by coniferous wood.

Furniture sector

The furniture market has been stable on average over the last few years. The moderate upward trend is coming to an end due to demographic developments. A slowdown is expected from 2040 onwards. Following the economic downturn in 2023, production is expected to stagnate in the long term.

The use of wood in the furniture sector amounted to 9.4 million m^3_{swe} in 2020. By 2050, the value of raw materials used will rise to 10.0 million m^3_{swe}. Due to conversion and also because wood-based panels contain other wood in the rough, the share of wood in the rough was 52.7 % in 2020. It will remain constant until 2050. The share of solid wood will decline slightly to 23.2 % by 2050.

Packaging sector

The scenarios show hardly any growth for the packaging sector compared to the period from 2000 to 2020. The use of wooden semi-finished products averaged approx. 6.5 million m^3_{hwe} including offcuts between 2019 and 2023. Of this, 1.8 million m³ or 28.1 % was accounted for by wood-based panels and 4.6 million m^3_{hwe} or 71.9 % by solid wood. Particleboard accounted for 85.8 % of wood-based panels. The dominance of softwood was even more pronounced in solid wood, at 99.1%.

The use of raw materials will increase from 9.6 million m^3_{swe} in 2020 to 11.1 million m^3_{swe} in 2050. Given the current economic challenges of 2025 and increasing deglobalisation, this scenario appears optimistic. However, compared to the spectacular upswing of the years 2000 to 2020, the assumption of stagnation is rather cautious.

Paper sector

The newsprint sector has already undergone a significant structural change, and production will continue to decline moderately in the scenario. This also applies to writing and printing paper. Its moderate growth in the first half of the 2030s is due to demographic factors. Hygiene and speciality papers are developing largely steadily due to demographic developments and technological competitive advantages. The production of packaging papers has passed its peak and is tending to decline. Economic developments in the sectors of finished products have very different effects on chemical pulp production, as they are covered by different proportions of wastepaper. In 2020, the paper industry used 63.7 % wastepaper, 14.3 % additives and 22.0 % chemical pulp.

In 2020, a total of 9.1 million m^3_{swe} of wood raw materials were used. In economic terms, demand will decline until 2030 (8.3 million m^3_{swe}) and rise moderately until 2050 (8.9 million m^3_{swe}) due among other things, to the higher proportion of pulp in hygiene and speciality papers.

New bio-based wood products

UPM's biorefinery in Leuna provides guidance for future planning of raw material use for wood-based plastics and their precursors (raw material use: 500,000 m^3_{swe}/year of beech for a production volume of 220,000 tonnes).

It is assumed that capacity will be expanded at the same rate every five years from 2035 onwards. This will result in a production capacity of 1.1 million tonnes by 2050. Decayed hardwood (beech) is used as the raw material. The expansion of production capacity to 1.1 million tonnes would thus correspond to 2.5 million m^3_{swe}.

Residual quantities

Based on demand in the specified end-demand sectors, there is, as expected, a delta between the resulting quantity of semi-finished products and the fully determined semi-finished products production based on Wood Resource Monitoring. On an annual average for the years 2000 to 2020, an unspecified volume of 15.0 million m^3_{hwe} of semi-finished products was recorded in the finished goods sector. This figure corresponds to a 32.1 % share of the material use of wooden semi-finished products. For the period from 2021 to 2050, an average unspecified volume in the end-use sector is projected in line with the development of the specified sectors. This corresponds to an average annual volume of 15.7 million m^3_{hwe}. This represents 28.1 % of the material use of wood products.

Total material wood use Enclosed to the material use of raw materials (excluding wastepaper and other materials), 65.9 million m^3_{swe} were used in 2020. Use will increase by +15.8 % to 76.3 million m^3_{swe} by 2050. The share of wood in the rough will be 82.1 % in 2050.

Energy wood products Energy wood products (pellets, briquettes, charcoal) are initially classified as intermediate products (semi-finished products). The raw material input occurs during their production. In a second step, they are allocated to users. In 2020, of the 7.3 million m^3_{swe} used, 70.6 % was used in private households, 26.5 % in municipal and small combustion plants and 2.9 % in large combustion plants. The uses follow the overall development of the sectors. For this reason, use will fall to 5.0 million m^3_{swe} by 2050. A scenario in which pellet production remains constant or increases and other raw materials, especially wood in the rough, are substituted is also conceivable.

Private households Wood use in private households was already stagnating or declining at the current level. The assumptions of the scenarios lead to a decline in wood energy use in private households between 2020 and 2050 in EZF from 18.1 million m^3_{swe} to 13.5 million m^3_{swe} for single-fire systems. Wood use in central heating systems will initially increase from 8.9 million m^3_{swe} in 2020 to 10.3 million m^3_{swe} in 2030 due to system expansion. After that, efficiency gains and a decrease in the influence of cold weather will lead to a decline in wood use to 6.7 million m^3_{swe} by 2050. Overall, this will lead to a decline in the use of wood as an energy source in private households from 21.8 million m^3_{swe} in 2020 to 16.5 million m^3_{swe} in 2050.

Large combustion plants Large combustion plants will reach a largely stable plateau of approx. 23 million m^3_{swe} between 2010 and 2020. By 2030, there will be a sharp decline to a level of approx. 11 million m^3_{swe}, which will remain largely constant until 2040. This will be followed by a continuous increase to 17 million m^3_{swe}.

Small combustion plants Small combustion plants will reach their highest wood demand between 2023 and 2033, averaging 12.5 million m^3_{swe}. According to the specified scenario, wood use will then decline to 8.9 million m^3_{swe} by 2050.

Other uses of energy wood Other uses include biofuel (ex-Choren industries), charcoal and other wood briquettes. The latter refers to quantities that are reported in the statistics of the Federal Statistical Office and exceed the quantities recorded in resource monitoring surveys. The use of wood for other energy wood products amounts to 1.0 million m^3_{swe} and is assumed to remain constant in the scenario.

Total wood use for energy Energy wood use will fall from 59.4 million m^3_{swe} in 2020 by 12.2 million m^3_{swe} to 47.2 million m^3_{swe}. This corresponds to a decline of one fifth (20.5 %).

Total wood use

In 2020, total wood use amounted to 123.8 million m^3_{swe}. The decline in wood use for energy purposes is partly offset by the increase in material wood use. Overall, wood use will fall to approx. 116.5 million m^3_{swe} in 2030 and 2040. By 2050, it will rise to 122.5 million m³. The numerous, sometimes very different developments will thus balance out overall to a relatively stable wood use structure. The proportion of solid wood is 61.1 % (74.9 million m^3_{swe}.

Sensitivities

The change in the share of wooden buildings will have limited effects on quantities, as the current weak economic development will compensate for some of this and wood use in non-wooden buildings will decline because of substitution. The difference in wood products used will remain limited at 645,000 million m^3_{hwe} in 2050. Enclosed into wood raw materials, the additional quantities used in 2050 will amount to 873,000 m^3_{swe}. For the simulation period 2026 to 2050, this corresponds to an additional wood use of 18.6 million m^3_{swe}.

The 15.0 % reduction in waste during the production of finished products leads to a lower annual use of semi-finished products amounting to 1.216 million m^3_{hwe}. In terms of raw material input, this results in an average annual reduction of 1.399 million m^3_{swe}.For the simulation period 2026 to 2050, this corresponds to a saving of 35.0 million m^3_{swe}.

The increase in the use of hardwood from 17.1 % to approx. 25.0 % corresponds to approximately 1.5 times the previous amount. This is a zero-sum game, as the higher quantities of hardwood are deducted from softwood. In total, this could replace 3.2 million m^3_{swe} per year. Of this, 44.9 % of the substitution is accounted for by material use and 55.1 % by energy- e uses. For the simulation period 2026 to 2050, this corresponds to a saving of 79.5 million $m^3(_{swe)}$.

Doubling the use of waste wood in material applications assumes that wood in the rough will be substituted. Between 2026 and 2050, this will lead to an average annual substitution of wood in the rough by waste wood amounting to 2.230 million m^3_{swe}. Overall, the effects balance each other out. For the simulation period 2026 to 2050, this corresponds to a substitution of 55.7 million m^3_{swe}.

Adjustment scenario

The simultaneous implementation of all measures results in a projected reduction in the use of roundwood of -85.9 million m^3_{swe} between 2026 and 2050. This consists of a reduction in the use of softwood of -142.3 million m^3_{swe} and an additional use of hardwood of +56.4 million $m^3_{swe)}$. This could postpone a softwood shortage by years. However, the actual extent of the effect also depends on forest growth (Fabio).

2. Method of the TRAW model (Total Resource Assessment of Wood)

2.1 Problems of market modelling for the circular economy

Challenge: finished products

Circular economy processes can hardly be modelled without including the end-use sectors. Without the finished products sector (finished products synonymous with end-use products), a crucial link is missing to close the cycle. All stages of the waste hierarchy (KrWG 2012, §6) are inextricably linked to the use of products.

Challenge: market modelling

Previous timber market models (European Forest Sector Outlook Study (EFSOS, UNECE (2011); NAFSOS USDA Forest Service Model (2012); GFTM, TiMBA) determine the demand for wooden semi-finished products (e.g. sawn timber, wood-based panels, chemical pulp) based on the development of gross domestic product (GDP). The only end-use sector is the paper sector. The sole reason for this approach is data availability. The latter usually refers to the FAO database (FAOSTAT). This may have been a sufficient approach in the past. However, it is not enough in the age of the circular economy. A lack of available data or the simple use of existing databases cannot be the limit of the knowledge process. What can timber market models tell us about the current world if they do not take into account either sectors of finished products or wood energy use?

Even greater is the problem of underreporting and other data issues. What are equilibrium models and statistical quality characteristics worth, if they show a market equilibrium with high significance, even though the data only show half of the real sawn wood production? The current scientific challenge lies in obtaining new data and new market structures relevant to our understanding of new phenomena in the bioeconomy, raw material availability and the circular economy.

The author is aware that this version of the TRAW-model is only a starting point. International transferability has only been partially tested (Mantau 2010. Mantau, Blanke 2016) and scarcity modelling is incomplete. If the alternative is elegant models in a limited data world with yesterday's market structures, the weakness is – temporarily – acceptable.

Increasing value added leads to increasing product diversity

While semi-finished product sectors are characterised by a small number of products (softwood and hardwood), sectors of finished products consist of many products. The study on the construction market covers 142 wood products by component (Mantau, Blanke, Döring 2018). As part of the study on the furniture market, 60 different statistical furniture groups were examined (Mantau, Hiller, Gieseking, Blanke 2022).

Furthermore, the proportion of wood in the sector of finished products is not directly apparent from the product (kitchen) and varies within a product group. It must therefore be determined by product surveys. Random surveys are rarely possible, as there is no population from which random samples could be drawn. It is often considered a success if sufficient documentation with complete information on the ingredients is available. The sample is therefore usually the result of a search process. This may also be one reason for the lack of interest in such studies among scientists, as a lack of statistical validation is mistakenly regarded as a scientific shortcoming. If the consequence is ignorance, this cannot be a convincing argument.

The quantities recorded in surveys are assigned to reporting numbers from production and foreign trade statistics in order to extrapolate market quantities. Another challenge is ensuring that the sample matches the statistical classification and that the statistical classification matches market reality.

Once the wood materials to be used have been determined, the final challenge is posed by the different specific weights of semi-finished products in the finished products sector and feedstock in the semi-finished products sector. The values given in the literature differ due to the divergent nature of the goods and the types of wood used, whose measured values in turn vary themselves. This discrepancy is unavoidable due to the nature of wood as a material. The methodological problem can only be solved by transparency of the selected technical indicators. Overall, this means that macroeconomic market material flow analyses have a different level of difficulty and measurement accuracy than technological material flow analyses in the laboratory or in a single process.

Definition

Material flow analysis and market material flow analysis

The terms "material flow analysis" and "market material flow analysis" are used synonymously in different contexts. In this context, material flow analysis refers to the determination of the input factors for a single product in a specific production process. The relevant factors are usually known or can be determined with reasonable effort. Market material flow analyses focus on macroeconomic material flows that are composed of many products with different input factors. Determining the material composition requires recording many products and combining them into product groups (commodity codes).

Connection

Material flow analysis and market material flow analysis

Nevertheless, there is a connection between the two methods. As part of the analysis of the furniture market, 1,000 individual material flow analyses were carried out. The furniture items recorded were assigned statistical reporting numbers and extrapolated using average material quantities and production figures. Representativeness was ensured in the furniture study (Mantau, Hiller, Gieseking, Blanke 2022) by adjusting the data to reflect the quantity and value of the furniture groups in the production statistics. The structural data on wood use remain constant as long as no new empirical surveys are available. However, they can also be used as a basis for quantifying changes. The extrapolated wood use is adjusted over time using the determined input factors and production statistics.

2.2 Definitions

Cascading principle

The distinction between raw materials, semi-finished products and finished products is an essential aspect for understanding, structuring and quantifying the principle of cascading use. Residual materials are continuously generated during the processing of raw materials (yield) and semi-finished products (offcuts). After use, the finished products are either consumed or sent for further recycling. They then become post-consumer materials.

Raw materials

According to the available statistics, production stages are differentiated according to raw materials, semi-finished products and

Semi-finished products

Finished products

finished products. According to the NACE Rev. 2 (Eurostat, 2008) , "semi-finished products" are defined as products that have undergone some processing but require further processing before they can be considered ready for use. Typical examples for the timber market are sawn timber, boards and chemical pulp. "Finished products" do not require further processing before they are ready for use/consumption by the end user, who may be a private household, an institution or a company.

However, semi-finished products (particleboard) are also sometimes used directly by end consumers. It is not unusual for social science terms to be difficult to distinguish clearly from one another. They describe the normal case. Although further differentiation is possible in purely factual terms, it often does not correspond to statistical categories or leads to a complexity of terms that defeats the purpose of better understanding. Inaccuracies must be regarded as an acceptable price to pay for reducing complexity. A characteristic example for this study is the distinction between construction methods. This is based on the predominant use of materials in the construction. As a result, buildings constructed using timber also contain concrete parts, and vice versa.

Definition
Offcuts and yield

The term "offcuts" refers to quantities that arise during the processing of semi-finished products into finished products and are not attributed to the semi-finished products. The offcuts are attributed to industrial wood residues.

The term "yield" refers to quantities that arise during the processing of raw material into semi-finished products and are not attributed to the semi-finished products. The resulting residual materials are also generally attributed to industrial wood residues.

Offcuts and yield describe the origin and wood residues describe the result. Subgroups can be formed for relevant phenomena, i.e. those that are better treated separately. Due to their untreated nature and high market relevance, sawmill by-products are recorded in a separate category. Due to its special material properties, black liquor is also recorded in a separate category.

From cubic metre of construction m^3_b to product wood equivalent m^3_{pwe}

An analysis of the quantities of wood used in the construction sector (Mantau, Blanke, Döring 2018) has shown that recording in cubic metres is not appropriate. Building specifications and service specifications only allow the volume of wood used in the building structure to be determined. The quantities derived from this do not correspond in any way to the volume of semi-finished products, which is greater due to offcuts, nor to that of raw materials, which is greater due to the ratio of input quantities to yield.

The analysis of the wood content in finished products requires a large number of terms for cubic metres, including cubic metres for construction, packaging, furniture and toys. The implementation of a product wood equivalent (m^3_{pwe}) therefore proves to be useful. The term "product wood equivalent" refers to the wood content of a specific finished product.

Definition

Raw materials (swe)

In terms of calculation, the product wood equivalent does not correspond to the semi-finished products used, as the offcuts must be added. Since the aim of the analysis is to determine the flow of goods,

Semi-finished products (hwe)
Finished products (pwe)

this quantity is used more frequently, and one would have to speak of "wood product equivalent plus offcuts". In this case, it is easier to refer to wood semi-finished product equivalent (m^3_{hwe}), as this evokes the correct association. The wood semi-finished product equivalent describes the quantity of semi-finished products used to manufacture a finished product.

The effectiveness of terms correlates with the number of phenomena that they accurately summarise and distinguish from other phenomena. Following on from "swe", the units "pwe" or "product wood equivalent" and "hwe" (half-finished wood equivalent) are introduced to describe quantities of wood in sectors of finished products.

This classification fits clearly into the stages of the value-added chain and enables the exact quantity of wood to be determined.

The product equivalent therefore describes the quantity of wood used in the end product, which can be calculated by backward calculating the raw material input (m^3_{swe}, solid wood equivalent).

$m^3_{swe} = (m^3_{pwe} + V_p) * D_h / A_r$[1]

or based on the semi-finished products input

$m^3_{swe} = m^3_{hwe} * D_h / A_r$[2]

One solid wood equivalent (m^3_{swe}) [logs] corresponds to one wood product equivalent (m^3_{pwe}) [roof beams] plus the offcut (V_p) multiplied by the density of the semi-finished products used (D_h) [sawn timber=1.0], and divided by the yield when using the feedstock (A_r ; e.g. sawn timber 0.6).

Why not m^3_{rwe} for raw wood equivalent? In principle, this would be possible, but like the other cubic metre terms, it would have a strong reference to the processing level. Solid wood equivalents (m^3_{swe}) express the volume of wood in a fictitious average cubic metre of raw wood used, but they can also be used at the semi-finished and finished product levels. This is always the case when a uniform unit of comparison across all value-added chains is desired.

Example of cubic metre types and conversion

Let's take the installation of a wooden window in a building as an example. The wooden window, which occupies 0.6 m^3_{pwe} of space in the building structure, would correspond to 1.2 m^3_{hwe} of sawn timber, because sawn timber is first used to produce window scantlings, which are then milled, sanded and cut to size, with about half of this becoming wood residues (factor 2.0). The quantity of semi-finished products required for the production of the windows is 1.2 m^3_{hwe} sawn timber. In order to obtain the raw materials used, the yield would have to be taken into account in addition to the offcuts for a softwood window (factor 1.67). This means that 2.0 m^3_{swe} of softwood logs would be used to produce 0.6 m^3_{pwe} of wooden windows (volume occupied by the windows in the building structure) (0.6*2.0*1.67).

2.3 Model structure of TRAW

From the wood resource balance to the circular economy model

The method of wood resource balancing is assumed to be known (see Mantau 2023, 2023a). Wood resource balances have so far enabled a transparent analysis of the structures and quantitative relationships between wooden semi-finished products and wood raw materials. The DIFENs project has comprehensively integrated the sectors of finished products, thereby supplementing the method of wood resource balancing with a further balance (finished product balance, Table 2-1). The circular economy model therefore consists of a large number of wood resource balances which can be combined to form a closed organism due to their interconnectivity. A second aspect of significant relevance is the fact that realistic modelling of the circular economy is only possible through the use of wood in sectors of finished products. The material cycle is initiated by consumers and ends with product storage, either starting afresh through recycling or ending in incineration or disposal. Without a doubt, analysing the sectors of finished products is more difficult than analysing semi-finished products due to the more complex data situation, but missing data should not prevent us from seeking answers to new questions at other times.

Uses

Calculation

Production

The model is based on the development of finished products and corresponds to the economic direction of impact. Since it is not possible to determine from a tree trunk what purpose it will ultimately be processed for, the calculation method for determining the cycles must be carried out in the opposite direction. In contrast, production or the value-added chain runs from raw materials to finished products.

Markets

The list of integrated finished products can be found in Figure . For systematic and communication reasons, a semi-finished product stage has also been added to energy uses. This systematically prevents double counting (e.g. for pellets) and clearly shows the raw material groups in processed form. This also further differentiates the number of markets reported. Finally, the TRAW circular economy model makes it theoretically possible to call up the various types of wood resource balances at all relevant points for any given year.

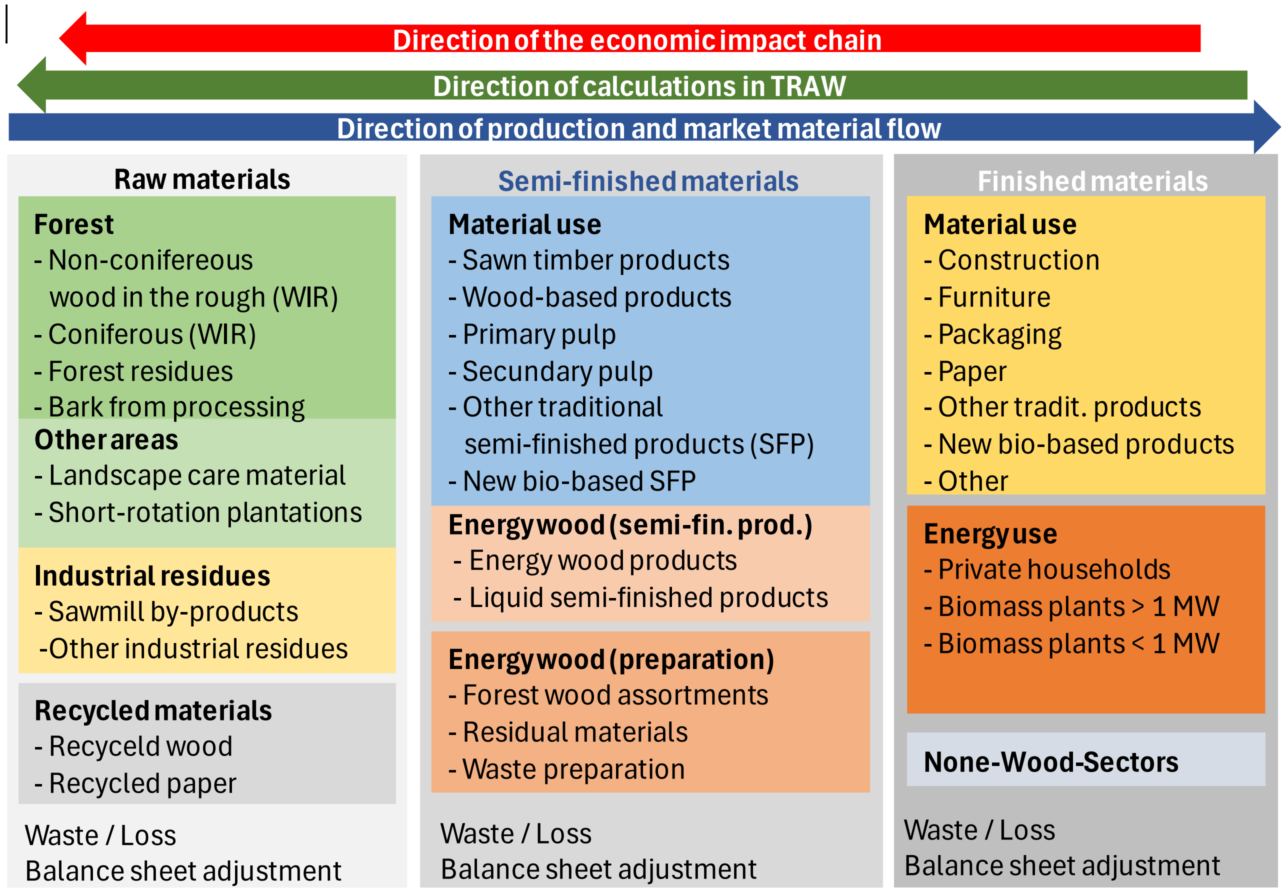
Example: Furniture market

The previous Table 2-1 shows the procedure using the example of the furniture market. Starting from 60 statistical commodity codes (GP19) with the potential of wood content, these are grouped into 9 product groups to calculate the input factors. The back calculation to raw materials is again carried out using the yield and input factors between raw materials and semi-finished products. In this case, the figures are presented in solid wood equivalents (m^3_{swe}) so that the balance sheet items balance each other out. The yields between raw materials and semi-finished products are included in the calculation.

From the terms to the model

The model begins by determining developments in the sectors of finished products (base scenario). This is discussed in the following sections 2.4 and 2.5. Since gross domestic product is too undifferentiated for estimating the development of the timber market sectors, a considerable part of the work involves developing a driver structure (Figure 2-2, No. 1), which makes it possible to estimate market developments regressively and over the long term. Fluctuations/changes that are not included in the developments of the framework data cannot be reflected in the scenarios at a later stage.

Figure 2-1: Product structure of the TRAW model



Source: Mantau (2025)

Table 2-1: Example of a finished wood product balance sheet for the furniture market

Wood Resource Balance of the Furniture Industry 2020 in million m³swe					
Row materials	**Mio. m^3_{swe}**	**Mio. m^3_{swe}**	**Semi-finished prod.**	**Mio. m^3_{swe}**	**Finished products**
Roundwood, C	2,150	0,852	Sawn timber, C	0,207	Seating furniture
Roundwood, NC	2,645	2,123	Sawn timber, NC	0,706	Office furniture
Roundwood, trop.	0,163	0,163	Sawn timber, trop.	2,065	Kitchen furniture (wood)
Sawmill by-prod., C	2,373	0,737	Plywood boards *)	0,094	Spring frames
Sawmill by-prod., NC	0,125	1,104	Fiberboards **)	0,451	Metal furniture, excl. office
Industrial residues	0,252	4,400	Particleboard	2,456	Home furnishing
Waste wood	1,593	0,011	Other boards ***)	0,473	Wooden furniture, other
Used wood	0,279	0,279	Used wood	0,404	Wooden parts
Other	0,108	0,019	Other ****)	0,337	Other
				2,493	Residues (semi-finished)
Total	**9,687**	**9,687**	**Total**	**9,687**	**Total**

*) Plywood, multiplex, blockboard, laminated veneer; **) honeycomb panel, MDF, HDF; HPL, WPC; ****) rattan, wicker, etc.

Second. input rate⁺) 48,2% ⁺) without others 1,930 Cascade factor ⁺)

Source: Mantau/Hiller/Gieseking/Blanke (2022):

From the terms to the model

The selection of developments in the driver structure and in the regression context constitutes a choice that potentially influences the results. Under optimal conditions, it is determined by the available data and the interest in gaining knowledge. Due to existing discrepancies between economic theory, available data and regressive analysis, the generation of realistic estimates cannot be guaranteed without the relevant specialist knowledge, both in theoretical and practical terms.

An optimisation between computational automation and the desired degree of realism must therefore be achieved at this point. This can also be expressed as follows: "Automation as far as possible, but not at the expense of realistically expected developments." In complex social science fields, every specification of a regression is also a question of variable selection, the time period and its effects on a possible course of events. A high R^2 and significant variables are a good prerequisite, but do not necessarily lead to more realistic findings. This is the result of the interplay between data, regression and technical and economic expertise (Figure 2-2, No. 2).

For simulations at this level, the use of wood per functional unit could be changed by reducing it if, for example, it is assumed that a building could also be constructed with less wood. These processes are also not clear-cut. The reduction in the use of wooden windows in non-wooden buildings can be associated with a lower use of wood. In a building constructed of wood, the larger wall area required may lead to increased use of wood. When analysing mega-products that consist of a large number of small products that are interconnected and together form a specific function (e.g. a building), feedback loops must also be taken into account.

Figure 2-2: Structure of the TRAW model (calculation steps)

Nr.	Procedure	Possible influences
1	Development of a driver structure (framework data)	Selection
2	Scenarios for the end product sectors (pwe)	Material savings
3	Material shares of semi-finished products in finished products	Material substitution
4	Scrap rates of the semi-finished product sectors	Efficiency
5	Development of the semi-finished product sectors (hwe)	Material savings
6	Material shares of raw materials in finished products	Material substitution
7	Yield of the raw material sectors	Efficiency
8	Development of the raw material sectors (swe)	

Source: Mantau (2025)

Derived wood quantities

From the third step onwards, the upstream production stages are determined by technical coefficients. These can initially be assumed to be constant variables. Compared to economic developments, technological relationships are more stable. Nevertheless, they are also subject to change over time. Determining these coefficients usually requires extensive preliminary studies, such as in wood resource monitoring.

The development of finished products and their share in semi-finished products (3) results in the development of the semi-finished product sectors (5). The material composition and offcuts (4) are variable. At this stage, material savings would mean that more hollow core panels would be used instead of solid particleboard when manufacturing doors in the future.

The raw material shares (6) in semi-finished products lead to the development of the raw material sectors (8). This can also lead to material substitutions (hardwood replacing softwood) or changes in the yield (7).

2.4 Driver structure

Demographics driver

Empirical time series extending to 2050 are hardly available. Data on demographic developments can be derived with reasonable certainty in the long term. The calculations are based on the 15th coordinated population projection of the Federal Statistical Office. The results of the 2022 census from 2024 have been integrated using our own calculations, as the updated calculations from the Federal Statistical Office will not be available until this report has been completed. This enables further developments to be derived, such as the number of households and employment indicators.

Economic drivers

For the development of economic sectors, only data on gross domestic product (GDP) as a whole is available for the long term until 2050. This is problematic because monetary and real economic variables develop differently, meaning that the data allows only a limited degree of differentiation for projections. In order to refine the forecast, assumptions were therefore made about the relative development of the sectors (section 3) and presented transparently with the framework data.

GDP driver problem

It remains to be questioned to what extent GDP can still be considered representative and specific enough for the development of the manufacturing sectors. Gross domestic product is the expenditure side of the national accounts. A comparison with the source side (gross value added) shows that these are closely related (Figure 2-3). Comparisons with the source side follow. The Figure 2-4 clearly shows that gross value added (GVA) is increasingly determined by the service sector. In 1970, this sector accounted for 44.9 % of GVA, rising to 54.2 % in 2023, while the share of manufacturing and construction fell from 36.5 % to 29.6 %.

Figure 2-3: Real developments (2015=100) in gross domestic product (GDP) and gross value added in billion euros

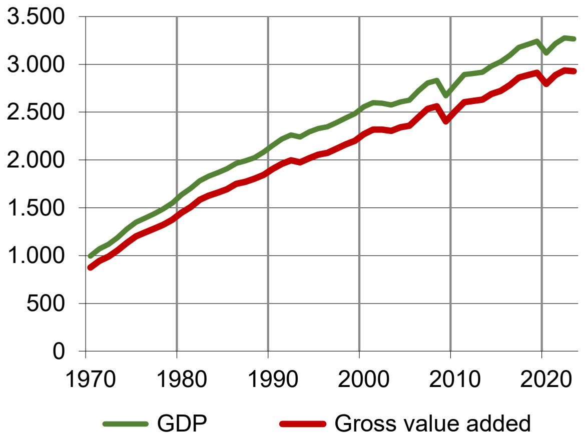
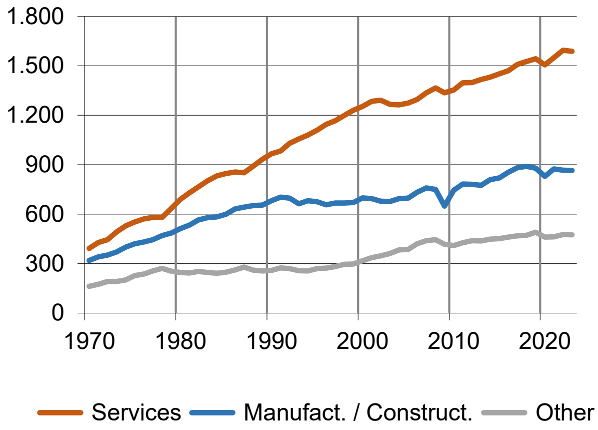


Figure 2-4: Real developments (2015=100) in services *), manufacturing including construction and other sectors **)



*) Information and communication; financial and insurance service providers; real estate and housing; business service providers; public service providers, education, health; other service providers**) Determined here as a residual variable, includes agriculture, trade and transport

Source: Federal Statistical Office (2023)

Source: Federal Statistical Office (2023)

Figure 2-5: Index development of gross value added, services and manufacturing (1970 = 100)

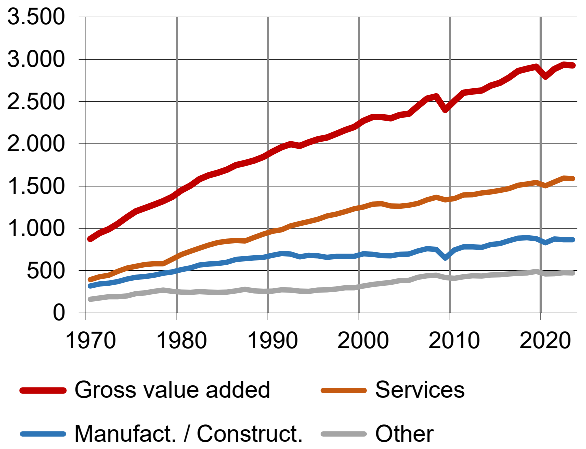
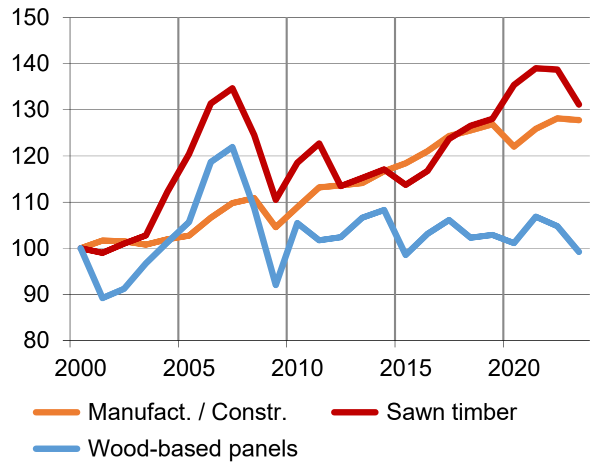


Figure 2-6: Index development of manufacturing and construction, as well as the production of sawn timber and wood-based panels (2000 = 100)



*) Information and communication; financial and insurance service providers; real estate and housing; business service providers; public service providers, education, health; other service providers

Source: Federal Statistical Office (2023)

Source: Federal Statistical Office (2023)

Different correlations on the timber market.

The dynamics of developments can be better illustrated in the form of indices (Figure 2-5). The figure shows the different dynamics, but also that these can change significantly. For example, the manufacturing and construction industries followed gross value added until 1990, largely decoupled until 2020, and then converged again in terms of dynamics from 2020 onwards.

The segments of the timber market also behave differently in relation to gross value added. While the production of sawn timber follows the trend of the manufacturing industry and the construction industry, the production of wood-based panels decouples from it (Figure 2-6).

Conclusion

The suitability of gross domestic product for estimating developments in the timber industry is considered to be low. The problem can be mitigated by determining elasticities over shorter, factually similar periods. However, this does not solve the problem of updating data under the influence of structural changes.

It may seem elegant to link all products and all countries in the world to a single variable. This saves time in data collection and enables uniform mathematical schemes. But how meaningful are the results? In an age of major structural changes, it is essential to pay more attention to changing data. In order to analyse the transition from a borderless economy that follows the consumption function to an economy with limited resources (circular economy), it also makes sense to consider completely new model structures.

2.5 Procedure for calculating regressions

Determination of the initial value

The initial value of a scenario is of significant importance for determining the situation dimension of the subsequent development. At the beginning of 2024, the German construction industry is in a deep crisis. The analysis of long-term scenarios can lead to an atypical situation level due to atypically high or low starting values.

Table 2-2: Estimation parameters for the development of the private home construction

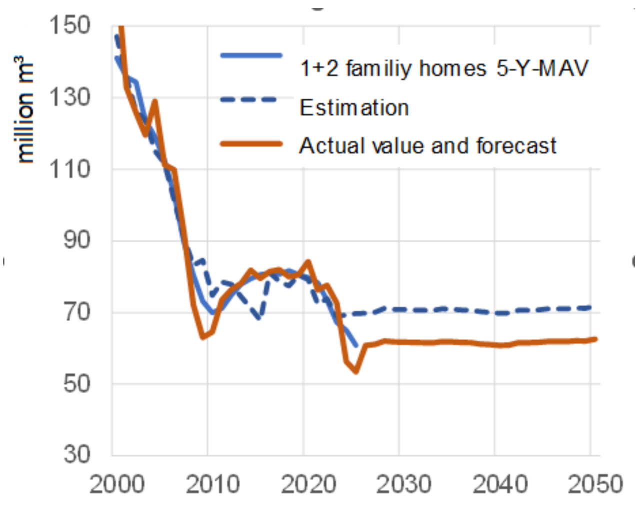
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	15971	5323.74097	62.51	<.0001
Error	22	1873.51989	85.15999		
Corrected Total	25	17845			

Root MSE	9.22822	R-Square	0.8950
Dependent Mean	89.18842	Adj R-Sq	0.8807
Coeff Var	10.34688		

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	-612.28865	99.91453	-6.13	<.0001
HHDH3MAN	3 und mehr Pers. HH #	1	0.03334	0.00636	5.25	<.0001
VDIB00AN	Bauinvestitionen #	1	0.39543	0.10748	3.68	0.0013
VDVPANAN	% Privater Verbrauch #	1	4.47613	2.36240	1.89	0.0713

Source: Mantau 2025

Figure 2-7: Comparison of previous development, 5-year MAV and scenario



Source: Mantau 2025

Different variances

Another problem in estimating long-term scenarios is that the past is characterised by strong annual fluctuations, while long-term exogenous variables tend to have a smooth curve shape. A five-year moving average of the data on construction market developments was used to extrapolate the current values. The rate of change of the estimated variables was then applied to the last smoothed value (2023).

The following Table 2-2 and the Figure 2-6 illustrate the approach using the example of the development of enclosed space in private home construction. The approach is not theoretically mandatory, but rather a question of plausibility and proven effectiveness in application.

2.6 Future challenges

Lack of data in the finished goods sector

Empirical studies on raw material input in the sectors of finished products construction and furniture are already available. For the packaging sector, final theses written under the supervision of the author (Konsemöller 2016, Peters 2015) were used. As part of the FNR project "Wood utilisation indicators for analysing the bioeconomy and circular economy along the entire value-added chain" (2223HV004X Lignum Quo Vadis, LQV), other significant sectors of finished products are being analysed in terms of their quantity and raw material composition. Wood as a feedstock has a high market penetration, ranging from toys to coffins. A complete survey is difficult, but the currently determined delta (15.7 million m^3_{hwe} of just under 30% between the finished and semi-finished products sectors can still be significantly reduced.

3. Framework conditions

3.1 Demographics

Population

Data

In December 2022, the Federal Statistical Office presented its 15th population forecast with new data on population development.

"The new census was conducted on 15 May 2022. The 2022 census provides a new basis for updating population figures. The previous population figures based on the 2011 census will be gradually replaced. The demographic indicators, including birth rates and life expectancy, are expected to be enclosed to the new basis by mid-2025. On this basis, the 16th coordinated population projection will then be carried out as scheduled and is expected to be published in the fourth quarter of 2025." (Federal Statistical Office 2024)

"According to the results of the 2022 census now available, around 82.7 million people were living in Germany on 15 May 2022. Compared to the previously valid population figures from the official population register, this means that on the census reference date, there were around 1.4 million fewer inhabitants in Germany than assumed in the 15th coordinated population projection." (Federal Statistical Office, Census 2022)

This represents a significant change in an important data basis for long-term forecasts. The data will be provisionally adjusted as part of the project. Since the Federal Statistical Office presents the reporting errors as data breaks in the survey year (-1.4 million inhabitants in 2022), the data do not adequately reflect the actual development. In our own calculations, the survey errors for 2011 and 2022 were distributed linearly between the survey years. Actual fluctuations, such as immigration in 2015, remain unchanged in the modelling.

Population

Drivers

The population forecast should not be understood as a prediction, but rather as an attempt to illustrate the effects of the various driving factors. The assumptions made in the last 14th forecast are shown in brackets. The influencing factors are listed in the following table:

1 *Birth rate*: This is currently stabilising at 1.55 (1.55) children per woman aged between 25 and 45.

2. *Life expectancy*: This is calculated at the time of birth. It has more than doubled for both sexes since the end of the 19th century. It is 88.2 (88.1) years for women and 84.6 (84.4) years for men.

3. *Migration*: With regard to the further development of migration, an average net migration of 290,000 (221,000) is assumed.

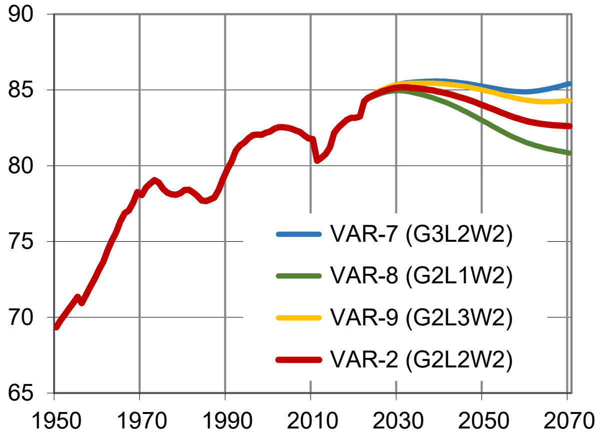
There are upper and lower values for each of the above assumptions. These are shown in the following Table 3-1 . The different assumptions regarding the above influencing factors result in 27 variants, which have been supplemented by a number of theoretical variants. With a few exceptions, the following table shows the theoretically possible developments.

Table 3-1: Influencing factors of population development and assumptions of the scenario

F=Women M=Men	Life expectancy 2070 L1 - F 86,1 M 82,6 L2 - F 88,2 M 84,6 L3 - F 90,1 M 86,4	Average values		
Net migration		Decrease 1,40 (G1)	Constant 1,55 (G1)	Increase 1,70 (G1)
Annual 180,000 W1	L1	G1-L1-W1	G2-L1-W1	G3-L1-W1
Annual 290,000 W2	L1	G1-L1-W2	**G2-L1-W2**	G3-L1-W2
Annual 400,000 W3	L1	G1-L1-W3	G2-L1-W3	G3-L1-W3
Annual 180,000 W1	L2	G1-L2-W1	G2-L2-W1	G3-L2-W1
Annual 290,000 W2	L2	**G1-L2-W2**	**G2-L2-W2**	**G3-L2-W2**
Annual 400,000 W3	L2	G1-L2-W3	G2-L2-W3	G3-L2-W3
Annually 180,000 W1	L3	G1-L3-W1	G2-L3-W1	G3-L3-W1
Annual 290,000 W2	L3	G1-L3-W2	**G2-L3-W2**	G3-L3-W2
Annual 400,000 W3	L3	G1-L3-W3	G2-L3-W3	G3-L3-W3

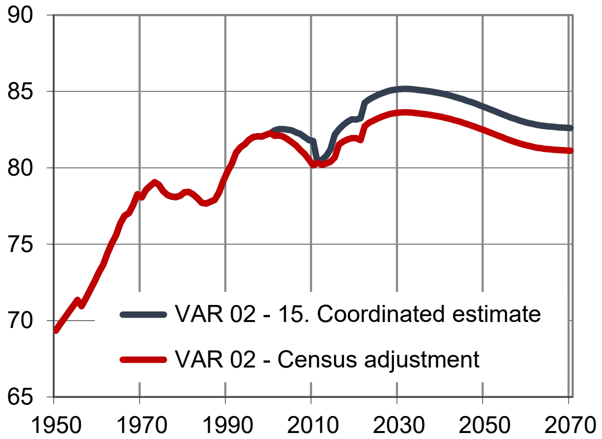
Source: Federal Statistical Office (2022) 15th Coordinated Population Forecast

Figure 3-1: Population development and variants of the forecast



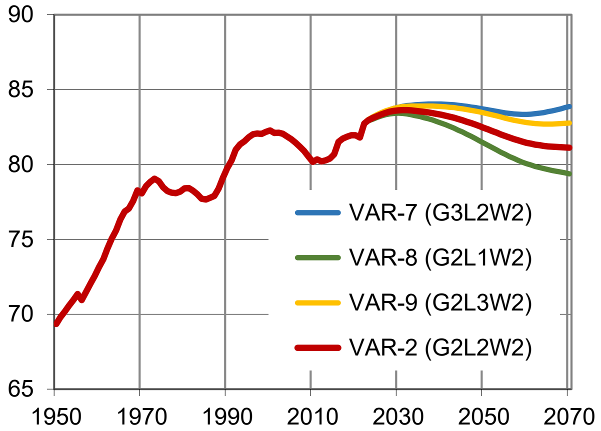
Source: Heinze Marktforschung (2023) according to the 15th Coordinated Population Forecast

Figure 3-2: Comparison of variant 02 according to the 15th population forecast and census adjustment in millions of persons



Source: Federal Statistical Office (2022) 15th coordinated population forecast

Figure 3-3: Population development of selected variants in millions of persons according to census adjustment



Source: INFRO calculations based on the 2022 census Heinze Market Research (2023) and according to 15th coordinated population forecast (2022)

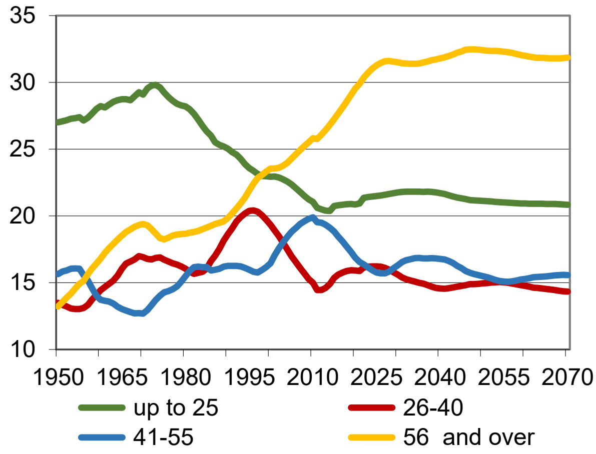
Variants

The following figures are based on the medium scenario (G2-L2-W2). According to this scenario, the population will rise from 81.9 million in 2020 to 83.5 million in 2035, before falling back to 81.1 million by 2070. Figure 3-1 shows the range of the selected variants.

Age groups

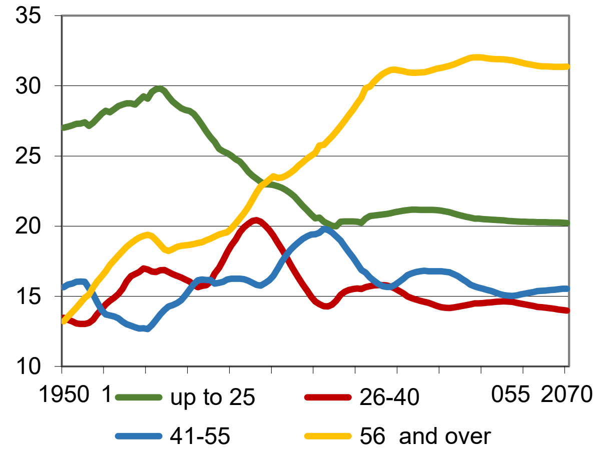
The development by age group can be summarised in groups according to their activity in the construction sector. This classification is also relevant for demand in other areas. Based on construction activities, a classification is made into the categories of young builders (up to 25 years), nest builders (26–40 years), prosperity builders (41–55 years) and retirement builders (aged 56 and above). For the analysis of long-term scenarios, those drivers that are based on empirical findings and are capable of explaining existing fluctuations are particularly relevant.

Figure 3-4: Population development in Germany (in millions) by age group (15th population forecast)



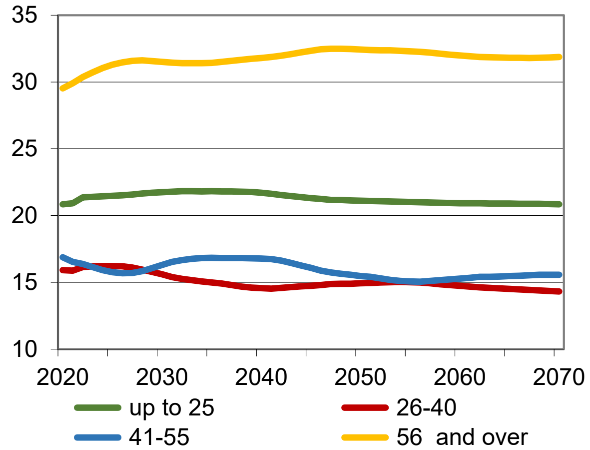
Source: Heinze Marktforschung (2023) according to the 15th coordinated population forecast (2022)

Figure 3-5: Population development in Germany (in millions) by age group after census adjustment



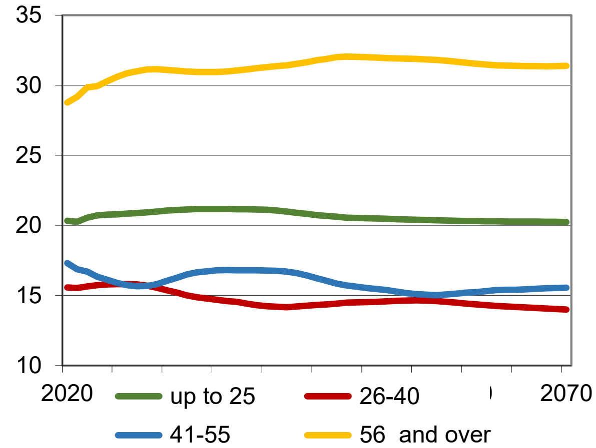
Source: INFRO calculations based on the 2022 census Heinze Marktforschung (2023) and according to 15th Coordinated Population Forecast (2022)

Figure 3-6: Population development in Germany (in millions) by age group (15th population forecast) for the period 2022–2060 in the scenario



Source: Heinze Marktforschung (2023) according to the 15th coordinated population forecast (2022)

Figure 3-7: Population development in Germany (in millions) by age group (15th population forecast) for the scenario period after census adjustment



Source: INFRO calculations based on the 2022 census Heinze Marktforschung (2023) and according to 15th Coordinated Population Forecast (2022)

Households

Data

The latest household projections from the Federal Statistical Office from 2020, which continue the household data until 2040, form the basis for the forecasts (Federal Statistical Office 2020). The household projection is based on the 14th population projection and assumed household sizes. To derive drivers of demand in the wood use sectors in the longer term, the 15th population projection was used after adjustment to the results of the 2022 census. Within the trend variant, the average household size is expected to fall from 1.996 persons per household in 2020 to 1.990 persons per household by 2040. As no new household forecast is available and this does not extend as far as the population forecast, a projection model is also being developed for households.

The underlying assumption is that the trend in household size in the last decade of the forecast (2031-2040) will continue until 2070. Accordingly, there would be an annual reduction in household size of 0.001967 persons by 2070, which would correspond to 1.931 persons per household in 2070.

The distribution of household sizes in 2040 was used as the basis for the forecast (household projection for 2020). For the projection, the annual rate of change in the proportions between 2031 and 2040 was extrapolated to 2050. In the period from 2051 to 2060, this rate of change was halved, and in the period from 2061 to 2070, it was quartered. Based on this assumption, annual growth in the share of single-person households is forecast at 0.176%, 0.088% and finally 0.044% until 2050. According to calculations by the Federal Statistical Office, the proportion of single-person households will be 45.3% in 2040 and, according to assumptions, will rise to 48.3% by 2070. Corresponding assumptions have been made for the other household size categories. Figure illustrates the resulting development of household size categories.

Housing behaviour

Heinze Market Research regularly conducts studies on modernisation activities in private households. Statistical characteristics include household size and type of dwelling. The Figure 3-9 shows housing behaviour by household size in percent by owner-occupied and rented households in one- and two-family homes and multi-family homes for the year 2023.

2022 census

With the lower population, the number of households is also falling. According to the last household projection, the figure was 41.935 million, but the 2022 census shows 40.236 million households. This means that the population was overestimated by 1.4 million people in the projection, and the number of households was overestimated even more, by 1.6 million.

The adjustment was made in the following steps:

1. The values of the 2020 household projection will be retained until 2020.
2. The household size between 2021 and 2040 will be determined using the ratio of the 15th population projection and the 2020 household projection and then updated with a reduced change in share (see above).
3. From 2041 onwards, it is assumed that the number of persons per household (2040= 1.9904) will develop in line with the average annual change between 2030 and 2040 (-0.001967).
4. Finally, the number of households is calculated using the population development adjusted according to the 2022 census and the extrapolated household size, in accordance with steps 1-3.

Figure 3-8: Household development in Germany by household size (Census adjustment) in million households

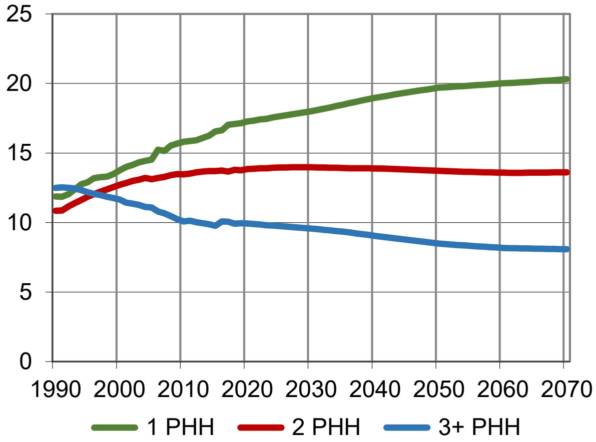
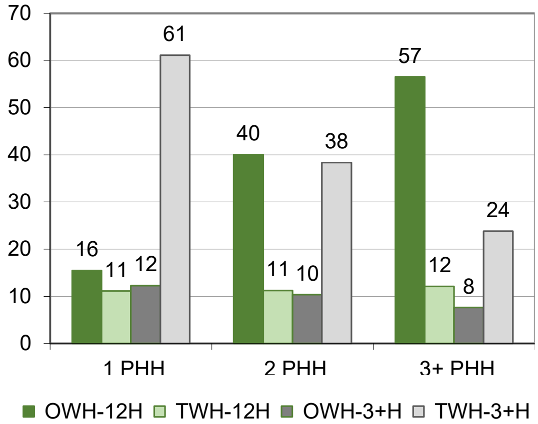


Figure 3-9: Housing behaviour by household size as a percentage of the respective groups



PHH = private households with 1, 2 and 3 or more persons; TOH-12H = owner of private home; TOH-12H = private home tenant; OWH-3+H = owner of a flat in multi-family home; TWH-3+H = tenant in a multi-family home.

Source: Federal Statistical Office until 2040. From 2041 onwards, own calculations.

Source: Heinze Market Research: Medium-term forecast for 2023

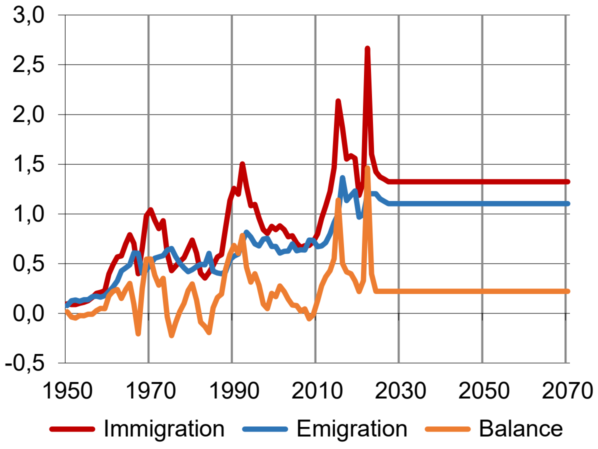
Migration

Data

Net migration represents the difference between inward migration and outward migration. A distinction is made between internal migration and external migration. In terms of a country's population development, external migration (balance in 2023: +663,000 persons (2022: +1,462,089 persons) is relevant. Population development is also influenced by natural migration (balance in 2022: -335,217 persons), which represents the balance between births and deaths. Despite rising birth rates, the natural migration balance continues to decline as the number of deaths increases more sharply. The sum of these figures gives a net change in population of 327,783 people in 2023 (balance in 2022: +1,134,567). This means that the population in Germany in 2023 will have grown by approximately 800,000 fewer people than in the previous year. (Federal Statistical Office 2024a)

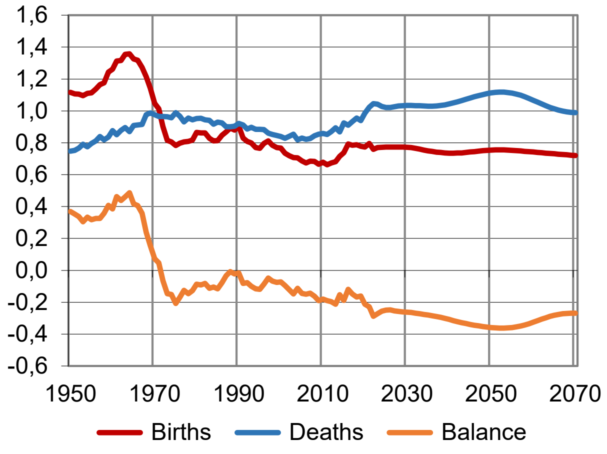
Migration trends from 2022 onwards are in line with the data from the 15th coordinated population forecast. External migration is assumed to remain constant. Historical analysis shows that fluctuations in the past were difficult to predict. In this study, variant 02 with 290,000 net immigrants is used as a basis. These data therefore show no variance for future scenarios. Natural population development, on the other hand, is characterised by a certain degree of variability, as it relates to developments in fertility and mortality.

Figure 3-10: External migration in millions of persons



Source: Federal Statistical Office, Genesis until 2022. 15th coordinated population projection, variant 02 until 2070.

Figure 3-11: Natural migration movements in millions of persons



Source: Federal Statistical Office, Genesis until 2022. 15th coordinated population projection, variant 02 until 2070.

Employment

Definitions

The **labour force**, also referred to as the "labour supply", represents the total number of employed and unemployed persons. The group of **economically inactive persons** represents the difference between the population and the number of economically active persons. **Employed persons** are persons aged 20 and over who, during the reference period (at least 1 hour/week), are engaged in any kind of professional activity for pay or other remuneration. Unemployed persons are persons without gainful employment. The **unemployment rate** is the proportion of unemployed persons in the labour force (labour supply). The **registered unemployment rate** represents the proportion of registered unemployed persons in the labour force. The registered unemployment rate is usually higher than the unemployment rate, as persons who are not in employment can also register as unemployed.

Data sources and updating

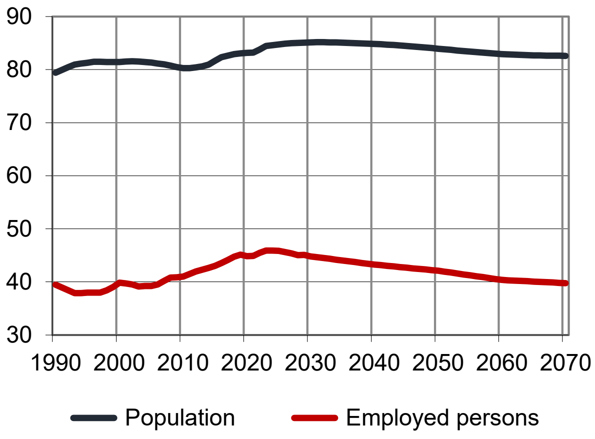
The development of employment is based on the national accounts of the Federal Statistical Office (2024b). The following values, which are related in terms of definition, are reported: Population - persons not in employment = potential employment - Unemployed = employed (domestic) - Self-employed = employees (domestic) + commuter balance = employees (domestic) + self-employed = employed (domestic). Here, too, the challenge of updating the data for a longer scenario arises.

The latest forecast by the Federal Statistical Office on the working population dates from 2020 and is based on the 14th coordinated population forecast (Federal Statistical Office 2019). First, an adjustment was made to the 15th coordinated population forecast regarding the ratio of population to working population. The unemployment rate was assumed to be 3.0% and the unemployment rate 5.3%. Furthermore, the number of self-employed persons (4.0 million) and the net commuter balance (139,000 persons) were assumed to remain largely constant in relation to the total number of persons in employment. The data on employment were updated on the basis of the assumptions on population development (see above) made by the Federal Statistical Office.

Census adjustment

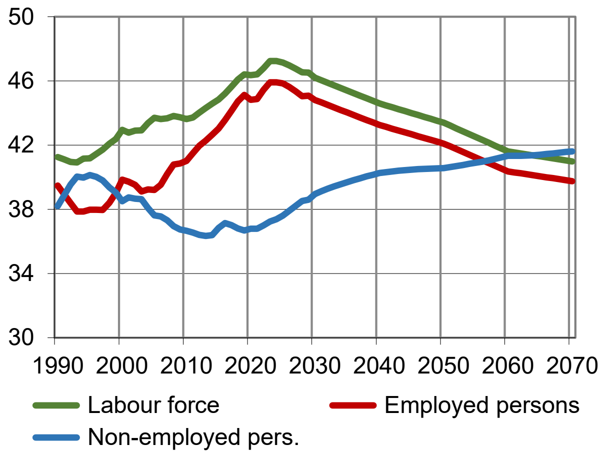
Until 2023, the data was taken from the segment mentioned (GENESIS 81000-0011). The update is based on the labour force. Starting in 2023, it is assumed that they will develop in line with the rate of change for 21–65-year-olds. Due to the definitional relationship, the other values are derived accordingly.

Figure 3-12: Comparison between population and employment in millions of persons



Source: Federal Statistical Office, Genesis 810000 to 2022. 14th coordinated population update and own calculations.

Figure 3-13: Persons of working age, employed persons and persons not in employment in millions



Source: Federal Statistical Office, Genesis 810000 to 2022. 14. Coordinated population projections and own calculations.

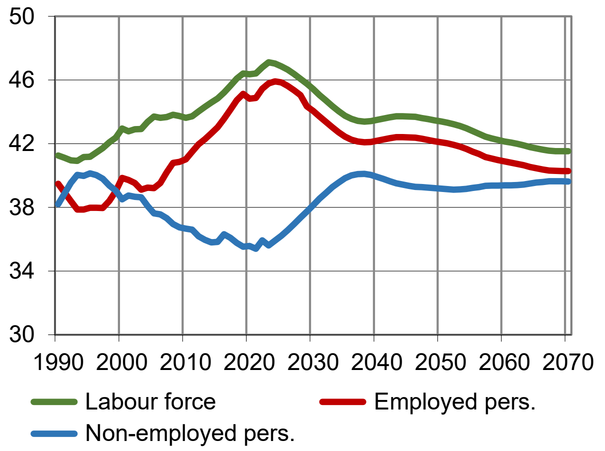
Deviations due to census adjustments

The figures up to 2023 are the same, as they were determined using national accounts rather than population calculations. The previous calculation (Figure 3-12) was based on a trend projection. The current calculation (Figure 3-13) follows the development of the working population, for which persons aged between 21 and 65 years are used as the development indicator. The moderate upturn between 2040 and 2050 is due to the development of the corresponding population groups (see Figure 3-5). The development of the working population is not linear. The number of non-working persons is calculated by subtracting the working population from the total population.

Development

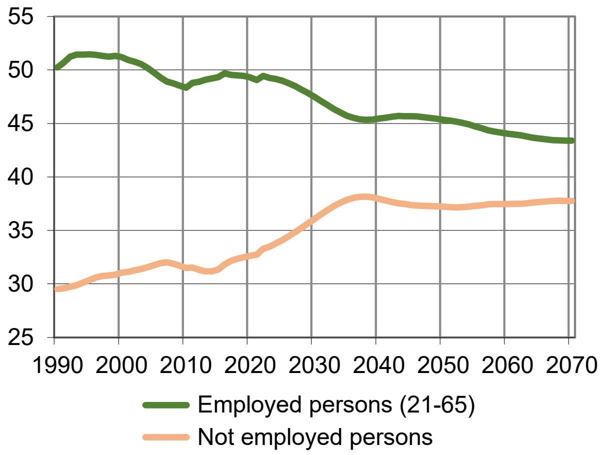
Since 2000, the number of people in employment has risen from 39.8 million to 45.8 million in 2023. It has thus largely reached its peak (2024: 45.9 million persons). Unemployment stood at 5.7 % in 2023. From 2025 onwards, it is expected to remain constant at 5.3 %. From 2026 onwards, a long-term decline will set in, assuming a constant working life. By the end of 2070, the number of people in employment will tend towards 40.0 million.

Figure 3-14: Population and employed persons in millions according to census adjustment



Source: Federal Statistical Office, Genesis 810000 to 2022. 14th coordinated population update and own calculations.

Figure 3-15: Indicator of employment (21-65) and economically inactive persons in millions according to census adjustment



Source: Federal Statistical Office, Genesis 810000 to 2022. 14. Coordinated population statistics and own calcations.

3.2 Economic framework conditions

Limitations of the forecast of economic developments

Forecasts about economic development usually refer to the current year and the following year. Medium-term forecasts, on the other hand, cover a period of five years. Within this time frame, economic institutes also present the economic sectors (private and government consumption, investment, foreign trade). However, from the third year onwards, the forecasts shift to potential growth. From the fifth year onwards, only scenarios for gross domestic product (GDP) derived from production potential are available.

Definition of production potential

The potential of an economy to produce goods is made up of the available production factors (labour, capital, land). The term land is used in the sense of environment and resources. There are various concepts and calculation methods, but in simple terms, production potential describes the possible growth of an economy under normal utilisation of production factors. In addition to the absolute availability of production factors, productivity, i.e. the knowledge or efficiency of their use, also plays a role. GDP growth fluctuates around production potential depending on the economic situation.

Data

The data published by the Federal Statistical Office for the national accounts up to 2022 were used for the present calculations (see

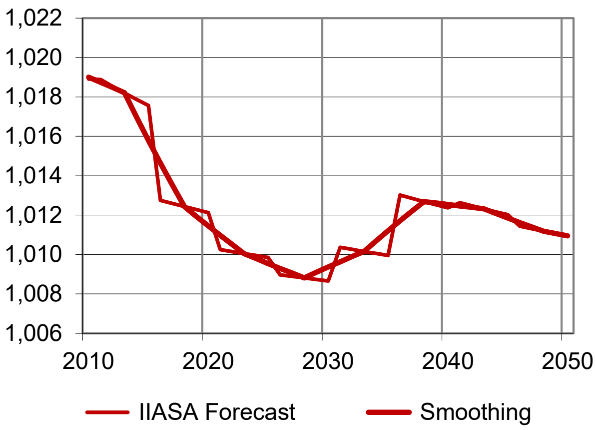
Federal Statistical Office 2023). For the first forecast period, the medium-term projection of the Kiel Institute for the World Economy (IfW 2023) dated 15 September 2023 was used. This extends to 2027. For the following period up to 2050, the IIASA SSP database (2018) was used as a basis.

Adjustment of SSP-IIASA

The IIASA data is adjusted using the following calculation steps:

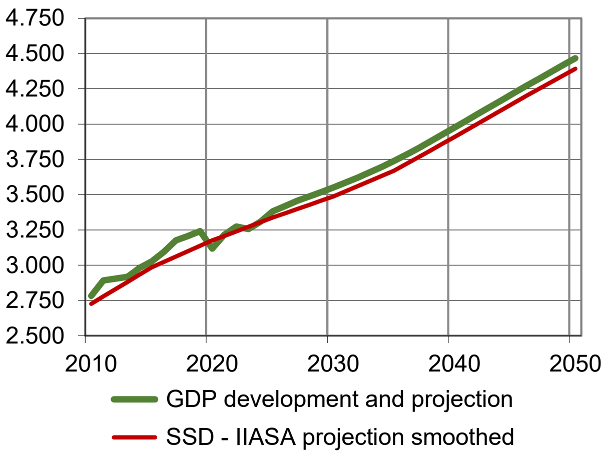
1. The starting point is the last forecast year (2027).
2. The jumps in the IIASA GDP projections are due to calculation methods and do not reflect economic developments. They are smoothed using a five-year average.
3. The initial value (2027) is extrapolated using the smoothed rate of change in the IIASA GDP projections. The absolute initial value is slightly higher in the latest forecast values, which is why the projection is correspondingly higher than the IIASA values.
4. Assumptions are made for the development of the share of economic sectors in GDP.

Figure 3-16: GDP scenario according to SSP-IIASA and moving 5-year average (extrapolation factor)



Source: IIASA SSP Database (Shared Socioeconomic Pathways) – Version 2.0 (https://tntcat.iiasa.ac.at/SspDb)

Figure 3-17: GDP scenario according to SSP-IIASA and moving 5-year average (in billion euros)



Source: IIASA, SSP Database (Shared Socioeconomic Pathways) – Version 2.0. Federal Statistical Office FS 18 R4.1. Kiel Institute for the World Economy (IfW). 2022 No. 96. Own calculations, INFRO. 3-18

Development of economic sectors

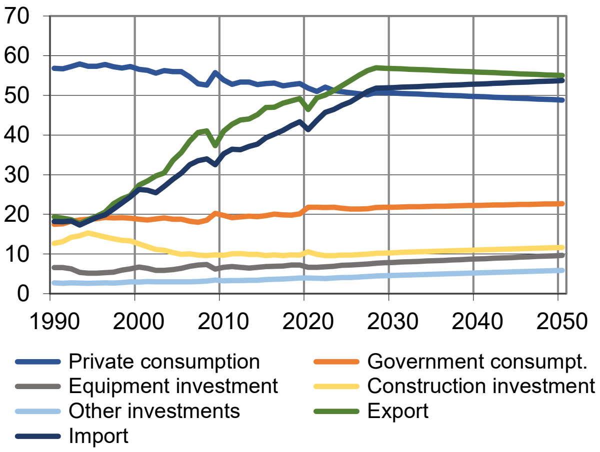
The following assumptions are made for the shares of the sectors of gross domestic product (GDP) for the period from 2027 to 2050 in total (Figure 3-18): Private consumption (-2.0); government consumption (+1.0); equipment investment (-2.0); construction investment (+ 1.5); other investment (+1.5); exports (-2.0); imports (+2.0). This development assumes that private consumption will continue to decline in line with the trend. Foreign trade will not gain further importance, and the export surplus will decline. The challenges of the future favour government spending and investment. Real monetary values will rise in all areas (Figure 3-19) in line with GDP growth. Relative changes therefore often prove to be more realistic estimates.

Based on these assumptions, a more differentiated and consistent set of data for the scenarios was obtained from the development of GDP. In addition, smoothing the theoretical stages proves to be advantageous, as they reveal breaks in timber industry developments that have no factual basis.

Estimation problems with monetary variables

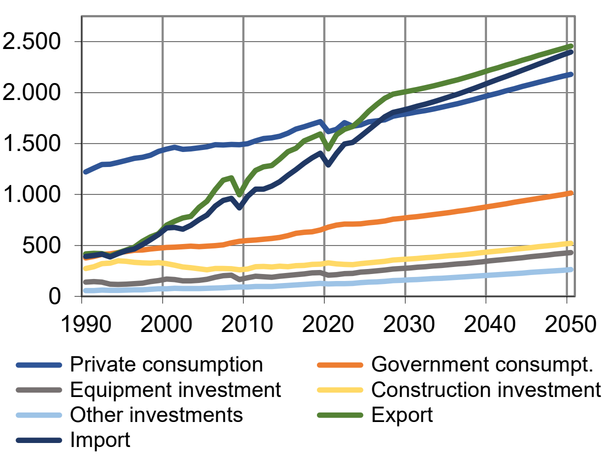
Monetary developments involve price changes. For this reason, they are only of limited use for estimating real developments. The problem can be mitigated primarily by using price-adjusted data (real data). Nevertheless, it should be noted that this does not guarantee that the problem will be completely neutralised. Price-adjusted developments may contain components that are decoupled from raw material use. These include shifts between sectors, for example from the construction sector to the service sector, and productivity gains. Assuming that productivity gains are achieved, an increase in GDP can be achieved while reducing raw material consumption.

Figure 3-18: Development of economic sectors (share of GDP in %)



Source: Own calculations based on IIASA SSP (2018), Federal Statistical Office (2024b) and IfW (2023).

Figure 3-19: Development of economic sectors in billion euros (real)



Source: Own calculations based on IIASA SSP (2018), Federal Statistical Office (2024b) and IfW (2023).

3.3 Specific framework data

Service life

The service life of building components is assessed according to the Sustainable Building Assessment System (BBSR 2017) for an average service life of 50 years. These are adjusted by correction factors depending on the product group and are generally shortened (Bahr/Lennerts 2010). Comparing these estimates with the housing stock reveals contradictions.

Housing stock

The housing stock grew steadily from 30.1 million residential units in 1980 to 38.4 million residential units in 2000, reaching 41.1 million residential units by 2022 (2022 census). The demolition rate, defined as the proportion of demolitions in the total stock, reached only 0.100% in the post-reunification period of the 1990s and is currently below 0.050%. In absolute terms, approximately 20,000 residential units have been demolished per year in recent years.

If the construction of buildings and flats were to be dismantled every 50 to 70 years, the housing stock would currently have to be reduced and not further expanded. The demolition rate would be around 0.650% or approximately 300,000 residential units per year. In fact, it is not even a tenth of this figure.

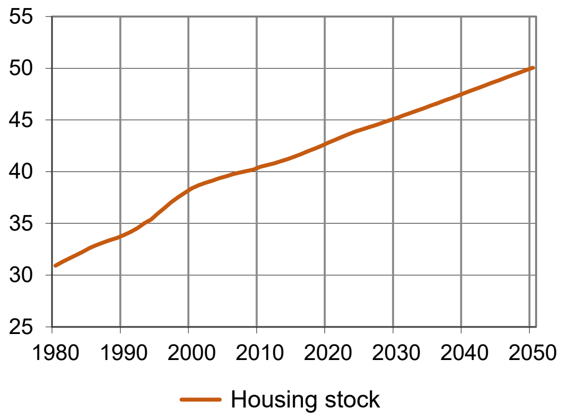
Even if we consider not only the demolition of entire buildings but also the renovation and modernisation of buildings, the assumed service life appears low. Gross fixed assets at replacement prices in residential construction amounted to €13,110 billion in 2022 (Stat. BA). The modernisation volume in residential construction amounted to €147.1 billion in real terms in 2022 (DIW). This corresponds to a modernisation rate of 1.1%. According to this, the existing stock would be completely renovated in 91 years. Taking into account the modernisation volume at current prices (€213.7 billion, DIW), this results in a renewal period of 61 years.

It cannot be deduced from this whether this refers to heating systems or roof trusses. However, there are indications that the service life of structural components of a building is longer than that of typical modernisation products (walls, ceilings, heating). The basis for calculating service life proves to be inaccurate for wood products in building structures, especially for timber construction methods where wood is the main construction material. This hypothesis is supported by the amount of waste wood, which should be significantly higher with such short cycles.

Housing stock

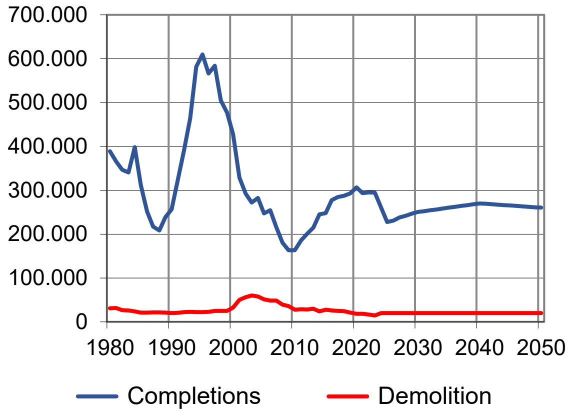
The housing stock was calculated based on completions and a constant demolition rate of 0.048%. This means that the housing stock is growing steadily, and with it the wood storage in the housing stock.

Figure 3-20: Development of the housing stock in million dwellings



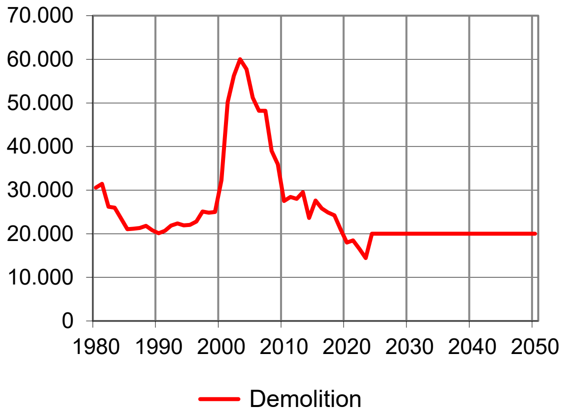
Source: Federal Statistical Office until 2021 and own calculations.

Figure 3-21: Number of dwellings completed (inflow) and demolished (outflow)



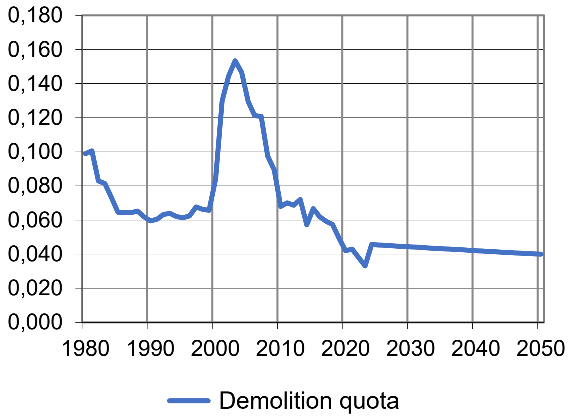
Source: Federal Statistical Office until 2021 and own calculations
Check completions

Figure 3-22: Housing departures in number of dwellings



Source: Federal Statistical Office until 2021 and own calculations.

Figure 3-23: Outflow rate (number of outflows / stock)



Source: Federal Statistical Office until 2021 and own calculations

Completions offset by 65 years

The following Figure 3-24 shows the number of completions since 1950. The Figure 3-25 shows current completions and completions offset by 65 years. Even if the correlation is smoothed out and some of the buildings are excluded due to complete modernisation, there remains a huge contradiction between the assumed service life (50 to 70 years) and the actual outflows or the amount of waste wood generated.

Figure 3-24: Number of completed dwellings since 1950

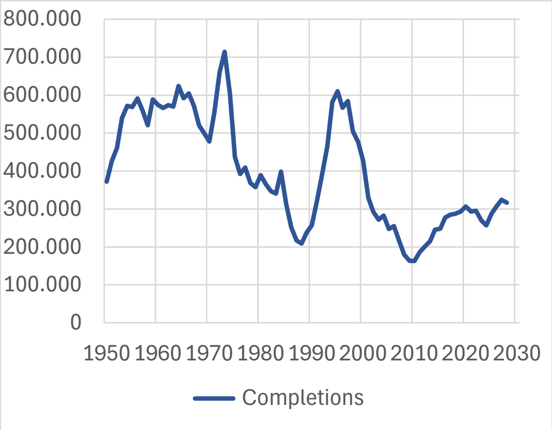
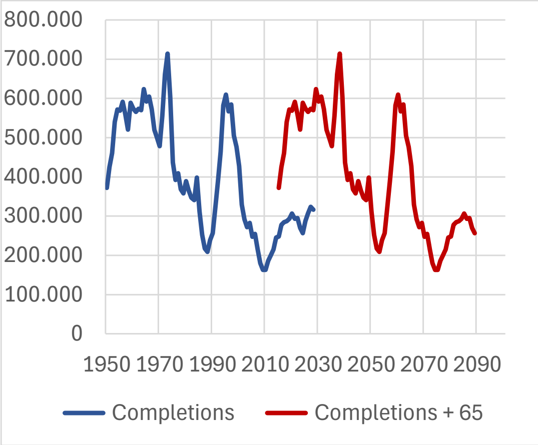


Figure 3-25: Completions offset by 65 years



It is likely that not only the product lifetime is underestimated in most THG-models but also the type of renovation required. Removing old rafters is often too costly. New rafters are added and take over the structural stability. The old ones remain in the wood product storage. A similar procedure is likely to be followed for floors and other components. There are many indications that the service life of the products is significantly longer and far exceeds the assumed observation periods. The TRAW's cycle modelling shows a clear cumulative increase in wood product storage (see chapter 6.6).

Discrepancy between households and housing stock

The housing stock can only be reduced if the number of completions falls below the number of dwellings demolished. There are no indications that the demolition rate is significantly underestimated. In principle, the demolition of a building is subject to approval. The number of authorised demolitions is around one tenth of completions.

3.4 Monetary framework

Limited usability

Monetary conditions include interest rates, loans, costs and prices. They govern the short-term relationships between the players involved. Long-term forecasts of these factors are speculative and can lead to opaque manipulation rather than generating new insights. In addition, the causal relationships are multi-causal, extend far beyond the timber market and are therefore largely unknown. The problem with using gross domestic product data as a driver highlights the limitations.

Even in the rudimentary market structures of previous models, the availability of adequate prices was a problem. It is not possible to make projections regarding the use of wood without taking all these factors into account. Prices contain far more signals of scarcity than those of the timber market. Price elasticities are also volatile and not static. The short-term causal and theoretical relationships are undisputed. Prices have a major, but not sole, influence on the decisions of market participants. However, long-term projections are both theoretically impossible and practically fictitious.

The problem of using gross domestic product data as a driver highlights the issue. Even if they result from the model, they remain stuck in historical elasticities. Monetary variables are not used in this paper.

Even in the simple market structures of previous models, the availability of adequate prices was a problem. In a circular economy model, there is also a lack of statistical basis for the multitude of prices, especially in the sectors of finished products. Nevertheless, the optimisation problem remains due to shortages. This was not necessary for the gap projection undertaken here. Only for the following model version are there considerations to derive scarcity indicators based on inherent quantity developments.

4. Material wood use

4.1 Construction

4.1.1 Structure of the scenarios and usage indicators

Type of scenarios

In the baseline scenario, developments in the sectors of finished products are derived in a regressive form on the basis of the framework conditions described above. If developments within a sector diverge, sub-sectors may be formed.

For the construction sector, a second scenario (wood construction scenario) is calculated with a share of wooden buildings that exceeds the current level by at least 25%. With regard to Figure 2-2 ‘Structure of the TRAW model (calculation steps)’, step 2 ‘Scenarios for the sectors of finished products (m³pwe)’ is expanded to include an additional step in which the share of wooden buildings is increased. Otherwise, the model remains unchanged.

Due to limited volume effects, the wood construction scenario is assumed for later simulations and for data transfer for forest timber modelling and GHG calculations.

Technical coefficients, such as shares of input mix in products, offcuts and efficiency, are extrapolated from 2020 levels to 2050. Sensitivity analyses are used to examine the effects of changes in technical coefficients on wood use.

4.1.2 Construction activity statistics and construction volume

Definition

Segments

The following sub-segments are used to determine wood use in the construction sector:

New

- One- and two-Family Homes (EGH; 1+2 dwellings)
- Multi-Family Dwellings (MFD; 3+ dwellings)
- Industrial Buildings
- Residential-Type Commercial Buildings
- Agricultural Buildings

Remodelling (construction work on existing buildings)

- Residential Construction
- Non-Residential Construction

Civil Engineering

Definition

New construction

The extrapolation basis for new construction measures is determined in accordance with the reports on construction activity statistics on the basis of the enclosed space (Federal Statistical Office 2022b).

Definition

remodelling

The Federal Statistical Office records "construction measures on existing buildings". These only cover the part of the construction activities in the building stock that require a permit. Most renovations and modernisations do not require a permit.

The term "modernisation" has become established as a short form for all "construction measures on existing buildings". This includes measures such as flooring and painting work, which do not require a permit, as well as the term "renovation".

Data basis for construction volume

The basis for extrapolation for the areas of remodelling and civil engineering is the construction volume calculation of the German Institute for Economic Research (BBSR 2023). The construction volume calculation of the DIW Institute (Gornig/Michelsen/Révész, 2023) is based on statistics from the construction industry and other economic sectors involved in construction. To determine the volume of remodelling, the estimated construction costs for new buildings are extrapolated from construction activity statistics. The difference between this and turnover is allocated to remodelling.

Civil engineering is included as a separate sector in the construction industry statistics. In this category, no distinction is made between new construction and modernisation, but only between commercial and public civil engineering.

Construction volume Problem of monetary values

The construction volume calculation shows nominal values and a chain index. The latter is used to show real developments. However, neither of these can be used directly to calculate wood use. No usage indicators can be related to the chain index, and the nominal construction volume would overestimate the material use by the price increases. Thus, the development of the real construction volume is formed from the nominal construction volume and the chain index.

Real values are also not without their problems. The basis changes at certain intervals, e.g. every 10 years. This also has an impact on the calculated value of the amount of wood per billion euros of real construction volume. Since the new basis usually has a higher index due to price increases (e.g. 2015=110; 2010=100), using the wood input factor from the base year 2010 would result in a ten percent higher calculated wood input. In other words, if the survey had been conducted at the current point in time, the wood input (m³/billion euro) would have been lower. In order to maintain the ratio of wood used to real construction volume in the base year, a corresponding reduction in wood use per billion construction volume is necessary. The survey was conducted in the base year 2010. Consequently, the wood use indicators must be adjusted accordingly when the index year for the construction volume calculation is changed to 2015.

$$m^3/\text{billion}€_{2015} = \text{Index } t_{2010} \ / \ \text{Index } t{+}1_{2015} \ * \ m^3/\text{billion}€_{2010}$$

The above explanations suggest that calculations based on nominal values are subject to greater uncertainty than calculations based on real variables such as the enclosed space in new buildings.

Development of new construction

Following strong growth in the 1990s, new residential construction activity declined between 2000 and 2010. Between 2010 and 2020, new residential construction experienced another moderate upturn, with very optimistic expectations for the period that followed. Capacity and material shortages led to significant price increases, which, together with the end of the zero interest rate phase, caused financing problems for many builders and deterred new construction demand. In 2023, the optimistic expectations faded. By contrast, the construction of new non-residential buildings remained largely stable. Figure 4- shows the development of enclosed space in new construction up to the current reporting year 2023.

Development of remodelling

Remodelling in residential construction experienced a sustained strong upturn until 2010. It then entered a phase of weakness. This was also a consequence of strong growth in new construction. Due to limited capacities, construction companies tend to choose the more attractive new construction contracts. The current slowdown, however, is a consequence of cost developments.

Modernisation measures in non-residential construction have slowed significantly over the last decade. This development is attributable to low economic growth and higher modernisation costs, which play a greater role in the commercial sector than among private decision-makers.

Gross fixed capital formation in non-residential construction also grew less than in residential construction due to depreciation, meaning that the stock is growing more slowly.

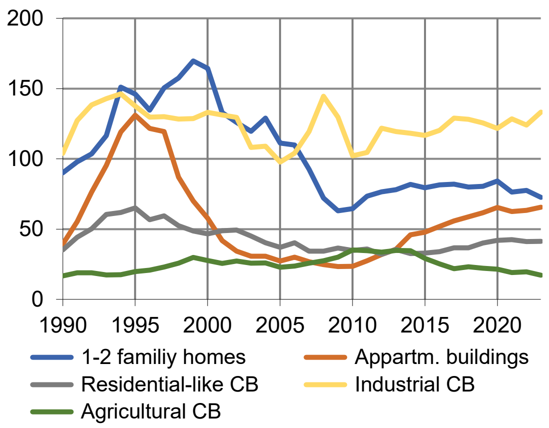
Civil engineering

Civil engineering is on a moderate upward trend due to the high demand for infrastructure measures.

Developments in construction volume

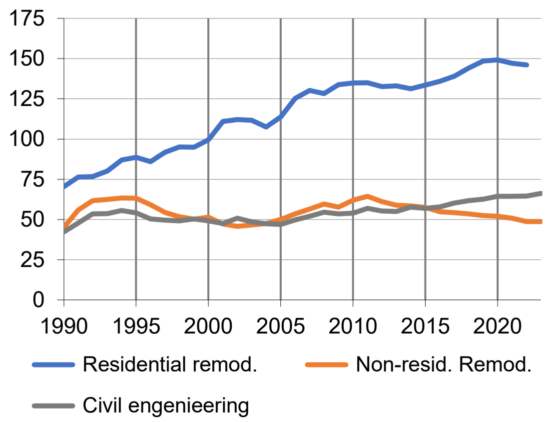
Figure 4-2 shows the real development of construction volume (2015 = 100) up to the current reporting year 2023 by the German Institute for Economic Research (BBSR 2023).

Figure 4-1: Development of new construction activity by building type in million m³ of enclosed space



CB = company building; Source: Federal Statistical Office, Statistics on Construction Completions (2022b)

Figure 4-2 : Developments in remodelling and civil engineering in billion euros of real construction volume (base 2015=100)



Source: BBSR 2023, DIW Weekly Report 2023

Development of the share of wooden buildings

Figure 4-3 shows the development of the share of wooden buildings in the building groups between 1990 and 2023. Figure 4-4 shows the share of buildings constructed predominantly from other materials. Market share gains for one- and two-family homes in timber construction are offset by market share losses for one- and two-family homes constructed from other materials. This also means that greater use of wood because of an increased share of wooden buildings does not lead to a corresponding increase in demand for wood, as wood is also used in the buildings of other materials that are displaced (e.g. roof trusses, doors, floor coverings), so that their share of wood is substituted.

Development of timber construction methods

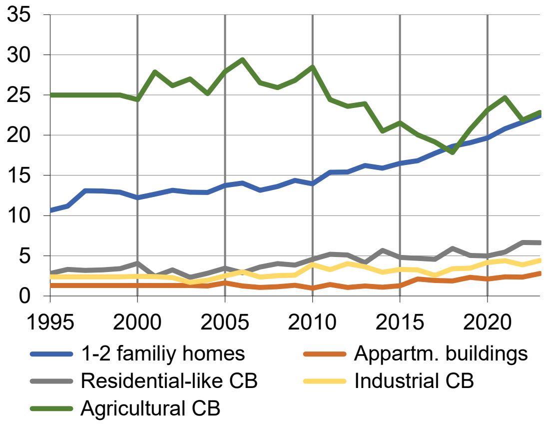
Traditionally, agricultural buildings accounted for the largest share of timber construction. Now, one- and two-family homes also account for 20 per cent or more of timber construction. In multi-family housing construction, the technical and legal framework for timber construction has improved over the last decade, but the share measured in terms of enclosed space has only risen slightly. In non-residential construction, apart from agricultural construction, timber construction has traditionally played a minor role. However, its share has increased over the last fifteen years.

Example

Multi-family houses

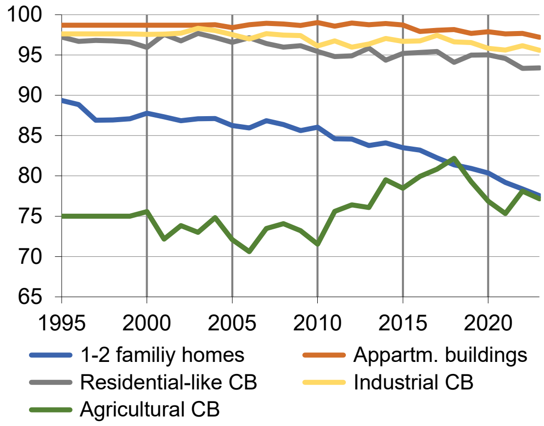
Published share values usually refer to approved buildings. The completed enclosed space is shown here. While the share of timber construction in completions for multi-family houses was 3.2 % in 2023, the share of timber construction in enclosed space was 2.1 %. The difference can be explained by the fact that multi-family houses built using timber construction have less enclosed space than buildings constructed using conventional methods.

Figure 4-3: Development of the share of wooden buildings as a percentage of completed enclosed space



Source: Federal Statistical Office 2022b. (WAS and NAS – tables)

Figure 4-4: Development of construction shares of other building materials as a percentage of completed floor space



Source: Federal Statistical Office 2022b. (WAS and NAS tables)

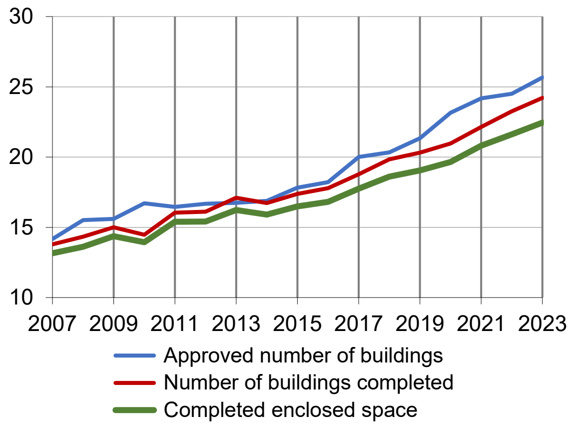
The share of wooden buildings varies greatly

In the press and in literature, the share of wooden buildings in building permits is usually used in relation to the number of buildings. The following figures show that this is not identical to the share of wooden buildings in terms of completed enclosed space. Discrepancies between approvals and completions indicate that lower completion rates are temporarily associated with longer construction times or, if the discrepancies persist, that a larger number of building permits have expired. This phenomenon is very pronounced in multi-family dwellings. Since 2020, the number of multi-family dwellings approved for timber construction is no longer a reliable indicator of the number of buildings constructed. In 2023, it was 2.4 times higher than the completed floor space.

The difference between the number of completed buildings and the completed enclosed space is due to differences in building sizes. The reasons for the differences between approvals and completions since

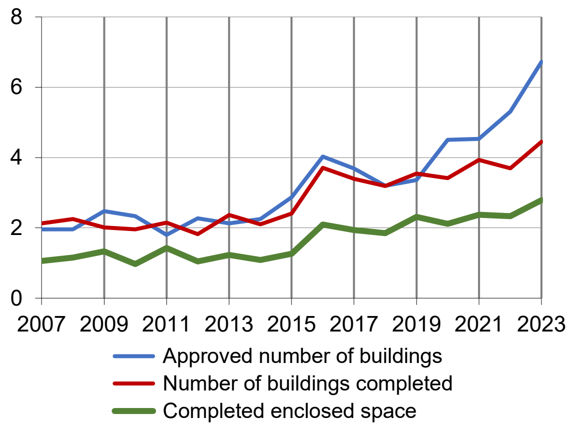
2020 are beyond the scope of this study. One possible explanation is that inhibiting factors (construction costs, supply bottlenecks, financing) have had a greater impact on timber construction than on multi-family dwellings constructed predominantly from other materials. For further calculations, the completed enclosed space is used as a basis, as this characteristic correlates more strongly with the actual use of timber.

Figure 4-5: Development of the share of wooden buildings in one and two family homes with different characteristics



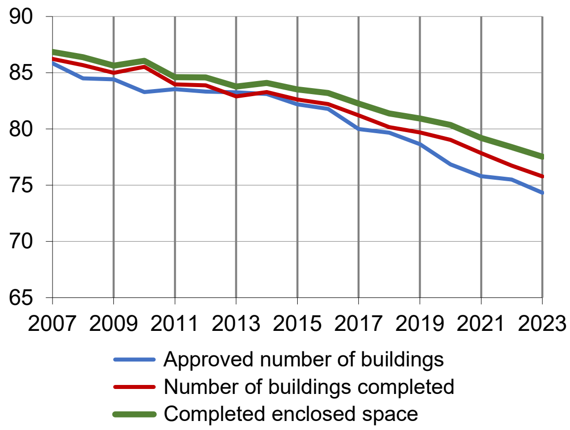
Source: Federal Statistical Office 2022b.

Figure 4-6: Development of the share of wooden buildings in multi-family houses with different characteristics



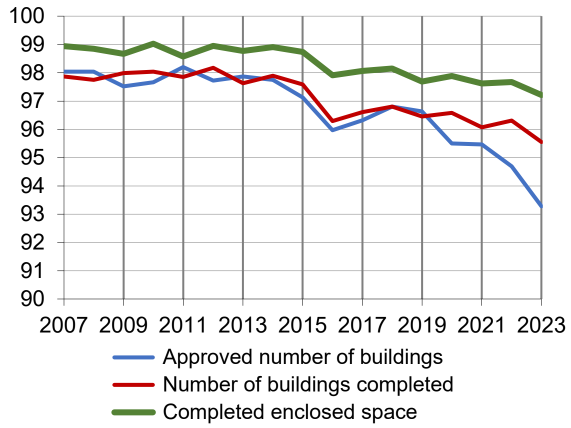
Source: Federal Statistical Office 2022b.

Figure 4-7: Development of the shares of other building materials in one and two family homes with different characteristics



Source: Federal Statistical Office 2022b.

Figure 4-8: Development of the share of other building materials in multi-family homes with various characteristics



Source: Federal Statistical Office 2022b.

4.1.3 Scenarios for the construction market and share of wooden buildings

Starting year and entry level

Economic developments in a national economy are generally volatile. Sectoral economic developments such as the timber market are subject to additional specific influencing factors that can further increase volatility. Therefore, the current year may randomly take on an extreme value as the starting value. In order to reduce the resulting uncertainty when selecting a starting value, a special procedure was developed (Section 2).

New building development

The completion volume for one- and two-family homes will remain at a high level in 2023 due to a high number of building permits issued. However, this volume is expected to decline significantly in 2024. The situation is likely to recover subsequently, although the level of the 2010s will not be reached again. The expected annual construction activity is around 80,000 dwellings (60 million m³ of enclosed space). The construction of multi-family dwellings will continue to be supported by high construction backlogs and housing demand. However, it will subsequently be increasingly influenced by demographic developments with declining household numbers. It will grow moderately to 190,000 completed dwellings (75 million m³ of enclosed space) and then decline slightly again. In summary, new residential construction will develop at a stable level of around 270,000 dwellings or 135 million m³ of enclosed space in the coming years.

Permits for newly constructed dwellings in existing buildings are allocated to the remodelling category. Dwellings in non-residential buildings are considered part of the building type. This classification is in line with the classification of the Federal Statistical Office, according to which the characteristics of a building are allocated to the predominant type of use. The classification according to predominant use corresponds to the recording system of a service specification. For example, the materials used in a building that also contains dwellings but is predominantly used for commercial purposes are allocated in full to the commercial buildings group.

Industrial buildings remain stable at a level of around 140 million m³ of enclosed space. Residential-type commercial buildings are declining from 41 million m³ to 36 million m³ of enclosed space. Agricultural construction is developing largely steadily from a very low level between 19.0 and 20.0 million m³ of enclosed space.

Remodelling and civil engineering development

As already mentioned, only monetary values are available for remodelling and civil engineering. Residential remodelling experienced a significant upswing in the post-reunification period between 1990 and 2010, with average annual real growth of +5.9 %. In the period between 2011 and 2023, the average annual growth rate was +0.6 %. For the scenarios (2024 to 2050), an annual growth rate of +1.0% is assumed. Measured against desired modernisation rates of two to three percent, the growth appears low. Higher financing and material costs mean that higher growth rates are unlikely. The estimates are based on demographic developments and changes in the importance of economic sectors.

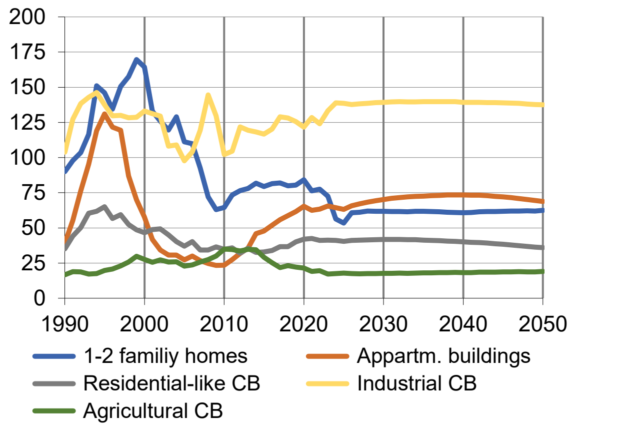
Analysis of the data shows that remodelling in non-residential construction recorded an average annual increase of +1.9 % in the first period under review. In the period between 2010 and 2023, however, an annual decline of -1.9 % was observed. The forecasts predict an annual real average growth rate of +0.8 % for the period up to 2050. The higher future growth is due to the low starting level and the high investment requirements.

In civil engineering, an annual real growth rate of +1.4 % was observed in the first period under review, falling to +1.2 % between 2010 and 2023. Continued growth of +1.4 % is forecast for the period up to 2050. The estimate is based on figures from the national accounts. The development can be explained by the backlog in infrastructure.

Scenarios for developments in the construction market

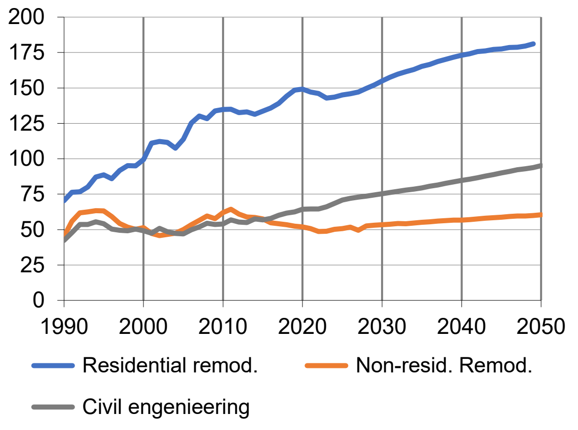
Figure 4-9 und Figure and figure present the economic development scenarios for the individual segments of the construction market. These form the economic basis for further calculations in the construction sector.

Figure 4-9: Development of new construction activity by building type in million m³ of enclosed space (1990-2050)



Source: Federal Statistical Office until 2023. Own extrapolation

Figure 4-10: Developments in remodelling and civil engineering in billion euros of real construction volume (2015=100)



Source: DIW weekly reports until 2023. Own extrapolation

Consideration of technical building equipment (TGA)

The calculations were not based on the total construction volume. The construction volume was reduced by the technical components (sanitary facilities, heating, electrical systems, lifts/stair lifts), as these were not included in the surveys. Studies by Heinze Marktforschung (2012) show that this share is 22.5 % in residential renovation and 33.5 % in non-residential remodelling. No comparable studies are available for civil engineering. A significantly lower share of technical equipment is assumed, estimated at 10.0 %.

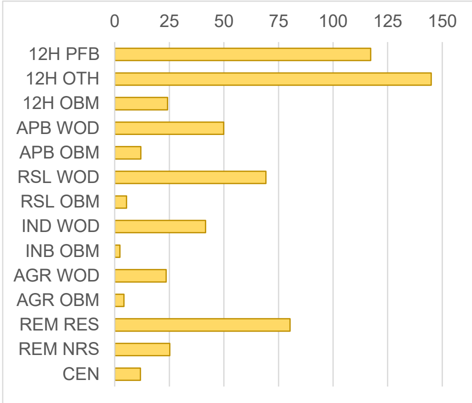
Key figures for wood use by sector

As part of the KlimaBau project, all wood-based components were recorded by type (e.g. sawn timber, particleboard, insulation boards) and the space they occupy in the building structure (m^3_{pwe}). The quantities do not yet include cutoffs from production (e.g. windows) and on the construction site (rafters). This can account for up to 50% of the wood used.

Table 4-1: Wood use by construction sector in m³(pwe) Wood products

Building type	Building material	Abbrev.	Unit	2016
1+2 fam. Homes	Wood, prefabricatec	12H PFB	m³ / 1.000	117,3
	Wood, other	12H OTH	m³ / 1.000	145,0
12H	Other build. mater.	12H OBM	m³ / 1.000	24,2
Apartment buildings	Wood construction	APB WOD	m³ / 1.000	49,9
APB	Other build. mater.	APB OBM	m³ / 1.000	11,9
Residential-like BG	Wood construction	RSL WOD	m³ / 1.000	69,2
RSL	Other build. mater.	RSL OBM	m³ / 1.000	5,4
Industrial BG	Wood construction	IND WOD	m³ / 1.000	41,6
IND	Other build. mater.	INB OBM	m³ / 1.000	2,4
Agricultural BG	Wood construction	AGR WOD	m³ / 1.000	23,5
AGR	Other build. mater.	AGR OBM	m³ / 1.000	4,2
REM resid. constr.	Total	REM RES	m³ / m. €	80,3
REM non-resid. constr.	Total	REM NRS	m³ / m. €	25,2
Civil engineering	Total	CEN	m³ / m. €	11,8

Figure 4-11: Wood use by construction sector in m³(pwe) Wood



Abbreviations: PFB = prefabricated timber construction; OTH = other timber construction; ABS = other building materials; WOD = timber construction; CB = company building; REM = remodelling; RES = residential construction; NRS = non-residential construction. Basis: New construction 1,000 m³ enclosed space; remodelling and civil engineering with a construction volume of €1 million (DIW) in real terms (2015 = 100). Source: Mantau/Blanke/Döring (2018)

Offcuts and semi-finished products

As part of the KlimaBau project, 135 different wood products were recorded with the quantity they occupy in the building structure (m^3_{pwe}). Residue factors in production and on the construction site were estimated using a construction analysis. The total amount of semi-finished products used in construction is made up of the quantities used in the building structure and the offcut. The offcut quantities are allocated to the semi-finished products used in proportion to their weight.

Offcuts increase the quantity by slightly more than a fifth on average. Offcuts are considered in the following quantity figures. In this case, the figures refer to semi-finished wood equivalents (m^3_{hwe}). The yield for the raw material input is not included. This is only calculated when converting to raw materials (m^3_{swe}).

Table 4-2: Residue factors for construction products used and proportions of semi-finished products used in percent

Percentage of use / type of building	Offcut product.	Offcut on site	Sawn-wood	Particle-board	MDF/ HDF	OSB	LDF/ ULDF	Veneer	Plywood	Other
1+2 fam. homes, PFB	10,9	8,2	49,1	1,6	0,6	7,2	21,8	0,1	1,0	18,6
1+2 fam. homes, OTH	12,3	8,8	62,8	0,9	0,3	3,0	22,7	0,1	0,5	9,7
1+2 fam homes, OBM	13,1	9,2	65,6	3,4	1,6	4,7	12,3	0,5	1,2	10,7
Appartment build.,	10,0	9,2	50,0	0,8	1,2	15,0	24,3	0,3	1,7	6,8
Appartment build.,	13,0	9,0	54,9	4,7	3,5	3,8	22,5	1,2	1,7	7,8
Residential-like BG,	12,8	8,5	55,3	1,4	0,8	5,2	16,4	0,1	0,8	20,0
Residential-like BG,	13,6	12,2	53,8	11,6	2,5	12,8	7,6	0,9	1,2	9,6
Industrial BG, WOD	10,4	8,3	54,0	1,6	0,1	5,3	22,1	0,0	0,3	16,5
Industrial BG, OBM	11,7	17,0	35,7	22,8	2,1	22,0	6,3	0,7	0,8	9,6
Agricultural BG, WOD	11,1	9,9	64,7	2,9	0,0	4,3	15,5	0,0	0,1	12,4
Agricultural BG, OBM	12,0	12,3	71,6	5,4	0,2	5,4	4,4	0,1	0,1	12,9
REM resid. constr.	12,8	6,3	44,5	2,6	8,0	2,9	13,8	0,7	1,2	26,2
REM non-resid. constr.	13,3	9,2	64,6	6,3	1,7	9,9	6,1	0,5	1,8	9,1
Civil engineering	10,0	30,0	45,0	2,5	2,5	5,0	0,0	0,5	39,5	5,0

Source: Mantau/Blanke/Döring (2018); Abbreviations: WOD = wood; PFB = prefabricated construction; OTH = other timber construction; OBM = other building materials; CB = company building; REM = remodelling

4.1.4 Construction – base scenario (BAS)

Wood use in the base scenario

The use of wood in new construction is based on the economic development of the enclosed space of individual building types and their use of wood (m³ of wood / 1,000 m³ of enclosed space). In the remodelling and civil engineering sectors, the figure is extrapolated using the factor (m³ of wood / million euros of construction volume).

Figure 4-12 provides an overview of the construction sectors as a whole. It clearly shows that the use of wood in remodelling is most significant and will continue to grow with the segment. Figure 4-13 only shows the new construction segments. In new construction, one- and two-family homes account for the largest quantities of wood used. Figure 4-14 shows new construction excluding one- and two-family homes in order to illustrate the development of the other areas more clearly. Figure 4-15 compares the use of timber in timber-frame buildings with buildings constructed predominantly from other materials. In the past, more wood was used overall in buildings that were not predominantly constructed from wood than in timber construction. With the growing importance of timber construction, the gap has narrowed.

Figure 4-12: Use of wood by construction segment in million m^3_{pwe}

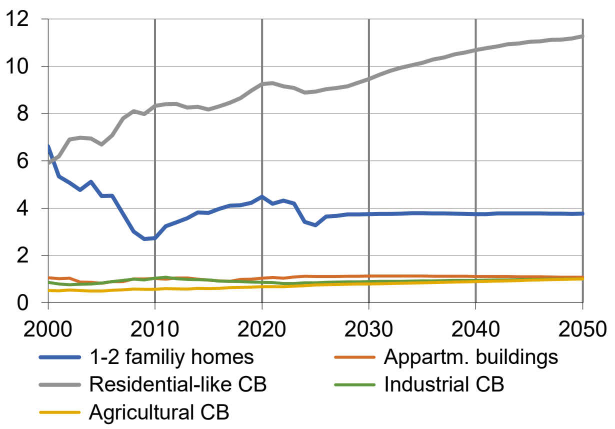


Figure 4-13 : Wood use in new construction by building group in million m^3_{pwe}

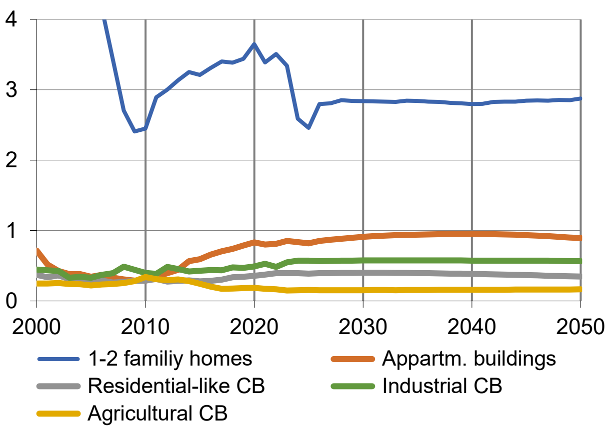
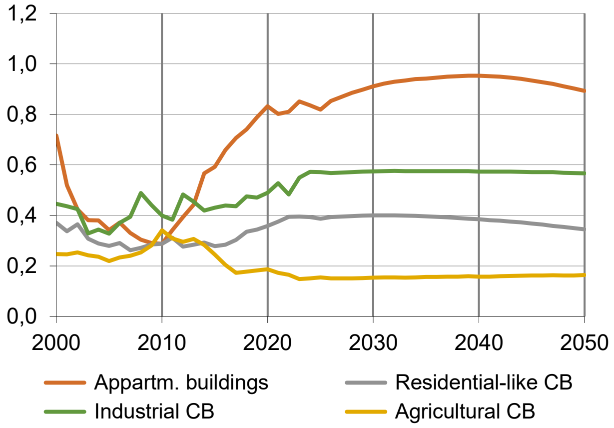
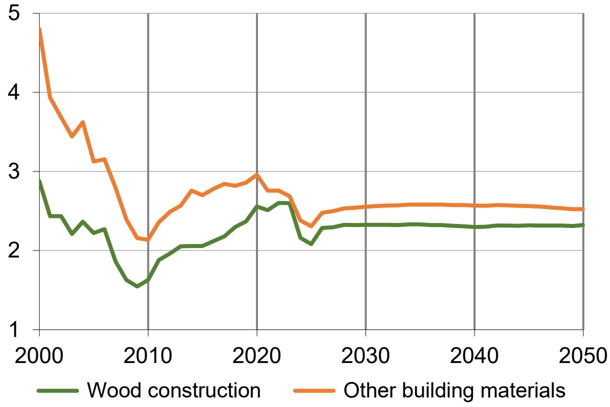


Figure 4-14: Wood use in new construction by building group in million m^3_{pwe} excluding private house construction



Source: Federal Statistical Office. Construction activity statistics and own scenarios from 2024 onwards

Figure 4-15: Use of wood in new construction by type of timber construction and type of construction using other building materials in million m^3_{pwe}

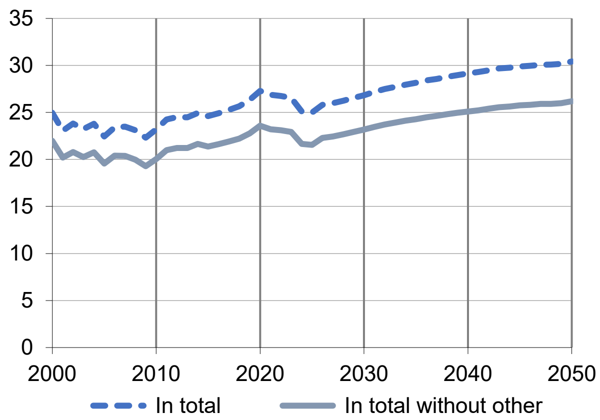


Source: Federal Statistical Office. Construction activity statistics and own scenarios from 2024 onwards

Use of wood by raw materials

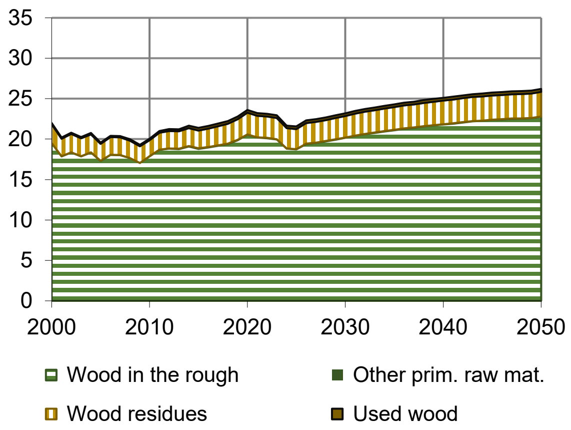
To determine the volume of raw materials used, factors such as the yield from sawn timber production and the compression of particleboard must be considered. Wood in the rough is divided into logs and other wood in the rough. Logs are defined as roundwood that is processed in a sawmill. Other wood in the rough is wood in the rough that is used in other areas, such as wood-based panels. The quantities of wood used for the production of veneer and plywood are allocated to logs in the back calculation. In 2020, 75.3% of the wood raw materials used in construction were wood in the rough. Other primary feedstocks such as forest residues, landscape care material, short-rotation plantations and bark account for only a marginal share of 0.2% in the construction sector. Even this small proportion is attributable to the low bark content in particleboard. Wood residues account for approximately ten percent (9.8 %). The share of waste wood amounts to 0.3 million m^3_{swe} or 1.2 % of the wood raw materials used. The surveys only took into account the share of waste wood in particleboard. No data is currently available on the share of used wood from reuse that is relevant to the construction sector. Other materials include those that are closely related to or combined with wood products. These include, for example, cellulose insulation or metal parts that occupy space in the end product. For systematic reasons, they are recorded but not included in the calculations. However, their share of the recorded volume is significant at 13.5 %.

Figure 4-16: Total wood use in construction and excluding other materials in million m³$_{swe}$



Source: Mantau (2025)

Figure 4-17: Wood use in construction by raw material group in million m³$_{swe}$(cumulative)

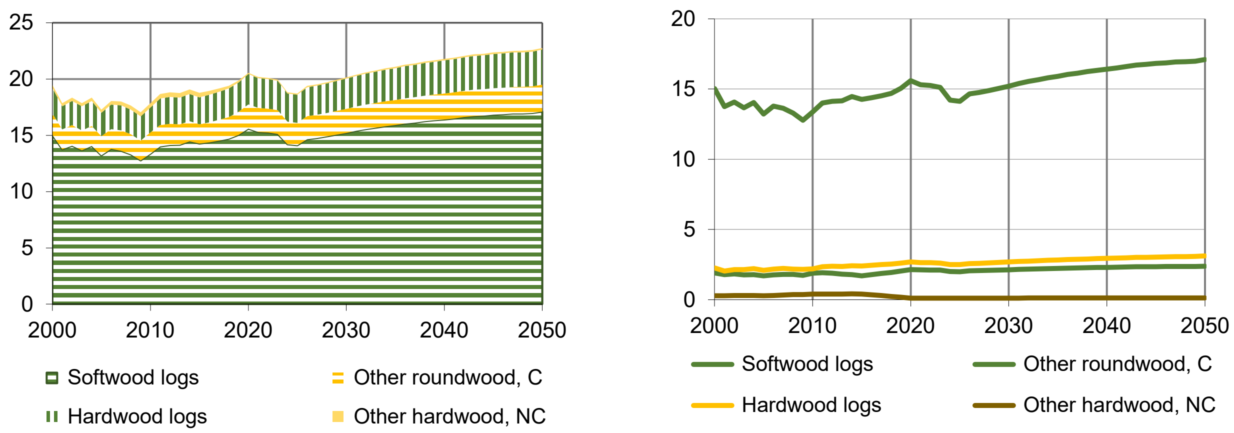


Source: Mantau (2025)

Figure 4 18: Wood use in construction by roundwood type in million m³$_{swe}$

Developments, cumulative

Developments, comparing



Source: Mantau (2025)

Source: Mantau (2025)

Hardwood assortments

Due to the great importance of wood in the rough, the assortments are shown in more detail in the following graphs. In 2020, coniferous logs accounted for 75.9 % of wood in the rough. Other coniferous wood in the rough accounted for 10.5 %. Coniferous wood in the rough accounts for 86.3 % of the wood in the rough used. Hardwood accounted for 13.1 % and other hardwood 0.5 %.

Outlook for 2050

As the baseline scenario does not assume any structural changes in the material mix, minor shifts are attributable to the different economic developments in the various construction sectors. Wood in the rough will see a decline in its share of raw materials of -0.5 %. This is offset by a moderate increase in other (+0.4%) and wood residues (+0.2%). This development is probably due to the opposing trends in new construction and remodelling. Substitution possibilities are examined in the sensitivity analyses.

4.1.5 Construction – wood construction scenario (HBS)

Assumptions regarding the development of the share of wooden buildings

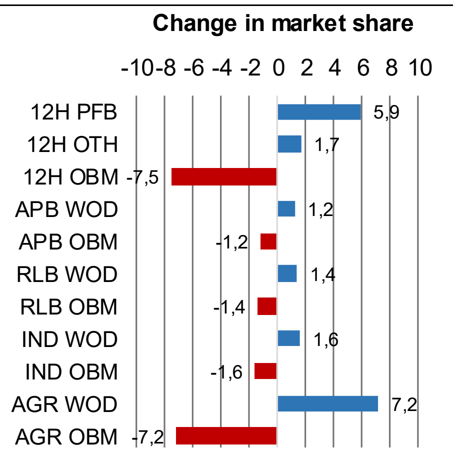
A building is classified as a timber construction based on the primary building material used in its construction. For one- and two-family homes, a distinction was also made between prefabricated construction and other timber construction, as the latter also includes solid construction with significantly higher quantities of wood. The percentage share is based on the finished enclosed space. It should be noted that this may differ significantly from the frequently used figure for the number of approved buildings.

Table shows the market shares of timber construction and other building materials in 2023 in the first column and the 25% increase in the share of wooden buildings in the second column. The third column shows a rounded value, which is usually slightly above the calculated value of 25% in order to be able to show relevant changes for smaller segments. This value was assumed for the calculations in the wood construction scenario and averages 31.9%. The share of wooden buildings is subject to a linear increase from the 2023 value to the target value in 2050. The fourth column shows the relative change in the assumed share of wooden buildings within the period from 2023 to 2050. The fifth column illustrates the absolute percentage change between 2023 and 2050.

Wood construction has seen an increase in market share in recent years. Such growth is easier to achieve in an expanding market than in a tight or shrinking market, where competition for customers is increasing. For this reason, it is not realistic to expect the current growth rates to continue.

Table 4-3: Derivation of a development scenario for the share of wooden buildings in completed enclosed space and absolute percentage change

Building type	Construc-tion	Basis 2023		Target and change		
		2023	2050	2050	Change from 23	
Enclosed space in %		Actual value	25%	Target	in %	% abs.
	12H PFB	**19,1**	23,9	**25,0**	*30,8*	*5,9*
1+2 family homes	12H OTH	**3,3**	4,2	**5,0**	*49,4*	*1,7*
12H	12H OBM	**77,5**	71,9	**70,0**	*-9,7*	*-7,5*
Appartment build.	APB WOD	**2,8**	3,5	**4,0**	*43,5*	*1,2*
APB	APB OBM	**97,2**	96,5	**96,0**	*-1,2*	*-1,2*
Residential-like CB	RLB WOD	**6,6**	8,3	**8,0**	*21,0*	*1,4*
RLB	RLB OBM	**93,4**	91,7	**92,0**	*-1,5*	*-1,4*
Industrial CB	IND WOD	**4,4**	5,5	**6,0**	*35,8*	*1,6*
IND	IND OBM	**95,6**	94,5	**94,0**	*-1,7*	*-1,6*
Agricultural CB	AGR WOD	**22,8**	28,5	**30,0**	*31,3*	*7,2*
AGR	AGR OBM	**77,2**	71,5	**70,0**	*-9,3*	*-7,2*



Abbreviations: PFB = prefabricated wood construction; OTH = other timber construction; WOD = wood; OBM = other building materials; CB = company building; Source: Mantau (2025)

Figure 4-19: Change in the shares of construction methods as a percentage of enclosed space in the wood construction scenario

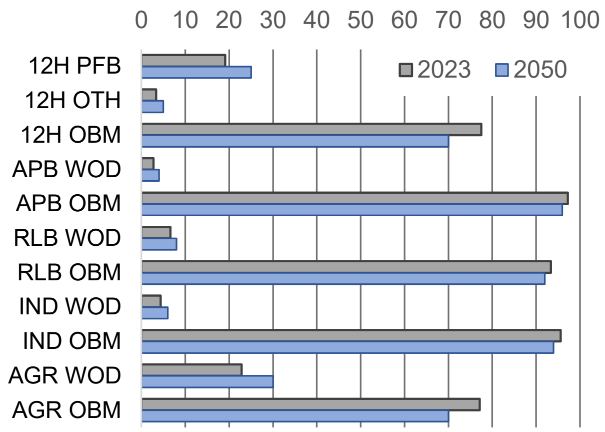
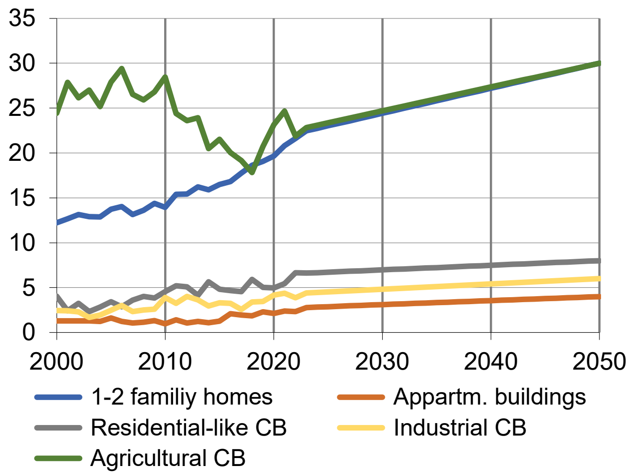


Figure 4-20: Share of wooden buildings as a percentage of enclosed space and projection in the wood construction scenario



EGH = one and two family homes; MFH = multi-family homes; WBG – IBG – LBG = residential, industrial and agricultural buildings; HFT = prefabricated timber construction; SON = other timber construction; ABS = other building materials; HOL = timber construction ; Source: Mantau (2025)

Understanding the relative growth rates

A 25 % increase in the share of wooden buildings in the total enclosed space of completed buildings refers to single-family homes with a market share of 22.4 % and multi-family homes with a market share of 2.8 %. According to this, the market share of single-family homes would be 28.1 % and that of multi-family homes 3.5 %. Rounded up, the assumed value for single-family homes is 30.0% and for multi-family homes 4.0 %. According to this scenario, the market share of single-family homes in completed floor space would increase by 0.3 % annually.

Growth in the use of wood and substitution effect

Table 4-3 shows that the market share gains of timber construction are offset by market share losses of other building materials. As these also include wood products, the additional wood extraction results from the net effect of the additional use of wood in timber construction minus the use of wood in buildings whose construction consists predominantly of other building materials.

The increase in the share of wooden buildings from 25.0 %, which is assumed as the starting point for the change, is rounded up in total to 31.9 %. As a result, this will lead to an increase in the use of wood in timber construction (gross value) in 2050 of 782,000 m^3_{hwe}. The cumulative amount between 2023 and 2050 corresponds to 10.9 million m^3_{hwe}. On an annual average, this corresponds to an additional amount of 419,000 m^3_{hwe}.

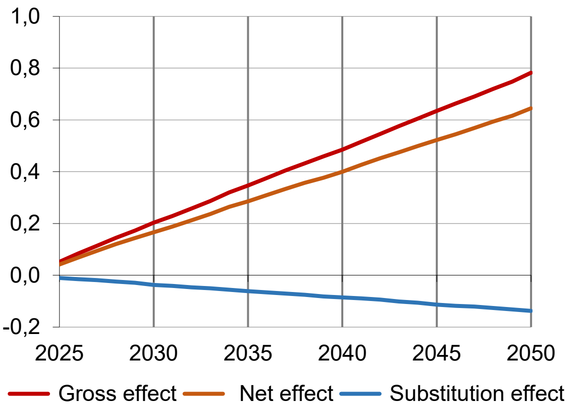
The substitution effect in 2050 is 137,000 m^3_{hwe} or 17.5 %. On average for the entire period, it deviates slightly at 17.6 %. In the cumulative amount between 2023 and 2050, this corresponds to 1.9 million m^3_{hwe}. The net effect in 2050 was therefore 646,000 m^3_{hwe} or 9.0 million m^3_{hwe} in the cumulative period. On an annual average, this corresponds to an additional volume of 333,000 m^3_{hwe}.

Annual changes

The following graphs illustrate the effects of the assumed development of the share of wooden buildings in percentage and absolute terms.

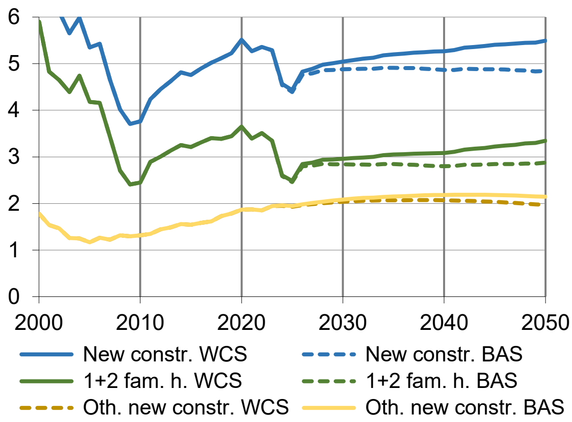
The percentage values are based on the use of wood in new buildings. This approach is appropriate, as the changes in the share of wooden buildings only relate to newly constructed buildings. In 2050, 29.2 % of wood use will be in new construction. 70.8 % will be in remodelling and civil engineering. This explains why an increase in the share of wooden buildings does not lead to a corresponding increase in wood use in construction.

Figure 4-21: Additional wood use as a percentage of total wood use in new construction



Source: Mantau (2025)

Figure 4-22: Wood use with and without increased share of wooden buildings in million m^3_{pwe}



BAS = Base scenario; WCS = Wood construction scenario

Wood construction scenario as base scenario

Given the limited volume effects triggered by an increased share of wooden buildings, the effects in the subsequent calculations of forest growth modelling and greenhouse gas effects also remain limited. This means that the data is only transferred via a single data set. This contains the wood construction scenario in the construction sector and the baseline scenario in all other sectors.

Quantitative effects of increased shares of wooden buildings

Table shows the results of the calculations. Weak economic growth is expected in the first decade. Overall timber consumption is the result of the higher share of wooden buildings and the underlying economic trend. A decline in timber consumption due to economic effects reduces the impact of the increased share of wooden buildings through lower overall growth.

Overall, the use of wooden semi-finished products will increase between 2020 and 2050 from 16.0 million m^3_{hwe} to 18.4 million m^3_{hwe} by +14.5 %. A comparison of the rates of change provides information about the interaction between wood products and building types. Because wood insulation materials are also more likely to be used in timber buildings, the quantity of insulation boards used will increase more (+6.2%) than other wooden semi-finished products. Plywood will grow significantly in economic terms due to developments in civil engineering. However, there is hardly any difference between the scenarios because plywood does not play a significant role in new construction. Overall, more than half of the semi-finished products used in the construction sector in 2050 will be softwood sawn timber (55.6%).

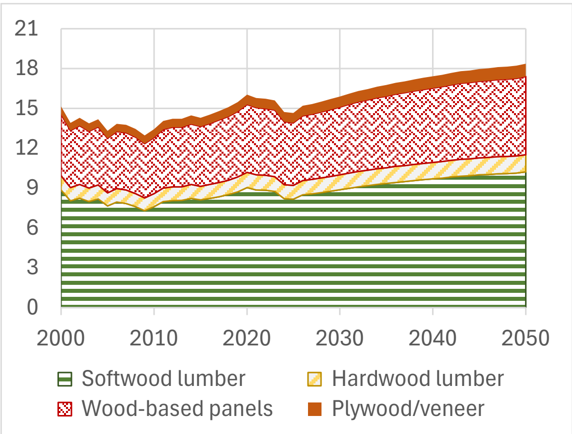
Table 4-4: Results of the timber construction scenario for wooden semi-finished products in million m^3_{hwe}

	Wood construction scenario (HBS)				Changes in	
Used	2020	2030	2040	2050	2050 to	Shares
Semi-finished prod.	in million m³hwe				2020	2050
Softwood sawn	9,037	8,869	9,688	10,213	13,0	55,6
Hardwood sawn	1,154	1,126	1,240	1,305	13,1	7,1
Wood-based panels	2,601	2,622	2,870	3,006	15,6	16,4
Insulation boards	2,508	2,479	2,730	2,881	14,9	15,7
Veneer / plywood	0,739	0,798	0,888	0,965	30,6	5,3
Total	**16,039**	**15,894**	**17,416**	**18,370**	**14,5**	**100,0**

Source: Mantau (2025)

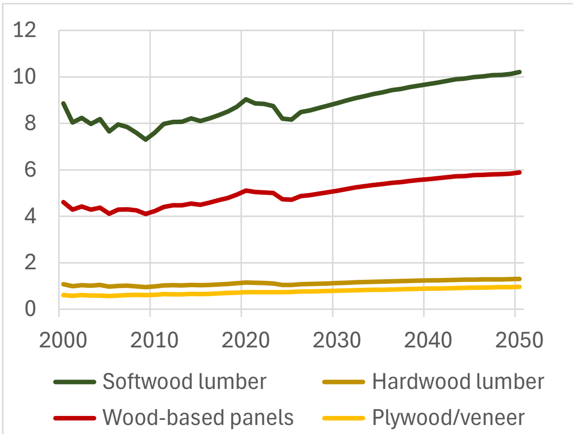
Figure 4-23: Wood use in the construction sector by semi-finished product group in million m^3_{hwe}

Developments, cumulative



Source: Mantau (2025)

Developments, comparing



Source: Mantau (2025)

Quantity effects for raw materials

The quantity of wood raw materials used will rise from 23.6 million m^3_{swe} in 2020 by 3.5 million m^3_{swe} to 27.1 million m^3_{swe} in 2050. This represents an increase of 14.7 %. This is due to economic developments in new construction, remodelling and civil engineering. In new construction, the increase in the share of wooden buildings will also have an additional effect.

The changes in raw materials in this illustration do not relate solely to new construction, but to the development of the construction sector as a whole. The smaller relative changes between the scenarios for other primary raw materials (input particleboard) and for hardwood are due to their greater share in remodelling, which is not affected by the change in the share of wooden buildings.

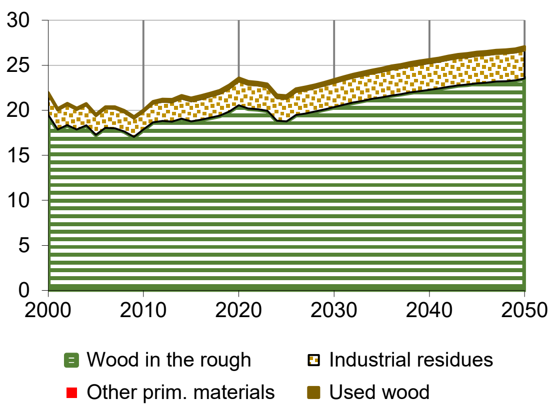
Table5: Results of the timber construction scenario for raw materials

	Wood construction scenario (HBS)				Changes in		
Used	**2020**	**2030**	**2040**	**2050**	50 to 20	50 to 20	Shares
Wood raw materials	in million m³swe				in %	n million m³sw	2050
Logs	18,286	18,081	19,799	20,926	14,4	2,640	77,3
Other wood in the rough	2,262	2,270	2,484	2,611	15,4	0,349	9,6
Roundwood, NC	*17,742*	*17,536*	*19,175*	*20,239*	*14,1*	*2,497*	*74,8*
Roundwood, NC	*2,806*	*2,815*	*3,108*	*3,297*	*17,5*	*0,491*	*12,2*
Other primary raw	0,044	0,044	0,049	0,051	16,2	0,007	0,2
Industrial wood residues	2,677	2,685	2,967	3,116	16,4	0,439	11,5
Recycled waste wood	0,325	0,326	0,350	0,363	11,7	0,038	1,3
Total	**23,594**	**23,405**	**25,649**	**27,066**	**14,7**	**3,472**	**100,0**

(HPS = wood construction scenario; BAS = baseline scenario) Source: Mantau 2025

Figure 4-24: Raw wood use by raw material group in million m³$_{swe}$

Developments, cumulative



Developments, comparing

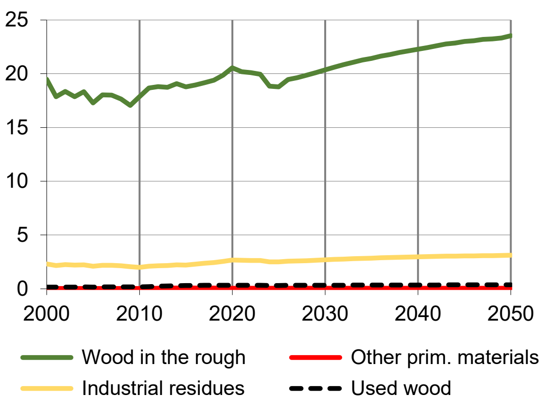
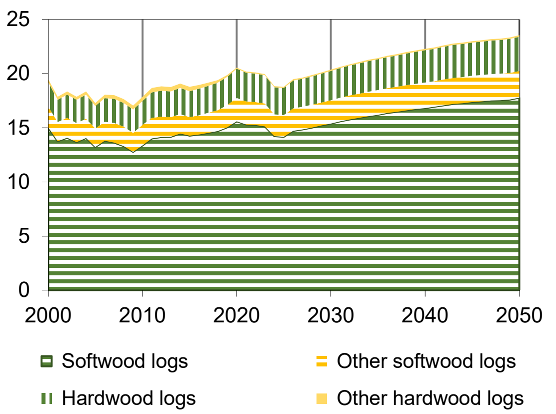
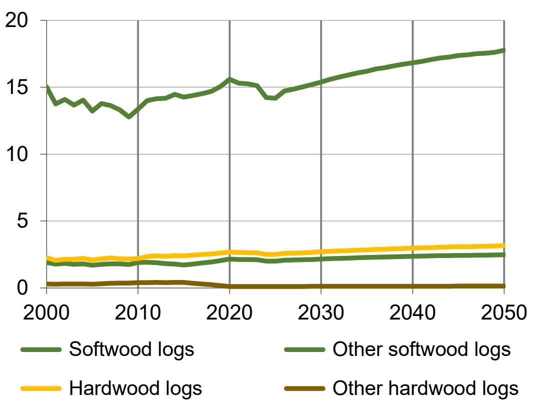


Figure 4-25: Use of wood in the rough in timber construction scenarios by roundwood type in million m³$_{swe}$

Developments, cumulative



Developments, comparing



Source: Mantau (2025)

Source: Mantau (2025)

4.2 Furniture

Definitions

Data

The production statistics of the Federal Statistical Office list furniture items in various groups in Section 31 of the goods classification (GP). In addition to Section 31 (furniture), other GP numbers are added for furniture-like products that may contain wood. Between June 2019 and July 2021, 1,002 items of furniture were recorded and subsequently assigned to the appropriate furniture groups. Previous goods lists (GP 2002 and GP 2009) were assigned to the GP 2019 production statistics. A detailed description of the methodology can be found in the furniture study (Mantau/Blanke/Döring (2018).

Materials

The recording template used covers a wide range of materials used in wood furniture production. These materials can be assigned to the main groups of solid wood, wood-based panels and other materials. The following table shows the documented numbers of pieces of furniture according to the production statistics for 2022. This is followed by the average values for wood use per piece of furniture recorded. The total weight of furniture produced in 2022 can be calculated from the values determined in this way.

Table 4-6: Projected wood use by furniture groups

2022	Furniture	Wood weight per piece			Wood weight of production		
	Piece	Wood	Solid	WBP	Wood	Solid	WBP
Furniture group	in million	kg/pc.	kg/pc.	kg/pc.	1.000 t	1.000 t	1.000 t
Seating furniture	9,787	11,5	6,5	5,0	112	63	49
Office furniture	7,266	61,8	22,0	39,8	449	160	289
Wooden kitchen furniture	28,892	43,4	7,7	35,7	1.254	221	1.033
Spring frames	2,142	18,5	6,4	12,2	40	14	26
Metal furn., excl. office	17,590	18,0	8,2	9,8	317	144	173
Wooden home furniture	15,074	94,1	34,2	59,9	1.418	516	902
Wooden furniture	10,111	27,0	14,0	13,0	273	141	132
Wooden furniture parts	12,456	26,9	24,4	2,5	335	304	31
Plastic furniture	0,891	14,7	0,8	13,8	13	1	12
Furn. parts for media	0,070	39,6	0,1	39,5	3	0	3
Medical, practices, other	5,213	50,6	0,0	50,6	264	0	264
Furn. parts and other mat.	0,092	27,1	21,3	5,8	2	2	1
Total	**109,584**	**40,9**	**14,3**	**26,6**	**4.480**	**1.566**	**2.914**

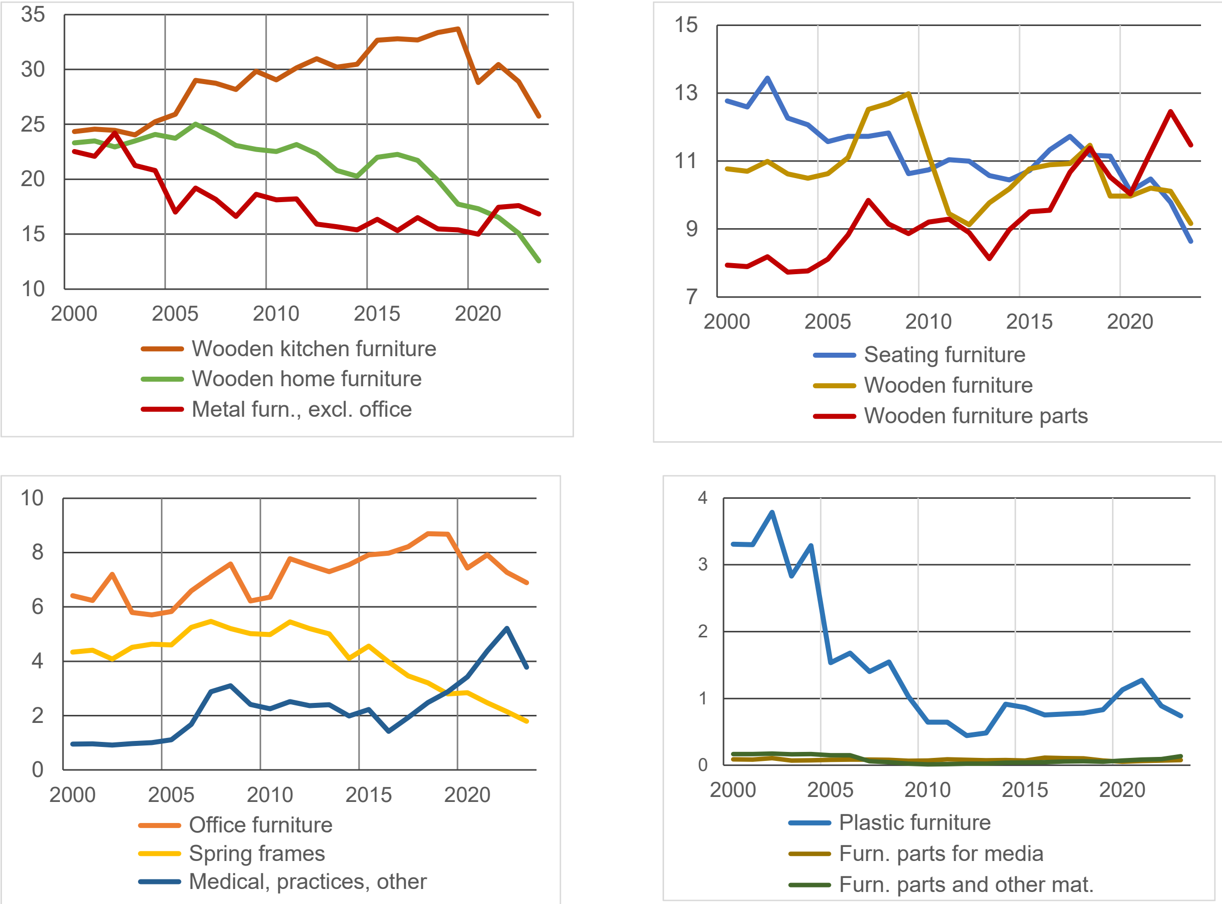
Abbreviations: Wood = wood weight of furniture items; solid = solid wood use; WBP = use of wood-based panels

Source: Mantau/Hiller/Gieseking/Blanke (2022)

Developments

The development of furniture groups is shown below for the period from 2000 to 2023. Since 2020, production of most furniture groups has been declining. Analysis of trend developments reveals clear differences between segments. However, the economic downturn affects all areas in the year 2023.

Figure 4-26: Development of selected furniture ranges by number (in million units)



Source: Federal Statistical Office until 2022 (production statistics) and own calculations

Key figures for wood use

The following table shows the weight percentages of wood materials by furniture group for 2022. Basis is the half-finished product equivalent (m^3_{hwe}).

The two most important groups, wooden home furniture (32.4 %) and wooden kitchen furniture (29.7 %), account for almost two-thirds of the total weight. The second part of the table shows the proportions of solid wood and wood-based panels. In wooden kitchen furniture, solid wood accounts for 14.9 %, while wood-based panels account for 85.1 %. In residential furniture, on the other hand, solid wood accounts for around one third (32.2 %), while wood-based panels account for two thirds (67.8 %).

Table 4-7: Wood content of furniture groups and proportions of assortments

2022	Furniture	Wood weight per piece			Wood weight of production		
	Piece	Wood	Solid	WBP	Wood	Solid	WBP
Furniture group	in %	in %	in %	in %	in %	in %	in %
Seating furniture	8,9	2,4	4,1	1,6	100,0	52,1	47,9
Office furniture	6,6	9,6	10,1	9,4	100,0	31,8	68,2
Wooden kitchen furniture	26,4	29,7	14,6	36,3	100,0	14,9	85,1
Spring frames	2,0	0,9	1,0	0,9	100,0	31,6	68,4
Metal furn., excl. office	16,1	6,8	9,0	5,8	100,0	40,1	59,9
Wooden home furniture	13,8	32,4	34,2	31,6	100,0	31,9	68,1
Wooden furniture	9,2	5,7	8,8	4,4	100,0	46,4	53,6
Wooden furniture parts	11,4	6,2	18,1	1,0	100,0	88,2	11,8
Plastic furniture	0,8	0,3	0,0	0,4	100,0	4,9	95,1
Furn. parts for media	0,1	0,1	0,0	0,1	100,0	0,2	99,8
Medical, practices, other	4,8	5,9	0,0	8,5	100,0	0,0	100,0
Furn. parts and other mat	0,1	0,1	0,1	0,0	100,0	75,8	24,2
Total	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**30,2**	**69,8**

Solid = solid wood; WBP = wood-based panels; wood = total.

Source: Mantau/Hiller/Gieseking/Blanke (2022)

Basis for the scenarios

The statistics provide information on the production and foreign trade of furniture in kilograms. In 2023, production amounted to 4.4 million kilograms, of which 23.8 % was solid wood and 76.2 % was wood-based panels.

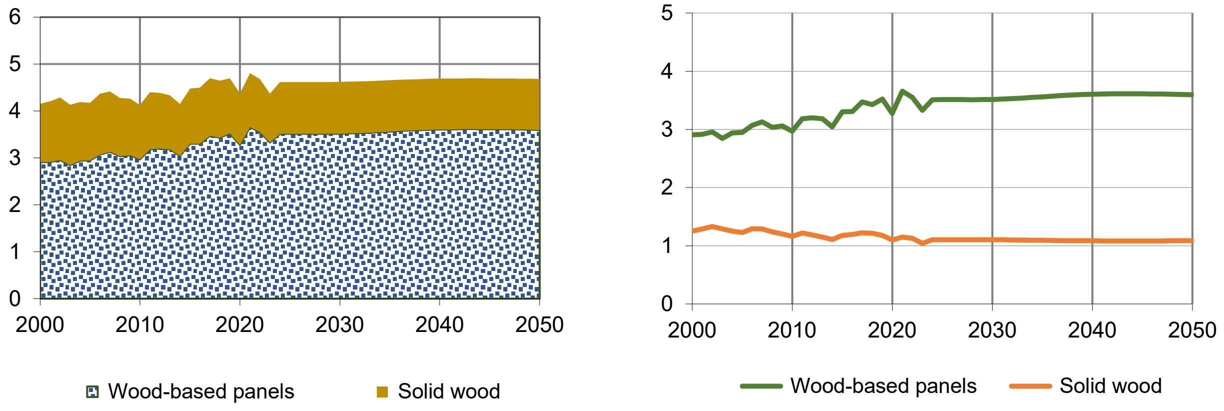
The scenario is primarily based on demographic developments. In this context, a distinction is made between the influence of the development of one-, two- and three-person households. In addition, the development of the share of private consumption in GDP was integrated into the estimate. The development of the distribution between solid wood and wood-based panels was carried out as a univariate estimate in relation to the development of consumption. Imports follow consumption trends and the share of gross imports in GDP. Exports are also influenced by overall trends and are negatively affected by import trends.

Results

The scenarios analysed show a largely stable development of the furniture market. This will be slightly supported by demographic developments until 2040, which is attributable to the significant increase in single-person households. From 2040 onwards, this increase will slow down, with the result that the downward trend in the other household groups will have a greater impact. Following the economic downturn in 2023, production stagnated at around 4.7 million kg. The share of solid wood will decline slightly to 23.2 % by 2050.

Figure 4-27: Development of wood use by semi-finished product group in million kg

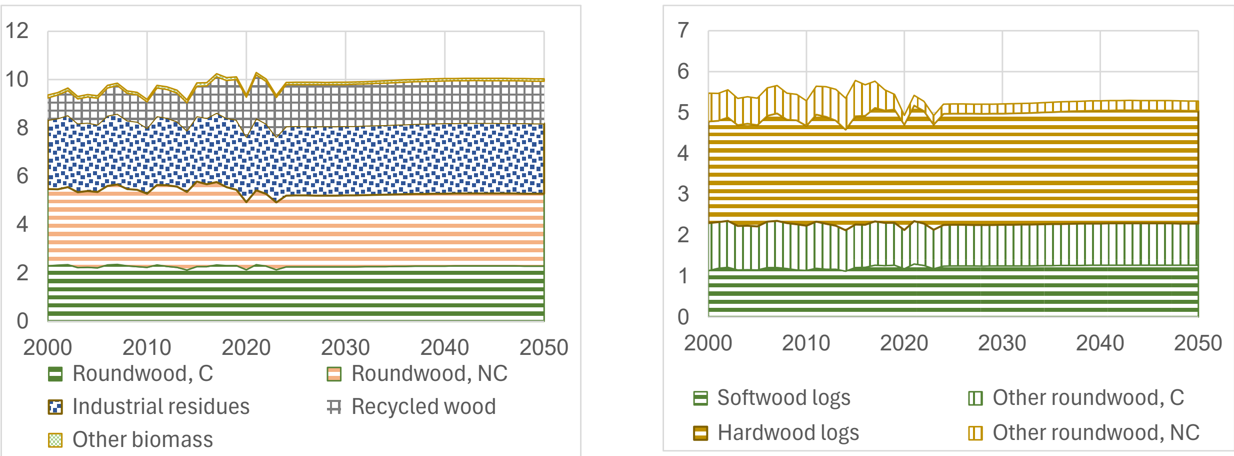
Developments, cumulative | **Developments, comparing**



Source: Mantau/Hiller/Gieseking/Blanke (2022)

Figure 4-28: Development of wood use by wood raw material used in million m^3_{swe}

Wood raw materials, cumulative | **Roundwood, cumulative**



Source: Mantau/Hiller/Gieseking/Blanke (2022)

Wood use by raw material

Based on the wooden semi-finished products used, density and yield indices are used to determine the quantity of raw material input in solid wood equivalents. According to this, the uses of wood raw materials in the furniture sector amounted to 9.4 million m^3_{swe}. By 2050, the value of wood raw materials used will rise to 10.0 million m^3_{swe}. Due to conversion and also because wood-based panels contain other wood in the rough, the wood in the rough share was 52.7 % in 2020. It will remain constant until 2050. Table 4-8 shows the quantities of raw material groups used.

Table 4-8: Scenario for wood use in the furniture sector by wood raw material in million m³$_{swe}$

m³$_{swe}$	Wood in the rough		Other prim. biom.		Wood residues		Recycled wood		Total	
	in Mio.	*in %*	in Mio.	*in %*	in Mio.	*in %*	in Mio.	*in %*	in Mio.	*in %*
2020	4,931	*52,7*	0,091	*1,0*	2,712	*29,0*	1,630	*17,4*	9,364	*100,0*
2030	5,209	*52,7*	0,096	*1,0*	2,865	*29,0*	1,722	*17,4*	9,892	*100,0*
2040	5,287	*52,7*	0,097	*1,0*	2,908	*29,0*	1,748	*17,4*	10,040	*100,0*
2050	5,280	*53,4*	0,097	*1,0*	2,756	*27,9*	1,746	*17,7*	9,879	*100,0*

Source: Mantau (2025)

4.3 Wood packaging

Definition

Statistical classification

The production data is based on the annual data from the quarterly production surveys of the goods register for 9-digit codes and cover the following products. The basis was GP 2002-2008 (group 20), GP09 2009 to 2018 (group 16) and GP19 20019.2023 (group 16) for the products:

GP19-162411330 / Flat pallets, pallet collars (units)

GP19-162411350 / Box pallets and other load carriers (units)

GP19-162412000 / Barrels, troughs, vats, buckets and other cooper's ware (m³, no data)

GP19-162413201 / Boxes, crates, drums and similar items made of plywood (m³)

GP19-162413209 / Boxes, crates, drums from other wood (m³)

GP9-162413500 / Cable drums made of wood (m³)

Foreign trade statistics have similar items but only report flat pallets and pallet collars (pieces).

Use of wood

Analyses in accordance with the furniture study on the use of wood in packaging are still pending. Initial indications of the quantities of wood used are provided by final theses from the "Forest Economics" department of the Centre for Wood Technology.

Table 4-9: Wood use in packaging products m³$_{pwe}$ / unit

Product	m³pwe / unit	Product	m³pwe / unit
Euro pallet	0,0452	Solid wood crate	1,847
EPAL industrial pallet	0,0502	Plywood crate	1,259
EPAL industrial pallet 3	0,0579	OSB crate	1,259
		Box shed	1,415
Mean	**0,0511**	**Mean**	**1,445**

Source: Surveys from the "Forest Economics" section lead by U. Mantau [Peters (2015), Konsemüller (2016)]

Data issues

The survey of wood use in individual products does not correspond to the product group classification used in production statistics. As a result, average values were determined for pallets (0.0511 m³$_{pwe}$ / unit) and for the remaining products (1.4451 m³$_{pwe}$ wood / unit). Due to the diverging methodology used in the calculations and the uncertain data situation, the results of this calculation and those for the comparable years 2009-2015 from WEHAM were calibrated. As a result, a reduction in the calculation results per unit of 0.712 was observed, which ensured continuity with previous work. The identification and quantification of existing uncertainties can therefore only be achieved by conducting comparable surveys, such as those carried out in the furniture study.

Structure

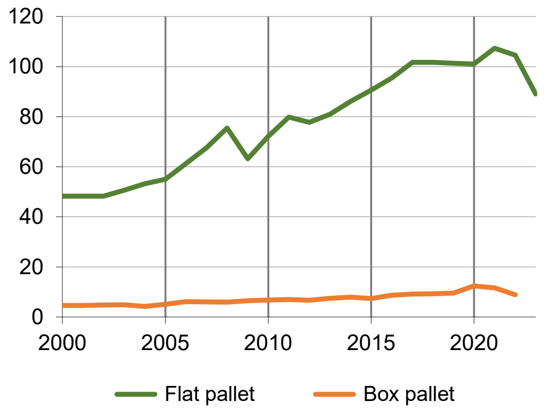
In 2020, a total of 113 million packaging products were produced. Of these, 101 million were flat pallets. Flat pallets are therefore the most important product in the packaging sector in terms of wood use. In combination with box pallets, pallets account for an estimated 80% of wood use, while the remaining 20% is accounted for by crates and cable drums.

Development

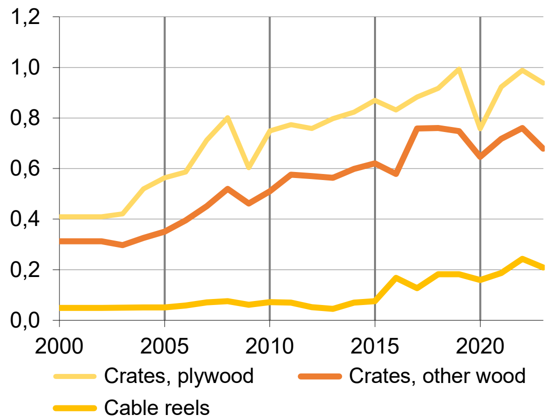
Between 2000 and 2020, the industry experienced continuous growth in the wake of globalisation, which was marked by economic fluctuations. From 2017 onwards, a tendency towards stagnation became apparent, which ultimately led to a significant slump at the end of the data available in 2023.

Figure 4-29: Development of packaging market products in million units.

Pallets



Boxes and cable reels



Source: Federal Statistical Office

Scenario

Data sources

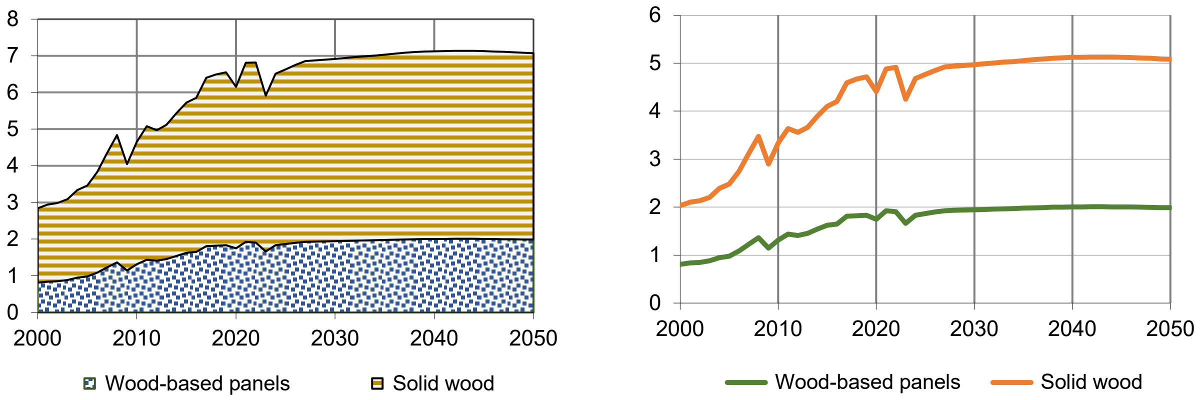
The latest developments at the current margin once again highlight the problem of the starting year already discussed. Even with a downturn that continues until 2025, the model-theoretical problem remains. However, this approach was used in all calculations in accordance with standard practice. The five-year average for 2019-2023 was chosen as the starting year and then extrapolated using the rates of change in the estimate.

Development and scenario

This study covers the data reported up to 2023. The "upturn" forecast for 2024 is based on calculations. The starting value of the scenario should therefore not be understood as a forecast for 2024, but rather as the baseline value for the scenarios up to 2050. Compared to the period from 2000 to 2020, the scenarios show hardly any growth. The volume development in the scenario period only slightly exceeds the baseline level.

Figure 4-30: Development of wood use by semi-finished product group in million m³$_{hwe}$

Developments, cumulative **Developments, comparing**



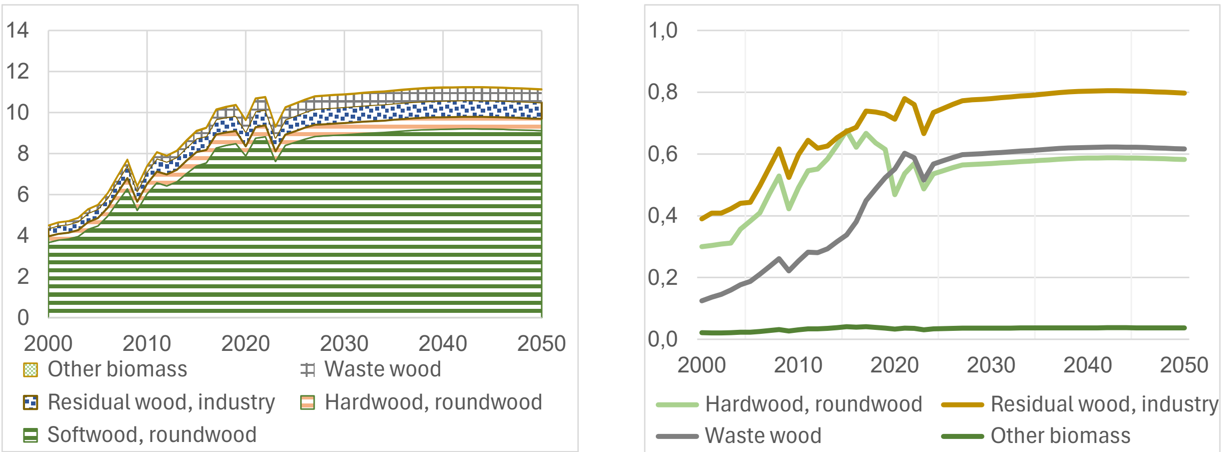
Source: Mantau (2025)

Semi-finished products input

The use of wooden semi-finished products averaged approx. 6.5 million m³$_{hwe}$ between 2019 and 2023. Of this, 1.8 million m³$_{hwe}$ or 28.1 % was accounted for by wood-based panels and 4.6 million m³$_{hwe}$ or 71.9 % by solid wood. Particleboard accounted for 85.8 % of wood-based panels. At 99.1 %, softwood clearly dominated the solid wood market.

Figure 4-31: Development of wood use by raw material group in million m³$_{swe}$

Developments, cumulative **Developments, comparing**



Source: Mantau (2025)

Raw material input

The following calculation step to determine the raw material shares highlights the importance of coniferous roundwood. The share of raw material input averages 71.2% for the years 2019 to 2023. This is illustrated by the Figure with cumulative values.

A comparison of the raw materials used without coniferous roundwood shows a decline in the use of deciduous roundwood with the onset of a slowdown in production. The data does not allow any conclusions to be drawn as to the cause. It could be hypothesised that with the end of strong growth, the shortage in purchasing will ease and demand for the preferred coniferous roundwood will increase again.

Table 4-10: Scenario for wood use in packaging by wood raw material in million m^3_{swe}

m³(swe)	Wood in the rough		Other prim. biom.		Wood residues		Recycled wood		Total	
	in Mio.	*in %*	in Mio.	*in %*	in Mio.	*in %*	in Mio.	*in %*	in Mio.	*in %*
2020	8,349	86,6	0,033	*0,3*	0,713	*7,4*	0,551	*5,7*	9,646	*100,0*
2030	9,481	87,0	0,036	*0,3*	0,780	*7,2*	0,603	*5,5*	10,901	*100,0*
2040	9,768	87,0	0,037	*0,3*	0,803	*7,2*	0,621	*5,5*	11,231	*100,0*
2050	9,696	87,0	0,037	*0,3*	0,797	*7,2*	0,617	*5,5*	11,147	*100,0*

Source: Mantau (2025)

4.4 Paper

Definition

The paper sector is considered for the following segments

Total paper =
- Graphic paper (*newspaper printing paper* and *other*)
- *Packaging paper*
- *Hygiene paper*
- *Speciality papers*.

The development of consumption in the paper sector is modelled using regression analysis based on the sectors printed in italics.

Domestic production is calculated from the difference between consumption and an estimated development of the foreign trade balance.

Domestic use of wood input factors is based on the feedstocks used for the production of the paper sector as a whole (source: VDP Table N17).

Key figures for wood use

The data for the paper sector of finished products is taken from the performance reports of the VDP (Association of German Paper Manufacturers). This applies to the economic development of production and foreign trade as well as to the raw materials used (wastepaper, chemical pulp, fillers).

The data for the chemical pulp semi-finished goods sector is taken from the Wood Resource Monitoring report. This is based on surveys conducted by Wood Resource Monitoring and supplemented by the performance reports of the VDP (Association of German Paper Manufacturers).

Development

The development of the sub-sectors is very heterogeneous.

The newsprint sector experienced a significant decline between 2005 and 2020, which largely stabilised by 2023 and maintained a production volume of one million tonnes. This development is of little significance for forest timber extraction, as wastepaper is used.

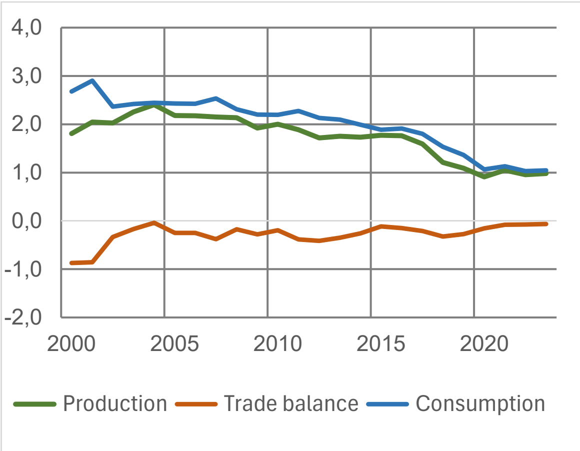
Writing and printing paper has also seen a steady decline in production since 2010. The economy slumped particularly sharply in 2022 and 2023. The market for writing and printing paper is affected by structural changes (digitalisation) and is very sensitive to economic cycles.

The market for hygiene paper is showing a much more stable development. These products have limited substitutes, serve fundamental human needs and are also benefiting from demographic trends.

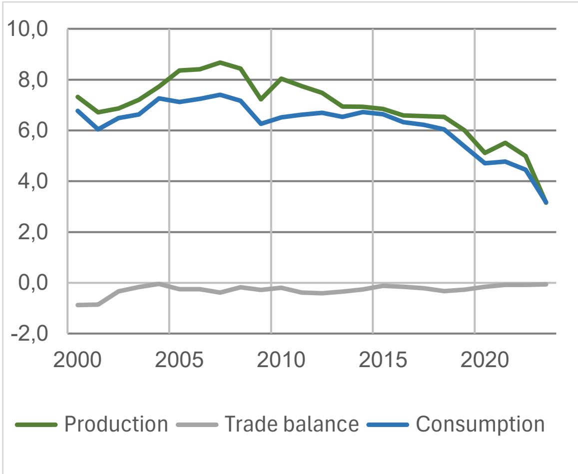
The production of speciality papers is characterised by a high degree of stability. This is due to the technologically leading products of the German paper industry. As a result, foreign trade has a stabilising effect on production.

Figure 4-32: Development of paper market products in million tonnes

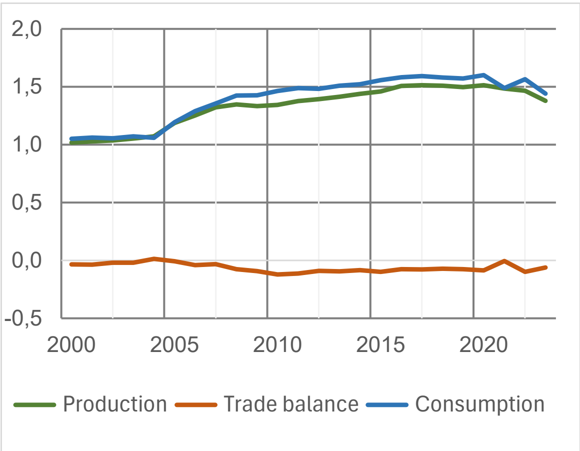
Newsprint



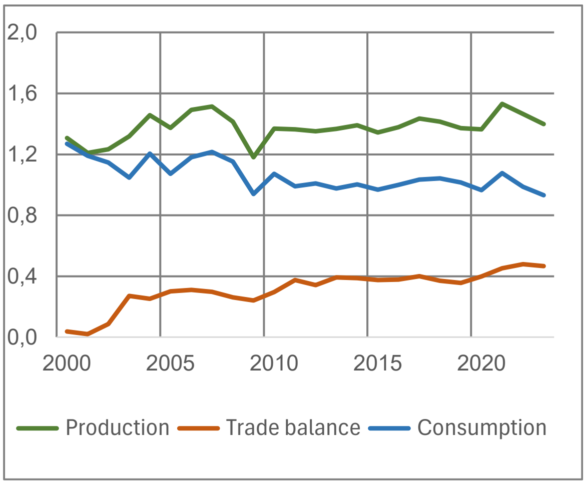
Writing and printing paper



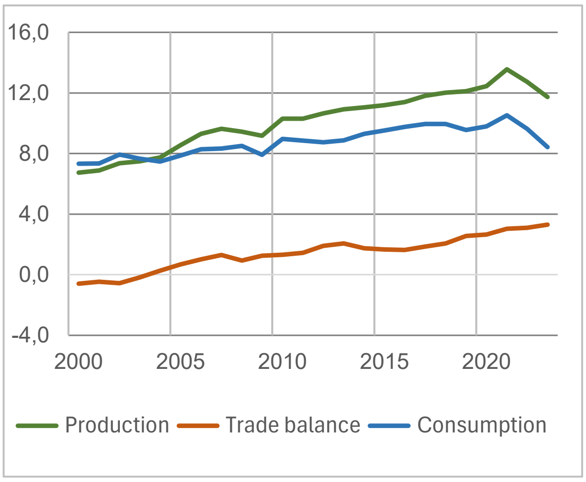
Hygiene paper



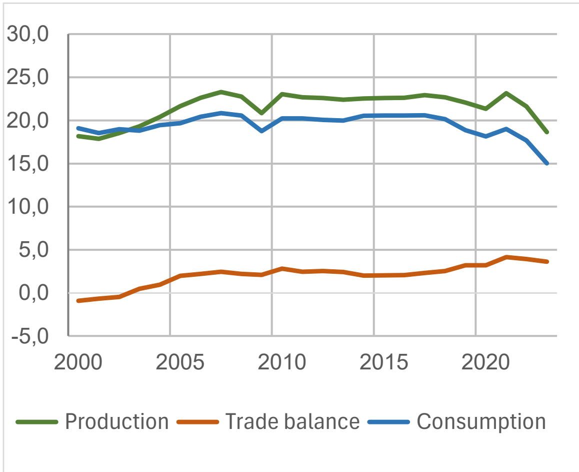
Speciality papers



Packaging paper



Paper, total



Source: The paper industry (2024)

Development

Between 2000 and 2021, the production of packaging paper experienced an almost uninterrupted economic upturn. However, the current economic downturn is also affecting the production of packaging paper, which is now declining. The increase in foreign trade activities is leading to a stabilisation of production. Apart from the current economic downturn, production in the paper sector is relatively stable overall.

Scenario

Data sources

The scenarios for production and the foreign trade balance are based on an analysis of available exogenous variables, as outlined in the "Framework conditions" section 3.

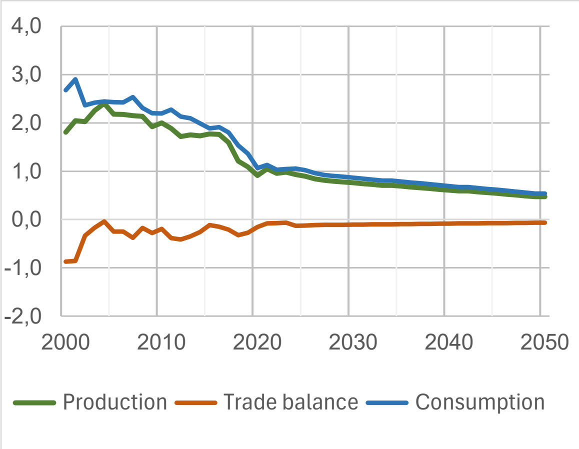
This limits the number of potential explanatory variables. The study did not take into account developments in mail order or Internet use as substitutes for paper products up to 2050.

However, it is possible to evaluate the estimation results taking qualitative factors into account. The assessment of future developments should include the structural changes that have already taken place in the course of previous developments.

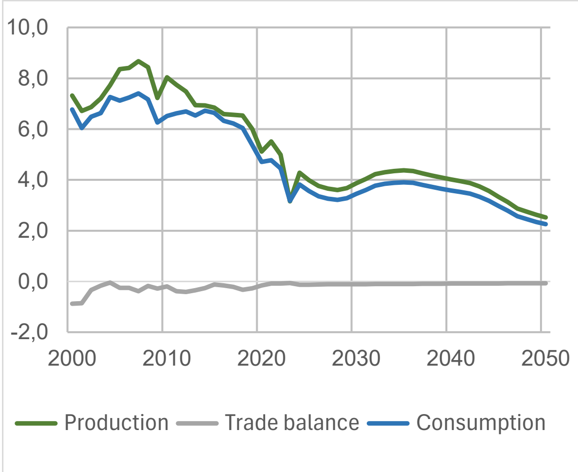
The starting year was derived in line with scenarios for other markets using the five-year average. It should be noted that this is not a forecast for 2024. Instead, the starting year should be assessed in terms of whether it is a reasonable starting point for the development of the scenario period.

Figure 4-33: Development and scenarios for paper market products in million tonnes

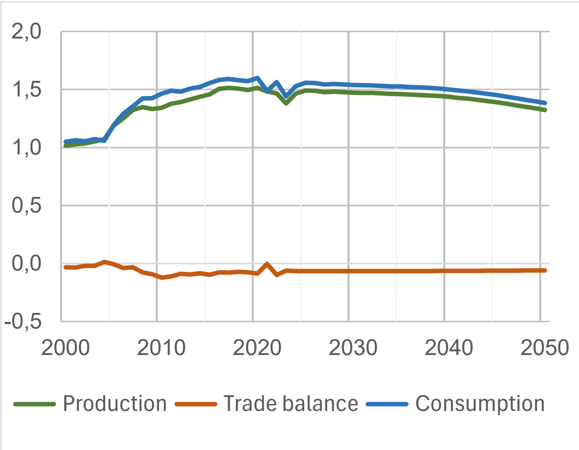
Newsprint



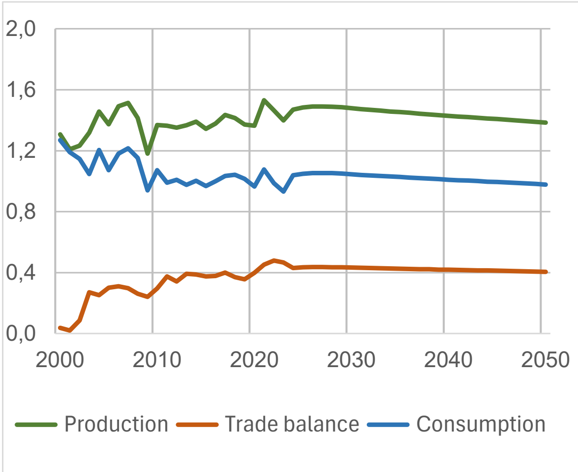
Writing and printing paper



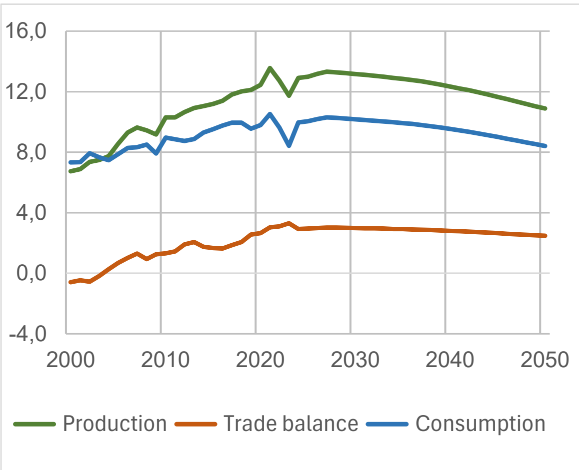
Hygiene paper



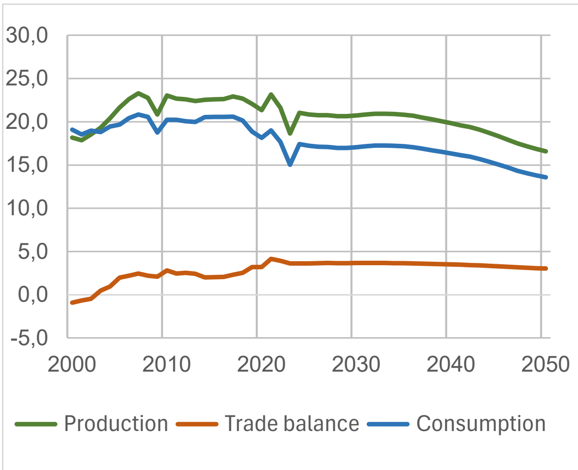
Speciality papers



Packaging paper



Paper, total



Source: The paper industry (2024) and TRAW scenarios

Scenarios

A significant decline in the production of newsprint was recorded between 2010 and 2020. From 2019 onwards, despite the economic downturn, the trend levelled off. This suggests that the majority of the structural change has already taken place. Further developments will follow the downward trend in the share of private consumption in GDP.

In terms of structural change, it can be said that an advanced process is already underway in the writing and printing paper sector.

The current low point is a special economic effect and therefore not suitable for long-term scenarios. The temporary upturn in the years 2025 to 2035 may not be immediately apparent. In addition to the share of private consumption in GDP, the significant estimates are also based on the development of the 25 to 55 age group (see Figure 3-6). This group is growing due to immigration and subsequent births. As a result, this leads to an increase in potential growth.

Scenarios

Hygiene paper products are mainly used for private consumption and are attributable to the number of households. They are largely basic necessities and are therefore not very sensitive to economic cycles. Their development is steady and tends to decline in line with private consumption and the number of households.

Speciality papers are more dependent on economic growth, but demand for them is more stable due to the high quality of the products.

Packaging paper experienced a significant upturn between 2000 and 2020 in the context of online retail. A structural break is already apparent in the latest data and will lead to a moderate decline in the long term.

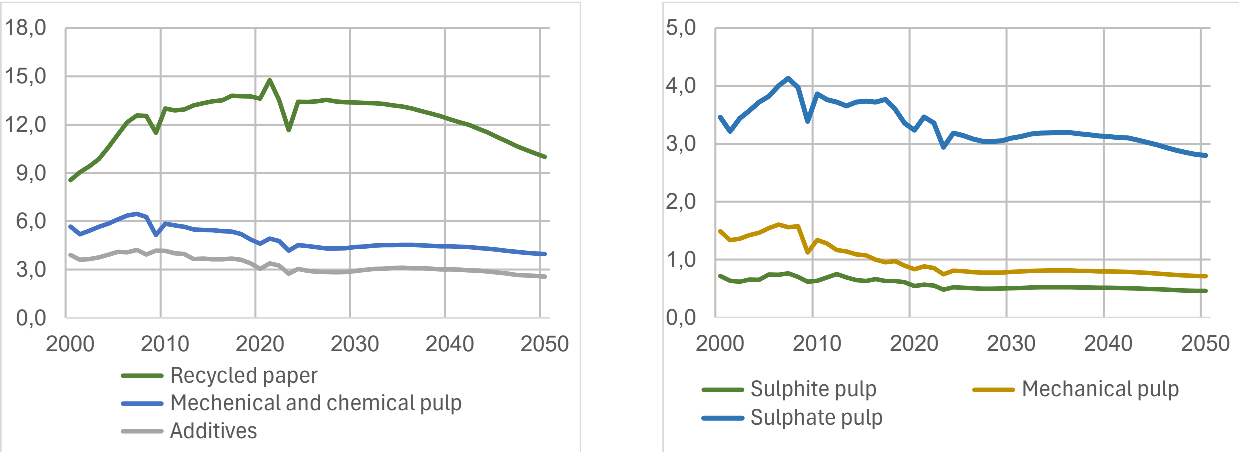
The different developments in the paper production segments partially offset each other. Production is expected to remain largely stable until 2040. The last decade has seen a significant increase in the downturn. This trend can be attributed to the estimated parameters of demographic development and developments in the share of private consumption, imports and exports.

Semi-finished products input

In 2020, the paper industry used 63.7 % wastepaper, 14.3 % additives and 22.0 % chemical pulp. Wastepaper accounted for 72.8 % of fibre materials (excluding additives), while fresh fibres accounted for 27.2 %. Sulfate pulp accounted for the largest share of wood fibre materials at 70.1 %, followed by mechanical pulp at 18.0 %, sulfite pulp at 11.7 % and other chemical pulps at 0.2 %. The average use of mechanical and chemical pulp between 2019 and 2023 was approximately 4.7 million tonnes. Of this, 3.3 million m³ was sulphate pulp, 0.6 million tonnes was sulphite pulp and 0.8 million tonnes was mechanical pulp.

Figure 4-34: Development of wood use by semi-finished product group in million tonnes

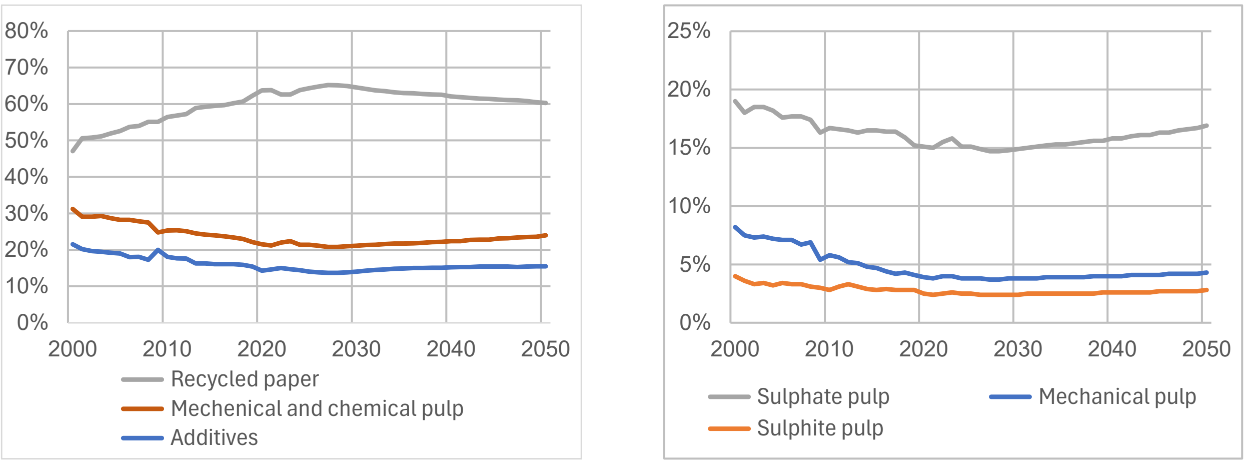
Input materials for paper production | **Mechanical and chemical pulp**



Source: The Paper Industry (2024) and TRAW scenarios

Figure 4-35: Development of wood use by semi-finished product group in million tonnes

Input materials for paper production in % | **Mechanical and chemical pulp in %**

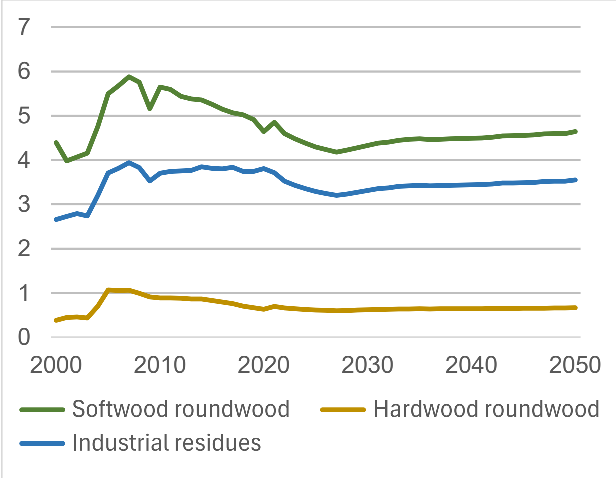


Source: The Paper Industry (2024) and TRAW scenarios

Figure 4-36: Development of wood use by raw material used in million m³$_{swe}$ (excluding waste paper)

Developments, cumulative

Developments, comparing



Source: The Paper Industry (2024) and TRAW scenarios

Raw material input

The apparent contradiction between a slight decline in semi-finished products input and a slight increase in raw material input can be explained by the different developments in product ranges with a high proportion of wood and pulp or a high proportion of wastepaper. While product ranges with a high pulp content are stable or increasing slightly, those with a high wastepaper content are declining. This opposite trend is reinforced by the conversion factors (sulphite pulp 4.700 and sulphate pulp 2.480).

In 2020, 58.1 % of other wood in the rough and 41.9 % of wood residues were used for the production of mechanical and chemical pulp. In 2020, a total of 9.1 million m³$_{swe}$of wood raw materials were used. Economically, demand will decline until 2030 (8.3 million m³$_{swe)}$) and then rise moderately (8.9 million m³$_{swe}$), partly due to the higher proportion of pulp in hygiene and speciality papers.

Table11: Scenario for wood use in the paper sector by wood raw material in million m³$_{swe}$

m³(swe)	Wood in the rough		Other prim. biom.		Industrial residues		Total	
	in Mio.	in %	in Mio.	in %	in Mio.	in %	in Mio.	in %
2020	5,273	*58,1*	0,000	*0,0*	3,807	*41,9*	9,080	*100,0*
2030	4,947	*59,9*	0,000	*0,0*	3,314	*40,1*	8,261	*100,0*
2040	5,133	*59,9*	0,000	*0,0*	3,439	*40,1*	8,572	*100,0*
2050	5,304	*59,9*	0,000	*0,0*	3,553	*40,1*	8,857	*100,0*

Source: The paper industry (2024) and Mantau (2025)

4.5 New bio-based wood products

Definition

Product environment

Numerous research projects are currently being conducted on products based on the chemical building blocks of wood (cellulose, hemicellulose, lignin). Innovations are expected in the area of lignin in particular. At this point in time, it is not possible to make precise predictions regarding the market maturity or quantitative significance of these products.

UPM's biorefinery in Leuna could provide guidance for future planning of raw material use for wood-based plastics and their precursors (raw material use: 500,000 cubic metres of beech per year for a production volume of 220,000 tonnes). The product range there, consisting of Bio-MEG, Bio-MPG, RFF and industrial sugar as a by-product, could substitute products based on other feedstocks. Based on the feedstock input and product mix in Leuna, a numerical basis for scaling up would be available, even for a significantly higher feedstock input (several times that of the production site in Leuna).

Although it would also be conceivable to model carbon fibres from wood (polyacrylonitrile), for example, the lack of a market breakthrough to date makes it difficult to estimate the market potential. Another option for modelling would be the use of cellulose solutions. Cellulose fibres in particular are already produced in significant quantities worldwide and are well established on the market. Corresponding applications are also conceivable at production sites in Germany. (Knauf Consulting 2024)

Definition

The term "new bio-based wood products" refers to product developments based on wood raw materials and residues. In the context of this study, the term refers to the chemical processing of wood raw materials into platform chemicals, plastics and polymers, pharmaceuticals and fibres for specific applications, such as in textile production.

Data

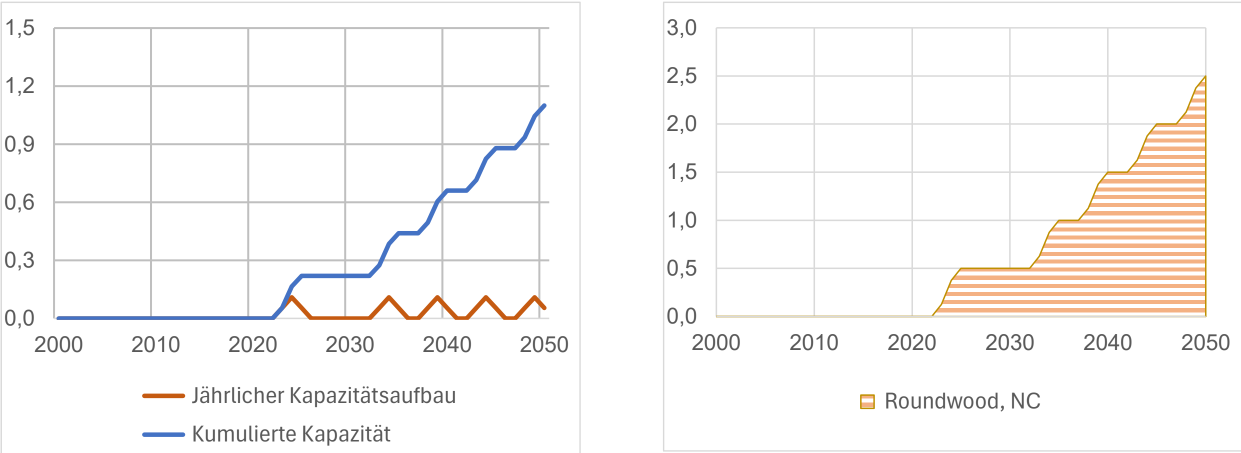
As these are predominantly new products, no official statistical data is currently available. In addition, it is possible that the products are classified in other chemical product categories and therefore cannot be separated. In accordance with the working hypothesis presented above, the scenario framework provides for the construction of additional biorefineries with a capacity of five plants each, as exists in Leuna. The wood feedstock used comprises exclusively other hardwood waste.

Expectation

As part of the Delphi study, the following hypothesis was put forward for evaluation: "The production of bioplastics/chemical raw materials will be of great importance in 2040." Fourteen percent rated this as "very likely", 41% as "likely", 23% were unsure, 6% rated the statement as "probable" and 4% considered it "very unlikely". This can be seen as qualitative confirmation of the assumed development.

Figure 4-37: Scenario for capacity and wood use for wood-based chemicals

Capacity development **Wood use in million m³$_{swe}$**



Source: Knauf (2024)

Scenario

Capacity expansion will begin with the completion of the plant in Leuna and continue every five years with the addition of a new plant. Each plant will have a construction period of three years and be commissioned in stages. This will result in a production capacity of 1.1 million tonnes by 2050. The figures provided by the Leuna biorefinery were used as the conversion factor for wood use. With a production of 220,000 tonnes, this would correspond to the use of 500,000 m³($_{swe}$) of hardwood (beech) and a conversion factor (t to m³) of 2.273. The expansion of production capacity to 1.1 million tonnes would thus correspond to 2.5 million m³($_{swe}$).

4.6 Other uses of wood (residual quantity)

Preliminary remark

Discrepancies may arise when different calculation methods are used. This problem is particularly evident in the present case, where the semi-finished products used in the finished goods sector can be compared in their entirety for the first time with the German Federal Statistical Office's semi-finished product statistics and the Wood Resource Monitoring (Rohstoffmonitoring). In this case, determining the deviation between the values represents the real challenge. One possible reason for these differences is that foreign trade flows in the construction sector can't be calculated using the calculation basis for buildings. For the furniture and paper sectors, however, this calculation could be done. Plus, there are areas of use that haven't been covered yet, like brushes, toys, and coffins.

Other uses

The following sectors of finished products were quantified in this study:

- Construction
- Furniture
- Packaging
- Paper
- New bio-based products

At the semi-finished product level, wood use can be determined in full and compared with raw material input. However, the sectors of finished products examined do not represent all material wood uses.

The use of wood for energy purposes is considered to be fully recorded, which, considering the household and biomass plant sectors, should also correspond to the actual use of wood energy.

The total amount of wooden semi-finished products used as material is determined by Wood Resource Monitoring. The quantity of finished products calculated can be subtracted from the raw material input in the semi-finished product sector. The residual quantity of raw materials determined in this way corresponds to the raw materials previously over- or under-recorded in the finished product sector.

The future development of unrecorded sectors is extrapolated on the basis of the growth rate of the recorded sectors. It is therefore assumed that the unquantified quantities of raw materials will develop in future in line with the quantities of raw materials determined in the finished product sector. Furthermore, it is assumed that the composition of feedstocks in the other unaccounted sectors will be similar to that in the accounted sectors.

The residual quantity for the period 2021 to 2050 is determined on this basis. This approach extrapolates the dynamics of wood demand using the sum of the individual sectors of finished products.

Determination of the delta of the calculation systems

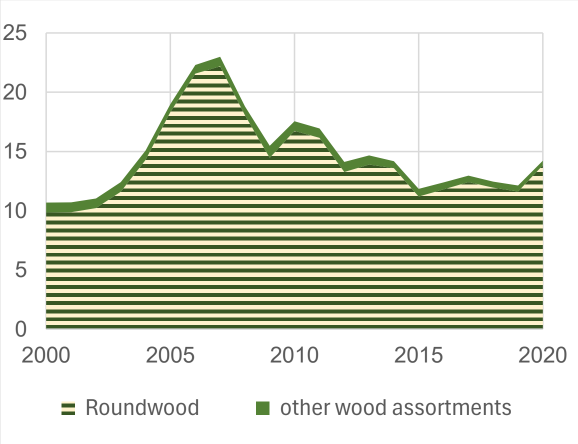
On average, between 2000 and 2020, an unspecified volume of 14.8 million $m^3_{swe}$was recorded in the end-use sector. This value corresponds to a share of 22.7% of material wood use. For the period from 2021 to 2050, an average volume of 15.4 million m³swe was determined for the end-use sector. This corresponds to a share of 26.0% of material wood use.

Surpluses and deficits

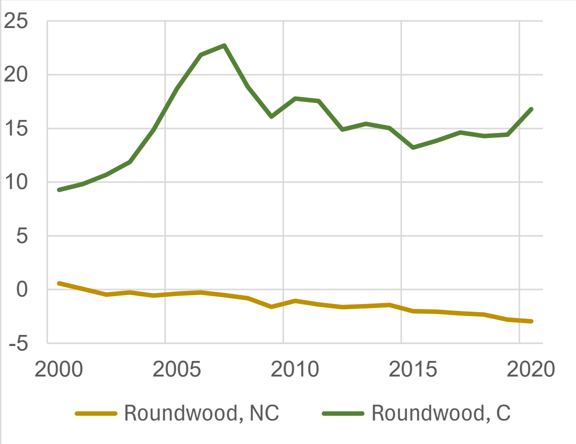
The difference between the calculations at the semi-finished and finished goods level consists of positive and negative deviations. A positive deviation means that the calculations at the semi-finished goods level show more wood uses (coniferous roundwood) than at the finished goods level. A negative deviation means that the calculations at the finished goods level show more wood uses (hardwood roundwood) than at the semi-finished goods level. This is not an error, but rather a finding that raises questions for further clarification of the differences.

Figure 4-38: Development of unspecified other wood uses by raw material group used in million m^3_{swe}(excluding waste paper)

Developments, cumulative



Developments, comparing



Source: Mantau (2025)

Causes of the delta

What are the possible causes of the differences between the calculations at the semi-finished and finished goods levels?

- Sectors of use not yet determined (toys, household goods)
- Foreign trade in semi-finished products: The increase in net exports of softwood sawn timber is due to a use at the semi-finished product level, but not at the finished product level.
- Foreign trade in finished products: The mega-product construction is calculated on the basis of buildings. The compressed product structure of 135 products contains domestic and foreign goods (e.g. plywood, parquet flooring). The origin cannot be determined from the tender documents and is generally not known to the respondents. The foreign trade share of building materials can only be determined in more detail through a very complex foreign trade analysis of the goods.
- The negative balance in the hardwood sector is probably a consequence of high domestic processing costs, which lead to a higher proportion of hardwood in finished products than in semi-finished products.
- The packaging sector has only been examined in terms of its product structure and the quantities of wood used in it in an

exemplary manner. This means that there may still be changes in the quantities of wood used.

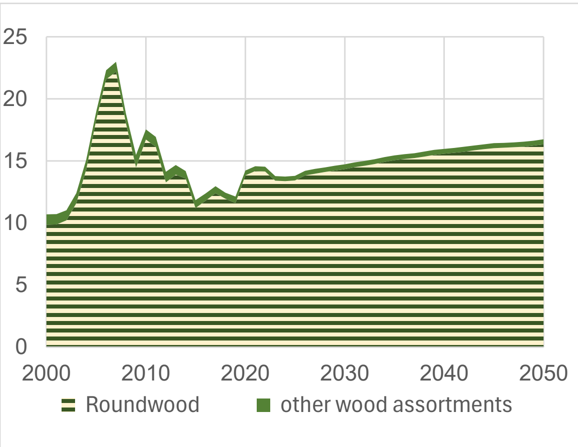
- In principle, the large number of usage indicators is part of the mathematical uncertainty. Empirically supported indicators were used.
- Further quantification of data will reveal further explanatory approaches. However, this is beyond the scope of the DIFEN project.

Update

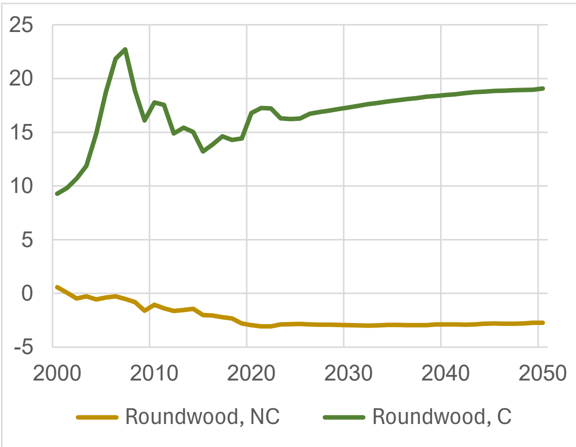
For the years 2000 to 2020, the development of wood use follows the raw material mix of the Wood Resource Monitoring. The year 2020 is the base year for the projection. It is assumed that the quantities of raw materials used will develop in line with the sectors of finished products as a whole. This results in a total quantity of raw material input. The difference between the total quantity and the specific sectors of finished products is the quantity of wood use that has not yet been specified in more detail. It thus corresponds to the complete recording of all raw materials in the semi-finished product sectors and the unrecorded partial quantity in the finished product sectors.

Figure 4-39: Development and updating of unspecified other uses of wood by raw material group used in million m³$_{swe}$(excluding waste paper)

Developments, cumulative



Developments, comparing



Source: Mantau (2025)

4.7 Total material wood use

Semi-finished products input

Definition

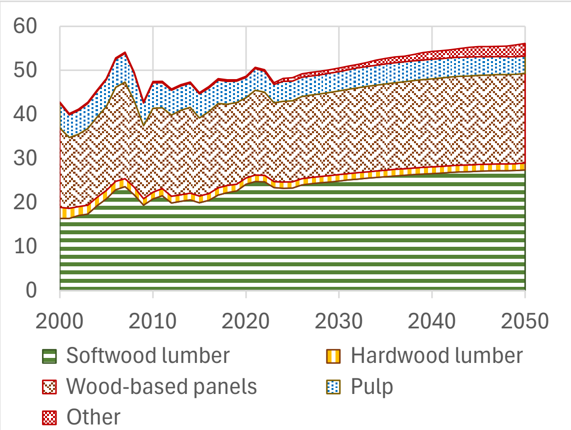
The use of wood raw materials for the production of wooden semi-finished products is taken from the Wood Resource Monitoring for the period 2000 to 2020. For the period from 2021 to 2050, an update is made based on the development of wooden semi-finished products in the construction, furniture and packaging sectors. The development of demand for mechanical pulp and chemical pulp is determined by the demand for the corresponding semi-finished products in the segments of the paper market.

Development and scenario for semi-finished products

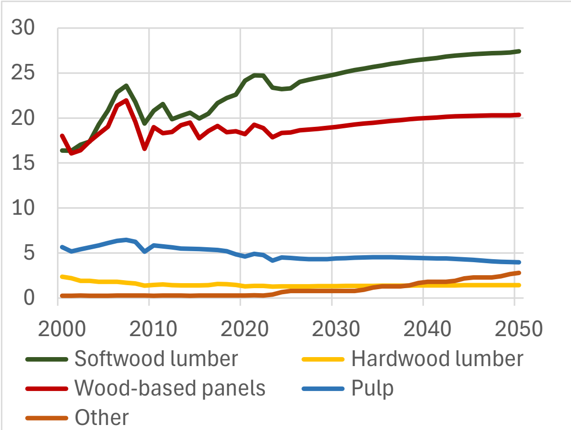
In 2020, the volume of wooden semi-finished products produced amounted to 49.6 million m^3_{swe}. Of this, 49.6 % was coniferous sawn timber, 2.9 % was hardwood sawn timber, 37.4 % was wood-based panels, 9.5 % was mechanical and chemical pulp and 0.6 % was other (used wood, new bio-based products). The volume will rise to 56.1 million m^3_{swe} by 2050, mainly due to developments in remodelling and civil engineering. This corresponds to an increase of 6.5 million m^3_{swe}) or +13.1 %. A look at the development of individual wooden semi-finished products shows that the increase is mainly attributable to softwood, which is primarily used in the construction sector.

Figure 4-40: Wood use for material wood semi-finished product production in million m^3_{swe}

Developments, cumulative



Developments, comparing



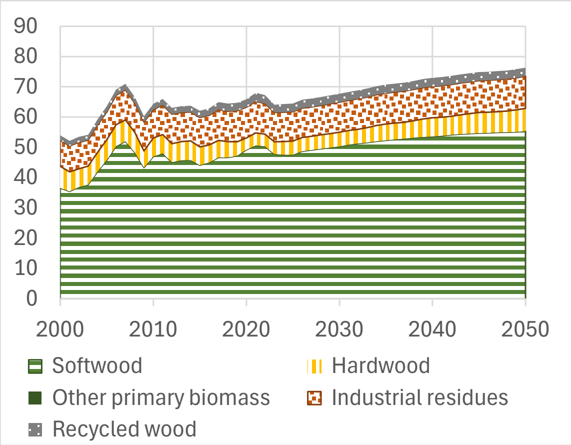
Source: Mantau (2025)

Development and scenario for raw materials

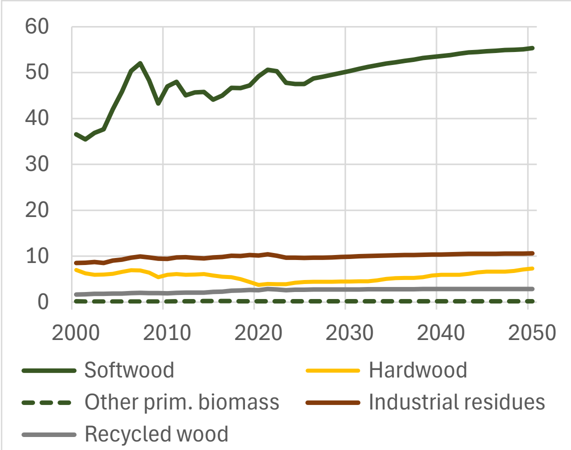
In 2020, the volume of wood raw materials used (excluding other) amounted to 65.9 million m^3_{swe}. Of this, 74.6 % was softwood roundwood, 5.7 % was hardwood roundwood, 0.2 % was other primary biomass, 15.4 % was industrial wood residues and 4.0 % was waste wood and used wood. The volume of raw materials used will rise to 76.3 million m^3_{swe} by 2050. This corresponds to an increase of 10.4 million m^3_{swe} or +15.8 %. The development of the individual raw wood assortments show that softwood is more important than sawn timber, accounting for 74.6 %. This difference can be explained by calculating back to solid wood equivalents, which increases the roundwood input by the yield (factor approx. 1.67).

Figure 4-41: Raw wood input for material wood use in million m³$_{swe}$

Developments, cumulative



Developments, comparing



Source: Mantau (2025)

Table12: Raw wood use for material wood use in million m³$_{swe}$ (excluding other)

m³(swe)	Round-wood, C	Round-wood, NC	Other prim. raw materials	Industrial residues	Waste and used wood	Total
2020	49,185	3,755	0,163	10,179	2,620	65,903
2030	50,338	4,500	0,171	9,899	2,771	67,680
2040	53,601	5,952	0,178	10,387	2,843	72,961
2050	55,345	7,314	0,180	10,648	2,849	76,337

Source: Mantau (2025)

5. Uses of wood energy

5.1 Wood use for energy wood products

Definition

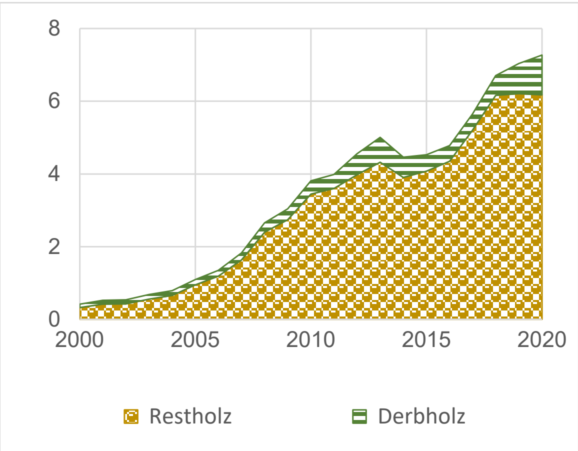
Energy wood products include pellets, wood briquettes and other wood raw materials that undergo processing before being used for energy. In the case of wood chips, these data can only be collected via their use. This may be wood residues that have already been chopped or processed wood chips.

Energy wood products are similar in calculation to semi-finished products for material use. For calculation reasons, the production of energy wood products was initially recorded and updated in a separate segment. The raw materials for these products were ultimately allocated to total energy wood use. To avoid double counting, the respective energy wood users were initially taken into account without the use of energy wood products.

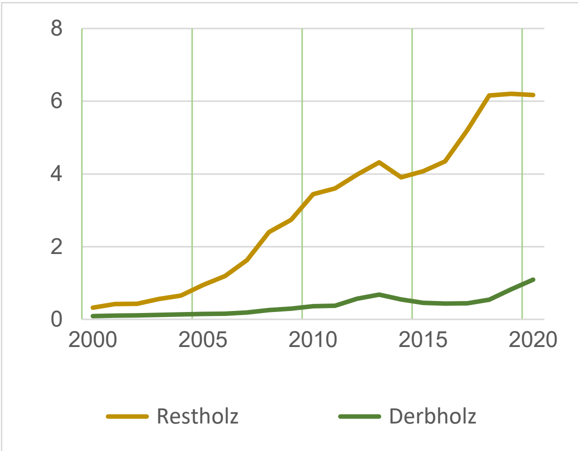
The use of energy wood products was then allocated to the respective users. This makes the fuel input visible in its form at the place of use. The raw materials used for energy wood production are recorded at the place of processing and their raw material input is allocated to the raw materials used for energy.

Figure 5-1: Raw material input for the production of energy wood products in million m³$_{swe}$

Developments, cumulative



Developments, comparing



Source: Mantau (2023a) and Henneberg et al. (2022)

raw material input

Sawmill by-products

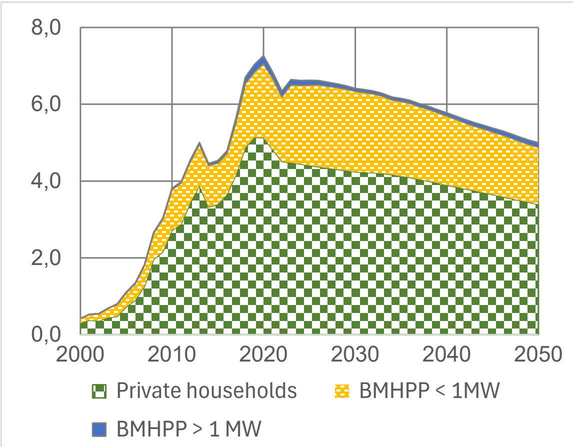
Sawmill by-products are mainly used, as sawdust can be pressed directly into pellets without further processing. Other coniferous roundwood accounts for around ten percent. Fluctuations may occur due to shortages or price shifts. Between 2000 and 2020, sawmill by-products accounted for 87.0 % of raw material input. For the scenario period, the share for 2021 was assumed to be 89.7 % sawmill by-products and 10.3 % coniferous roundwood.

Scenario

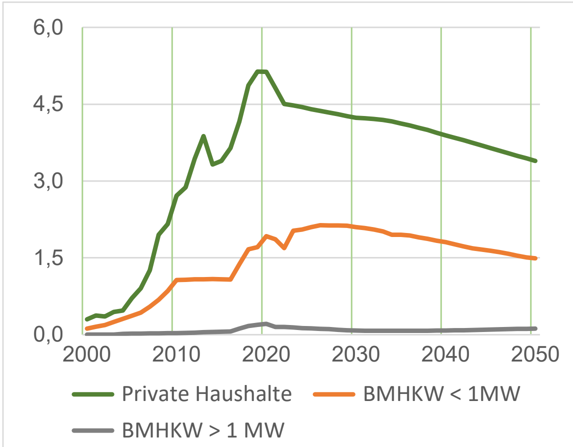
For further development, the share of energy wood products in the respective areas of use was kept constant. In 2020, of the 7.3 million m³$_{swe}$ used, 70.6 % was used in private households, 26.5 % in municipal and small commercial installations and 2.9 % in large installations. The uses follow the development of the sector as a whole. The sensitivity analysis examines the impact of substituting roundwood and wood residues with larger shares of energy wood products.

Figure 5-2: Scenario for raw material input for the production of energy wood products in million m^3_{swe}

Developments, cumulative



Developments, comparing



Source: Mantau (2023a) and Henneberg et al. (2022)

5.2 Energy wood use in private households

Definition

Federal Statistical Office

A private household is defined as persons who live together and share finances, who generally finance their livelihood together or share household expenses.

Dwellings are rooms that are closed off from the outside and are usually connected to each other, which can be used for living and sleeping. The actual use is not decisive here. The dwelling may currently be unoccupied or only used as a leisure or holiday home.

Procedure and assumptions for the calculations

The calculations are based on occupied residential units with active heating (39.3 million households in 2020).

Of these, 11.6% were single-fire heating systems (SHS) and 2.9% were wood-fired central heating systems (CHS) in 2020. (Thünen Household Study 2020)

Their average annual consumption (based on the 2018 (RM) and 2020 (TI) surveys) was 3.95 m³ for SHS and 9.00 m³ for CHS.

Thanks to efficiency gains and a decrease in the influence of cold weather (heat demand), average consumption will fall to 2.93 m³ for SHS and 4.73 m³ for CHS.

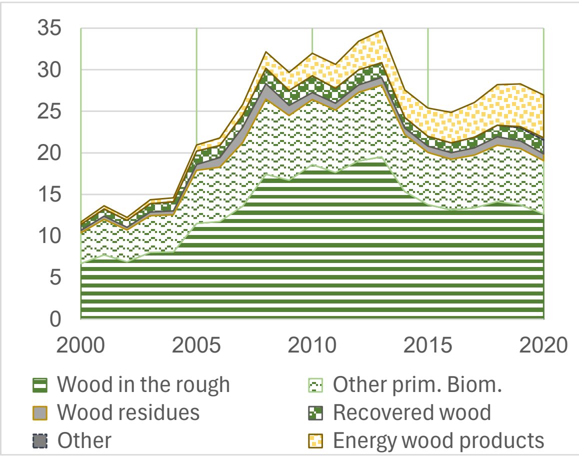
In 2050, 10.0% of households will still have an SHS and 3.1% a CHS (Hennenberg et al. 2022).

Previous development

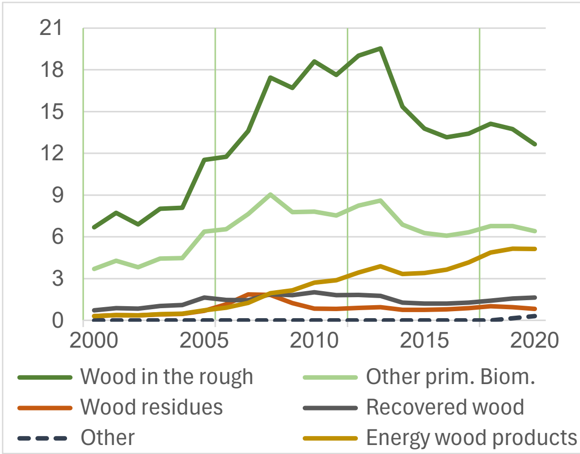
Until the mid-1990s, annual use rose only slowly (+0.9 %). Only reunification led to a jump in levels (+36.5 %) as a result of an expansion in the total number of households. During this phase, traditional firewood use dominated. From 2000 onwards, significantly higher growth rates emerged. These were a consequence of emerging support measures and sharply rising energy prices. The dramatic oil price increases from 2005 onwards led to a corresponding upturn in firewood use. The energy and timber markets merged during this period. Between 2009 and 2013, use grew more slowly and was also affected by cold winters (e.g. 2010). This was followed by a significant decline in demand for energy wood in individual combustion systems. The environment is characterised by stricter emissions regulations, moderate energy prices and warmer winters (Mantau 2023).

Figure 5-3: Energy wood use in private households in million m^3_{swe}

Developments, cumulative



Developments, comparing



Source: Jochem/Morland/Glasenapp/Weimar (2023), Mantau (2023a)

Raw material input

In 2020, private households used 12.7 million m^3_{swe} of wood, mainly splitwood, with 62.4 % coming from hardwood trees and 37.6 % from softwood. Splitwood accounted for 60.4% of the total, while other types made up the remaining 39.6 %. Other primary biomass sources include landscape care wood, which consists mainly of garden wood, and forest residues, which contain branches and logs. The total amount of landscape care wood amounted to 2.6 million m^3_{swe}, while the amount of forest residues amounted to 2.5 million m^3_{swe}. In addition, there is an additional 1.3 million m^3_{swe} of bark adhering to splitwood. Residual and waste wood will amount to a total of 2.5 million m^3_{swe} in 2020. The raw material composition was kept constant during the scenario period.

Energy wood products

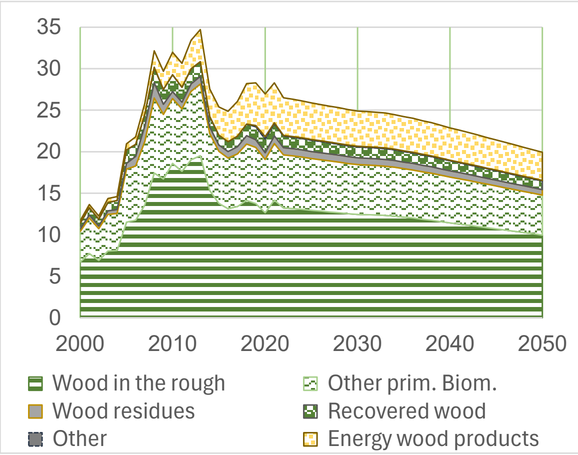
Energy wood products include pellets, wood briquettes and other wood raw materials that are processed before being used for energy. In the case of wood chips, this data cannot be collected by the producers, but by the users. This may be wood residues that have already been chipped or processed wood chips.

Energy wood products are comparable in terms of calculation to semi-finished products for material use. For calculation reasons, the production of energy wood products was initially recorded and reported in a separate segment. Their raw materials were ultimately allocated to energy wood use. The respective energy wood users were therefore calculated without pellets.

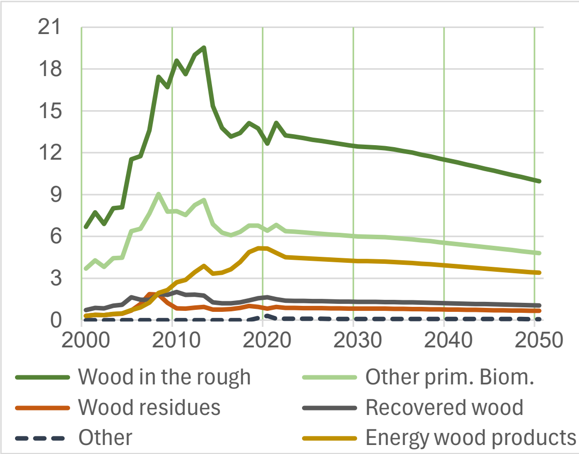
The following figures show the raw materials used and the pellets as a separate fuel. The preparation of the data therefore depends on the problem and the desired differentiation. The total number of end users is shown below. Only directly used raw materials and pellet production as a separate product range are included in the total energy wood usage.

Figure 5-4: Scenario for energy wood use in private households in million m³$_{swe}$

Developments, cumulative



Developments, comparing



Source: Jochem/Morland/Glasenapp/Weimar (2023), Mantau (2023a), 023a), Henneberg et al. (2022)

Scenario

The trend continues. The assumptions of the scenarios lead to a decline in wood energy use in single-burner systems, which will fall from 18.1 million m³$_{swe}$ to 13.5 million m³$_{swe}$ in private households between 2020 and 2050 in SHS.

Wood use in wood-fired central heating systems will initially increase from 8.9 million m³$_{swe}$ in 2020 to 10.3 million m³$_{swe}$ in 2030 due to system expansion. After that, efficiency gains and the declining influence of cold weather will lead to a decline in wood use to 6.7 million m³$_{swe}$ by 2050.

Overall, this will lead to a decline in energy wood use in private households from 21.8 million m³$_{swe}$ in 2020 to 16.5 million m³$_{swe}$ in 2050.

energy wood products

Energy wood products include pellets, wood briquettes and other wood raw materials that are processed before being used for energy. In the case of wood chips, this data cannot be collected by the producers, but by the users. This may be wood residues that have already been chipped or processed wood chips.

5.3 Energy wood use in large combustion plants (CHO > 1 MW)

Definition

Data collection structure

The distinction between biomass combustion plants in large combustion plants (>1 MW CHO, fire heat output) and small combustion plants (< 1 MW CHO) is for technical reasons. While the number of large combustion plants makes it possible in principle to record all plants (409 plants in 2020), this is impossible and also unnecessary for the approximately 45,000 small combustion plants/heating systems. Further details on the methodology can be found in the study by Döring/Weimar/Mantau (2021).

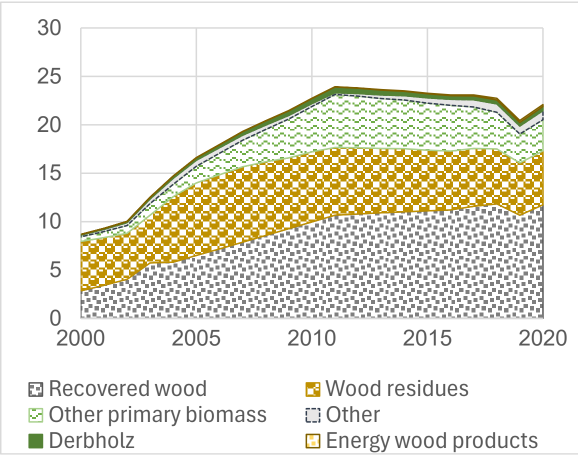
Development

Influence of the EEG

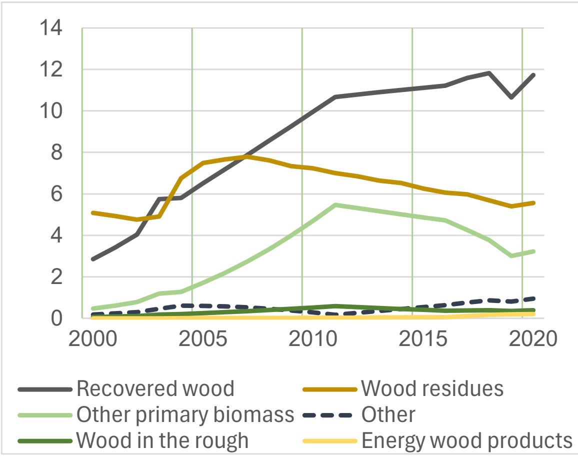
At the beginning of the development process, large combustion plants were mainly found in the pulp industry and in the traditional wood industry. The Act on the Sale of Electricity to the Grid and the Renewable Energy Act (EEG, 25 February 2000) led to a revival in the use of wood for energy. Fuel demand rose significantly from 2003 onwards, and capacity expansion continued until 2011. EEG subsidies for newly constructed plants were granted for 20 years. The moderate decline can possibly be explained by the fact that plants built early on are no longer eligible for subsidies or that repairs to older plants would no longer pay for themselves by the end of the subsidy period, leading to the plants being shut down. This is also supported by the decline in the number of plants (-18.8%) compared to the 2019 study. The 2019 survey year was an exception in that it 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. (Mantau 2024).

Figure 5-5: Energy wood use in biomass heat and power plants > 1 MW in million m³swe

Developments, cumulative



Developments, comparing



Source: /Weimar/Mantau (2021b), Mantau (2023a)

Key figures for wood use

Waste wood accounted for the largest share of wood assortments, with a consumption volume of 6.1 million tonnes (55.6%). Sawmill by-products (0.5 million tonnes) and other industrial residues (0.5 million tonnes) as by-products of the wood-processing and woodworking industries together accounted for 8.8 %. Forest residues also played a relatively important role, accounting for 1.0 million tonnes or 8.8 %. The consumption volumes of landscape care wood and loose bark amounted to 1.2 million tonnes and 0.6 million tonnes, representing shares of 10.5% and 5.5 % respectively. Forest roundwood accounted for 2.7 % with 0.3 million tonnes. The category "Other" (6.8 %) included wood resources that could not be defined more precisely, such as screen residues or wood chips of unknown origin (Döring/Weimar/Mantau, 2020).

Scenarios with further measures (MwMS) Scenario

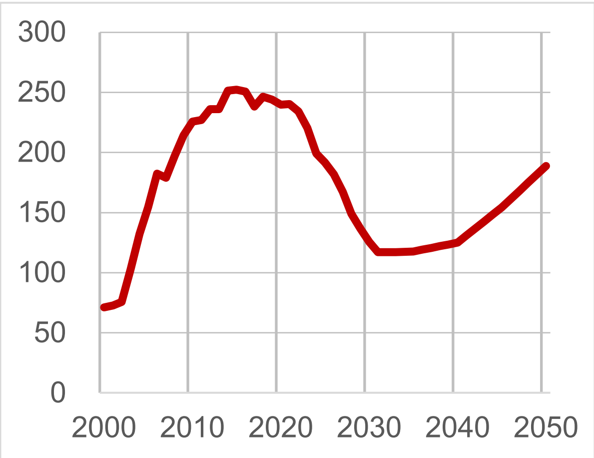
For the scenarios, the development of heat requirement (TJ) is based on the scenarios with further measures (MwMS) for solid fuels in the German government's projection report (Federal Environment Agency 2023). According to this, measures that are due to expire will not be continued. If support measures are foreseeable, they will be integrated into the scenarios. For large-scale installations (BMFA over 1 MW), the development of the energy industry is assumed in the MwMS. For BMFA under 1 MW, the development in the MwMS for the GHD sector (commerce, trade, services) is assumed.

Scenario

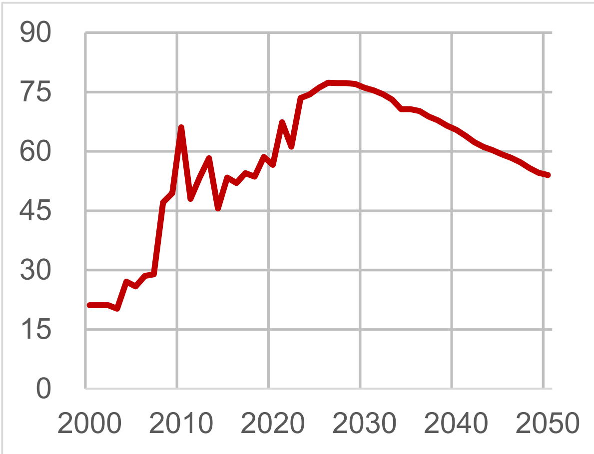
According to the assumptions of the Mit-weiteren-Maßnahmen-Szenario (MwMS) for biomass demand, there will be a significant decline in demand until around 2030. Demand will then level off before significant growth is expected again from 2040 onwards. Accordingly, demand for wood energy for large combustion plants is assumed to remain constant. The raw material composition will remain constant until 2050.

Figure 5-6: Development of biomass demand for energy production in biomass plants according to the 2024 greenhouse gas projection reports in TJ

Energy



Commerce, trade, services



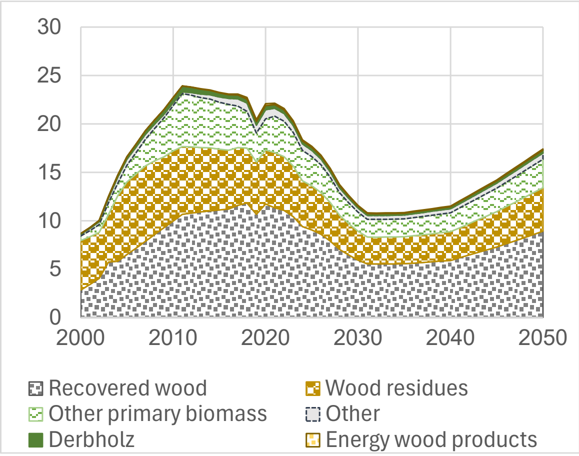
Source: Mantau (2023a) and Federal Environment Agency (2023)

Wood demand

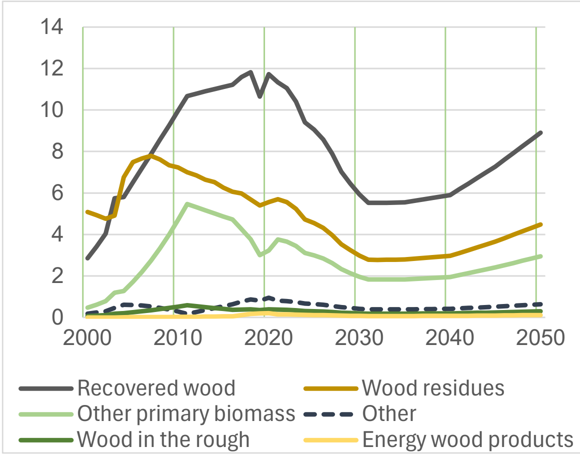
According to this, large combustion plants will reach a largely stable plateau of approx. 23 million m^3_{swe} between 2010 and 2020. By 2030, there will be a sharp decline to a level of approx. 11 million m^3_{swe}, which will remain largely constant until 2040. This will be followed by a continuous increase to 17 million m^3_{swe}.

Figure 5-7: Energy wood use in biomass heat and power plants > 1 MW in million m³swe

Developments, cumulative



Developments, comparing



Source: Döring/Weimar/Mantau (2021b), Mantau (2023a), Federal Environment Agency (2023), Mantau (2025)

5.4 Energy wood use in small combustion plants (CHO < 1 MW)

Definition

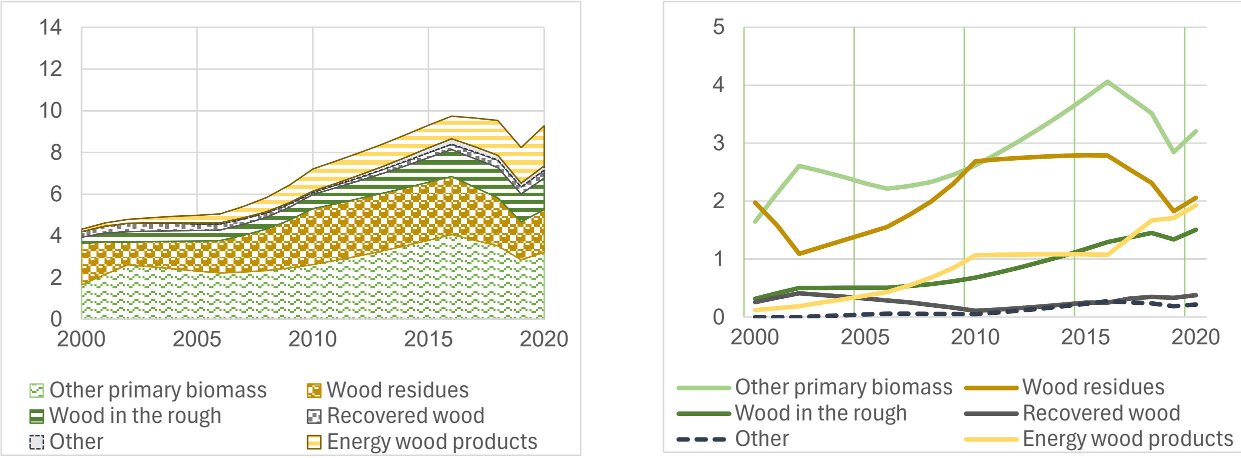
The term commercial encompasses all economic activities of private plants (trade, commerce, services and industry), not to be confused with the trade, commerce and services sector ("GHD" sector). The term "small combustion plants" refers to all combustion plants within the scope of the 1st BImSchV in which at least one fuel from fuel groups 4, 5, 5a, 6 or 7 according to §3 of the 1st BImSchV was used. Single combustion plants and all combustion plants with a rated heat output (NWL=RHO) of up to 15 kilowatts (kW) or a combustion heat output (FWL=CHO) of up to 17 kW were excluded from the analysis. It was assumed that these combustion plants are used almost exclusively in private households (Biomasseatlas 2020).

Development

Small combustion plants are mainly used in municipalities and commercial plants. Originally, they were probably mainly found in small wood-processing businesses. The EEG will bring about a change from 2020 onwards. Municipalities are also forest owners who operate heat-generating plants using forest residues. The share of industrial waste wood remains largely constant. With the introduction of a bonus for renewable raw materials (NAWARO 2012), the share of roundwood is growing. Energy wood products have been gaining in importance since 2000 (Mantau 2023a).

Figure 5-8: Energy wood use in biomass heat and power plants < 1 MW in million m^3_{swe}

Developments, cumulative | **Developments, comparing**



Source: Döring/Weimar/Mantau (2021a), Mantau (2023a)

Key figures for wood use

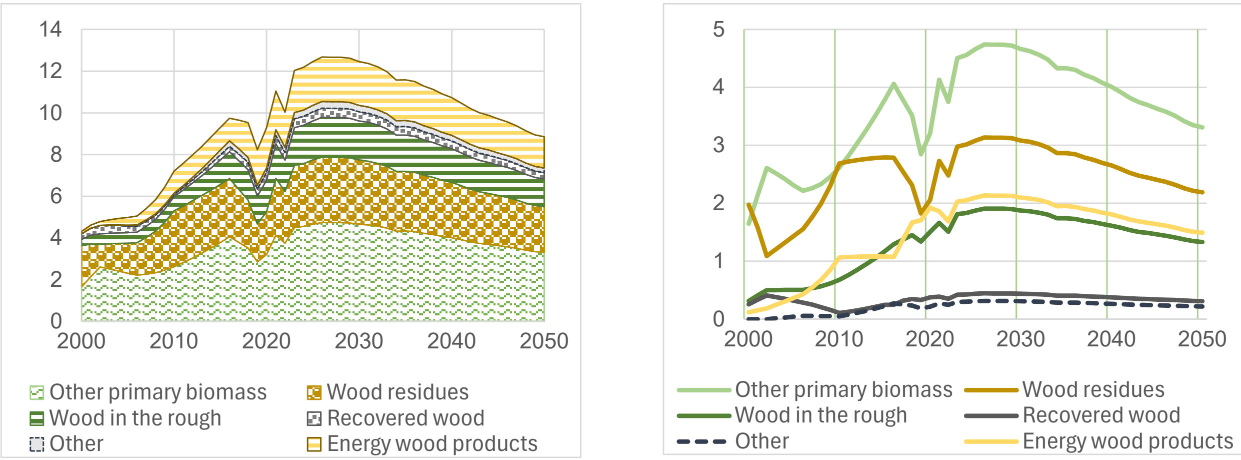
A comparison between the composition of raw materials in large combustion plants (Figure) and in small combustion plants (Figure) shows clear differences in the uses of raw materials. While waste wood plays a dominant role in the energy use of large combustion plants in 2020, it is hardly used in small 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.

Scenario

As already explained in the section on large combustion plants, overall wood use is based on the “With Further Measures Scenario” (MwMS) for biomass demand. The raw material composition is assumed to remain constant.

Figure 5-9: Energy wood use in biomass heat and power plants < 1 MW in million m^3_{swe}

Developments, cumulative | **Developments, comparing**



Source: Döring/Weimar/Mantau (2021a), Mantau (2023a), Federal Environment Agency (2023), Mantau (2025)

Wood demand

Small combustion plants will reach their highest wood demand between 2023 and 2033, with an average of 12.5 million m^3_{swe}. According to the specified scenario, wood use will then decline to 8.9 million m^3_{swe} by 2050.

5.5 Other uses of energy wood

Definition

General

Other uses of energy wood include energy wood uses that have not been assigned to the uses described above. There are currently two such uses.

Definition

Biofuel

As part of the promotion of renewable energies, the use of renewable feedstocks for transport was encouraged. Agricultural crops are primarily used for this purpose. Trials with wood were conducted in Germany by Sun-Diesel in Choren. These trials have since been discontinued. No consumption figures are currently available for this area. In the early years of the plant's construction in Choren, five plants with a capacity of 500,000 litres of biofuel each were under discussion. This would have meant an additional use of wood amounting to approx. 12.5 million m³swe. The example shows that this area can certainly become important and is therefore being kept as an open item.

Definition

Other wood briquettes

Wood briquettes did not appear in the statistics until 2018. The only source that systematically reported the use of wood briquettes in was the Wood Resource Monitoring in its studies on energy wood use in private households (Mantau 2023a). However, this only referred to use in private households. The household study for 2018 reported 0.564 million m^3_{swe} for wood briquettes and the study for 2020 reported 0.690 million m^3_{swe}. After conversion, this corresponded to 0.361 million t_{lutro} of wood briquettes.

Using the new production statistics system, the Federal Statistical Office reported on wood briquettes for the first time in 2020 for the year 2019 (GP19-162915003; Briquettes, or made from compressed sawdust and similar materials). At 0.841 million t_{lutro}, this corresponded to 1.605 million m^3_{swe}. The larger quantity could not be attributed to the users surveyed. However, as it corresponds to wood use, it cannot be disregarded.

A survey of selected manufacturers revealed a raw material input of 79.5% sawmill by-products, 16.5% other industrial residues and 4.0% forest wood. (Mantau 2023a).

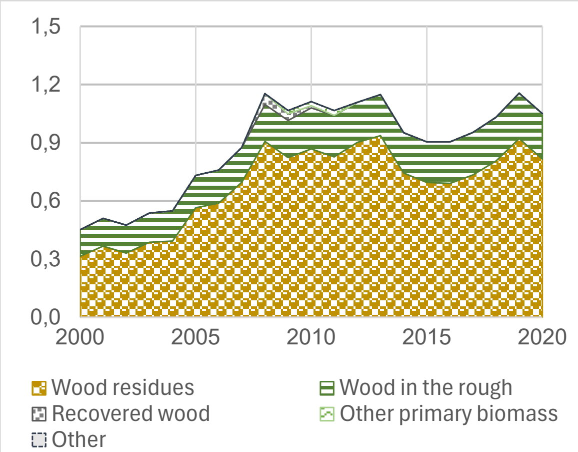
Development

The development is mainly determined by the simulated collection difference between 2000 and 2018. Between 2019 and 2020, it follows the calculated difference and is extrapolated from 2021 onwards using the 2020 value.

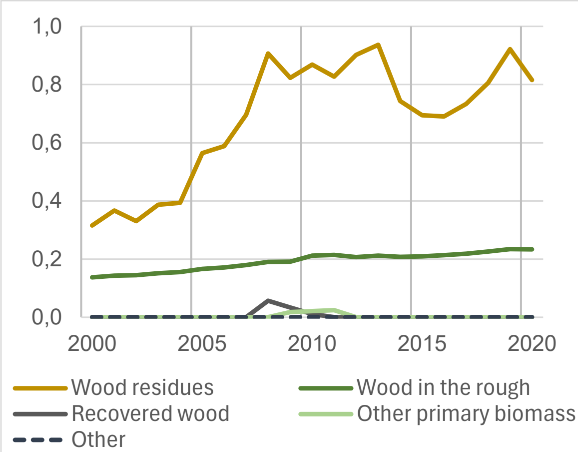
The presentation of the development and the following scenario refer to raw material input.

Figure 5-10: Energy wood use in other uses in million m³$_{swe}$

Developments, cumulative



Developments, comparing



Source: Mantau 2023a

Key figures for wood use

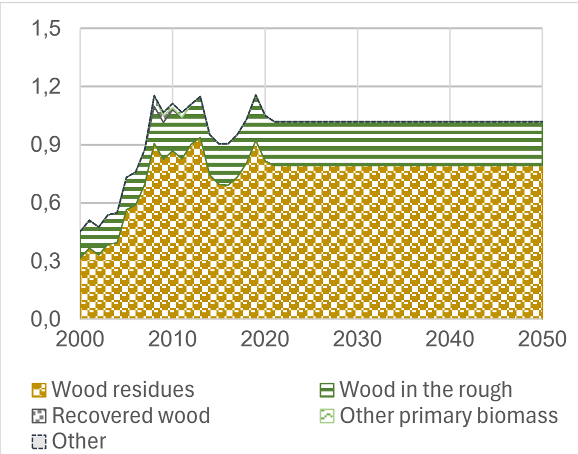
A survey of selected manufacturers revealed that 79.5 % of raw material input consisted of sawmill by-products, 16.5 % of other industrial residues and 4.0 % of forest wood. According to the available data, the share of sawmill by-products was 1.8 %, that of other industrial residues 7.5 % and that of forest wood 8.0 %. The total for all individual responses was 3.0 %. (Mantau 2024).

Scenario

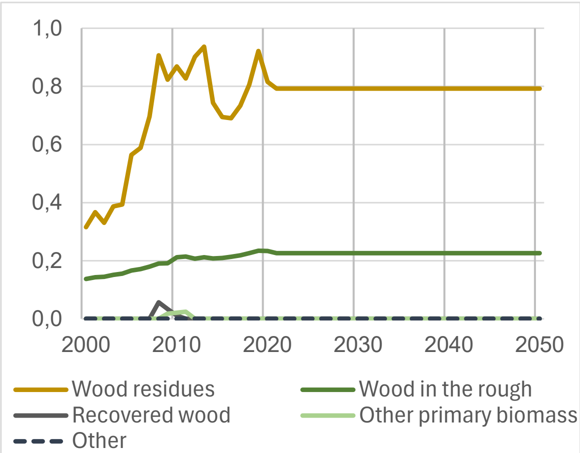
No specific assumptions were made for the scenario period, as the majority of the difference is due to a difference in data collection. It was extrapolated using the values for 2020.

Figure 5-11: Scenario for energy wood use in other uses in million m³swe

Developments, cumulative



Developments, comparing



Source: Mantau 2023a, Mantau 2025

5.6 Total energy wood use

Definition

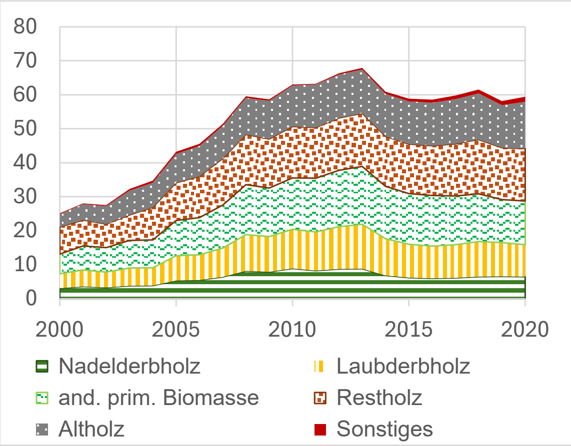
Energy wood use is fully covered by the segments described. The sum of the individual segments therefore corresponds to total energy wood use.

Development

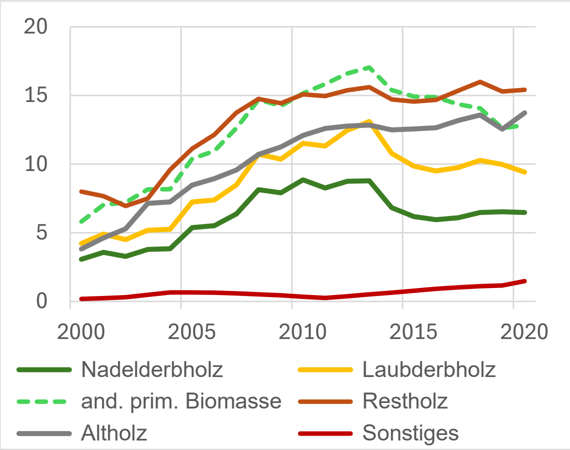
Energy wood use experienced a strong upturn in the first decade from 2000 to 2010. In the following decade, energy wood use stabilised at the level achieved. Expiring EEG support measures for large-scale installations and milder temperatures are leading to a decline in demand for energy wood.

Figure 5-12: Total energy wood use in million m^3_{swe}

Developments, cumulative



Developments, comparing



Source: Mantau 2023a

Key figures for wood use

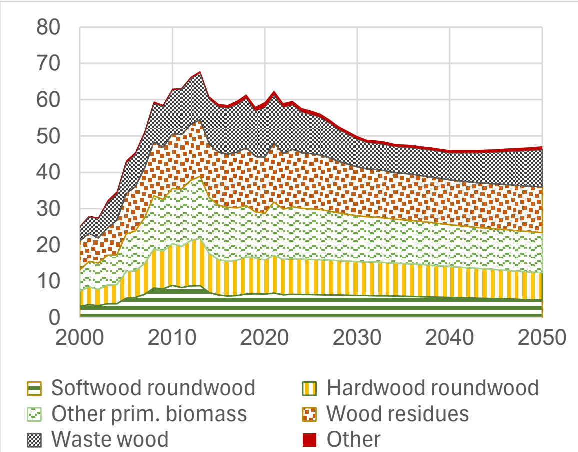
In 2020, the proportion of coniferous roundwood was 10.9% of energy wood use, while the proportion of deciduous roundwood was 15.9%. The proportion of wood in the rough thus accounted for a total of 26.8%. The proportion of wood in the rough amounted to a total of 26.8%. Other primary biomass accounted for 21.9%. Wood residues accounted for 26.0% and waste wood for 23.1%. The remaining 2.5% was accounted for by other raw materials.

Scenario

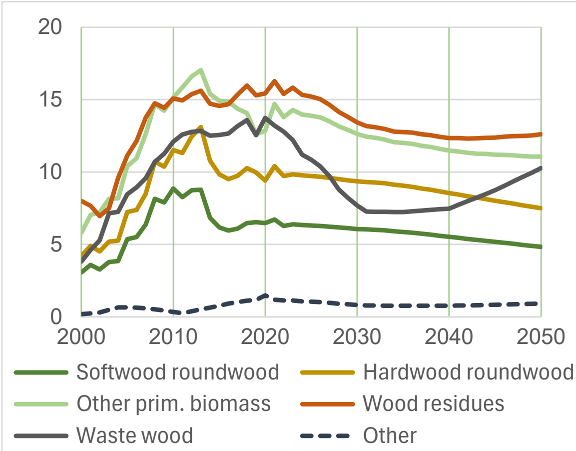
Even if the use of raw materials remains constant in the scenario, the proportions of the total may change due to different developments in the segments. The share of waste wood will initially decline sharply as the capacity of large combustion plants is reduced. Despite an increase later on, the share in 2050 will be 21.8%, which is below the share in 2020. Energy wood use will fall by 12.2 million m^3_{swe} from 59.4 million m^3_{swe} to 47.2 million m^3_{swe}. This corresponds to a decline of one fifth (20.5 %).

Figure 5-13: Scenario for total energy wood use in million m³$_{swe}$

Developments, cumulative



Developments, comparing



Source: Mantau 2023a, Mantau 2025

5.7 Total wood use

Definition

The total future use of wood is determined based on the recorded material wood use in the finished goods sector. Adding the total amount of wood used for energy purposes gives the specific amount of wood for end uses. The areas not yet specified or other phenomena not yet determined in the material sector are the difference between the fully recorded quantities in the semi-finished goods sector and the specified quantities in the finished goods sector.

Trend

Both material and energy wood use experienced a significant upturn in the period from 2000 to 2010. In the following decade up to 2020, both areas of use stabilised. The scenarios are initiated taking into account the data available for the years 2000 to 2023.

For the use of energy wood in biomass heat and power plants, the "Mit-weiteren-Maßnahmen-Szenarien" (MwMS) for solid fuels from the German government's projection report were used (Federal Environment Agency 2023). Analysis of the data suggests that wood use will decline significantly in the decade from 2030 to 2040. This decline is expected to bottom out in the 2040s, followed by a moderate increase.

The scenarios for material wood use were presented in detail for the individual sectors. Despite numerous differences between the individual sectors, the use of wood remains largely stable overall at the previous level. The increase shown is primarily attributable to use in building modernisation and civil engineering.

This means wood use will remain largely stable at around 120 million m^3_{swe} in the future. Although material and energy use of wood are expected to be largely balanced after 2010, there are already signs of a relative increase in the importance of material wood use. According to the scenarios, this trend will intensify until 2040. The share of material wood use will then be 62.3 % in 2050, with the demand for wood energy reaching 37.7 %.

Raw material shares

In 2050, 49.1 % of raw wood consumption will be softwood round wood in the rough and 12.1 % will be hardwood roundwood wood in the rough. These values are transferred to the forest modelling separately as logs (39.5 %) and other wood in the rough (21.7 %).

Industrial residues account for 19,0%, of which 14.7% is sawmill by-products, 1.8% is other industrial residues and 2.5% is black liquor. 10.7% is recycled wood, which consists of waste wood (10.5%) and used wood (0.2%). Other primary biomass accounts for 9.2%. Of this, landscape care wood accounts for 3.2%, short-rotation plantations 0.0%, forest residues 4.2% and bark 1.6%.

Figure 5-14: Wood use by main use in million m^3_{swe}

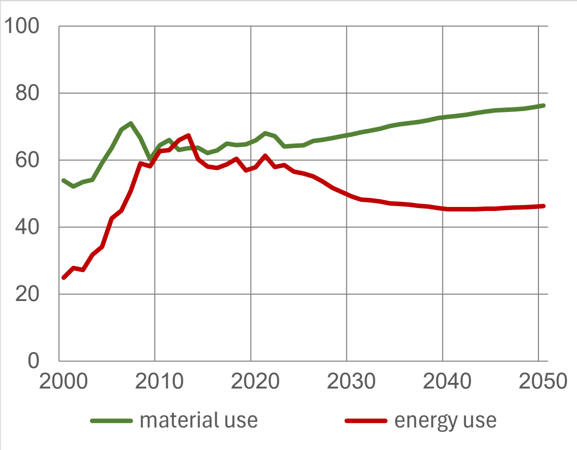
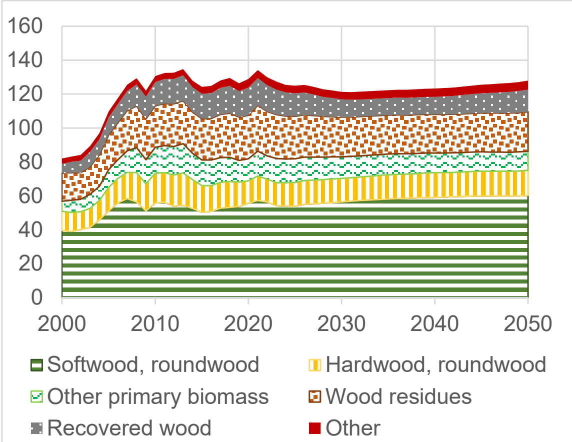


Figure 5-15: Wood use by raw material group in million m^3_{swe}



Source: Mantau 2023a, Mantau 2025

Presentation

The axes of the following graphs have been scaled identically. This allows them to be compared directly. The increase in coniferous trunk wood is a consequence of the expected growth in building modernisation and civil engineering. It should be noted that the growth rates assumed are lower than in the past. The changes in other raw materials are strongly influenced by the use of wood for energy.

Figure 5-16: Use of wood in the rough in million m^3_{swe}– Transfer to forest growth modelling (FABio)

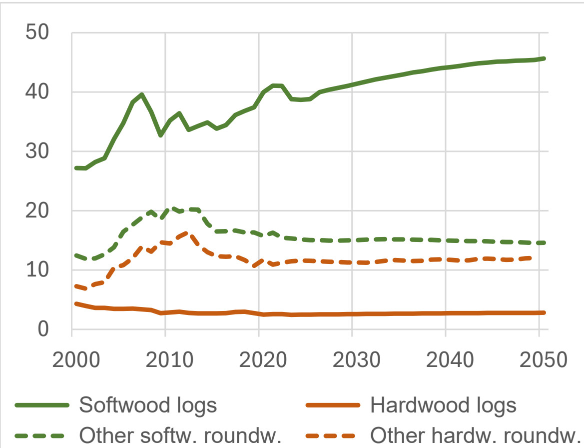
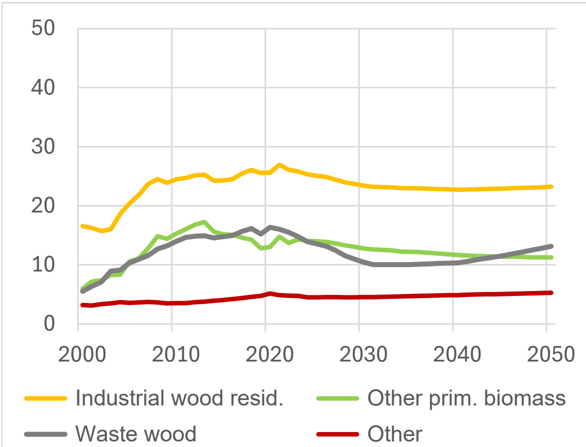


Figure 5-17: Other uses of raw materials in million m^3_{swe}



Source: Mantau 2025

6. Sensitivity analyses

6.1 Sensitivity of the share of wooden buildings

Wood construction scenario

The approach and results of the wood construction scenario have already been presented in the chapter 4.1.5. Since the wood construction scenario can be regarded as a variant of the sensitivity analysis in comparison to the baseline economic scenario, the results are repeated here. The aim is to place the sensitivity of the driver "share of wooden buildings" in the context of the other sensitivities.

Differences between the scenarios

The following tables (Table , Table 6-2) provide information on the differences between the economic baseline scenario and the wood construction scenario for semi-finished and raw materials. The first column shows the baseline value of the wood products used in 2020. For the years 2030, 2040 and 2050, the additional use of wood resulting from the increase in the share of wooden buildings is shown. The column "50−20" illustrates the percentage change between the values in 2020 and 2050. The last column illustrates the percentage difference between the scenarios in 2050.

Table 6-1: Difference in semi-finished products between the timber construction scenario and the baseline scenario in million m^3_{hwe}

Used wooden semi-fin. products	**2020**	**2030**	**2040**	**2050**	**50 - 20**	**Diff SZ**
	in million m³hwe				in %	in %
Sawn timber, C	9,037	8,869	9,688	10,213	11,5	3,8
Sawn timber, NC	1,154	1,126	1,240	1,305	11,6	1,8
Wood-based panels	2,601	2,622	2,870	3,006	13,5	1,9
Insulation boards	2,508	2,479	2,730	2,881	12,9	5,8
Veneer / plywood	0,739	0,798	0,888	0,965	23,4	0,7
Total	**16,039**	**15,894**	**17,416**	**18,370**	**12,7**	**3,5**

Table 6-2: Difference in raw materials between the timber construction scenario and the baseline scenario in million m^3_{swe}

Used wooden semi-fin. products	**2020**	**2030**	**2040**	**2050**	**50 - 20**	**Diff SZ**
	in million m³hwe				in %	in %
Stemwood	18,286	18,081	19,799	20,926	12,6	3,3
Other roundwood	2,262	2,270	2,484	2,611	13,4	3,4
Roundwood, C	*17,742*	*17,536*	*19,175*	*20,239*	12,3	3,7
Roundwood, NC	*2,806*	*2,815*	*3,108*	*3,297*	14,9	1,4
Other primary raw	0,044	0,044	0,049	0,051	13,9	0,4
Industrial residues	2,677	2,685	2,967	3,116	14,1	2,7
Recycled waste wood	0,325	0,326	0,350	0,363	10,5	1,1
Total	**23,594**	**23,405**	**25,649**	**27,066**	**12,8**	**3,2**

Source: Mantau 2025. "50-20" = change in 2050 compared to 2020; Diff SZ = share of higher timber construction use in total timber use in the construction sector in 2050

Low sensitivity

Although the share of wooden buildings in all new construction segments is increased from an initial value of 25 % to a total of 32 % by rounding up, the relative volume effects in total are only about one tenth of this value. In the area of wooden semi-finished products, the difference between the scenarios is 3.5 %, and in the area of raw materials, it is 3.2 %. The lower growth in raw materials is due to economic and structural changes. For example, stronger growth in the use of low-density insulation boards compared to logs can lead to a reduction in the difference in raw materials. However, the discrepancy between the relative change in the share of wooden buildings (+32 %) and the additional use of wood raw materials, which is only one tenth of this figure (3.2 %), is of greater interest. How can this discrepancy be explained?

Low share of timber construction in the overall construction sector

The change in the share of wooden buildings only refers to new construction. The share of new construction in wood use was 33.9 % in 2022 and fell further to 29.2 % by 2050. The share of timber construction is only increasing for buildings constructed using timber. Within new construction, the increase is only attributable to buildings constructed predominantly using timber, which have an unweighted average share of 15.6 %. About half of the wood used is in the remaining 84.4 % of non-wood buildings, which also include rafters and wooden floors. They contain significantly less wood per building. The fact that their wood use is just as high is due to the larger number of buildings. Their substitution reduces the effect of the higher share of wooden buildings by 17.5 %.

No changes in the proportion of wood used in remodelling and civil engineering are assumed. Any change is due exclusively to the change in the overall development. This assumption is supported by the fact that remodelling is more closely linked to the existing building stock and construction methods.

Expectations

Many market observers base their assessment of timber construction on the number of buildings approved. This leads to an overestimation of the importance of timber construction. The calculations are based on the significantly stronger correlation between the use of timber and the number of buildings constructed and their corresponding sizes. The finished floor space is therefore much more closely related to timber use than the number of buildings approved.

Linear change

The type of implementation of the effect is of significant relevance for quantifying the effects of a scenario. In the present case, the change will begin in 2024 and not in 2020, as the data has been updated to 2023. From 2024 onwards, the share of wooden buildings will increase linearly until 2050. Although it would have been theoretically possible to set the target value from 2024 onwards, this would not have been realistic. As a result, the cumulative volume effects would have been correspondingly higher. A scenario in which the increase in the share of wooden buildings is achieved halfway (in 2037) is also conceivable. In both cases, the effects would correspond to those shown here for 2050. Only the cumulative values would have been higher.

Comparison with other sensitivities

The following sensitivity calculations are based on the wood construction scenario. They affect not only wood construction, but the construction sector as a whole. Depending on the sensitivity examined (e.g. lower waste), they also affect all other material uses. The respective areas of impact are shown.

6.2 Reduction in offcuts

Definition

The term "offcut" refers to the residual materials produced during wood processing. Specifically, this refers to the further processing of semi-finished products into finished products in the value-added process. The waste produced is to be assigned to the raw material category of other industrial wood residues.

Procedure for reducing offcuts

The average residue factor per area serves as the starting point for the calculations. The reduction is 15.0 %. Reducing the residue factor by 15.0 % results in a reduction of the original residue factor from 1.197 to 1.167, or from 19.7 % to 16.7 %. This leads to a reduction in both the semi-finished products used and the residual materials produced.

The adjustment is made in accordance with the following procedure. The residue factor remains constant until 2025. In the period from 2026 to 2035, there is a linear reduction in the residue factor until the target value is reached.

The reduction will affect all semi-finished products used in proportion to their quantity. However, as the calculations are made per area of application, there will be differences depending on the quantities of offcuts, the raw material mix and the development of the various areas of application.

Back calculation to raw materials

When calculating back to raw material input, semi-finished products cannot be allocated directly to raw materials. Provided that logs and other wood in the rough are reported separately, the conversion factors can be applied specifically to logs (softwood sawn timber 1.650 and hardwood sawn timber 1.658). For all other semi-finished products, it is possible that different raw materials were used. For other wood in the rough and wood-based panels, a weighted average was calculated and weighted using the quantities for 2020. A conversion factor of 1.388 was determined for all other raw materials used for packaging. This means that the use of other wood in the rough and sawmill by-products for wood packaging was reduced by 1.388 cubic metres of raw materials used per cubic metre of semi-finished products saved.

Results – example

The following Table 6-3 shows the results of the calculations. The first column shows the areas in which the reduction in waste was applied. This is followed by a presentation of the average residue factor in the area to date (e.g. construction 21.1%, or factor 1.211). With a reduction of 15% (assuming 85% of the original value), the residue factor would only be 1.179. The volume effects are reported for the average of the years 2026 to 2050. Without reduction, this corresponds to semi-finished products input of 17.022 million m^3_{hwe}. These are semi-finished product equivalents (m^3_{hwe}), i.e. product cubic metres plus offcuts. By reducing offcuts, only 16.650 million cubic metres of wooden semi-finished products had to be used. This was an average of 372,000 m^3($_{hwe}$) per year less between 2026 and 2050. For the period 2026-2050 as a whole, this corresponded to 9.280 million m^3_{hwe}. In terms of raw materials, an average of 25.060 million m^3_{swe} was used in 2025.

Thanks to the reduction in waste, only 24.568 million m^3_{swe} was required, or an average of 492,000 m³ less per year.

The "Other" category was simulated in accordance with the weighted average quantities of the other categories. The material use categories paper and new bio-based products were not included in the simulation. Furthermore, the use of wood for energy purposes is not taken into account in this analysis, i.e. these categories remain unchanged.

Table 6-3 : Effects of a 15% reduction in waste

	Offcut factors			Semi-finished products in m³hwe				Raw materials in m³swe			
Period 2026-2050	before	after	Factor	before	after	Offcut	Offcut	before	after	Offcut	Offcut
Unit	Factor		Assump-tion	Mio. m^3_{hwe}				Mio. m^3_{swe}			
Value for	2025	2050		Mean			Sum	Mean			Sum
Construct. (no other)	1,211	1,179	0,85	17,022	16,650	-0,372	-9,280	25,060	24,568	-0,492	-12,301
Furniture	1,257	1,218	0,85	7,576	7,385	-0,191	-4,772	9,986	9,723	-0,263	-6,570
Packaging	1,097	1,082	0,85	7,032	6,955	-0,077	-1,922	11,088	10,964	-0,124	-3,086
Other	1,197	1,167	0,85	15,940	15,614	-0,326	-8,152	15,633	15,113	-0,520	-13,001
Total, material	***1,197***	***1,167***	***0,85***	***47,570***	***46,604***	***-0,966***	***-24,126***	***61,767***	***60,368***	***-1,399***	***-34,958***

Results – overall

An analysis of the available data shows that a 15 % reduction in offcuts leads to a 0.966 million m^3_{hwe} reduction in the use of semi-finished products. In terms of raw material input, this results in an average annual reduction of 1.399 million m^3_{swe}. The construction sector contributes 39.5 % to the reduction, the furniture sector 19.2 %, the packaging sector 7.7 % and the estimate for other semi-finished products accounts for 33.6 %.

Figure 6-1: Assumed development of residue factors for material processing of wooden semi-finished products

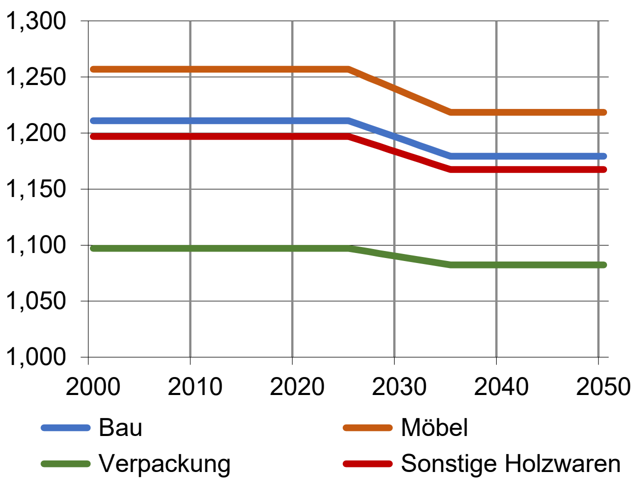
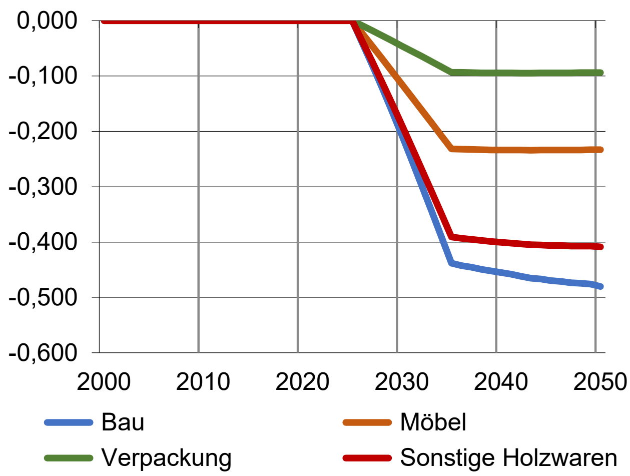


Figure 6-2: Development of annual material savings through changes in residue factors in million m^3_{hwe}



Source: Mantau 2025

6.3 Increase in the use of hardwood

Definitions

The increase in the use of hardwood takes place on two levels. The use of logs is defined as the processing of wood in the rough at the sawmill. The use of logs in the form of sawn timber takes place without further processing in another product. Modifications in the use of materials can be simulated at the semi-finished product level and then calculated back to the raw material level.

Other wood in the rough, on the other hand, has no direct use but is processed into wood-based panels. This material shift is therefore calculated directly at the level of the raw materials used.

Extent of the increase in the proportion of hardwood

According to the expert opinion in the Delfi study, it is a realistic assumption that the use of hardwood will increase from the current level of 17.1 % to 25.0 %. Assuming a rounded increase of fifty percent, the target value would be 25.7 %.

Approach

For both hardwood logs and other hardwood roundwood, the proportion of hardwood will be increased linearly during the transition phase from the 2025 value to 2035 so that it reaches 1.5 times the initial value in 2035. However, it is possible that the proportion of hardwood may change during this period as a result of the scenarios. The generally marginal change due to the framework conditions is taken into account. If, for example, the proportion of hardwood in the furniture sector falls by 0.01 in the scenario, the increase in the scenario would not be 1.50 but 1.49. This is also important for the comparability between the scenarios.

The recalculation to raw materials is carried out in accordance with the sensitivity analysis of the offcuts.

Zero-sum game

The substitution of softwood by hardwood has a broad impact and also includes the use of wood for energy. The quantity effects completely offset each other. As a result, an increase in the use of hardwood is offset by a corresponding reduction in softwood.

Results – example

The following Table shows the results of the calculations. The first column shows the proportion of hardwood in 2025. The second column shows the increase in the proportion of hardwood. If the proportion of hardwood is already very high (73.4 %), as is the case in the furniture sector, for example, this would lead to proportions of over 100 %. In such cases, it is also rather unlikely that significant growth can be expected. If the proportion of hardwood rises to 75.0 %, it is kept constant at this value. If the proportion of hardwood was less than five per cent and this figure was not reached despite being multiplied by 1.5, the scenario was adjusted so that five per cent was achieved.

In terms of material use, hardwood is used in wood-based panels in the form of logs (sawnwood) and other wood in the rough. The two proportions can vary greatly and were modelled separately.

In 2025, 1.209 million m^3_{hwe} of hardwood sawn timber was used in the construction sector. The increase in the share from 11.3 % to 16.0 % meant that 0.509 million m^3_{hwe} more was used in 2050. This corresponded to 0.839 million m^3_{swe}. Wood-based panels used in construction contained 0.123 million m^3_{swe}. The increase in the share of other hardwood from 5.1 % to 7.2 % resulted in an additional use of 61,000 m^3_{swe}. In the period from 2026 to 2050, the higher hardwood volumes will total 20.962 million m^3_{swe} of hardwood logs and 1.524 million m³ of other hardwood roundwood. The wood species shares of industrial wood residues have not been changed.

Table 6-3: Effects of a 1.5-fold increase in the proportion of hardwood

	Hardwood share			Semi-finished products in m³hwe				Raw materials in m³swe			
Period 2026-2050	Before	After	Factor	Before	After	Change	Change	Before	After	Change	Change
Unit	Share	Share	Assump-tion	Mio. m^3_{hwe}				Mio. m^3_{swe}			
Value	2025	2035		Mean			Sum	Mean			Sum
WCS (logs HW)	11,31	15,99	1,50	1,209	1,718	0,509	12,704	2,900	3,739	0,839	20,962
WCS (other roundwood)	5,09	7,22	1,50					0,123	0,184	0,061	1,524
FUR (logs HW*)	73,42	75,00	1,50	1,413	1,445	0,034	0,860	2,745	2,802	0,057	1,426
FUR (other roundwood)	18,84	28,26	1,50					0,236	0,366	0,130	3,270
PAC (logs HW*)	0,89	1,25	1,50	0,045	0,063	0,018	0,462	0,499	0,530	0,031	0,767
PAC (other roundwood)	18,19	27,28	1,50					0,080	0,126	0,046	1,144
Paper	12,52	18,79	1,50					0,638	0,902	0,264	6,602
Total, material			***1,50***	***2,667***	***3,226***	***0,561***	***14,026***	***7,221***	***8,649***	***1,428***	***35,695***
Private households	62,40	75,00	1,50					7,230	8,606	1,376	34,417
Large combust. plants	56,90	75,00	1,50					0,128	0,164	0,036	0,906
Small combust. plants	56,90	75,00	1,50					0,940	1,203	0,263	6,581
Energy wood production	31,04	46,56	1,50					0,190	0,266	0,076	1,901
Total, energy				***0,000***	***0,000***	***0,000***	***0,000***	***8,488***	***10,239***	***1,751***	***43,805***
Total	**0,00**	**0,00**	**1,50**	**2,667**	**3,226**	**0,561**	**14,026**	**15,709**	**18,888**	**3,179**	**79,500**

Source: Mantau 2025. HBS = construction (wood construction scenario); MBL = furniture; VPK = packaging; HW = use as semi-finished products; RW = use as raw materials

Total simulation effects

The following figures refer to average values for the years 2026 to 2050, which lead to a substitution of softwood by wood in the rough amounting to 1.428 million m^3_{swe} in material use. In terms of wood use for energy, there is a substitution effect of 1.751 million m^3_{swe}. A total of 3.179 million m^3_{swe} of softwood will be replaced by hardwood.

A small step for softwood – a big one for hardwood

Figure 6-4 illustrates that the relative effects of change vary greatly. For softwood, it will be 6.2 % less in 2050, and for hardwood, 46.9 % more. For softwood, the relative change in material wood use in 2050 will be 3.2 % and in energy wood use 3.0 %. In contrast, for hardwood, a relative change in material wood use of 24.6 % and in energy wood use of 17.9 % will be observed in 2050.

Figure 6-3: Simulation effect of softwood as a result of substitution by hardwood (+50%) in million m³$_{swe}$

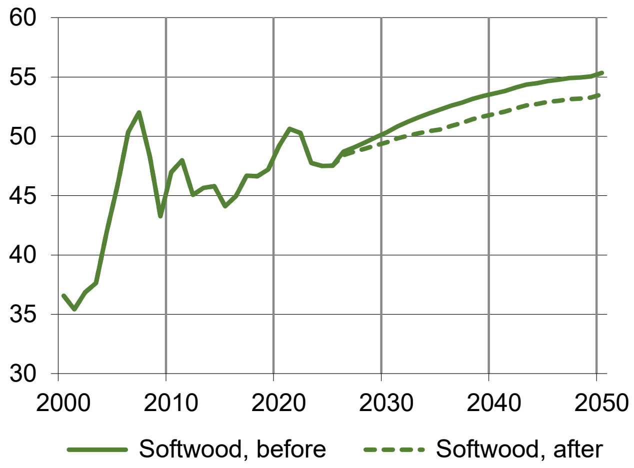
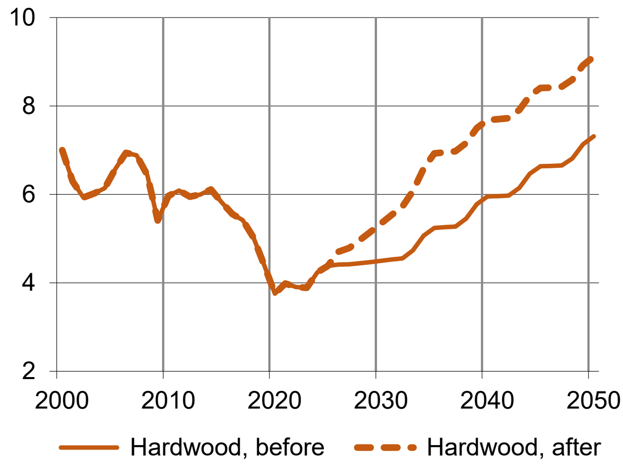


Figure 6-4: Simulation effect of hardwood as a result of an increase in hardwood (+50%) in million m³swe



Source: Mantau 2025

6.4 Waste wood replaces wood in the rough

Definition

According to the Wood Resource Monitoring (Döring/Mantau, 2021), waste wood is defined as wood that is disposed of in waste disposal facilities. In the furniture sector, quantities of used wood were identified that are treated as waste wood in the simulation.

Procedure

It is assumed that the material use sectors in which waste wood is used will double their waste wood use. The increased use of waste wood is deducted from the use of solid wood. The deduction is made in accordance with the relative shares of solid wood assortments softwood and hardwood logs and other softwood and hardwood in the corresponding use sectors. Substitution in the area of wood energy use does not make economic sense and is not considered.

In terms of material use, waste wood is used in the form of wood-based panels. In the furniture industry, approximately 300,000 m³ of used wood is also taken into account.

Results – example

The following Table shows the results of the calculations. The first column shows the proportion of waste wood in 2025. The second column shows the increase in the proportion of waste wood.

In 2025, 0.343 million m³$_{swe}$ of waste wood will be used in the construction sector. By increasing the share from 1.4 % to 2. 6%, an average of 0.257 million m³$_{swe}$ more waste wood and less wood in the rough will be used between 2026 and 2050. In the period from 2026 to 2050, the higher quantities of waste wood will add up to 6.427 million m³$_{swe}$ waste wood. This corresponds to a correspondingly lower use of solid wood.

Table 6-4: Doubling the use of waste wood and its impact on the substitution of wood in the rough

	Waste wood share			Semi-finished products in m^3hwe				Raw materials in m^3swe			
Period 2026-2050	before	after	Factor	before	after	Difference	Difference	before	after	Difference	Difference
Unit	Anteil	Anteil		Mio. m^3_{hwe}				Mio. m^3_{swe}			
Value	2025	2035	Assump-tion	Mean			Sum	Mean			Sum
WCS (logs HW)	1,414	2,617	2,00					0,343	0,600	0,257	6,427
WCS (other roundwood)								21,781	21,524	-0,257	-6,427
FUR (logs HW*)	17,41	34,688	2,00					1,738	3,159	1,421	35,520
FUR (other roundwood)								5,259	3,838	-1,421	-35,520
PAC (logs HW*)	5,533	10,291	2,00					0,613	1,072	0,459	11,471
PAC (other roundwood)								9,644	9,185	-0,459	-11,471
Other (waste wood)	0,856	1,484	2,00					0,123	0,216	0,093	2,331
Other (roundwood)								15,250	15,157	-0,093	-2,331
Total, material			***1,50***	***0,000***	***0,000***	***0,000***	***0,000***	***54,752***	***54,751***	***0,000***	***0,000***

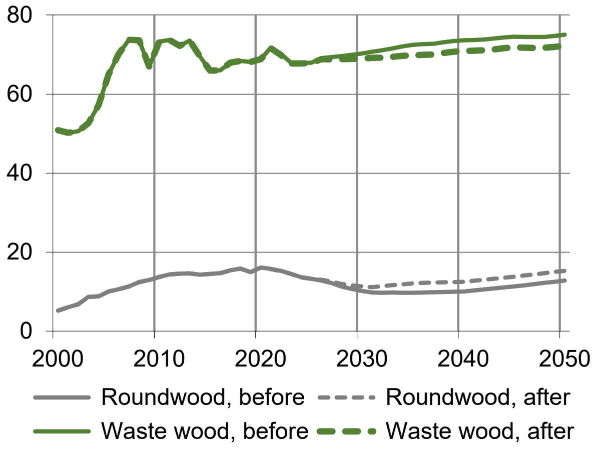
HBS = construction (wood construction scenario); MBL = furniture; VPK = packaging.

Source: Mantau 2025

Simulation effects

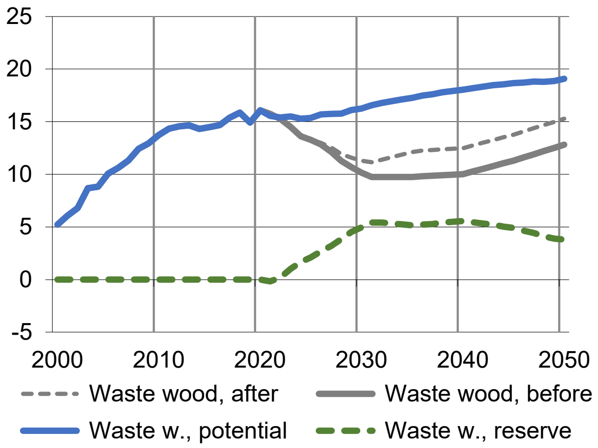
The figures refer to average values for the years 2026 to 2050. During this period, there was an average annual substitution of wood in the rough by waste wood amounting to 2.230 million m^3_{swe}. Overall, the effects cancel each other out.

Figure 6-5: Simulation effect of doubling waste wood use in million m^3_{swe}



Source: Mantau 2025

Figure 6-6: Waste wood potential and uses in million m^3_{swe}



Source: Mantau 2025

Waste wood market

The simulation allows further conclusions to be drawn about the waste wood market. The significant decline in waste wood use from 2020 onwards is due to the assumed development of large combustion plants (see chapter 5.3). However, the volume of waste wood is driven less by demand than by the amount generated as a result of economic activity. The waste wood potential was estimated using a regression based on the volume of modernisation and employment. Despite a doubling of the material use of waste wood, a residual amount of available waste wood remains. It can be assumed that this amount of approx. 5 million m^3_{swe} (2.3 million t_{lutro}) will be used primarily in large combustion plants. This assumption is supported by the landfill ban, which makes alternative use mandatory. On the other hand, increased material use leads to more rigorous quality selection, so that the remaining quantities are likely to be sent for thermal recovery.

Consequences of the waste wood surplus

The waste wood surplus therefore contradicts the assumed scenarios, in particular those for large combustion plants. The cause can be found in the scenarios of the projection report or in the equating of the scenarios (energy industry, industry) with wood use in large combustion plants. In a further calculation stage, the waste wood reserves of 5 million m^3_{swe} (2.3 million t_{lutro} could be reallocated to higher combustion. In principle, it is possible to incorporate them into the particleboard as well, provided that doubling the amount of waste wood use still leaves quantities that can be recycled.

6.5 Adjustment scenario – combination of variants

Adjustment scenario

In an adjustment scenario, the simulations carried out previously are combined. This therefore represents the cumulative effects of reducing offcuts, substituting softwood with hardwood and doubling the proportion of waste wood.

According to respondents in the Delphi study, a shortage of softwood is already to be expected within the period under consideration. This is also confirmed by the forest wood modelling in the DIFENs project.

If wood usage develops as predicted in the markets described, a significant shortage of softwood is expected around 2040. This can be postponed by several years through the adjustments described. However, the actual timing depends heavily on the development of damaged wood.

This means that these scenarios will not occur. From 2035 onwards, supply problems with softwood will arise and then increasingly influence market activity.

Figure 6-7: Simulation effects of the adaptation scenario for wood in the rough in million m^3_{swe}

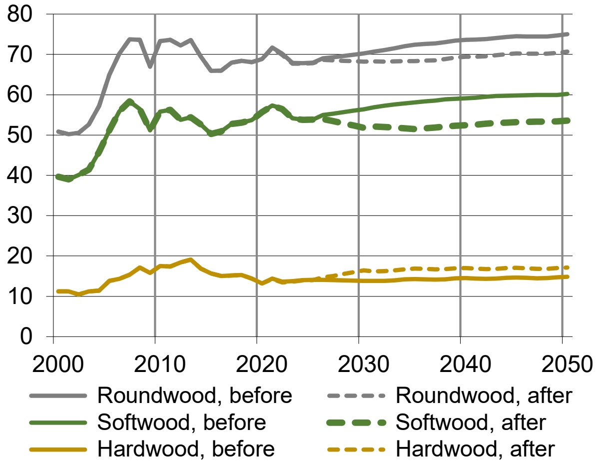
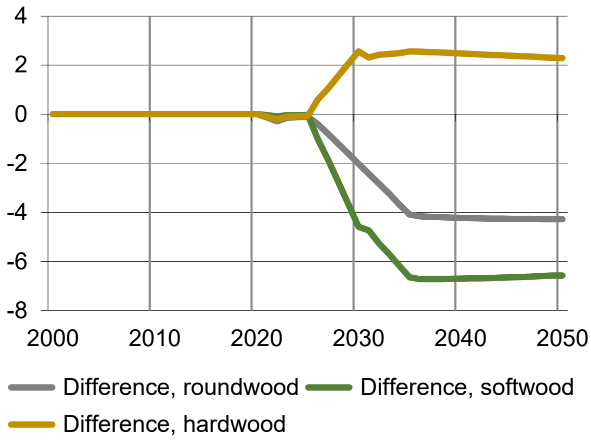


Figure 6-8: Simulation differences of the adaptation scenario for wood in the rough in million m^3_{swe}



Source: Mantau 2025

Effects of the adaptation scenario

Table provides an overview of the simulation results. The simulations were applied to the scenario with an increased share of wooden buildings. The table first shows the simulations that were carried out. This is followed by the average annual effect for the years 2026 to 2050 and the cumulative volume effect for all years.

The reduction in offcuts leads to raw material savings of 1.4 million m³swe per year or 35.0 million m³ in total.

The increase in the proportion of hardwood by a quarter replaces the proportion of softwood by an annual average of 3.2 million m^3_{swe} and a total of 79.5 million m^3_{swe}. About half of this is used for material and energy purposes.

If the proportion of waste wood in material wood use is doubled and wood in the rough is substituted accordingly, this leads to an average substitution of 2.2 million m^3_{swe} or a total of 55.7 million m^3_{swe}.

Finally, if all simulations are implemented simultaneously – let's call this the adjustment scenario – this results in total raw material savings of -85.9 million m^3_{swe}, which is made up of a reduction in softwood use of -142.3 million m^3_{swe} and an increase in the use of hardwood of +56.4 million m^3_{swe}.

The reduction in coniferous timber harvesting of 142.3 million m^3_{swe} would correspond to approximately 2.2 times the annual coniferous timber harvest (Thünen, harvest backcast 2020-2023). This could counteract a shortage lasting several years. However, the actual extent of the effect over time also depends on forest growth and the expected occurrence of damaging events.

Table 6-5: Simulation effects of the adaptation scenario following measures for wood in the rough in million m^3_{swe}

Simulation results aw materials in million m³sw		
Projection period 2026-2050	ɔn average / a	Total 26-50
Waste reduced by -15.0	-1,4	-35,0
Hardwood use increased by +20.7 % *)	+-3,2	+-79,5
Waste wood use doubled **)	+-2,2	+-55,7
Adjustment scenario	-3,4	-85,9
of which softwood	-5,7	-142,3
of which hardwood	+2,3	+56,4

Source: Mantau 2025

Results for other raw materials

The results of the simulations for other raw materials are largely limited. This is due to the objectives of the simulations. The reduction in offcuts only has an effect on material use and has virtually no impact on other primary raw materials. Industrial wood residues and waste wood only have an effect on material use within the limited quantities used. Furthermore, the simulation "hardwood replaces softwood" only affects wood in the rough. The substitution "waste wood replaces wood in the rough" only affects the use of wood in the rough in the material sector. This is in line with the objectives set.

6.6 Clear increase in wood storage in product use

Inflow

An interesting side effect of calculating the wood cycle is the balance between wooden semi-finished products (inflow) and the amount of waste and used wood (outflow). The inflow in 2020 was calculated at 44.0 million m³swe. This consists of semi-finished products used, namely sawn timber (2020: 58.0 %), wood-based panels (2020: 41.3 %) and other wooden semi-finished products (2020: 0.6 %). Offcuts have no storage effect. However, they were included in the analysis to ensure valid comparability with existing calculation methods.

Outflow

The outflow is assumed to be the amount of waste wood in the collection system and small amounts of used wood (2020: -16.1 m^3_{swe}). If the collection system were complete, this would correspond to the actual outflow. This can be assumed to be largely the case for Germany. A potential amount of 10% used wood in private households and a further 10% for unrecorded waste wood was also taken into account, resulting in an outflow of -19.3 m^3_{swe} in 2020. The projection was made using a regressive estimate based on the development of modernisation activities in the construction sector and the number of people in employment.

Figure 6-9: Inflow, outflow and storage balance in million m^3_{swe}

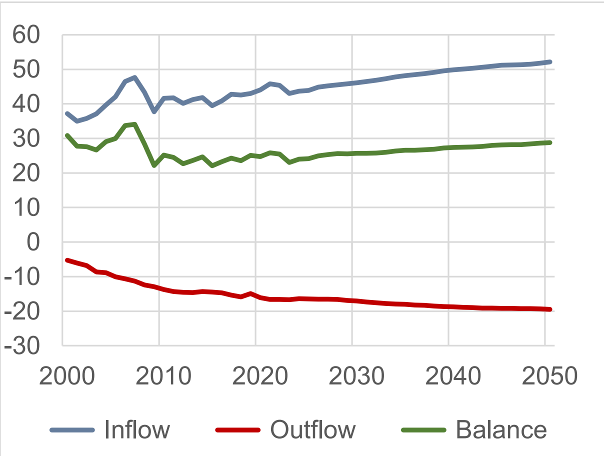
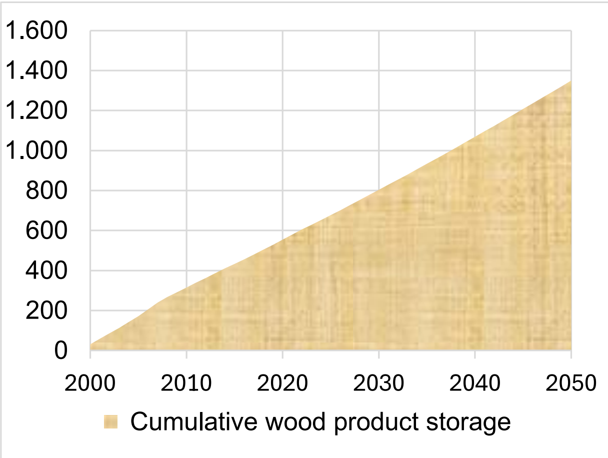


Figure 6-10: Cumulative wood storage in million m^3_{swe} between 2000 and 2050



Source: Mantau 2025

Wood product storage clearly positive and growing in the long term

On average between 2000 and 2050, 26.5 million m^3_{hwe} will remain in wood use each year. Over the period from 2000 to 2050, this results in a cumulative wood product storage of 1,350 million m^3_{hwe} in total in wood use. It is not apparent why the situation should have been significantly different in the past. Reference should be made here to the chapter 3.3. If there were no positive wood storage, how can the increase in the housing stock be explained? Why is the demolition rate less than five per cent compared to the number of buildings completed 65 years ago? It could be argued that the wood products were replaced by modernisation measures. If that were the case, there would have to be a significant increase in waste wood. However, there is no evidence of this.

Example: What can be assumed spontaneously often does not correspond to reality (perception). When a roof truss is renovated, the entire roof is not usually torn down; instead, new rafters are placed on top of the old ones.

Similar results were obtained by Mantau/Blanke (2016) in the Cascade Study for the European Commission (DG GROW). This suggests that calculating the wood storage capacity based on assumed service lives underestimates the actual storage capacity. Empirical circular economy models arrive at significantly higher storage effects from wood use.

7. Outlook

Methodological approach

In the current version of the TRAW model, a comprehensive derivation of raw material demand from the finished products sectors was carried out. Previously, this was based on the use of semi-finished products.

This makes it possible to derive changes in demand specifically for each sector (construction, furniture, packaging, paper, etc.). Economic impact analyses in the sectors of finished products are carried out using demographic and economic drivers derived from the long term.

The use of semi-finished and raw materials is derived consistently from a combination of economic analyses and technological application indicators.

The model structure allows for the differentiated derivation of impacts in a material cycle at all stages of the value-added chain.

Studies on wood use in the sectors of finished products are further developing the method of wood resource balancing into a complete circular economy analysis.

The product structure is designed in such a way that it can be linked to official production and foreign trade statistics. This approach ensures that the model can be updated on an ongoing basis. It also opens up possibilities for transfer to other countries.

Technical significance

The diverse effects of different changes in the wood cycle can be derived in a comprehensible and practical manner.

Substitution processes and technological changes can be quantified. The effects of these processes are traceable at all stages of the value chain and for all goods.

At all interfaces of the value-added process, wood resource balances can be used to transparently illustrate the material relationships for each product area.

The cycle is closed by quantifying the increased use of waste wood and its effects.

Further developments

The timber market is characterised by a highly differentiated product structure, ranging from toys to coffins. As part of the FNR project "Lignum Quo Vadis (LQV; FKZ 2223HV004X)", the product areas that are still open are to be analysed in terms of their use of wood.

The individual sub-areas of the model can be further linked interactively. However, there are conflicting goals between the programmatic, mathematical automation and the integration of practical market knowledge.

In Germany, the collection of technical usage indicators is more advanced than in other countries. Nevertheless, it remains a constant challenge.

The transfer of the model to other countries can be considered approximately possible due to the use of identical indicators in international statistics.

The analyses took into account the areas of foreign trade and waste paper. In view of the complexity of the issues, the present report focuses on raw material input. The primary aim of this study was to derive forest wood extraction from the sectors of finished products. For a transparent analysis of the circular economy, the areas of foreign trade and waste paper could be examined in greater detail in a revised version.

8. Appendix

8.1 Glossary

Agricultural buildings	Agricultural construction includes the erection of buildings that are predominantly used for agricultural, forestry, horticultural or fishing purposes. Agricultural buildings include, for example, barns, silos, stables and garages for tractors, and residential buildings only if the usable space predominates in cases where residential and usable space occur simultaneously in one building.
Approval / building permit	Approvals are issued for new buildings and modernisation measures requiring approval. They form the basis for construction activity statistics because they record characteristics such as dwellings, enclosed space, etc.
Building material – predominantly used building material	According to statistics, the construction of wooden houses is based on the most predominantly used building material. A distinction is made between: • Steel • Reinforced concrete • Brick • Lime sandstone • Aerated concrete • Lightweight concrete/pumice • Wood • Other building materials The predominantly used building material is the material that is mainly used in the construction of the load-bearing structure of the building.
Building construction	Construction of structures whose main parts are above ground level. The construction of structures also includes the associated foundation work. Building construction includes residential construction, commercial and industrial building construction, agricultural building construction, building construction for non-profit organisations, local authorities, social security and the federal railways and postal service.
Buildings	According to the classification system for structures, buildings are defined as independently usable, covered structures that are permanently erected and can be entered by people. They serve to protect people, animals or property. The presence of walls is not a determining factor. Buildings in this sense also include independently usable underground structures. Accommodation such as barracks, garden sheds, temporary shelters and similar structures that are only erected for a limited period or have little residential value are not included, nor are temporary non-residential buildings and detached independent structures. A single building is any detached building or, in the case of connected buildings (e.g. semi-detached and terraced houses), any building that is separated from other buildings by a fire wall extending from the roof to the basement. If there is no fire wall, the

	connected building units are considered individual buildings if they have their own access system (separate entrance and staircase) and can be used independently.
Completion of construction	See completion, approval
Building permits (approval)	
Completion	Once a building has been approved by the building authorities, the statistical data from the approval statistics are transferred unchanged to the completion statistics.
Component	For the purposes of this report, wood products used in construction are classified according to components. Components are classified according to the building trades in construction. A building trade generally comprises the work that can be assigned to a self-contained area of construction activity. A distinction is made between the following components: • Exterior wall • Sloping roof • Flat roof • Facade • Interior wall • Floor slab • Floor • Window • Sun protection • Interior doors • Exterior doors • Stairs • Insulation • Construction site equipment • Outdoor installations
Construction	Depending on the type of construction, a distinction is made between skeleton structures (panel construction, timber frame construction) and solid structures. Both types of construction can be used as prefabricated construction and as solid construction. Construction projects using mixed construction methods are classified according to the predominant type of construction.
Construction method	In construction, the term "construction method" refers to the way in which a building is erected. A distinction can be made between various aspects: • Building material: timber construction, masonry construction, combined construction • Building construction: lightweight construction, solid construction • Assembly of components: prefabricated construction, large panel construction, modular construction Supporting structure: skeleton construction, bulkhead construction

Construction statistics	To understand the figures, the following statistical classification features must be distinguished: • Construction method • Type of construction • Main building material used
Conventional construction	Construction of a building using non-prefabricated components (see "Prefabricated construction").
Conventional timber construction	Construction of a building using non-prefabricated components (see "prefabricated construction") and wood as the predominant building material (see "predominant building material").
Domestic product gross, net	The production value of an economy (economic turnover) minus all intermediate consumption and depreciation
Gross value added	Gross domestic product is calculated from the economic turnover of the various sectors of the economy. If you subtract the goods and services that an industry purchases from other industries (inputs) from its economic turnover, you arrive at the gross value added of that industry. In the case of the construction industry, this is significantly lower than the construction volume, which includes all other services.
Gross national product Gross, net	Domestic product minus all income from employment and assets that has flowed abroad, plus all income from the rest of the world. Gross and net refer to calculations with and without depreciation.
Industrial plants	Industrial buildings belong to the group of non-residential buildings. This includes the following types of buildings: • Factory and workshop buildings • Commercial and storage buildings (market and exhibition halls, retail buildings, warehouses) • Transport buildings (garages, station halls, aircraft hangars, television towers)
Intermediate consumption	Intermediate consumption represents the value of all goods that domestic economic entities have purchased from other (domestic and foreign) economic entities and consumed within the accounting period in the course of production.
Multi-family houses	Detached or built-in residential buildings with three or more apartments. Multi-family buildings regularly extend over several floors (e.g. apartment blocks, high-rise buildings).
Non-residential buildings	Buildings that are primarily intended for non-residential purposes (measured by total usable floor space). Non-residential buildings include, for example, institutional buildings, office and administrative buildings, agricultural buildings and non-agricultural buildings such as factory buildings, hotels and the like.
Offcuts	The term "offcuts" refers to the residual materials produced during wood processing, i.e. the further processing of semi-finished products into finished products in the value-added process. The

	offcuts produced are allocated to the raw material category of “other industrial wood residues”.
One and two family homes	One and two family homes are detached or terraced residential buildings with one or two apartments, whereby secondary apartments are permitted.
Prefabricated construction	Construction of a building using prefabricated components (prefabricated parts). In building construction, a structure is considered prefabricated if predominantly floor-to-ceiling or room-wide prefabricated elements, e.g. large-format wall panels for exterior or interior walls, are used. In this case, it is necessary that the majority of the load-bearing structure consists of prefabricated elements. The foundations or basement floors, which are usually constructed conventionally, must be taken into account for the assessment.
Product wood equivalent (m^3_{pwe})	The product wood equivalent describes the amount of wood used in the end-product, i.e. the amount of wood contained in the product.
Economic turnover	Economic turnover includes all sales of goods and services from own production as well as merchandise to other domestic and foreign economic entities.
Remodelling	Remodelling involves structural changes to existing buildings through conversion, extension or restoration. The statistics on construction activity cover only remodelling measures that require planning permission.
Residential-type buildings	Buildings of a residential nature. - Institutional buildings (hospitals, homes, barracks, prisons, holiday homes) - Office and administrative buildings (official, office, bank, court and government buildings) - Hotels and restaurants - Other non-residential buildings (school buildings, daycare centres, museums, theatres, libraries, churches, medical institutes, sports buildings, leisure and community centres)
Solid wood equivalent (m^3_{swe})	In addition to the semi-finished wood equivalent, the solid wood equivalent also includes the residual materials that are produced during the processing of raw materials into semi-finished products (yield + residual materials).
Semi-finished wood equivalent (m^3_{hwe}) Half-finished wood equivalent	In addition to the product equivalent, the semi-finished goods equivalent also includes any offcuts generated. The abbreviation was derived from the term ‘half-finished’ to avoid confusion with the abbreviation ‘solid wood equivalent’.
Service / building specification	A bill of quantities is part of a service description and describes, in the form of partial services, the total service to be provided within the scope of an order.

Solid construction	In construction, this refers to a type of structure in which space-enclosing elements such as walls and ceilings also fulfil a load-bearing function. Solid construction is the opposite of skeleton construction (see "skeleton construction"). The term "solid construction" is sometimes used as a contrast to prefabricated construction. In practice, most buildings are constructed using conventional methods, but this use of the term is not correct. A current look at timber construction shows that solid timber houses in prefabricated construction are becoming increasingly popular.
Timber construction	Construction of a building using wood as the predominant building material (see "predominantly used building material").
Wooden house construction	The core element of the definition of timber house construction is that the load-bearing structure is predominantly made of wood. Most timber houses are prefabricated buildings with a skeleton structure. Timber houses are also conceivable as prefabricated buildings in solid construction (e.g. buildings with load-bearing multi-layer wood composite panels). This group has gained increasing market share in recent years (Holz100 house). Finally, there are also wooden houses in conventional construction, which can be either frame construction (e.g. half-timbered) or solid construction (e.g. log construction).
Wood products	In the construction sector, wood products are used as finished products (e.g. windows, doors, parquet flooring) and as semi-finished products (e.g. floorboards, planks, particleboard). Raw materials are determined by back calculation.
Yield	The term "yield" refers to the residual materials produced during wood processing, i.e. the further processing of raw materials into semi-finished products in the value-added process. The residual materials produced are allocated to the raw material category sawmill by-products or, if they are produced outside the sawmill industry, to other industrial wood residues. Offcuts are as well included in other industrial wood residues.

8.2 List of abbreviations

BAS	BAsisAzenario (see HBS), base case scenario
BBSR	Federal Institute for Research on Building, Urban Affairs and Spatial Development
BG	Operational buildings
BIMSchV	Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes Regulation implementing the Federal Immission Control Act
BWS	Gross value added
CHO	Combustion heat output (Feuerwärmeleistung, FWL)
CHS	Central heating system
DIFENs	Project acronym: **D**ealing with **I**mpacts on **F**orests under Changing **E**nd-Use Demand, Climate Change, **N**atural Disturbances and Policy Goal**s** (FNR-FKZ: 2220WK32A4)
DIW	German Institute for Economic Research, Berlin
EFSOS	European Forest Sector Outlook Study
EPAL	European Pallet Association
FABio	Forestry and Agriculture Biomass Model (Oeko-Institute)
FAO	Food and Agricultural Organisation
FAOSTAT	FAO database
FNR	Fachagentur Nachwachsende Rohstoffe (Projects and Networking on Renewable Resources)
FKZ	Funding Reference Number
EGH	One- and two-family homes (buildings with 1+2 apartments)
GDP	Gross domestic product
GENESIS	Gemeinsames Neues Statistisches Informations-System (destatis)
GFTM	Global Forest Trade Model
GVA	Gross value added
HBS	Wood construction scenario (BAS and increasing market share of wooden houses)
HDF	High Density Fibrebord

HWE	Semi-finished wood equivalent (Half-finished wood equivalent)
IBG	Industrial buildings
IfW	Kiel Institute for the World Economy
IIASA	International Institute for Applied Systems Analysis
INFRO	Informationssysteme für Rohstoffe (Information Systems for Resources)
KrWG	Kreislaufwirtschaftsgesetz, Circular Economy Act
LBG	Agricultural buildings
LDF	Low Density Fibrebord
LDF/ULDF	Insulation boards
LQV	Project Acronym: Wood utilisation indicators for analysing the bioeconomy and circular economy along the entire value-added chain" (FKZ: 2223HV004X, Lignum Quo Vadis)
MDF	Medium Density Fibrebord
MDF/HDF	Fibrebord
MFH	Multi-family houses (buildings with 3 or more apartments)
MwMS	Mit-weiteren-Maßnahmen-Szenario (Scenario involving further measures)
NACE	Nomenclature statistique des Activités économiques dans la Communauté Européenne
NAWARO	Renewable feedstock (Nachwachsende Rohstoffe)
NAFSOS	North American Forest Sector Outlook Study
OHR	(NWL, Nennwertleistung)
OSB	Oriented strand boards
PWE	Product wood equivalent (Finished product wood equivalent)
RHO	Rated heat output (NWL Nennwertleistung)
REA	Renewable energy act (EEG)
RM	Rohstoffmonitoring (Resource Monitoring)
SHS	Single-fire heating system
SSP	Shared Socioeconomic Pathways
SWE	Solid wood equivalent (Raw material wood equivalent)

THG	Treibhausgas
TI	Thünen Insitut
TiMBA	Timber market Model for policy-Based Analysis
TRAW	Total Resource Assessment of Wood (Circular Economy Model)
ULDF	Ultra Low Density Fibrebord
UNECE	United Nations Economic Commission for Europe
USDA	United States Department of Agriculture
VDP	Verband Die Papierindustrie (Association of the Paper Industry)
WBG	Residential-type commercial buildings
WE	Wohneinheit (Residential unit)

8.3 Table of tables

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8.4 Sources

Literature

Bahr C, Lennerts K (2010): Service life and useful life of building components, BBSR. https://www.bbsr.bund.de/BBSR/DE/research/programmes/zb/contract-research/2sustainable-construction-building-quality/2009/lifespan-service-life/final-report.pdf;jsessionid=A347FF95D4C5F70E79A59E3FEAC13790.live21323?__blob=publicationFile&v=1

BBSR (2017): https://www.nachhaltigesbauen.de/fileadmin/pdf/Nutzungsdauer_Bauteile/BNB_Nutzungsdauern_von_Bauteilen_2017-02-24.pdf

Gornig, M.; Michelsen, C.; Révész, H. (2023): Structural data on production and employment in the construction industry: Calculations for the year 2022. Published by BBSR – Federal Institute for Research on Building, Urban Affairs and Spatial Development within the Federal Office for Building and Regional Planning (BBR) (ed.), (2023): BBSR online publication 53/2023, Bonn. Available online at https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/1Wertschoepfung/2008/StrukturdatenBaugewerbe/Downloads/DL_Strukturdaten_Endbericht2021.pdf;jsessionid=A59103DDA94D5F4004C1646EA22FFBC0.live21323?__blob=publicationFile&v=3, zuletzt geprüft am 06.06.2025.

Gornig M, Pagenhardt L (2023): Construction boom coming to an end – political strategy change required. German Institute for Economic Research Berlin. DIW Weekly Report No. 1+2/2023

Döring, P.; Mantau, U. (2021): Waste wood in the disposal market. Sources and recycling in 2020. Hamburg. Wood Resource Monitoring. Information systems for raw materials. Hamburg. Available online at http://infro.eu/img/pdf/rohstoffmonitoring/R%202021%2005%20Altholz.pdf, last checked on 06.06.2025.

Döring, P.; Glasenapp, S.; Mantau, U. (2020): Energy wood use in private households 2018, market volume and wood assortments used, Wood Resource Monitoring. Information systems for raw materials. Hamburg. Available online at http://www.infro.eu/downloads/studien/HH_2018_Teilbericht.pdf, last checked on 06.06.2025.

Döring, P.; Weimar, H.; Mantau, U. (2021a): The use of wood for energy in biomass combustion plants under 1 MW in non-households in 2019. Information systems for feedstocks. Hamburg. Available online at http://www.infro.eu/downloads/studien_neu_2022/S08%20Kleinfeuerungsanlagen%202019.pdf, last checked on 06.06.2025.

Döring, P.; Weimar, H.; Mantau, U. (2021b): Use of wood in large-scale biomass combustion plants in 2019. Information systems for feedstocks. Hamburg. Available online at http://infro.eu/downloads/studien_neu_2022/S07%20Grossfeuerungsanlagen%202019.pdf, last checked on 06.06.2025.

European Forest Sector Outlook Study (EFSOS). UNECE. Geneva (2011): http://www.unece.org/efsos2.html

Heinze Marktforschung (2023): Medium-term forecast 2023-2028 and long-term prospects for the construction industry. Celle 2023.

Hennenberg, K.; Böttcher, H.; Braungardt, S.; Köhler, B.; Reise, J.; Köppen, S.; Bischoff, M.; Fehrenbach, H.; Pehnt, M.; Werle, M.; Mantau, U. (2022): Current use and promotion of wood energy – Partial report on the BioSINK and BioWISE projects (Climate Change, 12/2022). Öko-Institut; ifeu Institute for Energy and Environmental Research Heidelberg; Information Systems for Feedstocks. Federal Environment Agency (ed.). Dessau-Roßlau. Available online at https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/cc_12-2022_aktuelle_nutzung_und_foerderung_der_holzenergie.pdf, last checked on 29 March 2022.

IfW (2023): Boysen-Hogrefe J., Gern K.-J., Groll D., Hoffmann T., Jannsen N., Kooths S., Reents J., Sonnenberg N., Stamer V., Stolzenburg U. (2023): Medium-term projection in autumn 2023: Growth in decline, scope for expansion not particularly high. Kiel Economic Reports, No. 108 (2023|Q3)

Jochem, D.; Morland, C.; Glasenapp, S.; Weimar, H. (2023): Energy consumption of wood in private households, final report (Texts, 15/2023). Federal Environment Agency. Available online at https://www.fnr.de/fileadmin/heizenmitholz/HH_2018_Teilbericht.pdf, last checked on 29 September 2023.

FNR Media Library (2025): Wood in the circular economy. Available online at https://holz.fnr.de/kreislaufwirtschaft/holz-in-der-kreislaufwirtschaft

Heinze Market Research (2012): Internal evaluation of various studies on the remodelling market in residential construction (2001, 2004, 2007, 2011) and non-residential construction (2012). www.baudatenon23line.

Knauf, M. (2024): Potential of new products in the wood-based bioeconomy in Germany. Presentation as part of the DIFENs project on 9 July 2024

Knauf, M. (2025): Uncertain times. Delphi study on the development of the German forestry and timber industry until 2040. Study as part of the DIFENS Forest Climate Fund project. Results report, July 2024, Bielefeld. https://delphi-holz.de/wp-content/uploads/2024/07/Delphi_Ergebnisbericht.pdf

Konsemöller, F. (2016): Packaging industry – Wood volumes and proportions in packaging products, bachelor thesis in the field of forestry and timber industry economics (Mantau, U.) at the Centre for Wood Science at the University of Hamburg

Mantau, U. (2025): Modelling the Material Wood Flow from Finished Products to Forest Wood. Circular Economy Model for Wood (TRAW, Total Resource Assessment of Wood). Partial report of the DIFEN project. FNR FKZ 2220WK32B4. 116 pages. 2nd edition. Available online at www.infro.eu

Mantau, U. (2023a): Wood Resource Balancing, Circular Economy and Cascade Use – 20 Years of Wood Resource Monitoring, Gulzow, FNR, FKZ: 22015918. Available online at https://www.fnr.de/fileadmin/Projekte/2024/Mediathek/FNR_Brosch_Rohstoffmonitoring_Holz_2024.pdf

Mantau, U. (2023b): Wood Resource Balances – Circular Economy and Cascading, 20 years of Wood Resource Monitoring, Gulzow, FNR, FKZ: 22015918. https://mediathek.fnr.de/wood-resource-balances-circular-economy-and-cascading.html

Mantau U., Hiller, D., Gieseking L., Blanke C. (2022): Wood use in the furniture sector – Use of solid wood and wood-based panels by furniture group. FNR FKZ 22015918. Celle 2022 (www.infro.eu)

Mantau U, Blanke C, Döring P (2018): Structural report on the use of wood in construction – use of wood products by construction sector and component. Partial report of the WKF KlimaBau project. Hamburg. 77 p. (www.infro.eu)

Mantau U., Blanke, C. (2016): Status of cascading use in the EU. In: Vis M., U. Mantau, B. Allen (Eds.) (2016) Study on the optimised cascading use of wood. No 394/PP/ENT/RCH/14/7689. Final report. Brussels 2016. 337 pages. Available online at: https://op.europa.eu/en/publication-detail/-/publication/04c3a181-4e3d-11e6-89bd-01aa75ed71a1, last checked on 06.06.2025

Mantau, U. et al. 2010: EUwood - Real potential for changes in growth and use of EU forests. Final report. Hamburg/Germany, June 2010. 160 p.

North American Forest Sector Outlook Study 2006-2030. UNECE. Geneva 2012 https://www.srs.fs.fed.us/pubs/ja/2012/ja_2012_prestemon_004.pdf

Peters, M. J. (2015): Economic Development and Wood Use in the Packaging Industry, Bachelor's thesis in the field of Forestry and Wood Economics (Mantau, U.) at the Centre for Wood Science and Technology at the University of Hamburg

UBA - Federal Environment Agency (ed.) (2023): National Inventory Report on German Greenhouse Gas Emissions 1990–2021, reporting under the United Nations Framework Convention on Climate Change 2023. Available online at https://cdr.eionet.europa.eu/de/eu/mmr/art07_inventory/ghg_inventory/envy8fz9q/DE_EU-NIR_2023_DE.pdf, last checked on 23 March 2023.

UBA - Federal Environment Agency (2022): Greenhouse gas emissions in Germany, emission overviews by sector. Available online at https://www.umweltbundesamt.de/daten/klima/treibhausgas-emissionen-in-deutschland#emissionsentwicklung, last checked on 9 November 2022.

Verification of data sources used

Biomass Atlas (2020): www.biomasseatlas.de (accessed on 11.09.2020)

The paper industry – Performance report PAPIER (2024): VDP Performance Report (2024): Various years between 2000 and 2024, Bonn

Eurostat (2008-2024): NACE Rev. 2 (Statistical Classification of Economic Activities in the European Community). Available online at https://ec.europa.eu/eurostat/de/web/nace

FAOSTAT-Forestry database (2024): https://www.fao.org/forestry-fao/statistics/84922/en/

IIASA SSP (2018): Database (Shared Socioeconomic Pathways) 2018 Release, (Version 2.0, December 2018) - Version 2.0 (https://tntcat.iiasa.ac.at/SspDb).

Federal Statistical Office (2024): https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Bevoelkerungsvorausberechnung/aktuell-zensusergebnisse.html; accessed on 23 July 2023

Federal Statistical Office (2024a): Net migration. https://www.destatis.de/DE/Themen/Gesellschaft/Umwelt/Bevoelkerung/Wanderungen/_inhalt.html?templateQueryString=wanderungsbewegung

Federal Statistical Office (2024b): National Accounts Federal Statistical Office GENESIS 81000-0011)

Federal Statistical Office (2023a): National Accounts. Specialist Series 18 Series 1.4. GENESIS 81000. Wiesbaden, September 2023.

Federal Statistical Office (2023b): WAS and NAS – Tables. Construction completions by type of building and main building material used. Various years up to 2022. Wiesbaden 2023.

Federal Statistical Office (2022a): 15th coordinated population projection – Germany. Reporting period 2021-2070. EVAS number 12421. Wiesbaden 2022.

Federal Statistical Office (2022b): Construction activity and dwellings. FS.5 R.1

Federal Statistical Office (2020a): Development of private households until 2040. Results of the 2020 household projection. Wiesbaden 2020.

Federal Statistical Office (2020b): Labour force projections 2020. Wiesbaden 2020.

Federal Statistical Office (2019): Results of the 14th Coordinated Population Projection. https://www.destatis.de/DE/Presse/Pressekonferenzen/2019/Bevoelkerung/pressebroschuere-bevoelkerung.html