Is there Enough Biomass to Defossilise the Chemicals and Derived Materials Sector by 2050?

The Bio-based Industries Consortium (BIC) and the Renewable Carbon Initiative (RCI) commissioned a study from the nova-Institute with the co-operation of EuroCARE Agricultural Policy Research and the Thünen Institute of Forestry (TI-WF).

A Joint BIC and RCI Scientific Background Report

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On behalf of BIC, the report was coordinated by Dr. Dirk Carrez and Marco Rupp. On behalf of RCI, the report was coordinated by Michael Carus and Christopher vom Berg.

Executive Summary – Is there enough biomass to defossilise the chemicals and derived materials sector by 2050?

Can agricultural and woody biomass combined sustainably provide enough biomass to meet 20% of the future carbon demand of the chemical and derived materials industries in 2050, up from 5.5% (EU27) and 10% (global) in 2023?

When it comes to setting priorities for the use of biomass, a clear statement must first be made: Before the chemical industry is supplied with biomass, the overall demand for food and feed must be met – food is a necessity and has the highest priority. In addition, the existing European and global regulatory framework[1] with quotas drives demand for biofuels, although there is a need for a level playing field between fuels, chemicals and materials. As long as there are no corresponding quotas for bio-based chemicals and derived materials, they are only a lower priority.

Despite the demand of these other sectors, the principal answer is: yes, covering 20% of overall carbon demand of the chemical and derived material sector in 2050 with biomass appears to be a realistic and achievable estimate. Providing much more than 20% of the carbon demand via biomass would be unreasonable, but about 20% of the renewable carbon can be sustainably supplied by biogenic carbon to the chemical and derived material industries. Furthermore, this share can be sustainably delivered without compromising the food and feed supply and the demand for biofuels.

Agriculture: By 2050, under the BAU scenario, production is projected to increase by 31% to 5.07 billion tonnes. Cereals increase by 32% to 3.1 billion tonnes, sugar by 40% to 340 million tonnes and vegetable oils by 45% to 317 million tonnes (see Fig. 2). In the Green LRD scenarios, production is projected to increase by 24–26%, and in the Green HT scenarios by 38–53% – compared to 31% in the BAU scenario.

The projected future demand for starch, sugar and vegetable oil – still the dominant feedstocks for the chemical industry in 2050 – can be met: The additional yield required is around 10% (compared to BAU), so the moderate Green HT +10% scenario is fully sufficient to meet the demand. Stronger High Tech scenarios can even provide enough biomass to significantly exceed the 20% target, up to 40%.

Technological innovation therefore appears to play the most important role in achieving the 20% target. At the same time, the more efficient production and use of biomass in HT scenarios allows more land to be set aside and used for nature restoration.

To increase the share of available biomass, more lignocellulosic feedstocks such as straw, wood and biowaste can be used. However, access to these feedstocks faces strong competition from Sustainable Aviation Fuels (SAF), which have large volumes and strong political support through quotas.

1 Harrandt, J., Carus, M., vom Berg, C., Hark, N. 2024: EU and global: Biomass Demand for Transport Fuels, Aviation and Shipping up to 2050 and Implications for Biomass Supply to the Chemical Sector. (not yet published, DOI will be added after publication)

The amount of wheat, barley, rye and oat straw available for use could be greatly increased by using not only cereal straw, but also tapping into maize and rice straw. This could turn straw into an important feedstock.

However, a critical challenge is the increasing competition for biomass from other sectors, particularly sustainable aviation fuels (SAF). This competition could increase pressure on available feedstocks and make it more difficult for the chemical and derived material industries to secure second generation biomass supply. In this context technological advances such as Carbon Capture and Utilisation (CCU) could play an important role in ensuring that all sectors can meet their carbon reduction targets and reduce the pressure on highly demanded biomass resources. As the production of synthetic aviation fuels increases beyond 2030, there will be opportunities to use the co-product naphtha in crackers of the chemical industry.

Forestry: Global supply and demand of industrial roundwood (coniferous and non-coniferous) will increase by an estimated 38% between 2020 and 2050, from 0.9 to 1.3 billion tdm. The largest increase in supply is expected in Asia (69%), including China and Russia, but a significant increase of 32% is also seen for Europe.

The additional demand from the chemical and materials industries is comparatively small compared to the traditional applications of wood. This means that, in principle, it is very feasible to meet this demand in a sustainable way. There are several options for meeting this demand: (1) use a relatively small proportion of total industrial roundwood supply (evaluate cost-effectiveness), (2) preferred: use of by-products from industrial roundwood processing (problem of high competition), or (3) divert a relatively small proportion from the fuelwood sector.

The Bio-based Industries Consortium (BIC)

- BIC is Europe's leading industry association, putting circularity, innovation and sustainability at the heart of the European bioeconomy and the private partner in the €2 billion public-private partnership with the European Commission – the Circular Bio-based Europe Joint Undertaking (CBE JU).
- BIC's membership includes 300+ industry members covering the whole value chain, from primary production to the market, across multiple and diverse sectors including agriculture & agri-food, aquaculture & marine, chemicals and materials, including bio-based fibres and bioplastics, forest and forest-based sectors, market sectors, technology providers and waste management & treatment.
- BIC also has over 200 Associate Members representing academia, research organisations, trade associations, etc.
- BIC's mission is to build new circular bio-based value chains and to create a favourable business and policy climate to accelerate market uptake.

The Renewable Carbon Initiative (RCI)

- RCI is a unique, industry-driven organization that combines the roles of think tank and association. It plays a pivotal role in advancing the defossilisation of the chemical and materials industries.
- RCI's vision is to enable the carbon-dependent chemicals and materials industry to become a climate-neutral sector. To achieve this, RCI's mission is to replace fossil carbon with renewable carbon, which includes bio-based, CCU-based and recycled carbon. This enables sustainable carbon cycles which do not need further fossil feedstock extraction from below ground.
- RCI's membership includes almost 80 companies coming from a diverse range of sectors, including major industry players, SMEs, innovative startups, and research institutions. Members span the entire value chain including the chemical industry, innovation and technology, energy, agriculture, and recycling.
- The RCI has further partnered with 15 organisations supporting and promoting common goals like a sustainable chemicals and materials industry.

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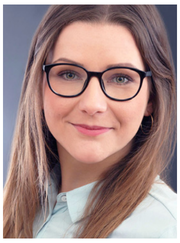
Michael Carus is one of the leading European experts, market researchers and policy advisers of the renewable carbon economy – including bio-based, CO_2-based and recycling. At the end of 1994, he and five other scientists founded the private and independent nova-Institute for Ecology and Innovation. Ever since the beginning, Carus has been involved in the company as owner and one of the two Managing Directors. Today nova-Institute has nearly 50 scientists from a wide range of disciplines, covering markets, technologies, sustainability, communication and policy. In the year 2020, Carus founded the Renewable Carbon Initiative (RCI), which has today more than 70 members from chemicals and materials industries.

Olaf Porc has been working for nova-Institute as part of the policy and economy department since the beginning of 2020. He leads various projects with research, data acquisition and analysis. His main focus is on the work in the field of techno-economic evaluation and topics considering bio-based feedstocks and applications. During his master's degree in crop science, he gained expertise in agriculture and botany, which he incorporates into many areas of his work.

Christopher vom Berg is Executive Manager of the RCI and develops strategic concepts for transforming the chemical and material industry towards renewable carbon. He joined nova-Institute in 2017 and has worked on various projects for the Sustainability department and the Economy & Policy department. In 2020, Christopher helped founding the Renewable Carbon Initiative (RCI), where he took over increasing responsibilities over time. Today, he is mainly involved in the management, advocacy and networking of RCI, investigates policies and regulations that impact renewable carbon management, and shares and discusses its positions and opinions. He is also author and co-author of multiple background reports and position papers of the RCI.

Dr. Markus Kempen is an agricultural economist with expertise in agricultural policy and farm modeling. He is affiliated with EuroCARE GmbH, a research and consulting company based in Bonn, Germany. He is listed as an independent expert who frequently contributes to EuroCARE studies. Kempen's research interests include agricultural policy, farm modeling, CAP (Common Agricultural Policy) analysis and EU-wide agricultural analysis using spatially disaggregated data. Kempen has contributed to the development and documentation of the CAPRI (Common Agricultural Policy Regionalised Impact) model, which is used for agricultural policy analysis in the European Union and in this project.

Dr Franziska Schier (TI-WF) has been with the Thünen Institute of Forestry (TI-WF) since 2015, focusing on wood product markets. She was instrumental in establishing forest sector modeling at TI-WF and co-developing the TiMBA model (Timber Market Model for Policy-Based Analysis). Currently, she leads the TiMBA modeling team and related research. Her expertise spans the forest-based bioeconomy, policy-related leakage analysis, forest-based climate mitigation, and international trade. Franziska Schier holds a PhD in Forest Science from the University of Göttingen and a Master's in Environmental and Bioresources Management from BOKU, Vienna.



Julia Tandetzki (TI-WF) has been working at the Thünen Institute of Forestry since 2020, specialising in the forest sector model TiMBA (Timber market Model for policy-Based Analysis). Her main focus is to analyse global forest dynamics, including the causes and impacts of deforestation and forest degradation, while improving the representation of roundwood production in the market model. In parallel to her work, she is pursuing a PhD on global drivers of forest area change, using a variety of econometric techniques and machine learning methods. She holds a Master's degree in Economics with a thesis on the macroeconomic analysis of the EU Common Agricultural Policy.

Project Advisory Board

Throughout this project, experts from the members of BIC and RCI significantly supported the work with their knowledge, ideas and feedback. We would like to thank the following individuals:

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Is there enough biomass to defossilise the chemicals and derived materials sector by 2050?

The Bio-based Industries Consortium (BIC) and the Renewable Carbon Initiative (RCI) commissioned a study from the nova Institute with the co-operation of EuroCARE Agricultural Policy Research and the Thünen Institute of Forestry (TI-WF). The result: By 2050, approximately 20% of the global carbon demand for the chemical and derived material industries can be met sustainably from agricultural and woody biomass. High-tech agriculture and effective utilisation of waste and residue can further increase volumes.

Preface

The results of such a project are largely determined by the research question, the availability and robustness of the data, a large number of assumptions that are presented transparently, the selected scenarios and methodology, and the strengths and limitations of the modeling systems for agriculture and forestry. Not everyone will agree with every assumption or scenario, and different stakeholders in agriculture, forestry, and the chemical industry see the world differently. However, we have tried to develop consistent scenarios based on a wide range of plausible assumptions, in collaboration with experts from primary production and the processing industry, and thus can comprehensively illuminate the range of supply and demand for biomass for food and feed, energy and fuels, and chemicals in 2050 under the given question.

We have deliberately refrained from drawing conclusions, making recommendations, and possibly making demands on policymakers, because the results can be interpreted and recommendations derived in very different ways, depending on the perspective and objective. The report is intended to serve as a solid basis for the many associations, companies and politicians to develop positions and draw conclusions. See Executive Summary on page 3.

Scope

After the decarbonisation of the energy sector, the defossilisation of the chemicals and derived materials sector[1,2] is the next big challenge on the climate agenda. Unlike the energy sector, the chemicals and derived

1 Polymers/plastics and rubber are by far the most important application, accounting for 65% of the total chemical value chain of "derived materials". Other derived materials include solvents, detergents, additives, personal care and pharmaceuticals.

2 The report focuses on biomass as feedstock for the chemicals and derived materials. It does not cover bio-based materials that are not derived from the chemical industry, such as paperboard packaging or cellulose films, which also replace fossil-based plastics.

materials sector is dependent on the carbon embedded in its products. Today, 90–95% of the embedded carbon comes from fossil carbon, oil, natural gas and coal. To achieve sustainability, renewable carbon sources such as biomass, CO_2 utilisation and recycling must replace fossil carbon sources. The key question BIC and RCI posed to the authors of the study was: **What proportion of carbon can biomass sustainably provide for a fully defossilised chemical and derived material industry by 2050?**

Biomass demand today

The first milestone of the project was to determine the current biomass use of the chemical and derived materials industry – a figure that is not readily available. Combining the input obtained from literature review, expert knowledge and industry insiders – including the BIC/RCI advisory board of the project, nova-Institute provided a realistic estimation of current biomass use in the sector. Table 1 shows that food and feed crops account for a significant proportion of current use. Starch, sugar and vegetable oil are estimated to account for 71% (world) and 62% (EU) of total biomass use, which amounts to 100.6 million tonnes of dry matter (world) and 11.5 million tonnes of dry matter (EU).

Table 1: Overview of the estimated use of the most important feedstock in the chemical and derived material industry (World & EU) 2020–2023[3] (in million t dry biomass)[4]

Feedstock	World	EU
Starch	35.8	4.2
Sugar[5]	18.3	1.4
Vegetable oils	17.6	1.6
Animal fats	1.4	0.4
Chemical pulp[6]	9.0	2.0
Natural rubber	14.0	1.1
Glycerol	3.4	0.5
Used Cooking Oil (UCO)	1.0	0.3
Palm Fatty Acid Distillate (PFAD)	0.1	0.006
Total	100.6	11.5
Total in Mt C	55.8	6.2

3 Various sources with reference years between 2020 and 2023.

4 A detailed background paper on the data in the table will be published shortly (end of February). The input has come from literature reviews, expert knowledge and industry insiders. The data on UCO and PFAD are, unlike the other data, only estimates based on total global availability of the primary feedstocks.

5 "Sugar" does include the additional sugar that can be obtained from molasses as a by-product of sugar production (this amounts to 15% additional sugar on average worldwide, which is included in the modelling).

6 This study only covers chemical or, more specifically, dissolving pulp, which is mainly used for the production of cellulose fibres. Total pulp volume for paper and paper boards is much bigger.

The high share of food & feed crops in the biomass feedstock mix is largely due to the well-established industry, high availability and favourable properties. Fermentation, for example, is most efficient with sugar and starch, both of which are readily available at reasonable costs. Similarly, oleochemistry is based on plant oils and animal fats as key inputs.

Currently, bio-based feedstocks are estimated to account for 10% of the entire carbon demand in the global chemical and derived-material industries, but only 5.5% in the EU. This lower figure in the EU reflects decades of easy access to cheap crude oil and natural gas, particularly from Russia.

Which shares can biomass deliver by 2050?

To fully defossilise the chemical and derived materials industries by 2050, more than 1 billion tonnes of carbon will need to be sourced from renewable carbon. Biomass plays an important role here, complemented by CO_2 utilisation (CCU) and recycling. The evaluation of 16 scenarios from nine recently published reports on achieving a net-zero chemical industry in 2050 results in the following average feedstock shares: biomass 22%, CCU 33%, recycling 20% and fossil 24%. For net-zero plastics, the shares were different, especially for recycling: biomass 21%, CCU 17%, recycling 42% and fossil 19%.[7]

Based on the average shares found in the evaluated reports and in line with the RCI-nova 2050 scenario[8] (see Figure 1), we defined the target share of biogenic carbon to be 20% of the total carbon demand of the chemicals and materials industry by 2050.

7 Harrandt, J., Carus, M., vom Berg, C., 2024: Evaluation of Recent Reports on the Future of a Net-Zero Chemical Industry in 2050 (DOI No.: https://doi.org/10.52548/SXWV6083)

8 Kähler, F. et al. 2023: RCI carbon flows report – Compilation of supply and demand of fossil and renewable carbon on a global and European level. DOI No.: https://doi.org/10.52548/KCTT1279

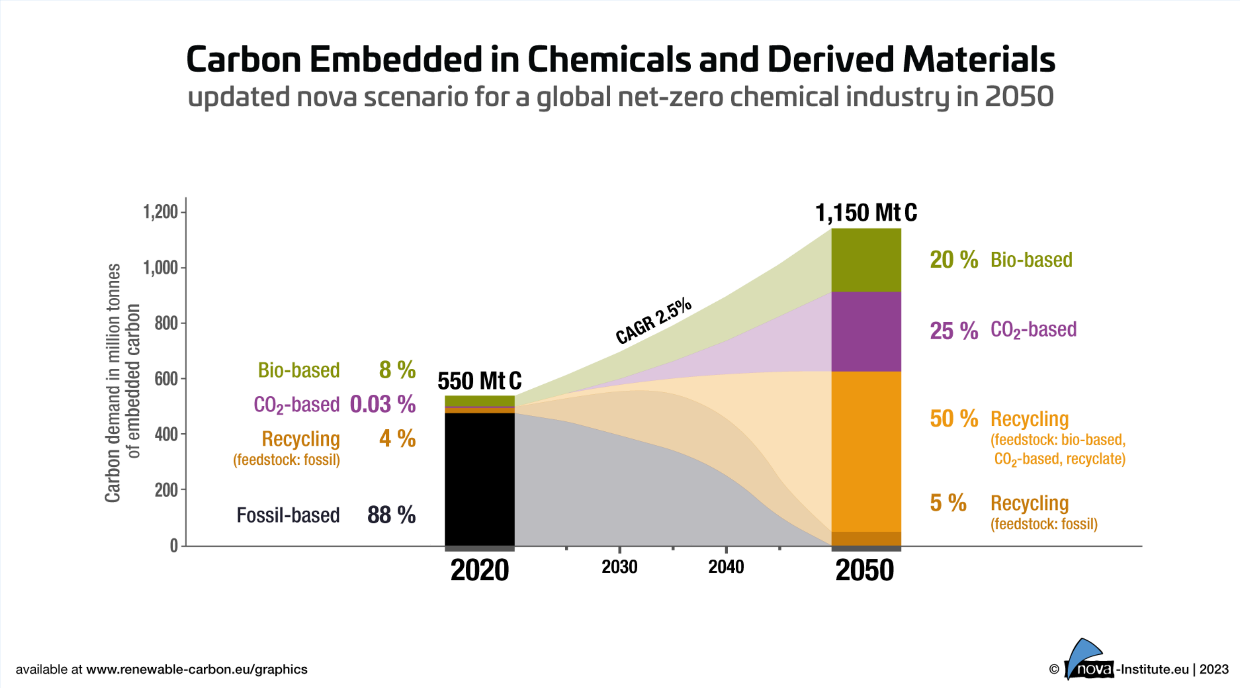

Figure 1: RCI/nova Scenario for the Renewable Carbon Demand of the Chemical and Related Industries in 2050 Worldwide

With this introduction, the central question of this report is: **Can biomass sustainably supply 20% of the future carbon demand for the chemical and derived material industries by 2050, up from the current 5.5% in Europe and 10% globally in 2023?** It is important to note that before biomass can be supplied to the chemical industry, it must first meet the future demand for food and feed, as well as the competing demand for biofuels, mainly driven by European and global legislation and quotas.[9]

How to scale up biomass supply?

In Europe and globally, the supply of biogenic carbon will need to quadruple between now and 2050 to meet the anticipated demand. In the EU-27, to be precise, we expect the total demand for carbon in chemicals and derived materials to remain almost constant until 2050, while the share of bio-based carbon is only 5.5% today. Globally, the bio-based share is already 10%, but the total global demand for carbon in chemicals and derived materials is expected to double. In both cases, therefore, the total biomass demand is expected to increase by a factor of four. A critical issue in the project was to determine appropriate scaling factors for each of the different biomass feedstocks available. While scaling up by a factor of 4 to 8 is relatively straightforward for some biomass feedstocks, such as starch, sugar, plant oil and chemical pulp, it is a significant challenge for others, such as animal fats, natural rubber, glycerol, used cooking oil (UCO) and palm fatty acid distillate (PFAD). Consequently, different scaling factors are required for different biomass feedstocks.

9 Harrandt, J., Carus, M., vom Berg, C., Hark, N. 2024: EU and global: Biomass Demand for Transport Fuels, Aviation and Shipping up to 2050 and Implications for Biomass Supply to the Chemical Sector. (not yet published, DOI will be added after publication)

Experts from nova-Institute and the project advisory board[10] – professionals from a wide range of companies, members of BIC and/or RCI – discussed scaling options via email and an online workshop. Two main scenarios were developed, one envisioning that a 10% share of biogenic carbon demand would be covered by wood, straw and biowaste[11] and the other with a 20% share. Both scenarios would require large investments in new biorefineries. The findings are detailed in Table 2[12].

Table 2: Feedstock consumption in the chemical and derived materials industry (World & EU) in two scenarios 2050 (in million t dry biomass)

Feedstock	World 10% wood & waste	World 20% wood & waste	EU 10% wood & waste	EU 20% wood & waste
Starch	156	114	10.9	7.8
Sugar	70	55	4.3	4.1
Vegetable oils	79	79	7.2	6.4
Animal fats	5.6	5.6	1.6	1.6
Chemical pulp	36	36	8.0	8.0
Natural rubber	28	28	2.2	2.2
Glycerol	5.1	5.1	0.7	0.7
Used Cooking Oil (UCO)	4.0	4.0	1.3	1.3
Palm Fatty Acid Distillate (PFAD)	0.3	0.3	0.04	0.04
Wood & straw, biowaste (mainly lignocellulosic biorefineries)	24 wood 36 straw, biowaste	48 wood 72 straw, biowaste	2.3 wood 3.4 straw, biowaste	4.6 wood 6.8 straw, biowaste
Total	444	447	42	44
Total in Mt C	230	230	22	22

Table 2 illustrates that food and feed crops will remain a major source of biomass in 2050, with starch, sugar and vegetable oil accounting for 55–69% (world) and 4–53% (EU) of the total biomass use, of correspondingly 445–447 million tonnes dry matter (world) and 42–44 million tonnes dry matter (EU). However, their share will be lower than today, mainly due to the expansion of lignocellulosic biorefineries utilising wood and biowaste.

10 See list of experts in annex.

11 In this report, and in the CAPRI model, biowaste includes a wide range of biogenic feedstocks: Biowaste comes from utilised side-streams from the field, throughout the processing chain, markets and households (food losses), excluding straw as a separate category.

12 Please note that the 20% share and factors are calculated for biogenic carbon, but the table shows total biomass. The conversion factor of biomass to biogenic carbon is quite different for the various types of biomass.

As the demand for first-generation biomass for biofuels declines – due to changing policy frameworks, particularly in Europe – the demand for first-generation biomass for biotechnology and oleochemicals in chemicals is expected to increase. The existing cultivation and processing infrastructure is expected to adapt to meet these new demands, ensuring its continued relevance and utility.

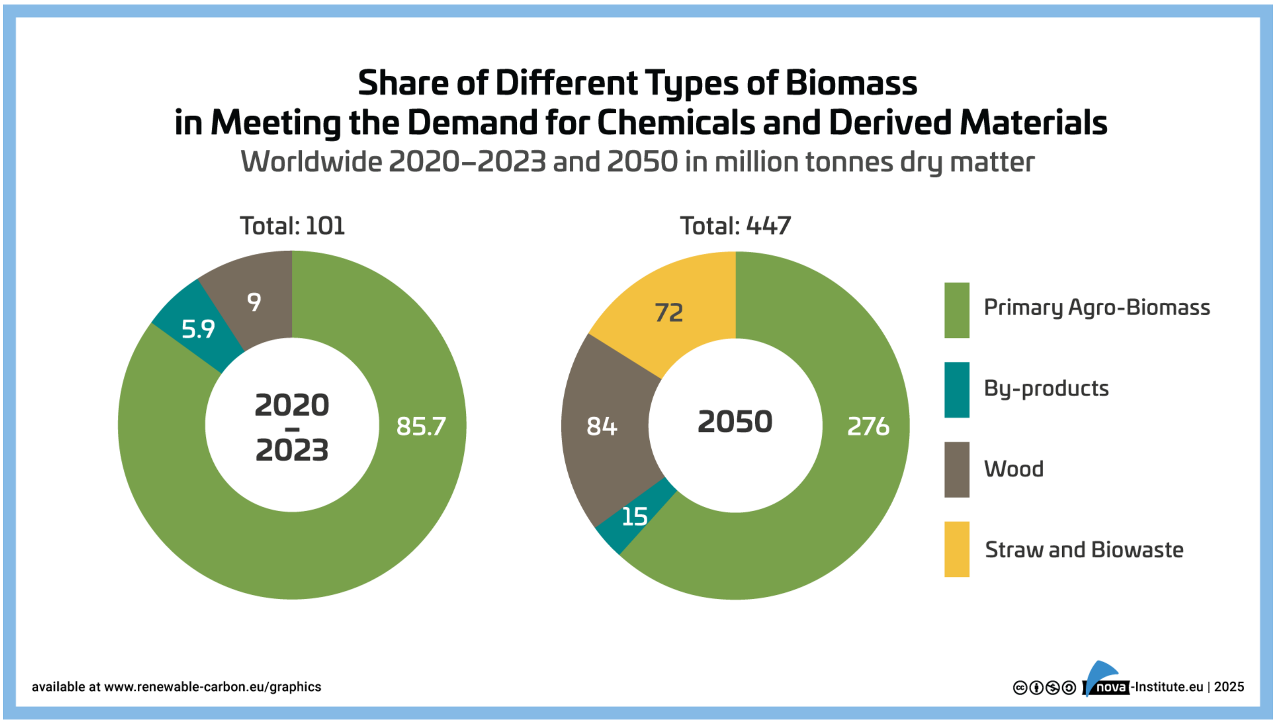

Figure 2: Share of Different Types of Biomass in Meeting the Demand for Chemicals and Derived Materials Worldwide 2050 (nova 2025)

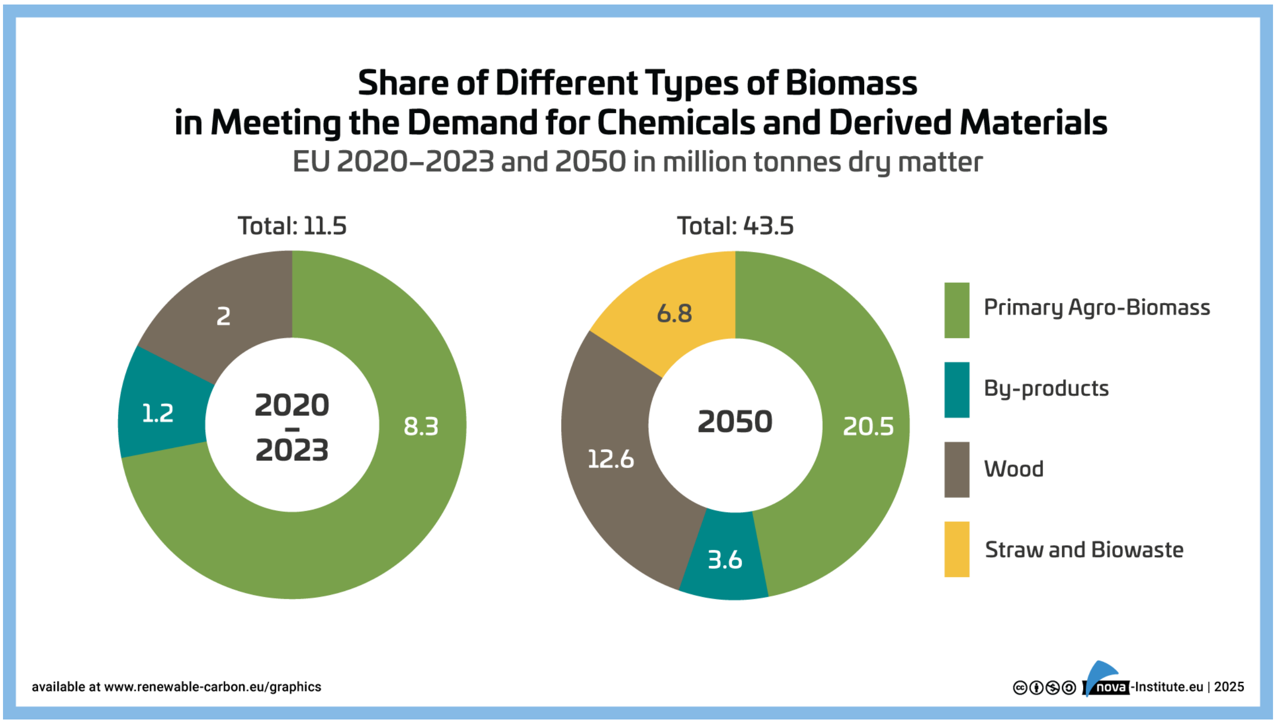

Figure 3: Share of Different Types of Biomass in Meeting the Demand for Chemicals and Derived Materials EU 2050 (nova 2025)

Can the agricultural industry of the future meet the projected demand for chemicals and derived materials in 2050?

“Can the agricultural industry of the future meet the projected demand for chemicals and derived materials in 2050 – without compromising other sectors?” To answer this question, different scenarios were developed and analysed using the CAPRI model. The calculations incorporated economic feedback loops and the resulting complex data were summarised to provide the main results presented here.

The CAPRI market module can be characterised as a comparative-static, deterministic, partial, spatial, global equilibrium model for most agricultural primary and some secondary products, in total about 50 commodities[13]. Its deterministic as stochastic effects are not covered and partial as it excludes factor (labour and capital) markets, non-agricultural products and some agricultural products such as flowers. It is spatial as it includes bilateral trade flows and the related trade policy instruments between the trade blocks in the model. The term partial equilibrium model or multi-commodity model stands for a class of models written in physical and valued terms. Demand and supply quantities are endogenous in that model type and driven by behavioural functions depending on endogenous prices. These models do not require an objective function; instead their solution is a fix point to a square system of equations which comprises the same number of endogenous variables as equations.

In agricultural models such as CAPRI, future projections are based on historical trends, extending past patterns without taking into account new factors such as increased health awareness. If a trend, such as declining sugar consumption, has occurred in the past, it will continue in the future, even if the underlying reasons (such as health concerns) aren‘t explicitly included. Emerging trends, such as a shift towards healthier diets, are not automatically reflected unless they are visible in past data and require separate exploratory scenarios.

The baseline projection includes information from the OECD-FAO Agricultural Outlook and consolidated trend projections from the CAPRI database, supplemented by assumptions and scenario choices from this project based on a wide range of scientific and industrial data. The exploratory scenarios are based on a plausible range of assumptions (e.g. land availability and yield trends) to assess impacts, with a focus on the sustainable[14] availability of biomass.

13 There may be additional biomass sources that become relevant in the future that are not included in the modelling, such as beet pulp, bagasse and agave.

14 The definition of “sustainability” used in this report, follows the original definition: The Brundtland Report (1987) defines sustainable development as:”Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (https://www.iisd.org/mission-and-goals/sustainable-development)

Assumptions

In all scenarios, the world population is projected to grow from 7.7 billion to 9.6 billion by 2050, and average dietary energy availability increases from 2,358 to about 2,500 kcal per person per day.

The authors modelled two “Green Low Resource Depletion (LRD)” scenarios with different levels of reduced biomass production compared to the rather conservative “Business-as-usual (BAU)” scenario, and three “Green High Tech (HT)” scenarios with different levels of increase. Both “LRD” and “HT” are called “green” because they result in lower environmental impacts compared to BAU and today‘s agriculture.

Scenarios and assumptions: Global

In the BAU scenario, the harvested agricultural area is expected to expand from 4,427 million ha in 2020 to 4,870 million ha in 2050. This projection includes the assumption that the cropping index will increase from 0.96 to 1.05. The cropping index indicates how many times a piece of land is planted and harvested in a year, reflecting the intensity of land use. In the LRD and HT scenarios, the cultivated agricultural area is projected to increase to 4,466 million ha and 4,716 million ha respectively. This lower increase in the LRD scenario is due to a greater emphasis on biodiversity protection, with 369.9 million ha of land set aside for conservation purposes.

While the BAU scenario projects an additional 60 million ha of available land due to ongoing deforestation by 2050, both the LRD and HT scenarios assume a halt to deforestation after 2030. The HT scenario additionally assumes a significant increase in agricultural land by 75 million ha, achieved through the conversion of marginal lands such as deserts and thawing permafrost due to better technological advancements. In contrast, BAU anticipates a 50 million ha and LRD assumes a 20 million ha increase in agricultural area.

The various scenarios make different assumptions about land sealing, deforestation and set-aside land for biodiversity conservation. In the Green LRD and HT scenarios, land sealing and deforestation cease by 2030. The Green LRD scenarios allocate most land to biodiversity through set-aside. The increase in organic farming from 10% to 30% results in a yield reduction of approximately 10%. In contrast, accelerated technological progress in agricultural practices, including precision farming, AI, robots and drones, and GMOs, increases yields by 35–40% by 2050 in the Green HT scenarios.

Table 3: Assumptions for global agricultural development under different scenarios (BAU, LRD, HT)

Parameter	Units	2020	BAU	Green Low Resource Depletion (LRD)	Green HighTech (HT)	Comments/Sources
World population	Million people	7,772.1	9,649.2	9,649.2	9,649.2	Projected population growth from 7.7 billion to 9.6 billion by 2050.
Nutrition – average dietary energy availability	kcal 'per capita per day	2,358	2,491.9	2,515.5	2,546.8	Increase in energy availability to about 2,500 kcal per person per day by 2050.
Harvested agricultural area	Million ha	4,427.6	4,870.7	4,466.1	4,715.7	Increase in land area due to cropping index and land expansion.
Cropping index	–	0.96	1.05	1.05	1.05	Increase in cropping index from 0.96 to 1.05, indicating more intensive land use.
Land set aside for biodiversity protection	Million ha	–	– 0%	-369.9 8%	-187.1 4%	In LRD, most land is allocated for biodiversity conservation.
Deforestation (additional available Land)	Million ha	–	60.0	20.0	20.0	BAU assumes 60 million ha of deforestation by 2050, while LRD and HT stop deforestation after 2030.
Conversion of wasteland, marginal land, thawing permafrost to agricultural land	Million ha	–	50.0	20.0	75.0	LRD assumes 20 million ha conversion; HT assumes 75 million ha due to technological advancements.
Land-take for settlements and transport infrastructure	Million ha	–	-83.2	-27.7	-27.7	Land-take for settlements and infrastructure (~0.06% p.a.). More intelligent land use concepts stop land sealing in LRD & HT by 2030.
Area under organic farming	% of agricultural area		10%	30%	10%	Organic farming share increases to 30% in LRD by 2050 (with a yield reduction of 10%).
Increasing crop yields through technology	% per year		0.5%	0.7%	1.1%	HT scenario shows significant increases in crop yields due to technologies such as precision agriculture and GMOs (increases yields by 35–40%).

The combinations of different assumptions for harvested area and yield result in two Green LDR scenarios with -20% and -10% biomass production compared to BAU and three Green HT scenarios with +10%, +20% and +30% compared to BAU, on global level. The CAPRI model adjusts projections through economic feedback loops, resulting in revised changes of -6% and -4% (LDR) and +6, +12 and -18% (HT).

Table 4: Global primary agricultural biomass production in six scenarios compared to BAU through economic feedback effects

Scenarios	Green LRD		BAU	Green HT		
Biomass production	-20%	-10%	0%	+10%	+20%	+30%
Biomass production after economic feedback	-6.1%	-4.4%	0%	+5.8%	+11.5%	+17.6%

Scenarios and assumptions: EU 27

The cultivated agricultural area in the EU is projected to decrease from 176.7 million ha in 2020 to 168.2 million ha in 2050 under the BAU scenario. However, it is expected to decrease further to 162.0 million ha in the LRD scenarios due to more sustainable land management practices. In the HT scenarios, cultivated area remains the highest at 169.1 million ha, because the scenario assumes a halt to land sealing from 2030 (in contrast to BAU) and sets aside less land for biodiversity than the LRD scenarios. The reduction in land use for settlements and infrastructure is consistent between the LRD and HT scenarios, with both assuming a reduction of 0.5 million ha. Furthermore, it is assumed that the cropping index in the EU does not change by 2050.

No deforestation is assumed, and additional agricultural land from conversion of wasteland or other marginal land is not taken to account. The protection of biodiversity in the LRD and HT scenarios is expected to require significant land set-aside.

Table 5: Assumptions for European agricultural development under different scenarios (BAU, LRD, HT)

Parameter	Units	2020	BAU	Green Low Resource Depletion (LRD)	Green HighTech (HT)	Comments/Sources
European population	Million people	176.7	169.1	169.1	169.1	Projected population decrease from 177 million to 169 million by 2050.
Nutrition – average dietary energy availability	kcal per capita per day	2,358	2,491.9	2,515.5	2,546.8	Increase in energy availability to about 2,500 kcal per person per day by 2050.
Harvested agricultural area	Million ha	176.7	168.2	162.0	169.1	Minor land lost to settlement/ infrastructure and preserving biodiversity.
Cropping index	–	1.0	1.0	1.0	1.0	Multi-cropping index remains constant at 1.0.
Land set aside for biodiversity protection	Million ha	–	-7.0 4%	-7.0 8%	-7.0 4%	In LRD, most land is allocated for biodiversity conservation.
Deforestation (additional available land)	Million ha	–	–	–	–	No deforestation.
Conversion of wasteland, marginal land, thawing permafrost to agricultural land	Million ha	–	–	–	–	No additional potential for agricultural land through conversion of grasslands, deserts, wetlands or thawing permafrost/ tundra.
Land-take for settlements and transport infrastructure	Million ha	–	-1.6	-0.5	-0.5	Land-take for settlements and infrastructure (~0.03% p.a, lower value assumed compared to global). More intelligent land use concepts stop land sealing in LRD & HT by 2030.
Area under organic farming	% of agri-cultural area		20%	45%	25%	Organic farming share increases to 45% in LRD by 2050 (with a yield reduction of 15–20%).
Increasing crop yields through technology	% per year		0.5%	0.3%	1.0%	HT scenario shows significant increases in crop yields due to technologies such as precision agriculture and GMOs (increases yields by 35–40%).

For the EU27, the potential increase in biomass production due to high technology is lower compared to global projections, because EU27 agriculture is already at a high technological level. Therefore, the authors considered half of the global increase a realistic assumption: +5, +10 and 15% in the three HT scenarios, resulting in adjusted increase of +2%, +2% and +4% due to economic feedback loops.

Table 6: European primary agricultural biomass production in six scenarios compared to BAU through economic feedback effects

Scenarios	Green LRD		BAU	Green HT		
Biomass production	-20%	-10%	0%	+5%	+10%	+15%
Biomass production after economic feedback	-5.8%	-4.2%	0%	+2.0%	+1.6%	+4.4%

Main results from the agricultural sector modelling

Global and EU Agricultural Production

In 2020, global crop production totals 3.88 billion tonnes, including 2.35 billion tonnes of cereals, 244 million tonnes of sugar and 218 million tonnes of vegetable oils. “Sugar“ represents the total weight of sugar molecules produced by plants such as sugar cane and sugar beet, and includes additional sugar that can be utilised from molasses, a by-product of sugar production (about 15% additional sugar from molasses). By 2050, under the BAU scenario, production is projected to increase by 31% to 5.07 billion tonnes. Cereals increase by 32% to 3.1 billion tonnes, sugar by 40% to 340 million tonnes and vegetable oils by 45% to 317 million tonnes (see Fig. 2). In the Green LRD scenarios, production is projected to increase by 24–26%, and in the Green HT scenarios by 38–53% – compared to 31% in the BAU scenario.

The lion‘s share of global agricultural production goes to food and feed, followed by biofuels, other industries and finally the chemical industry.

Covering the 2050 demand of biomass from agriculture for the chemical and plastic sector

In regards to covering 20% of the global carbon demand of the chemical industry in 2050 through biomass, only the Green HT scenarios are able to meet the additional biomass demand. The Green Low Resource Depletion (LRD) and even the Business-as-usual scenarios cannot provide enough biomass when taking into account the feedstock needs of other sectors such as food, feed and bioenergy/biofuels.

Starch, sugar and oil crops are the main agricultural feedstocks to meet biofuel and chemical demand in 2020. Starch, sugar and oil crops will also remain the main biomass feedstocks for the chemical industry in 2050, both globally and in Europe. Residues and biowaste are too limited to take higher shares (see below).

Among the feedstocks, the greatest potential for expansion is found in starch, where Green HT +10% can already cover 160% (Europe: 198%) of demand in the “10% wood and biowaste” scenario and 219% (Europe 279%) in the “20% wood and biowaste” scenario. The supply of oil crops is also sufficient to meet the needs of the chemical industry in all three Green High Tech scenarios.

In the case of sugar, demand can only be met in Green HT +20 and Green HT +30. However, this shortfall is not a major concern as sugar can be replaced by starch in most bio-based pathways, and starch is readily available in additional quantities.

Biomass supply is slightly better in the EU than globally due to the EU‘s trading strength, but overall the EU‘s net trade in 2050 remains at the same level as in 2020. With limited arable land and a high population density, the EU will need imports from world markets

Summary: Agriculture

If agriculture develops towards the Green High Tech scenarios with precision farming, AI, robots and drones, GMOs and correspondingly higher yields, there will be enough starch, sugar and oil available to meet the chemical industry's target of 20% biogenic carbon by 2050 – while meeting the feedstock demand for food, feed and bioenergy/fuels. The additional yield required is around 10% (compared to BAU), so the moderate Green HT scenario is fully sufficient to meet the demand. Stronger High Tech scenarios can even provide enough biomass significantly to exceed the 20% target, up to 40%.

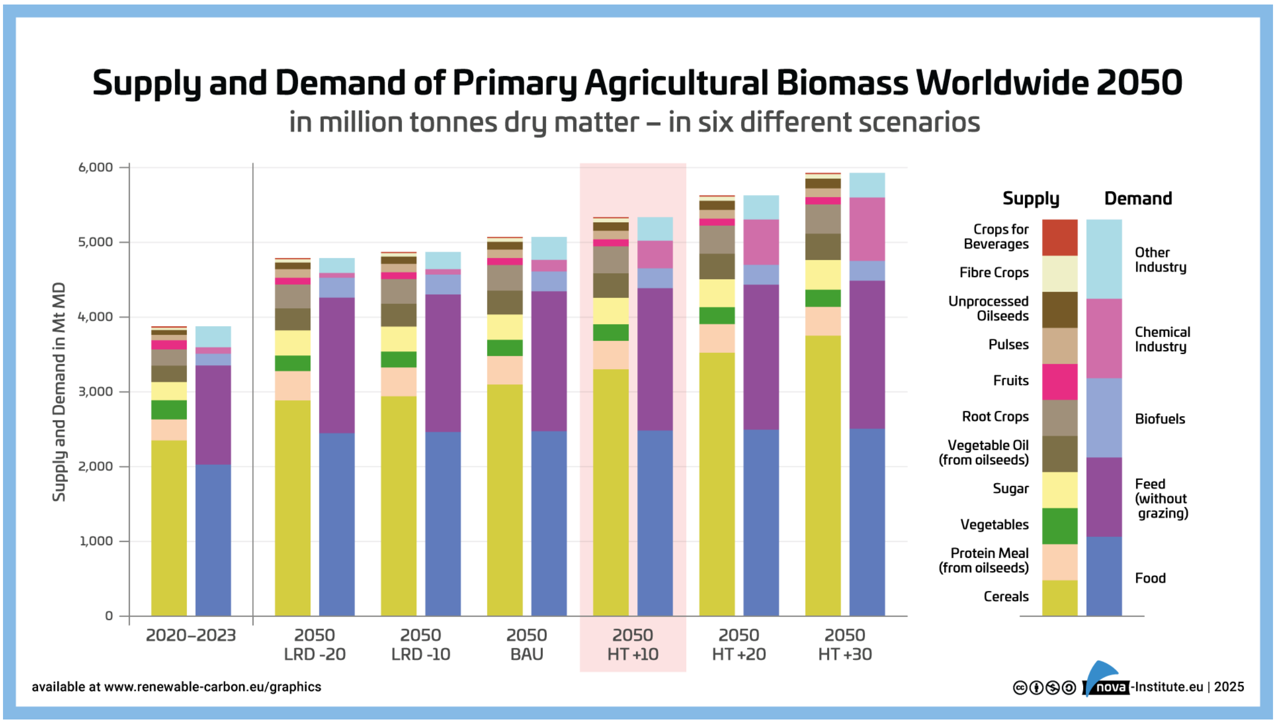

Figure 4: Supply and Demand of Agriculture Biomass Worldwide 2050 – Different Scenarios (nova 2025)

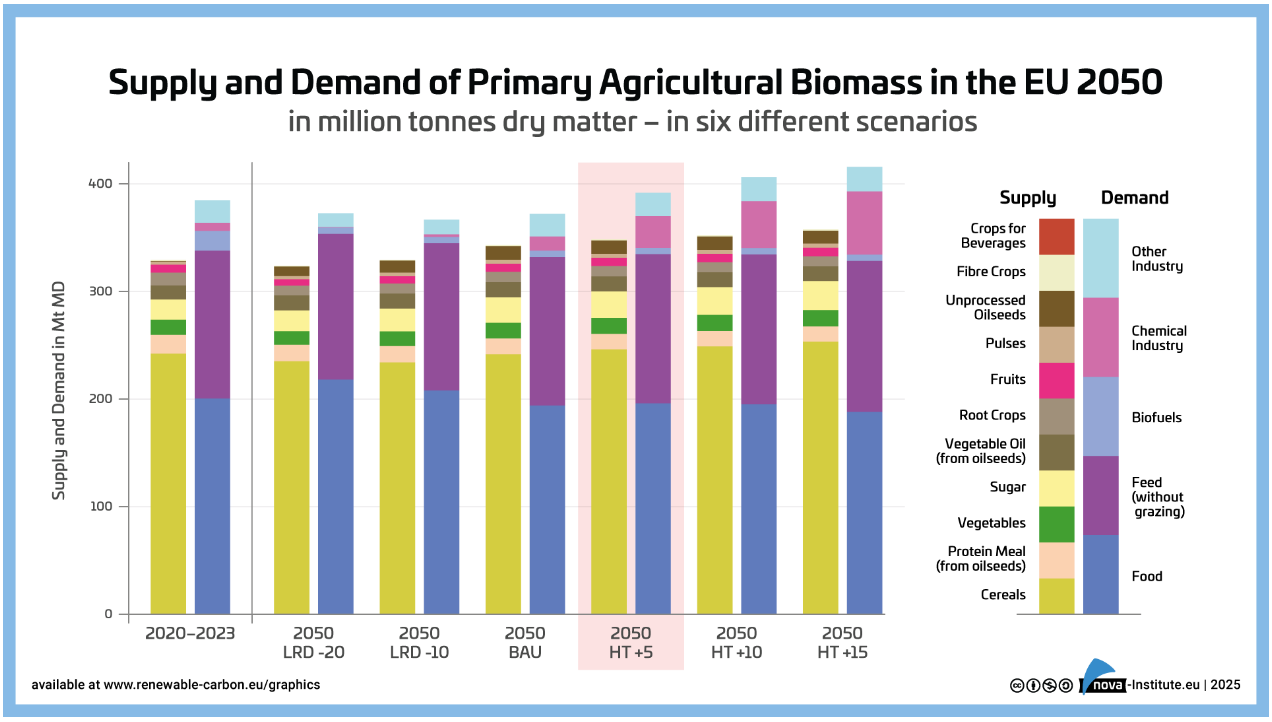

Figure 5: Supply and Demand of Agriculture Biomass in the EU 2050 – Different Scenarios (nova 2025)

The four figures summarise the main results of modelling six different scenarios. At the global level, supply and demand are equal; for the EU, demand can only be met by imports, with the import share remaining at the same level in 2050 as in 2020–2023. The HT +10 (world) and HT +5 (EU) scenarios are highlighted because in these scenarios the 20% biomass share of demand for chemicals and derived materials can be met, and because most experts consider such a moderate high-tech scenario to be the most likely way forward. The results of these scenarios are shown in more detail in the pie charts.

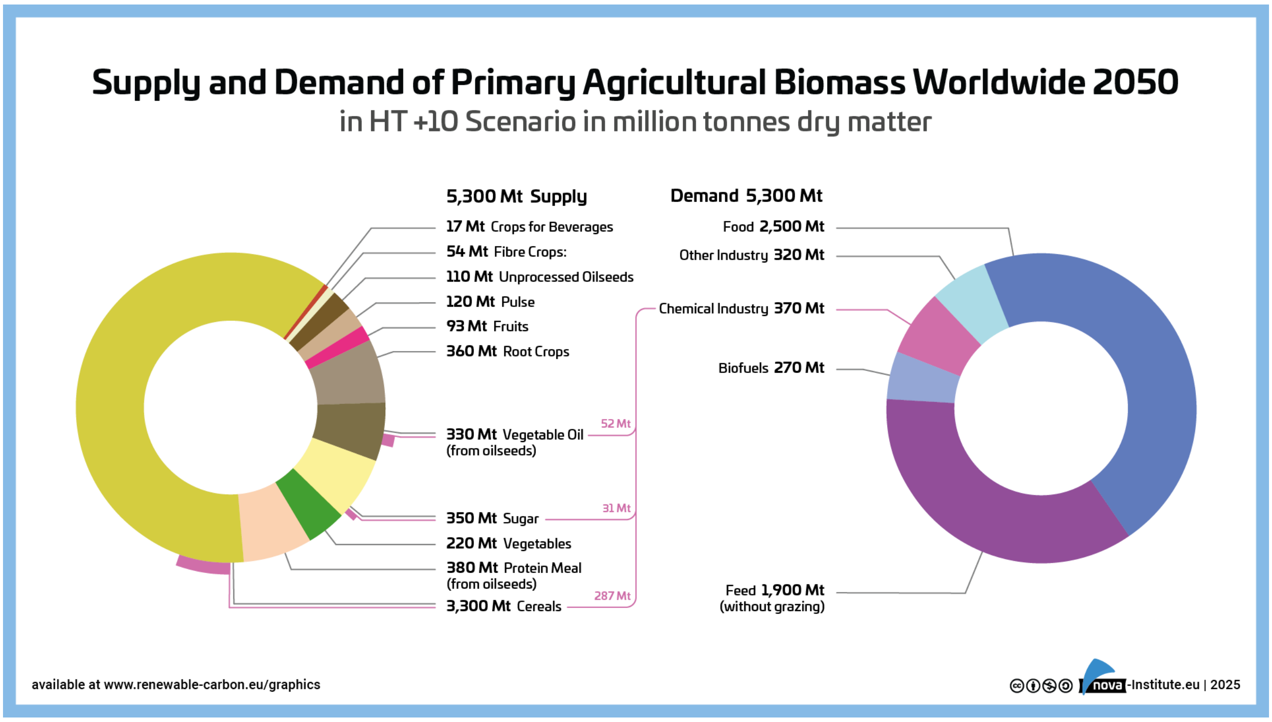

Figure 6: Supply and Demand of Agricultural Biomass Worldwide 2050 (nova 2025).
Main source of biomass for biofuels is expected to be other than primary agricultural biomass.

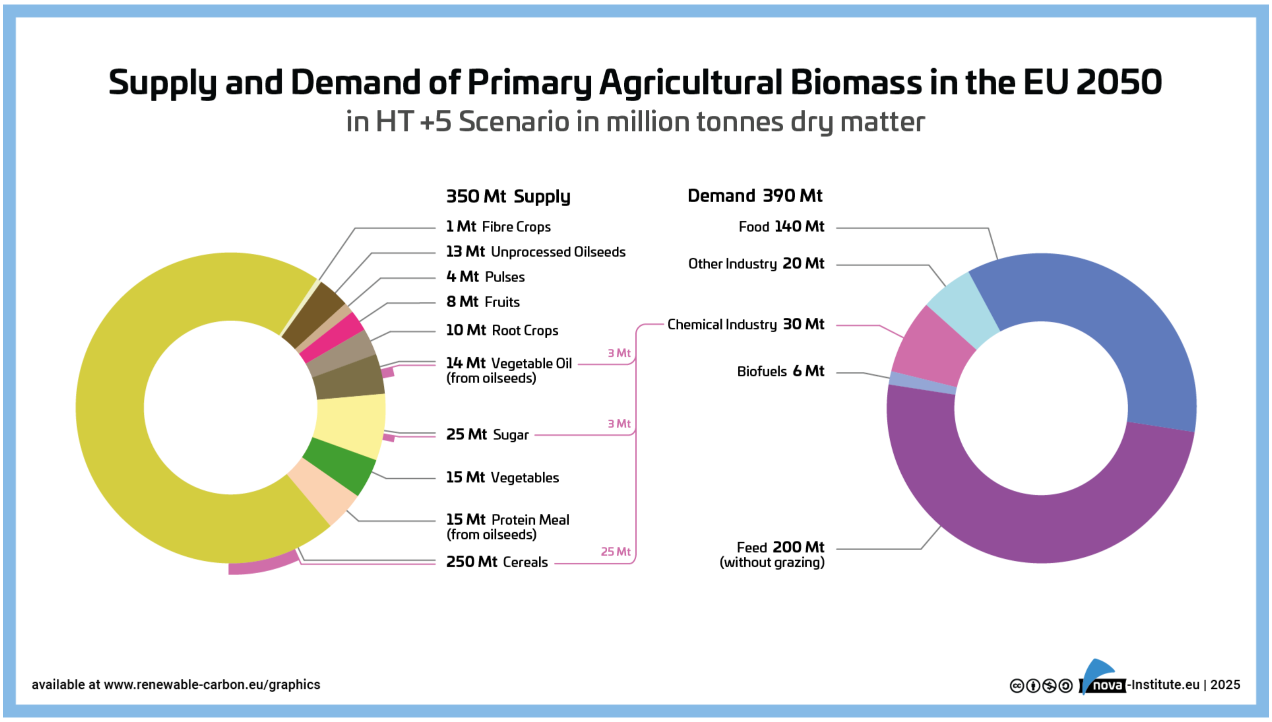

Figure 7: Supply and Demand of Agricultural Biomass in the EU 2050 (nova 2025).
Main source of biomass for biofuels is expected to be other than primary agricultural biomass.

Some special results – oil crops, starch and sugar

The supply of oil crops remains relatively stable across the scenarios because oil production is closely linked to protein demand. The high value of the protein-rich press cake drives this stability, because oil supply is consequently mainly driven by the demand for protein from feed and food, which stays consistent in all scenarios. On a global scale, the share of oil supply is higher than in Europe.

Starch supply varies greatly between scenarios, highlighting the huge potential for starch under the right conditions. Starch requirements for the chemical industry are expected to be around 5% of total cereal production. The aforementioned lower availability of sugar compared to starch due to limited scalability, is already reduced by sugar from molasses, a by-product of sugar production, which is already used in the ethanol production. Furthermore, this gap can be effectively filled by increased starch production, as scaling up starch production is obviously easier than sugar production. In addition, the overall global volume of starch production is much higher than that of sugar, making it easier to meet additional demand. The sugar supply situation is better in Europe than globally, as sugar is a well-established feedstock due to its long-established use in the EU bioethanol industry.

Some special results – straw, residues and biowaste

Residues and biowaste are very similar across the different scenarios because they are mainly related to food consumption and the cultivation of food and feed crops, and here all scenarios are relatively consistent. However, the available quantity is limited. To maintain soil quality and humus health, and for logistic reasons, realistically only an average of maximum 1/3 of post-harvest straw and residues should be used. Cereal straw[15] alone is therefore not sufficient to meet the projected (see Table 2) demand for biofuels and chemicals. The modelling shows that global use of straw from maize/corn and rice has huge, untapped potential and that harvesting and logistics could be developed within a few years. Combined, straw from cereals, maize/corn and rice could become an important feedstock for the chemical industry – but a number of technological challenges need to be overcome to make efficient use of the new feedstocks.

If only cereal straw is used, there will not be enough to meet the demand for fuels and chemicals in all scenarios (assumed demand for chemicals see Table 2, demand for biofuels from the CAPRI database). If cereal straw plus maize/corn and rice straw are used, about 1/3 of these feedstocks are required to meet the demand for fuels and chemicals in all scenarios. Among the different scenarios, Green HT requires the least amount of straw, but the differences between the scenarios are minor because straw is mainly a by-product of food and feed production, which remains constant between scenarios. Finally, the additional use of straw and residues from oilseeds and legumes (which are hardly used today) are also used, further reducing the share of straw needed for fuels and chemicals.

Biowaste from the field, throughout the processing chain, markets and households (food losses) is smaller in volume than straw. However, it faces significant demand for biofuels/SAF, particularly in Europe. The total demand for biowaste for biofuels and SAF in the EU is much larger than the demand from the chemical industry shown here, in particular because it is supported by quotas. As a consequence, only in the three Green HT scenarios is there sufficient biowaste for use in the chemical and materials sectors – mainly because the Green HT scenarios identify a higher share of CO_2-based SAF, which reduces the demand for biowaste for the production of SAF.

Some special results – meat consumption, Ukraine, agro-PV and urban farming

Meat consumption: A reduction in global meat consumption by 50%–70% in countries with high meat consumption and no change (0%) in countries with low meat consumption has an impact on the availability of biomass for the chemical industry, such as the additional biomass from BAU to Green HT 10%.

Another effect of reduced meat consumption is the reduced availability of plant oil, as in most cases oil is a by-product of protein feed production (e.g. soy). Animal fats such as tallow will also be less available.

If the demand for protein feed falls (more than can be offset by additional protein food), oil production will also decrease and, correspondingly, the price of oil will rise accordingly until it becomes feasible to grow oil as the main product. Although not on the same scale, plant proteins could find new and wider applications in chemicals and materials, such as adhesives.

Ukraine: When focusing on EU, the impact of Ukraine is of high relevance, as it is one of the major agricultural producers in Europe. If Ukraine were to join the European Union, the supply of cereal and maize starch and straw to the chemical industry would increase by 15%.

15 In the context of CAPRI, cereal straw includes wheat, barley, rye and oat straw – but not rice and maize straw.

Agro-PV: In the future, the integration of agriculture and solar power production will become more common, not only to generate additional income, but also to shade agricultural land to protect it from intense solar radiation and drying out. This shift is expected to have little impact on the world's agricultural land, as only 1–2% of the world's agricultural land could be combined with PV to generate more solar power than humanity needs. Agro-PV will mainly be used for niche crops such as vegetables, beets, fruit and potatoes, rather than for commodities such as cereals, sugar and oil crops, because of the harvesting process and market price.

Urban farming: Urban farming is particularly useful for speciality crops such as vegetables, salads and mushrooms, as it allows fresh produce to be delivered to cities over short distances. As vegetables, lettuce and mushrooms account for a very small proportion of biomass production and agricultural land, even scaled-up urban farming would have a limited impact on the overall availability of biomass.

Can the forest industry of the future meet the projected demand for chemicals and derived materials in 2050?

In our two demand scenarios for 2050, we define that biorefineries using wood and biowaste should provide 10% and 20% of the chemical sector's biogenic carbon demand, respectively. Since the demand scenarios for the chemical industry assume that a further 10% of biogenic carbon is supplied by chemical pulp, the forest industry contributes between 20–30% of the biogenic carbon required by the chemical and materials industry. Is this a realistic assumption? Can the forest industry supply this amount without affecting the demand from other industries?

TiMBA market model and data sources

To model the production and consumption of wood, TiMBA – Timber Market Model for Policy-Based Analysis (TI-FSM (2024)[16])– from Thünen-Institut of Forestry was used. It is a partial economic equilibrium model for the global forest products market, which endogenously simulates the production, consumption, and trade of wood and wood-based products in 180 countries[17]. TiMBA optimises welfare (for consumers & producers) in the global forest sector for each country and product in a given period. TiMBA distinguishes between raw, intermediate and end products. For this study, it covers 19 products: four types of roundwood (fuelwood,

16 TI-FSM*, Morland, C., Schier, F., Tandetzki, J., & Honkomp, T. (2024). TiMBA (Timber Market Model for Policy-Based Analysis) (v1.0.1). Zenodo. https://doi.org/10.5281/zenodo.13842492. *Authors' collective; the individual authors are listed as Co-authors in alphabetical order.

17 The global model excludes only a few (smaller or non-forested) countries. These countries have no or very low reported forest area and/or production, trade and consumption of forest based products. As a result, the error is likely to be negligible.

coniferous and non-coniferous industrial roundwood, other industrial roundwood), two additional raw products for paper production (other fibre pulp and waste paper), three intermediate products (mechanical, semichemical and dissolving pulp) and ten finished products (coniferous and non-coniferous sawnwoods, veneer sheets and plywood, particle board, fibreboard, newsprint, printing and writing paper, other paper and paperboards, lignocellulose-based fibres and lignocellulose-based derivatives).

The supply and use of forest residues are not explicitly modelled but are implicitly included: Forest residues in the form of "logging losses, stumps, burls, and wood chips made in the forests“[18] are included in the reported roundwood supply data used as model input for fuelwood and industrial roundwood, only if they have been removed from the forest and utilised.[19]

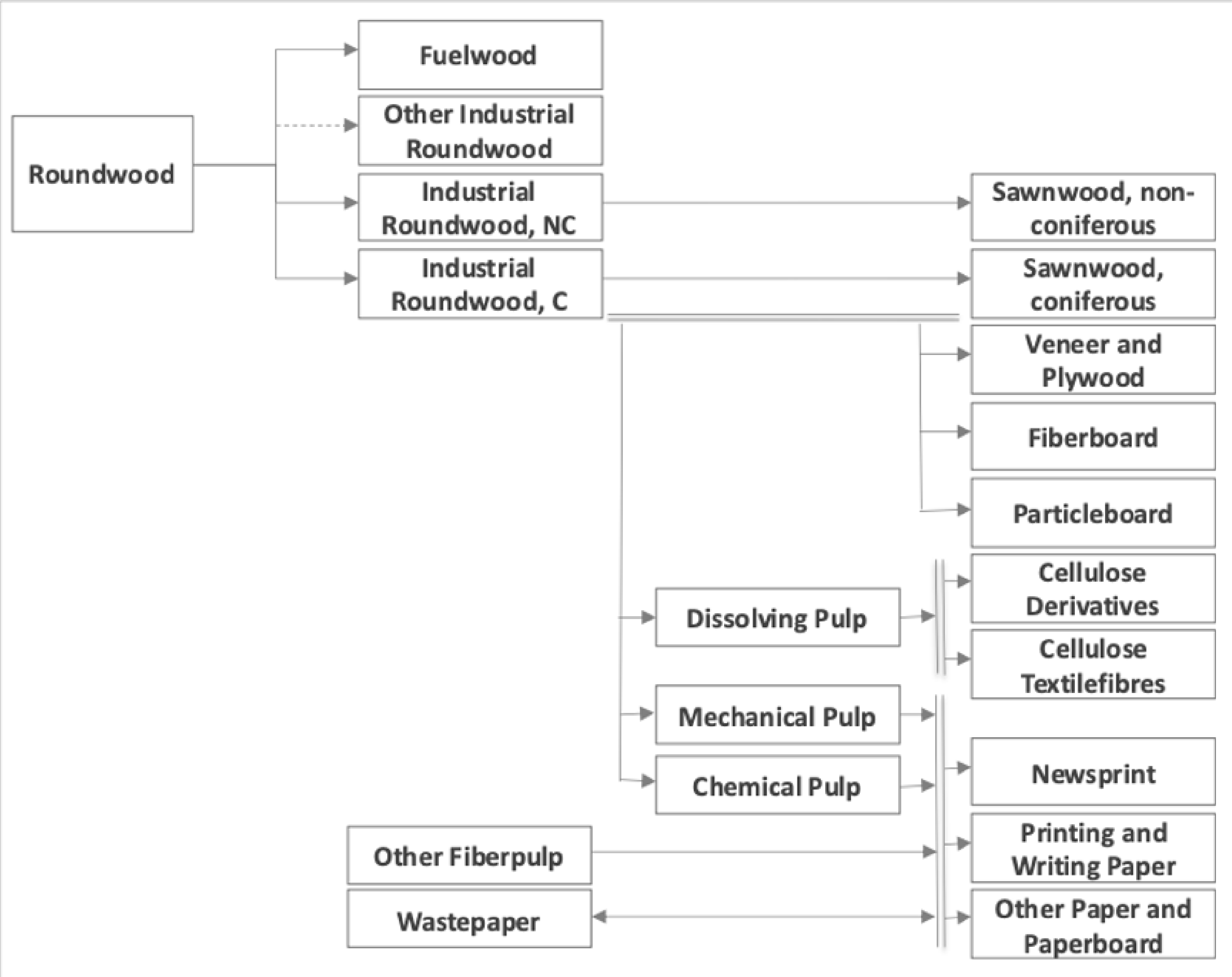

Figure 8: Product Structure of TiMBA With 19 Products From Forest Sector

18 https://unece.org/sites/default/files/2024-04/DEF-EN-JQ-for-2023-data.pdf.

19 Potential high volume of additional logging residues is not yet covered in the supply data.

Data on forest area and forest stock are obtained from FRA 2020[20]; traditional forest products, including dissolving pulp, supply and trade are derived from FAOSTAT 2024. Information on imports and exports of cellulose fibres and derivates for the base year is obtained from Comtrade 2023, supplemented with additional information from Thünen Institute of Forestry and nova-Institute based on The Fiber Yearbook 2023[21] & Skoczinski et al. 2024[22]. Forest area development follows the environmental Kuznets curve, which correlates with GDP per capita growth.

Similar to the method used for the agricultural sector, the authors developed a green low resource depletion (LRD) scenario and a green high technology (HT) scenario in addition to the Business-as-usual scenario (BAU).

Main scenarios and assumptions

BAU: In the Business-as-usual scenario, all developments including deforestation, are endogenous, coupled to GDP and population growth. Deforestation trends are reversed by 2035 and follow the EKC.

Green LRD: The Low Resource Depletion scenario is based on the narrative of SSP1 (Shared Socioeconomic Pathways), which is characterised by higher GDP per capita, higher demand for wood and wood-based products, and greater use of post-consumer wood. In this scenario, we assume that the panel industry uses 20% less industrial roundwood in its input mix to produce one unit of panels compared to BAU due to the increased use of post-consumer wood in manufacturing. SAFs are to a higher extent derived from woody biomass. This puts SAFs in direct feedstock competition with raw materials with other sectors, including biorefineries[23].

An immediate halt to deforestation is assumed, which in combination with lower population growth, greater prosperity and greater environmental awareness will lead to a net increase of forest area on a global scale. The increase in forest area favours forest growth and increases national forest stocks and roundwood availability compared to BAU.

Green HT: The High-Tech scenario follows SSP2, which is characterised by a moderate progress in economic, social and environmental areas, based on historical patterns. It assumes an increasing use of post-consumer wood, resulting in a 30% reduction of industrial roundwood demand compared to BAU in the panel industry. SAFs are to a higher extent derived from CCU and to a lower extent from wood, reducing wood demand for aviation fuels. However, a higher share of biorefineries leads to an increased wood demand in this sector[24].

20 Forest Resource Assessment 2020, https://fra-data.fao.org/

21 The Fiber Year 2024, World Survey on Textiles & Nonwovens, The Fiber Year GmbH, Rogwill (CH).

22 Skoczinski, P. et al. 2024: Bio-based Building Blocks and Polymers – Global Capacities, Production and Trends 2023–2028; DOI No.: https://doi.org/10.52548/VXTH2416

23 Please note, that raw material supply for and demand of SAFs and biorefineries are not considered in modelling with TiMBA`s but accounted for via experts judgement and Harrandt, J., Carus, M., vom Berg, C., Hark, N. 2024: EU and global: Biomass Demand for Transport Fuels, Aviation and Shipping up to 2050 and Implications for Biomass Supply to the Chemical Sector.

24 Same comment and source as above.

Deforestation is halted after 2030 and more forest area will be available due to higher agricultural efficiency, reducing the demand for additional agricultural land.

Table 7: Assumptions for forest production development under different scenarios (BAU, LRD, HT)

Parameter	Units	BAU	Green Low Resource Depletion (LRD)	Green HighTech (HT)
		Projection 2050 (EU / global)	**Projection 2050 (EU / global)**	**Projection 2050 (EU / global)**
Biorefineries	Million t dry matter/year	–	2.3 / 24	4.6 / 48
Cellulose fibres	Million t	Endogenous, linked to GDP and price developments	1.65 / 16,5	1.65 / 16.5
Cellulose derivates	Million t	Endogenous, linked to GDP and price developments	0.7 / 2.7	0.7 / 2.7
SAF	Million t	–	81 / 682	36 / 269
Deforestation		Endogenous, coupled to GDP and population development	More areas of commercial forest set aside and an increase in overall forest area. No deforestation	No deforestation after 2030, more forest through higher agricultural efficiency
Increasing stock per area		Endogenous, depending on previous stock	Yes, compared to BAU	Yes, compared to BAU
Use of post-consumer wood in wood panels (particle and fiberboard)		Input-output in panel production, higher production efficiency; -1% to -2% on global average	20% gradual reduction of country-specific input-output by -20% compared to BAU	30% gradual reduction of country-specific input-output by -30% compared to BAU
GDP and population growth		SSP 2	SSP1	SSP 2

Main results from the forest sector modelling

Forest area and stock

In all scenarios, the net forest area increases globally from 2020 to 2050, with the largest increases in Asia and in the LRD scenario. The top 4 Asian countries in production of roundwood in 2050 will be China with a share of 42%, Russia with 21%, India and Indonesia with each 10%.

In LRD, the "no deforestation" mandate is exogenously imposed in the model from the beginning of the simulations, in HT from 2030 onwards, and in BAU forest development is an endogenous process (following the EKC) where the net deforestation trend reverses after 2035, with global forest area returning to 2020 levels between 2040 and 2045. Note that at the continental level, the results differ both in terms of year and area, so that, for example, deforestation in the BAU scenario continues until 2050 in Africa (-10%) and South America (-1%). In contrast, the ban on deforestation in the HT and LRD scenarios counteracts land use change. On the other hand, forest areas increase, especially in Asia, followed by Oceania and Europe, compensating for the loss in Africa and South America.

In 2050, the global net forest stock in BAU is 2% lower than in 2020 while in LRD the decrease is only -0.5% and in HT we even observe an +0.6% increase of global net forest stock. Again, in should be noted that regional and national results vary. However, globally, the pressure on forest resources is decreasing in LRD and HT compared to BAU. The example of LRD shows, that a high demand for forest-based products, triggered by rising GDP per capita, leads to increased production. The global forest stock slightly decreases due to this higher demand; however, this decline is disproportionate compared to the increase in production due to improved resource availability and technology.

Global supply of industrial roundwood

Global supply of industrial roundwood (including coniferous and non-coniferous industrial roundwood) is projected to increase by 38% between 2020 and 2050, from 0.9 to 1.3 billion tonnes dry matter (tdm) in the LRD scenario. The largest increase in supply is expected in Asia (69%), including China and Russia. For Europe, an increase of 32% is simulated. Although these figures are from the Green LRD scenario, the results are very close across the scenarios compared to the wide range of the agricultural scenarios.

The highest demand for industrial roundwood is seen in the LRD scenario, where increased prosperity leads to increased demand for wood. However, this increased demand can be well met by supply. A key factor enabling this balance is the halting and reversing of deforestation, which ensures that sufficient forest resources are available (see above).

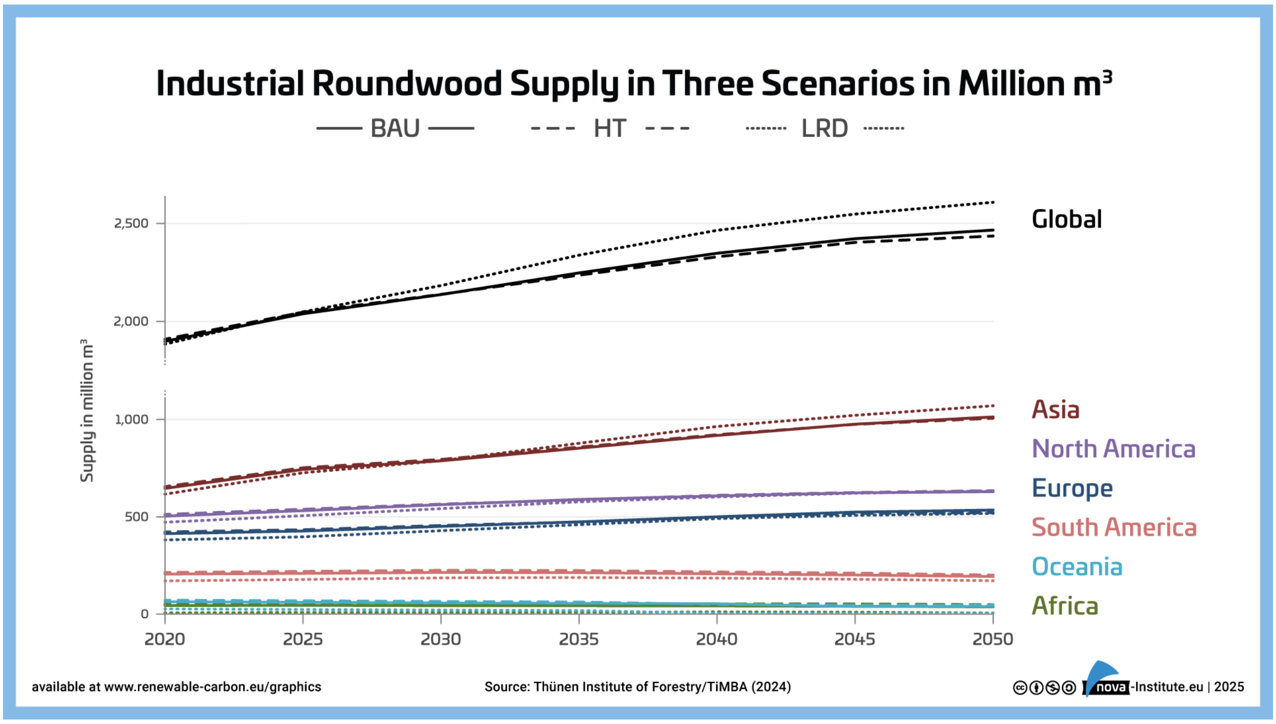

Figure 9: Aggregated global Industrial Roundwood Supply over six continents (nova 2025)

Significant demand growth is expected in all traditional applications such as sawnwood (increase from 228 in 2020 to 310 million tonnes dry matter in 2050; growth of 36%), particleboard, OSB and fibre board (increase from 109 in 2020 to 248 million tdm in 2050; growth of 127%), paper pulp (increase from 197 in 2020 to 280 million tonnes in 2050; growth of 43%) and plywood/veneer (increase from 65 in 2020 to 118 million tonnes tdm in 2050; growth of 81%). The highest demand is again expected in the LRD scenario, with the highest supply growth in Asia.

Particularly high growth is expected in new applications: dissolving pulp (increase from 9 in 2020 to 44 million tonnes in 2050; growth of 406%), cellulose fibres (increase from 7 in 2020 to 38 million tonnes in 2050; growth of 447%) and cellulose derivatives (increase from 2 in 2020 to 6 million tonnes in 2050; growth of 190%) all show remarkable growth. Still, the share of the total demand of these new applications remains small compared to the traditional applications (see Figure 8).

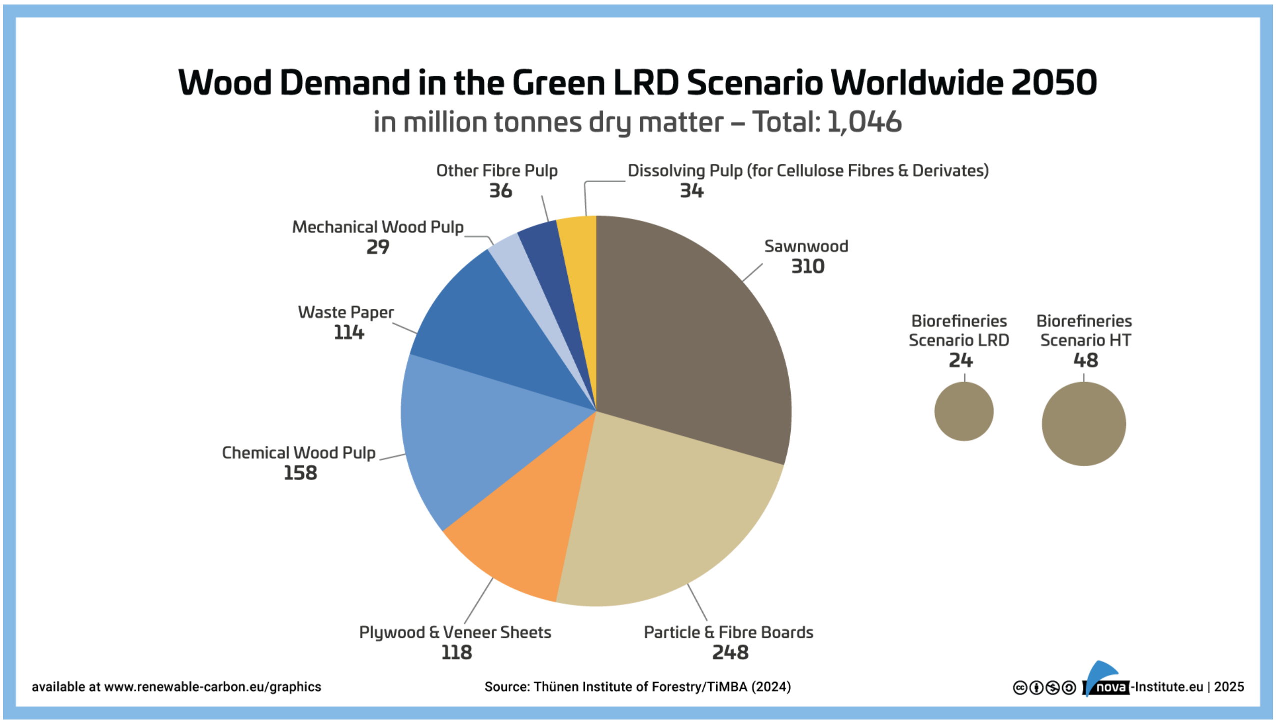

Figure 10: Global Wood Demand for Wood-based and Associated Products by Product Groups (nova 2025)

Of the 1.266 million tdm of roundwood in 2050, 931 million tdm will be used for the production of wood-based and related products. The remaining gap of 335 million tdm is due to losses and by-products such as wood chips, particles and residues. In addition, about 114 million tdm of waste paper will be reused in the paper industry, giving a total of about 1,046 million tdm of wood-based products in 2050.

How is it possible to achieve a significant increase in production (+38%) while at the same time halting global net deforestation and improving national forest stocks? First, compared to other forest reports, the 38% increase in production projected here is in the middle of the range (10 to 55%).[25]

As noted above, the slight increase in global net forest area will increase resource availability over time. In addition, increased efficiency throughout the value chain due to technological change reduces the input requirements for industrial roundwood. This effect is reinforced by the assumption of an increase in recycled wood for the production of wood-based panels. The replacement of industrial roundwood in the input mix frees resources for other or increasing applications.

Irrespective of the results of the modelling study, it can be assumed that the expansion of planted and managed forests will continue. At the same time, optimising the management and planting of tree species may play an important role in the future.

25 Daigneault, A. et al. 2022: How the future of the global forest sink depends on timber demand, forest management, and carbon policies. https://doi.org/10.1016/j.gloenvcha.2022.102582

Calculated amount of sidestreams

The quantification and use of sidestreams from wood processing is not included in the model. However, potential sidestreams can be calculated post-modeling. The key findings of this approach are as follows:

Depending on the scenario, by 2050 the amount of by-products in the form of wood chips, particles and residues[26] is estimated to be between 200 and 210 million tdm/year worldwide, and between 42 and 43 million tdm/year in Europe.

Globally, the LRD scenario has the highest amount of co-products in 2050 due to the overall higher demand and supply. In Europe, sidestreams increase between 2020 and 2050 mainly due to a strong increase in sawnwood, veneer and plywood production, which overcompensates for the theoretical reduction in sidestreams due to technological improvements and efficiency gains. Another part of the explanation is that overall efficiency in Europe is already relatively high, so future improvements are limited compared to other regions.

Although production also increases in the high temperature sector, the global amount of sidestreams is projected to be lower in 2050 than in 2020. Here, technological improvements overcompensate for the quantity effect.

Meeting the additional demand for forest biomass for the chemicals and derived materials sectors in 2050

Back to the original question: "Can the forest industry of the future meet the projected demand for chemicals and derived materials in 2050?" According to the scenarios developed for this report, the additional wood consumption of the chemicals and derived material sector results from the growing demand of lignocellulosic biorefineries. As the additional demand of 24 to 48 million tdm/year (worldwide) by 2050 is very small compared to the demand for traditional wood applications (see below), there are different ways to meet the demand.

Option 1: Use of Industrial Roundwood

Comparing the total industrial roundwood supply of 1.3 billion tdm with the biorefinery demand of 24 to 48 million tdm/year (worldwide), this demand is relatively small (1.8–3.7% of the total roundwood supply). Therefore, there is a realistic possibility that this additional demand could be met without significantly affecting the supply of other sectors.

Option 2: Use only wood chips, particles and residues

This is principally the preferred option to avoid pressure on forests and primary production.At first glance the potential availability of 200–210 million tdm/year of sidestreams worldwide seems adequate to meet

26 Definition according to the United Nations Economic Commission for Europe. (2021). Definitions of Key Terms in the Common Quality Assurance Framework. https://unece.org/sites/default/files/2022-04/jq2021def-e.pdf

the demand of 24–48 million tdm/year from biorefineries. However, there is strong competition from other sectors, the largest being the pellet industry (projected global demand of up to 85 Mt by 2050, see discussion on fuelwood below) and sustainable aviation fuels (SAF)[27], where, at least in the EU, SAFs can only be produced from wood by-products and residues when it comes to biomass from forestry. In our scenarios, SAF demand is calculated for

- 2050 – Green LRD, Chem A: 80 million tdm/year in the EU and 680 million tdm/year globally.
- 2050 – Green LRD, Chem B: 26 million tdm/year in EU and 270 million tdm/year globally (most SAF from CO_2).

This results in a significant gap between potential supply and potential demand for wood by-products and residues from the pellet, aviation and biorefinery industries. Due to existing quotas and subsidies in the energy/fuel sector, between the three main demand sectors, it seems unlikely that in the current legislative framework, biorefineries will have competitive access to a significant amount of wood co-products and residues. All of this will be required to meet the regulatory requirements in the energy/fuel sector.

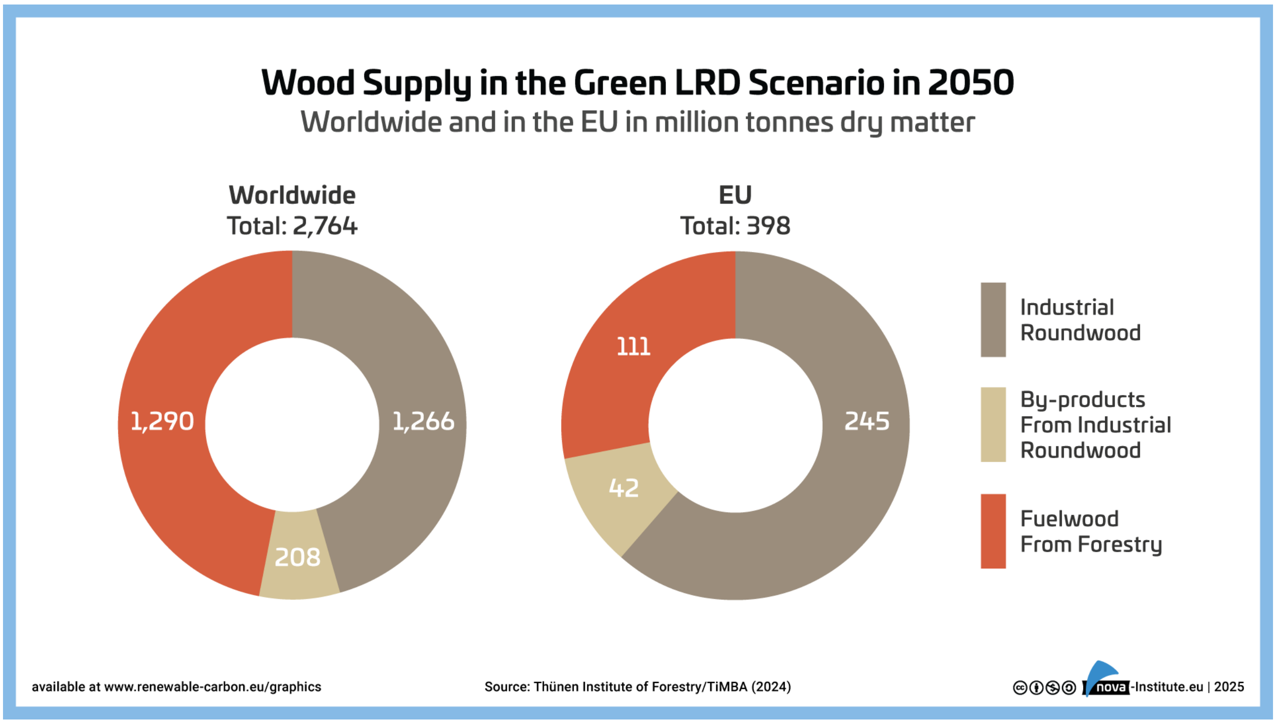

Figure 11: Wood Supply in the Green LRD Scenario in 2050 (nova 2025)

27 Harrandt, J., Carus, M., vom Berg, C., Hark, N. 2024: EU and global: Biomass Demand for Transport Fuels, Aviation and Shipping up to 2050 and Implications for Biomass Supply to the Chemical Sector. (not yet published, DOI will be added after publication)

Option 3: Use of fuelwood

The third option is to capture a share of the fuelwood market to feed biorefineries. Although fuelwood is not the focus of this study, the demand for fuelwood is significant, continues to grow and should not be ignored when comparing total volumes.

In all scenarios (most of all in the LRD) the use of fuelwood is expected to continue growing.

Globally, the ratio of wood from forests used for material production to wood from forests used for energy purposes is modelled to be close to 50:50 by 2050 (from 59:41 in 2020). However, on a continental scale, the ratio of wood from forests used for material production to wood from forests used for energy purposes in 2050 varies considerably: while in Africa, for example, the supply of fuelwood is many times greater than the supply of industrial roundwood, in North America only about 20% of the roundwood supply is used for energy purposes.

Option 3 would therefore be to reduce the proportion of fuelwood that is burned directly, thus freeing up potential for use in biorefineries. This could include attempts to achieve sustainable fuelwood use, improved, more efficient stoves/kilns to reduce the need for fuelwood, and renewable energy alternatives, such as solar power that could significantly reduce the use of fuelwood.

This option should include a focus on sustainable, regional use of forest resources.

Summary: Forestry

Global supply and demand for industrial roundwood (coniferous and non-coniferous) is estimated to increase by an estimated 38% between 2020 and 2050, from 0.9 to 1.3 billion tdm,. The largest increase in supply is expected in Asia (69%), including China and Russia, but a significant increase of 32% is also seen for Europe.

The additional demand from the chemical and materials industries is comparatively small compared to the traditional applications of wood. This means that, in principle, it is very feasible to meet this demand in a sustainable way. There are several options for meeting this demand: (1) use a relatively small proportion of total industrial roundwood supply (evaluate cost-effectiveness), (2) preferred: use of by-products from industrial roundwood processing (problem of high competition), or (3) divert a relatively small proportion from the fuelwood sector.

The evaluations for by-products and fuelwood are based on expert opinion derived from post-modelling considerations. What is economically and regionally the best solution should be examined in an additional study that also models the by-products and fuelwood.

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The Bio-based Industries Consortium (BIC) is a non-profit organisation connecting industry, academia, regions and citizens to transform bio-based feedstocks into novel sustainable products and applications, and create circular bioeconomy ecosystems through investments, innovation and know-how.

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