Peat replacement in horticultural growing media: Availability of bio-based alternative materials

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Abstract

Peat is a fossil material and is since decades the major growing media constituent for horticulture in Europe. Because of its climate impacts, some European countries developed national strategies to reduce peat use. A coordinated European action would bring fairer and more effective impacts than isolated national strategies. The replacement of peat is possible using alternative growing media constituents based on biomass. Potential limitations of the resource availability for the production of alternative growing media constituents is one of the major concerns of the growing media industry. Although this paper does not constitute a final evaluation, it aims to initiate further discussions and investigations on this aspect of peat reduction. We compare potential amounts for the supply and demand of raw materials for the production of wood fibres, composted bark, green compost and coir pith in European countries. Moreover, we discuss the economic and legal conditions for the availability of alternatives. Our findings suggest that the resource supply does not generally indicate a limitation to an extended use of alternative growing media constituents in Europe. In a maximal demand scenario, the amounts considered would also be sufficient to completely replace peat. However, in this scenario, the current supply for nationally sourced alternative materials could be scarce for some countries like the Netherlands or the Baltic States. Competition for wood resources, e.g., with the energy sector, could limit their use in the growing media sector. Moreover, the conditions set by the EU Fertilising Products Regulation (EU) 2019/1009 might hamper a large use of wood fibres as growing media constituent. For bark, green waste and coir by-products, an increased demand from the growing media sector may support mobilization of additional resources. For coir by-products, a future rise of the international demand might lead to a strong competition and an exhaustion of the world's potential. Transportation costs play an important role for the access to biomass potentials. They could be reduced with the development of the infrastructure for processing available resources. Other growing media constituents like *Sphagnum* are not significantly used today but could represent additional potentials for the replacement of peat in future. In order to avoid displacement effects, the focus of peat substitution should be set on potential amounts of biomass that are currently not or not fully used, or the creation of new potentials.

Keywords: Growing media, horticulture, peat, peat alternatives, availability, biomass resources

JEL-Codes: Q21, Q31, Q54

Zusammenfassung

Torf ist ein fossiler Rohstoff und seit Jahrzehnten der wichtigste Bestandteil von Substraten für den Gartenbau in Europa. Aufgrund der damit verbundenen Klimawirkungen haben einige europäische Staaten nationale Strategien zur Reduzierung der Torfnutzung entwickelt. Eine koordinierte europäische Initiative würde fairere und effektivere Wirkungen entfalten als isolierte nationale Strategien. Der Ersatz von Torf ist durch die Nutzung alternativer, biomassebasierter Ausgangsstoffe für Kultursubstrate möglich. Mögliche Begrenzungen der Ressourcenverfügbarkeit für die Produktion alternativer Kultursubstrate stellt eines der größten Bedenken der Erdenindustrie dar. Dieses Papier stellt zwar keine abschließende Evaluierung dar, es zielt aber darauf ab, weitere Diskussionen und Untersuchungen dieses Aspekts der Reduzierung der Torfnutzung zu initiieren. Dafür vergleichen wir die Angebots- und Nachfragemengen von Rohstoffen für die Produktion von Holzfasern, kompostierter Rinde, Grünkompost und Kokosfasern in europäischen Ländern. Anschließend diskutieren wir die ökonomischen und rechtlichen Rahmenbedingungen für die Verfügbarkeit von Torfsubstituten. Unsere Ergebnisse legen nahe, dass das Rohstoffangebot insgesamt keine Begrenzung für eine erhöhte Nutzung von alternativen Kultursubstraten in Europa darstellt. In einem Szenario mit maximaler Nachfrage würden die betrachteten Mengen ausreichen, um Torf vollständig zu ersetzen. In diesem Szenario könnte die aktuelle, nationale Versorgung mit alternativen Rohstoffen allerdings für einige Länder zu knapp ausfallen, beispielsweise in den Niederlanden oder den baltischen Staaten. Der Wettbewerb um Holzressourcen, z. B. mit dem Energiesektor, kann die Nutzung für die Substratherstellung begrenzen. Darüber hinaus könnten Anforderungen gemäß EU Düngemittelverordnung (EU) 2019/1009 eine umfangreiche Nutzung von Holzfasern als Ausgangsstoff behindern. Im Fall von Rinde, Grünkompost und Kokosprodukten kann eine erhöhte Nachfrage der Erdenindustrie zur Mobilisierung zusätzlicher Mengen beitragen. Für Kokosnebenprodukte kann ein künftiger Anstieg der Nachfrage zu einem verstärkten Wettbewerb und einer Erschöpfung des weltweiten Potentials führen. Transportkosten spielen eine wichtige Rolle für den Zugang zu Biomasse-Potenzialen. Diese können durch die Entwicklung von Infrastruktur für die Verarbeitung verfügbarer Biomasse-Ressourcen verringert werden. Andere Bestandteile von Substraten wie Torfmoose werden bisher in keinem signifikanten Umfang genutzt, könnten aber ein zusätzliches Potenzial für den künftigen Torfersatz darstellen. Um Verlagerungseffekte zu vermeiden, sollte der Schwerpunkt der Torfsubstitution auf Mengenpotenziale gelegt werden, die derzeit nicht vollständig genutzt werden, oder auf der Erschließung neuer Potenziale.

Schlüsselwörter: Kultursubstrate, Gartenbau, Torf, Torfersatz, Verfügbarkeit, Biomasse

JEL-Codes: Q21, Q31, Q54

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Extended summary

Peat is a fossil material which is extracted from peatlands. It is used mostly for the production of electricity and/or heat (i.e. energy use) as well as for the production of growing media in horticulture for professional and hobby markets (i.e. non-energy use). Peat extraction and its use for horticultural purposes constitute a relevant source of greenhouse gas emissions, which accounted for 12 Mt CO_2 per year in 2019 in the EU27 (UN Climate Change, 2022). Most of these emissions come from the decomposition of peat itself when used as growing media constituent.

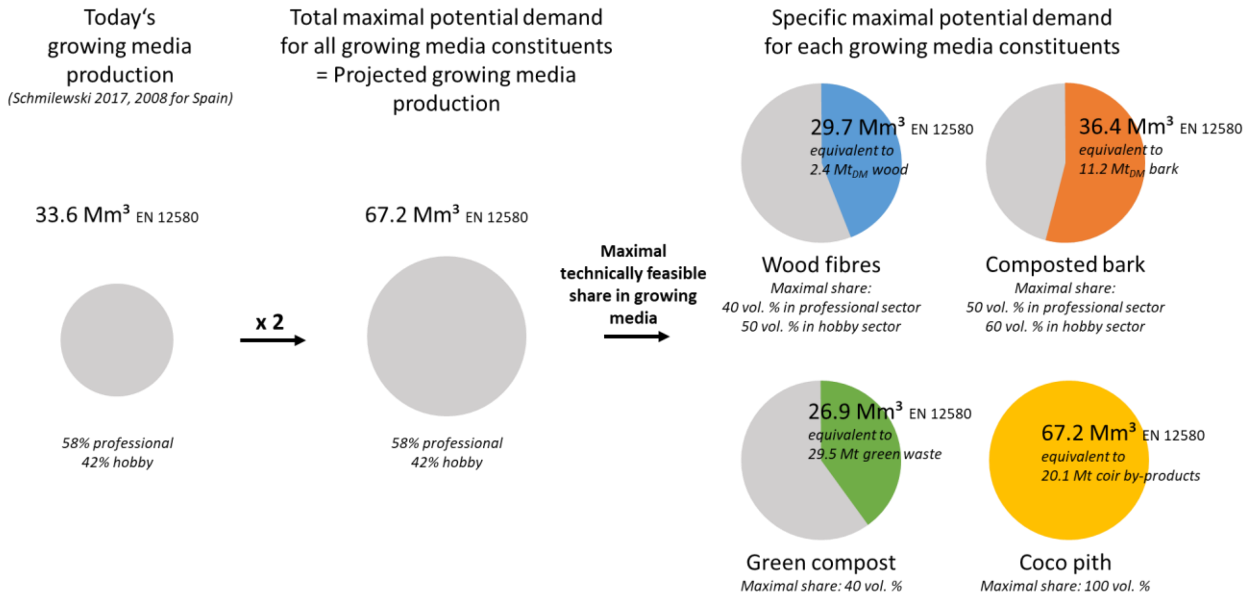
Reducing peat use and developing renewable alternatives for peat substitution in growing media are essential elements of a greenhouse gas mitigation strategy for horticulture and the land use sector. Peat can be substituted by mixtures of alternative growing media constituents. The main alternatives today are wood fibres, composted bark, green compost and coir pith. These materials are renewable and have much lower climate footprints compared to peat. In fact, alternative materials could turn climate neutral in the future if transport and energy sectors are successfully de-carbonised. Peat cannot achieve climate neutrality due to its fossil nature and its inevitable decomposition during use.

In the European Union, peat extraction will be included in mitigation targets defined in the LULUCF regulation (EU) 2018/841 as part of the category “Wetlands” from 2026 onwards. So far, national political strategies to reduce and phase out peat use in horticulture have been engaged in Germany, Ireland, the United Kingdom, Switzerland, and Norway. Recently, a parliamentary motion has been filed in the Netherlands regarding the reduction of peat use. However, considering that peat and growing media are widely traded within the EU, individual national efforts could suffer from competitive disadvantage and leakage effects on the EU domestic market. This would limit the climate mitigation effect of these strategies. A coordinated European action on peat reduction in growing media would have economically fairer and environmentally more effective impacts than isolated national strategies.

Potential limitations of the resource availability for the production of alternative growing media constituents is one of the major concerns of the growing media industry. The objective of this discussion paper is to present a first investigation on the availability of alternative materials in EU countries. Although some conclusions can be drawn from these first results, this study should not be considered a final evaluation. It rather aims to initiate further discussions and investigations on challenges associated with the availability of alternative materials to replace peat. This paper focuses on the four most used alternative growing media constituents: wood fibres, composted bark, green compost and coir pith.

Based on available information for EU member states, we compare the current demand for the four most used alternative growing media constituents with the current domestic supply of raw materials for the production of these alternative constituents. Further, we project the total maximal potential demand for peat alternatives, presuming a duplication of the current growing media production as well as a complete substitution of peat in the future. From the total maximal potential demand, we derive specific maximal potential demands for each alternative constituent. Specific maximal potential demands consider the maximal feasible share of alternative constituents in growing media due to technical limitations in horticulture. The sum of all specific maximal potential demands for each raw material is superior to the total maximal potential demand. Figure 1 depicts the method to derive the total maximal potential demand and the specific maximal potential demands for each constituent.

Figure 1: Calculation of the maximal potential demand (total and specific for growing media constituents) applied to the European countries considered



Notes:
EN 12580 is the European norm for the determination of volume of growing media, applied here to growing media constituents.
Countries: Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Spain and Sweden.

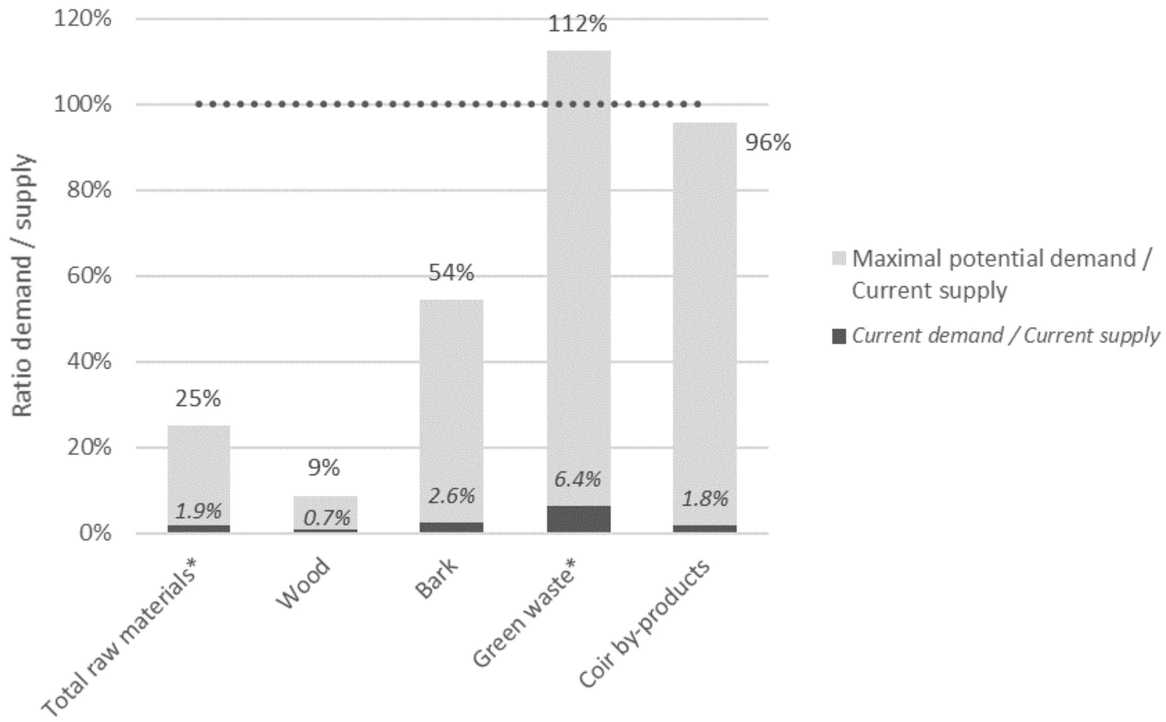
Figure 2 shows the ratios of the specific demand (current and maximal potential) and current supply of each raw material for the production of alternative growing media constituents. In addition, a ratio of the total usable supply and the total demand (current and maximal potential) for growing media constituents is presented. The total usable supply considers the limitation in the mobilisation of the supply due to maximal technically feasible share of each constituent in growing media.

Our findings suggest that the resource supply does not generally indicate a limitation to an extended use of alternative growing media constituents. For all materials, the current demand for growing media constituents represents a minor fraction of current supply. For wood (i.e. coniferous sawmill by-products), bark and coir by-products, the specific maximal potential demand of growing media constituents is also below current supply. However, for green waste, the specific maximal potential demand overshoots slightly current supply.

In some countries in the EU, the current supply for nationally sourced alternative materials could be scarce in a maximal demand scenario. This situation especially concerns countries with an important role in production and trade of peat and growing media, like the Baltic States or the Netherlands. Thus, an extensive peat replacement can change the international structure of the supply chain of growing media. In general, the availability of data on growing media, growing media constituents (including peat) and biomass residues needs to be improved in order to develop informed strategies towards peat reduction.

In addition to the potentially available resource supply, the economic and legal conditions for the growing media industry to access raw materials should be considered. A precise assessment of the economic availability should also take into account costs and infrastructure required to collect, transform and transport resources, as well as the competition with other sectors for the access to these resources. In this study, these aspects where considered mostly qualitatively. Further research would be needed in the future to investigate these aspects more closely.

Figure 2: Ratio of demand for growing media constituents (current and maximal potential) and supply of raw materials for the European countries considered



Notes:
Current demand: Schmilewski 2017 (year 2013). For Spain Schmilewski 2008 (year 2008)
Maximal potential demand: own calculation based on a total peat replacement, a duplication of the growing media production and, for each corresponding constituent (wood: wood fibres; bark: composted bark; green waste: green compost; coir by-products: coir pith), its maximal technically feasible share in growing media (see chapter 2.3)
Supply wood: production of coniferous sawmill by-products (2018-2020)
Supply bark: potential based on bark from the apparent consumption of industrial roundwood (coniferous and non-coniferous) (2018-2020)
Supply green waste: collected green waste (2017)
Supply coir by-products: potential based on the world coconut production (own calculation based on average 2017-2019)
Supply total raw materials: Total usable supply considering maximal share in growing media (see chapter 3.5)
Countries: Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Spain and Sweden. Due to lack of data on green waste, Finland, Ireland and Lithuania are not considered in the ratio for green waste and the total for all growing media constituents.

In general, the infrastructure to access wood resources is well developed in the EU. The forest products market is much larger in absolute terms than the growing media market and comprises a great variety of products. In our assessment of wood supply we focused mainly on sawmill by-products, which are currently the main source to produce wood fibres for growing media and are cheaper than other forest products (e.g. roundwood). Nevertheless, sawmill by-products are used for other purposes, e.g., the production of wood panels, pulp or pellets. The energy sector demands significant quantities of wood residues and by-products too. Thus, competition for such resources can be strong. Energy and climate policies supporting the bioenergy sector can exacerbate the competition for wood resources.

The EU Fertilising Products Regulation (EU) 2019/1009 addresses organic fertilisers, soil amendments and growing media, and aims to improve market conditions for such inputs produced from recycled and organic materials within the EU. However, the legal framework for fertilising products also could constitute a limitation to the substitution of peat. A recent amendment of this regulation defines that “an EU fertilising product may contain plants, plant parts or plant extracts having undergone no processing other than (…) fiberisation at a temperature not higher than 100 °C …” (Regulation (EU) 2021/1768, Annex II (2)). As defibring of wood is usually run at temperatures up to 160°C, this requirement might restrict the use of wood fibres in growing media. Especially, the trade of alternative growing media using CE marking might be affected. Potential impacts of the new rules for EU fertilising products produced from recycled and organic materials on production of and trade with peat-free and peat-reduced growing media should be part of the report on impacts of Regulation (EU) 2019/1009 envisaged according to Article 49.

The use of bark, green waste and coir by-products for horticultural growing media seems to constitute a particularly high-valued option in comparison to alternative utilisations. Bark is usually burnt at the wood processing plant although impurities can encumber the burning process. Green waste is only partially collected and composted. Most of the compost produced in Europe is spread on agricultural fields. In coconut producing countries, large amounts of coir by-products remain unused, sometimes causing environmental problems.

Transportation costs seem to play an important role for the access to biomass. Transportation costs are not necessarily linked to a local resource scarcity, but can reflect the lack of local infrastructure for processing the available resources, e.g., composting facilities producing green compost which meets quality standards for growing media.

An increased demand, e.g. from the growing media sector, can increase price levels and may support mobilization of additional resources of bark, green compost/waste and coir by-products. We presume that potentials for the collection of green waste are high in EU member states. Additional amounts of green waste could be obtained with an improved collection system and meet the specific maximal potential demand for growing media. For coir by-products, a future rise of the international demand, especially in Asia, might lead to a tight competition for the access to material and the current amounts could constitute a limit to the use of coco pith in horticulture in Europe.

Cultivated *Sphagnum* moss is a very suitable growing media constituent. Technically, it can entirely replace white peat and improve the quality of growing media based on alternative constituents. Sphagnum farming also constitutes an opportunity for the creation of new value chains and business models on rewetted peatlands. Its production is not significant yet because of the production costs, but technologies for cultivation and harvest are currently being developed. Other constituents based on biomass, e.g., agricultural products like rice hulls, corn fibres or *Miscanthus*, are also the subject of research for a utilisation as growing media constituent. If their production and use could be extended, these materials could represent additional potentials for the replacement of peat.

In order to avoid displacement effects, the focus of peat substitution should be set on potential amounts of biomass that are currently not or not fully used, or the creation of new potentials like *Sphagnum* moss cultivation with paludiculture. The costs of peat extraction and use in horticulture are currently low in comparison to other growing media constituents. Increasing the price of peat, for example through a carbon pricing system, would contribute to increase the demand for growing media alternatives and accelerate their economic efficiency, acceptance and success.

1 Introduction

1.1 Background and disclaimer

This document aims to provide information on the relevance of peat use in horticulture as a source of greenhouse gas emissions and to present a first investigation of the possibilities of replacing peat in Europe from the perspective of the supply of alternative materials for growing media. It was drafted at the Thünen Institute at the request of the German Ministry of Food and Agriculture. At the Thünen Institute, we investigate possibilities and effects of a reduction of peat use in horticultural substrates in Germany within the framework of the research project MITODE[1]. Analyses with specific focus on wood, not being part of the MITODE project, were included in this study. With this document, we hope to support further discussions and investigations on the challenges linked to the availability of peat alternatives. Comments, additional information and insights into national experiences from other European member states are welcome[2].

1.2 Status Quo on peat and growing media

1.2.1 Peat use and climate impacts

Peat is a carbon-rich material built from the long-term accumulation of organic matter in peatland soils. Although they only represent 3% of the Earth's land area, peatland soils contain 30% of the world's soil carbon stocks (Parish et al., 2008). The role of protecting peatlands in order to address climate change is widely recognised. Worldwide, peatlands are directly and indirectly impacted by anthropogenic activities, for example through drainage for agriculture or peat extraction. These activities threaten the carbon storage capacity of peatland ecosystems and turn peatland soils from potential sinks into net greenhouse gas (GHG) emitters. Although peat extraction concerns a limited fraction of peatlands, its climate footprint is higher than any other land use like agriculture, even including positive effects linked to on-site rewetting after extraction. The emissions from peat extraction are mainly CO_2 and originate for around 80% to 90% from the extracted peat itself (off-site emissions) during its decomposition or combustion (calculated using UN Climate Change, 2022).

Extracted peat is used as a fuel in some countries and is also the main component of horticultural growing media in Europe, for hobby gardening as well as for professional horticulture (production of ornamental plants, tree nurseries, vegetable seedlings, soft fruits, and mushrooms). Other uses exist but are only limited to comparatively insignificant amounts. Greenhouse gas emissions from peat extraction and use are reported by UNFCCC Parties in their National Inventory Reports in the categories 4.D "LULUCF[3] - Wetlands" for extraction sites and extracted non-energy peat and 1. "Energy" for peat fuel consumption. In the European Union (EU27), emissions from peat extraction in 4.D "LULUCF - Wetlands" amounted to a total of about 11.8 million tons CO_2-eq per year in 2019 (UN Climate Change, 2022). Emissions from peat use as fuel, reported under the category 1.A. "Fuel combustion" accounted for 9.7 million tons CO_2-eq per year in 2019.

Other organic constituents are used in growing media and can be considered to replace peat. These constituents based on biomass are renewable. Life Cycle Analyses (LCA) showed that the climate footprint of peat is much higher than that of other growing media constituents (Peano *et al.* 2012, Eymann *et al.* 2015, Stucki *et al.* 2019).

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[1] MITODE: Possibilities and effects of a reduction of peat use in horticultural substrates in Germany, a research project of the Thünen Institute and the Julius Kühn-Institute in Germany, see https://www.mitode.de/en/

[2] Please contact olivier.hirschler@thuenen.de and bernhard.osterburg@thuenen.de

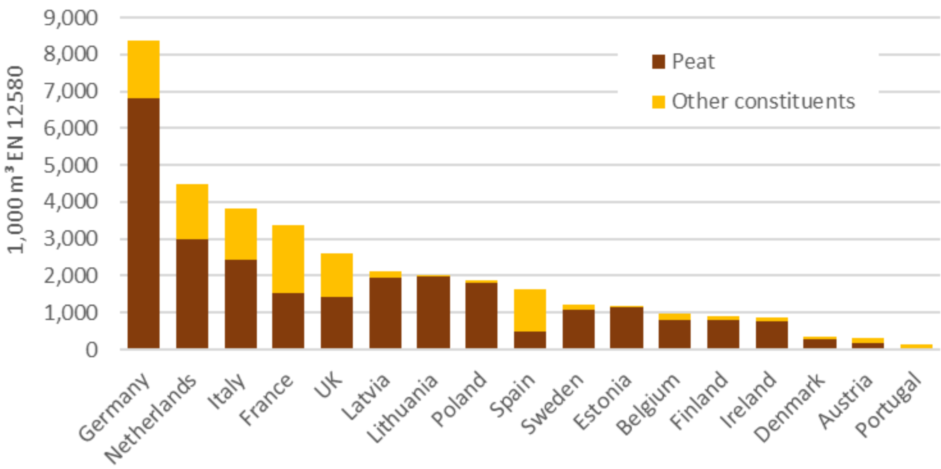
[3] Land Use, Land Use Change and Forestry

Moreover, peat's carbon footprint is mostly constituted by fossil emissions whereas emissions from other constituents are mostly linked to transport, electricity and processing, which can be reduced in a scenario toward climate neutrality for the economy as a whole. An exemption are methane emissions from compost production, which can be reduced by improving biowaste management.

1.2.2 Horticultural peat in Europe and in the world

The development of growing media for soilless horticultural systems in Northern Europe has been based on peat since the second half of the 21th century (Rivière & Caron 2001, Bohlin & Holmberg 2004, Gerding *et al.* 2015, IVG 2022). Peat for horticulture comes from bogs and originates from the accumulation of biomass composed mostly of *Sphagnum*. Peat is often characterised using its humification grade determining its properties and is differentiated between white peat (H1-H5 on Post's scale) and black peat (H6-H10). Fen peat is only used in insignificant amounts for horticulture. In 2013, peat constituted 75% of the volume of components used in the production of growing media in Europe (Schmilewski 2017). Unofficial industry data suggest that the peat rate is decreasing but peat is still by far the major growing media constituent. The size of the growing media production for European countries and the corresponding amount of peat is presented in Figure 3. The main producer of growing media is by far Germany (8.4 Mm³ EN12580 in 2013, 11.3 Mm³ EN12580 in 2019 according to recent industry data).

Figure 3: Use of growing media constituents for the production of growing media in Europe in 2013 (Spain: 2005). Unit: tds cubic meter based on EN 12580 (growing constituents before mixing)



Source: Schmilewski 2017 and Schmilewski 2008 (Spain)

Nowadays[4], most of the peat used for horticulture in Europe is extracted in the Baltic States, Germany and Ireland. Europe is by far the main region for peat extraction in the world. The only other significant extracting country is Canada, which produces almost only for the Northern American market. The use of peat for horticulture is also almost only limited to Europe and North America. In Europe, peat for horticultural purposes is intensively traded, as bulk material as well as mixed with other components in growing media. Exports from European countries to EU and non-EU countries amounts to 85% of the extracted volume (own calculations). Imports of peat from outside Europe (including from Russia) are almost non-existent. The growing media industry in Western Europe, including Germany, is dependent on imports from extracting countries. Most of the end consumption of peat in the form of growing media in the horticultural production sector or by private gardeners

[4] Data on peat extraction, trade and consumption for horticultural purposes presented are based on an own analysis and modelling using available statistics, for which methods and results are not yet published.

takes place in Western Europe, with the Netherlands and Germany being the main consumers. The trade of horticultural products within Europe is also important: Exports of horticultural products within Europe represent around 50% of the European horticultural production in value (years 2016-2018, comparison based on Eurostat data).

Future projections from Blok *et al.* (2021) suggest an expansion of the growing media demand on the European market (26 Mm^3 in 2017 to 60 Mm^3 by 2050) and on a world level, especially in Asia (from 7 to 80 Mm^3). Although the share of peat would decrease in comparison to today's situation, these projections estimate that the demand for peat would double, implying an expansion of the trade on a world basis. According to Xianmin (2016), the Chinese demand for peat would even amount to 250 Mm^3. Europe, especially the Baltic States, is by far the main supplier of peat and peat-based growing media in the world. In this situation, the European growing media industry expects to increase its production and exports in order to supply these developing markets. However, the current world flows show that we are still far from this situation.

In addition to economic feasibility of meeting the expected demand for peat, implications in terms of climate impacts and the current growing political awareness on peat climate impacts must also be taken into account. Considering its world role in the extraction and trade of peat, the European Union has a strong global responsibility in the future development of the growing media market and its potential climate impacts. This applies also to growing media and related technologies exported from EU member states to other world regions. On this background, the feasibility and the desirability of these projections must be considered critically.

1.2.3 Peat reduction and policies

In the European Union, peat extraction will be included in mitigation targets defined in the LULUCF regulation (EU) 2018/841 as part of the category "Wetlands" from 2026 onwards. Germany and Ireland decided to include this category already from 2021 onwards (German Federal Environmental Agency, personal communication; Government of Ireland 2021). Policies and measures regarding peat in the European countries will then become relevant for internationally binding mitigation targets. However, the LULUCF regulation defines the so-called "no-debit" target for the LULUCF emissions and removals. Current emissions and removals are compared to historic emissions in the years 2005 to 2009 (all land uses except forest land) or to a modelled reference level (forest land including harvested wood products). LULUCF credits generated beyond the "no-debit" target can be transferred into the no-ETS sector to a limited extent. Thus, the "no-debit" target provides only limited incentives for climate action in the LULUCF sector. In July 2021, the EU Commission presented the "Fit-for-55" package including an amendment of the LULUCF regulation. The proposal includes absolute targets for the LULUCF sector for the year 2030 in million tons CO_2-eq per year. Further, the AFOLU sectors (agriculture, forestry and land use, i.e. the emission sectors agriculture and LULUCF) shall be net-GHG-neutral by 2035 at the EU level. Compared to the expected LULUCF development in the projection reports of the EU Member States, the proposed new targets are ambitious and have thus the potential to trigger intensified national efforts to realise additional climate mitigation activities in the LULUCF sector.

In the context of increased climate ambitions, some initiatives and governmental strategies were developed in European countries to address the extraction and use of peat in horticulture. The institutions involved, the goals set on peat reduction and the literature for the different countries are presented in Table 1. In Germany, the United Kingdom, Switzerland and Norway, the government has set specific goals. In Ireland, the government supports the reduction and a working group proposed a time frame to phase out peat. These efforts are developed in the context of a crisis for the Irish peat industry due to a legal procedure based on inconsistencies with the EU laws, which lead to a sudden shutdown of the peat extraction in 2020 (GMI 2021). In the Netherlands, which constitute a central actor in the European growing media industry, two members of the House of Representatives requested the government in July 2021 to carry out first investigations to phase out and replace peat in horticulture.

Table 1: Current national goals set to reduce horticultural peat use or extraction in European countries

Country	Last goals set on horticultural peat	Form / Authority	Documentation
Germany	Hobby sector: 100% reduction by 2026; professional sector: strong reduction by 2030. The new government aims to develop an exit plan on peat use and extraction.	German Ministry of Agriculture (in discussion with stakeholders)	Climate Action Plan 2050 (BMUB 2016), Former coalition agreement between governing Parties (CDU *et al.* 2018), Climate Action Programme 2030 (BMU 2019), BMEL 2020, IVG 2020; ZVG *et al.* 2020 New coalition agreement between governing Parties (SPD *et al.* 2021)
	Hobby sector: 50% peat rate by 2025 and 30% by 2030; professional sector: 80% peat rate by 2025 and 70% by 2030.	Self-commitment of the industry groups IVG, ZVG, BdB, BHB and VDG	
Ireland	Hobby sector: 100% peat use reduction by 2025; all sectors: by 2030, maximum 2035.	Proposal from the Working group report to the Department of Housing, Local Government and Heritage	Government of Ireland 2019, Government of Ireland 2020 GMI 2021, Prasad 2021, Government of Ireland 2022
United Kingdom	Hobby sector: 100% peat use reduction by 2024 ("end of this parliament"); all sectors: 100% peat reduction by 2030	UK Government	Mineral Planning Guidance 13 (HM Government 1995), UK BAP (UK Biodiversity Group 1999), Natural White Paper (HM Government 2011), 25 Year Environment Plan (HM Government 2018), England Peat Action Plan (UK Government 2021)
Switzerland	Hobby sector: 5% peat rate by 2020; professional sector: 50% peat rate by 2025 and 5% by 2030	Agreement between the Ministry of Environment and the stakeholders	Torfausstiegskonzept (Federal Council of Switzerland 2012) BAFU 2021
Norway	Hobby sector: 100% peat reduction by 2025; professional sector: 100% peat reduction by 2030.	Norwegian Ministry of Climate and Environment	Norway's Climate Strategy (Norwegian Ministry of Climate and Environment 2017), Norwegian Ministry of Climate and Environment 2018 Norwegian Environment Agency 2018, Norwegian Environment Agency 2020, Norwaste 2020, Pedersen & Løes 2022
Netherlands			Request from the House of Representatives to investigate the possibilities to phase out peat (House of Representatives 2021)

The engagement to phase out peat use is also part of the protocol of the Alpine Convention on soil conservation (1998), signed and ratified by all parties including the European Union in 2006. However, no strategy was designed at the EU level at this time.

Although political initiatives in Ireland and the Netherlands are being developed, Germany is the only member state of the European Union to have officially set political reduction targets on peat use in horticulture. The growing media industry and the horticultural sector consider the reduction of peat as a challenge which implies both an adaptation of the sector to new materials and the potential increase of production costs. Therefore, in a situation where peat, growing media and horticultural products are intensively traded within the common European market, displacement effects could occur if only some countries act while others continue to extract and/or use peat without restrictions. A potential relocation of the peat extraction could occur e.g., from German to the Baltic States. In the same way, displacements of horticultural production could occur from Germany to neighbouring countries where no political engagement has been taken. For this reason, if a common effort can be established between members of the European Union, a political action to reduce peat extraction and use in horticulture could lead to a more fair and effective impact.

In the energy sector, Ireland and Finland, as the two main EU member states using peat as fuel, pursue exit strategies. Energy peat is also included in the European Emissions Trading System (ETS) of carbon emissions, which obliges companies in the energy sector to buy the necessary emitting rights. In Ireland, the half-public peat extracting company Bord na Móna and the Ministry for Energy announced in 2015 their intention to phase out the harvesting of peat for the production of electricity and heat by 2030 (Bord na Móna 2015). In Finland, the reduction of peat use for energy was first set in the National Energy and Climate Strategy in 2013, with a reduction goal of a third by 2025 (Finnish Government, 2013). In 2019, in the scope of the Finland's carbon neutrality target, the government set a new goal of 50% by 2030 (Finnish Government 2019). This strategy is implemented by increasing the energy tax on peat set by the government, which was almost doubled in 2019 (Statistics Finland 2021). A statement of the Ministry of the Environment in 2020 implies that peat should be phased out on the long term, although no official target year was defined (Finnish Government 2020). According to statements from the peat industry in Finland, the actual reduction of energy peat use is going to outpace the goals of the government, but mostly due to the high ETS price since 2018.

1.3 Replacement of peat in horticulture

1.3.1 Growing media and alternative constituents

In order to reduce the use of peat in horticulture without strongly negatively affecting the horticultural sector and maintain existing production systems relying on growing media, peat needs to be replaced by other growing media constituents. Because the properties of the growing media strongly depend on its constituents, these need to meet specific quality criteria in order to be used.

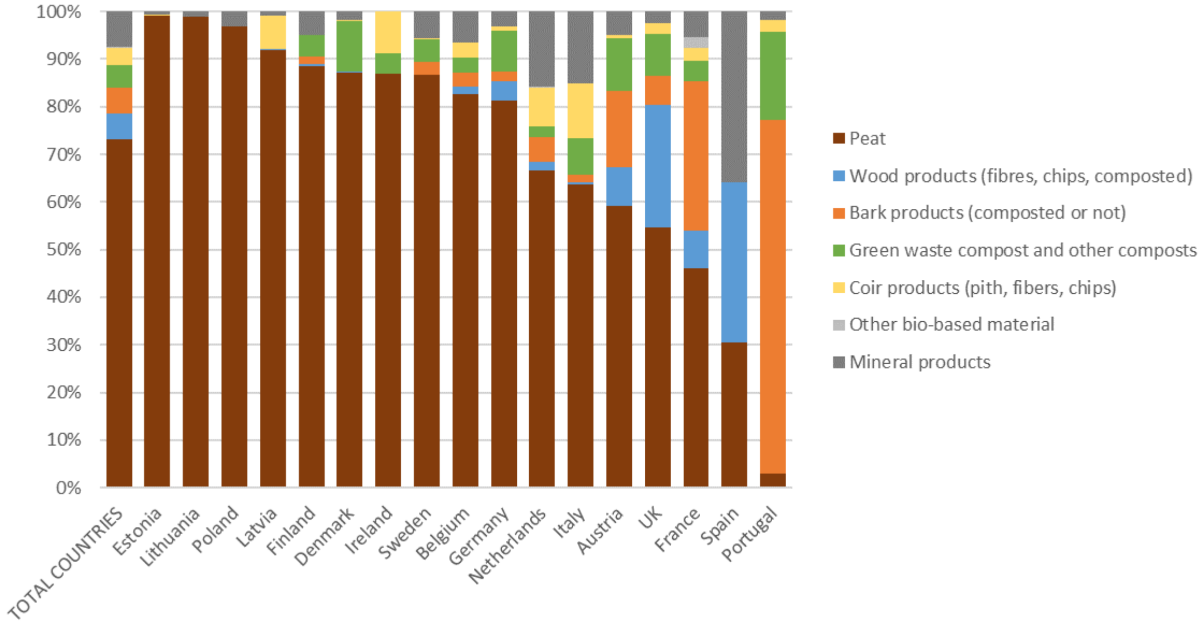
The physical growing media properties can be specifically influenced by the nature of the raw materials (e.g., wood fibres of different fractions) and their proportion in the mixture. The growing media must have sufficient air and water holding capacity. Thus, a sufficient exchange of air and gas is ensured and the plants do not suffer from oxygen deficiency in the root zone. Depending on whether the growing media are coarse or fine-pored, they have a good drainage or a good water holding capacity. Even though the composition influences mainly the physical properties of the growing media, the raw materials also have an impact on the chemical properties. Thus, the raw materials influence, among other things, the nutrient content, the salt content, the buffering capacity, as well as the pH of the growing media. These parameters must be carefully adjusted to the needs of the crop by the proportions of the individual constituents. To a certain extent, the optimization is also possible, e.g., by adding lime or sulphur. In addition, a possible higher microbial activity in peat-free or peat-reduced substrates with a resulting nitrogen immobilization should be considered when fertilising.

Nowadays, the main growing media constituents other than peat are:

- Green compost: Compost from green waste (woody and leafy material and grass, mostly from parks, gardens and landscaping). Organic waste other than green waste can be used in small amounts, but is generally not adapted to produce compost suitable for growing media. Because of high nutrient content, salt content and pH, the use of green compost in growing media can present limits. In order for green compost to meet the criteria as growing media constituent, the biomass and the processing need to be specifically adapted. Woody materials are needed in sufficient proportions, the composting time need to be minimum of 8 weeks in aerobic conditions and the compost needs to be cleaned of all impurities. Because of the different sources of green waste material used (e.g., type of plants, soils, time of year), the quality of green compost can vary considerably. Although some growing media companies are equipped to produce compost, a large share rely on external composting facilities for their supply.
- Wood fibres: Fibres from coniferous wood (mostly spruce and pine) produced through a thermic-mechanical process based on wood chips. This process usually takes place on the facilities of the growing media company. Non-coniferous wood breaks down too fast to be used for growing media. The wood used for the production of wood fibres needs to be chemically untreated and uncontaminated. Coniferous wood for the production of wood fibres mainly derives from wood residues, especially from the sawmill industry. In some cases, wood products (chips, saw dust, shavings…) can be used as growing media component without fiberisation. The main limits of wood fibres as growing media component are the high N-immobilisation and the low water holding capacity.
- Composted bark: Compost from shredded bark (most often from softwood). In some cases, raw bark from pine can be used without composting. Bark is mostly available as a by-product of the sawmill industry, but also possibly from the panel and pulp industries. The use of composted bark in growing media can be limited by its water holding capacity, nutrient content and concentration of heavy metals.
- Coir by-products: By-products of the processing of coconut fibres (Coir), which can be differentiated in coir pith (also referred as cocopeat), short coir fibres and coconut chips. Although coir pith and fibres are often referred as “coir” when used as growing media, we use the term “coir by-products” (for horticulture) in order to differentiate it from the coarse coconut fibres used for manufacturing, for which we use the term “coir”. Coir products can contain high salt concentrations. Therefore, they need to be intensively washed before being used as growing media component.
- Mineral components such as perlite, vermiculite, clay, lava, pumice or mineral wool. Mineral components are often used in growing media as complement to organic products.
- *Sphagnum*: Fresh *Sphagnum* moss produced from paludiculture. The characteristics of *Sphagnum* are comparable with white peat which make it an ideal alternative growing media component. The production presents risks of the presence of weeds. *Sphagnum* is not used in significant amounts because of its production costs.
- Other alternatives based on biomass such as rice hulls, *Miscanthus* fibres, corn fibres, reed, sea weed or residues from the wine industry. These products can be used mostly composted and/or processed. Numerous tests have also been conducted on the use of biochar as well as residues from digesting plants in growing media. Research on the re-utilisation of spent growing media after one growing cycle has also been conducted. Because of their properties and/or price, these materials are not used as growing media constituents in significant amounts in Europe yet.

The general composition of growing media produced in European countries is available in Figure 4. Differentiated data between professional and hobby market are available in the Appendix in Tables A1 and A2. The repartition per country shows that the peat rate in peat extracting countries is higher than for countries further from peat extracting sources. Although the horticultural production methods vary a lot between countries, it is to be expected that the lower availability of peat (especially through higher transportation costs) encourages the use of alternative growing media constituents.

Figure 4: Average composition of growing media in European countries for the year 2013 (Spain: 2005). Unit: volume percentage based on EN 12580 (growing constituents before mixing)



Source: calculation based on Schmilewski 2017 and Schmilewski 2008 (Spain)

1.3.2 Challenges of peat reduction and goal of this study

According to current discussions between stakeholders, peat replacement in horticulture can be linked to three main categories of feasibility challenges:

- Access to sufficient amounts of material for the production of growing media of sufficient quality
- Economic conditions for the access to these amounts: prices, regional availability, competitive situation.
- Optimisation of peat-reduced and peat-free growing media and technological adaptation of the horticultural production to the different properties of alternative materials (water capacity, pH, nutrient content, etc.)

The use of peat-reduced and peat-free growing media in the horticultural sector is the subject of numerous research projects in Europe. The challenge of availability is considered a key factor, or even a limiting factor, by stakeholders from the growing media industry. A spokesperson from the industry group Growing Media Europe declared in 2021: “There are simply not enough other constituents available today”. Contrary to the use of alternative growing media in horticulture, few research projects have been focusing on the question of the availability, the economic conditions and possible supply structures of alternative constituents. Two studies found on this question were commissioned in the UK (ADAS UK Ltd. 2009) and in Norway (Norwaste 2020) and linked to the reduction strategies in these countries. In the study for the UK, the availability of alternative material was considered critical although the quantities of raw material did not seem to be the limiting factor. In the study for Norway, the authors stated that there is sufficient access to alternative raw materials to be able to phase out peat use. In the study from Blok *et al.* 2021, amounts of constituents available worldwide are also estimated. This study stated that the volume of wood and bark available worldwide do not constitute a limit but that coir resources would be too scarce to meet the world’s demand.

In this situation and in order to contribute with facts to the growing debate on peat replacement at EU level, the objective of this discussion paper is to present a first investigation on the availability of alternative materials for EU countries. This analysis is based, in the first place, on the comparison of the supply of alternative materials and the potential demand for the future growing media production for each country. These quantitative results are discussed with regard to other aspects, like economic conditions, quality and regional differences. These aspects could not yet be studied extensively, but need to be considered in order to precisely assess the feasibility for the growing media industry to access these materials. Therefore, although some conclusions can be drawn from these first results, this study should not be considered a final evaluation. It should rather initiate further discussions and investigations on challenges related to the availability of alternative materials to replace peat.

2 Method for the evaluation of availability of alternative growing media constituents

2.1 General approach

Our first consideration of the availability of material is based on the quantitative comparison of amounts of raw material currently supplied to or potentially present on the market ("current supply") with the current and maximal quantities needed for the growing media production ("current demand" and "maximal potential demand").

A comprehensive assessment of the availability is not a simple question of quantities and cannot be considered independently from the economic situation where various market participants are demanding the material, looking for possibilities to access. These possibilities depend on the conditions in which the considered amounts can be obtained and the effort/costs that the considered stakeholder is ready to pay to access these amounts. Therefore, such assessment should be based on an extended analysis of the economic situation of all stakeholders involved in production (suppliers) and use (competitors) of the considered material, also including costs and prices. The latter especially depend on the competition for the access to the material and regional availability, which is also linked to transportation costs. Limited data are available on costs and prices. In this study, these aspects where considered mostly qualitatively. Further research would be needed in the future to investigate these aspects.

We focus on raw materials for the production of wood fibres (wood), composted bark (bark), green compost (green waste) and coir pith (coir by-products), which are currently the most used alternative components in Europe. Mineral products are considered to have only a limited potential to replace peat. The case of *Sphagnum* is also discussed although not quantitatively, since at present it is not produced in significant amounts. Other bio-based components are not considered in this analysis because they generally constitute insignificant amounts today. However, they could play a more significant role in the future.

The unit used to quantify amounts of growing media and growing media constituents is the cubic meter based on the European norm EN 12850 on the determination of a quantity of soil improvers and growing media. Because raw materials are processed before becoming growing media constituents and because the different sectors do not use the same units, data have to be converted for comparison in a single unit. For wood and bark, the unit used is tons of dry matter (t_{DM}). For green compost, the unit is tons of green waste before composting. For coir products, the unit is tons. The amounts are always considered per year. Factors used in this study for the conversion between mass and volume as well as other factors linked to transformation process are used and presented in the appendix in Table A3. In order to compare supply and demand for all constituents together, amounts are converted in cubic meter growing media constituent equivalent based on EN 12580.

2.2 Current demand and supply of material for the growing media production

Due to different market structure and inequal data availability for each material, the definition of supply for each constituent is not the same for all materials considered. Therefore, for each material, the definition of supply is explicitly specified within the corresponding chapter. The most recent data and, if possible, a 3-year-average are taken depending on the data availability for each material. As a result, the supply of wood and bark was based on the years 2018-2020, the supply of coir by-products on the years 2017-2019 and the supply of green waste on the year 2017. The supply is based on the current resources available on a national level. Further evolutions of the production of alternative materials or a development of the international trade between countries are not considered.

The current demand is calculated based on the most recent data on the growing media production available. Data on the use of components are taken from Schmilewski (2017) based on the year 2013, except for Spain which is taken from Schmilewski (2008) based on the year 2005. No other data are available since then and for other countries. The current demand is compared to more recent data on supply with the assumption that the demand did not change significantly. The analysis was carried out for the EU countries available in these studies: Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Spain and Sweden. These countries can be assumed to represent by far the most part of the growing media production in the EU and results for these countries can be considered relevant for the European Union. The growing media production for these countries amounts to 33.6 Mm³ EN12580 growing media constituents, including 19.3 Mm³ EN12580 for the professional market and 14.2 Mm³ EN12580 for the hobby market.

The lack of data on growing media, peat and biomass residues like wood residues, bark, green waste or coir by-products, especially as time series and differentiated between countries, represent a strong challenge for an in-depth evaluation of the available amounts of alternative growing media constituents and the demand of the growing media industry.

2.3 Maximal potential demand for the growing media production

The calculation of the total maximal potential demand for alternative materials for the growing media production is based on future scenarios without specific time reference using the following assumptions:

- It is considered that the maximal volume of components used for the growing media production will double in comparison to the volume needed in 2013 (33.6 Mm³ EN12580 based on Schmilewski (2017) for the countries considered). This demand of 67 Mm³ EN12580 is in the same range as the estimation from Blok *et al.* (2021) on the demand for growing media in Europe in 2050 (60 Mm³). The increasing trend can be observed, e.g., in Germany where the volume of growing media produced increased from 8.4 Mm³ EN12580 in 2013 (Schmilewski 2017) to 11.3 Mm³ EN12580 in 2019 according to the German industry (IVG 2020).
- Peat is expected to be completely replaced.

From this total maximal potential demand, we derive a specific maximal potential demand for each alternative constituent. This specific maximal potential demand considers technical limitations in the use of alternative constituents in growing media. For each constituent, we estimate the maximal share of the component technically feasible for the growing media to meet the criteria for a sufficient quality. The determination of this share is explained in the following paragraph. Potential changes in shrinkage factors during the growing media production (by mixing) due to a different composition are not considered.

So far, wood fibres, green waste compost, composted bark and coir pith, in particular, have proven to be suitable as growing media components in numerous trials as well as in practice. In order to estimate the maximal technically feasible share of each constituent, we take figures from the literature which apply for a wide range of horticultural branches. It is important to note that these figures can evolve with more research on peat-reduced and peat-free growing media, and there might be numerous exceptions to these limits depending on growing conditions. The share in which these growing media components can be mixed together depend on various factors and were chosen as followed:

- The use of wood fibres in substrates can lead to an improvement of air content. Since the water capacity of wood fibres is low, they can also reduce the water holding capacity of growing media. Irrigation rhythm must be adjusted if the growing media contain a high percentage of wood fibres. Wood fibres also have low salt contents and low buffering capacity. Possible nitrogen immobilization should be checked regularly. According to Neumaier & Meinken (2015), wood fibres can be used in substrates up to a proportion of 40% by volume (vol. %). A maximum of 20 vol. % is recommended by the German organisation for the quality of growing media (GGS 2021a) for wood fibers with Δ N ≤ 200 for the respective mixtures, depending on the degree of nitrogen immobilization. If the nitrogen dynamics is Δ N ≤ 100, a maximum of 40 vol. % is recommended as a mixing component. Wood fibres have been the subject of successful tests in different countries concerning their properties and use as growing media constituents, including some with significantly higher share than 40 vol. %, e.g., up to 50 vol. % tested by Zucchi *et al.* (2017) and Beretta and Ripamonti (2021), 60 vol. % in the German project TerZ on ornamental plants or even up to 100 vol. % tested by Muro *et al.* (2005) and Woznicki *et al.* (2021) or according to the growing media producer Florentaise (Laming 2018). No other literature source was found which provides a general estimation of the possible share of constituents for all branches. Therefore, these sources are taken although this maximal share for wood fibres could be considered conservative, especially with the perspective of a complete peat reduction.
- For composted bark, proportions of a maximum of 50 vol. % are recommended (Neumaier & Meinken 2015). This depends, among other things, on the chemical properties of the bark.
- Green compost often has high contents of phosphorus and potassium, as well as a high salt content. These must be considered when fertilising the growing media. The buffering capacity of composts is high. Due to the usually high pH values, the use of composts in substrates for acidophilic plants is limited. During process of composting the temperatures must be high enough to kill seeds, insect eggs and spores, so it can be considered sanitised and free of phytopathogens. In peat-reduced substrates, composts can be used at levels of 20 vol. % to 40 vol. % (Neumaier & Meinken 2015). The German compost organisation Bundesgütegemeinschaft Kompost (BGK 2018) differentiates between two types of compost based on salt content and nutrient content. Up to 40 vol. % is recommended for Type 1 (low salt content) and up to 20 vol. % for Type 2 (high salt content) in the mixtures.
- Coir pith has a very good rewettability. Nitrogen and phosphorus contents are low. Unbuffered coir materials may have high potassium contents. Coir fibres can be used in growing media up to proportions of 20 vol. %. Coir pith can also be used as the stand-alone growing media. Depending on the respective substrate properties, proportions of a maximum of 30 vol. %, 60 vol. %or 100 vol. % are recommended for coir products in growing media (GGS 2021b).

As a result of these findings, the maximal share considered for the professional horticultural sector are 40 vol. % for wood fibres, 50 vol. % for composted bark, 40 vol. % for green compost and 100 vol. % for coir pith. For the hobby sector, the requirements on quality are in practice lower than for the professional sector. Examples show that a good functioning hobby growing media can be achieved with higher rates of alternative materials. Based on the composition of five peat-free growing media primed by the German consumer organisation Stiftung Warentest (2014), we considered that a share of 50 vol. % wood fibres and 60 vol. % composted bark was possible for the hobby market. The maximal shares considered for the professional and hobby sector are presented in Table 2. It is important to note that these figures are estimates of the maximal share of alternative constituents in the growing media production as a whole, and should neither be considered as absolute limits of their use in growing media, nor as recommendations from the authors.

Table 2: Maximal share of growing media constituents considered for the calculation of the maximal potential demand

	Maximal share in growing media	
	Professional	Hobby
Wood fibres	40 vol. %	50 vol. %
Composted bark	50 vol. %	60 vol. %
Green compost	40 vol. %	40 vol. %
Coir pith	100 vol. %	100 vol. %

Considering the increased production of growing media, the specific maximal potential demand is calculated for each alternative constituent and each country considered. The detailed data for each country are presented in the appendix in Table A4. The sum of the maximal feasible shares of all growing media constituents (230%) is significantly superior to 100%. Accordingly, the sum of all the specific maximal potential demands of the different constituents is superior to the total maximal demand of materials. Therefore, the specific maximal demands can be considered as a particularly high upper limit of the future use of each growing media constituent. We do not elaborate projections for future supply of alternative materials for growing media. Thus, we use current supply data to depict the relation between maximal potential demand and supply.

3 Results

3.1 Wood and bark

3.1.1 Roundwood from forest

Forests in the European Union (EU27)[5] provide various services, including the provision of wood resources for material and/or energy use. Within the EU27, countries aim for a sustainable use of forest resources by enforcing sustainable forest management principles (FOREST EUROPE 2020). A major objective of sustainable forest management includes the establishment of at least a balance between regrowth and removal of trees. Therefore, we do not assess potentials to increase harvests within EU, but focus exclusively on wood resources which are already harvested in and removed from forests as well as the flows of wood utilization.

EU27 countries also pursue an efficient use of wood resources in the wood-based sector through implementation of circularity and cascading concepts. Efficient use of wood resources requires a primary use for material purposes. Energy generation constitutes the final stage and should follow many cascades of material use.

From 2015 to 2020 an annual volume of 214 to 229 million tons dry matter (t_{DM}) roundwood was harvested from forests of EU27 member states. Roughly two-thirds of harvested roundwood removals comprise coniferous wood. Information on roundwood removals by member states and wood species composition is provided in the appendix in Tables A5 and A6.

Forest products statistics (FAOStat or Eurostat) allow for a distinction between the use of roundwood for material purposes (i.e., industrial roundwood) as well as roundwood used directly for energy generation (i.e., wood fuel). In addition, forest products statistics distinguish between production and trade (i.e., import and export) of forest products. Apparent consumption is computed from this information by summing up production and net trade

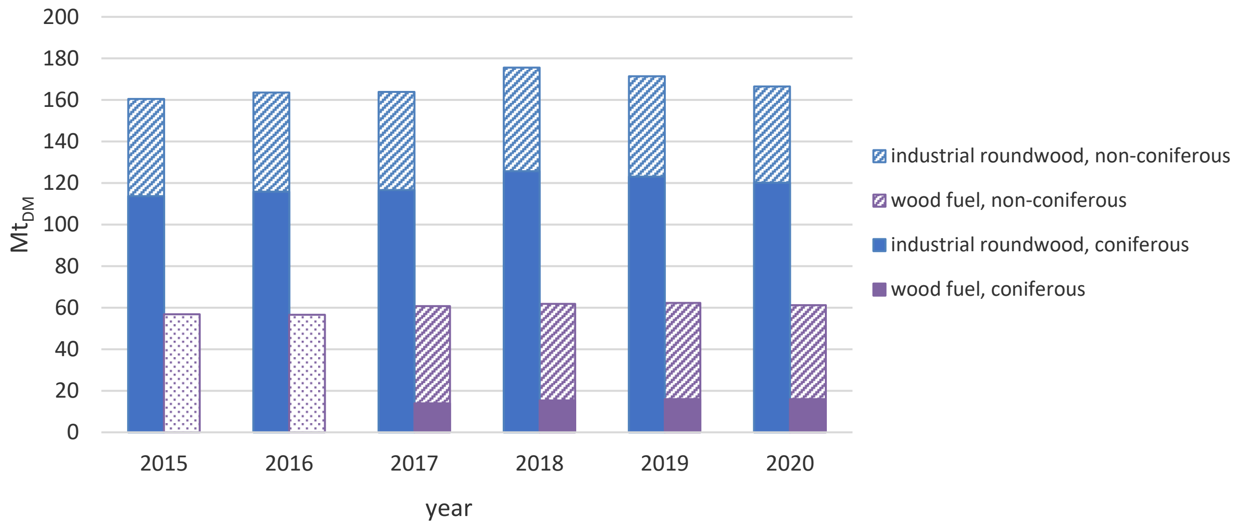
5 EU27 member states: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden

(i.e., import minus export). Apparent consumption is often used as an estimate for real consumption. However, neglecting information like stock change can lead to data inconsistencies. For instance, wood fuel consumption can be particularly affected by stock changes.

Figure 5 shows that industrial roundwood accounted for most of the apparent consumption of roundwood removals. Industrial roundwood comprised mostly coniferous wood. Wood fuel consumption comprised major shares of non-coniferous wood.

From 2015 to 2020 domestic production generated most of the roundwood supply in EU27. Aggregated net trade[6] of coniferous as well as non-coniferous industrial roundwood of EU27 countries was less than +4 million t_{DM} per year respectively, with the exception that net trade of coniferous industrial roundwood was -2 and -4 million t_{DM} in 2019 and 2020, respectively. Net trade of wood fuel was between -1 and 1 million t_{DM} per year.

Figure 5: Apparent consumption of industrial roundwood and wood fuel by wood species in EU27



Source: own calculation, FAOStat (2021), FAO et al. (2020)

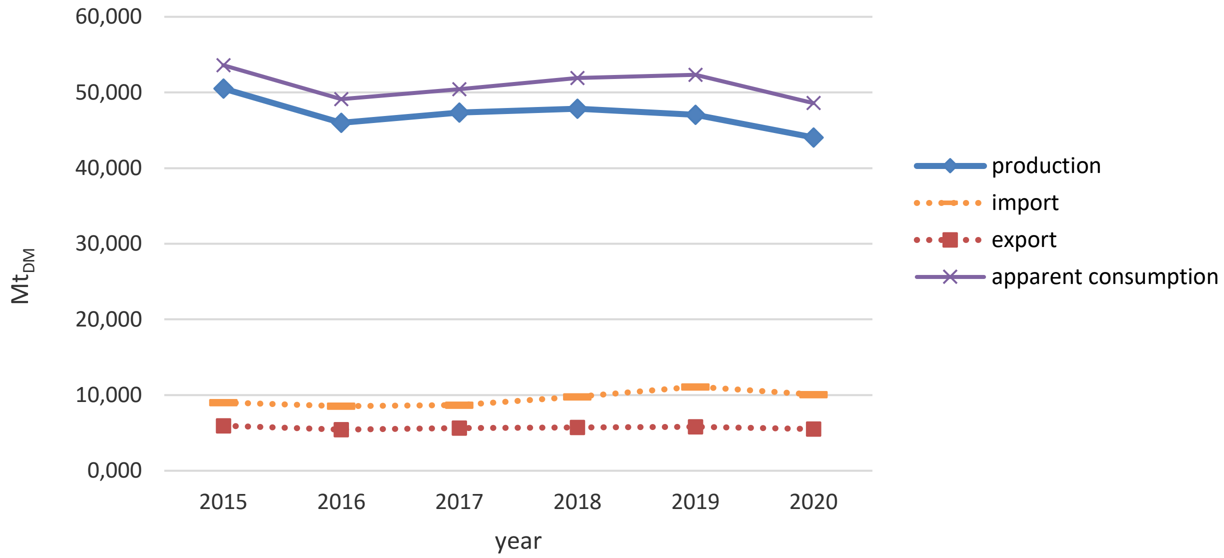
Note: apparent consumption of wood fuel in 2015 and 2016 shows an aggregate of coniferous and non-coniferous wood, disaggregated figures for trade are not available until 2017.

3.1.2 By-products from the wood processing industry

The wood processing industry demands wood resources for production of forest products. However, some sectors of the wood processing industry – in particular the sawmill industry but also planing mills and other manufacturers of wood - supply wood resources which accumulate during the processing of wood (e.g., wood residues, chips and particles, saw dust, etc.). Figure 6 shows the production, trade and apparent consumption of wood processing residues (which are represented by the product categories wood chips and particles as well as wood residues in international statistics such as FAOStat) in EU27 member states. More information on the production of wood chips and particles, as well as wood residues by member states, is provided in Appendix in Table A7.

[6] Note: positive signs of net trade figures indicate an import surplus. Calculations were first done on country level. We then aggregated net trade of EU countries. We did not consider only EU-Extra-trade so far due to time constraints. If necessary, we could add this calculation step – but alignment of different data sources is required for that.

Figure 6: Production, trade and apparent consumption of wood chips and particles and wood residues in EU27



Source: own calculation, FAOStat (2021), FAO *et al.* (2020)

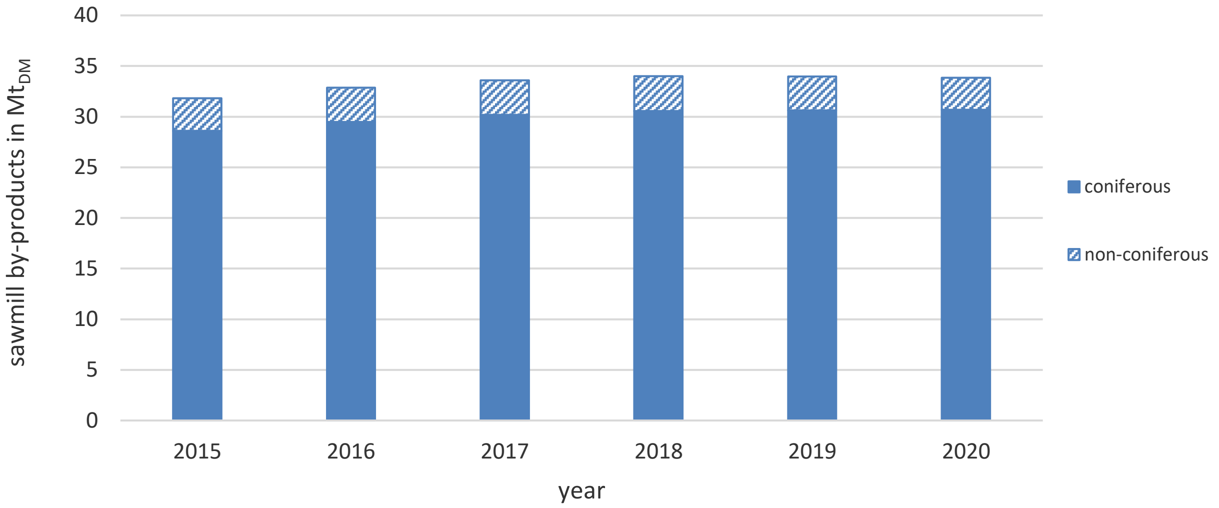
Information on use patterns (e.g., distinction between material and energy use) and wood species composition of by-products is not available in FAOStat or Eurostat. However, supporting information can be derived from information on sawnwood production. The sawmill industry represents the most important supplier of wood processing residues such as chips, slabs, sawdust and shavings. Forest product statistics distinguish between production of coniferous and non-coniferous sawnwood.

Figure 7 shows production volumes of sawmill by-products ($by\_products_{vol}$) in EU27. Information was derived by following computation:

$$by\_products_{vol} = sawnwood_{vol} \cdot \left(\frac{1 - shrinkage\_loss_{share}}{sawnwood_{share}} - 1\right)$$

where $sawnwood_{vol}$ denotes sawnwood volume, $shrinkage\_loss_{share}$ and $sawnwood_{share}$ represent volume shares that account for the shrinkage loss and sawnwood output during sawnwood production respectively. More information on production of sawmill by-products (incl. chips/slabs, sawdust and shavings) in EU27 by member states and wood species is provided in appendix in Tables A8 and A9.

Figure 7: Production potential of sawmill by-products (e.g., chips, slabs, sawdust, shavings) in EU27



Source: own calculation, FAOStat (2021), FAO et al. (2020)

Besides this calculation of potential supply of sawmill by-products, there is no information available to which share these production potentials are already used on European level. Definitions of wood processing residues by FAOStat and of sawmill by-products are not fully congruent. Hence, a comparison of data of potential supply of sawmill by-products and apparent consumption of wood chips, particles and residues based on FAOStat is not possible.

3.1.3 Woody biomass from outside-forests

Available information on woody biomass from outside forests (i.e., parks, short rotation coppice, etc.) is limited. Mantau *et al.* (2010) estimated an annual potential of 41.4 million t_{DM} woody biomass sourced from outside forests in the EU[7]. While the potential was projected to remain unchanged until 2030, the use was expected to increase until 2030 in a "medium scenario" (Table 3). Most of the wood is used for energy generation, while only a minor share is used for composting.

Table 3: Projected potential and use of woody biomass sourced from outside forests in EU27. Unit: Mt$_{DM}$

	2010	2015	2020	2030
Total potential	41.4	41.4	41.4	41.4
Used for energy generation	18.6	20.7	22.8	24.8
Composting	8.3	7.6	6.9	6.2
Unused	14.5	13.1	11.7	10.4

Source: own calculation, Mantau et al. (2010), FAO et al. (2020)

[7] Mantau et al. 2010 refer to following countries as EU27 member states: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Germany, Estonia, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Sweden and United Kingdom

As far as energy generation is concerned, forest products statistics provide recent but scattered information on woody biomass sourced from outside forests. Table 4 provides an overview on available information on woody biomass from outside forest used for energy generation in EU27 member states as well as estimates on bark from this source which is also used for energy generation.

Table 4: Woody biomass and bark sourced from outside-forests in EU27. Unit: Mt_{DM}

	Woody biomass		Bark	
Area	**2015**	**2017**	**2015**	**2017**
Austria	0.835	0.814	0.109	0.106
Croatia	0.473	0.473	0.053	0.053
Cyprus	0.003	0.001	0.000	0.000
Czechia	0.922	0.944	0.120	0.123
Estonia	0.094	0.306	0.012	0.040
France	2.325	2.844	0.443	0.542
Germany	2.019	2.488	0.225	0.277
Ireland	0.002	0.009	0.000	0.001
Netherlands	0.830	0.726	0.164	0.144
Slovakia	0.205	0.282	0.024	0.033
Slovenia	0.129	0.126	0.016	0.016
Sweden	0.080	0.068	0.010	0.008

Source: own calculation, UNECE/FAO (2021), FAO et al. (2020)

The potential of bark sourced from woody biomass from outside forests is rather theoretical. It's unlikely that bark will be removed from woody biomass which is primarily used for energy generation. In addition, the bark potential has to be reduced by volumes lost during felling processes.

3.1.4 Bark sourced from forests

International forest products statistics provide very little information on bark supply. Thus, bark potentials ($bark_{vol}$) were estimated based on the following equation:

$$bark_{vol} = wood_{vol} \left(\frac{1}{\Delta} - 1\right)$$

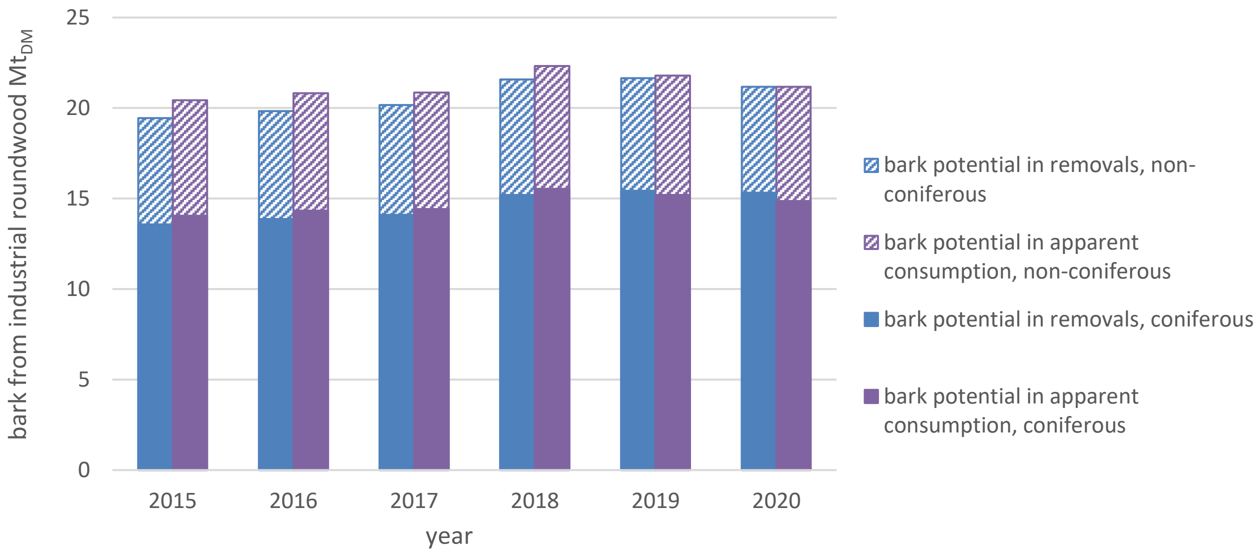
where $wood_{vol}$ denotes volumes of wood (i.e., industrial roundwood or wood fuel) without bark. Δ represents the volume ratio of wood without bark by wood inclusive of bark.

3.1.4.1 Bark sourced from industrial roundwood

Figure 8 shows estimates for bark potentials sourced from industrial roundwood removals as well as apparent consumption of industrial roundwood in EU27. More information on bark sourced from apparent consumption of industrial roundwood by member states is provided in appendix in Tables A10 and A11.

Bark sourced from removals describes the domestic potential of bark. Bark sourced from apparent consumption of industrial roundwood accounts for production and net trade of industrial roundwood. We assume that such potentials are more realistic because debarking (i.e., removing bark) is a common first step of processing roundwood in wood processing industries. Hence, bark can be seen as a by-product of processing of industrial roundwood. It has to be noted, however, that the bark potential should be lowered due to losses of bark during the harvesting and transportation of roundwood which are not accounted for in this estimation scheme. Bark which remains in the forests can have an ecological value when providing nutrition for the subsequent generation of trees.

Figure 8: Bark potential of removals and apparent consumption of industrial roundwood in EU27



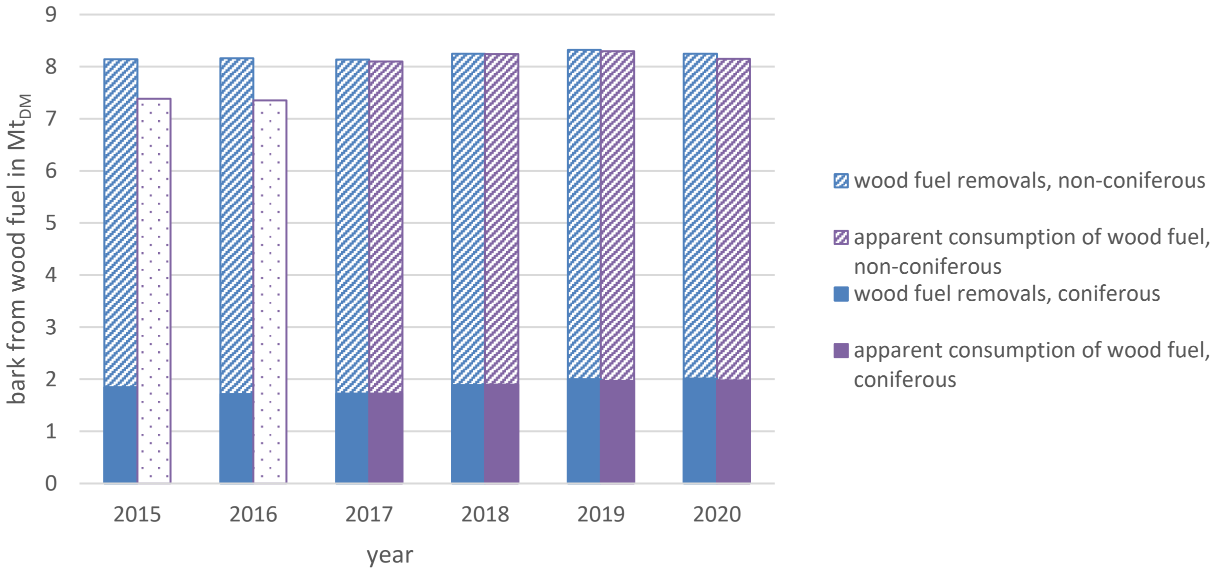
Source: own calculation, FAOStat (2021), FAO et al. (2020)

3.1.4.2 Bark sourced from wood fuel

Figure 9 shows bark potentials of removals and apparent consumption of wood fuel in the EU27. More information on apparent consumption of bark in conjunction with apparent consumption of wood fuel by member states is provided in appendix in Tables A12 and A13.

The potential of bark sourced from wood fuel seems to be rather theoretical. It is unlikely that bark will be removed from wood fuel logs before combustion. Bark which is lost during felling of fuelwood will remain in the forest. Bark which might occur during processing of fuelwood seems unlikely to be utilised in a specific way other than combustion or disposal.

Figure 9: Bark potential in wood fuel removals and apparent consumption in EU27



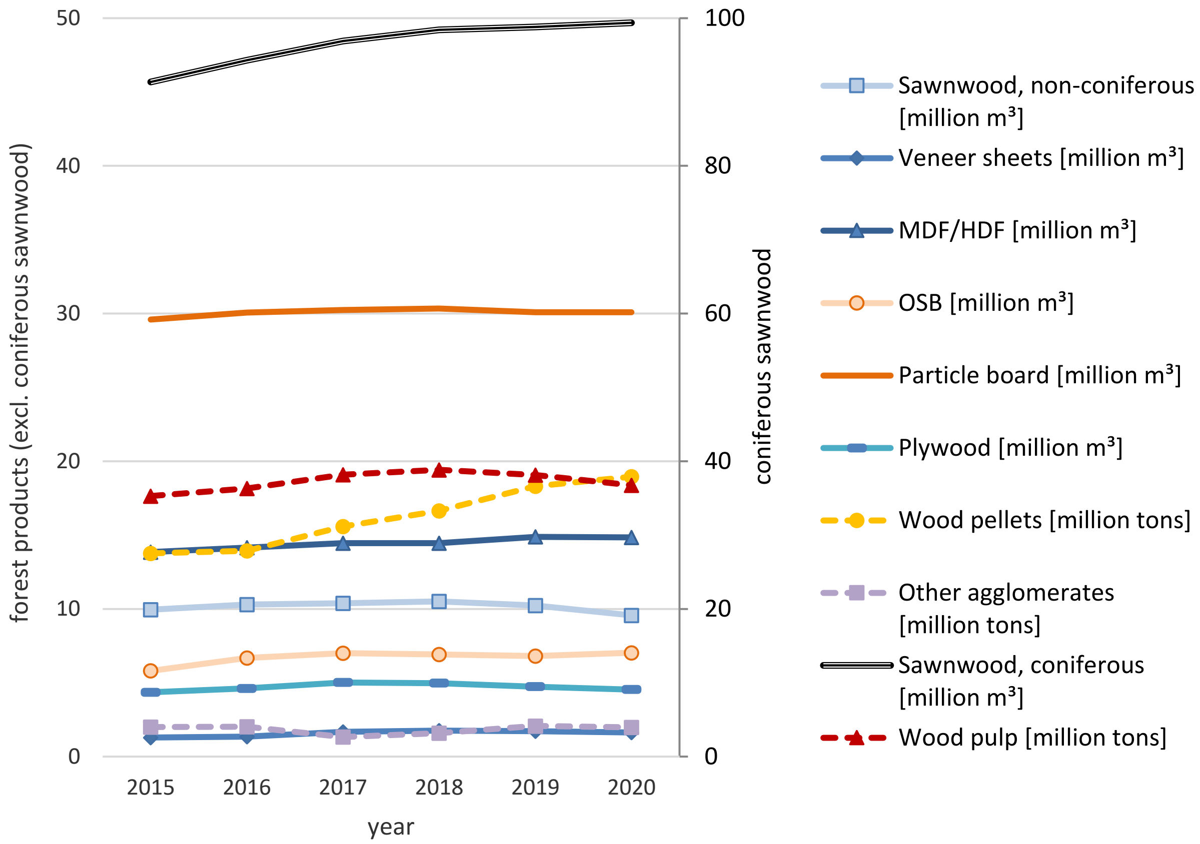
Source: own calculation, FAOStat (2021), FAO et al. (2020). Note: In the years 2015 and 2016 no disaggregated trade data is available

3.1.5 Competition for wood resources

Roundwood removals are the primary and most important input resource for the wood processing industry. Figure 1010 shows the production of major forest products in the EU27 in the most common units. Sawnwood denotes the major product of wood processing industry. Production of coniferous sawnwood is ten times higher compared to non-coniferous sawnwood production while production of veneer sheets in EU27 can be neglected due to low production figures.

Besides the use of roundwood directly sourced from forests, industry also demands wood processing residues and post-consumer recovered wood which is used, e.g., in the panel and pulp industries or for energy generation. In addition, producers of wood pellets and briquettes source major quantities of wood from secondary sources.

Figure 10: Production of forest products in EU27 in common units



Source: FAOStat (2021)

Wood processing residues or by-products denote wood resources which are traded on wood resource markets. They are mostly used for the production of particle board, fibre board, wood pulp, wood pellets and briquettes as well as directly for the production of heat and/or electricity. There is no distinct information available to which extent industrial roundwood, wood processing residues and post-consumer wood are used for the manufacturing of above-mentioned products in EU member states. However, some information is available regarding the use of by-products for energy generation.

Table 5 displays the shares of selected wood resources used for energy generation. This information derives from the Joint Wood Energy Enquiry (JWEE) and combines data from different domains – in particular data gathered for forest products statistics as well as energy statistics – which can lead to inconsistencies. Nevertheless, comparison of the data can give a very initial overview on the use patterns of wood resources (i.e. material vs. energy use).

Table 5 shows that considerable quantities of wood processing residues (by-products), bark and wood fuel from forests as well as outside forests are used for energy generation. Among the considered wood resources the share of energy generation is lowest for wood processing residues as this resource is strongly demanded and used for the manufacturing of wood products. Bark and wood fuel show high shares of energy generation according to JWEE data (UNECE/AO 2021). This can also be assumed because bark and wood fuel data from the JWEE are, to a certain extent, reported by wood energy experts and not by experts of forest products data. Hence, a comparison of these quantities used for energy generation with other data sources on potentially available quantities may reveal a possible underestimation of the supply of these woody assortments.

Table 5: Share of energy use in apparent consumption of forest products in 2017

Area	Industrial roundwood sourced from forests	Wood fuel sourced from forests	By-products	Bark	Industrial roundwood sourced from outside forests	Wood fuel sourced from outside forests
Austria	0%	*101%*	*121%*	49%	-	*361%*
Croatia	12%	99%	8%	100%	-	100%
Cyprus	0%	58%	44%	39%	-	27%
Czechia	0%	*147%*	*174%*	*101%*	-	*403%*
Estonia	0%	51%	53%	83%	0%	100%
Finland	0%	*109%*	20%	71%	-	-
France	0%	100%	21%	76%	-	92%
Germany	3%	92%	44%	*142%*	-	-
Ireland	0%	*100%*	18%	90%	-	96%
Italy	0%	*236%*	*160%*	*154%*	-	-
Lithuania	0%	0%	0%	0%	-	0%
Luxembourg	0%	95%	42%	14%	-	-
Netherlands	0%	100%	13%	*101%*	0%	100%
Slovakia	0%	*202%*	100%	100%	0%	100%
Slovenia	0%	*185%*	17%	*218%*	-	97%
Sweden	0%	*173%*	0%	12%	-	97%

Source: UNECE/FAO (2021). Note: grey shaded figures denote obvious data inconsistencies.

In general, the European market for wood processing residues (e.g., wood chips and particles) is well developed. Regional structures for supply and demand are likely well developed too. Consideration of regional structures is important as transportation of wood raw materials is cost intensive. Markets for supply and use of bark as well as for wood from outside forest seem less developed. This might be due to low demand for material utilization of these resources. After debarking of industrial roundwood, the bark is usually burnt at the wood processing plant although impurities can encumber the burning process. The use of bark as growing media seems very promising given the beneficial growing media properties, integration in industry processes and minor usability for alternative utilization. The use of woody processing residues, bark and wood from outside forest as a substrate for growing media and compost already exists in various regions. A rising demand might especially lead to increased supply of bark and wood from outside forests as collection processes might be adjusted.

The market for wood resources is constantly changing. New competitors are entering the market, others are leaving. In the last two decades many producers of wood pellets were able to establish procurement with resources. In recent years, e.g. new manufacturers of insulation board built new plants in Europe, demanding wood processing residues such as saw dust. Also, supply of coniferous by-products might still increase due to new capacities in the sawmill industry.

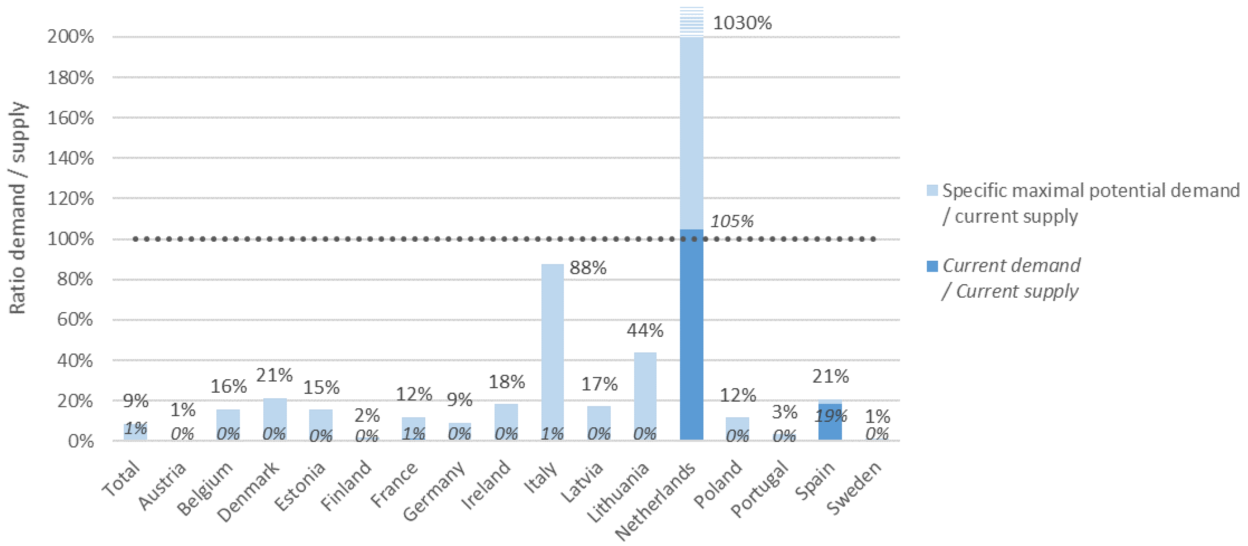
3.1.6 Demand for wood and bark for the growing media sector

For the comparison of supply and demand for wood fibres, we focus on coniferous sawmill by-products. Sawmill by-products are already available to the growing media sector mostly in form of chips or sawdust which can be directly used for the production of wood fibres for growing media, assuming that companies are equipped to transform chips into wood fibres. In addition, sawmill plants provide well developed infrastructure for dissemination of this resource. Within the scope of this analysis, we consider industrial roundwood not appropriate for the production of wood fibres for growing media. The use of industrial roundwood would require considerable processing, i.e., chipping before defibring of wood. In addition, industrial roundwood is generally of higher value as compared to wood processing residues and is primarily be used for material purposes (e.g., production of sawnwood). Wood resources from outside forest are assumed to be mostly constituted by non-coniferous wood, like suggested by Maack *et. al* (2017) for the German region Baden-Württemberg, and thus not suited for the production of wood fibres for growing media.

Bark supply is estimated through information on consumption of industrial roundwood, fuel wood and wood from outside forests. Significant amounts of bark accumulate during roundwood processing which are often used for energy generation, although possible impurities such as stones and dirt can encumber the burning process. For the comparison of supply and demand of bark, we focus exclusively on the bark sourced from industrial roundwood processing (coniferous and non-coniferous). We believe that it would be rather unlikely that bark from fuelwood and wood outside forests is removed. However, it should be noted that the supply figures for bark denote estimates. The real bark potential has to be lowered by quantities lost during felling operations and/or transportation of roundwood. Additionally, these estimates include bark which might not be suitable for growing media production due to, e.g., high salt and/or cadmium content.

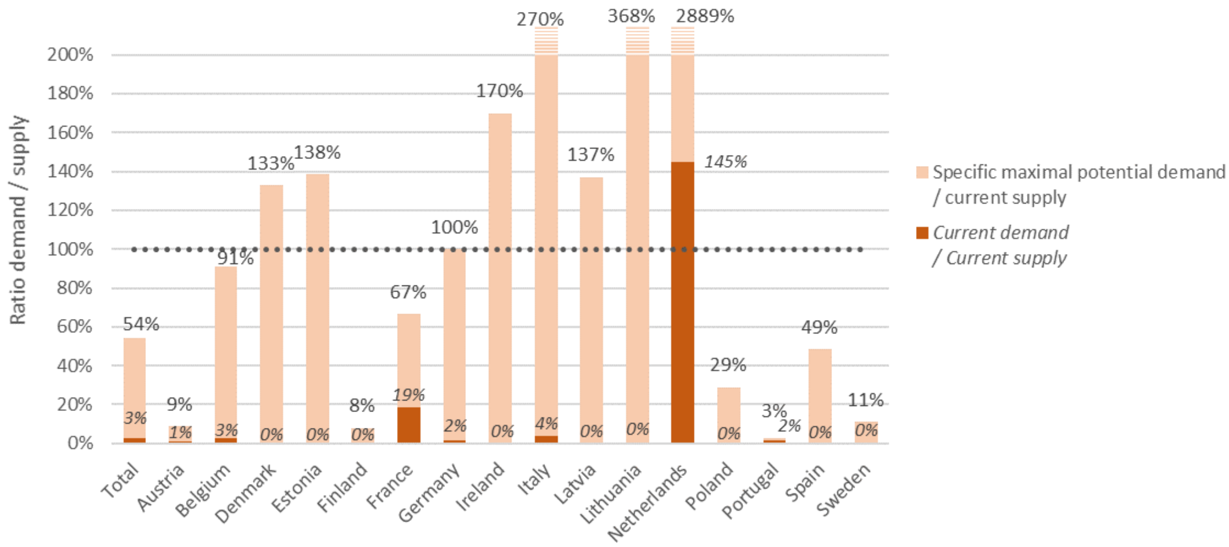
Figures 11 and 12 show the ratios of demand and supply of sawmill by-products and bark respectively. Supply figures denote the average supply in 2018-2020 period. The method for the calculation of the current and specific maximal potential demand is explained in the previous chapter 2.3.

Figure 11: Ratio between demand for wood for the growing media production and potential supply of sawmill by-products in selected European countries



Sources:
Supply: Production of sawmill by-products (2018-2020)
Current demand: calculation based on Schmilewski 2017 (year 2013)
Specific maximal potential demand: See chapter 2.3 "Maximal potential demand for the growing media production"
Raw data available in Appendix in Table A15

Figure 12: Ratio between demand for bark for the growing media production and current potential supply in selected European countries



Sources:
Supply: Bark from the apparent consumption of industrial roundwood (coniferous and non- coniferous) (2018-2020)
Current demand: calculation based on Schmilewski 2017 (year 2013)
Specific maximal potential demand: See chapter 2.3 “Maximal potential demand for the growing media production”
Raw data available in Appendix in Table A15

Total wood demand for growing media production amounted to 0.2 Mt_{DM} in 2013 in considered countries[8] representing 0.7% of the potential average supply of sawmill by-products in 2018-2020 period. The specific maximal potential demand calculated for growing media amounts to 2.4 Mt_{DM} and represents about 9% of the potential supply of sawmill by-products for the average of the years 2018-2020. The growing media sector – like any other wood resource demanding sector - is economically challenged when procuring wood resources in a competitive market with many different possibilities of utilisation. Nonetheless, data suggest that wood processing residues are generally available on regional markets in EU27 and could be used in the growing media sector. The Netherlands constitute the only exception to this. In 2013, the demand for wood for growing media was above the average supply in 2018-2020 period. The projected maximal demand for growing media would even exceed average domestic supply of sawmill by-products in 2018-2020 period, requiring, e.g., additional imports or the mobilisation of unused domestic potentials to satisfy the maximal demand.

Bark demand for growing media amounted to 0.5 Mt_{DM} in 2013, which represents 2.6% of the potential supply from processing of coniferous and non-coniferous industrial roundwood in 2018-2020 period. The specific maximal potential demand would amount to 11.2 Mt_{DM} which represents 54% of the potential bark supply. Comparisons of supply and demand reveal that the situation in EU countries differs significantly. Most of the countries seem to have sufficient domestic potentials of bark for now. Projections suggest that the total demand will still below current supply in the future. However, in some countries, the demand may be above the potential domestic supply.

[8]Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Spain and Sweden

3.2 Green waste and green compost

Green waste is collected separately or mixed with other bio-waste as part of the municipal solid waste. According to a study from the European Environment Agency (EEA 2020), around 30 million tons of green waste were collected in the EU28 in 2017.

Table 6: Amounts of municipal waste, bio-waste and garden waste in the EU28 in 2017

	Per capita (kg)	Total quantity (Mt)
Municipal solid waste	488	249
Bio-waste	168	86
Garden waste	59	30

Source: EEA (2020); total amounts of garden waste calculated using value per capita.

According to the European Compost Network (ECN), 48 Mt of bio-waste were treated in bio-waste management facilities in European ECN countries[9] (ECN 2019). The remaining amounts are landfilled or burned to produce energy, which is particularly the case for the woody parts of green compost.

Data on treated bio-waste do not allow to differentiate green waste from food waste and other types of bio-waste. The bio-waste treatment is differentiated in compost, which concerns all bio-waste types, and anaerobic digestion, which generally does not concern green waste. A mass shrinkage of 50% is expected during the composting process of green compost (Bundesgemeinschaft Kompost e.V., personal communication). The quantities of compost from all types of bio-waste generated in Europe (ECN countries) amounted to 11.7 Mt.

Compost for growing media must meet specific quality standards, especially regarding the biological stability and the salt content. In order to fulfil these requirements, a particularly long maturing process is required and the input material needs to be a mixture of green waste with a minimum amount of woody material. We consider that virtually every type of green waste is suited for the production of growing media and thus, the entire supply of green waste could be technically used to produce growing media compost.

According to the ECN, a share of 15% of the amount of compost corresponding to 1.8 Mt was used as component for the production of growing media, which only concerns compost based mostly on green waste (green compost). According to Schmilewski (2017), 1.66 Mm^3 EN12580 equivalent to 0.9 Mt[10] green compost was used for the growing media production in 2013 in Europe[11]. Although the geographical scope of these data is different, a positive trend is confirmed in the case of Germany with an amount of bio-waste used for composting of 6 Mt in 2013 and 7.8 Mt in 2020 (+30%) and a share of compost for growing media of 16.9% in 2013 and 21.6% in 2020 (+28%). The other uses of compost are mostly as fertiliser and soil improver for agriculture (50% of the use in 2017 for the ECN country members), landscaping (15%) and hobby gardening (14%).

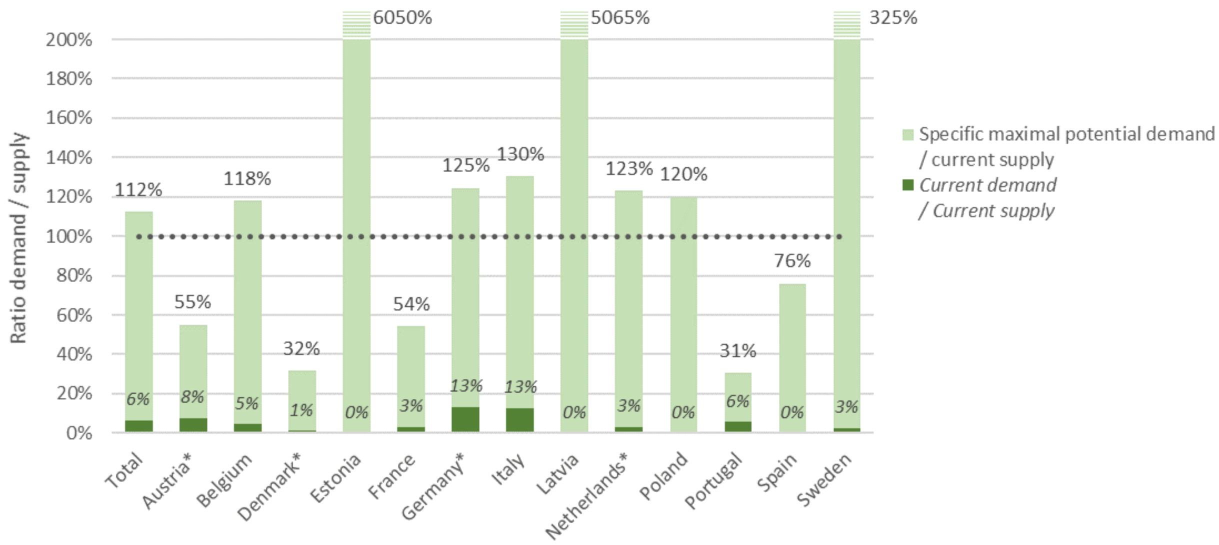
The ratio of current demand for green waste for the production of growing media compost and the current supply of green waste presented in Figure 13 shows that the amounts of green waste are far from limiting the current use of green compost for growing media. However, in the case of a maximal potential scenario of green compost, the current supply of some countries, especially important growing media producers, would not be sufficient to cover the demand and this supply would have to be increased (ECN).

[9] Estonia, Portugal, Hungary, Lithuania, Norway, Ireland, Finland, Slovenia, Denmark, Poland, Austria, Sweden, Belgium, the Netherlands, France, Italy, the United Kingdom, Germany. Years: 2016 or 2017 depending on the sources.

[10] With a density factor of 0,55 t/m^3 (Schmilewski 2018)

[11] Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Sweden, the United Kingdom

Figure 13: Ratio between demand for green compost for the growing media production and current potential supply in selected European countries



Sources:
Supply: calculation based on EEA 2021 (year 2017), *Germany: Destatis F19 R1; Netherlands, Denmark, Austria: ECN Country Report
Current demand: calculation based on Schmilewski 2017 (year 2013)
Specific maximal potential demand: See chapter 2.3 "Maximal potential demand for the growing media production"
Raw data available in Appendix in Table A15

With a density of 500 to 600 kg/m³ EN12580, green compost is a particularly heavy material to transport in comparison with most of the other components. Currently, growing media factories in Northern Germany which buy their compost reported that they have to transport it more than 100 km, which reduces the incentive to use this product. We assume this situation to be the consequence of an insufficient regional infrastructure to process green waste into compost meeting the criteria as growing media component. In Germany, growing media producers reported long waiting time and a complex administrative process at the municipal level for the construction of their own green compost facilities. In order to further evaluate the regional situation, an analysis of regional/local availability of green waste and of the composting infrastructure would be necessary.

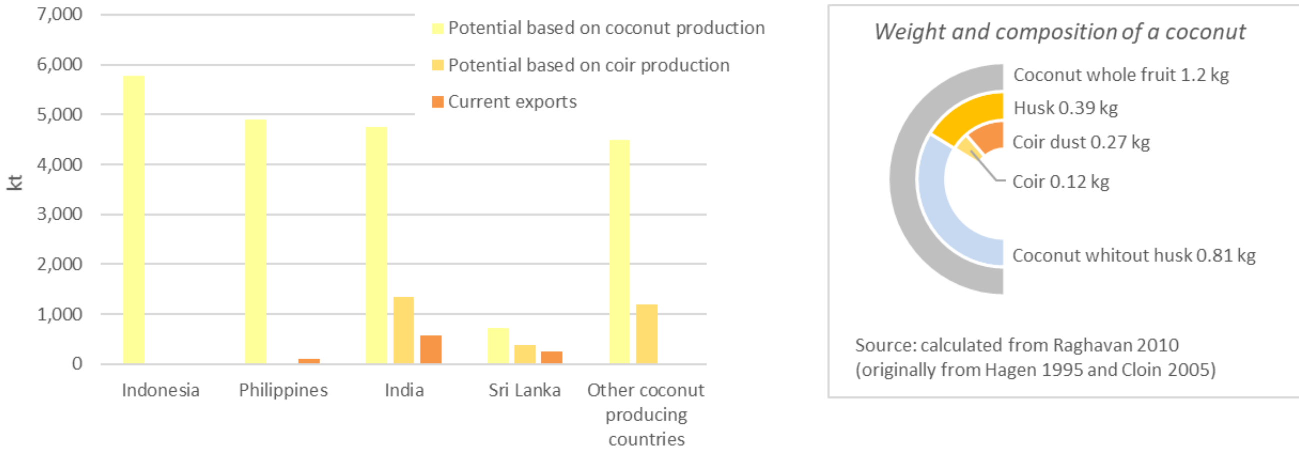
According to a study of the Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg & LUBW (2015) in Baden-Württemberg (Germany), the collection of green waste amounts to only between 22 and 37% of the green waste potential. We found a similar result using the same method for Germany as a whole (between 15 and 28 Mt, own calculation) and comparing it with data on collected green waste (5.9 Mt in 2017 according to Destatis). In this case, the potential amounts for Germany significantly outpace the specific maximal potential demand calculated for growing media (7.4 Mt). Although no calculation of the potential was found for Europe, it is to be expected that generally, large additional amounts of green waste could be obtained with an extension of the collecting system.

Since compost for growing media has a high value in comparison with other uses of compost, we can expect that waste management facilities could be encouraged to produce more of it if the demand of the growing media sector increases. This is especially the case of private facilities, which are expected to be more sensitive to market opportunities. Public facilities managed by communes could be incentivised politically to encourage the reduction of peat use by looking for a valorisation of their product in growing media.

3.3 Coir by-products

Coir by-products for horticulture (coir pith/cocopeat, coir fibres, coco chips) are residues from coir processing and consist of non-fibrous material or fibres too small to be used for other uses, also referred as “coir dust” (Nagaraja & Basavaiah 2010, Coir Board of India 2016). Coir is processed for the manufacture of a large variety of products like ropes, floor mats, mattresses or padding in the automobile industry. This processing takes place in countries where coconuts are produced. Because the supply chain of coir by-products for horticulture is intercontinental, the availability analysis is conducted on a world scope. The leading coconut producing countries are Indonesia, the Philippines, India and Brazil. The potentials for coir by-products were calculated based on the current coconut production and on the current coir production from FAOStat using ratios based on Raghavan (2010) (Figure 14). We interpreted coir by-products for horticulture use as “coir dust” which correspond to the part of the husk that is not constituted of coarse fibres interpreted as “coir” (Coconut Development Authority Sri Lanka 2019, Coir Board of India 2019).

Figure 14: Potential production and current exports of coir by-products (coir dust)



Sources:
Coconut and coir production: FAOStat 2021, average 2017-2019
Exports: Coir Board of India (2019, year 2018-2019), Coconut Development Authority of Sri Lanka (2019, year 2018), Philippine Coconut Authority (year 2018, source not available anymore).

The theoretical potential based on the coconut production amounts to 21 Mt. An estimation of 7.5 Mt was calculated by Blok *et al.* (2021) using a factor of 125 g/kg[12] coconut without husk (vs. 340 g/kg in the own calculation based on Raghavan 2010). The theoretical potential based on coir production is much lower: 2.9 Mt, which is due to the fact that only a few of producing countries process the coir from the coconut husks in significant amounts. Current exports of coir by-products for horticulture from India, Sri Lanka and the Philippines amounted to 0.9 Mt in 2018[13]. This situation is confirmed by a report on coir pith from the Coir Board of India (2016) with the following statements: “If all the coconut husks available in India are processed, it is estimated that about 2.25 million tons of coir pith could be obtained annually. But in reality, all the available coconut husks are not diverted for coir extraction and it has been reported that only 10 lakh tons [1 000 000 t] of coir pith is produced in India annually (p7)” and “Despite many advantages and availability in large quantities, coir pith is not fully utilised for productive purposes and every year large amounts of coir pith accumulate nearby coir processing units, causing severe disposal problems, fire hazards and ground water contamination due to the release of phenolics compounds (p8)”.

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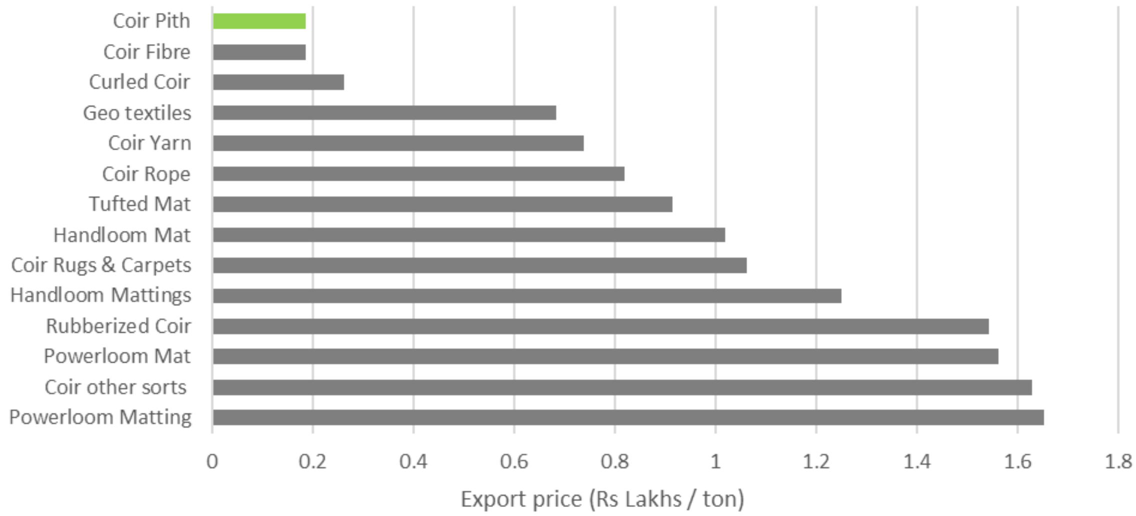
[12] Original source was not found

Therefore, the current availability problem of coir by-products does not seem to be explained by a lack of material. It is the result of an economic situation where the transportation costs are too high, which limits the mobilisation of its potential. Transportation costs can be expected to be incurred for a large part in the exporting country, as is the case, for example, for exported cocoa (Asante-Poku & Angelucci 2013 on Ghana, Table 9). Figure 15 shows well that the price of coir pith, as a residual material, is lower than all other products from coir. In a scenario where the demand for coir by-products significantly increases, it is to be expected that more of these amounts could be mobilised and be exported.

Figure 15: Export price of different coir products from India



Sources: calculated from Coir Board of India, Year 2017-2018

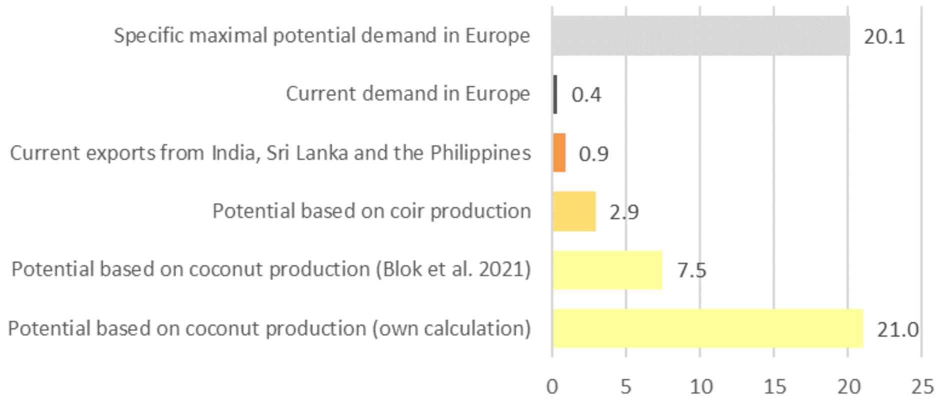
Coir by-products are specifically used for horticulture, and no other uses seem to be developed. Research has been done for the utilisation of coir by-products for energy purposes. However, it does not seem to be used for energy generation in significant amounts. Therefore, export of these products to Europe does not seem to be currently linked to competition with local uses which could lead to a loss of economic value in the exporting countries. However, Europe is in competition with other regions in the world for the access to coir by-products in order to produce growing media. In 2013-2014, the first importers of coir pith from India were South Korea, the Netherlands, the USA, Spain and Australia.

The comparison between potential supply and demand is presented in Figure 16. The current demand for coir pith for growing media in Europe[14] and the current exports worldwide represent a minimal share (respectively 1.8% and 4.4%) of the world potential calculated. However, the specific maximal potential demand is estimated at 20.1 Mt, which represents 96% of the world potential supply calculated and is far above the one calculated in the study from Blok *et al.* (2021). According to the same study, the world demand for growing media is also expected to increase, especially in Asia. Because coir pith presents good properties as stand-alone growing media and is produced in Asia, we expect the growth of the Asian demand for this material to be particularly important and the competition between countries for the access to coir pith will strongly tighten. The maximal demand scenario taken here is based on 100% coir pith in growing media in the future, which is a strong assumption considering the other alternative materials available. However, the data indicate that, in a maximal demand scenario in Europe, the available resources of coir by-products could represent a limit to the supply, especially if the demand in other parts of the world strongly increases.

[14] Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Spain and Sweden

The social conditions under which coir by-products are currently processed and transported for the exports constitutes a potential concern for politics and the growing media industry. Therefore, the import of coir by-products for the growing media production in Europe should be associated with the definition of standards. Initiatives for the development of certification including social standards are being discussed in Germany (call for projects from the FNR) and in the Netherlands (Foundation RHP).

Figure 16: Comparison of world potential and European demand for coir by-products



Sources:
Current demand: calculation based on Schmilewski 2017 (year 2013)
Specific maximal potential demand: See chapter 2.3 "Maximal potential demand for the growing media production"
Coconut and coir production: FAOStat 2021, average 2017-2019
Exports: Coir Board of India (2019, year 2018-2019), Coconut Development Authority of Sri Lanka (2019, year 2018), Philippine Coconut Authority (year 2018, source not available anymore)

3.4 Comparison of total supply and total demand

For the comparison of total supply and total demand, all quantities have to be converted in cubic meter EN 12580 growing media constituents.

Due to the technically feasible share in growing media, wood fibres, composted bark and green waste are assumed to be used only mixed with other constituents. Therefore, if only one constituent is available in large amounts, it is possible that the total supply of alternative constituents can not be used entirely. For example, the supply of wood residues to be used for growing media constitutes 66% of the sum of the supplies of all materials considered although its maximal share in growing media is set to be under 40-50 vol. %. Thus, in order to compare total supply and total demand for all constituents together, the supply needs to be calculated considering the maximal share of each constituent. Following this consideration, we calculated the total supply of growing media constituents technically usable for each country, referred as "total usable supply".

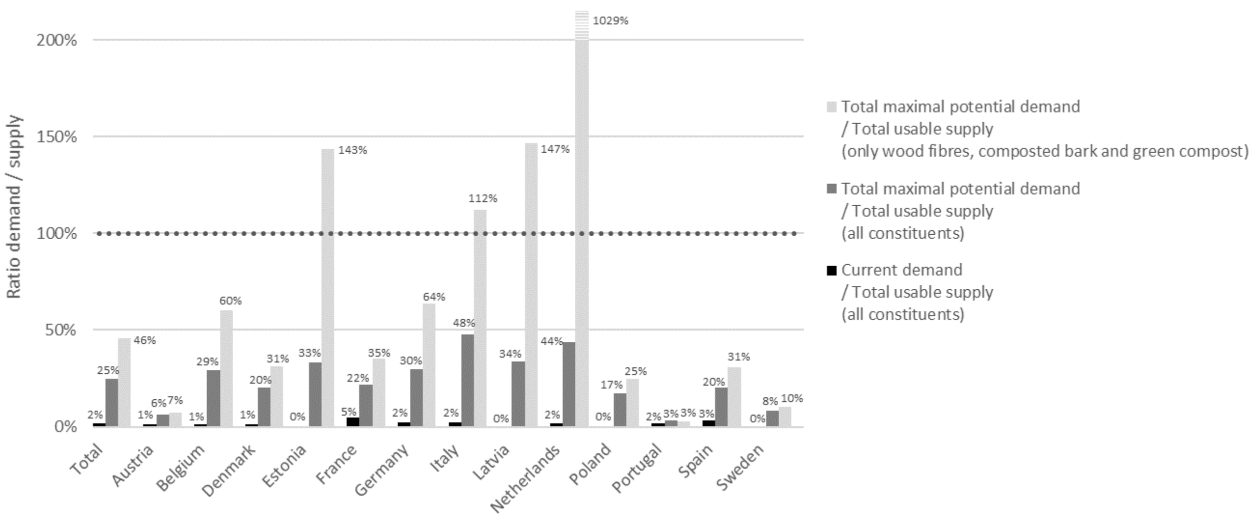
We calculated this supply first for the materials available nationally/locally: wood, bark and green waste. The total usable supply including coir by-products is then calculated by dispatching the potential supply of coir by-products using the following rules:

- The supply of coir by-products is used primarily to meet the maximal demand in countries where the total usable supply of wood fibres, composted bark and green compost is not sufficient to meet the total maximal potential demand.
- The rest of the supply of coir by-products is dispatched between countries proportionally to their total maximal potential demand.

Since the maximal share of coir pith is 100 vol. %, no restriction applies on the mobilisation of the supply of coir by-products. It is to note that the additional supply of coir by-products leads to a higher potential mobilisation of the supply of other constituents for which their mobilisation is limited by their maximal share in growing media.

Figure 17 shows the ratios of demand and total usable supply (without and with coir by-products) for each country considered. All underlying data are provided in Table A16. Results show that for all countries, the current demand is very limited compared to the total usable supply, which was strongly suggested by the separated analysis on each material. For most countries, the national supply of wood, bark and green waste would be sufficient to meet their total maximal potential demand. However, especially in the case of the Netherlands but also for Latvia, Estonia and Italy, these resources would be scarce. However, if the supply of coir by-products is considered, the supply would largely outreach the total maximal potential demand for all countries. Overall, countries that are strongly involved in the production and trade of peat and growing media, like the Netherlands and the Baltic States, would need to mobilise their supply the most. Thus, an extensive peat replacement could have an influence the international structure of the supply chain of growing media.

Figure 17: Ratio of total demand for growing media constituents (current and maximal potential) and total usable supply of raw materials in selected European countries



3.5 *Sphagnum* and other renewable materials from rewetted peatlands

The production of *Sphagnum* in Europe takes places at several sites, mostly linked to research projects. In Finland, there are also private initiatives to harvest wild *Sphagnum* growing on semi-natural peatlands. The production is minimal compared to the potential demand for growing media.

Currently discussed political measures on climate change include rewetting European peatlands in order to stop carbon loss and restore their carbon storing capacity. Since economic activities, especially agriculture, take place on drained peatlands, countries face a complex socio-economic challenge. In this situation, the production of agricultural products on wetlands (also called paludiculture) is a promising perspective in order to overcome these trade-offs. *Sphagnum* farming constitutes one of these options. Gaudig *et al.* (2008) estimated that the need for white peat for Germany (3 Mm^3 per annum) would be covered by a mobilisation of 45 kha for Sphagnum farming on bog peatlands, which she compared to the 165 kha grassland on bog peatlands in Lower Saxony.

Because of its properties, a complete 1:1 replacement of peat using *Sphagnum* can be considered. *Sphagnum* farming seem to be particularly well suited on former peat extraction sites where the soil surface is constituted of peat and nutrient levels are low. In this configuration, *Sphagnum* can be produced locally in the regions where a large part of the growing media industry is already based because of its historic development tightly linked to peat extraction. Since no other uses seem to be suited for *Sphagnum* except punctually as input material to reintroduce Sphagnum vegetation on rewetted peatlands, the growing media sector would not face direct competition for the access to this product. In order to create and develop its potential, a further development of the technology for its production and processing, as well as strong incentives for rewetting and paludiculture, are necessary.

Other plants from paludiculture on fens like reed can also be considered for peat replacement, which would have comparable positive climate effects as *Sphagnum*. However, due to their properties, their use as growing media constituent is linked to technical challenges and needs more research.

4 Limitations due to legal conditions

The use of material in growing media is regulated by legal framework conditions, in particular the Regulation (EU) 2019/1009 laying down rules on supplying the market of EU fertilising products. This regulation replaces Regulation (EC) 2003/2003 relating to fertilisers, which has been limited to inorganic fertilisers. The new regulation also addresses organic fertilisers, soil amendments and growing media, and aims to improve market conditions for such inputs produced from recycled and organic materials within the EU. This may help to improve the marketing of alternative growing media and non-peat constituents. The conformity of an EU fertilising product with this regulation is indicated by CE marking. However, this harmonisation is optional, i.e., fertilising products can also be placed on the market under national rules, but this decision could hamper the trade of the products if trade partners require CE marking. The option to use national rules can be more attractive if requirements for EU fertilising products and additional transaction costs for registration are high. According to Regulation (EU) 2019/515, goods can also be traded on basis of the mutual recognition of goods lawfully marketed in another member state. For growing media based on non-peat constituents, the new rules for EU fertilising products are especially relevant because growing media are highly traded products within the EU, so that CE marking is likely to be a relevant aspect. As non-peat growing media are mixtures of different constituents which all have to comply with the new EU requirements, the development of the market for alternative growing media is especially challenging. Still, impacts of the regulation on the trade with peat-free and peat-reduced growing media have to be observed during the next years. We recommend including this specific aspect in the report of the Commission on the application and impacts of the regulation according to Article 49 due by 16 July 2026.

Wood fibres have a large potential to substitute peat. However, a recent amendment of the EU Fertilising Products Regulation (EU) 2019/1009 defines that "an EU fertilising product may contain plants, plant parts or plant extracts having undergone no processing other than (…) fiberisation at a temperature not higher than 100 °C …" (Regulation (EU) 2021/1768, Annex II (2)). As fiberisation is usually run at temperatures up to 160°C, this requirement could massively restrict peat substitution by wood fibres in the EU, unless a registration based on national legislation is applied. The intention of the requirement related to the process temperature is obviously to avoid the formation of potentially hazardous thermal degradation products from wood fibres. However, there are few studies on potential risks of wood fibres, which have been produced in this temperature range, for human health and the environment. Thus, the 100 °C threshold level obviously serves as a preventive measure. As a significant decomposition of wood materials starts to occur only at temperatures above 160-180 °C, it appears reasonable to close the knowledge gaps and, on an improved data basis, to reconsider this requirement.

5 Possible ecological trade-offs linked to increased demand for alternative growing media constituents

The environmental impacts of an increased demand for alternative materials for growing media has to be considered and compared to the environmental benefits of peat reduction. Indeed, the increased use of biomass for growing media can have indirect effects which need to be assessed. The following indirect effects need to be mentioned:

- Displacement effect due to competition with other sectors: If more biomass is used in the growing media sector, this biomass is not available for other sectors which also can have a climate mitigation effect by replacing fossil material, like it is the case in the energy sector or material uses with high substitution effects. In a situation where the supply can be extended and competition is relatively loose, an increased demand can be covered by an increased supply. However, if the competition is tight and the supply limited, these displacement effects are more acute. The risk of displacement effects decreases with the degree of sustainability and de-carbonisation of the sectors with which the growing media compete, e.g., the energy sector.
- Increasing/Intensifying biomass extraction might have negative effects on the nutritional basis of an ecosystem as well as on biodiversity.
- Effects due to an increased transport: If the increased supply of biomass cannot take place locally and regionally, the growing media companies or their suppliers need to increase the area from which they obtain their products. This is linked to increased transport activities which have an impact on the ecological footprint of the product. However, transport emissions are also expected to decrease with the expected shift to a de-carbonised transport.
- Indirect land use change (ILUC): In the case where agricultural primary products are used, an increase in demand can lead to displacement in the land use. However, since most of the alternative material are residues, we can assume that no land is used specifically for their production. Therefore, an increased demand of biomass from the growing media sector is unlikely to lead to changes in land use. In the case of *Sphagnum* farming, even a positive climate effect in land use by rewetting peatlands and developing paludiculture could be achieved.

Such effects must be assessed through scenario analyses and are therefore difficult to quantify and are linked to uncertainties due to numerous assumptions about future evolutions. Scenario analyses are not part of this study and will need further assessments.

6 Conclusion

Basically, the current supply of raw materials for the production of alternative growing media constituents to replace peat does not represent a significant limitation for strategies on the reduction of peat use against the background of climate policies. However, it is an economic challenge for the growing media sector to compete with other uses of biomass, especially for energy generation, mobilise currently unused amounts with potentially higher transportation costs and develop the infrastructure to process alternative materials.

When focussing on the supply of material for the production of alternative growing media constituents, available quantities are significantly above the current use of these alternatives. For most of the countries and constituents, these amounts seem to be sufficient to meet the demand of the growing media sector, even in the scenario of a strong increase in the growing media production and a complete peat replacement. In particular the market for coniferous sawmill by-products is much greater than the specific maximal potential demand for wood derived growing media constituents. In the case of green compost, where the current supply would not be sufficient, a stronger demand from the growing media sector could promote the development of collection systems and increase available amounts.

If the use of alternative materials significantly increases, the economic challenges linked to the availability, especially due to competition and transportation costs, would gain importance. In order to address these challenges, the structure of the current supply chain of growing media, based on the international trade of peat and peat-based products, would have to change, e.g., by relocating the supply on biomass resources to avoid transportation costs. There is also a need to invest in the development of the infrastructure for the production and the processing of biomass. All countries in the EU do not face these challenges equally: The Baltic States, which export high shares of peat and peat-based growing media, might forfeit their role of material suppliers. For the Netherlands, the second biggest producer of growing media in Europe which is completely dependent on peat imports, local biomass resources could be scarce to supply an entirely peat-free growing media sector of the same size without relying on imports.

Trade of alternative growing media and its constituents is important for regional availability of these products. Since recently, the trade in the EU with fertilising products produced from recycled and organic materials is regulated by Regulation (EU) 2019/1009. This harmonisation offers opportunities for the development of the market of alternative growing media. However, for these products the new requirements appear to be challenging, especially for wood fibres. Thus, impacts of the regulation should be observed during the next years and potential obstacles to the trade of non-peat constituents and peat-free and peat-reduced growing media should be removed as far as possible.

Despite of its relevance for GHG emissions, there are still only isolated national political strategies in Europe to reduce peat extraction and use in horticulture. Peat and growing media are goods traded widely in the EU and beyond. A coordinated European action on peat reduction in growing media would have economically fairer and environmentally more effective impacts than isolated national strategies.

Nowadays, the problem of availability of alternative growing media constituents takes place in a context where the costs linked to peat extraction and use for horticulture are low in comparison to the costs for the supply and use of biomass. These economic costs do not reflect the environmental costs of peat. It is to be expected that a higher price of peat would facilitate the conditions to access larger amounts of alternative materials and develop the infrastructure for its use in the growing media sector. In order to achieve this, the inclusion of peat in a carbon pricing system could be an option.

The development of *Sphagnum* farming, which is currently not relevant for the growing media sector, provides a growing media constituent of high quality and could supply a large peat replacement while contributing to creating value and rewetting peatlands. Its development depends on economic factors regarding the peat and growing media sector, but also on political incentives and conditions to rewet peatlands and encourage paludiculture.

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Appendix

Table A1: Average composition of growing media for the professional market in European countries. Unit: volume percentage based on EN 12580 growing constituents before mixing

Area	White peat	Black peat	Fen peat	Bark	Coir products	Wood fibres	Wood (chips, etc.)	Rice hulls	Heather soil / Leaf mold	Composted bark	Composted green waste	Composted wood	Other composted materials	Perlite	Clay	Sand	Vermiculite	Lava	Pumice	Grit	Loam	Mineral wool
Austria	51%	5%	0%	0%	1%	7%	0%	0%	0%	18%	6%	0%	0%	1%	4%	3%	0%	1%	0%	0%	1%	0%
Belgium	44%	44%	0%	1%	3%	0%	0%	0%	0%	2%	0%	0%	0%	1%	3%	0%	0%	0%	0%	0%	0%	0%
Denmark	70%	5%	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2%	0%	0%	0%	0%	0%	0%	19%
Estonia	91%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Finland	88%	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
France	35%	17%	3%	13%	3%	5%	0%	0%	3%	15%	0%	0%	1%	2%	1%	0%	0%	0%	0%	0%	0%	1%
Germany	41%	50%	0%	1%	1%	2%	0%	0%	0%	0%	2%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%	0%
Ireland	33%	66%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Italy	47%	27%	0%	0%	7%	0%	0%	0%	0%	0%	1%	0%	0%	2%	4%	1%	1%	0%	10%	0%	0%	0%
Latvia	86%	6%	0%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Lithuania	73%	26%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Netherlands	40%	27%	1%	5%	7%	0%	1%	0%	0%	1%	1%	0%	0%	3%	1%	0%	0%	0%	0%	0%	0%	14%
Poland	52%	25%	17%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%
Portugal	3%	0%	0%	41%	6%	0%	0%	0%	0%	41%	8%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%
Sweden	57%	17%	4%	0%	0%	0%	0%	0%	0%	2%	1%	0%	0%	1%	5%	13%	0%	0%	0%	0%	0%	0%
UK	42%	39%	0%	2%	2%	3%	2%	0%	0%	7%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Spain	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%	0%	3%	0%	0%	1%	3%	0%	0%	0%	0%

Source: calculation based Schmilewski 2017 and Schmilewski 2008 (Spain)

Table A2: Average composition of growing media for the hobby market in European countries. Unit: volume percentage based on EN 12580 growing constituents before mixing

Area	White peat	Black peat	Fen peat	Bark	Coir products	Wood fibres	Wood (chips, etc.)	Rice hulls	Heather soil / Leaf mold	Composted bark	Composted green waste	Composted wood	Other composted materials	Perlite	Clay	Sand	Vermiculite	Lava	Pumice	Grit	Loam	Mineral wool
Austria	40%	14%	0%	0%	0%	10%	0%	0%	0%	20%	14%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
Belgium	29%	55%	0%	2%	1%	1%	0%	0%	0%	3%	5%	0%	0%	1%	3%	1%	0%	0%	0%	0%	0%	0%
Denmark	68%	24%	0%	0%	0%	0%	0%	0%	0%	0%	3%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Estonia	75%	24%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
Finland	42%	34%	0%	4%	0%	0%	1%	0%	0%	0%	11%	0%	0%	0%	1%	8%	0%	0%	0%	0%	0%	0%
France	24%	7%	7%	15%	1%	7%	0%	0%	3%	27%	5%	0%	3%	1%	1%	0%	0%	0%	0%	0%	0%	0%
Germany	33%	50%	0%	1%	0%	3%	0%	0%	0%	1%	10%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
Ireland	1%	84%	0%	0%	6%	0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Italy	49%	11%	0%	3%	5%	0%	0%	0%	0%	0%	19%	1%	0%	0%	2%	2%	0%	0%	8%	0%	0%	0%
Latvia	84%	6%	0%	0%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lithuania	72%	28%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Netherlands	39%	36%	2%	4%	6%	0%	1%	0%	0%	2%	7%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%	0%
Poland	36%	35%	28%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Portugal	3%	0%	0%	34%	0%	0%	0%	0%	0%	34%	20%	0%	7%	0%	1%	1%	0%	0%	0%	0%	0%	0%
Sweden	68%	17%	3%	0%	0%	0%	0%	0%	0%	2%	1%	0%	4%	0%	1%	3%	0%	0%	0%	0%	0%	0%
UK	24%	31%	6%	0%	1%	10%	5%	0%	0%	10%	8%	2%	0%	0%	0%	0%	0%	0%	0%	0%	3%	0%
Spain	12%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	42%	0%	0%	23%	23%	0%	0%	0%	0%	0%	0%

Source: calculation based Schmilewski 2017 and Schmilewski 2008 (Spain)

Table A3: Conversion factors used in this study

	Value	Unit	Source
Density factors			
Wood fibres	0.08	t_{DM}/m^3 EN12580	Based on Schmilewski (2018), Table 8 (70-90 g/l)
Composted bark	0.2	t_{DM}/m^3 EN12580	Based on Schmilewski (2018), Table 8 (170-230 g/l)
Green compost	0.55	t/m^3 EN12580	Based on Schmilewski (2018), Table 8 (400-500 g/l)
Coir pith	0.3	t/m^3 EN12580	Based on Schmilewski (2018), Table 8 (250-350 g/l)
Coniferous wood	0.41	t_{DM}/m^3 (solid wood)	Based on FAO, ITTO and United Nations (2020)
Non-coniferous wood	0.56	t_{DM}/m^3 (solid wood)	Based on FAO, ITTO and United Nations (2020)
Wood by-products	0.41	t_{DM}/m^3 (solid wood)	Based on FAO, ITTO and United Nations (2020)
Woody biomass from outside forests	0.48	t_{DM}/m^3 (solid wood)	Based on FAO, ITTO and United Nations (2020)
Proportion of bark			
Bark	Country specific	m^3/m^3 solid wood over bark	Based on FAO, ITTO and United Nations (2020)
Mass loss during composting			
Composting green waste	50%	%mass	Pers. comm. Bundesgemeinschaft Kompost e.V.
Composting bark	35%	%mass	Pers. comm. Heinz Stichnothe
Volume share during sawmilling (sawnwood production)			
Shrinkage loss	Country specific		Based on FAO, ITTO and United Nations (2020)
Sawnwood	Country specific		Based on FAO, ITTO and United Nations (2020)

Area	**Current demand**					**Maximal potential demand (note: the sum of the constituents is superior to the total for growing media)**				
	Total growing media	**Wood fibres, chips, composted wood**	**Bark products (composted or not)**	**Green waste compost and other composts**	**Coir products (pith, fibers, chips)**	**Total growing media**	**Wood fibres**	**Composted bark**	**Green compost**	**Coir pith**
Austria	313	25	50	35	2	625	297	360	250	625
Belgium	980	15	30	30	30	1,960	862	1,058	784	1,960
Denmark	333	1	0	35	1	665	313	380	266	665
Estonia	1,150	0	0	1	3	2,299	1,001	1,231	920	2,299
Finland	905	4	15	40	1	1,809	815	996	724	1,809
France	3,352	267	1,051	145	91	6,704	3,018	3,689	2,682	6,704
Germany	8,373	350	159	720	87	16,746	7,497	9,172	6,698	16,746
Ireland	884	0	0	38	77	1,768	834	1,011	707	1,768
Italy	3,833	14	60	296	440	7,666	3,320	4,087	3,066	7,666
Latvia	2,123	1	0	0	150	4,245	1,806	2,231	1,698	4,245
Lithuania	1,984	0	2	0	0	3,969	1,689	2,086	1,587	3,969
Netherlands	4,485	74	237	95	367	8,970	3,734	4,631	3,588	8,970
Poland	1,880	0	0	0	0	3,760	1,694	2,070	1,504	3,760
Portugal	135	0	100	25	4	270	122	149	108	270
Sweden	1,223	0	34	58	3	2,446	1,166	1,410	978	2,446
Spain	1,631	550	0	0	0	3,262	1,544	1,870	1,305	3,262
UK	2,601	665	161	226	59	5,202	2,480	3,000	2,081	5,202
TOTAL Countries	36,183	1,966	1,899	1,744	1,314	72,366	32,194	39,431	28,946	72,366

Table A4: Current and maximal potential demand for growing media constituents. Unit: 1,000 m³ EN 12580 growing media constituents

Source current demand: Schmilewski 2017 and 2008 (Spain). Maximal potential demand: see chapter 2.3 “Maximal potential demand for the growing media production”

Table A5: Coniferous roundwood removals in member states of EU27. Unit: Mt_{DM}

Area	2015	2016	2017	2018	2019	2020
Austria	6.017	5.721	6.027	6.623	6.597	5.759
Belgium	1.477	1.477	1.477	1.394	1.394	1.394
Bulgaria	1.252	1.333	1.324	1.435	1.272	1.171
Croatia	0.346	0.333	0.361	0.361	0.361	0.361
Cyprus	0.004	0.006	0.006	0.004	0.003	0.003
Czechia	5.940	6.576	7.324	9.999	12.930	13.231
Denmark	1.363	1.203	1.203	1.203	1.203	1.203
Estonia	2.305	2.448	2.607	2.782	2.476	2.324
Finland	19.355	20.131	20.732	22.373	20.605	19.548
France	7.814	7.865	7.931	7.987	7.991	7.841
Germany	20.209	19.010	18.887	22.812	23.677	26.992
Greece	0.135	0.135	0.096	0.107	0.110	0.110
Hungary	0.392	0.414	0.393	0.382	0.379	0.379
Ireland	1.159	1.232	1.188	1.418	1.418	1.418
Italy	1.039	1.034	1.032	1.031	3.226	2.190
Latvia	3.405	3.644	3.200	3.262	3.262	3.262
Lithuania	1.425	1.547	1.571	1.523	1.508	1.474
Luxembourg	0.076	0.067	0.088	0.117	0.105	0.101
Malta	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.285	0.435	0.395	0.372	0.361	0.361
Poland	12.649	13.142	14.419	14.821	13.659	12.752
Portugal	1.234	1.670	1.647	1.772	1.895	1.801
Romania	2.488	2.238	2.179	2.458	2.201	2.669
Slovakia	1.925	2.145	2.279	2.391	2.212	1.666
Slovenia	1.265	1.442	1.200	1.422	1.149	0.870
Spain	3.749	3.114	3.646	4.100	4.094	4.157
Sweden	27.774	27.977	27.019	26.387	27.274	27.576
European Union (27)	125.082	126.339	128.230	138.538	141.366	140.617

Note: conversion factor: 0.41 tdm/m³; Sources: FAOStat, 2021, FAO et al., 2020

Table A6: Non-coniferous roundwood removals in member states of EU27. Unit: Mt_{DM}

Area	2015	2016	2017	2018	2019	2020
Austria	1.671	1.632	1.712	1.769	1.642	1.595
Belgium	1.030	1.030	1.030	1.030	1.030	1.030
Bulgaria	1.874	1.784	1.795	1.714	1.730	1.441
Croatia	2.435	2.445	2.487	2.662	2.662	2.662
Cyprus	0.001	0.001	0.001	0.001	0.001	0.001
Czechia	0.997	0.950	0.927	0.828	0.714	0.732
Denmark	0.567	0.521	0.521	0.521	0.521	0.521
Estonia	2.207	2.408	2.886	3.079	2.741	2.595
Finland	7.035	7.116	7.334	7.915	7.724	7.234
France	17.669	18.591	17.419	17.125	16.986	17.141
Germany	11.253	11.300	11.208	11.214	11.491	10.482
Greece	0.620	0.620	0.788	0.670	0.613	0.613
Hungary	2.690	2.571	2.658	2.766	2.613	2.613
Ireland	0.057	0.037	0.037	0.060	0.060	0.060
Italy	5.925	5.920	5.919	5.918	5.920	5.911
Latvia	2.271	2.372	2.887	2.829	2.829	2.829
Lithuania	1.662	1.683	1.678	1.847	1.704	1.569
Luxembourg	0.106	0.092	0.086	0.092	0.074	0.058
Malta	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.873	1.234	1.231	1.258	1.083	1.083
Poland	6.027	5.933	5.832	6.070	5.716	5.443
Portugal	4.719	5.083	5.372	5.072	5.009	5.020
Romania	5.212	5.440	5.169	5.630	5.889	5.086
Slovakia	2.430	2.285	2.156	2.139	2.020	1.915
Slovenia	1.117	1.059	0.900	0.895	1.030	0.995
Spain	4.683	4.885	4.534	5.068	4.736	4.623
Sweden	3.949	3.955	4.909	5.205	5.287	5.206
European Union (27)	89.081	90.945	91.477	93.377	91.823	88.455

Note: conversion factor: 0.56 tdm/m³; Sources: FAOStat, 2021, FAO et al., 2020

Table A7: Production of wood chips and particles and wood residues by member states of EU27. Unit: Mt_{DM}

Area	2015	2016	2017	2018	2019	2020
Austria	2.460	2.813	2.812	2.956	2.990	2.968
Belgium	0.420	0.420	0.420	0.420	0.546	0.557
Bulgaria	0.282	0.182	0.161	0.088	0.060	0.060
Croatia	0.406	0.367	0.365	0.365	0.365	0.365
Cyprus	0.003	0.002	0.002	0.004	0.004	0.003
Czechia	0.573	0.579	0.586	0.642	0.695	0.695
Denmark	0.070	0.070	0.070	0.070	0.070	0.070
Estonia	1.255	1.285	1.269	1.479	1.162	1.162
Finland	5.666	6.017	6.041	5.876	5.839	5.435
France	10.647	5.739	6.036	5.937	5.605	3.906
Germany	5.740	5.648	5.905	6.200	6.178	6.687
Greece	0.003	0.003	0.003	0.003	0.003	0.003
Hungary	0.109	0.380	0.317	0.398	0.417	0.417
Ireland	0.329	0.349	0.390	0.367	0.367	0.367
Italy	1.992	2.191	2.191	2.191	2.301	1.452
Latvia	1.685	1.664	1.925	1.967	1.931	1.908
Lithuania	0.803	0.829	0.817	0.802	0.795	0.690
Luxembourg	0.216	0.216	0.216	0.216	0.216	0.216
Malta	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.377	0.395	0.410	0.407	0.390	0.390
Poland	4.016	4.086	4.232	4.367	3.898	3.900
Portugal	1.496	1.075	0.964	0.907	0.847	0.747
Romania	1.091	1.050	1.082	1.049	1.242	1.112
Slovakia	0.527	0.498	0.565	0.541	0.527	0.471
Slovenia	0.456	0.456	0.539	0.560	0.552	0.593
Spain	1.536	1.336	1.532	1.487	1.419	1.330
Sweden	8.357	8.358	8.514	8.552	8.637	8.548
European Union (27)	50.515	46.008	47.363	47.853	47.057	44.053

Note: conversion factor: 0.41 tdm/m^3; Sources: FAOStat, 2021, FAO et al., 2020

Table A8: Production of coniferous sawmill by-products (incl. chips/slabs, sawdust and shavings) in EU27 member states. Unit: Mt_{DM}

Area	2015	2016	2017	2018	2019	2020
Austria	2.083	2.240	2.342	2.470	2.477	2.503
Belgium	0.453	0.422	0.407	0.416	0.438	0.453
Bulgaria	0.234	0.215	0.199	0.192	0.183	0.183
Croatia	0.081	0.066	0.070	0.070	0.070	0.070
Cyprus	0.000	0.000	0.000	0.000	0.000	0.000
Czechia	1.003	0.980	1.041	1.113	1.196	1.215
Denmark	0.114	0.117	0.117	0.117	0.117	0.117
Estonia	0.490	0.477	0.483	0.517	0.513	0.528
Finland	3.959	4.246	4.371	4.410	4.242	4.063
France	1.925	1.981	2.060	2.081	2.029	1.936
Germany	5.605	5.790	6.048	6.201	6.393	6.917
Greece	0.019	0.019	0.015	0.016	0.016	0.016
Hungary	0.051	0.043	0.045	0.042	0.043	0.043
Ireland	0.325	0.355	0.378	0.364	0.364	0.364
Italy	0.278	0.287	0.293	0.303	0.303	0.303
Latvia	0.848	0.968	0.991	0.935	0.803	0.785
Lithuania	0.318	0.377	0.350	0.320	0.317	0.287
Luxembourg	0.012	0.012	0.012	0.012	0.012	0.012
Malta	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.042	0.041	0.036	0.027	0.030	0.030
Poland	1.134	1.145	1.161	1.156	1.167	1.143
Portugal	0.411	0.394	0.354	0.368	0.331	0.224
Romania	1.388	1.309	1.234	1.227	1.207	1.201
Slovakia	0.247	0.258	0.280	0.279	0.271	0.254
Slovenia	0.181	0.181	0.181	0.199	0.237	0.253
Spain	0.340	0.435	0.569	0.597	0.607	0.572
Sweden	7.040	7.113	7.132	7.118	7.257	7.206
European Union (27)	28.580	29.472	30.171	30.555	30.622	30.677

Note: conversion factor: 0.41 tdm/m^3; Sources: FAOStat, 2021, FAO et al., 2020

Table A9: Production of non-coniferous sawmill by-products (incl. chips/slabs, sawdust and shavings) in EU27 member states. Unit: Mt_{DM}

Area	2015	2016	2017	2018	2019	2020
Austria	0.090	0.110	0.124	0.128	0.154	0.169
Belgium	0.099	0.099	0.056	0.056	0.049	0.049
Bulgaria	0.054	0.038	0.040	0.041	0.036	0.036
Croatia	0.402	0.399	0.457	0.457	0.457	0.457
Cyprus	0.000	0.000	0.000	0.000	0.000	0.000
Czechia	0.102	0.103	0.104	0.088	0.062	0.064
Denmark	0.030	0.030	0.030	0.030	0.030	0.030
Estonia	0.048	0.039	0.054	0.034	0.033	0.033
Finland	0.013	0.016	0.014	0.013	0.009	0.011
France	0.490	0.565	0.569	0.519	0.476	0.471
Germany	0.263	0.271	0.278	0.289	0.315	0.250
Greece	0.014	0.014	0.001	0.005	0.005	0.005
Hungary	0.105	0.124	0.120	0.123	0.115	0.115
Ireland	0.001	0.001	0.003	0.001	0.001	0.001
Italy	0.181	0.181	0.181	0.181	0.197	0.164
Latvia	0.220	0.229	0.206	0.222	0.197	0.197
Lithuania	0.189	0.194	0.190	0.200	0.198	0.135
Luxembourg	0.013	0.013	0.013	0.013	0.013	0.013
Malta	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.020	0.021	0.021	0.021	0.018	0.018
Poland	0.120	0.136	0.141	0.141	0.130	0.122
Portugal	0.009	0.009	0.009	0.041	0.041	0.025
Romania	0.559	0.559	0.526	0.526	0.526	0.531
Slovakia	0.074	0.062	0.071	0.070	0.064	0.056
Slovenia	0.033	0.035	0.039	0.039	0.041	0.041
Spain	0.086	0.102	0.123	0.158	0.140	0.128
Sweden	0.033	0.032	0.032	0.033	0.033	0.033
European Union (27)	3.245	3.378	3.403	3.427	3.342	3.153

Note: conversion factor: 0.41 tdm/m³; Sources: FAOStat, 2021, FAO et al., 2020

Table A10: Bark in apparent consumption of coniferous industrial roundwood in EU27 member states. Unit: Mt_{DM}

Area	2015	2016	2017	2018	2019	2020
Austria	0.886	0.937	0.954	1.080	1.083	1.097
Belgium	0.254	0.256	0.245	0.254	0.213	0.215
Bulgaria	0.121	0.118	0.106	0.122	0.116	0.106
Croatia	0.038	0.037	0.037	0.037	0.037	0.037
Cyprus	0.000	0.000	0.000	0.000	0.000	0.000
Czechia	0.487	0.495	0.520	0.631	0.607	0.407
Denmark	0.063	0.053	0.053	0.069	0.061	0.061
Estonia	0.169	0.186	0.180	0.197	0.184	0.194
Finland	2.447	2.599	2.633	2.894	2.642	2.448
France	1.054	1.062	1.081	1.092	1.113	1.095
Germany	2.315	2.193	2.177	2.583	2.403	2.573
Greece	0.014	0.014	0.009	0.010	0.010	0.011
Hungary	0.032	0.033	0.030	0.040	0.038	0.038
Ireland	0.137	0.136	0.156	0.182	0.182	0.182
Italy	0.117	0.123	0.124	0.168	0.365	0.231
Latvia	0.400	0.424	0.384	0.391	0.392	0.408
Lithuania	0.090	0.103	0.098	0.088	0.089	0.087
Luxembourg	0.011	0.009	0.011	0.021	0.014	0.028
Malta	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.029	0.042	0.035	0.028	0.032	0.032
Poland	1.526	1.588	1.723	1.633	1.553	1.513
Portugal	0.357	0.486	0.481	0.505	0.560	0.550
Romania	0.336	0.313	0.284	0.307	0.268	0.365
Slovakia	0.128	0.168	0.187	0.206	0.198	0.158
Slovenia	0.077	0.070	0.069	0.086	0.097	0.093
Spain	0.414	0.411	0.515	0.539	0.536	0.537
Sweden	3.096	3.124	3.016	3.077	3.139	3.104
European Union (27)	14.050	14.327	14.416	15.537	15.205	14.858

Note: conversion factor: 0.41 tdm/m³; Sources: FAOStat, 2021, FAO et al., 2020

Table A11: Bark in apparent consumption of non-coniferous industrial roundwood in EU27 member states. Unit: Mt_{DM}

Area	2015	2016	2017	2018	2019	2020
Austria	0.170	0.162	0.153	0.150	0.138	0.124
Belgium	0.173	0.178	0.122	0.131	0.158	0.102
Bulgaria	0.072	0.077	0.081	0.079	0.079	0.066
Croatia	0.132	0.130	0.138	0.138	0.138	0.138
Cyprus	0.000	0.000	0.000	0.000	0.000	0.000
Czechia	0.085	0.088	0.083	0.067	0.054	0.056
Denmark	0.025	0.021	0.021	0.025	0.024	0.024
Estonia	0.075	0.080	0.087	0.073	0.075	0.098
Finland	1.109	1.137	1.070	1.246	1.180	1.101
France	0.605	0.630	0.602	0.608	0.590	0.605
Germany	0.294	0.322	0.289	0.322	0.302	0.265
Greece	0.013	0.013	0.031	0.021	0.017	0.017
Hungary	0.156	0.149	0.143	0.157	0.137	0.137
Ireland	0.000	0.000	0.001	0.001	0.001	0.001
Italy	0.183	0.183	0.186	0.205	0.221	0.209
Latvia	0.138	0.130	0.134	0.126	0.067	0.118
Lithuania	0.089	0.098	0.092	0.099	0.092	0.069
Luxembourg	0.020	0.017	0.028	0.030	0.015	0.015
Malta	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.031	0.031	0.020	0.020	0.018	0.018
Poland	0.713	0.707	0.676	0.658	0.635	0.612
Portugal	1.175	1.244	1.282	1.193	1.199	1.216
Romania	0.404	0.421	0.411	0.428	0.444	0.407
Slovakia	0.263	0.241	0.247	0.260	0.268	0.220
Slovenia	0.028	0.025	0.021	0.023	0.025	0.024
Spain	0.586	0.613	0.619	0.661	0.636	0.639
Sweden	0.474	0.462	0.578	0.717	0.728	0.697
European Union (27)	6.385	6.499	6.442	6.791	6.592	6.315

Note: conversion factor: 0.56 tdm/m^3; Sources: FAOStat, 2021, FAO et al., 2020

Table A12: Bark in apparent consumption of coniferous wood fuel in EU27 member states. Unit: Mt_{DM}

Area	***2015****	***2016****	**2017**	**2018**	**2019**	**2020**
Austria	*0.151*	*0.136*	0.161	0.180	0.194	0.174
Belgium	*0.003*	*0.003*	0.006	0.004	0.003	0.003
Bulgaria	*0.030*	*0.040*	0.040	0.038	0.029	0.028
Croatia	*0.003*	*0.003*	0.000	0.000	0.000	0.000
Cyprus	*0.000*	*0.001*	0.001	0.000	0.000	0.000
Czechia	*0.068*	*0.070*	0.070	0.160	0.238	0.276
Denmark	*0.069*	*0.061*	0.062	0.064	0.063	0.063
Estonia	*0.060*	*0.055*	0.072	0.078	0.070	0.068
Finland	*0.239*	*0.206*	0.220	0.208	0.220	0.266
France	*0.211*	*0.225*	0.186	0.177	0.181	0.186
Germany	*0.454*	*0.426*	0.425	0.459	0.482	0.451
Greece	*0.005*	*0.005*	0.007	0.008	0.007	0.008
Hungary	*0.007*	*0.007*	0.006	0.006	0.005	0.005
Ireland	*0.005*	*0.013*	0.008	0.006	0.006	0.006
Italy	*0.059*	*0.059*	0.071	0.070	0.068	0.065
Latvia	*0.010*	*0.010*	0.006	0.010	0.006	0.005
Lithuania	*0.037*	*0.038*	0.032	0.019	0.024	0.028
Luxembourg	*0.001*	*0.001*	0.002	0.003	0.002	0.002
Malta	*0.000*	*0.000*	0.000	0.000	0.000	0.000
Netherlands	*0.012*	*0.037*	0.032	0.035	0.029	0.029
Poland	*0.149*	*0.142*	0.139	0.141	0.133	0.123
Portugal	*0.029*	*0.030*	0.022	0.053	0.046	0.060
Romania	*0.051*	*0.044*	0.057	0.068	0.057	0.048
Slovakia	*0.011*	*0.011*	0.014	0.011	0.015	0.012
Slovenia	*0.012*	*0.011*	0.001	0.006	0.006	0.006
Spain	*0.224*	*0.110*	0.080	0.151	0.124	0.111
Sweden	*0.158*	*0.156*	0.154	0.126	0.125	0.125
European Union (27)	*1.851*	*1.719*	1.725	1.898	1.974	1.977

Note: 2015 and 2016 data comprise production figures excluding net trade; conversion factor: 0.41 tdm/m³; Sources: FAOStat, 2021, FAO et al., 2020

Table A13: Bark in apparent consumption of non-coniferous wood fuel in EU27 member states. Unit: Mt_{DM}

Area	*2015**	*2016**	2017	2018	2019	2020
Austria	*0.152*	*0.144*	0.164	0.167	0.159	0.157
Belgium	*0.064*	*0.064*	0.071	0.071	0.069	0.067
Bulgaria	*0.172*	*0.164*	0.155	0.147	0.147	0.126
Croatia	*0.095*	*0.095*	0.065	0.091	0.091	0.091
Cyprus	*0.000*	*0.000*	0.000	0.000	0.000	0.000
Czechia	*0.069*	*0.067*	0.054	0.045	0.038	0.044
Denmark	*0.047*	*0.044*	0.047	0.049	0.043	0.043
Estonia	*0.144*	*0.160*	0.212	0.225	0.200	0.198
Finland	*0.368*	*0.340*	0.391	0.386	0.401	0.424
France	*2.269*	*2.419*	2.213	2.147	2.152	2.202
Germany	*0.795*	*0.759*	0.790	0.750	0.793	0.742
Greece	*0.074*	*0.074*	0.083	0.075	0.073	0.070
Hungary	*0.195*	*0.191*	0.206	0.205	0.196	0.196
Ireland	*0.007*	*0.005*	0.005	0.008	0.008	0.008
Italy	*0.740*	*0.740*	0.791	0.800	0.817	0.779
Latvia	*0.077*	*0.115*	0.134	0.138	0.133	0.131
Lithuania	*0.095*	*0.092*	0.085	0.088	0.077	0.080
Luxembourg	*0.003*	*0.003*	0.003	0.003	0.003	0.002
Malta	*0.000*	*0.000*	0.000	0.000	0.000	0.000
Netherlands	*0.125*	*0.187*	0.163	0.169	0.145	0.145
Poland	*0.235*	*0.229*	0.221	0.221	0.212	0.202
Portugal	*0.049*	*0.109*	0.109	0.112	0.110	0.143
Romania	*0.311*	*0.329*	0.311	0.341	0.355	0.280
Slovakia	*0.022*	*0.018*	0.023	0.028	0.022	0.018
Slovenia	*0.058*	*0.061*	0.039	0.045	0.054	0.051
Spain	*0.161*	*0.149*	0.121	0.158	0.119	0.111
Sweden	*0.268*	*0.264*	0.254	0.209	0.210	0.210
European Union (27)	*6.291*	*6.442*	6.376	6.346	6.325	6.171

Note: 2015 and 2016 data comprise production figures excluding net trade; conversion factor: 0.56 tdm/m^3; Sources: FAOStat, 2021, FAO et al., 2020

Table A14: Raw data for the ratios between demand and supply of raw materials for the production of growing media constituents (total for all considered European countries)

Growing media constituent	Unit	Supply	Current demand for growing media	Maximal potential demand	Ratio current demand/supply	Ratio maximal potential demand/supply
Wood	ktDM	27,406	201	2,377	0.7%	9%
Bark	ktDM	20,617	528	11,210	2.6%	54%
Green waste*	kt	23,340	1,495	26,232	6.4%	112%
Coir by-products	kt	21,050	377	10,929	1.8%	52%
Total raw materials*	$1000m^3$ EN 12580	480,718	5,636	59,618	1.2%	12%

Units are different for each constituent, lines are not meant to be summed together.
Supply total growing media constituents: Total usable supply (see chapter 3.5)
Countries: Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Spain and Sweden. *Due to lack of data for green waste, Finland, Ireland and Lithuania are not considered in the ratio for green waste and the total for all growing media constituents.

Table A15: Raw data for the ratios between demand and supply of each raw materials for the production of growing media constituents in each considered European country

	Wood (Unit: kt_{DM})					Bark (Unit: kt_{DM})					Green waste (Unit: kt)				
Definition Supply	Production of coniferous saw mill by-products (incl. chips/slabs, sawdust and shavings) (2018-2020)					Bark in apparent consumption of industrial roundwood (coniferous and non-coniferous) (2018-2020)					Green waste collected (2017)				
Area	**Supply**	**Current demand for growing media**	**Specific maximal potential demand**	**Ratio current demand/supply**	**Ratio specific maximal potential demand/supply**	**Supply**	**Current demand for growing media**	**Specific maximal potential demand**	**Ratio current demand/supply**	**Ratio specific maximal potential demand/supply**	**Supply**	**Current demand for growing media**	**Specific maximal potential demand**	**Ratio current demand/supply**	**Ratio specific maximal potential demand/supply**
Austria	2,483	2	24	0%	1%	1,224	15	111	1%	9%	499	39	275	8%	55%
Belgium	436	1	69	0%	16%	358	9	326	3%	91%	730	33	862	5%	118%
Denmark	117	0	25	0%	21%	88	0	117	0%	133%	929	11	293	1%	32%
Estonia	519	0	80	0%	15%	274	0	379	0%	138%	17	0	1,012	0%	6050%
Finland	4,238	2	65	0%	2%	3,837	5	306	0%	8%	-	44	796	-	-
France	2,015	21	241	1%	12%	1,701	320	1,135	19%	67%	5,443	160	2,950	3%	54%
Germany	6,504	31	600	0%	9%	2,816	48	2,822	2%	100%	5,914	792	7,368	13%	125%
Ireland	364	0	67	0%	18%	183	0	311	0%	170%	-	42	778	-	-
Italy	303	3	266	1%	88%	466	18	1,257	4%	270%	2,588	326	3,373	13%	130%
Latvia	841	0	144	0%	17%	501	0	686	0%	137%	37	0	1,868	0%	5065%
Lithuania	308	0	135	0%	44%	175	1	642	0%	368%	-	0	1,746	-	-
Netherlands	29	30	299	105%	1030%	49	71	1,425	145%	2889%	3,200	105	3,947	3%	123%
Poland	1,155	0	136	0%	12%	2,201	0	637	0%	29%	1,378	0	1,654	0%	120%
Portugal	308	0	10	0%	3%	1,741	30	46	2%	3%	386	22	119	6%	31%
Spain	592	110	124	19%	21%	1,183	0	575	0%	49%	1,888	0	1,435	0%	76%
Sweden	7,194	0	93	0%	1%	3,821	10	434	0%	11%	332	9	1,076	3%	325%
Total of considered countries	27,406	201	2,377	0.7%	9%	20,617	528	11,210	2.6%	54%	23,340	1,495	26,232	6%	112%

Table A16: Raw data for the ratios between demand and supply of all raw materials for the production of growing media constituents in each considered European country. Unit: 1,000 m³ EN 12580 growing media constituents

Area	Current demand for growing media constituents	Total maximal potential demand for growing media constituents	Supply wood	Supply bark	Supply green waste	Total supply wood + bark + green waste (sum)	Total usable supply (only wood + bark + green waste)	Supply coir by-products	Total usable supply (all constituents)	Ratio current demand / total usable supply (all constituents)	Ratio total maximal potential demand / total usable supply (all constituents)	Ratio total maximal potential demand / total usable supply (only wood + bark + green waste)
Austria	110	625	31,042	3,978	454	35,473	8,455	620	9,638	1%	6%	7%
Belgium	75	1,960	5,446	1,162	663	7,272	3,259	1,945	6,732	1%	29%	60%
Denmark	36	665	1,463	286	845	2,593	2,137	660	3,253	1%	20%	31%
Estonia	1	2,299	6,492	889	15	7,396	1,602	2,979	6,879	0%	33%	143%
France	1,463	6,704	25,192	5,528	4,948	35,668	19,056	6,654	31,159	5%	22%	35%
Germany	1,229	16,746	81,296	9,152	5,376	95,824	26,304	16,621	56,397	2%	30%	64%
Italy	370	7,666	3,788	1,516	2,353	7,656	6,824	8,451	16,107	2%	48%	112%
Latvia	1	4,245	10,513	1,627	34	12,173	2,891	5,568	12,582	0%	34%	147%
Netherlands	406	8,970	363	160	2,909	3,432	871	17,002	20,434	2%	44%	1029%
Poland	0	3,760	14,442	7,154	1,253	22,849	15,300	3,732	22,092	0%	17%	25%
Portugal	125	270	3,846	5,658	351	9,855	9,416	268	8,181	2%	3%	3%
Spain	550	3,262	7,400	3,844	1,717	12,960	10,558	3,238	16,198	3%	20%	31%
Sweden	92	2,446	89,921	12,417	301	102,639	24,297	2,428	28,935	0%	8%	10%
Total of considered countries	4,458	59,618	281,200	53,373	21,218	355,790	130,969	70,166	238,587	1.9%	25%	46%

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