Wood cascading in Scotland

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Contents

Background

This study explores the current level of timber cascading that exists in Scotland. To date, there have been no previous studies of this kind carried out. Although there is no standard definition of wood cascading, there is a consensus of wood being efficiently utilised and allocated to the most valuable purposes possible in sequential stages to prolong its life cycle, with its eventual end of life being used for energy recovery.

Timber cascading aligns closely with the principle of a circular economy; to eliminate waste, optimise resource use and reduce the environmental impacts of products by keeping them in use as long as possible, whilst keep them at the highest value possible. For this work, wood cascading has been split into two stages, defined as:

- Single stage: wood is processed into a product which at end of use is utilised as biomass/energy recovery.

- Multi-stage: wood is processed into a product which is used at least twice in a product form before being used for biomass/energy recovery.

Fig. 1 shows the idealised timber cascading steps, where wood products, including any by products and residues, are continuously reutilised until they get to their “true” end of life. Often recovery as biomass energy is seen as the final stage in the cascading chain. However, there is also opportunity to reutilise the by-products of biomass energy, ash, as fertiliser for forests – making the cascading chain truly circular.

Through increasing the cascading potential of wood products, the material life cycle can be increased significantly. This potentially lowers both embodied carbon and associated manufacturing emissions, as well as reducing the strain on the natural environment. Mindful of these potential carbon savings, timber cascading directly aligns with the Principles of Circularity.

Since 2015/16 there has been limited research relating specifically to timber ’cascading’. A larger, more recent pool of research exists surrounding the circular economy and resource efficiency of wood fibre products. Therefore, this study has been broadened to include this.

This report reviews the state of the art of timber cascading, both nationally and internationally, looking at any pre-existing regulatory barriers, enablers, strategies, and applications used to increase the cascading and lifecycle of timber products. The report has been enhanced via collaboration with an extensive stakeholder network to gauge industry-driven opportunities for timber cascading within Scotland.

The report concludes with a review of pre-existing and innovative technologies that could be used to increase the cascading potential of timber, alongside recommendations for the increased adoption of cascading and the research required to facilitate it.

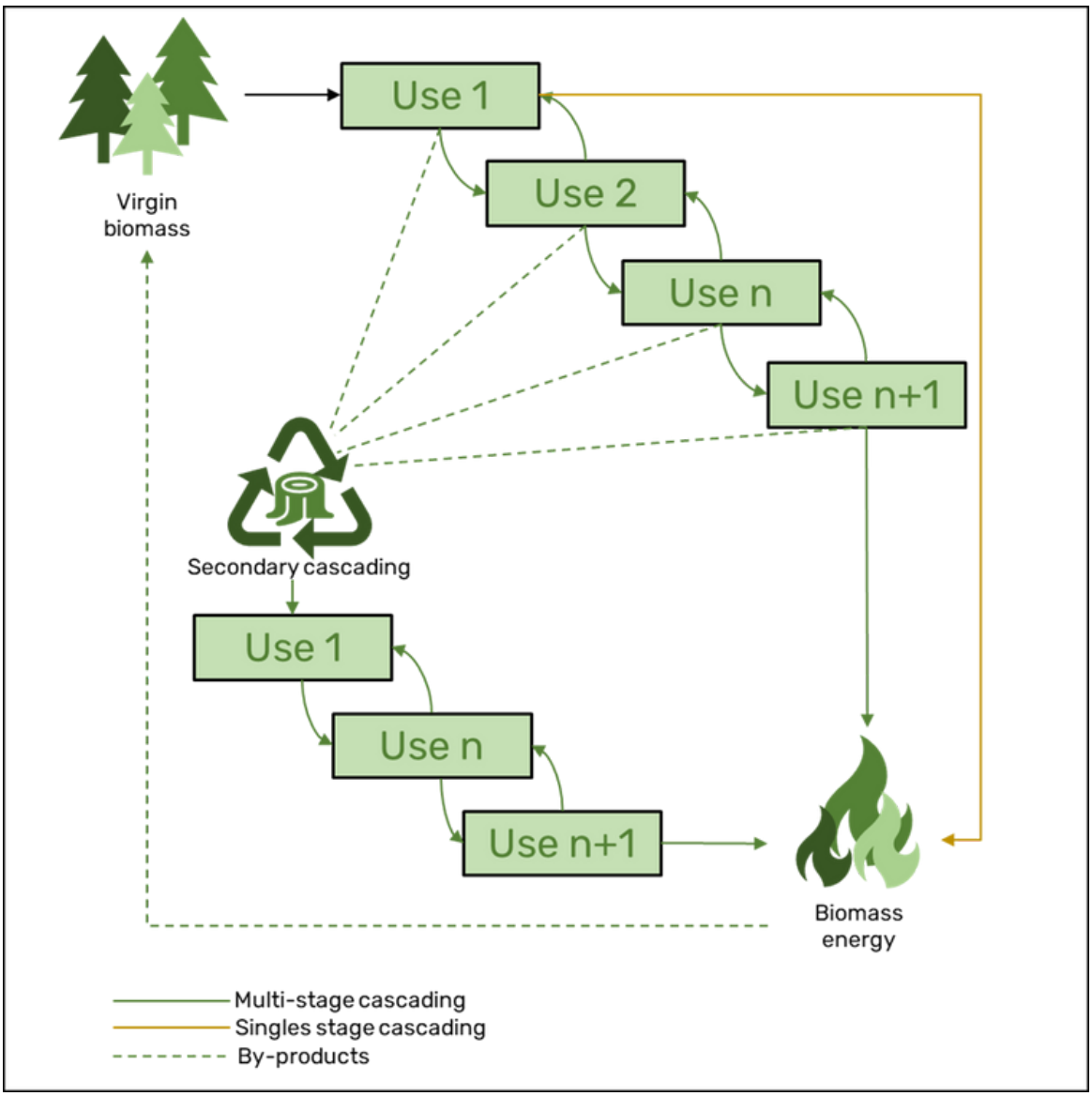

Fig. 1: Idealised wood cascading creating a circular material flow.

State of the art

Current material flow in Scotland

Prior to identifying suitable cascading options for timber materials, it is first useful to review the current material flow in Scotland and identify what sectors have the most potential to both implement cascading and utilise cascaded materials. Given that softwood makes up the largest proportion of material removals in Scotland, this has been focused on. However, future studies should look to account for hardwood also.

Statistics on the processing of timber into basic wood products for the year 2022 have been provided by Forestry Research [1]. These statistics give an introductory overview into the material flows within the UK. Although this study focuses on Scotland, comprehensive data is unavailable, so UK-wide data must be utilised. To provide some relativity to the softwood removal statistics provided, 53% of the UK's total removals occurred in Scotland.

Fig. 2 illustrates the deliveries of roundwood (trunks and branches) to processors. Focussing on the largest deliveries, it can be seen that nearly two thirds of the raw materials go direct to sawmills, where it is processed into sawn softwood. Following on from this, equal volumes of deliveries are made for wood fuel and wood-based panels at 15%.

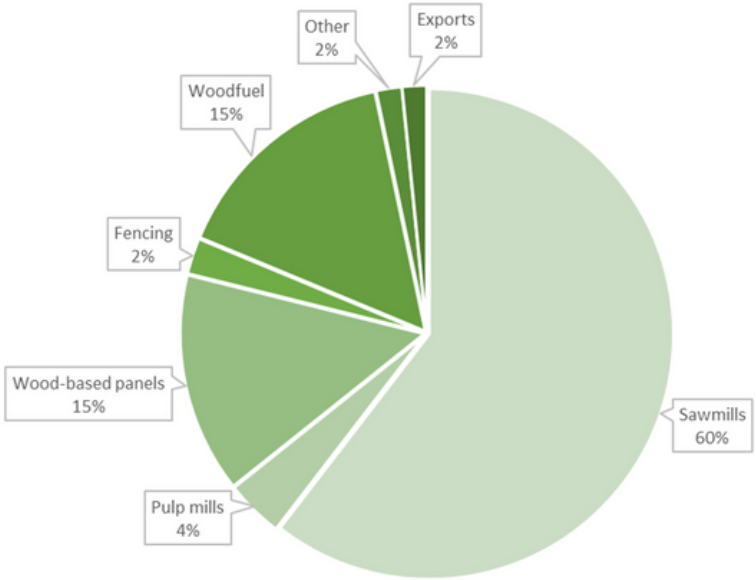

Fig. 2: Deliveries of UK-grown softwood to wood-using industries in 2021 [2]

Given the largest proportion of deliveries are made to the sawmills, it is useful to review the end products produced via the sawmillers. Complementary to the statistics provided, Forestry Research also carried out the Annual Sawmill Survey which concluded that from sawn softwood, sawmills produced construction products (37%), fencing (30%) and packaging/pallets (22%), with the remainder (11%) being sold between the wood processing and bio-energy industries, as well as being used internally by the millers for heat and/or energy.

The wood panel industry and biomass energy plants are viewed as competing industries as both sectors use low value timber to create a high value product. Although utilising the same feedstocks, the longevity of the end product's life cycle differs greatly, with the panel industry adopting a single stage cascade, and the material sent to biomass energy plants without any prior use.

It can be concluded from the statistics above that wood products are utilised across several industries. The material flows within each of these industries are extensive, and outside the scope of this work. However, the recent publication by Timber Development UK has illustrated the flows of timber material to and between different industries **(Fig. 3)**. The figure below can be further enhanced with a report produced for Scottish Enterprise which details the potential of biotechnology in Scotland and the corresponding material flow [3].

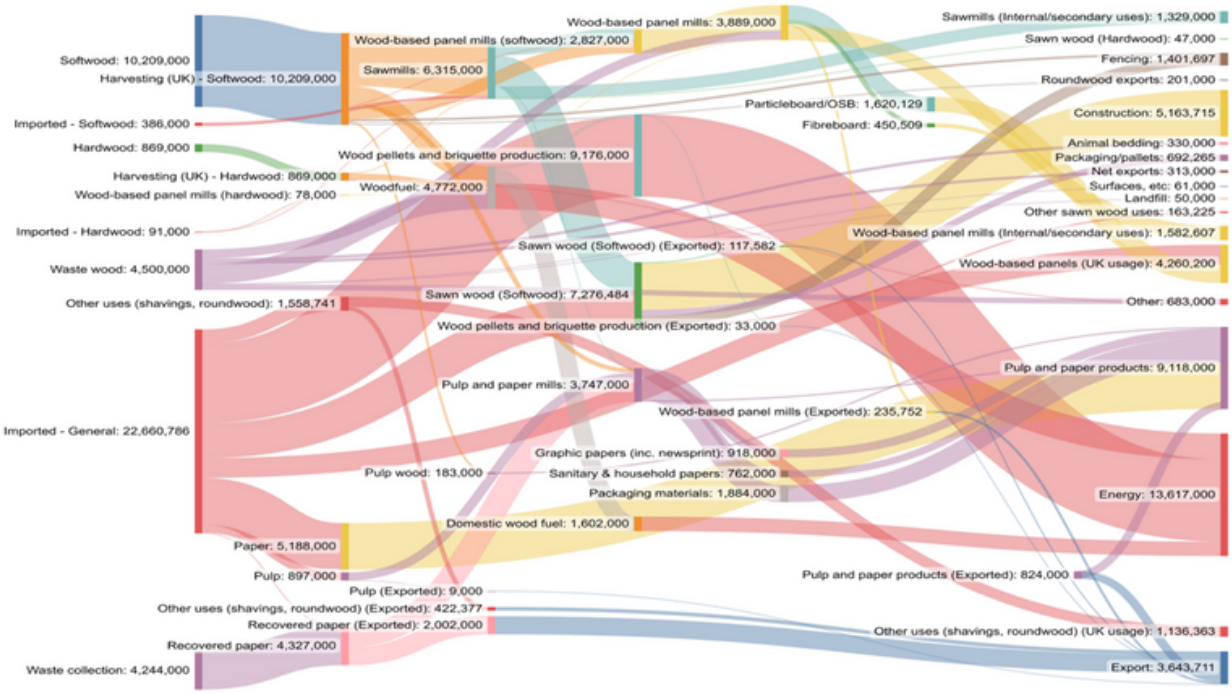

Fig. 3 Resource balance of the UK timber industry in tonnes [4]

Since cascading will occur at the end of use of a particular product, it is useful to review how much timber is currently being sent off as waste. In 2021 the waste wood market in the UK produced 4.5 million tonnes of waste wood, with 4.17 million tonnes of this waste wood being processed for secondary use, i.e., panel boarding, animal bedding, biomass energy [5]. From **Fig. 4**, it can be concluded that at least 63% of this waste wood material reaches its end of life via incineration and only 37% of waste wood material is re-used in other products.

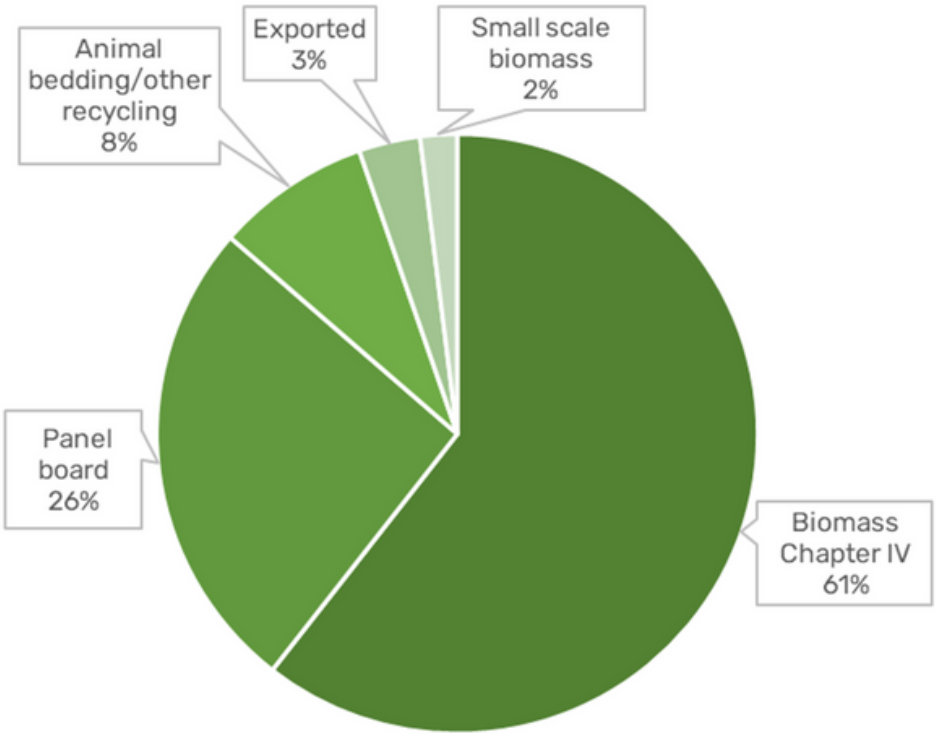

Fig. 4: UK waste wood end market distribution.

It is unclear from the statistics provided as to the condition of the material being sent for recycling. However, in line with the wood waste grades found in Table 1, it can be assumed waste wood is Grade C or better. Given the unprecedented need to increase the life cycle and circularity of wood products, there is clearly significant opportunity to implement timber cascading within the current and future supply chain. This is further emphasised by the commitments made in Scotland's Forestry Strategy 2019 – 2029 to increase the use of Scottish wood products in construction from 2.2 million m^3 in 2018 to 3.0 million m^3 in 2031/32 [6].

Table 1 Adapted from The Wood Recyclers' Association wood waste grade table [7]

Wood Grade	**Typical markets**	**Typical sources**
Grade A Clean, untreated wood	Animal bedding, landscape surfacing, pellets, briquettes, non-IED Chapter IV biomass	Solid softwood and hardwood Packaging Pallets Cases and drums Untreated board products
Grade B Business waste, treated, non hazardous wood	Panel boards and IED Chapter IV biomass	Products containing Grade A material Building and demolition materials Solid wood furniture
Grade C Municipal, treated, non-hazardous wood	IED Chapter IV biomass and some panel products	Grade A & Grade B Furniture made from board products DIY materials
Grade D Treated, hazardous wood	Required disposal	Agricultural fencing Telegraph poles Railway sleepers

Cascading enablers

National enablers

There are currently no legal requirements in Scotland to design products with end of use in mind. As a result, both the implementation of cascading principles into the design of products and the use of pre-used material as a feedstock for new products remains limited.

However, the Scottish Government has been looking at ways to increase material efficiencies and create a more circular economy. For example, the Scottish Government is looking to form a Scottish Programme for Reuse of Construction Materials and Assets by 2024 [8]. This programme hopes to provide a marketplace for the purchase of pre-used construction materials whilst simultaneously instilling confidence in pre-used components. As a result, it is hoped that this will encourage the supply chain to consider the reuse potential of their products and consequently enable the establishment of cascading principles.

Industry is already responding to these potential new markets. Early adopters, British Land, now require a minimum of 15% recycled content in any major developments, with a preference for 20% [9]. Whilst not directly stipulating that this should consist of timber products, sustainability targets will enhance this likelihood, creating significant opportunities for timber cascading.

The Green Alliance highlighted the opportunity to facilitate supply chains in the reuse of products through the launch of a successor to the National Industrial Symbiosis Programme, which focused on helping business to reduce their waste and find uses for pre-used materials [10]. Its implementation in England from 2005 to 2013 resulted in the diversion of 47 million tonnes of industrial waste from landfill and saved 60 million tonnes of virgin material [11].

In partnership with ReLondon and AECOM, the Greater London Authority published their Circular Economy Statements [12]. London is leading the way in its drive to become a more circular city and this guidance sets out a systematic process in how to apply circular principles to the construction sector in London. This guidance is applicable to large scale developments however, smaller developers are encouraged to apply this guidance to their own projects.

There is little integration between the use of biogenic material and biomass energy production in policies as they are typically dealt with separately [13]. Other industries that rely on biogenic materials, including feed, food, and land use, have encountered similar challenges. To ensure the sustainability of industries who either rely on biobased materials as a feedstock or are impacted by the increased harvesting of organic materials, policymakers must carefully examine the potential effects of increased cascading on established supply chains when evaluating the proportions of virgin and waste wood fibre materials being utilised.

International enablers

In 2016, the European Commission determined that there was no regulatory policy surrounding the cascading of wood fibre products [13], which still is the case in 2023. It is therefore beneficial to examine both regulations and initiatives linked to the circular economy, as they have an indirect impact on the potential for timber products to be cascaded.

The Circular Economy Action Plan (CEAP) goes into detail on the importance of reducing our reliance on virgin resources and looking at ways in which Europe can become more resource efficient [14]. It highlights that there is no legislation requiring new products placed on the EU market to increase sustainability and integrate circular principles, which this initiative is looking to tackle.

Both the CEAP and the recently published Critical Raw Materials Act highlight that the current waste management legislation does not provide enough incentive to incorporate circularity into new products and that there are significant challenges surrounding the development of pre-used material markets [15].

There are examples internationally where governments have begun implementing circular initiatives. The Netherlands have recognised the need to become more circular across all of their industries and as a result they have set challenging cross-sector resource reduction targets. Their biomass transition agenda directly identifies cascading as an opportunity to utilise biogenic products more efficiently and includes it as one of their four strategic goals [16].

Similarly, the Governments of France, Finland and Sweden have been increasing the use of natural materials in the built environment [17]. Enacted in 2022, France mandated that at least 25% natural materials be utilised in the construction of new builds or in any major refurbishment of pre-existing public buildings, with ambitions of increasing this to 50% by 2030.

Published in 2021, the National Strategy for Sustainable Construction for Finland states that it will be phasing in limits for embodied carbon emissions generated through construction [18]. A similar standard has been published by the Scottish Government, however as it stands this is only voluntary [19]. It is anticipated that as embodied carbon targets are included in regulatory policy, and more countries follow suit to align with their climate change commitments, there will be a greater reliance on biobased materials. Consequently, the legislation surrounding biobased products and their circulatory will only increase. Although this would be a significant step in the right direction, it should be noted that conflicting demand is concurrent across all wood-reliant industries, as has been further discussed below.

Cascading barriers

National barriers

There are distinct regulatory and policy barriers to wood cascading in Scotland. Some of these barriers are unintended consequences of regulation originally designed to increase the potential for cascading. Others are either restrictions to ensure fair trade or the effects of an immature supply chain and the associated logistical issues this can causes. Some examples, whilst not exhaustive, are outlined below:

Energy Incentives

An example of oversight has been the successful uptake of the Renewables Obligation (Scotland) Incentives, which the Scottish Government introduced to subsidise the use of wood for biomass energy. The increased demand for feedstock material is causing price rises for the other industries which manufacture products with a longer life cycle, such as the panel board industry.

A 2020 European Forest Institute report [20] observed that over the last 60 years around half of the global roundwood production has been used for wood fuel and the other half used as industrial roundwood. More recently, this distribution has been changing. The quantity of roundwood production for wood fuel has decreased as industrial roundwood use has risen from the 40% share in 1961 to slightly more than 50% in 2018.

Waste Regulations

The current Waste (Scotland) Regulations 2012 require businesses to separate their waste streams and ensure that wood waste is reused, recycled, or recovered wherever possible. This was considered a positive step, designed to increase sustainability whilst reducing material sent to landfill [8].

However, these regulations can be complex and difficult to navigate, particularly for micro or small and medium-sized enterprises (SMEs) that may not have the necessary resources or expertise to comply with them. They can also be time and cost intensive, disincentivising the organisation from undertaking the activity. As a result, timber waste may not be separated effectively into the correct grade which

may lead to high grade waste timber being downcycled and consequently reducing the reuse value of the material.

The Scottish Government recognises these challenges and is looking to review opportunities to support compliance by increasing reuse and recycling opportunities and consequently reducing waste.

Building Regulations

Building regulations can also create barriers to wood cascading, particularly affecting urban areas where greater density and taller buildings are required to accommodate the growing population. Following the fire at Grenfell Tower in London in 2017, both the Scottish and UK Governments sought to revise existing building regulations as a response to the clear failure of the regulatory system to ensure life safety.

As a response, both Governments subsequently banned the use of combustible materials in buildings of a certain type and height. In 2021 in England, the Mayor of London announced a set of conditions for housing suppliers applying for funding from its Affordable Housing Programme. This included prohibiting the use of combustible materials in any external walls. The ban covers homes of any height, making it stricter than the regulations enforced by the UK Government, which bans combustibles in the external walls of residential buildings above 18 meters.

Procurement Policies

Procurement policies in Scotland can also inadvertently create barriers to wood cascading, particularly in the public sector. Many public sector organisations have policies that unintentionally prioritise the use of virgin materials over recycled or recovered materials, which can limit the demand for recycled wood products and prevent businesses from accessing valuable wood resources.

This can be seen in the specification definition “equal or equivalent”, which was designed to enable contractors to be agile and react quickly to material and product shortages. However, without the time or finances to adequately assess cascaded products, it is difficult to see how suppliers could evidence “equal or equivalent” without standardised specifications for recycled or recovered materials.

Lack of Infrastructure

A lack of infrastructure can create barriers to wood cascading in Scotland. For example, there is an absence of suitable facilities for processing and manufacturing reclaimed wood products. This could be facilitated if existing information on the reclaimed timber composition was available, such as previous treatments, contamination, grading and so on. The complexities of assessing the chemical make-up of these prior wood treatments, alongside scanning for any remaining metalwork, make the commercial business case difficult to justify without the required economies of scale.

Furthermore, designated transportation infrastructure to move wood waste materials from one location to another, on a regular and contracted basis, exists within the biomanufacturing industry but is not readily available at a smaller scale. This infrastructure is essential to facilitate greater wood cascading.

Limited Market Demand

The above issues compound the limited market demand for recycled wood products, creating another barrier to wood cascading in Scotland. While there is a growing demand for environmentally sustainable products, some businesses may still prefer to use virgin materials for their products. This can limit the potential for wood cascading and prevent businesses from accessing valuable wood resources.

International barriers

Lack of energy infrastructure

The utilisation of wood harvested from forests varies globally. Typically, countries with less developed energy infrastructure and distribution systems use a greater proportion of harvested wood for energy production. These countries have adopted a contrary position to circularity, prioritising the energy use of wood over the material use of wood.

For instance, 97% of wood harvested in Ethiopia, 51% of wood harvested in Brazil, and 89% of wood harvested in India is used as fuel. In India, this translates to an estimated 435 million m^3 of wood fuel being harvested annually, which can generate approximately 1000TWh of energy – more than twice the amount consumed by UK households each year [21].

However, as energy infrastructure becomes more advanced, the demand for wood fuel for cooking and heating is reduced. This increases the availability of wood in the forest for non-energy purposes or for international trade. In countries like China, Canada, and Sweden, where energy infrastructure is more developed, less than 10% of harvested wood is used as wood fuel [21]. Instead, the principles of circularity are adopted, where a greater proportion of wood is prioritised for material use over energy use. This has been facilitated through these country's non-energy wood processing supply chains receiving greater investment and becoming more developed.

Existing Research and Solutions

This report has identified that regulatory and policy barriers can limit the potential for wood cascading, particularly for SMEs. To address these barriers, policymakers in Scotland may need to consider implementing measures to simplify waste regulations, promote the use of recycled wood products in procurement policies, and invest in infrastructure to support wood cascading initiatives. By addressing these barriers, Scotland can unlock the potential of wood cascading and create a more sustainable and circular economy.

Although several applications of wood cascading have been detailed above, the level of adoption within Scotland has been limited. In 2019, the Confederation of Forest Industries (Confor) identified that both the cost in recovering pre-used timber products, alongside a lack of information on the quality of the recovered wood, imposes challenges with its reuse potential [22]. They concluded that to overcome these challenges, investment into equipment that can increase sorting efficiency, alongside new processes which allow timber to be cleaned of paints, varnishes, and treatments would increase the cascading potential of timber products.

Similarly, there are only a handful of pre-existing markets for the buying and selling of pre-used wood products. In the UK, there are groups, such as Community Wood Recycling, who recycle and sell reclaimed wood products. Community Wood Recycling is made up of 30 social enterprises, two of which can be found in Scotland's central belt [23]. It is promising to see that these markets exist, but they are influenced by the same challenges above, having a lack of material quality assurance, therefore limiting the resale potential and curbing demand.

The InFutURe Wood project sought to overcome this challenge and demonstrated the structural viability of pre-used timber building products, by developing processes which allow pre-used construction timber to be structurally graded using non-destructive test methods [24]. This is an important step in the right direction; however, additional research and innovation is still needed in this area to instil the industry with confidence.

As discussed at length, there are governance and policy barriers which prevent the uptake of timber cascading, particularly when it comes to incentivisation of biomass energy production and the reuse of pre-used products. To overcome this, The Forest Fibre Industry 2050 Strategy was published with the intention of stimulating discussion among policy makers [25].

This strategy lays out some of the technical, financial and resource constraints that will have to be overcome to achieve the CO_2 reduction commitments as part of the Climate Change Act 2008. The roadmap highlights the need for policies to be harmonised to align with worldwide trends and investment cycles. Strategies for addressing climate change should go beyond carbon pricing and target-setting and encompass a comprehensive, industry-specific approach.

This approach should prioritise technological advancements, coordinate with global initiatives and industry investment timelines, and consider both raw materials and end products. Whilst this represents a good foundation, there is still extensive work to be done in this area and a balance must be struck to ensure any new incentives or requirements don't have a negative impact on other sectors.

In an idealised world, cascaded wood products would result in a circular life cycle negating the need to extract virgin resources. However, due to material losses that occur in the re-manufacturing of each cascaded product and losses in the quality of recycled materials due to reprocessing, there will always be a reliance on virgin raw materials. Due to the ever-increasing global demand for wood, especially for its carbon sequestration benefits, it is imperative that productive forestry and cascading hierarchies be developed to overcome supply uncertainty.

Cascading opportunities

The opportunities below are based upon secondary products which can be manufactured using either waste virgin material or waste wood. Although not discussed in this report, the materials and products highlighted are not limited to a single use. There are opportunities for the products to be recycled and manufactured into a new, high value product.

Panel board and animal bedding

The panel board and animal bedding industries are already well versed in using waste biogenic product as a feedstock and it is already a common practice undertaken in Scotland and the wider UK.

The Egger group manufacture timber-based furniture, flooring and building products for the construction sector. Egger recognised the value in processing their own feedstock for their manufactured products. As a result, they became a part of the wood cascading chain through their sister company, Timberpak, who provide cross-sector waste management services and specialise in the recycling of waste wood. They use co-products from the industrial wood processing stage (wood chips, saw dust and shavings), residues from furniture manufacture, and post-consumer recycled waste wood (pallets, untreated construction waste wood and furniture). As a result, 64% of the wood used in Egger products comes from by-products or recycling [26]. In 2021/22, Egger timber products contained 20% recycled content and they have set a new target to increase this to 25% recycled content.

In their Environmental Product Declarations (EPD's), Egger identified different recycling strategies for different types of panelised product. For example, OSB can be reused for the same purpose as its original application, or untreated boards can be reprocessed into recycled content for new OSB panels. Where reuse or recycling isn't possible, they can be used for biomass energy.

MDF boards are more limited at their end of use, as they are not suited to being reused for the same application. MDF boards cannot yet be commercially manufactured using recycled material. Egger is tackling this issue head on by running trials to assess the performance of MDF boards containing recycled content, which is already showing promising results when compared to the manufacture of MDF from fresh wood feedstock. This is due to the lower moisture content and energy requirements of the recycled material.

West Fraser are a UK based timber panel manufacturer who produce a variety of panelised products (OSB, MDF, Chipboard). Similar to Egger, West Fraser utilise a combination of fresh wood and recycled content in their manufacturing process. Their chipboard products contain up to 80% recycled content and all their products can be recycled at their end of use.

West Frasers EPD's for each of their products do not consider end of life scenarios. However, based on other industry practices, it can be assumed that where appropriate, the products can be reused in the same application, recycled into new products or used for biomass energy. West Fraser products are therefore part of a multi-stage cascade.

Similar to Timberpak, Enva also provide collection and recycling services of wood waste and have focused on developing a range of animal bedding products using their recycled waste wood and supply recycled material to panel manufacturers and biomass energy plants. They collect wood mixes in line with the wood waste grades provided by the Wood Recyclers Association grade table (seen in Table 1). Grade A product is the highest quality wood waste (solid timber, pallets, packaging, plywood, OSB) and is used to manufacture their award-winning animal bedding. Grade B (window frames, doors, fence panels, decking) and Grade C (Melamine faced chipboard, hardboard and DMF and other mixed wood) is formed of mixed wood waste and is a feedstock for panel board manufacture and biomass fuel, respectively.

Wood pallets

As of 2022, it was estimated that there were around 18 million pallets in circulation in the UK, with only 10% being reused. To deliver a more circular pallet industry, there are several pallet return and recycling schemes available. Two of the more recent developments within this area have been discussed in further detail.

The Pallet Loop is a UK based pallet return and reuse scheme who are working closely with the construction sector to supply stronger, more durable pallets across the country [27]. The scheme works by incentivising pallet returns. Paying a deposit for each pallet, manufacturers receive the pallets and use them to transport products to construction sites. As the pallets move through the supply chain, the deposit is transferred from the manufacturer to the merchant and finally to the end-user. Once the pallets reach their end of use, The Pallet Loop collects them, and any required repairs are made before redistributing the pallets. Being dynamic enough to accommodate both short- and long-term demand makes them well suited to the construction industry. This has been demonstrated by the recent backing of large industry players such as Tarmac, BAM and Morgan Sindall [28].

Upall is a joint venture between forest products group, James Jones & Sons and German technology innovation business PM Ventures. Upall have created a durable pallet protector which reduces downtime for repairs and keeps the pallets in circulation for longer. The system has been in development since 2015, with the first full scale trials undertaken in 2020. Upall worked with Virginia Tech and Edinburgh Napier University to assess the durability of the protection system, determining that its lifecycle was on average 300% longer than conventional timber pallets.

The schemes above demonstrate that circular principles are already being applied to the pallet industry. Pallets are designed to remain in circulation for as long as possible and have maintenance and repair procedures in place to facilitate this. Pallets are made from clean timber and are typically untreated. They can easily be recycled into other products such as animal bedding and panel boards, exemplifying that when done right, the pallet board industry can be easily integrated into the cascading chain.

Mass timber

Homegrown mass timber products, such as cross laminated timber (CLT), glue laminated timber (GLT) and nail laminated timber (NLT), have gained significant traction within Scotland and the wider UK. Ecosystems Technologies are a Scotland based start up who are the only company who manufacture homegrown mass timber products in the UK. With the ability to lock up 676kg of CO_2 per m^3 , mass timber products offer architects, engineers, and specifiers environmentally conscious alternatives to traditional materials such as structural steel and concrete, whilst achieving the same structural requirements. Mass timber products are formed by gluing or nailing timber sections together to create large format panels and components. As with the manufacture of all products, waste is inevitable. However, in an effort to minimise this waste and create a more circular product, both academia and industry are looking at innovative ways to tackle this.

Recycled CLT was founded in 2019. The founders recognised that although CLT was a sustainable building product that is manufactured from a renewable resource and locks in carbon, there is significant offcut waste generated through perimeter trims and the cutting of door and window openings. Typically, this offcut material is chipped and burned. However, to overcome this, Recycled CLT developed a manufacturing process which allows the offcut sections to be remanufactured into new CLT panels [29]. Not only does this solution generate environmental benefits through extending the materials life cycle, but it also creates financial incentives, where waste uplift costs are avoided and the new recycled CLT product can be sold to consumers.

Researchers at University College London ran a pilot project using reclaimed floorboards from a 1970s housing block which were de-nailed, planed and cut to size [30]. These reclaimed boards were used as lamella in CLT panels, replacing the fresh sawn timber feedstock. Whilst this pilot project was successful, the researchers concluded that the selection and processing of the boards is an incredibly resource intensive task. To make it commercially feasible, significant investment in an automated production line would be required. It is anticipated that as the manufacture of mass timber products increases in the UK, innovation around manufacturing and automation will increases and consequently enhance the opportunity to produce mass timber products from reclaimed materials.

Insulation products

There are no facilities that manufacture woodfibre insulation products in the UK. Therefore, a general overview of the potential opportunities and applications of timber cascading within the woodfibre insulation sector have been identified further afield, with the assumption that their application abroad would be broadly the same were it to be in Scotland.

Solid woodfibre insulation products are growing in popularity within the construction industry. Companies such as Pavatex and Steico are market leaders in the production of woodfibre insulation, which uses waste wood in the form of woodchips as a feedstock. Steico manufacture woodfibre insulation as a by-product of their laminated veneer lumbar (LVL) manufacture, where the residues of LVL are re-used to manufacture solid woodfibre insulation [31].

Similar to the wood panels manufactured by West Fraser, solid woodfibre insulation is also part of a multistage cascade, with the raw material coming from recycled timber and its end of use scenario being biomass energy.

Cellulose insulation is a bio-based blown insulation made from wastepaper, boric acid and magnesium sulphate. The use of wastepaper is a particularly good example of cascading, as paper can be recycled multiple times prior to use as a cellulose insulation raw material. Due to the fertilising nature of boric acid and magnesium sulphate, using cellulose insulation as composting material is the end of use scenario [32].

Wood-based bio refining

Wood based bio refining is viewed as one of the more innovative solutions that can be implemented to increase cascading potential which involves converting wood, which can be derived from low value products such as wood chips and saw dust, into a higher value product in the form of hydrocarbon building blocks which can be utilised across multiple industries and reduce the reliance on fossil fuels.

There are already well-established companies working in this area. Recognising the need to diversify and move away from paper milling due to depreciating demand, Borregaard, one of the leaders in this sector, converted their paper mill into a wood-based bio refinery. They have developed a system which enables wood fibre to be an alternative to oil-based feedstocks. Their products are used in food, pharmaceuticals, and cosmetics as well as construction, agriculture.

The UK-based start-up, Bio-Sep, developed an innovative solution which utilises ultrasonic energy to convert wood into cellulose, natural sugars, and lignin. Bio-Sep is working with the Innovation Centre for Applied Sustainable Technologies to look at how their products can be applied to both biobased composites and as cement admixtures. Early results of this project are promising and hope to enable the concrete industry to adopt bio-based materials into their admixtures.

Cambond are another UK based company who use industry waste along with algae and their binding agent to create a bio-resin that can be used across several industries. These resins can be used in packaging as an alternative to traditional plastic materials. The resins can act as a binding agent with other biogenic materials such as straw, coffee grinds and wood chips. As a result, Cambond have developed formaldehyde-free building panels for use in the construction industry.

Renewable energy

The final stage of a wood products life cycle in a cascading system is biomass energy production. Biomass energy refers to the renewable energy derived from organic sources, such as wood, crops, agricultural and forest residues, which can be converted into various forms of energy, such as heat, electricity, and fuel. Currently, 63% of wood waste is utilised as biomass energy in the UK, as seen in **Fig. 4**.

In the UK, biomass energy accounted for 12.9% of the total UK electricity supply in 2021, making it the second largest renewable energy source. Due to insufficient supply of biomass feedstock, approximately one third of the biomass energy feedstocks are imported. This has been criticised, as the potential environmental benefits gained from biomass energy could be negated through the importation process [33].

Fertilisers

Most reports and studies suggest that the final stage of a timber products life cycle is biomass energy. However, further research has suggested that there is great opportunity to utilise bioenergy by products, i.e., ashes, as fertiliser. Biomass ashes can be spread in forests to provide nutrients, such as potassium and phosphorus, and improve forest productivity [34].

By using biomass by-products as fertiliser for the growth of new trees, the products can become fully circular. Although this could be viewed as an ideal circular solution, using biomass ashes as fertiliser is not without its challenges. For it to be an effective solution, ashes must be of good quality and care must be taken to ensure that heavy metals or organic pollutants are not accumulated as a result of repeated applications.

Case study

In 2018, Faraca et al. [37] assessed the difference in global warming potential (GWP) savings when increasing cascading steps were applied to particleboards. As illustrated in the figure below, the cascaded product always remained the same. They concluded that the activity producing the largest savings in a system occurred in the first cascade step, when the quality of feedstock was at its highest point. Within the first step, 78% of GWP savings were achieved, by the time the final scenario was reached, these savings had reduced to only 15%. This is a result of reprocessing the cascaded material, where half of the feedstock is lost due to the chip dimensions, presence of resin and material quality. This study highlights the importance of the recycling choices at the early stages of the of the cascade chain and demonstrates the opportunity for a high reward outcome from a low work input.

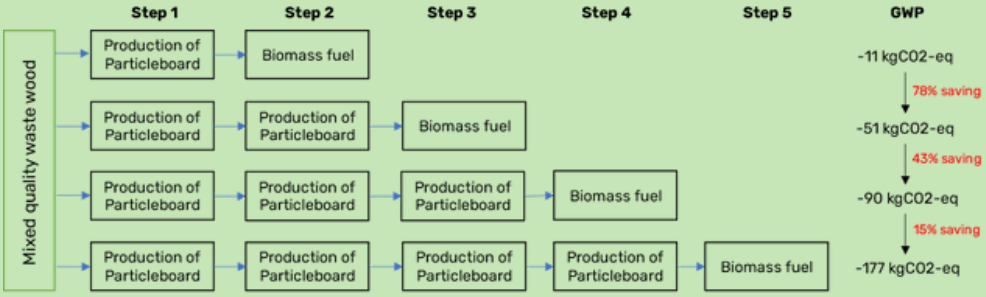

Figure 5 The timber cascading steps assessed by Faraca et al. and their corresponding Global Warming Potential (GWP).

Recommendations

The main factors influencing a transition to timber cascading-focused forest economy will likely also inform and support the development of a wider, overarching circular bioeconomy. To drive the early stages of this transformation, policy makers and industry leaders need to work collaboratively to deliver incentives designed to support timber cascading in Scotland.

It is worth highlighting that many of the recommendations outlined below are interdependent and undertaking each recommendation in isolation will not deliver transformational change. There will be clear benefits and improvements in process, but the paradigm shift needed to establish a robust cascading culture requires change to be delivered as a whole across the sector.

This report has identified the two most critical barriers for timber cascading as:

1. The prioritisation and competition between the material use of wood and energy use of wood. This is evidenced in the market, infrastructure, and policy.
2. Lack of information relating to reclaimed timber, such as previous treatments, re-grading, and future processing.

In order to overcome these barriers, there are actions which policy makers and industry leaders should consider to support the most efficient and circular use of timber products in Scotland.

Policy Makers

Incorporate Circularity into Planning Policy

As the second circular economy principle, reuse could become a standardised feature of compliance within planning policy. For example, demonstrating at planning stage that a building can be deconstructed, with its timber components reused for additional service life, appears a viable option for the Scottish Government.

The built environment sector is increasing the use of advanced digital technology and the adoption of the design for manufacture and assembly (DfMA) and disassembly and reuse methodology. This suggests that the type of policy enhancement outlined above is being implemented by industry already, simplifying the route to change.

This model need not be exclusive to structural components in construction. The manufacturing sector has long been admired for its advanced DfMA systems and processes. Windows, doors, kitchens, bathrooms, furniture, even wind turbine blades and toilets can now be manufactured using timber. Each of these examples has the potential to be reused or at least recycled, but there are no policies requiring organisations to consider this at the design stage.

Redesign waste and energy policies

Policy only works when what it seeks to achieve does not inadvertently incentivise alternative activities which subsequently adversely impact the very process it is designed to support. This occurred with the incentivisation of using wood for energy generation through biomass. It is symptomatic of a lack of coordination between departments to establish a common policy framework for energy and waste.

However, displacing the biomass industry and its associated labour force, tax revenue, and energy production is not a viable option. Rather, forestry stakeholders should collaborate to develop supply chains which disincentivise the use of timber which can be reutilised as a product with a longer life cycle and significantly incentivise the use of waste wood at its end of ‘productive’ life. This would ensure timber continues to cascade across several life cycles, keeping the sequestered carbon locked up for longer and reducing the use of virgin raw materials and hereby maximising the value of what would typically be waste.

Material Passports for Composition of Timber Products

This report has already established the link between the lack of information on reclaimed timber’s composition and the inability to reprocess it to leverage its maximum value. Therefore, the first logical step in reversing this issue would be to stop using additives and treatments wherever possible. Whilst these additives might increase the product’s initial design life, they may also prevent it being repurposed for another life cycle. This needs to be assessed alongside a shorter initial design life without the use of additives, but potentially enable another, or several other, future life cycles.

Where the use of additives or treatments is essential, manufacturing organisations are likely to be in possession of the data required to create product passports. These documents could be held on a nationwide digital platform, contain all relevant data pertinent to the reuse or recycling of the specific product, and facilitate more systematic deconstruction programmes, as opposed to current standard demolition.

Support the Development of Processing Facilities

The above passports would enable processors and manufacturers to develop sorting, recycling, and treatment plants, either as complementary on-site assets within existing facilities, or through a network of collaborative partners. This would facilitate the reprocessing of timber to leverage the highest value possible at each stage of the cascade.

However, due to a lack of investment and research, there is a lack of technical expertise and processing knowledge, creating major barriers for further material uses of waste wood. This expertise is fundamental in remediating the contamination associated with additives, decomposition, moisture, and small particle sizes.

Invest in R&D

To maximise the reprocessing opportunities and ensure timber is leveraged at its greatest value at end of a given life cycle, it is essential that investment is made into research and development. There are several areas requiring research, but the greatest value is likely to come from the knowledge required to fundamentally realign the timber supply chain.

For example, to ensure best value, the lowest suitable grade timber would be utilised for manufacture to prevent over-engineering and reduce the impact and reliance on virgin wood. Virgin graded timber would be directed towards higher grade, higher value products such as engineered and structural timber. Products whose technical standards do not require virgin material for manufacture would utilise reclaimed and recycled material wherever possible, such as pallets, fencing, sarking to name a few. The manufacture of products such as panel boards and insulation would use the above components once they have come to the end of their productive life cycle.

This research would underpin the potential development of reprocessing and enhancement, seeking to fill the knowledge gaps and lay the foundations for rapidly assessing the chemical composition of additives and treatments used with timber.

Further research investment should identify the potential for waste mitigation, both in terms of manufacture and consumption. Therefore, it would be valuable to investigate how improvements in the design and engineering of manufacturing processes, alongside wider consumer behaviour, could deliver significant waste reductions. More open collaboration and communication between supply chain partners would also increase industry-wide efficiencies and productivity, leading to improved reductions in waste generation.

Industry leaders

Collaboration, deeper industry engagement, and open dialogue all have positive impact and benefits. Industry leadership groups, associations, and membership organisations have the ability to support collaboration between their partners to increase waste reduction and process improvement. However, there are several wider benefits for timber cascading which can be achieved through collaboration such as:

Access to new markets

Collaborating with competitors can provide access to new markets that would be difficult to penetrate alone. By pooling resources, companies can leverage their collective strengths to enter new markets, increase their customer base and support the scaling up of the markets. This would be particularly relevant to SMEs operating in the timber supply chain who have the potential to deliver on some of the opportunities highlighted earlier in this report but lack the resources to take the work forward.

Innovation

Collaboration can foster innovation by bringing together diverse perspectives and expertise. Companies can share knowledge, technologies, and best practices, leading to the development of new products, services, and business models. This report has highlighted gaps in the market such as homegrown mass timber solutions and wood fibre insulation. These innovation opportunities often require significant research, evidence of scalability, and business case delivery. It is unlikely that an individual company would have the expertise to deliver a remit of this scale. However, partners collaborating to share knowledge and expertise have a greater likelihood of success.

Cost savings

Collaborating with competitors can lead to cost savings through shared resources, such as marketing expenses, production facilities, and the above research and development costs. High capital expenditure may also be reduced to acceptable levels when considering investment in new processing or manufacturing facilities.

Risk reduction

Collaborating with competitors can also help to reduce risk by spreading it across multiple companies. By working together, companies can share the burden of uncertain market conditions, regulatory changes, and other factors that could negatively impact their businesses. This is particularly relevant when considering research and development for future cascading opportunities, and investment in facilities to enhance timber cascading.

Improved industry standards

Industry stakeholders can work together to lead on the development of industry standards, such as those required for the commercialisation of new products, processes, and systems detailed above. By agreeing on common standards, companies can reduce uncertainty and improve efficiency across the industry.

Collaborate for end of life

As discussed, a lack of information on the quantity, quality, and relevant properties of timber and waste complicates recycling, as well as the assessment of sustainability impacts of cascading. By collaborating with other organisations, both within industry and academia, to share adequate information on material composition and transformations undertaken, timber cascading can be enhanced. This will increase the understanding around common product boundaries and the recommended processes to maximise future value at end of the material life cycle.

Summary

This report summarises the current state of the art surrounding the cascading of timber products within Scotland and further afield. Opportunities for cascading applications have been identified, and the challenges surrounding the wider adoption of cascading have been highlighted. It can be concluded that there is significant economic and environmental value which can be achieved through widespread implementation of wood cascading. However, detailed challenges will need to be overcome through further research, innovation, and regulation, if these gains are to be capitalised upon.

The proposed areas of further research are as follows:

- A material flow and life cycle analysis of the most optimum cascading streams to utilise the natural resource most efficiently. This would involve reviewing each of the cascading opportunities above and producing a series of material flows which demonstrate the cascading potential of wood products. By undertaking this work, it will be useful to determine the different feedstock materials that can be used in the different product, out with what is normally adopted by the industry. For example, is there merit in utilising waste panel products in woodfibre insulation and what are the carbon benefits and implications of this?

- As detailed, there are significant barriers surrounding the use of secondary materials in high value applications, such as construction and the built environment. This is both due to a lack of confidence in specifying and a lack of market demand. Therefore, it is recommended that a Scotland specific roadmap be developed, in collaboration with researchers, industry and policy makers, which will look to tackle these technical barriers and encourage the adoption of pre-used wood products and stimulate the second-hand material market.

- Through the anticipated outputs of the above works, the final stage will involve assisting policy makers and building regulators to incentivise the design and use of cascaded wood products and as a result create a more resource efficient Scotland. This will necessitate full cross-sector engagement to ensure policy alignment, stakeholder engagement, and a commitment throughout the supply chains to drive forward the transformational change required.

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Further resources

Title	URL	Author	Year
Embodied Carbon. Status quo and suggested Roadmap (Scotland)	link	Zero Waste Scotland	2020
2050 roadmap to a low-carbon bio-economy	link	Forest Fibre Industry	2017
A sustainable bioeconomy for Europe	link	European Commission	2018
Cascades – Study on the optimised cascading use of wood	link	European Commission	2016
Cascading - Utilisation of Wood: a Matter of Circular Economy?	link	Claudia Mair / Tobias Stern	2017
A new Circular Economy Action Plan	link	European Commission	2020
Establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem	link	European Commission	2023
A Green Deal Industrial Plan for the Net-Zero Age	link	European Commission	2023
Trading to Build a Better World	link	European Commission	2021
Establishing a framework for ensuring a secure and sustainable supply of critical raw materials	link	European Commission	2023
Delivering Scotland's circular economy	link	Scottish Government	2022
New EU Forest Strategy for 2023	link	European Commission	2021
Real potential for changes in growth and use of EU forests	link	EUwood	2010
Forestry Statistics 2022 Chapter 2: UK-Grown Timber	link	Forest Research	2022
Forestry and Wood Processing Sector Plan (draft)	link	SEPA	2019
Forestry Facts and Figures 2022	link	Forest Research	2022
Guidance on cascading use of biomass with selected good practice examples and woody biomass	link	European Commission	
Updated Circular Economy Implementation Programme 2021-2022	link	Ministry of Infrastructure and Water Management	2021
The timber industry Net Zero Roadmap	link	Timber Development UK	2022
Permitting Guidance for Biomass Combustion	link	SEPA	2012
Resource efficiency of multifunctional wood cascade using LCA and energy analysis, exemplified by a case study for Germany	link	Michael Risse, Gabriele weber-Blaschke, Klaus Richter	2017
Roadmap to a Resource Efficient Europe	link	European Commission	2011
Roots for Further Growth	link	Confor	2018
Scottish Government biomass incentives review: best use of wood fibre	link	Forest Research	2012
Towards a circular economy: A zero waste programme for Europe	link	European Commission	2014
Reusing timber	link	TRADA	2020
Wood waste and reuse	link	TRADA	2020
Transforming the bio-based sector towards a circular economy – What can we learn from wood cascading	link	Matteo Jarre, Anna Petit-Boix, Carmen Priefer, Rolf Meyer, Sina Leipold	2020
Biomass and Food	link	Transition Agenda	2018
Cascading use of wood in Finland – with comparison to selected EU countries	link	Laura Sokka, Kati Koponen, Janne T. Keranen	2015
Waste and repealing certain Directives	link	European Parliament	2018
Waste Wood Assessment Guidance for the UK Waste Wood Industry	link	Wood Recyclers' Association	2021
Grades of Waste Wood	link	Wood Recyclers' Association	2021
Mapping Study on Cascading use of Wood Products	link	World Wildlife Fund (WWF)	2016
What is a circular economy?	link	Ellen Macarthur Foundation	
The potential for forest-based industrial biotechnology in Scotland	link	NNFCC The Bioeconomy Consultants	2014
Biorefinery roadmap for Scotland – Building a sustainable future	link	Scottish Enterprise	2015
Barriers and enablers of wood cascading	link	Circular Economy Series	2022
London Plan Guidance: Circular Economy Guidance	link	Greater London Authority	2022
Seeing the wood in the forests	link	European Forest Institute	2020
Net zero public sector buildings standard	link	Scottish Government	2021
Cascading of woody biomass: definitions, policies and effects on international trade	link	IEA Bioenergy	2016

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