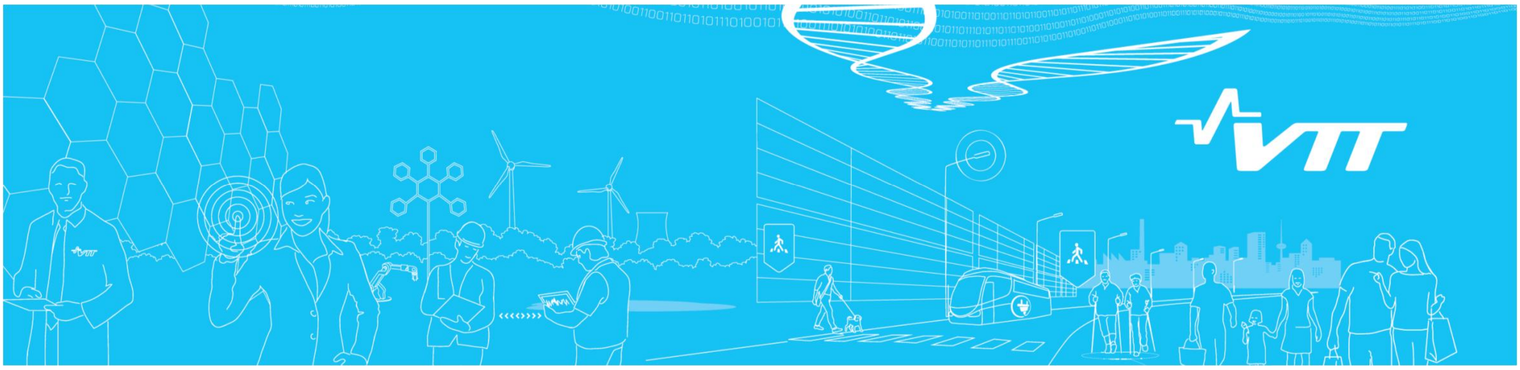
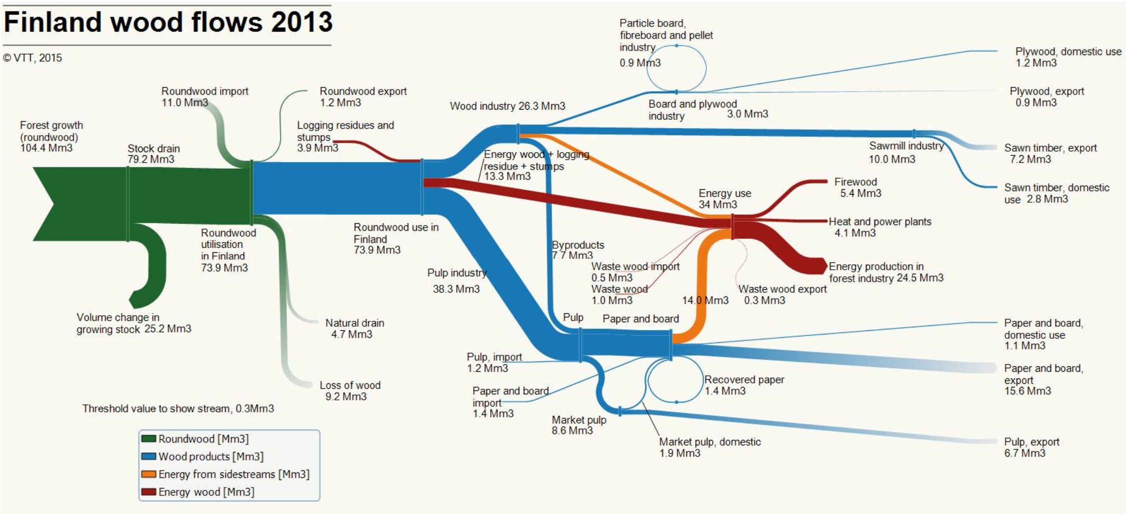


RESEARCH REPORT VTT-R-03979-15



Cascading use of wood in Finland – with comparison to selected EU countries

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Summary

Cascading use of woody biomass is getting increasing attention in current European discussions to ensure the sustainable and resource-efficient use of wood in future bioeconomy. So far however, there is no exact agreement on what is meant by "cascading". This report shortly summarizes several definitions on cascading use of biomass and discusses their differences.

In addition, the wood flows in Finland on the year 2013 are presented, as well as examples of wood flows in selected other EU countries. Based on the comparison, the differences between the countries are discussed. Finland exports most of the products processed from woody biomass. Thus, the cascading cycles often take place outside Finland. Therefore the role of a wood producing country (e.g. Finland), supplying virgin fibre, differs significantly from the consumer countries (e.g. Germany and Holland) with more recycling, which creates challenges for creation of common cascading concept .

Cascading should be considered from the perspective of the whole wood using cycle, recognising the regional differences in wood flows, when discussing about the cascading principles. Furthermore, the overall efficiency of recycling needs to be taken into account.

Confidentiality	Public

Espoo 4.9.2015

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Preface

Cascading use of woody biomass is getting increasing attention in current European discussions on the use of wood in future bioeconomy. For example, the European Commission communication on “Circular Economy” (COM(2014) 398) and the European Union Forest Strategy (COM(2013)659) highlight cascading use. The cascading use is also mentioned in the recently accepted ILUC proposal (outcome of the European Parliament's second reading, April 2015, 8037/15), concerning the sustainability criteria of transport biofuels. In addition, European Commission is currently (2015) carrying out a ’Study on the optimised cascading use of wood’.

This report gives a short introduction on the discussion on cascading principles and definitions, and shows examples of the cascading flows in Finland and selected other European countries. In addition, recommendations regarding the use of cascading concept in policy-making are given. This report concentrates on woody biomass, but cascading principle could also be used in relation to other limited resources, such as other biomass and fossil resources.

The work was completed in the first half of 2015 by Senior Scientist Laura Sokka, Research Scientist Kati Koponen and Senior Scientist Janne T. Keränen. It was a part of a project related to the sustainability of forest energy in Finland, and done under supervision of The Ministry of Employment and the Economy (steering group: Juhani Tirkkonen, Reetta Sorsa, and Hanne Siikavirta).

The statements expressed in this report are from clearly marked references or those of the authors, and do not necessarily represent the view of the Finnish Ministry of Employment and the Economy.

Espoo 4.9.2015

Authors

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1. Introduction to the concept of cascading use of wood

1.1 Background

Wood products are typically considered to have lower environmental impacts than equivalent products made out of non-renewable raw materials. Woody biomass is presently used in many different industrial sectors and in many different value chains, such as wood-based products and materials, bio-chemicals, and bioenergy (e.g. power, heat and biofuels). Targets for greenhouse gas emission reduction and more resource efficient society are expected to further increase the demand for wood raw material in Europe during the next decades. Woody biomass is, when sustainably grown, a fully renewable resource and a largely recyclable and reusable material. Only a small fraction of wood products cannot be re-used or recovered directly (e.g. hygiene paper or contaminated wood material). However, as woody biomass is a limited resource, its use and the service life of wood fibres should be optimized.

In addition, many studies published during the recent years have presented critical views on the climate impacts of using long-rotating forest biomass (e.g. 80 years rotation) for products with short life cycles or for energy. These studies argue that the use of wood for such purposes is not carbon neutral due to a time lag between the carbon released through harvesting and combustion of wood, and its sequestration back into new biomass (e.g. Cherubini 2011, Pingoud 2012, Holtsmark 2013). Also another challenge has been pointed out, concerning intensified harvests, which decrease the development of the forest carbon sink compared to less intensive harvest (Kallio et al. 2013). Presently the emissions due to changes in forest carbon sinks are accounted for in the land use sector (LULUCF), but the carbon sink is only partly taken into account in emission reduction commitments. To achieve the most effective climate change mitigation impacts, the wood resources should be used in a way that helps to store carbon or to replace the most emission intensive fossil fuels, while securing development of forest carbon sinks at the same time.

As a response to the above-mentioned challenges, the concept of cascading use has been presented in many studies and reports. Simply put, the cascading use of biomass means that biomass is used (and reused or recycled) at least once or several times as a product before its end-of-life (e.g. energy use or landfill) (Figure 1).

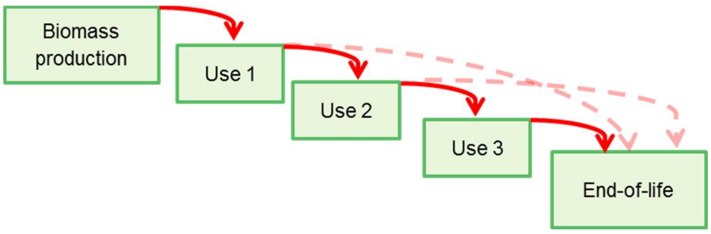


Figure 1 Simplified presentation of cascading use (figure adapted from Odegard et al. 2012)

The resource use hierarchy of the cascading principle can be considered to have its roots in the waste hierarchy of the Waste Framework Directive (2008/98/EC). According to the waste hierarchy, waste prevention, re-use and recycling go over energy recovery (Figure 2).

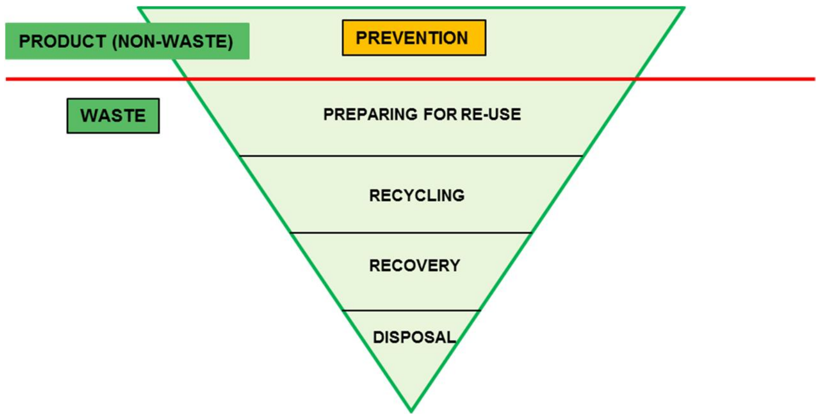


Figure 2 The waste hierarchy according to the Waste Framework Directive (figure adapted from http://ec.europa.eu/environment/waste/framework/).

1.2 Cascading use in policy making

In its communication on "Circular Economy" (COM(2014) 398), the European Commission states that it "will encourage the cascading principle in the sustainable use of biomass, taking into account all biomass using sectors so that biomass can be utilized in a most resource efficient way". In the Communication, Figure 3 is used to illustrate the main phases of a circular economy model. The phases are interlinked because materials can be used in a cascading way. Energy recovery, including also waste-to-energy recovery and biofuels, "will have a role to play with respect to non-usable and non-recyclable waste".

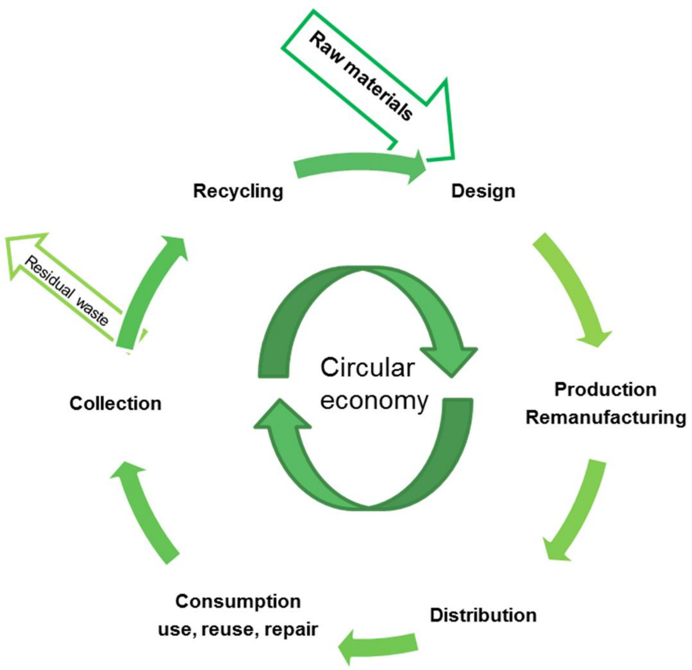


Figure 3 Simplified illustration of the use of resources in circular economy (adapted from COM(2014) 398).

Furthermore, the EU Forest Strategy (COM(2013)659) states that cascade use fulfils the criteria of resource-efficiency. According to the strategy, under the cascading principle, wood should be used in the following order of priority: wood-based products, extension of their service life, re-use, recycling, bioenergy and disposal. However, the strategy also recognises that in some cases, such as in changing demand or environmental protection, different approaches may be needed. Moreover, it is said in the strategy that the Commission will together with Member States and stakeholders develop good-practice guidelines for the cascade principle.

In the recently accepted ILUC proposal (Outcome of the European Parliament's second reading, April 2015, 8037/15), waste hierarchy and cascading use have been mentioned as one of the criteria that the Member States need to take into account in their reporting to the European Commission (article 22 of Renewable Energy Directive 2009/28/EC, RED) on the use of waste and residue raw materials for biofuels and bioliquids:

[… The report shall detail, in particular:]

> *"(i) the development and share of biofuels made from feedstocks listed in Annex IX including a resource assessment focusing on the sustainability aspects relating to the effect of the replacement of food and feed products for biofuel production, taking due account of the principles of the **waste hierarchy** established in Directive 2008/98/EC and the **biomass cascading principle** taking into consideration the regional and local economic and technological circumstances, the maintenance of the necessary carbon stock in the soil and the quality of the soil and the ecosystems"*

In some EU Member States the cascading principle has already been considered in policy making. For example, in the Netherlands, the cascading principle has been included in the sustainability criteria for solid bioenergy. In the criteria, the intensified cascading for material use and energy has been listed as a specific request for biomass, and a limit for the promotion of biomass co-firing in power plants has been set to 25 PJ (Kwant 2015). In the German Forest strategy 2020 (Federal Ministry of Food, Agriculture and Consumer Protection 2011), the cascading use of wood has also been brought up.

In addition, Carus et al. (2014) from the Nova Institute are concerned that the strong incentives to use biomass for renewable energy and fuels can distort the markets and hinder the development of bio-economy. They claim that the incentives cause unfair competition between the actors using biomass for energy or material purposes, especially concerning wastes and residues benefiting from the double counting system in the EU Renewable Energy Directive (RED)[1]. They propose that the RED should be transformed to a "Renewable Energy and Materials Directive", meaning that both the use of biomass for energy and for materials could be counted in the current national targets for renewable energy. They further propose that the double counting in the RED should be based on cascading use, as the biomass would then be used at least two times to replace fossil resources - first as raw material and then as energy.

1.3 Cascading definitions

The concept of cascading use has been presented in many studies and reports, but the definitions used in these publications differ. So far there is no full consensus on what is considered as cascading use of wood products. In the following, some examples of the definitions are presented. The references used here were chosen among the most recent studies.

1) Cascading in time and in value

The concept of cascading use of biomass can be defined as 'cascading in time' meaning that the life span of biomass use is increased (e.g. paper recycling). It can also be defined as 'cascading in value' meaning that the maximum value of the whole life cycle of biomass is gained through optimising the use of biomass for multiple services (Odegard et al. 2012).

[1] In the RED it is stated, that biofuels from waste and residues can be double counted (1MJ as 2MJs) to the national targets on renewable energy use in transport by 2020.

Figure 4 presents an often used hierarchy of the cascading in value for different wood uses. There, the energy use of wood is considered to have the lowest value.

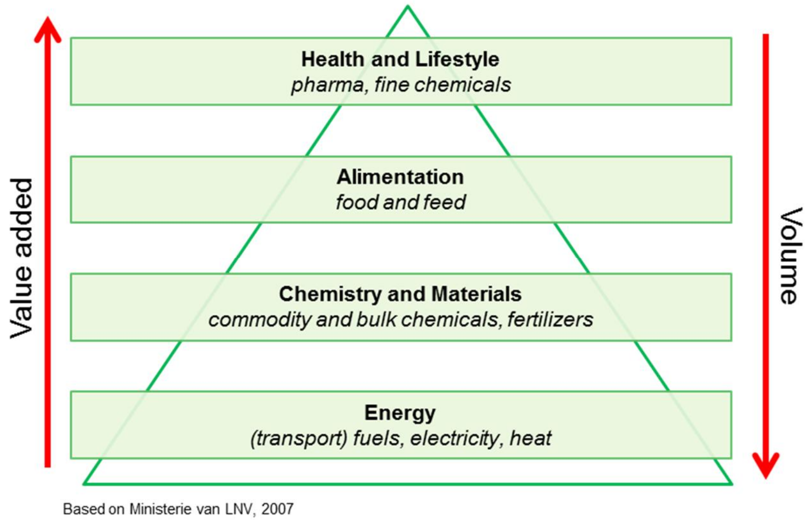


Figure 4 Schematic representation of the cascading in value for the different uses of wood (figure adapted from Odegard et al. 2012)

To value the different uses of biomass, several principles could be used, for example: added value, environmental impacts, greenhouse gas emissions, or societal value of product (e.g. for food). One view point to the cascading discussion is whether all types of energy production should be classified to the lowest level of the hierarchy or not? For example, the efficiency of wood use in different energy production plants can vary significantly. Condensing power plants typically reach an efficiency of 30-40% whereas combined heat and power production (CHP) plants can reach an overall efficiency of 80-90%. Thus fuel (e.g. woody biomass) is used much more efficiently in the latter. On the other hand, one can ask whether refining of wood for transportation biofuels should have the same value as using wood directly in electricity or heat production. Refined biofuel products could also be considered to have a similar value as other biochemistry products aimed to substitute fossil resources. Furthermore, the energy use of wood might not be the last step of its life cycle, as in some cases the ash from wood combustion can be circulated back to the forest as a fertilizer, allowing for closed nutrient cycles.

2) Cascading use takes place only when wood is first used as a final product and only later as energy

"Cascading use of biomass takes place when biomass is processed into a bio-based final product[2] *and this final product is used at least once more either for materials or energy.*
Cascading use of biomass is described as single-stage, when the bio-based final product is directly used for energy.
Cascading use of biomass is described as multi-stage when biomass is processed into a bio-based final product and this final product is used at least once more as a material. It is only after at least two uses as a material that energy use is permitted."

[2] Carus et al. (2014) define final product as "a product at the end of a processing chain, which is traded and used by industry and/or consumer for its material or product properties. Process intermediates are not counted as final products. Energy carriers such as wood pellets, biodiesel or bioethanol are explicitly excluded in this context because they are not materially used (also in a material value chain all three would only be intermediates)."

This definition for cascading use is presented in German literature by Essel et al. (2014) and Carus et al. (2014). The "*final product*" is further defined as "a product at the end of a processing chain, which is traded and used by industry and/or consumer for its material or product properties". Since the definition requires a final product for material uses, all forms of intermediate products without a real material use by private or industrial consumers are not considered cascading use. Carus (2014) further stresses that direct energy use of biomass (i.e. energy use without preceding material use) is not considered cascading use. Multi-stage cascading results in a larger efficiency gain than single stage cascading. However, it can only be achieved for a limited number of biomass value chains. Single-stage cascading results in a larger efficiency gain compared to direct energy use, and is also available for many more value chains (Carus et al. 2014). Therefore both approaches can be supported if one aims for increased resource use efficiency (see Figure 5).

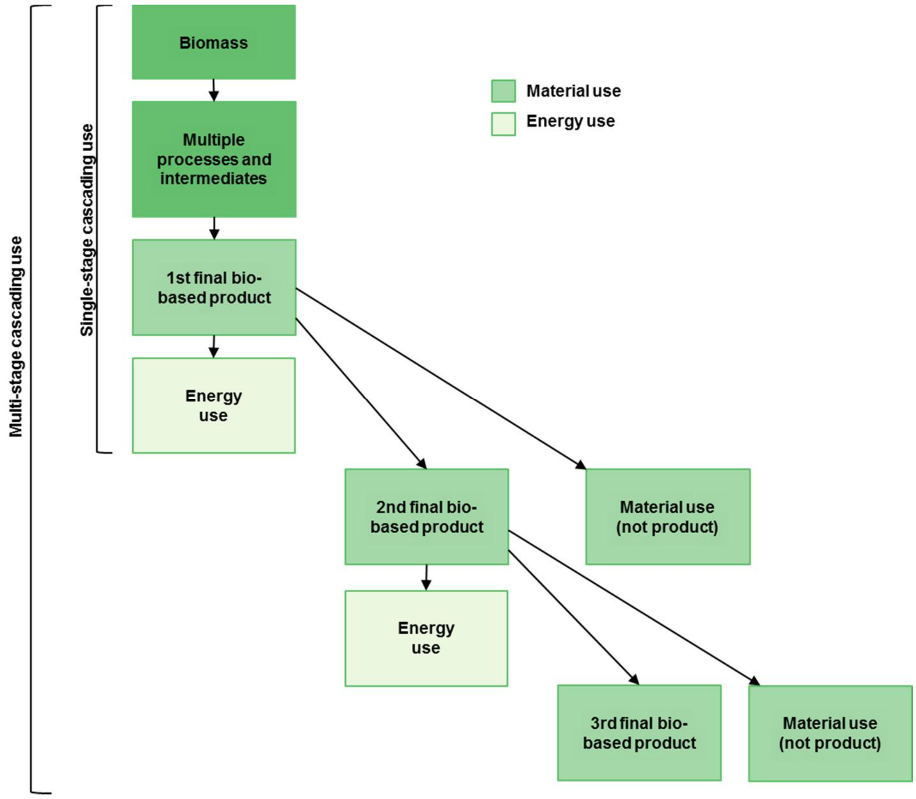


Figure 5 Difference between single-stage and multi-stage cascading use of biomass (figure adapted from Carus 2014).

3) Cascading use can also include direct energy use of wood residues

In the commonly cited report by Mantau (2012), cascading use is defined as the multiple use of wood resources from trees by using residues, recycled (utilization in production) resources or recovered (collected after consumption) resources. Mantau (2012) also presents a concept of cascading factors, which he calculates for the European wood flows (see Section 2.1). In the calculation of the total cascading factor, he takes into account the energy use of recycled wood (post-consumer wood), but also the direct energy use of industrial residues. He also points out that cascades do not take place in one single sector, but between several sectors.

4) Cascading and biorefinery as complementary concepts

Keegan et al. (2013) define cascading use as a systematic effort to first exploit biomass for higher-value product, as material input, before using it as an energy source. However, they further argue that higher economic added value does not always coincide with higher environmental added value, and that cascading use of biomass is not the only system through which these aims can be promoted. The concept of biorefinery, where biomass is sustainably processed into a range of marketable products and energy, is also valuable and more relevant in some cases. Cascading implies a linear system in which biomass goes through a series of material uses, by reuse and recycling, until it is used for energy recovery. Keegan et al. (2014) therefore see cascading and biorefinery as complementary concepts. A similar point is made by Odegard et al. (2012) who write as follows: "What people call 'cascading in function' is actually co-production, which can be achieved by using bio-refinery. Co-production is the production of different functional streams (e.g. protein, oil and energy) from one biomass stream, maximising total functional use. Of course, after cascading in function, cascading in value or time follows."

5) No consensus on cascading definition

Fritsche and Iriarte (2014) point out that there is no consensus yet on what is meant by the "cascading" or how it should be applied. Generally Fritsche and Iriarte agree that cascading aims at creating incentives for first using biomass for high-value products (such as construction materials or chemicals) and then using residues from this production and post-consumer wood for other, lower value, products. Thus, material reuse and recycling of biomass is prioritised over use for bioenergy. However, they list some restrictions to this definition:

- Not all biomass resources are suitable for highest levels of value chains and the cascading is therefore limited. An example of this are certain forest residues, which are not suitable for use as sawn timber or feedstock in pulp and paper production.
- The economic value of biomass uses varies between countries and circumstances. For example, in some developing countries there may not be any biochemical industries, and the cost for oil imports may be high. Thus, utilisation of biomass for modern energy uses may be preferable over use as material. On the other hand, in industrial countries the high near-term GHG reduction targets can make energy use preferable over material use (provided that burning of wood is considered to have zero CO_2 emissions).

Main differences in cascading definitions:

- The main difference in the cascading definitions presented here is whether the direct use of wood residues can be counted as cascading or not
  - Carus et al. (2014) are very clear that cascading use happens only when the biomass is used at least once for a final product before using it for energy purposes. According to this definition, the use of intermediate products (e.g. residues) for energy is not cascading use.
  - Mantau's (2012) definition is vaguer, and direct energy use of wood residues is counted in the cascading cycles.
- Some consider biorefineries as a supplementary measure to cascading use (Keegan et al. 2014, Odegard et al. 2012).

2. Cascading flows of wood in the EU and in Finland

In this section the cascading flows are presented for the EU and for Finland. To enable comparison between different types of Member States, the cascading flows are also presented for Austria, Germany, and the Netherlands. The EU Member States can be divided to three different groups according to their wood use profile: net exporters, traders and net importers. Finland and Austria can be classified as net exporters, Germany as a trader, and the Netherlands as a net importer (Indufor 2013).

2.1 EU total

Figure 6 presents the EU wood flows according to Mantau (2012). The flow chart starts from the growing wood stock in forests and ends up to end use of wood as products or energy. The chart also includes the cascading cycles: industrial residues from wood production are recycled in pulp production, pulp production has its inner cycles, and recycling of paper forms one cycle. Only a small portion of the total use of wood (around 9%) is disposed as waste. Almost 60% of the wood resources finally end up in energy use, and 60 % of this energy use is direct energy use of wood, mostly taking place in households.

In the EU, the amount of wood traded is relatively small as only wood flows to and from the EU27 countries are considered trade in Mantau's (2012) figures. Internal trade between the EU27 countries is thus not included in exports and imports in Figure 6. Exports are slightly higher than imports, being 132.5 and 94.8 Mm^3, respectively.

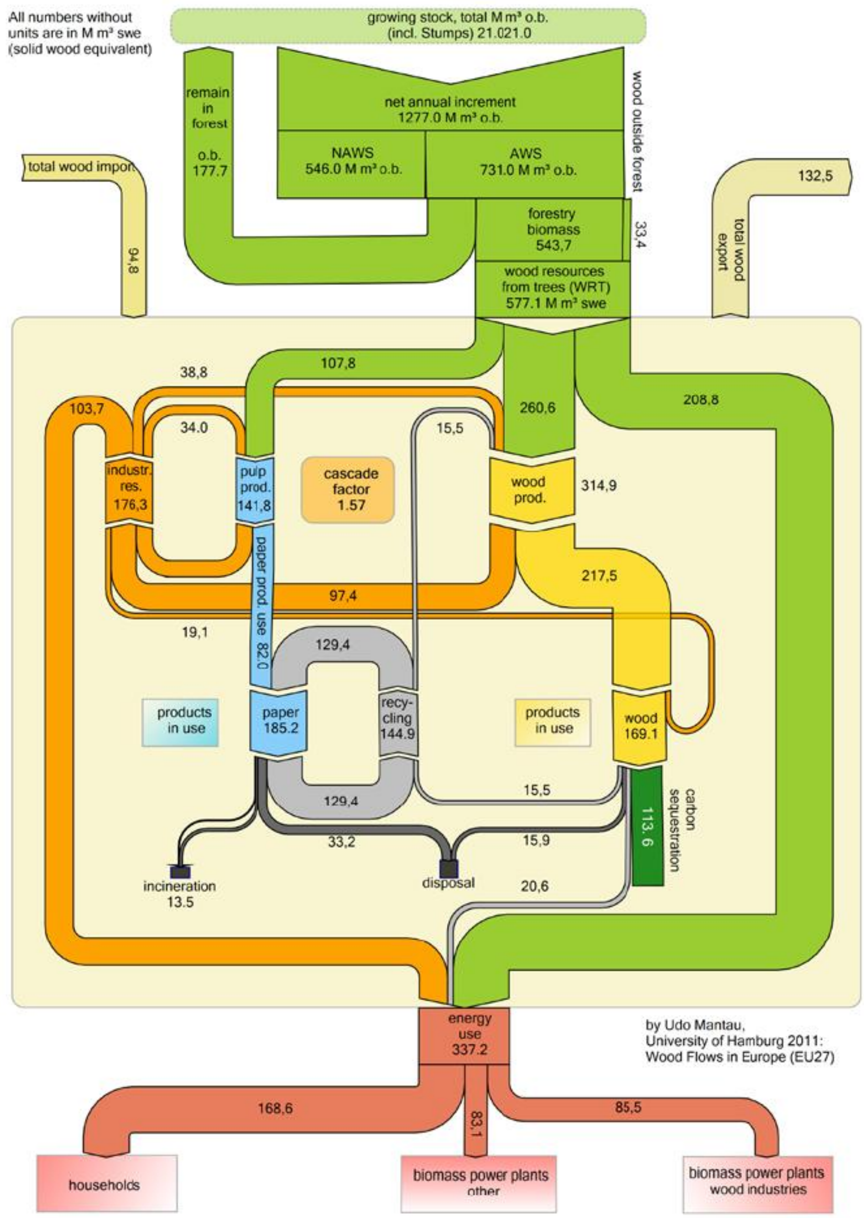


Figure 6 Wood flows in EU (figure from Mantau 2012)

The cascading factors presented by Mantau (2012) are shown in Table 1. The values from Figure 6 are used for the calculation. The more the wood products are recycled, and the recycled products and residues used, the higher the cascading factor becomes. The cascading factor is 1.00 when only wood directly from trees is used. The total cascading factor in Europe (EU27) is 1.57 meaning that the wood resources have been used a bit more than one and a half time.

Table 1 Cascade factors for the wood resource balance as a whole, and for the wood industry (table from Mantau 2012).

	UTILIZATION FACTORS	TOTAL WOOD RESOURCE BALANCE			WOOD INDUSTRY	
	2010	M m³	Factor	Calculation	M m³	Factor
A	wood resources from trees	577.1			368.4	
B	residues in wood products	72.9	1.13	(A+B)/A	72.9	1.20
C	residues in energy	103.4	1.18	(A+C)/A		
D	recycling in products	130.2	1.23	(A+D)/A	130.2	1.35
E	recovery in energy	24.4	1.04	(A+E)/A		
F	residue utilization	176.3	1.31	(A+B+C)/A		
G	recycl. + revoc. cascades	154.6	1.27	(A+D+E)/A		
H	cascades in products	203.0	1.35	(A+B+D)/A	203.0	1.55
I	resid. + recycl. in energy	127.9	1.22	(A+C+E)/A		
J	total cascades	330.9	1.57	(A+H+I)/A		

2.2 Finland

The cascading flows of wood in Finland in 2013 are presented in Figure 7. The information is collected from various sources[3]. The main stages shown in different colours in the flows are: roundwood from forests, processing in wood products (in chemical and mechanical forest industries), energy use from byproducts and from wood, and export of products. This illustration was initially chosen to highlight the large export share of products made from forest biomass and to follow the principle described by Mantau (2012). More detailed description of the flows listed can be found in Appendix I.

The forest resources in Finland have been steadily increasing and this development is predicted to continue (Asikainen et al. 2012). The forest resources are used mostly in chemical and mechanical forest industries. The byproducts from the mechanical forest industry are used in the chemical industry, and there are optimised inner cycles in the chemical industry (e.g. use of black liquor). The residual streams are used mostly for energy production, which supports the total efficiency of the industry. Most of the products from chemical industry are exported as pulp, paper and board. The mechanical industry exports mostly timber and plywood. The level of paper recycling is high in Finland: paper recycling rate was 86% in 2012[4]. Moreover, the recycling rate of cardboard and paper packaging is presently about 75% and the recovery rate (incl. energy recovery) almost 90%[5].

When comparing the wood flows of Finland (Figure 7) and the EU (Figure 6), the figures show that the Finnish wood flows differ significantly from the average European wood flows presented by Mantau (2012). First, the direct use of wood for energy is relatively much lower, and the use of wood for pulp industry much higher in Finland than in the EU. Second, as Finland exports a significant part of its wood biomass as products, the cascading cycles of these products take place outside the Finnish borders, e.g. in other EU Member State. This limits the cascading cycles inside

[3] Peltola A. (ed.), Finnish statistical yearbook of Forestry 2014, Finnish Forest Research Institute Metla, ISBN 978-951-40-2505-1 ISBN 978-951-40-2506-8 (2015), Finnish Forest Industries statistics, https://www.forestindustries.fi/statistics/, Finnish Customs Statistics, ULJAS - database - Foreign Trade Statistics, http://uljas.tulli.fi/, Confederation of Finnish Industries, http://ek.fi/en/materials/infographics/, Suomen Kuitukierrätys Oy, http://www.kuitukierratys.fi/tietoa-ja-tapahtumia

[4] http://www.ymparisto.fi/fi-FI/Kartat_ja_tilastot/Jatetilastot/Tuottajavastuun_tilastot/Kerayspaperitilastot

[5] http://www.kuitukierratys.fi/tietoa-ja-tapahtumia

Finland. Third, the energy use of wood industry by-products is very significant in Finland. If the direct energy use of forestry residues was not counted as cascading use, the cascading cycles in Finland would be even more limited. Finally, the amount of wood ending up to disposal is very small in Finland.

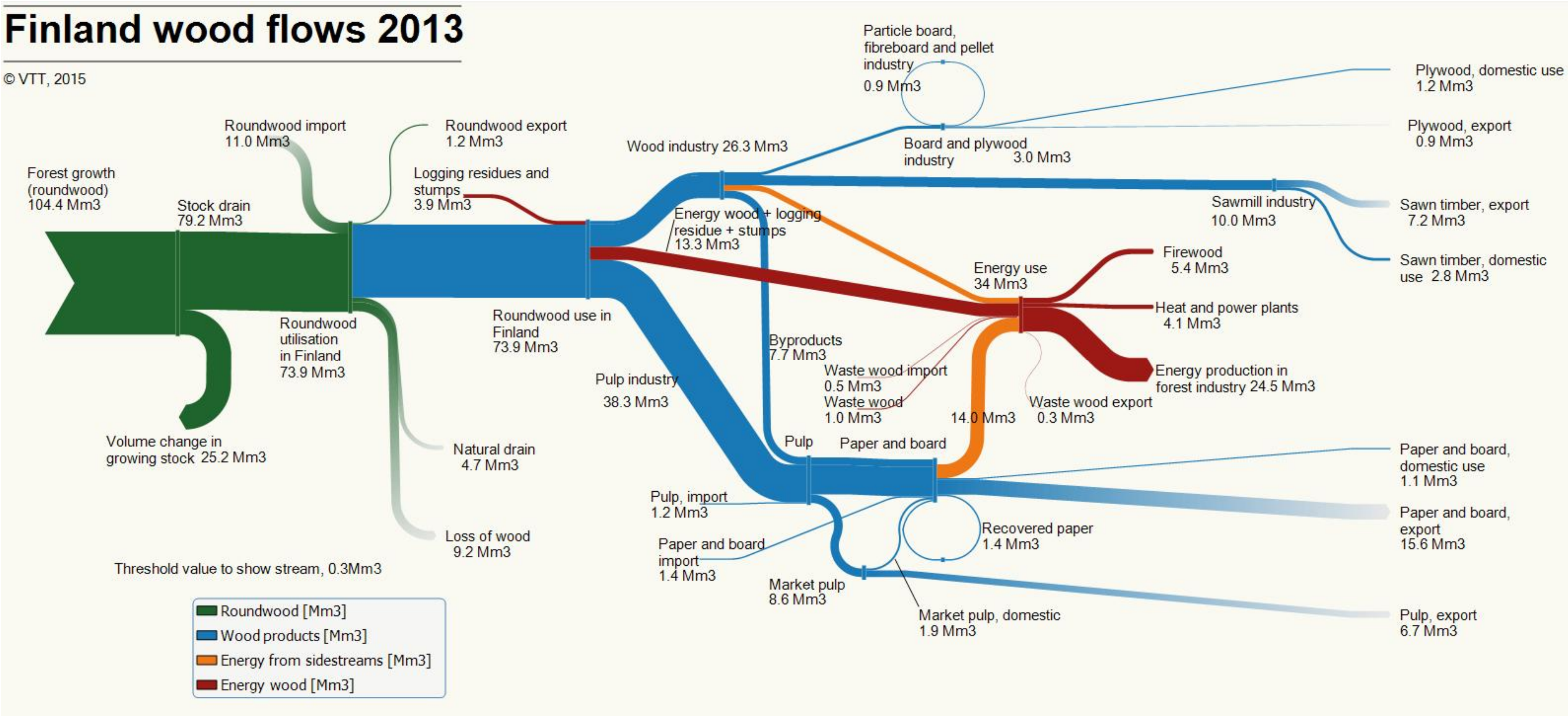
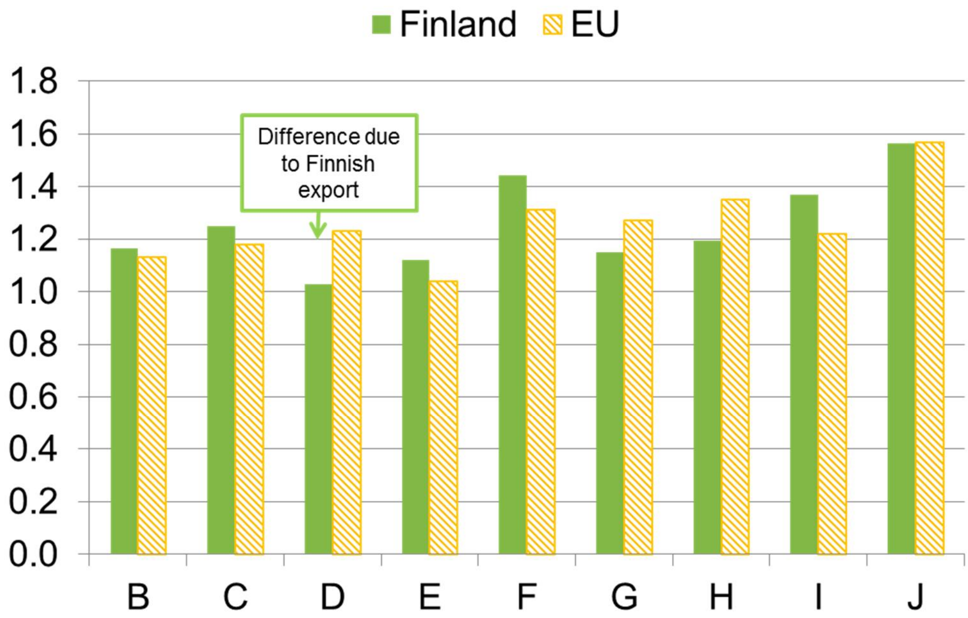


Figure 7 Wood flows in Finland (VTT 2015). The threshold value for showing the streams is 0.3 Mm3. Therefore, e.g. the production of tall oil products is not visible in figure.

The cascading factors in Finland and in the EU are presented in Figure 8. It can be seen that the cascading factor for recycling in products (factor D) is significantly lower for Finland than for the EU, due to export of products. However, the utilisation of residues in energy (I) is higher in Finland than in the EU. Thus the total cascading factor for Finland (1.56) is just slightly lower than for the EU (1.57) (when also the direct energy use of logging residues is included).



	Cascading factors for Finland	
B	Residues in wood products	1.16
C	Residues in energy	1.25
D	Recycling in products	1.03
E	Recovery in energy	1.12
F	Residue utilization	1.44
G	Recycl. + revoc. Cascades	1.15
H	Cascades in products	1.19
I	Residues + recycl. in energy	1.37
J	Total cascades	1.563

Figure 8 Cascading factors for Finland and EU - a comparison (calculated in accordance with Mantau 2012)

The Finnish forest industry has built optimised wood use cycles and integrates over many decades. The direct energy use of streams, like black liquor or bark, can be considered as reasonable in pulp and paper industry with highly developed facilities and elevated self-sufficiency, and sometimes even a surplus in energy use. These residual streams are the most significant renewable energy source in Finland (Figure 9). A strictly defined cascading principle should not be seen as the only option to improve overall efficiency of forest industry but also the benefits of the integrated systems should be recognised. Moreover, the wood use cycle should be considered as a system including the export markets. Some countries are primarily producing virgin fibres while the other ones are the consumers taking the major liability for cascading and efficient use of the products. The paper and board products exported to Europe from Finland are usually efficiently recycled in destination countries. For example, the recovery rate for paper in the EU27 is around 74% and has already almost reached its technically possible maximum (Mantau 2012).

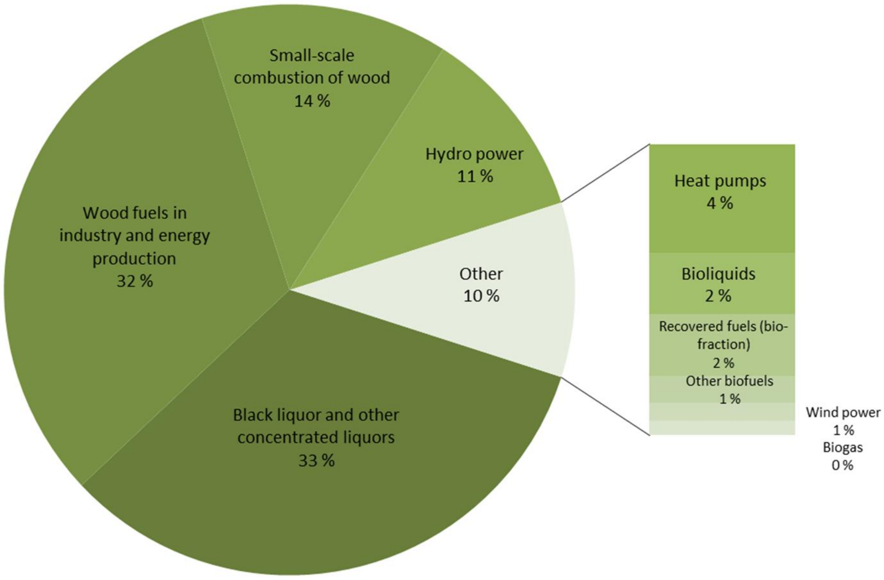


Figure 9 Use of renewable energy in Finland (Statistics Finland 2014)

2.3 Germany[6]

The German forests were severely destroyed by the Second World War and by cuttings for the reparation purposes in the 1940s. Therefore there have been high growth levels during the recent decades and large stocks have been built up, in fact the highest in Europe when measured as density per hectare (Federal Ministry of Food, Agriculture and Consumer Protection 2011). Thus, German forests are now aging and approaching a stage where growth is levelling off. At the same time, demand for wood is expected to rise in Germany. The German Forest strategy 2020 (Federal Ministry of Food, Agriculture and Consumer Protection 2011) therefore calls for increased resource efficiency and cascading.

In Germany, a *trader* country, there is a trade deficit of wood fibre. In 2010, the flow of wood fibres to Germany was 67 million m^3 while the exports were 60.4 million m^3 (Bösch et al. 2015). This trade deficit is mainly generated by recovered wood and paper industries, wood-processing industry and pulp industry. In other industries, i.e. sawmill and wood-based panel industry and paper industry, exports are higher than imports. Similar to Finland, Germany also imports a lot of wood from Russia (Indufor 2013). Moreover, Germany is the largest paper producer (and also consumer) in Europe and therefore also the largest importer of pulp in Europe. According to Indufor (2013), Germany is Europe's largest consumer and producer of particleboard. Most of the trade takes place within the European countries because particle board is mainly consumed by European industries for further processing.

In Germany, it is not allowed to dispose untreated municipal solid waste (including wood) in landfills. Moreover, practically no industrial wood waste is disposed in landfills. Therefore it can be assumed that any wood waste generated is burnt to generate electricity and heat (Bösch et al. 2015). The use of recovered wood for energy is relatively high in Germany, about 11% (Indufor 2013). Moreover, Germany is one of the largest importers of post-consumer wood in the EU and it was also the largest consumer of recovered paper in the EU-27 in 2011 (Indufor 2013). It was also one of the biggest importers of recovered paper in the same year and its paper industry is dependent on recovered paper. Forest residues are widely utilised for energy in Germany as well, their use is about 20% of the total wood raw material use (Indufor 2013).

[6] No suitable figure on the total wood flows of Germany was found, so the main characters are described in the text.

2.4 Austria

Austria is similar to Finland in that forestry and wood processing industries form central elements of its economy (Kalt 2015). However, compared to Finland, there are more imports of wood, the share of wood used for pulp and paper production is lower and the energy use of wood is higher (Figure 10). In Finland almost half of the energy use of wood originates from pulp production, while in Austria the share of black liquor of the total energy production is about 15% (Lang & Nemestothy 2013b).

Moreover, contrary to e.g. Finland, the use of the Austrian forest resources is close to its maximum sustainable level, and thus in order to increase the wood use, more efficient management of the resources, recycling and cascade use would need to be emphasised (Kalt 2015). Round wood flows for sawmill production form the largest wood flows in Austria, followed by pulp and paper, and wood panel industries. Energy uses directly or indirectly related to the wood processing industries account for 45% of all biomass used for energy in Austria (Kalt 2015).

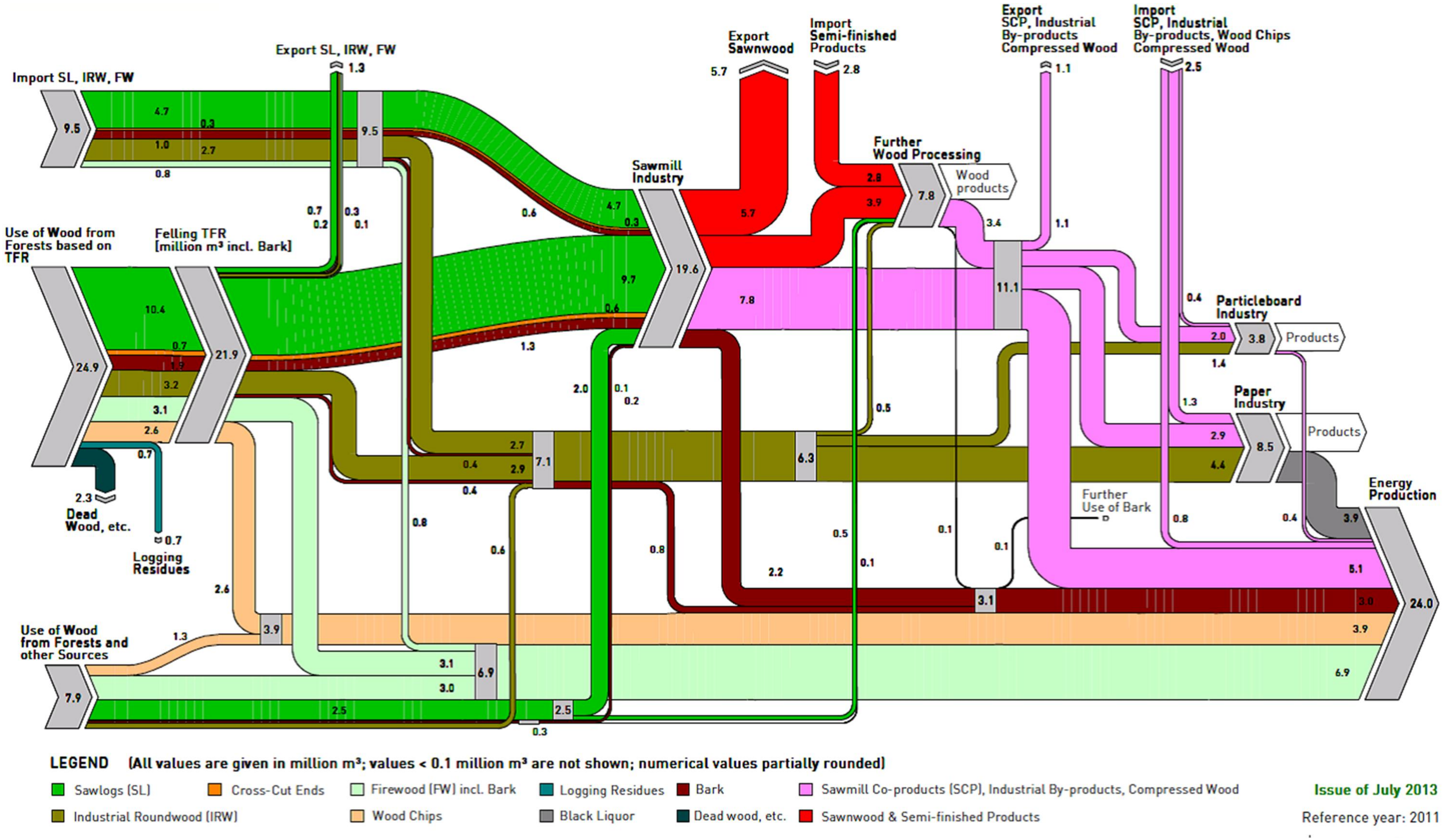


Figure 10 Wood flows in Austria (dry mass) (figure from Lang & Nemesthoty 2013a).

2.5 Netherlands

The origin and use of wood in the Netherlands differ a lot from that in Finland, Austria or Germany. In the Netherlands, imports are a central source of wood and wood products (Figure 11). Considerable amount of paper is imported and the same applies for sawn wood and wood panels. The Netherlands produces some round wood but about half of it is exported. Although the use of pellets has been decreasing during the recent years from 1.59 Mt in 2010 to 0.59 Mt, wood pellets remain the largest group of solid biofuels consumed in the Netherlands (Kwant et al. 2014). Most of the pellets are imported. Compared to the European average, the energy use of wood by households is very low. As the wood biomass resources in the Netherlands are limited, it is understandable that the cascading use is gaining attention in the country.

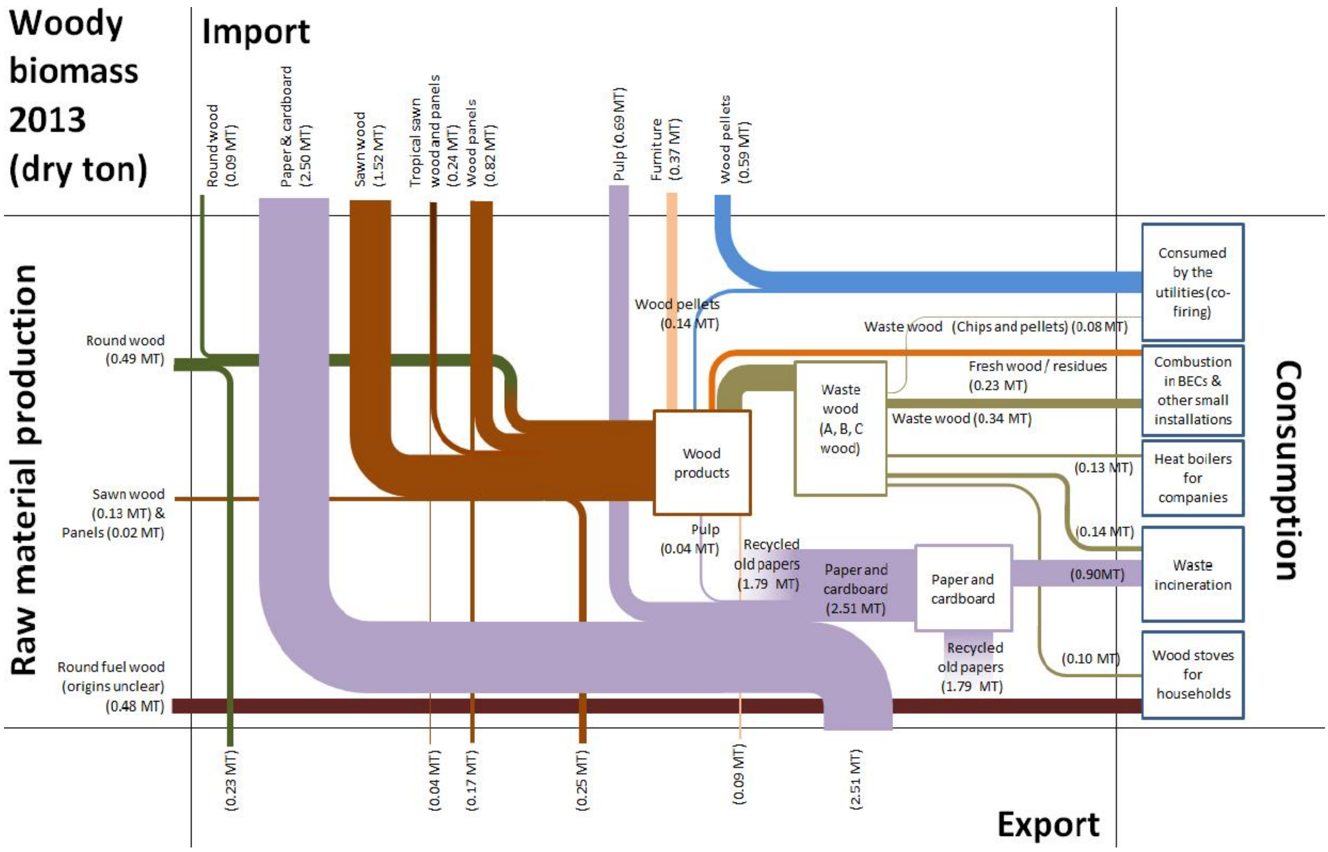


Figure 11 Wood flows in the Netherlands in 2013 (dry mass) (figure from Kwant et al. 2014)

3. Recommendations

1. **Cascading should be considered from the perspective of the whole wood using cycle**

- Woody biomass is a limited resource and its use and the service life of wood fibres should be optimized.
- However, the role of the wood producing countries supplying virgin fibre differs from the consumer countries with more recycling.
- The benefits of recycling should be weighed against its impacts. For example, if residues from wood processing are increasingly used as raw materials of bio-based products, the wood industry sector may become more dependent on external energy resources.

2. **Cascading hierarchy should be applied prudently, considering national and regional circumstances**

- The cascading definition should take into account the efficiency of the recycling of raw materials. For example, if cascading use requires a lot of energy and other auxiliary inputs, it might not be beneficial for the total material and energy efficiency.
- There might be limitations in reasonable cascading cycles e.g. due to logistical challenges.

3. **Cascading principle is not the only way to secure efficient use of natural resources**

- Also other material and energy efficiency measures should be acknowledged such as the use of biomass in so-called biorefineries, where biomass is sustainably processed into a range of marketable products and energy. Thus, also the benefits of integrated systems should be recognised.

4. **Agreement on the cascading definition is needed**

- If cascading principle is used in legislation, a common understanding on the cascading definition is needed. International discussion on cascading principle should therefore be promoted, to understand the regional and national differences.
- In practice, it may be very difficult to find a uniform principle for cascading use of wood that would lead to best possible solutions in countries with various circumstances.
- Controlling of specific cascading cycles could be very challenging, as the biomass flows circulate among several operators, sectors and countries.

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Appendix I

Table A1. *Short explanation of the wood flows and their estimated volume (at year 2013), as presented in Figure 7*

Term in English	Term in Finnish	Mm3	Explanation
FOREST RESOURCES			
Forest resources (not in figure)	Metsävarat	2357	Total forest resources; stem wood with bark altogether 2 357 Mm3. "Stem wood" stands for the volume of the stem with bark starting after stump and ending up to the top. The branches, stump and roots are not included in figure.
Forest growth	Puuston kasvu	104.4	The yearly growth of forests is 104.4 million cubic meters of stem wood. From this, 99.1 Mm3 is situated on forest land that can be used for industrial purposes.
Stock drain	Puuston poistuma	79.2	At 2013, 79.2 Mm3 of roundwood was removed from forests. The stock drain is evaluated by adding to the total round wood removal the estimates of loss of wood and the natural drain of wood.
Volume change in growing stock	Puuston tilavuuden muutos	25.2	The difference of growth and stock drain is 25.2 Mm3, which is accumulated to the growing stock in forest.
Roundwood import	Raakapuun tuonti	11	Import of round wood. Most of wood imported to Finland is bought from Russia (73%).
Roundwood export	Raakapuun vienti	1.2	The total round wood removal (65.3 Mm3) is divided to domestic use (64Mm3) and exports (1.2 Mm3). From total round wood removal 23.8Mm3 is sawlogs and 32.2 Mm3 pulpwood
Natural drain	Luonnon-poistuma	4.7	The natural drain (natural mortality) of wood. A small part of natural drain and logging losses are used, and classified as waste wood.
Loss of wood	Metsä-hukkapuu	9.2	Part of wood harvested (tops, unfound logs, etc.) stays in forest as "loss of wood". Figure presents an estimate of this amount.
Logging residue and stumps	Metsätähde (hakkuutähteet ja kannot)	3.9	Use of logging residues (2.8 Mm3) and stumps (1.2 Mm3) for energy (altogether 3.9 Mm3).
WOOD PRODUCTS			
Roundwood use in Finland	Raakapuun käyttö kotimaassa	73.9	Roundwood use in Finland was 73.9 Mm3. Total use of wood (including also logging residues and stumps) was 77.9 Mm3 (26.3+13.3+38.3 Mm3) in wood industry, pulp industry and direct wood use for energy (energy wood, logging residues, stumps).
"Round wood inventory 2013" (not in figure)	Raaka-puuvarasto	1.2	Computational difference between the total roundwood removed from forest (79.2+11-1.2-4.7-9.2=75.1 Mm3) plus the removal of logging residues and stumps 3.9 and the total use of wood → 75.1+3.9-77.9=1.2 Mm3. The difference occurs for example due to over year stocking of wood etc. No public statistic available on round wood stocks.
Wood industry	Puutuote-teollisuus	26.3	The use of round wood in wood industry was 26.3 Mm3. Sawmill industry used 89% and board and other wood products industry 11%. Particle- and fibreboard industry mostly use sidestreams.
Board and other	Puulevy- ja	3	Use of round wood in board and other wood products.

wood products	muu puutuote-teollisuus		
Particle board, fibreboard and pellet industry	Lastulevy-, kuitulevy- ja pelletti-teollisuus	0.9	Particle board, fibreboard and pellet industry mostly uses residues from other mechanical industry processes.
Plywood, domestic use	Vaneri, käyttö kotimaassa	1.2	Domestic use of plywood
Plywood, export	Vaneri, vienti	0.9	Export of plywood
Sawmill industry	Sahateollisuus	10	Use of round wood in sawmill industry.
Sawn timber, domestic use	Sahatavara, käyttö kotimaassa	7.2	Export of sawn timber
Sawn timber, export	Sahatavara, vienti	2.8	Domestic us of sawn timber
Byproducts for mechanical and semichemical pulp industry	Mekaaninen ja puolikemi-allinen massa-teollisuus	7.7	Use of byproducts in pulp industry (5.9 Mm3 for chemical pulp, 1.6 Mm3 for to mechanical pulp)
Pulp industry	Massa-teollisuus	38.3	Wood used in pulp industry. 30.5 Mm3 for chemical pulp.
Pulp import	Sellun tuonti	1.2	Import of pulp
Paper and board import	Paperin ja kartongin tuonti	1.4	Import of paper and board
Pulp domestic	Sellu kotimaan kulutus	1.9	Domestic use of pulp
Pulp export	Sellun vienti	6.7	Export of pulp
Recovered paper	Keräyspaperi	1.4	Recovery of paper 0.71 Mt (with filling materials)
Paper and board, domestic use	Paperi ja kartonki kotimaan kulutus	1.1	Domestic use of paper and board.
Paper and board, export	Paperi ja kartonki vienti	15.6	Export of paper and board. (Paper and board includes approx. 3.5 Mt coatings and fillers which are reduced from fibre streams)
Waste 0.27 Mm3 (+to water systems 0.02 Mm3) (not in figure)	Jätteet 0.27 Mm3 (+vesistöihin 0.02 Mm3)	0.29	Waste from paper and board industry to landfills and water systems.
ENERGY USE			
Wood industry byproducts for energy use	Saha-teollisuuden sivutuotteiden energiakäyttö	5.5	Energy use of byproducts
Energy wood, logging residues and stumps	Energiapuu, hakkuutähteet ja kannot	13.3	Direct use for energy
Energy use, pulp industry (black liquor)	Energia sellu-teollisuudessa (mustalipeä)	14	The byproduct of chemical pulp industry (mostly back liquor from the production of sulphate pulp) is used for energy.
Waste wood import	Jätepuun tuonti	0.5	Waste wood used mostly in small scale energy production.
Waste wood	Jätepuu	1	Waste wood in small scale combustion

Waste wood export	Jätepuun vienti	0.3	Exported waste wood
Energy use	Energiakäyttö	34	Total energy wood use (5.5+13.3+14=34 Mm3)
Energy production in forest industry	Energian-tuotanto metsäteol-lisuudessa	24.5	Use of black liquor as energy and the heat plants mostly combusting forest chips, byproducts (chips, sawdust, and bark) and recycled wood.
Heat and power plants	Lämpö- ja voimalaitosten polttopuu	4.1	Use of small-dimensioned wood (delimbed logs, other small dimensioned wood, pulp wood) at heat and power plants.
Firewood	Pientalojen polttopuu	5.4	The small scale use of firewood mostly includes use in households, farms and in service sector (e.g. use of chopped firewood and wood chips). No annual information is available on all streams, for example the statistics for small scale use of saw industry and family houses are gathered every 5-10 years.
Flows below threshold of 0.3 Mm3 are not taken into account	Alle 0.3 Mm3 virtoja ei ole huomioitu		