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Cascading in the wood sector


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SAMENVATTING

Hout is een veelzijdige grondstof die kan worden toegepast in papier, verpakkingsmaterialen, meubelen, in de timmerindustrie en bouw, etc. Hout dient zo hoogwaardig mogelijk te worden toegepast met duurzame productie en herkomst als belangrijke randvoorwaarde. De vraag is wat hier precies wordt bedoeld met "hoogwaardig". In deze studie wordt onderzocht of het concept cascaderen kan helpen deze vraag te beantwoorden.

Dit rapport beschrijft de resultaten van de studie "cascaderen in de houtsector" waarin aandacht wordt besteed aan:

- mogelijke interpretaties van het concept "cascaderen"
- beleidsdoelen waaraan cascaderen in de houtsector kan bijdragen
- het op transparante wijze inzichtelijk maken van de effecten van cascaderen in de houtsector op deze beleidsdoelen.

Verder is onderzocht welke mogelijkheden er binnen de houtsector bestaan om cascadering (verdergaand) toe te passen. Dit heeft geresulteerd in concrete case studies over houtskeletbouw en product- en materiaalhergebruik van houten pallets.

Het concept cascaderen

Als uitgangspunt is een onderscheid gemaakt tussen cascaderen naar tijd, waarde en functie[1]. *Cascaderen in tijd* omvat product- en materiaalhergebruik in de tijd. Dit is internationaal gezien de meest gebruikelijke interpretatie van cascaderen en is ook terug te vinden in de ladder van Lansink. *Cascaderen naar waarde* omvat het idee dat materialen zodanig moeten worden ingezet dat de hoogste waarde wordt gecreëerd, meestal is dit economische waarde, maar dit kan ook betrekking hebben op sociale en milieuwaarde. Cascaderen in functie omvat coproductie van verschillende functionele stromen uit één biomassa soort, ook wel bioraffinage genoemd. In Nederland wordt cascaderen (in waarde) vaak geïnterpreteerd als vaste voorkeursvolgordes in de toepassing van biomassa, zoals in de biobased piramide en de vijf F's: 1. voedsel en diervoeding; 2. fijne en bulk chemicaliën en farmaceutische toepassingen; 3. vezels en biomaterialen 4. brandstof en energie 5. meststof en grondverbeteraars. Echter, de optimalisatie naar waarde hangt af van de gebruikte biomassasoort en de economische, milieukundige en sociale context, en kan niet worden gevangen in een vaste voorkeurslijst. In deze studie wordt cascaderen in tijd gecombineerd met waarde optimalisatie, waarbij waarde wordt gedefinieerd door Nederlandse en Europese beleidsdoelstellingen waaraan de houtsector kan bijdragen.

Beleidsdoelstellingen relevant voor de evaluatie van cascades in de houtsector

Cascaderen in de houtsector kan bijdragen aan de ontwikkeling van een circulaire economie waarin meer waarde wordt gecreëerd met minder materialen. "*A resource-*

[1] Odegard, I, H. Croezen, G. Bergsma (2012). Cascading of biomass, 13 solutions for a sustainable biobased economy, CE Delft.

efficient Europe"[2] is een van de zeven vlaggenschip initiatieven die onderdeel zijn van de Europe 2020 strategie gericht op slimme, duurzame en inclusieve groei. In juni 2013 heeft het Ministerie van I&M een brief[3] "*van afval naar grondstof*" naar het parlement gestuurd waarin de gewenste transitie naar een circulaire economie wordt beschreven en een aantal operationele doelstellingen worden geformuleerd. Sleutelindicatoren zijn materiaalefficiency en materiaalproductiviteit, d.w.z. meer toegevoegde waarde per eenheid gebruikte grondstof.

Ten tweede kan cascaderen in de houtsector bijdragen aan de reductie van broeikasgassen. Houten producten hebben vaak een lagere CO_2-voetafdruk dan het fossiele alternatief. Bovendien hebben houten producten de eigenschap dat ze koolstof vasthouden; een toename van het gebruik van hout leidt tot additionele CO_2-afvang.

De houtsector maakt momenteel een belangrijke bijdrage aan het behalen van duurzame energiedoelstellingen. Cascades in de houtsector eindigen normaliter met energieproductie, echter, door hout in de cascade te houden wordt de energieproductie uitgesteld. Daarom draagt cascaderen van hout niet noodzakelijkerwijs bij aan de duurzame energiedoelstellingen op korte termijn, maar leidt wel tot een stabiele toevoer van hout voor energieproductie op langere termijn.

De duurzame herkomst van het hout toegepast in de cascade is een belangrijke randvoorwaarde, in het bijzonder indien fossiele/minerale producten worden vervangen, waardoor de vraag naar hout toeneemt.

Beleidsinstrumenten relevant voor cascaderen in de houtsector

Diverse beleidsinstrumenten zijn geïdentificeerd die het huidige niveau van cascaderen beïnvloeden of zouden kunnen worden ingezet om cascaderen in de houtsector verder te bevorderen. Het Landelijk Afvalbeheerplan (LAP2) beschrijft minimum standaards voor de verwerking van verschillende soorten afvalhout, zoals oud papier, houten verpakkingsmateriaal pallets en afvalhout. De SDE+ regeling subsidieert duurzame energieproductie met biomassa, inclusief schoon houtafval dat nog gebruikt kan worden voor verdere cascadering. Dit kan een negatieve impact op cascades in de houtsector hebben, zoals geïllustreerd door de afname van materiaalhergebruik van gebruikte houten pallets de laatste jaren. Aan de positieve kant stimuleren fiscale instrumenten als MIA en VAMIL milieuvriendelijke investeringen die cascaderen bevorderen zoals machines om het gebruik van grondstoffen te beperken en machines voor recycling (upcycling, geen downcycling). Overheidsorganisaties passen steeds vaker duurzame inkoop- en aanbestedingsprocedures toe. De Europese commissie heeft een Besluit 529/213/EC genomen aangaande boekhoudregels voor het bijhouden van o.a. opslag van koolstof in geoogste houtproducten, die de lidstaten dienen toe te passen.

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[2] Source: COM(2011) 21 A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy

[3] Van afval naar grondstof. kamerbrief van 20 juni 2013 van W.J. Mansveld, staatssecretaris Ministerie van Infrastructuur en Milieu. Kenmerk IenM/BSK-2013/104405

Meetinstrument voor cascades in de houtsector

Op basis van de evaluatie van relevante beleidsdoelstellingen is een meetinstrument ontwikkeld om cascades in de houtsector te evalueren. De berekening is niet bedoeld om een levenscyclusanalyse (LCA) te vervangen, maar om te belangrijkste impacts van de geselecteerde cascades op relevante beleidsdoelstellingen op een transparante manier inzichtelijk te maken.

Er is een algemene methode voor de kwantitatieve beschrijving van op hout gebaseerde cascades en hun fossiele referenties ontwikkeld. Berekeningen worden gemaakt op basis van functionele eenheden, d.w.z. de dienst geleverd door het product, welke kan worden uitgedrukt als een cyclus (bijvoorbeeld een trip met een houten pallet) of als een tijdseenheid waarin de service geleverd is (bijvoorbeeld een jaar waarin een houten kozijn in een huis zit). Een *cascade* bevat één of meerdere producten die één of meerdere diensten leveren uitgedrukt in functionele eenheden welke elkaar opvolgen in de tijd. De functionele eenheden in de cascade zijn met elkaar verbonden door acties die arbeid, materialen, energie en investeringen vergen en broeikasgassen uitstoten. Iedere functionele eenheid in de cascade wordt vergeleken met een fossiel/mineraal of houten referentiesysteem. De fossiele/minerale referentie is relevant als niet houten producten worden vervangen door houten producten bijvoorbeeld houten kozijnen in plaats van aluminium kozijnen). De resultaten op het niveau van de functionele eenheid kunnen worden geëxtrapoleerd naar het nationale niveau, waarbij gebruik wordt gemaakt van aannames die beschreven zijn in specifieke doelscenario’s. Het meetinstrument bevat de indicatoren op gebied van materiaalefficiency, broeikasgas emissiereductie, koolstofopslag en economische prestaties waarmee de bijdrage van geselecteerde cascades in de houtsector aan beleidsdoelstellingen kan worden gemeten.

Verder wordt in het kader van het meetinstrument aangenomen wordt dat al het hout – al dan niet gecascadeerd – uiteindelijk voor duurzame energieproductie wordt ingezet en dat het hout duurzaam is geproduceerd. Deze aannames moeten bij daadwerkelijke implementatie van de cascade worden geverifieerd. Naast CO_2-emissies dienen in een later stadium ook andere duurzaamheidsaspecten te worden meegenomen, bijvoorbeeld d.m.v. een LCA studie en/of duurzaamheidscertificering.

De Nederlandse houtsector

In Nederland wordt hout veelvuldig toegepast. In 2012 bedroeg was de som van houtimport en productie 29,1 miljoen m^3 rondhout equivalenten[4], waarvan meer dan 95% import. Een grote hoeveelheid hout wordt direct weer geëxporteerd, waarmee het totale jaarlijkse binnenlands gebruik van hout uit 11,7 miljoen m^3 rondhout equivalent bestaat. Het binnenlands houtgebruik wordt verdeeld tussen papier en karton (50%), plaatmaterialen (15%), gezaagd hout (30%) en overig (5%). De huidige status van houtcascadering in de volgende sectoren is beschreven:

- houten verpakkingen
- timmerindustrie en bouw

[4] Probos, “Kerngegevens Bos en Hout in Nederland”, December 2013.

- papierproductie
- meubelindustrie.

Vervolgens zijn (additionele) mogelijkheden voor cascadering geïdentificeerd en beschreven. Uit dit sector overzicht zijn twee cascades geselecteerd voor evaluatie met het meetinstrument: houtskeletbouw en houten pallets.

Case houtskeletbouw

Houtskeletbouw (verder HSB genoemd) is een bouwmethode waarin woningen worden geassembleerd met pasklare prefab elementen. Er zijn in Nederland naar schatting 120.000 HSB woningen gebouwd op een totaal bestand van 7,15 miljoen woningen. De totale emissiereductie van een HSB woning t.o.v. een traditionele woning is 6,24 ton CO_2-eq per standaard twee-onder-één kap woning, of zelfs 6,62 ton/woning als biobased cellulosevezels zijn toegepast als isolatiemateriaal in plaats van minerale wol. Bovendien wordt 11,3 ton extra CO_2 opgeslagen in het hout van de HSB woning. Als de jaarlijkse bouw van HSB woningen zou toenemen van zo'n 1500 naar 10.000 woningen per jaar, hetgeen overeenkomt met een marktaandeel van 15%, dat ook gehaald wordt in omringende landen, dan zou dit resulteren in de verwijdering van 149.000 ton CO2-eq per jaar. Vooroordelen rondom brandwerendheid, geluidsisolatie, onzekerheid omtrent kwaliteit en waardevastheid etc. vormen de belangrijkste belemmering tot verdere toepassing van HSB in Nederland. Promotie, voorlichting en onderwijs zijn nodig om de HSB toepassing op grotere schaal mogelijk te maken. Aan de positieve kant is HSB als bouwmethode bij uitstek geschikt om energie-efficiënte gebouwen te realiseren, waardoor er kan worden geprofiteerd van de trend richting steeds strengere eisen op het gebied van energieverbruik en isolatie.

Houten pallets

De houten verpakkingen sector heeft betrekking op het produceren en repareren van houten pallets, kratten, boxen en industriële verpakkingen. Product hergebruik van pallets is vanzelfsprekend in deze sector. Gestandaardiseerde pallets worden meestal gerecycled, onder andere in open pools, d.w.z. door vrije handel in gestandaardiseerde pallets, en in gesloten pools, waarbij de gestandaardiseerde pallet in eigendom blijkt van één organisatie. Extra product hergebruik kan leiden tot extra CO_2-emissiereductie en materiaalbesparing (beide 6% bij 10% extra trips per pallet). Echter, in de praktijk wordt de meeste aandacht besteed aan materiaalhergebruik, omdat de sector in de Raamovereenkomst Verpakkingen 2013-2022 is overeengekomen dat in 2022 een percentage van 45% materiaalrecycling zal worden bereikt. Dit percentage is als doelscenario gebruikt in deze studie. Het baseline scenario gaat uit van 25% materiaalrecycling, de huidige materiaalhergebruikdoelstelling. Deze toename van 25% naar 45% materiaalrecycling leidt tot een jaarlijkse besparing van 66.700 ton hout per jaar ofwel een reductie 17% in materiaalverbruik.

Conclusies en aanbevelingen

Cascaderen in de houtsector kan worden beschreven door (een combinatie van) fossiele/minerale product substitutie, product hergebruik en materiaalhergebruik. Elk van deze acties heeft een specifieke impact op het gebied van CO_2-reductie, koolstofopslag, materiaalefficiency en materiaalproductiviteit. Dit wordt geïllustreerd in de onderstaande tabel.

Tabel 1 Matrix waarmee de belangrijkste impacts van cascaderende acties (product substitutie, product hergebruik en materiaalhergebruik) op beleidsdoelen (CO_2-reductie, koolstofopslag, materiaalefficiency en materiaalproductiviteit) inzichtelijk worden gemaakt.

Cascaderende actie / Beleidsdoel	**Product substitutie fossiele/minerale materialen door hout**	**Product reuse**	**Materiaal recycling**
Koolstofopslag	Positieve impact (per definitie)	Negatieve impact (per definitie)	Geen impact (per definitie)
CO2 emissiereductie	Positieve impact aannemelijk	Positieve impact	Positieve impact aannemelijk
Materiaalefficiency (en -productiviteit)	Niet op voorhand bekend	Positieve impact	Positieve impact

In de nabije toekomst waarin de vraag naar biomassa voor biobased producten en energie zullen toenemen, wordt cascaderen steeds belangrijker. Enkele maatregelen om cascaderen te bevorderen worden beleidsmakers ter overweging aanbevolen:

- Het is van belang dat de minimum standaarden zoals geformuleerd in het Landelijk Afvalbeheerplan (LAP2) worden toegepast en gehandhaafd in de praktijk. Voorts geeft sector plan 41 over verpakkingsmateriaal “materiaal hergebruik” als minimum standaard terwijl sector plan 36 over afvalhout “energiegebruik” als minimum standaard hanteert. Het is aanbevolen om dezelfde minimumstandaard te hanteren in beide sectoren om materiaal recycling te bevorderen.
- Het is zinvol om na te gaan of bepaalde biomassasoorten die geschikt zijn voor materiaalrecycling uit te sluiten van duurzame energiesubsidies. Gegeven het internationale karakter van de biomassahandel, is een dergelijke maatregel mogelijk alleen effectief indien deze op Europese schaal wordt genomen. Verder dient er voldoende marktvraag naar materiaalrecycling zijn.
- Het is aanbevolen om de impact van koolstofopslag in de houtsector te onderzoeken en te relateren aan koolstofopslag in bossen. Dit kan worden gecombineerd met de inventarisatie van koolstofopslag in geoogste houtproducten die de nationale overheid dient uit te voeren in het kader van de Beslissing 529/2013/EC aangaande boekhoudregels voor het bijhouden van o.a. opslag van koolstof in geoogste houtproducten.
- Het is aanbevolen om geen vastomlijnde prioritering van cascadering op te stellen en deze algemeen geldig te verklaren voor alle soorten biomassa; het is beter om de verdiensten van cascaderen te evalueren met de tool ontwikkeld in deze studie.

SUMMARY

Wood is a versatile raw material that can be used for various applications in the paper, packaging, furniture, and timber industries, building sector, etc. Wood should be produced in a sustainable way and used in the best possible way. A key question is what the "best possible way" means. The concept of cascading can help to answer this question.

This report covers the results of the study "cascading in the wood sector" and investigates

- the possible interpretations of the concept of "cascading";
- to what policy targets the wood sector could contribute and;
- how the effects of cascading in the wood sector could be measured in a transparent way.

Based on the current level of cascading in the wood sector, opportunities for further cascading were identified and elaborated in two case studies, one on timber frame construction and one on wooden pallets.

The concept of cascading

As a starting point, a distinction is made between cascading in time, value and function[5]. *Cascading in time* covers subsequent product and material reuse from a temporal viewpoint. This is internationally the most common interpretation of cascading and has a strong link with "Lansink's Ladder". *Cascading in value* covers the idea that materials should be used in such way that it creates the highest value, commonly referring to economic value added but this could be supplemented with indicators for social and environmental value. *Cascading in function* covers coproduction of different functional streams from a single biomass stream, often referred to as biorefining. In the Netherlands cascading (in value) is often interpreted in pre-set lists such as the biobased pyramid and the five F's: 1. Food & feed; 2. Fine & bulk chemicals & pharma; 3. Fibre & biomaterials; 4. Fuels & energy; 5. Fertiliser & soil conditioners. However, value optimisation depends on the biomass type used and on the economic, environmental and social context, which cannot be captured in a fixed preference list. This study focusses on cascading in time combined with value optimisation, with value being based on relevant Dutch and European visions, targets, and policies to which the wood sector can contribute.

Policy targets and vision relevant for evaluation of cascades in the wood sector

Cascading in the wood sector can contribute to the development of a circular economy in which more value is added with less material use. *"A resource-efficient Europe"*[6] is one of seven flagship initiatives that are part of the Europe 2020 strategy aiming to deliver smart, sustainable and inclusive growth. In June 2013 the Dutch Ministry of Infrastructure

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[5] Odegard, I, H. Croezen, G. Bergsma (2012). Cascading of biomass, 13 solutions for a sustainable biobased economy, CE Delft.

[6] Source: COM(2011) 21 A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy

and the Environment (I&M) submitted a letter to the parliament "*From waste to resource*"[7] that describes a desired transition from a linear to a circular economy and formulates a number of operational targets. Key indicators are resource efficiency and resource productivity, i.e. value added per unit of resource used.

Secondly, cascading in the wood sector can contribute to a reduction of greenhouse gas emissions. Wooden products often have a lower carbon footprint than their fossil reference products. Moreover, wooden products have the ability to store carbon, helping to avoid carbon emissions in the next decades.

The wood sector currently makes a significant contribution to meeting renewable energy targets. Cascades in the wood sector normally end with energy generation, however, when wood remains in the cascade the energy generation step is postponed. Therefore, cascading of wood does not contribute to short term renewable energy targets but leads to a steady sustainable supply of wood for energy generation in the long term.

The sustainable sourcing of the wood used in the cascade is an important precondition, especially if the cascade replaces fossil products thereby increasing the demand for wood.

Policy instruments relevant for cascading in the wood sector

Several policy instruments were identified that influence the state of cascading, or could promote further cascading, in the wood sector. The Dutch national waste management plan (LAP2) describes minimum standards for processing of various types of wood waste, like waste paper, wooden pallets, and waste wood. The Dutch SDE+ regulation subsidises renewable energy production from biomass including clean waste wood that still could be used for further cascading in the wood sector. This has a negative impact on cascading in the wood sector, as illustrated by a drop in the rate of material reuse for used wooden pallets in recent years. On the positive side, the fiscal instruments MIA and VAMIL already stimulate environmental-friendly investments that promote cascading like machinery to reduce the use of resources and machinery for recycling (upcycling, no downcycling). Government institutions increasingly apply sustainable procurement procedures. The European Commission has submitted Decision 529/2013/EC on accounting rules for carbon storage in harvested wood products that could increase the visibility of on-going and new mitigation efforts in the wood sector.

Measurement instrument for cascades in the wood sector.

Based on the evaluation of relevant policy targets and visions, a measurement instrument has been developed to evaluate concrete cascades in the wood sector. The calculation method does not intend to replace a full Life Cycle Assessment (LCA), but is meant to provide the main impacts of selected cascades on relevant policy targets in a transparent manner.

[7] Van afval naar grondstof. kamerbrief van 20 juni 2013 van W.J. Mansveld, staatssecretaris Ministerie van Infrastructuur en Milieu. Kenmerk IenM/BSK-2013/104405

A general framework for a quantitative description of the wood based cascade and its wood based or fossil reference has been established. Calculations are made on the level of a *functional unit*, e.g. the service delivered by the product, that can be expressed as a cycle (for instance a trip of a wood pallet) or as a unit of time the service is provided (for instance a year that a window frame is functional in a house), whatever is most appropriate. A *cascade* contains one or more products that generate one or more services expressed in functional units that take place after each other in time. The functional units in a cascade are linked with each other by actions that require labour, materials, energy and investments and cause carbon emissions. Each functional unit in the cascade will be compared to a fossil/mineral or wooden reference system. The wooden reference system is relevant in case extra cascading steps are made in an existing cascade (for instance extra product reuse of wooden pallets). The fossil/mineral reference is relevant if non biomass products are replaced by wooden products (for instance by using wooden window frames instead of aluminium frames). Based on the results on the level of a functional unit the impact of the cascade can be extrapolated to a national level, using assumptions described in specific goal scenarios. The measurement instrument contains the following indicators to measure the contribution of selected cascades in the wood sector to policy goals:

Resource efficiency:

- resource efficiency: kg of materials used per functional unit;
- recycling rate: tonnage of used materials that is collected for material reuse divided by total amount of material that is discarded;
- number of product cycles / product lifetime.

Greenhouse gas emission savings

- carbon footprint: greenhouse gas emissions per functional unit;
- relative carbon emission savings (compared to reference case);
- absolute carbon emission savings (kg CO_2-eq/functional unit);
- carbon stored in harvested wood products: using the carbon stock change model of IPCC (2006)[8] and the European Commission.

Economic performance:

- gross value added: output minus intermediate consumption;
- resource productivity: value added per kg material; this indicator is suggested as a main indicator by the Roadmap to a Resource Efficient Europe;
- employment generation.

It is assumed that wood – cascaded or not – will eventually be used for renewable energy generation. Also sustainability of the source of the wood and impact of the cascade on demand for wood will be monitored because these are relevant preconditions for any usage of wood. The impact of sustainability risks during processing like non-carbon

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[8] IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, chapter 12: Harvested wood products.

emissions to the air will be identified and assessed as well but without going into the level of detail of a full fledged LCA study.

The Dutch wood processing sector

Wood use in the Netherlands is widespread. In 2012 the sum of wood import and production stood at 29.1 million m^3 of roundwood equivalents[9], of which more than 95% was imported. A large amount of that wood was only in transit and exported again, leading to a total in-country use of 11.7 million m^3 of roundwood equivalent. Wood use in the Netherlands is commonly subdivided by application into paper and cardboard (50%), panels (15%), sawn wood (30%) and other uses (5%). The current status of wood cascading in the following sectors is described:

- Wooden packaging sector
- Timber and construction sector
- Paper production
- Furniture production

Subsequently options for (increased) cascading have been identified and described.

<u>Wooden packaging sector</u>

The wooden packaging sector involves the production and repair of wooden pallets, crates, boxes, and industrial packaging. The wooden packaging sector applies the cascade principle in different ways. Material recycling of pallets is advocated by agreements, but recently material recycling rates are dropping, with low demand from the particle board industry and renewable energy subsidies generally considered the most important causes. Product reuse is applied on a large scale as well.

<u>Timber and construction sector</u>

The timber and construction sector is a large consumer of wooden products. Customers in this sector can be subdivided into residential and utility construction (in Dutch: B&U) and infrastructural works in civil engineering (in Dutch: GWW). In the timber and construction sector four main types of cascading can be identified that focus on:

1. product and material reuse of wood (promotion of design and construction practices enabling wood to be reused after its functional use, for instance avoiding the use of plastic coatings that renders cascading impossible)
2. replacement of fossil products by wooden products (carbon emission reduction and storage for instance by timber frame construction, use of wood in window frames, bridges, cellulose based insulation materials etc.)
3. lifetime extension of wooden products (proper construction, wood preservation)
4. efficient use of wood (for instance use of I-bars with a H-profile, saving wood).

<u>Paper and cardboard sector</u>

The Dutch paper and cardboard sector produced 2.7 million tonnes of paper and cardboard in 2011[38]. In the Netherlands most paper contains a high content of recycled waste paper (80% in 2011[38]). Options to further increase material recycling are therefore

[9] Probos, "Kerngegevens Bos en Hout in Nederland", http://www.probos.nl/publicaties/kerngegevens/40-kerngegevens2013 December 2013.

limited. Cellulose fibres that are too short for further recycling could still be used for chemicals production, for instance biobased building blocks that could be used for bioplastics production. Also steps towards higher levels of resource efficiency are still possible, as illustrated in the project "sustainable book" in which sustainable practices to reduce e.g. losses during the cutting of paper were tested.

Furniture sector

The furniture industry used about 980,000 m^3 of wood in 2001[10]. For the most part use was made of board materials and sawn wood. Board materials like particle board are often partly based on wood residues. The current trend of explicit use of recycled materials like scaffolding wood for furniture is another good example of cascading in the furniture sector.

Based on this sector overview and possible cascades, two cases were selected: timber frame construction and wooden pallets.

Case timber frame construction

Timber frame construction (in Dutch: houtskeletbouw, further referred to as HSB) is a building method in which houses are assembled using quick fix prefab elements. It is estimated that on a total of 7.15 million houses 120,000 houses have been built with timber frame construction. The total emission reduction of the timber framed house compared to the traditional house is 6.24 tonnes CO_2-eq per standard duplex house, or even 6.62 tonnes/house if biobased cellulosic fibres instead of mineral insulation materials are used. In addition 11.3 tonnes extra CO_2 is stored in the applied woody materials. If the number of HSB houses built annually could be increased from the average of 1500 to 10,000 houses/year, corresponding to a market share of about 15% as found in neighbouring countries, this would lead to the removal of 149,000 tonnes of CO_2-eq from the air. Preconceptions about HSB such as poor fire resistance, poor noise insulation, uncertainty about general quality and value stability, etc. are main barriers to its further application in the Netherlands. Promotion and education will be needed to support HSB to be applied on a wider scale. HSB is a very effective building method to produce energy efficient buildings, and the trend towards stricter energy efficiency and insulation requirements creates opportunities for its increased use.

Wooden pallets.

The wooden packaging sector involves the production and repair of wooden pallets, crates, boxes, and industrial packaging. Product reuse is key to the use of wooden pallets. Standardised pallets are mostly recycled, among others in both open pools, i.e. by free trade in standardised pallets, and in closed pools, in which the standardised pallet remains in ownership of a single organisation. Increased product reuse would avoid CO_2-emissions related to production of new pallets and material savings (both 6% if 10% more trips are made per pallet). However, in practice most attention is paid to material, rather

[10] Stichting Bos en Hout, Houtverbruik in de meubel- en emballageindustrie, http://www.probos.nl/home/bosbericht_bestanden/bosenhoutberichten2001-06.pdf, 2001

than product, recycling, as the sector has agreed to reach a level of 45% material recycling by 2022 in the Packaging Agreement ("*Raamovereenkomst Verpakkingen 2013-2022*"). The 45% level is set as the goal scenario in this study. The baseline scenario is 25% material recycling, which is today's minimum material recycling level. An increase of 20 percent-points, from 25% to 45% material recycling, leads to avoiding the use of 66,700 tonnes of wood per year, which is a material saving of 17%.

Conclusions and recommendations

Cascading in the wood sector can be described by (a combination of) fossil/mineral product substitution, product reuse and material recycling. Each of these aspects has specific impacts to targets in the field of CO_2-reduction, carbon storage, resource efficiency and resource productivity. This is illustrated in Table 2.

Table 2 Matrix showing the main impacts of cascading actions (product substitution, product reuse and material recycling) on policy targets (carbon storage, carbon emission, reduction, resource efficiency)

Cascading action / Target	**Product substitution fossil/mineral materials by wood.**	**Product reuse**	**Material recycling**
Carbon storage	Positive impact (by definition)	Negative impact (by definition)	No impact (by definition)
Carbon emission reduction	Likely positive impact	Positive impact	Likely positive impact
Resource efficiency (and resource productivity)	Not known in advance	Positive impact	Positive impact

In the near future, with an increasing demand for biomass for biobased products and energy, cascading will be become ever more important. Some measures to promote cascading are recommended for consideration by policy makers:

- In order to promote cascading in the wood sectors the minimum standards as formulated in the Dutch Waste Management Plan (LAP2) should be enforced. Sector plan 41 on packaging materials uses "material recycling" as minimum standard, while sector plan 36 on waste wood uses "energy use" as minimum standard. It would make sense if the same minimum standard would be applied in both sector plans in order to promote material recycling.
- It is worth to explore if selected biomass types, suitable for material recycling, can be excluded from renewable energy subsidies. Given the international character of the biomass trade, this type of measure might only be effective if taken on a European level. Furthermore, there should be sufficient demand from the side of material recycling.
- It is recommended to investigate the impact of carbon storage in the wood sector together with carbon storage in the forest. This could be combined with the inventory on carbon storage in harvested wood products that all EU member

states have to carry out in the frame of the recently adopted Decision 529/2013/EC[11].

- It is recommended not to rigidly prescribe fixed cascades that are valid for all biomass types, but to evaluate the full benefits of cascading by using the evaluation tool developed in the frame of this study.

[11] Decision 529/2013/EU on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities.

1 INTRODUCTION

1.1 Background

Wood is a versatile raw material that can be used for various applications in the paper, packaging, furniture, and timber industries, building sector, etc. After the original use wooden products can be reused and recycled, and finally combusted in a heat and power installation or in a heat boiler. Wood should be produced sustainably and used in the best possible way. A key question is what the “best possible way” means. The concept of cascading can help to answer this question. Cascading is however a concept that can be interpreted in multiple ways, depending on the background and interest of the user. Companies in the wood sector would like to work toward a clear understanding of the cascading concept, and to evaluate cascades in a transparent and objective way from business perspective. Policy makers are interested in the potential contribution of wood cascading towards the development of environmental, economic and societal policy targets.

1.2 Objective

The objective of this study is to develop the concept of cascading into a measurement instrument for evaluation of cascades in the wood sector and to provide concrete and practical policy recommendations on what is needed to achieve environmental, economic and societal targets by cascading in the wood sector.

1.3 Target group

The primary target group consists of innovative companies in the wood sector and organisations active in the mobilisation of biomass (such as Platform Wood in the Netherlands and the Biomassaforum). Also policy makers at other organisations in the civil society active in biomass valorisation are part of the target group.

1.4 This report

This report presents the results the project “Cascading in the wood sector”.

Development of the concept of cascading

In chapter 2 the concept of cascading is studied in more detail. The study of Odegard et al (2012)[12] differentiates between cascading in time, value and function and will be used as starting point. The analysis also includes “Lansink’s Ladder” as applied in the Dutch national waste management plan and assesses the role of value pyramids and other

[12] Odegard. I, H. Croezen, G. Bergsma (2012) Cascading of biomass, 13 solutions for a sustainable bio-based economy, making better choices for use of biomass residues, by-products and wastes.

"ladders". The chapter concludes with an interpretation of the concept of cascading that is most relevant for the wood sector.

Policy targets and visions relevant for the evaluation of cascades in the wood sector
Cascading of biomass can help to achieve policy targets. Policy targets addressing carbon emission reduction, energy generation, resource efficiency, and waste management are discussed in chapter 3. Sustainability of the origin of the biomass will be discussed briefly as it is a basic condition for the use of biomass in any application, cascaded or not.

Cascading in the wood processing sector
In chapter 4 several options for cascading are identified for the different sub-sectors of the wood sector: the wooden packaging sector, the timber and construction sector, the paper and cardboard sector, and the furniture sector.

Cascade evaluation method
Based on the general concept of cascading and the relevant policy targets a cascade evaluation method has been developed to describe the impacts of the cascades on the basis of resource efficiency, carbon emission savings and carbon storage, and economic performance relative to a fossil or wooden reference system. The method consist of a step plan and a set of indicators that are presented in chapter 5.

Case studies timber frame housing and wooden pallets
Based on a stakeholder meeting, organised together with PHN, and follow-up discussions timber frame construction and wooden pallets have been selected for further evaluation. The results of these interesting case studies are provided in chapter 6 and 7.

In chapter 8 conclusions and recommendations are presented.

1.5 Acknowledgement

The project was guided by a Steering Committee with the following members:

Jaap van den Briel	Platform Wood in the Netherlands
Bert Kattenbroek	Platform Wood in the Netherlands
Rob Cornelissen	Ministry of Infrastructure and the Environment
Tjitske IJpma	Ministry of Infrastructure and the Environment
Peter van der Knaap	Ministry of Economic Affairs
Jan Iepsma	Netherlands Enterprise Agency

Furthermore, several Members of Platform Wood in the Netherlands have been consulted for expert advice:

B. Kattenbroek	Dutch Joinery Association (NBvT)
G.J. Koopman	Royal VNP
A.J.M. Ceelaert	EPV
C. Boon	AVIH / VHN
P.A. van den Heuvel	VVNH

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We thank all contributors for their valuable input and feedback.

The project has been carried out by BTG Biomass Technology Group B.V (BTG) and Institute for Energy and Environmental Research Heidelberg GmbH (IFEU) on behalf of the Ministry of Economic Affairs and the Netherlands Enterprise Agency (RVO), contact person Jan Iepsma.

2 DEVELOPMENT OF THE CONCEPT OF CASCADING

In the report *"Cascading of biomass"*[13] three different types of cascading are defined that will be used as a starting point in the development of the cascading concept to be applied in the wood sector.

Cascading in time, value and function
Source: Odegard, I, H. Croezen, G. Bergsma (2012)

1. Cascading in time
Subsequent use in time ensures a long(er) life span of the biomass; the option which leaves as many as possible options at the end-of-life open, should be preferred. A typical example is paper recycling.

2. Cascading in value
Cascading in time can be optimised by cascading in value to ensure the highest value possible is achieved when choosing between alternatives, and the value over the whole life cycle is maximised. An example is use of straw for ethanol production (which can subsequently be used to produce e.g. plastics), which provides benefits with respect to the original function.

3. Cascading in function
What people call 'cascading in function' is actually co-production, which can be achieved by using a bio-refinery. Co-production is the production of different functional streams (e.g. protein, oil and an energy carrier) from a single biomass stream, maximising total functional use. A nice example is a grass refinery. Of course, after cascading in function cascading in value or time follows.

2.1 Cascading in time

Cascading in time is the (internationally) most common interpretation of cascading and covers reuse / recycling of materials over time in similar or different applications. The Dutch national waste management plan 2009-2021 (LAP2) distinguishes three types of useful application by reuse:

a. Useful application by product reuse
b. Useful application by material reuse
c. Useful application by use as fuel.

By applying cascading in time (or simply "cascading"), the same unit of biomass can have more useful applications over a longer period of time. It is a way to reach resource

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[13] Odegard, I, H. Croezen, G. Bergsma (2012). Cascading of biomass, 13 solutions for a sustainable biobased economy, CE Delft.

efficiency. Another advantage is that carbon is stored in products; additional CO_2 storage can be created by application of cascading if this was no common practice yet.

Cascading in time is already applied in the wood sector, for instance in the paper industry (paper recycling), packaging industry (recycling of pallets) and particle board industry (particle board production from residual wood and used wood).

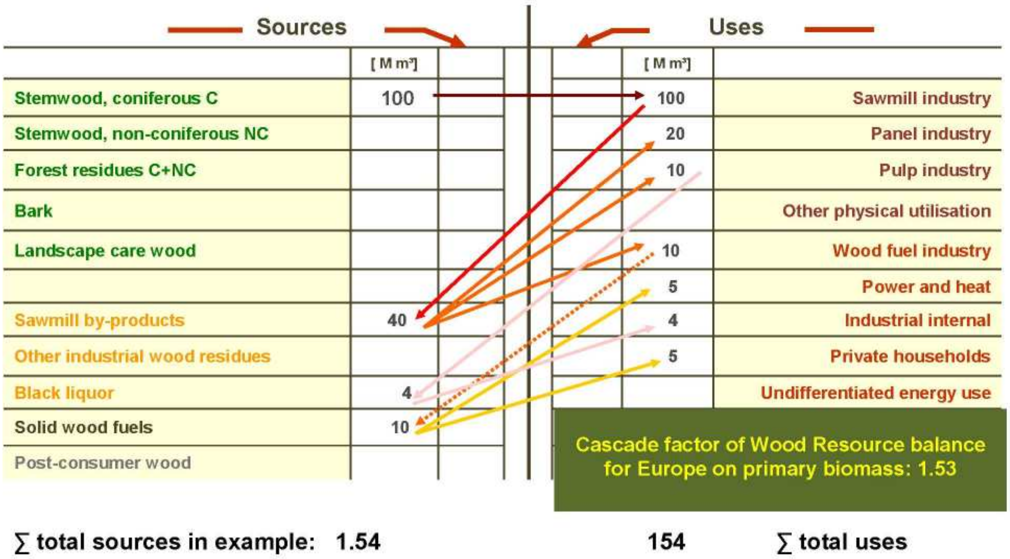

Figure 1 Example of cascading in the wood sector. Source: Mantau (2011)

2.2 Cascading in value

Cascading in value is the assessment and selection of those cascades (in time) with the highest value added. The concept of value is traditionally expressed in economic terms but could be extended to include environmental, social and moral aspects. Cascading in time can be optimised by cascading in value to ensure the highest value possible is achieved when choosing between alternatives, and the value over the whole life cycle is maximised. Cascading in value does not exist without cascading in time: without cascading in time, cascading in value becomes a (simple) selection process of what application is preferred with a given type of biomass, with or without cascading.

This selection process of the highest value added applications, with or without cascading, is covered by the various "ladders" and "pyramids" that have been developed recently, so-called[14] in analogy of "Lansink's Ladder". Examples are "Van Gerven's Ladder" on biomass use and "Moerman's Ladder" for food & food waste. The biobased pyramid

[14] Lansink's Ladder is however different, it does not state what *application* has the highest value, it states what *process* is preferred. Moreover, Lansink's Ladder is applied in the highly regulated waste sector, it can be questioned how it could be applied under normal market conditions where each producer in principle is free to produce whatever he can sell.

presented in the vision document of the Dutch government on the biobased economy in the energy transition of 2007[15] is also widely known and used to promote the applications with the highest value added first. Internationally this bioenergy pyramid ranking pharmaceuticals (fine chemicals), food, feed, (bulk) chemicals, fuel and fire is known as the five F's. See Figure 2.

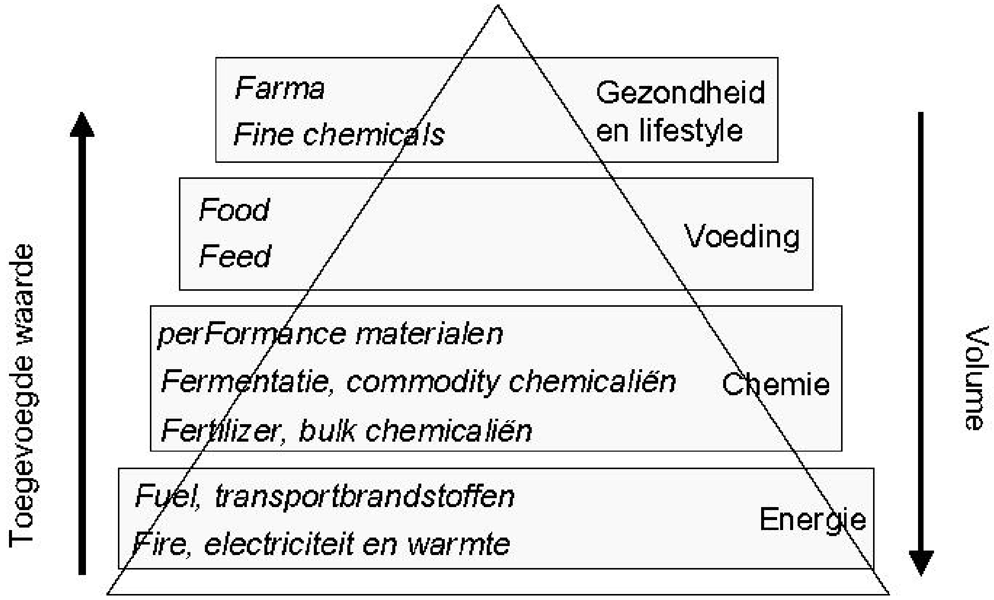

Figure 2 The biobased pyramid. Source: LNV 2007

Another example of the five F's can be found in BACAS (2011)[16]

1. Food & feed;
2. Fine & bulk chemicals & pharma
3. Fibre & biomaterials
4. Fuels & energy
5. Fertiliser & soil conditioners

In an undisturbed market, biomass will be used in the application with the highest economic value added, which is usually food and feed. In case of chemicals and energy production, fossil alternatives are available, and the value added depends on the difference in production costs between bioenergy and the fossil alternative. If fossil raw materials become scarce and expensive, or if the use of biomass for energy and chemicals is promoted, it becomes more attractive to use biomass for chemicals and energy production. The biobased pyramid and the ladders of Van Gerven and Moerman are not established to only present the economic status quo. The pyramid also reflects the food-

[15] Ministerie van LNV (2007) Overheidsvisie op de bio-based economy in de energietransitie, 'de keten sluiten'.

[16] BACAS (2011) Industrial Biomass: source of chemicals, materials, and energy! Implications and limitations of the use of biomass as a source for food, chemicals, materials and energy. Royal Belgian Academy Council of Applied Science (BACAS)

versus-fuel debate, by putting food higher in the hierarchy than fuels, which is usually (but not necessarily always) true from the perspective of economic value added but in fact is a moral statement.

The relevance of the actual application of ladders and pyramids to biomass other than food/feed crops could be debated. For instance, starch could be used for food, feed, chemicals (like bioplastics) production, while woody biomass is less versatile in this context and usually not used for food/feed production.

The concept of value optimisation is useful in combination with cascading in time. It makes however no sense to develop a fixed ladder for biomass in general. Value optimisation depends on many economic, environmental and social aspects and cannot be fixated in a one-size-fits-all ladder. In fact, for each biomass type and economic and environmental situation, a separate pyramid or ladder should be developed. In this study the concept of value optimisation will be elaborated in more detail for relevant cascades in the wood sector.

2.3 Cascading in function

Odegard, I, H. Croezen, G. Bergsma (2012) define cascading in function as co-production that can be achieved by using a bio-refinery. In their approach, co-production is the production of different functional streams from a single biomass stream, maximising total functional use. The paper industry is a good example of a conventional biorefinery, producing paper as main product while the co-product black liquor can be used for various applications, although energy recovery is most common. Cascading in function presents a technical viewpoint and might implicitly promote resource efficiency, as all parts of the biomass should be utilised as much as possible. However, biomass can also be used efficiently if it only serves a single function.

In this study cascading in function will not be used as a steering mechanism for cascade development, as it has no clear advantages over cascading in time combined with value optimisation.

2.4 Conclusion

This study will focus on cascading in time in which the functional use of wood in time is maximized. The evaluation and selection of the best cascading options will take place by value optimisation. Value will be defined in a broad way, covering economic, environmental and possibly other factors. The definition of value will be based on the Dutch and European visions, targets, and policies as presented in the next chapter.

3 POLICY TARGETS AND VISIONS RELEVANT FOR THE EVALUATION OF CASCADES IN THE WOOD SECTOR

In this chapter a number of European and Dutch policy visions and targets - as well as already implemented policies - are identified to which cascading in the wood sector could contribute. These visions and targets could play a role as a criterion in the evaluation and optimisation of cascades in the wood sector. The operationalization of selected targets into measurable units is elaborated in chapter 5.

The relevant policies can be categorised into the following themes:

- Resource efficiency & circular economy
- Reduction of greenhouse gas emissions
- Renewable energy generation
- Waste management policies
- Visions and policies directly addressing cascading of biomass.

3.1 Resource efficiency & circular economy

Europe has enjoyed many decades of growth in wealth and wellbeing, based on intensive use of resources. Over the 20th century, global fossil fuel use increased by a factor 12, whilst 34 times more material resources were extracted. Today in the EU, each person consumes 16 tonnes of materials annually, of which 6 tonnes are wasted, with half going to landfill. If we carry on using resources at the current rate, by 2050 we will need, on aggregate, the equivalent of more than two planets to sustain us, and the aspirations of many for a better quality of life will not be achieved. Our economic system still encourages the inefficient use of resources by pricing them below true costs. The World Business Council for Sustainable Development estimates that by 2050 we will need a 4 to 10 fold increase in resource efficiency, with significant improvements needed already by 2020[17].

Roadmap to a resource efficient Europe

"A resource-efficient Europe"[18] is one of seven flagship initiatives that are part of the Europe 2020 strategy aiming to deliver smart, sustainable and inclusive growth. This flagship initiative aims to create a framework for policies to support the shift towards a resource-efficient and low-carbon economy which will help to:

- boost economic performance while reducing resource use;
- identify and create new opportunities for economic growth and greater innovation and boost the EU's competitiveness;
- ensure security of supply of essential resources;
- fight against climate change and limit the environmental impacts of resource use.

[17] Source: COM(2011) 571 Roadmap to a Resource Efficient Europe

[18] Source: COM(2011) 21 A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy

The flagship initiative is further elaborated in a "*Roadmap to a resource efficient Europe*"[19]. It's vision is that *"by 2050 the EU's economy has grown in a way that respects resource constraints and planetary boundaries, thus contributing to global economic transformation. Our economy is competitive, inclusive and provides a high standard of living with much lower environmental impacts. All resources are sustainably managed, from raw materials to energy, water, air, land and soil. Climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored"*.

The Roadmap identified the building sector as a key sector and formulates the following milestone: "*by 2020 the renovation and construction of buildings and infrastructure will be made to high resource efficiency levels. The life-cycle approach will be widely applied; all new buildings will be nearly zero-energy and highly material efficient, and policies for renovating the existing building stock will be in place so that it is cost-efficiently refurbished at a rate of 2% per year. 70% of non-hazardous construction and demolition waste will be recycled"*.

A European Resource Efficiency Transition Platform has been established that will among others provide recommendations on how to achieve the milestones and realise the vision set out in the Roadmap.

Relevance for cascading in the wood sector

The Roadmap to a resource efficient Europe introduces a provisional lead indicator ***"resource productivity"***, to measure improving economic performance while reducing pressure on natural resources.

Other targets that could be reached simultaneously are:

- identification and creation of new opportunities for economic growth and greater innovation and boosting the EU's competitiveness;
- ensure security of supply of essential resources;
- fight against climate change and limit the environmental impacts of resource use.

Circular economy - from waste to raw material

In its vision on resources[20] the Dutch government supports the European flagship initiative on resource efficiency, as the continuity of resource supply is helped by an integrated European approach. It is emphasized that a substantial transition is needed to reach a resource efficient Europe and to support the development of an appropriate mix of instruments. In June 2013 the Dutch Ministry of Infrastructure and the Environment

[19] COM(2011) 571 Roadmap to a Resource Efficient Europe

[20] Grondstoffennotitie, 15 juli 2011, van Ministerie van Buza en EZ.

(I&M) published a paper "from waste to resource"[21] that describes a desired transition from a linear to a circular economy. The circular economy is defined as follows:

Circular economy is an economic system based on the reusability of products and raw materials and the conservation of natural resources, and aims to value creation in each part of the system.

The paper observes that the Netherlands has achieved considerable results in waste reuse and recycling, but that an extra transition step is needed towards optimisation at the source. In this transition the circular economy should be promoted, but also attention should be given to optimisation, and modernisation of existing waste and environmental policies. In order to achieve the transition towards a circular economy the following operational targets have been defined:

1. evaluation and adjustment of existing waste management policy to support circular economy and innovation
2. actions focussed on specific chains and waste types (examples: food, textile, synthetics, concrete, electrical equipment)
3. improvement of waste separation and collection
4. development of financial and market instruments
5. make consumption patterns more sustainable
6. promote sustainable eco-design, eco-innovation and eco-engineering
7. simplification of goals, criteria, evaluation methods, indicators and labels to enable proper monitoring and identification of opportunities
8. connect knowledge and education to the circular economy.

Relevance for cascading in the wood sector

The wood sector is part of the economy that has already achieved considerable results in reuse and recycling, but could make extra transition steps towards optimisation at the source. Although wood is not mentioned in the list of specific chains and waste types (food, textile, concrete, electrical equipment) the wood sector could contribute significantly to the circular economy and many of the operational targets could be applied to cascading in the wood sector. The current project actually addresses operational target 7: enabling proper monitoring and identification of opportunities.

Conclusion

The Roadmap to a resource efficient Europe and the Dutch interpretation show that resource efficiency and the transition towards a circular economy are important policy targets that are still under development. This creates opportunities for the wood sector. Relevant indicators to be included in the cascade evaluation method are resource efficiency and resource productivity.

[21] Van afval naar grondstof. kamerbrief van 20 juni 2013 van W.J. Mansveld, staatssecretaris Ministerie van Infrastructuur en Milieu. Kenmerk IenM/BSK-2013/104405

3.2 Reduction of greenhouse gas emissions

EU greenhouse gas emission targets

The EU has developed a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy targets for 2020. These targets, known as the "20-20-20" targets, set three key objectives for 2020[22]:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20% (see section 3.3)
- A 20% improvement in the EU's energy efficiency.

The EU is also offering to increase its emission reduction target to 30% by 2020 if other major economies in the developed and developing worlds commit to undertake their fair share of a global emissions reduction effort. This is currently not the case. In a recent communication[23] the EU proposes a 40% emission reduction target and an indicative target of 27% renewable energy by 2030.

The climate and energy package comprises four pieces of complementary legislation which are intended to deliver on the 20-20-20 targets:

- the EU Emissions Trading System (EU ETS)
- National targets for non-EU ETS emissions
- National renewable energy targets
- Carbon capture and storage.

EU Emission Trading System

The EU Emission Trading System (EU-ETS) targets the reduction of greenhouse gas emissions by large industries. Each tonne of CO_2-emission reduction in these sectors results in an EU Emission Allowance (EUA) that can be sold on the market. Prices for such carbon credits fluctuate and are currently historically low. Part of the Dutch paper industry participates in EU-ETS. Other Dutch wood processing sub-sectors are not included in the EU-ETS.

Carbon capture and storage

In addition to carbon captured and stored in forests, the UNFCCC and EU start to recognize and consider the storage of carbon in harvested wood products such as sawn wood, wood panels and paper. The EC has published a directive [24] on accounting rules for carbon storage in harvested wood products (HWP) that could stimulate and value on-going and new mitigation efforts in among others the wood sector.

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[22] http://ec.europa.eu/clima/policies/package/index_en.htm

[23] COM(2014)15 A policy framework for climate and energy in the period from 2020 to 2030

[24] Decision 529/213/EU on accounting rules and action plans on greenhouse gas emissions and removals resulting from activities related to land use, land use change and forestry and on information concerning actions relating to those activities.

Relevance for cascading in the wood sector

CO_2 reduction is an important policy target on national and EU level, and to a lesser degree on international level. Cascading in the wood sector can help to reduce carbon emissions, in several ways by:

- Carbon storage in wood products
- CO_2-saving by substitution of fossil products in the construction phase
- CO_2-saving by substitution of fossil products in the operation phase (maintenance & energy savings)
- CO_2-saving by re-use of final products
- CO_2-saving by end of life combustion, replacing fossil fuels.

In short, CO_2-reduction and storage is a relevant factor in the evaluation of cascades in the wood sector.

3.3 Renewable energy generation

Renewable Energy Directive

The Renewable Energy Directive[25] (RED) formulates a target of 20% renewable energy in 2020 in EU27; which is translated into a 14% renewable energy target for the Netherlands for the same year. Furthermore, it states that "*each member state shall ensure that the share of energy from renewable sources in all forms of transport in 2020 is at least 10% of the final consumption of energy in transport in that member state (RED art. 4)*".

Status of renewable energy generation Netherlands

In 2012 4.4%[26] of renewable energy was generated, of which 3.2% bioenergy (See Figure Figure 3). It is estimated that for each percent of the renewable energy target about 2-4 milion m^3 of biomass is needed[27], which is a substantial amount, also in comparison with the total in-country wood use in the Netherlands of 12.2 million m^3 of roundwood equivalent per year[28].

[25] 2009/28/EC on the promotion of the use of energy from renewable sources.

[26] Compendium voor de leefomgeving, voorlopig cijfer.

[27] Estimation BTG. Exact number depends on type of biomass and conversion efficiency.

[28] See section 4.1 for more details.

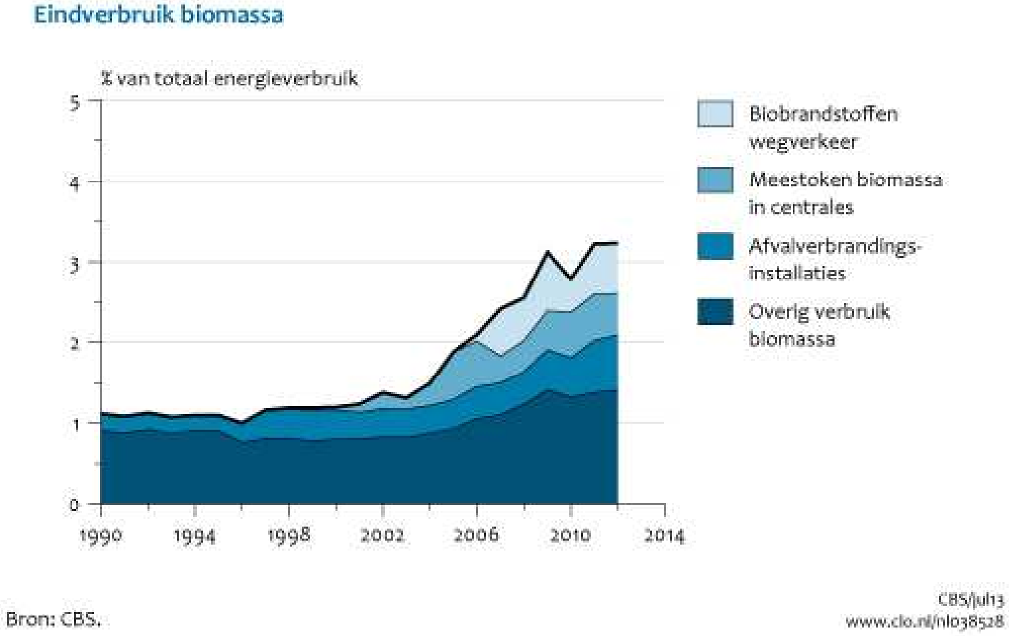

Figure 3 The share of bioenergy in final energy consumption (Source: CBS 2013)

Energy Agreement
The Rutte 2 coalition agreement[29] states that the Netherlands will strive to realise 16% renewable energy in 2020. In 2013 the SER has reached an Energy Agreement[30] that is supported broadly by all stakeholders. The EU target of 14% renewable energy in the Netherlands in 2020 would be followed, and the target of 16% is moved three years to 2023. Although much attention is paid to wind energy, the energy agreement can only be met with a substantial role for bioenergy. Co-combustion, one of the bioenergy options, will be limited to 25 PJ.

SDE+ regulation
Under the Dutch SDE+ regulation, which provides production subsidies to renewable energy producers, the combustion of biomass for heat and electricity production is financially supported. In 2013 SDE+ subsidy is made available for bio-energy generation using among others woody biomass, with the exception of B-wood. (See the next section for a discussion of the Dutch classification of construction and demolition wood into A- B- and C-wood). B-wood was excluded after ECN and KEMA, who advise the Ministry of Economic Affairs (EZ) on the base rates for renewable energy, concluded in 2012[31] that a new large bioenergy plant in Delfzijl would absorb the bulk of the available B-wood, rendering insufficient B-wood on the market to feed another B-wood combustion plant. Subsequently, EZ removed new B-wood fired installations from the list of SDE+-eligible plants. Existing B-wood fired installations would continue to be eligible for SDE+. Currently, the SDE+ does not distinguish biomass that could still be used for

[29] Bruggen slaan Regeerakkoord VVD – PvdA, 29 oktober 2012.

[30] http://www.energieakkoordser.nl/

[31] Basisbedragen in de SDE+ 2012, Eindadvies ECN en KEMA, ECN-E--11-054 September 2011

cascading from biomass at the end of a wood cascade that can only be applied for energy generation. This could frustrate current cascades in the wood sector. The SDE+ regulation could be adjusted to promote cascading in the wood sector, by excluding certain biomass types specified in NTA8003.

Relevance for cascading in the wood sector

Renewable energy targets are an important way to reduce greenhouse gas emissions and promote diversification of the energy mix reducing the energy dependence on a limited number of countries. Generally speaking cascading in the wood sector does not lead to an increase of wood available for energy. Most wood will eventually become available for energy generation, cascading will however keep the wood longer in use leading to delays in energy generation. Reuse and recycling of wood leads to a decrease in energy use per unit of service provided by the wood. However, the increased use of wooden products substituting fossil alternatives will eventually lead to an increased amount of wood available for energy generation at the end of its lifetime.

It is concluded that energy generation as such is not a target of cascading in the wood sector, but since renewable energy targets are relevant, the effects of cascading on renewable energy generation should be evaluated. Secondly, where relevant, the impact of energy subsidies on wood cascades needs to be assessed.

3.4 Waste management policies

Waste hierarchies are an important tool to stimulate reuse and recycling of waste in general, and directly impact various existing cascades in the wood sector.

European Framework Directive on Waste

The European Waste Directive uses the following waste management hierarchy:

a. Prevention
b. Preparation for re-use
c. Recycling
d. Other useful application, for instance energy recovery
e. Removal.

The European Waste Directive is elaborated in national policy, particularly in the national waste management plan 2009-2021 (LAP2).

Ladder of Lansink

Already in 1979 Dutch MP Ad Lansink introduced a waste hierarchy, which has become known as Lansink’s Ladder. Figure 4 shows Lansink’s Ladder, version 2.

Figure 4 Lansink's Ladder version 2.0.

Later this hierarchy was refined further and it is now part of the national waste management plan 2009-2021 (LAP2).

Dutch national waste management plan 2009-2021 (LAP2)

The Dutch Environmental Protection Act (Wet milieubeheer) describes a generic preference order for waste management, with the following steps.

a. Prevention
b. Design for prevention and design for useful application
c. Useful application by product reuse
d. Useful application by material reuse
e. Useful application by use as fuel
f. Removal by incineration
g. Removal by landfilling

In the second Dutch national waste management plan (known as LAP2) this preference order is elaborated and applied in sector-specific plans. These plans prescribe the 'minimum standard' i.e. the minimal application that is allowed for various types of waste. In this manner landfilling and incineration is prevented as much as possible, and cascading by reuse is promoted. Local authorities use the LAP2 in their decision making process on environmental permit applications, thereby enforcing the waste hierarchy.

For the wood sector the following sector plans are of specific interest:

- Sector plan 4: separately collected paper and cardboard
- Sector plan 36: wood
- Sector plan 41: packaging materials.

<u>Sector plan 4: separately collected paper and cardboard</u>

The minimum standard for processing of separately collected paper and cardboard is useful application by material re-use. If paper and cardboard is not suitable for material re-use, for instance wet or polluted paper and cardboard, the minimum standard is incineration.

Export of waste paper is allowed if material reuse takes place abroad. Import of waste paper is allowed if material reuse is applied in the Netherlands. The minimum standard implies obligatory cascading of separately collected paper and cardboard, if technically possible. This sector plan thus strongly promotes cascading in the paper industry.

Sector plan 36: (waste) wood

This sector plan concerns wood waste from building, renovation and demolition of buildings and constructions, including railway sleepers and wood from road and waterway construction. Three categories of construction and demolition wood are distinguished:

- A-wood: unpainted and untreated wood
- B-wood: wood not mentioned under A-wood and C-wood: among others painted, lacquered and glued wood.
- C-wood: impregnated wood like:
    - Wood treated with creosotes
    - Wood treated with wood preservatives containing copper, chrome and arsenic (CC and CCA wood) (in Dutch: gewolmaniseerd hout)
    - Wood treated with other means (fungicides, insecticides, etc.)

Minimum standard:

- The minimum standard for A- and B- wood is useful application. This could be product reuse, material reuse or use as fuel.
- C-wood treated with copper, chrome and arsenic has to be stored in a suitable landfill.
- Other C-wood can be used as fuel, but cannot be applied for product reuse or material reuse, with the exception of material reuse of creosoted wood as far as possible under Decision PAK-containing coatings.

Export is allowed if the treatment is in compliance with the minimum standard, although combustion of CCA-wood is allowed abroad and not in the Netherlands.

The minimum standard for A- and B-wood is useful application. This means that landfill and incineration are banned, which is good from the viewpoint of cascading. The number of useful applications are however wide: useful application by product reuse, material reuse and use as fuel are all three allowed. Cascading beyond combustion with energy recovery is not actively promoted (like in sector plan 41 on packaging materials). Given the polluted nature of C-wood the number of environmentally-sound processing options are limited, as laid down in LAP2.

Sector plan 41: packaging materials

Sector plan 41 describes that the minimum standard for processing of packaging materials is useful application by material reuse. Useful application by use as fuel is only allowed if material reuse is not possible anymore.

Relevance for cascading in the wood sector

The waste hierarchy itself implicitly presents a policy target to reduce waste as much as possible, and in fact stimulates resource efficiency and a circular economy as far as it concerns waste, including wood waste. The waste hierarchy used in LAP2 can be used as a tool to design cascades in the wood sector. The detailed sector plans can be used to ban certain applications and - if effectively enforced - could be used as a powerful policy tool to stimulate further cascading in the wood sector. Furthermore, it is observed that sector plan 41 on packaging materials uses material recycling as minimum standard, while sector plan 36 on waste wood uses energy use as minimum standard. It would make sense if both sector plans use the same minimum standard.

3.5 Other Dutch vision and policy documents addressing cascading of biomass

A number of policy visions and measures address cascading of biomass directly.

Government vision on the biobased economy – biobased pyramid

The biobased pyramid presented in the government vision on the biobased economy in the energy transition of 2007[32] is also widely known and used to promote the applications with the highest value added first. Internationally this order of pharmaceuticals (fine chemicals), food, feed, (bulk) chemicals, fuel and fire is known as the five F's. It was already discussed in section 2.2 on cascading in value.

The biobased pyramid does imply a preference for feed and food production over energy and chemical applications of biomass. Since wood is not used for food production, and no further explanation is given on the order in the pyramid, it does not contribute to the evaluation and optimisation of cascades.

Cascading in the Rutte 2 coalition agreement

The concept of cascading of biomass is addressed in the Rutte 2 coalition agreement[33]. It states that:

- Biomass should be used in such a manner that it generates the highest value added ('cascading') and guarantees the sustainable production and origin of the biomass .
- The coalition aims for a circular economy and wants to stimulate the (European) market for sustainable resources and reuse of rare materials.

The Rutte 2 coalition agreement vision promotes cascading of biomass, but does not specify what the "highest value added" in cascading is. This report will serve as input to further development of the concept of cascading.

[32] Ministerie van LNV (2007) Overheidsvisie op de bio-based economy in de energietransitie, 'de keten sluiten'.

[33] Bruggen slaan Regeerakkoord VVD – PvdA, 29 oktober 2012.

Van Gerven's Ladder

On 16 January 2013 MP Van Gerven of the Socialist Party (SP) submitted a motion[34] on the establishment of a hierarchy of biomass uses, analogous to Lansink's Ladder on the hierarchy of waste uses. This motion was adopted in parliament on 22 January 2013.

(…) constaterende dat biomassa een steeds belangrijkere bijdrage levert aan onze economie; constaterende dat biomassa met name wordt ingezet als brandstof in elektriciteitscentrales en in de transportsector, wat niet altijd de meest milieubewuste en duurzame toepassing is; overwegende dat voor een zo groot mogelijk milieuvoordeel de biomassa zo hoogwaardig mogelijk moet worden benut en toepassing van biomassa in de chemische industrie inmiddels aantoonbaar meer milieuvoordeel oplevert dan biomassa als brandstof; van mening dat er daarom, analoog aan de Ladder van Lansink bij afval, voor biomassa het volgende afwegingskader moet komen:

1. *voedsel voor mensen;*
2. *voedsel voor dieren;*
3. *meststof;*
4. *groene bouwstof;*
5. *brandstof;*

verzoekt de regering, nog dit jaar dit toetsingskader uit te werken met minimumstandaarden op basis van milieuvoordeel in de hele levenscyclus voor de toepassing en verwerking van biomassa, en gaat over tot de orde van de dag.

Van Gerven

The recent motion of Van Gerven shows that the discussion on the cascading use of biomass has reached the national political level. It is not clear yet how this "Van Gerven's Ladder" is intended to be applied. This could be quite complex in practice. Lansink's Ladder addresses the waste sector, which is a sector that is heavily regulated. However, many types of biomass are not classified as waste, or at least have a positive value, and can be traded and applied at the digression of the biomass owner. The government has limited power to impose rules on how non-waste biomass should be used.

Motion of Dik-Faber

The Motion of Dik-Faber of 15 October 2013 formulates that given biomass should be used in the best possible way ("cascading"), reuse of biomass should have priority over co-combustion. This requirement regarding cascading could added to the overall biomass sustainability requirements formulated in NTA8080 plus requirements regarding indirect land use and carbon dept, as described in the Energy Agreement.

[34] Tweede Kamer, vergaderjaar 2012–2013, 32 813, nr. 26, Kabinetsaanpak Klimaatbeleid op weg naar 2020, motie van het lid van Gerven.

MIA and VAMIL

The policy vision that a circular economy should be promoted is reflected in the fiscal stimulation system for environmental-friendly investments (MIA and VAMIL). Three categories are of specific importance:

- Since 2013 a new type of investment is introduced: *"machinery to reduce the use of resources (modification or replacement)"*[35]. The reduction in material use should be substantial and more than what is commonly achieved in the sector.
- Furthermore, machinery for recycling (no "downcycling", possible upcycling) of materials with respect to waste management or the raw material roundabout (grondstoffenrotonde) attracts a higher tax deduction under MIA/VAMIL than equipment for downcycling.
- The category *"machinery for (intermediate) products based on biological origin"*, is now also open for biomass that originates from the forest, e.g. residues from the paper and paperboard industry. This category should stimulate investments in biochemicals, natural fibers, biopolymers etc., i.e. the biobased economy, and thus increases competition for wood resources.

Investments in machinery that promote recycling (cascading) are supported through fiscal measures (tax deductions).

Conclusion

The biobased pyramid, Rutte 2 coalition agreement, and motions from MP's like Van Gerven and Dik-Faber show increasing awareness and interest in the issue of the best utilisation of biomass. The issue of cascading is already addressed to some degree in the fiscal instruments MIA and VAMIL. Also the current interest in biobased economy and the development towards a circular economy (see section 3.1) support cascading in the wood sector. However, this growing awareness requires further development into concrete policy measures that can really support cascading in the wood sector and the movement towards a circular economy.

3.6 Sustainability

Sustainability is a container concept often divided in environmental, social and economic issues elaborated in sustainability criteria and indicators. Sustainability is an important theme in the wood sector. Sustainability certification is applied to prove the sustainable origin of the wood and the use of certified wood (FSC, PEFC) is promoted throughout the wood sector. Voluntary schemes like NTA8080 can be used for certification of solid biomass like wood for energy generation. These schemes have strong similarity to forest certification schemes, but have in addition a criterion covering minimum greenhouse gas savings compared to a fossil reference. The calculation of greenhouse gas reduction of (cascaded) wood products is more complex as the fossil reference is not always as obvious as it is in the energy sector. In the coming years sustainability certification of solid biomass used for renewable energy generation might become obligatory; liquid

[35] Number A 8000 on the list

biomass and transport fuels already need to meet obligatory European sustainability criteria[36].

Sustainability certification can be used as a tool to show that the precondition of sustainable sourcing of the biomass is met. The generic sustainability criteria can also be used to screen the further processing and end use of the wooden product on possible sustainability issues. This concerns environmental issues like emissions to air, water and soil and socio-economic issues like human rights, employment, contribution to social well being of the local population.

Sustainable procurement

The Dutch Government procures almost 60 billon Euro in goods and services annually and has an important impact on the environment and social aspects inside and outside the Netherlands. In civil engineering works (GWW-sector), a lot of wood is used in waterworks, with the Ministry of Infrastructure and the Environment being an important buyer. Sustainable procurement is part of the policy. In the GWW-sector a sustainable procurement approach is used that makes use of an Ambition Web, DuboCalc for LCA type of calculation of environmental impacts resulting in an Environmental Cost Indicator (MilieuKostenIndicator MKI)[37]. It could be further investigated how cascading currently scores in the existing tools and whether adaptions would be needed. Cascading of wood could contribute to several targets as formulated in the ambition web.

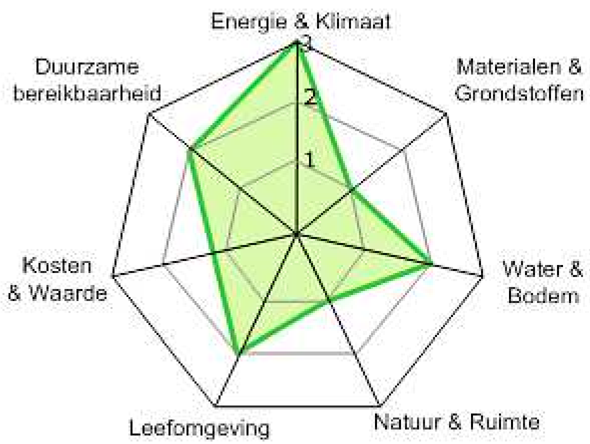

Figure 5 Ambition web as used in sustainable procurement in Dutch civil works

[36] See article 17 of the Renewable Energy Directive (2009/28/EC).

[37] For more information see http://www.aanpakduurzaamgww.nl/mainpage.aspx

3.7 Summary of policy targets and visions

Table 3 provides an overview of the policy targets and visions relevant for the evaluation of cascades in the wood sector.

Table 3 Summary of policy targets relevant for cascading in the wood sector

Theme	Policy measure / regulation	Targets	Relevance for cascading in the wood sector
Resource efficiency	COM(2011) 21 A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy COM(2011) 571 Roadmap to a resource efficient Europe From waste to raw material & circular economy. (Ministry of I&M)	This flagship initiative aims to create a framework for policies to support the shift towards a resource-efficient and low-carbon economy which will help us to: – boost economic performance while reducing resource use; – identify and create new opportunities for economic growth and greater innovation and boost the EU's competitiveness; – ensure security of supply of essential resources; – fight against climate change and limit the environmental impacts of resource use.	High level goal setting vision document, indirectly supporting cascading in the wood sector. Elaborated in more detail in letter of State Secretary Mansveld "from waste to raw material"
Greenhouse gas emission reductions	The EU climate and energy package	EU target of 20% reduction in EU greenhouse gas emissions from 1990 levels	Cascading could help to reduce greenhouse gas emissions
	Decision 529/2013/EU on accounting rules on greenhouse gas emissions and removals resulting from activities related to land use, land use change and forestry and on information concerning actions relating to those activities.	Introduction of accounting rules for greenhouse gas emissions, including carbon storage in harvested wood products (paper, panels and sawn wood).	EU member states will be obliged to account changes in carbon stocks in harvested wood products. This could promote the recognition of the role of the wood sector in carbon storage in harvested wood products
	EU Emission Trading System	Reduction of greenhouse gas emissions by large industries	Part of paper industry participates in EU-ETS
Renewable energy	Renewable Energy Directive (2009/28/EC)	Target of 20% renewable energy in 2020 in EU27; 14% renewable energy in Netherlands in 2020	This directive promote the use of biomass (incl. wood) for energy production throughout the EU
	SDE+ regulation	Promote renewable electricity heating and cooling by subsidizing produced energy	Competition for wood resources that could still be cascaded.
Waste manage-ment policies	National waste management plan (LAP2)	Introduction of waste hierarchy and its application to among other the wood sector.	Obligatory cascading of waste paper, and wood waste. Could be extended to wood products.
Sustain-ability	Renewable Energy Directive (2009/28/EC)	Obligatory sustainability certification for liquid biomass and biofuels	Could be extended to solid and gaseous biomass.
	Forest sustainability certification systems	Proof of sustainable origin of biomass	Sustainable origin wood is boundary condition for

			wood cascades
	Testing framework for sustainable biomass. NTA8080.	Proof of sustainable origin of biomass and CO_2 savings calculation	Contains criteria that could be used for cascade evaluation
	Sustainable procurement policies	Example GWW sector	Policy tool to promote cascading
Biomass cascading	Coalition agreement	Biomass should be used in the way with highest value added	General support for cascading
	Biobased pyramid	Promote high value added applications of biomass	General support for cascading
	Van Gerven´s Ladder	Biomass should be used in the way with highest value added, form environmental perspective.	General support for cascading
	MIA/VAMIL 2013	Fiscal stimulation of environmental friendly technology, a.o. machinery to reduce the use of resources; upcycling, and biobased products	Financial incentive for cascading.

Conclusion

The analysis of policy targets and visions has resulted in:

1. Policy goals to which cascading in the wood sector can contribute if the right policy and market conditions are met.
2. Boundary conditions that should be met when stimulating cascading in the wood sector.
3. Policy measures that influences the current state of cascading in the wood sector, in an either positive or negative way.

Ad 1. The main policy targets relevant for cascading in the wood sector are:

- Resource efficiency
- Reduction of carbon emissions including carbon storage
- Economic growth based on less material use (resource productivity).

Based on these policy targets, evaluation criteria for cascades in the wood sector will be operationalized into measureable units in the next chapter.

Ad 2. The most important boundary conditions for cascading are sustainable sourcing of wood, which could be checked by sustainability certification and the application of sustainable practices throughout the supply chain.

Ad 3. The national waste management plan and subsidies for renewable energy production are important instruments that shape the current state of cascading in the wood sectors. These and other policy plans require further attention in the design of measures that could support specific cascades in the wood sector.

4 OVERVIEW CASCADING IN THE WOOD SECTOR

4.1 Overview of the wood processing sectors in the Netherlands

Wood use in the Netherlands is widespread. In 2012 the sum of wood import and production stood at 29.1 million m^3 of roundwood equivalents[38], of which more than 95% is imported. A large amount of that wood is only in transit and exported again, leading to a total in-country use of 11.7 million m^3 of roundwood equivalent. See Probos (2012)[39] for a recent overview of wood flows in the Netherlands.

Wood use in the Netherlands is commonly subdivided by application into paper and cardboard (50%), panels (15%), sawn wood (30%) and other uses (5%). The wood production chain starts usually in other countries (Europe mostly, to a lesser extent North America, and tropical countries for tropical hardwood). Activities such as sawing and drying are increasingly carried out in these source countries. In the Netherlands wood is handled by wholesale traders and import-export companies. In some cases primary wood treatment (sawing, shaving, drying, preservation) is taking place in the Netherlands.

Wood is used in various economic sectors, of which the important ones are:

- Wooden packaging sector (SBI category 16.29)
- Timber and construction sector (SBI category 16.22)
- Paper production (SBI category 17)
- Furniture production (SBI category 31).

Wood is also supplied directly to other sectors, such as D-I-Y (Do-It-Yourself) stores, etc.

Once wooden products have reached the end of their life, collection by waste companies, followed by upgrading to new products or use as fuel for bio-energy applications is taking place. An overview of the Dutch wood market, including the wood processing sectors, is available at the website www.vvnh.nl/houtmarkt.

In this chapter the current status of cascading in the above mentioned wood processing sectors is described. Subsequently options for further cascading are identified and described as possible goal scenarios for the sector.

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[38] Probos, “Kerngegevens Bos en Hout in Nederland”, http://www.probos.nl/publicaties/kerngegevens/40-kerngegevens2013 December 2013.

[39] Oldenburger J., C. de Groot, A. Winterink (2012). Nederlandse houtstromen in beeld. Stichting Probos

4.2 Wooden packaging sector

4.2.1 Sector overview

The wooden packaging sector involves the production and repair of wooden pallets (for repeated use and for limited use), crates, boxes and industrial packaging. Of these products, wooden pallets form about 75% - 80% of the total production volume[40]. The total amount of wood used annually in the sector is more than 1 million m^3 of softwood (primarily sourced from other European countries, such as Scandinavia and Central and Eastern Europe). 90% of all pallets are made of wood.

The sector is well organised, with about 85% of the production volume coming from about 45 suppliers, united in the EPV (Emballage- en Palletindustrievereniging / Wooden packaging and pallet industry association, www.epv.nl). It is estimated that about 70% of the total market volume is produced by four large suppliers that are members of the EPV. The sector employs about 3400 people.

4.2.2 Current practices

The current actors on the Dutch pallet market are the following:

- Manufacturing companies / wholesale traders – often manufacturing companies procure and import their own wood. Smaller manufacturers predominantly purchase their wood from wholesale traders
- Business clients / pallet pool organisations – pallets and other wooden container products are supplied to clients or to pallet pool organisations. Pallet pool organisations are renting pallets to consumers, and take these back after use. In this manner, a single pallet can be used on average about 3 times per year and 25 times in total. If properly maintained and repaired, pallets can thus last up to 10 years. Pallets for limited use (about 50% of total production) are built less sturdy (e.g. for export use). Also part of these pallets are repaired/reused.
- Pallet repair or secondary use (chipboard industry or for energy generation).

The production chain of wooden packaging material is graphically presented in Figure 6. With respect to this figure the following remarks are made:

- During the production of wooden packaging material wood residues are generated. The sector has expressed its ambition of using these wood residues to generate heat for their own use. The intentions are formalised in one of the Green Deals with the national government[41].
- At the end of their useful life, wooden packaging materials are collected by waste collection companies. The collected wood is separated into A-wood (clean waste wood) and B-wood (painted, lacquered and glued wood). Most of the wooden

[40] Wageningen UR, "Kansen en barrières voor verduurzaming van houtketens", werkdocument 222, http://edepot.wur.nl/173280, April 2011

[41] https://zoek.officielebekendmakingen.nl/stcrt-2012-16773.html

packaging waste (a.o. pallets) classify as A-wood. Both A-wood and B-wood are used as feedstock for the chipboard industry (mainly located in Italy, Belgium and Germany) and as feedstock for bio-energy generation.

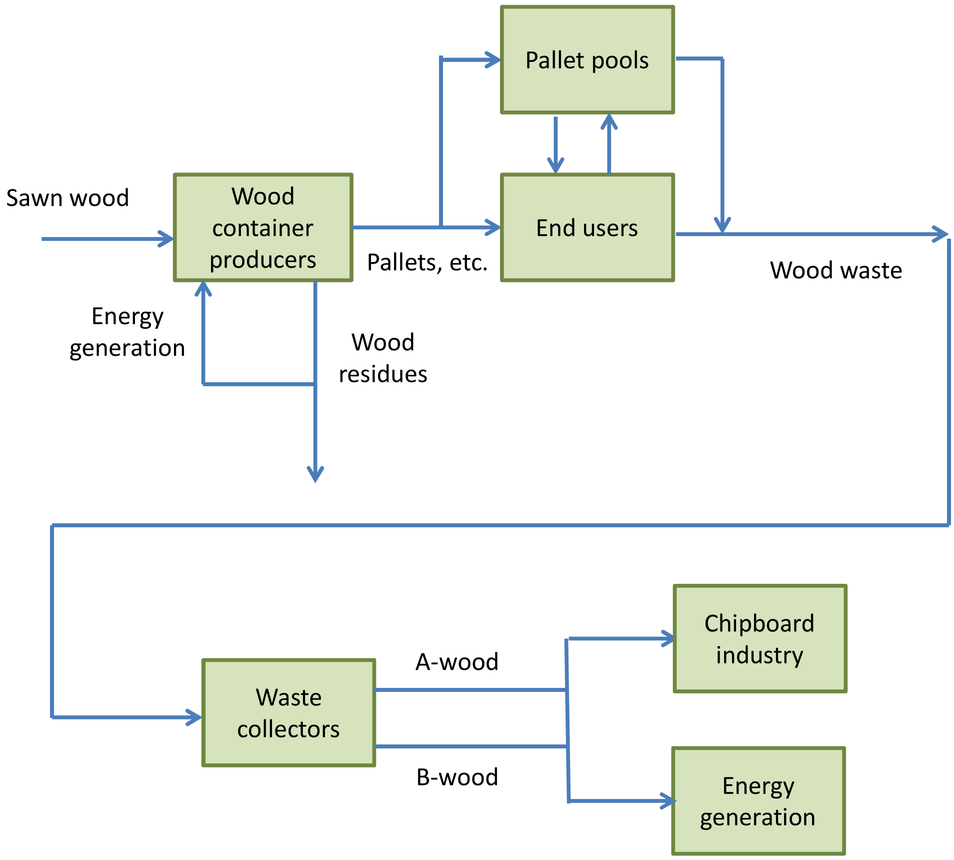

Figure 6: Production chain wooden packaging material

The wooden packaging sector monitors the amount of wood that is used in material recycling[42]. Until 2005 this amount increased steadily, to 39%, but it has dropped in recent years, to 30% in 2011. The sector investigated what has caused the drop, and it appeared that in 2010 a large portion of the wood waste (50%) was used for energy generation. The sector deems this not to be in agreement with Lansink's Ladder, and in general undesirable. According to the sector, the main single reason for the drop is the SDE+ subsidy for renewable energy production. The sector warns that if the declining trend continues due to such subsidies the target of 25% material recycling as agreed with the government may become unattainable in the future.

4.2.3 Options for cascading

The wooden packaging sector is already actively promoting the cascade principle. Reuse of pallets is advocated and measures to increase this reuse are being considered. Opportunities to increase the reuse would be for the government to ban energy generation from wood packaging waste that can be used for material recycling. In the current sector-

[42] http://www.kringloophout.nl/monitoring-recycling

specific waste plan (LAP2 sector plan 41) the minimum standard is useful application by material use. However if this is technically not possible, the minimum standard is any useful application. Energy generation and material recycling are both considered useful applications. Since there are no specific criteria to determine when material recycling is no longer possible, it is to be expected that the use for energy generation is increasing.

Goal scenario

In this project, maintaining the levels of reuse of pallets (product reuse) and material recycling before energy generation would be the main goal scenario for cascading in the package sector. The reference scenario could be defined as the level of reuse and material recycling that will occur if current policies with promotion of energy production from pallets would remain in place. The impact of increased product reuse and/or material recycling could be estimated as a goal scenario.

4.3 Timber and construction sector

4.3.1 Sector overview

The timber and construction sector is a large consumer of wooden products. Customers in this sector can be subdivided into two segments:

- The residential and utility construction (in Dutch: B&U)
- Infrastructural works in civil engineering (in Dutch: grond-, weg- en waterbouw, or GWW).

The amount of products that are supplied to these segments is very large and diverse. Examples are scaffolding, fences, window frames, roofing, flooring, etc. On the website www.houtdatabase.nl/?q=hout/bouw a large number of wood species and their application as products in these segments is shown.

Activities in these segments are usually carried out on a project basis. In the GWW segment the various levels of government (national, provincial, municipal) dominate as principal (about 51% of the wood is directly sourced by the government). The sector uses – in comparison with other sectors – a relative high percentage of tropical hardwood.

4.3.2 Current practices

The current actors on the Dutch market are the following:

- Wood wholesale traders. Wood wholesale traders are organised in the VVNH (Koninklijke Vereniging van Nederlandse Houtondernemingen / Royal association of Dutch wood trading companies, www.vvnh.nl). The VVNH actively promotes the use of certified wood (FSC or PEFC) and reports twice a year about the use of certified wood by its members. Recent results (over the first half of 2012) show that of the wood imported by VVNH members (1 million m^3 wood) about 80% was CoC-certified[43].

- Timber companies produce a part of the wooden products for the construction market. The sector is organised in the NBvT (Nederlandse Brancheverenigingvoor de Timmerindustrie / Dutch association of the timber industry, www.nbvt.nl/). About 250 larger and smaller timber companies are member of the NBvT. The NBvT is actively promoting the use of certified wood by their members.
- Construction companies. The construction sector is very large, consisting of about 1500 companies that supply to the GWW segment, with a combined annual turnover of 20 billion Euro. A small number of companies (Koninklijke BAM-groep, VolkerWessels, Dura Vermeer, etc.) controls a large part of the market. Construction companies are organised in Bouwend Nederland (Vereniging van bouw- en infrabedrijven / Association of construction and infrastructure companies, www.bouwendnederland.nl).

When the wooden products reach the end of their life, they are collected by waste collection companies. The collected wood can be separated into A-wood (clean waste wood), B-wood (painted, lacquered and glued wood) and C-wood (impregnated wood). Both A-wood and B-wood are used as feedstock for the chipboard industry (mainly located in Italy, Belgium and Germany) and as feedstock for bio-energy generation. The production chain for wood in the construction sector is graphically presented in Figure 7.

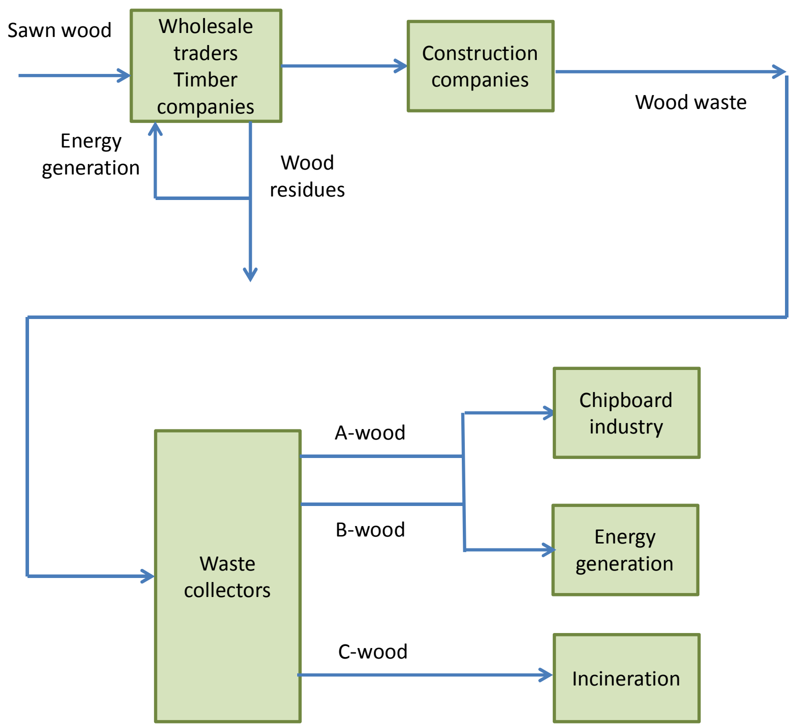

Figure 7: Production chain construction sector

[43] www.vvnh.nl/system/files/rapportage-vvnh-monitoring-eerste-helft-2012_30jan13.pdf

4.3.3 Options for cascading

There are currently no dedicated programmes explicitly encouraging wood cascading in this sector. The sustainability of the construction sector is however actively promoted via the Dutch Green Building Council (www.dgbc.nl/). This networking organisation, founded in 2008, aims to increase the sustainability with respect to buildings. DGBC choose to use the English BREEAM (Building Research Establishment Environmental Assessment Method) methodology as the basis for their own sustainability label, BREEAM-NL (www.breeam.nl). Relevant sustainability initiatives of the DGBC include:

Design and building phase:

- Development of a certificate detailing the sustainability of a building (BREEAM-NL Nieuwbouw and BREEAM-NL In-Use)
- A material database tool to determine the environmental impact of a building (DGBC Materialentool)
- Development of modular energy saving, low maintenance front walls (IPC initiative of the NBvT).

Demolition phase:

- Development of a certificate for sustainable demolition (BREAM-NL Slopen)
- A database tool to determine the environmental impact of demolition projects, promoting reuse of materials.
- The VERAS (Vereniging voor aannemers in de sloop / Association for demolition contractorswww.sloopaannemers.nl) is in favour of national rules for sustainable demolition. The current Dutch Buildings Decree (Bouwbesluit) allows the competent authorities to prescribe separation of waste for reuse, but they are not obliged to do so.

In the timber and construction sector four main types of cascading can be identified that focus on:

1. product and material reuse of wood
2. replacement of fossil products by wooden products
3. lifetime extension of wooden products
4. efficient use of wood.

Ad 1. Product and material reuse of wood

Options for cascading related to product and material reuse are:

- Design and construction enabling wood to be reused after its functional use, e.g. by avoiding wood and insulation materials to be glued together, or by keeping wooden bars unpainted.
- Increasing the separation efficiency of waste collection so that more wood is separated into A-, B- and C-wood which would make material recycling easier. This could be stimulated through specific (financial) measures.

Ad 2. Replacement of fossil products by wooden products

Compared to their fossil alternatives, wooden products have generally low emissions during the production phase, carbon is stored during the use phase and at the end of life energy can be generated. The following options to replace fossil products by wooden products were identified in cooperation with the NBvT:

- Timber framed construction (houtskeletbouw) versus traditional construction
- Wooden window frames versus synthetic or aluminium window frames.
- Wooden bridges instead of steel bridges.
- Use of biobased cellulose insulation materials.

Ad 3. Lifetime extension of wooden products

Options to increase the useful life of wood products that are discussed in the sector[44]:

- Utilise the right construction (in Dutch: detaillering) to avoid accumulation of moisture
- Use of wood preservation techniques. Several techniques exists:
    - Straight forward improvement (removal of cracks and knots) to decrease the risk of swelling and bending
    - Wood modification (changing the chemical structure of wood to increase the durability). Examples are the Plato process and acetylation of wood
    - Wood preservation (treatment of wood with preservatives such as borax)

Ad 4. Efficient use of wood

Options are: production of I-bars (I-liggers): resource efficient wooden bars with a H-profile.

Goal scenario

After the stakeholder meeting organized with PHN and further consultation of NBvT[45] the following goal scenarios were selected as being most relevant to the timber sector.

Goal scenario 1: Timber frame construction (houtskeletbouw) versus traditional construction.

Compared to neighbouring and Nordic countries Dutch houses generally contain a low share of wood in construction of houses. In this goal scenario an average timber framed house will be compared to a standard traditional house. Expected impacts are carbon emission savings and carbon storage. The maximum achievable level of timber framed construction in the Dutch housing sector will be determined. Policy measures to promote timber frames will be identified and their potential impact on carbon emission savings and storage will be estimated.

Goal scenario 2: optimal material reuse of demolition wood

In this case material reuse of demolition wood (A-, B-wood) will be compared to direct energy generation. The impacts will be extrapolated to national level. Several measures to increase material reuse like better separation of A-, and B-wood at demolition sites, and impacts of design for reuse will be estimated. Policy measures will be identified that could support these measures as well as their impacts.

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[44] http://www.profnews.nl/912735/hout-is-waardevol-voor-gww-sector

[45] Meeting with Bert Kattenbroek (NBvT) and Jaap van den Briel (PHN), Bussum, 18 April 2013

Goal scenario 3: wooden versus synthetic window frames
The last decades synthetic window frames have gained increased popularity especially among households. Synthetic window frames are perceived as being maintenance free. However, the lifetime of synthetic window frames is not proven, while wooden window frames have a very long lifetime in the order of 80 years. Wooden window frames have a carbon storage capacity and are easier to repair. Material reuse after the usage phase of wooden frames is also claimed to be better. Wooden and synthetic window frames could be compared to each other, and impacts extrapolated to sector level. The impacts of policy measures like a promotion campaign among households could be estimated.

4.4 Paper and cardboard sector

4.4.1 Sector overview

The Dutch paper and cardboard sector produced 2.7 million tonnes (2011)[38] of paper and cardboard in 2011. Imports amounted to 2.8 million tonnes and exports stood at 2.4 million tonnes. This means that about 3.1 million tonnes of paper and cardboard is used in the Netherlands. About 48% of all wood used in the Netherlands is used for the production of paper and cardboard.

Paper is produced from pulp, which can be produced from waste paper and wood. In the Netherlands most paper has a high content of recycled waste paper (80% in 2011[38]). Most of the wood used is sourced from European forests, while only some is sourced in North-America.

The recycling of paper is controlled by PRN (Stichting Papier Recycling Nederland / foundation Paper Recycling Netherlands www.prn.nl). This foundation promotes and oversees the recycling of waste paper, and represents practically the entire Dutch paper and cardboard sector. More than 70% of the companies that produce paper and cardboard and about 90% of the municipalities are members. One of the instruments of the PRN is that it guarantees a minimum price of for used paper to make sure that recycling of waste paper continues irrespective of current market circumstances.

4.4.2 Current practices

The current actors on the Dutch market are the following:

- Large paper factories. Both production and trade in paper are dominated by a few large multinationals, including UPM, Norske Skog Parenco, etc. They own part of the 21 paper and cardboard factories in the Netherlands. The industry is organised in the VNP (Koninklijke Vereniging van Nederlandse Papier- en kartonfabrieken / Royal association of Dutch paper and cardboard mills, www.vnp.nl/)
- The Dutch wholesale traders are united in VPG (Vereniging Papier Groothandel / Association of paper wholesale traders, www.verenigingpapiergroothandel.nl/). The wholesale traders import paper and sell this to small and medium sized companies in the printing sector.

- The printing sector is involved in the printing of books, magazines, leaflets, etc. The printing sector is associated in the KVGO (www.kvgo.nl). The KVGO has about 2000 members
- The printing sector supplies their products to companies, the government and private clients.

The production chain for wood in the paper and cardboard sector is graphically presented in Figure 8. Recycling of paper cannot be continued indefinitely. After each recycling step the wood fibres become shorter, and after 6 or 7 times the fibres cannot be used for paper production anymore. The residue which remains, paper sludge, is combusted for energy generation.

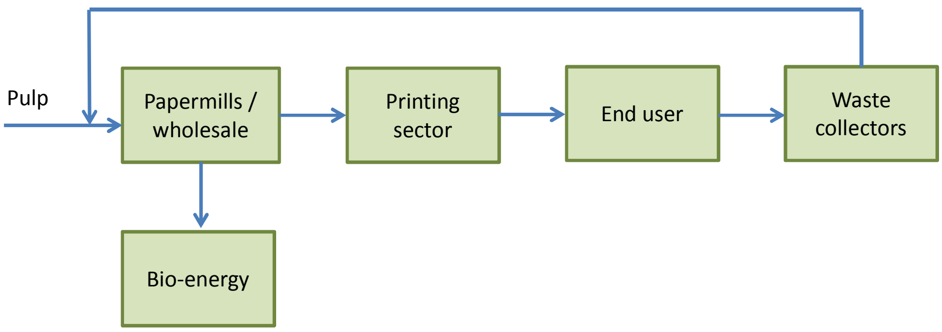

Figure 8: Production chain paper and cardboard sector

4.4.3 Options for cascading

The paper and cardboard sector actively promotes the re-use of paper and materials, as well as energy efficiency as a whole. Their knowledge center (Kenniscentrum Papier en Karton, www.kcpk.nl/), is active in research to minimize the environmental impact of paper and cardboard production and use. Two recent projects are:

- “Ketenkaarten”[46]. In this project a method was developed to investigate the material and energy use and losses in the entire chain from producer to end-user. In the framework of this project material losses for specific chains were determined, revealing that energy losses were primarily occurring near the end of the chain.
- “Slimme, slanke ketens”. This project, currently under implementation, has as goals increasing material efficiency, energy efficiency, decreasing environmental pressure and reduction of transport volumes. Results of this project are not public yet.

The VNP[47] suggests to divide the paper processing chain into three platforms:

1. Physical: Paper production and recycling
2. Chemical: production of biobased products from cellulose material that cannot be used for paper application anymore.
3. Energy: production of energy

[46] http://www.kcpk.nl/ep/projecten/kk

[47] Oral communication with Messrs. Koopman and Lambrechts of VNP on 25 June 2013

Especially the production of chemicals from paper industry residues is under development. For instance research on the production of building blocks like lactic acid for biobased plastics production that could be used for plastic bottles is on-going.

Another issue is resource efficiency in the paper industry. The project “sustainable book” has shown that substantial carbon and energy reduction can be achieved by reducing losses in cutting, and through several other measures in the production chain.

The level of paper recycling in the Netherlands is the highest of Europe. Possibilities to improve this excellent example of cascading are therefore limited.

Goal scenarios

After consultation of VNP two goal scenarios were identified:

- Resource efficiency by application of the practices developed in the project “sustainable book” on a larger scale.
- Production of bio-plastics from cellulose residues in the paper industry, that can among others be used in plastic bottle production.

4.5 Furniture sector

4.5.1 Sector overview

The furniture industry used about 980,000 m^3 of wood in 2001[48]. For the most part use was made of board materials (355,000, made from 510,000 m^3 of unprocessed wood) and sawn wood (205,000 m^3, made from 410,000 m^3 of unprocessed wood). The third category (ready made parts) is much smaller with a volume of 24,000 m^3 (made from 60,000 m^3 of unprocessed wood). Sawn wood species are predominantly (more than 50%) fir and European Oak. Lesser used species are American Oak and a variety of tropical species. Chipboard is the main board material used (48%). MDF (26%) and tri- and multiplex (21%) are also used in significant quantities. Like in other wood processing sectors, about 95% of the wood used is sourced outside of the Netherlands.

4.5.2 Current practices

The current actors on the Dutch market are the following:

- Wholesale traders that are supplying wood to the timber and construction sector are also supplying wood to the furniture industry. The wood wholesale sector is represented by the VVNH (www.vvnh.nl)
- Furniture industry. The furniture industry is organized in the CMB (Branchevereniging Interieurbouw & Meubelindustrie, www.cbm.ml). This association has 550 members, representing about 60% of the market[48]. The CBM unites a diverse group of companies, subdivided into three groups: interior

[48] Stichting Bos en Hout, Houtverbruik in de meubel- en emballageindustrie, http://www.probos.nl/home/bosbericht_bestanden/bosenhoutberichten2001-06.pdf, 2001

construction, furniture, and supply. The sector consists of many (over 50%) small companies that use less than 100 m^3 per year. Reversely, about 75% of the wood is processed in in just 10% of the companies.

The production chain is graphically presented in Figure 9.

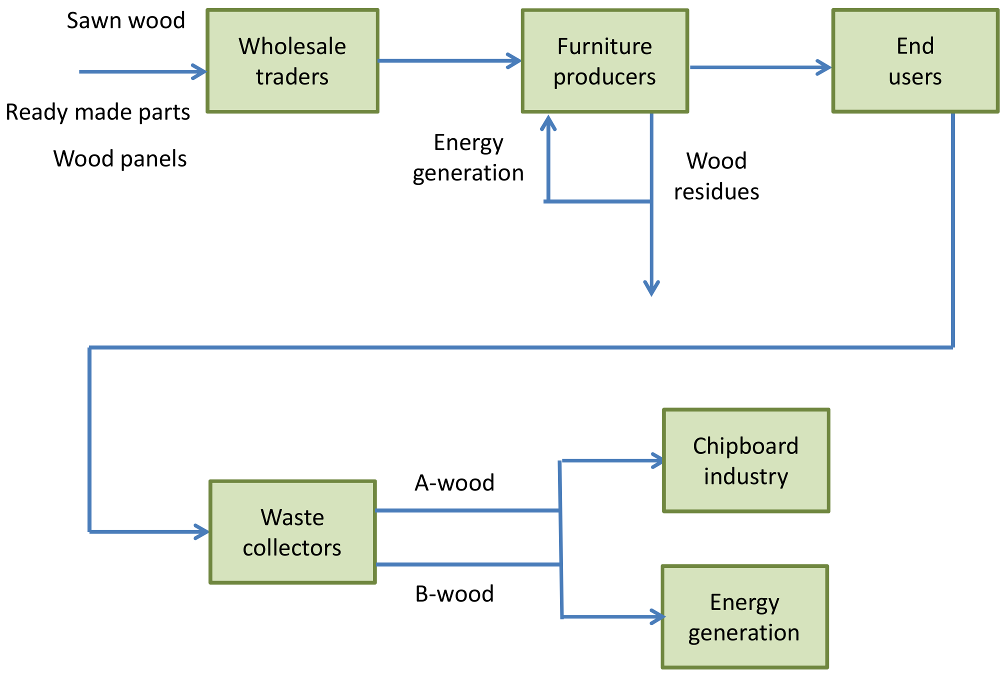

Figure 9: Production chain wood use in the furniture sector

4.5.3 Options for cascading

With respect to sustainability, the main topics in the sector are the drive to increase the share of wood from certified forests, and the EU decision to ban the use of illegally harvested wood (which entered into force on 3 March 2013).

Possibilities for cascading are:

- Explicit use of recycled materials in furniture. Following a trend towards sustainable products, various companies offer furniture in which recycled materials are – visibly – used. An example (www.steigerhoutenmeubelshop.nl) is the use of waste scaffolding material for all kinds of tables, chairs etc.
- The use of waste wood or recycled wood in wood-plastic composite materials. To increase sustainability the plastics can also be sourced from recycled materials. It is also possible to recycle these composite materials at the end of their lifetime. Typical products are wooden floor elements, roofing and scaffolding. The content of wood used in these products varies between 50-70%[49].

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[49] http://www.innohout.nl/tl_files/media/PDF/20110112_IPS_Rapport_web.pdf

- Wood preservation, wood coating, and inclusion of sustainable principles in designs are other ways to increase cascading in the sector.

4.6 Selection of cascades for further assessment

The various cascades that have been described as goal scenarios in the previous sections can be categorised in a number of themes that play a role in wood cascading:

Table 4 Summary of identified cascades ordered by theme

Theme	Estimated impact[a)]
Theme 1: Carbon storage in wooden products	
1A Timber framed construction	High
1B. Wooden window frames	Low
1C Wooden bridges	Low
1D Use of paper based insulation material in housing.	Unknown
Theme 2: Product and material recycling	
2A. Product and material reuse of demolition wood	High
2B. Design of wooden products for improved product and material reuse	Unknown
2C. Product and material reuse of wooden pallets	Medium
2D. Material recycling of cellulose residues paper industry	Unknown
Theme 3: Resource efficiency	
3A Sustainable book	Low
3B Use of I-frames in construction	Unknown

[a)] A first order estimation of the impact was made based on amount of wood involved:
High: > 100,000 tonnes of wood/year; medium: 10,000-100,000 ton/year; low: <10,000 ton/year; Unknown: not estimated.

In theme 1 fossil products are substituted by wooden products, in general leading to lower carbon emissions during production compared to the fossil reference and to long term carbon storage in wooden products.

In theme 2 resource efficiency and productivity are increased by making optimal use of one unit of wood compared to a reference in which wood is used in a less or non cascaded way.

Theme 3 covers resource efficiency at the initial production process, the first step in Lansink's Ladder. It reduces carbon and energy emissions and increases resource productivity.

In phase two of the project, three or four cases can be selected from the above cascades for more in-depth evaluation using the method presented in chapter 5. The selection of cases should meet the following criteria:

1. Potential impact should be substantial
2. At least two themes should be covered
3. Relevant for both wood sector and policy makers.

An indication of the potential impact is made based on the yearly amount of wood involved in the cascade. The different scenarios were presented to the Steering Committee of this project and resulted in the selection of (1) timber frame construction and (2) product and material recycling of wooden pallets as case studies.

5 METHOD FOR EVALUATION OF CASCADES

5.1 Introduction

The evaluation of cascades and assessment of their contribution to various policy goals consists of the following:

Step 1: definition and description of the cascade
Step 2: selection and description of relevant fossil and/or wood based reference systems that represent the baseline situation
Step 3: data collection
Step 4: calculation of results using the evaluation tool developed for this purpose
Step 5: extrapolation of the results to sector and/or national level
Step 6: determination of contribution to policy goals.

This step plan will be followed for three or four selected cascades in the wood sector, in phase 2 of the project. In section 5.2 a cascade system description method is presented that helps to define and describe the cascade and the fossil reference. Secondly, based on the policy targets described in chapter 3, three themes have been identified: resource efficiency, carbon emissions and economic performance. For each theme one or more specific indicators are developed and presented in sections 5.3 to 5.5.

5.2 System description

In this section the general framework for a quantitative description of the wood based cascade and its wood based or fossil reference is provided. This framework is used as a basis for further calculations with specific indicators.

Functional units

- Cascades will generate one or more different **products** that can provide certain services. Examples of products are: a pallet, a cardboard box, a window frame.
- The **functional unit** quantifies the service delivered by the product. A functional unit can be expressed as a cycle (for instance a trip of a wood pallet) or as a unit of time the service is provided (for instance a year that a window frame is functional in a house), whatever is most appropriate. The functional unit is the ultimate basis for comparison with the fossil or wooden references.
- The functional unit should be defined in such a way that all the options deliver the same service during the operation phase.
- Products can have multiple cycles of service, providing multiple functional units.
- Each product has an average lifetime, that can be expressed in time or as a number of cycles.

Cascades

- A **cascade** contains one or more products that generate one or more services expressed in functional units that take place after each other in time.

- The products in a cascade are linked with each other by **cascading actions** like initial production, product reuse, material recycling or preparation for energy use.
- Cascading actions require labour, materials, energy and investments and can cause carbon emissions. These are the inputs needed to make the service by the subsequent functional unit possible.
- The first cascading action is the production with fresh raw materials, the last cascading action is the preparation for end use (incineration, energy generation, landfill).
- After product reuse the functional unit does not change, after material recycling a new type of functional unit is introduced in the cascade that provides a different service.
- The total lifetime of the cascade is the duration of all functional units provided by the cascade.

Fossil/mineral reference system

- Each functional unit in a wood cascade can be compared to a fossil/mineral reference production system. If a cascade contains more than one functional unit, usually for each functional unit a fossil reference production system needs to be selected.
- If a wooden cascade is very dominant in the market (for instance paper from wood), comparison with a fossil reference is not so relevant. In this case comparison with a wooden reference system would be more appropriate to show the effect of further cascading.

Wooden reference system

- Each functional unit in a cascade can also be compared to a common wooden reference system that usually has a lower degree of cascading. If the cascade contains more functional units, for each functional unit a wooden reference system needs to be selected. In case the cascade and the wooden reference are very similar, one wooden reference containing more functional units can be selected.
- The wooden reference systems should be representative for the common practice in the wood sector.

In the next sections various indicators are defined that can measure the performance of a cascade compared to a fossil or wooden reference system. This performance will eventually be extrapolated to measure progress towards policy goals. The indicators are clustered around three themes: resource efficiency, greenhouse gas emissions and economic performance.

5.3 Indicators to measure resource efficiency

Resource efficiency is an important relatively new policy target as described in "*Roadmap to a resource efficient Europe*"[50]. The roadmap suggests to use Resource Productivity: the ratio of Gross Domestic Product (GDP)[51] to Domestic Material Consumption (DMC) expressed in Euro/tonne as a provisional lead indicator to measure resource efficiency. The higher the ratio, the better the performance. This is an indicator that is easy to communicate to the public, but – as the European Commission states - cannot be used properly for policy making without a "dashboard" of supporting indicators that have a life cycle, or value chain, perspective on water, land, materials and carbon plus indicators that measure environmental impacts and the global aspects of EU consumption and thematic indicators to monitor progress towards existing targets in other sectors.

5.3.1 Material use

Material use is the consumption of mineral and biogenic resources used to produce a functional unit divided by functional unit (kg/functional unit). This indicator is relevant for the calculation of calculation savings and resource efficiency.

5.3.2 Resource savings

Resource savings is the material use of the reference cascade minus the material use in the wooden or fossil reference (kg material savings/functional unit)

5.3.3 Resource efficiency

Resource efficiency is the material use of a functional unit divided by the material use in the wooden or fossil reference (% material savings compared to a reference). Efficiency is always related to a reference situation, in this case the material use of the selected fossil reference or another configuration of the wooden cascade.

Comparison with a fossil reference is somewhat problematic, since wood and for instance aluminium or steel are not comparable on a per kg basis. It could be considered to limit the comparison to energy and carbon intensity. However, then the "resource dimension" is lost. In the analysis associated with the Roadmap to a resource efficient Europe, part II, p 67, it is suggested to disaggregate the material use in main categories such as biomass, fossil energy carriers (linking with energy and energy efficiency), industrial minerals and ores, and construction materials.

[50] COM (2011) 571

[51] Gross Domestic Product is the market value of all officially recognized final goods and services produced within a country in a given period of time.

5.3.4 Material recycling rate

The material recycling rate is the tonnage of material that is collected for material reuse divided by the tonnage of material that is discarded. Material recycling rates are sometimes related to recycling targets.

In the wooden packaging sector, the tonnage of waste generated is related to the amount of material that is brought on the market. In a stable (balanced) market this will also be the amount that is discarded. The recycling rate is usually determined each calendar year.

5.3.5 Product reuse rate

The number of cycles that a functional unit is in operation is a measure of product reuse. This indicator is part of the system description of the cascade. For each application of wood the number of product cycles will be different. For many applications the technical maximum number of cycles will be more or less known, so a percentage of achieved cycles related to the maximum possible cycles could be defined as an indicator.

5.3.6 Product lifetime

In many cascades – like wood used in construction - the number of product cycles is not so relevant, instead the lifetime of the product should be increased as much as possible, making replacement needed less often, thereby saving material use. The product lifetime is also already part of the system description. In relevant cases the increased product lifetime of the functional unit could be compared with the lifetime of the functional unit in the fossil or wooden reference.

5.4 Carbon emissions

5.4.1 Greenhouse gas emission savings

The greenhouse gas emission savings are regarded as a main indicator of the environmental benefits of cascading. Carbon savings are relevant to mitigate climate change, a relevant topic for policy makers. Different processes can be relatively easily compared on basis of their carbon emissions. Several methods to calculate carbon emission savings are available:

CDM and JI methodologies

CDM and JI methodologies take into account the carbon emission savings on a project basis. The emission savings are calculated as the difference between the baseline emissions (of the fossil reference or the reference cascade) and the project emissions (generated by the project). Methods for various types of small and large scale projects are elaborated in detail and can be found on http://cdm.unfccc.int/methodologies/index.html. The application of CDM and JI methods is rather straightforward. However, some drawbacks can be noted. Not all emissions are taken into account, for instance the emissions related to the production of equipment. The CDM methods do not cover (cascaded) processes in the wood sector. A method to calculate the emission savings by combustion of biomass for heat and electricity production is available though.

Carbon foot printing

The carbon footprint is a measure of the total amount of emissions of carbon dioxide (CO_2) and other greenhouse gases such as methane (CH_4) emissions or nitrous oxide (N_2O) of a defined population, system or activity, considering all relevant sources, sinks and storages within the spatial and temporal boundary of the population, system or activity of interest. The carbon footprint is calculated as carbon dioxide equivalent (CO_{2e}) using the relevant 100-year global warming potential (GWP100)[52]. Carbon footprints can be calculated for products, which makes them interesting for the evaluation of cascades.

Life cycle assessment (LCA)

LCA measures the potential environmental impacts of a product, process or service over its life cycle. In addition to greenhouse gas emissions, the LCA takes into account all other material and energy inputs and environmental releases and assesses their potential impact on the environment. The spectrum of impact categories is broad and includes: human health, ecosystem degradation, climate change and natural resource depletion. LCA is therefore a multi-criteria analysis that assesses multiple impacts. The carbon footprint is essentially a mono-criterion analysis as it focuses on a single environmental impact, i.e. climate change.

Both methods rely on functional approaches for impact assessment. In fact, a "functional unit", or quantified performance of a studied product, serves as the basis for analysis and enables comparability between products with similar functional units.

Suggested indicators

In the study on cascading in the wood sector it is suggested to use the following indicators:

> **Carbon footprint –** the greenhouse gas emissions per functional unit. (kg CO_{2-}eq/functional unit). These emissions include the emissions of raw materials used, initial production, cascading actions and end-of-life emissions. Emissions during the use phase of the functional unit will not be taken into account except when these are needed to render the cascading use possible[53].
>
> **(relative) carbon emission savings –** the carbon footprint of the cascaded product divided by the carbon footprint of the fossil or wooden reference (%).
>
> **(absolute) carbon emission savings -** the carbon footprint of the fossil or wooden reference minus the carbon footprint of the cascaded product (kg CO_{2e}/ functional unit).

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[52] Wright, L.; Kemp, S., Williams, I. (2011). "'Carbon footprinting': towards a universally accepted definition". Carbon Management 2 (1): 61–72. doi:10.4155/CMT.10.39.

[53] For instance return transport for reuse of pallets.

End-of-life emissions of cascaded products versus non cascaded use

When comparing options of wood use with and without product reuse, the carbon balance of the option without product reuse appears to be much more beneficial than the option with recycling, because of the higher emissions savings by combustion of the wood for energy generation. For instance, combustion of 10 single use pallets for energy generation results in 10 times more substitution of fossil fuels than combustion of 1 recycled pallet that has been used ten times. In order to make a fair comparison of options, it should be known what the fate is of the wood that has been saved by cascading. The saved wood could:

- be used for production of more units of the same product
- be used for production of another product
- be directly used for energy generation
- remain untouched in the forest.

Full analysis of the fate of the non-used wood will not be possible in the frame of this evaluation tool. However some assumptions can be made. Wood is a restricted resource with a considerable and increasing market demand. Therefore, it is unlikely that the saved wood will remain untouched in the forest. Some of the wood will be used in products, other directly used for energy. At the end of their productive lifetime, most of the wood will be combusted for energy generation. Therefore, it is reasonable to assume that all the wood that is saved by cascading, is harvested and eventually used for energy generation. Therefore, the advantage of additional energy generation by non-cascading use of biomass is nullified.

5.4.2 Carbon storage in harvested wood products

One of the benefits of wooden products is that carbon is stored during the lifetime of the product. Several methods have been developed to calculate the amounts of carbon stored in harvested wood products (HWP). See for instance Brandao et al (2011)[54]. The IPCC (2006)[55] has developed a method for calculating HWP in national greenhouse gas inventories. The European Commission has decided[56] to introduce obligatory monitoring of harvested wood products based on the same method. This emphasises the relevance of this method for policy makers.

The carbon stock change is described in the following way:

$$C(i+1) = e^{-k} * C(i) + \left[\left(\frac{1-e^{-k}}{k}\right)\right] * Inflow(i)$$

[54] Miguel Brandao, Annie Levasseur, Miko U. F. Kirschbaum, et al. (2012), Key issues and options in accounting for carbon sequestration and temporary storage in life cycle assessment and carbon footprinting, Int J Life Cycle Assess, published 2 June 2012.

[55] IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, chapter 12: Harvested wood products.

[56] Decision 259/2013/EU Decision on accounting rules on greenhouse gas emissions and removals resulting from activities related to land use, land use change and forestry and on information concerning actions relating to those activities.

in which,

C(i)	carbon stock in year i in tonnes carbon
C(i+1) - C(i)	carbon stock change in year i in tonnes carbon
inflow (i)	the inflow in Gg C in year i
k	decay constant (k = ln(2)/half life)

One important variable is the half life of wooden product. The EU decision provides the following default-half life values:

- 2 years for paper
- 25 years for wood panels
- 35 years for sawn wood.

The half life of the products is derived from the average lifetime of the products in the following way:

Half life = average lifetime * ln(2)

Ln(2) equals 0.693, so the average total lifetime in the EC proposal are:

- 3 years for paper
- 36 years for wood panels
- 50 years for sawn wood.

To illustrate this method, an example is provided of carbon stored in sawn wood. Figure 10 shows the average carbon stock of 10 kg carbon related to 20 kg of sawn wood that was produced in the year 2010. After a sharp increase in carbon stock after production of the sawn wood, the carbon stored decreases. The calculated decreasing line shows the average carbon storage in sawn wood, based on a half life of 35 years, which means that after 35 years half of the sawn wood has reached end of life. Note that if an individual piece of sawn wood would be followed, the curve would stay horizontal at 10 kg carbon stored, until the end of life, after which the carbon stock would drop to zero. On sector level however the proposed method represents reality better, as it works with an average lifetime of the sawn wood.

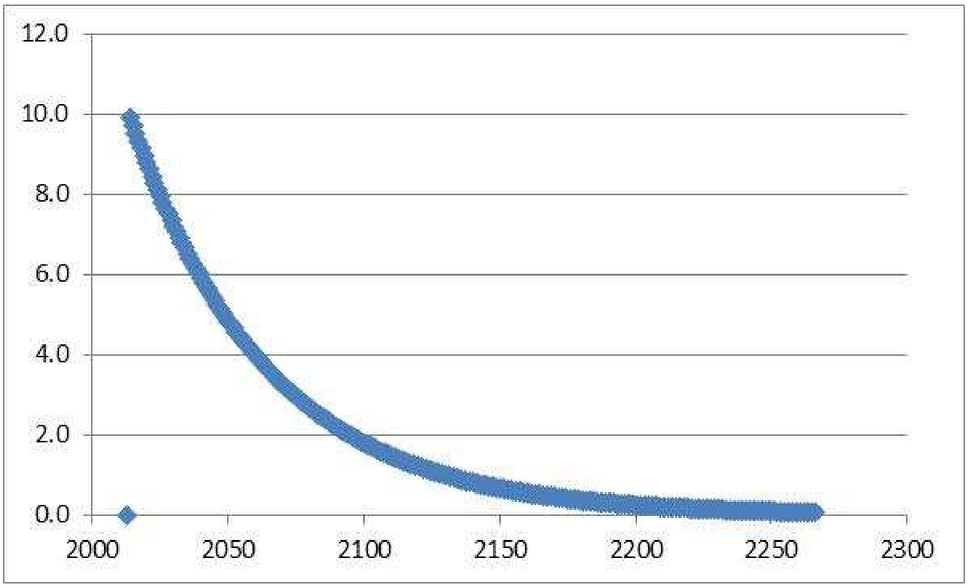

Figure 10 Carbon storage (kg) over time of 10 kg carbon stored in sawn wood

Figure 11 shows the carbon storage if each year 20 kg sawn wood is produced and utilised containing 10 kg of carbon. It shows that after time a new equilibrium is reached. The storage of 500 kg carbon will be maintained as long as each year 20 kg of sawn wood is produced and utilised.

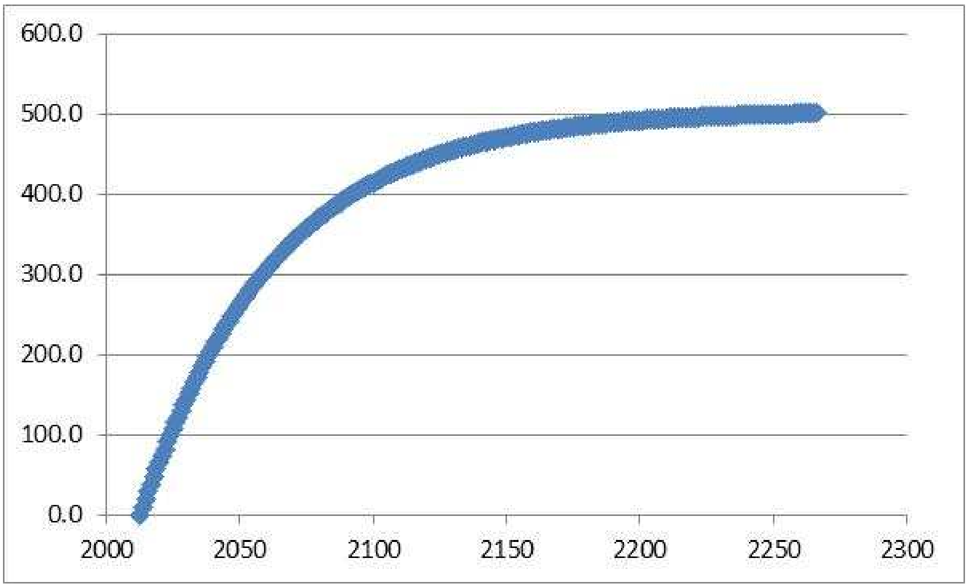

Figure 11 Carbon storage (kg) over time in case each year 10 kg carbon is stored in sawn wood

Figure 12 shows what happens if the production of 20 kg of sawn wood stops after 10 years. The total carbon stock drops immediately after 10 years.

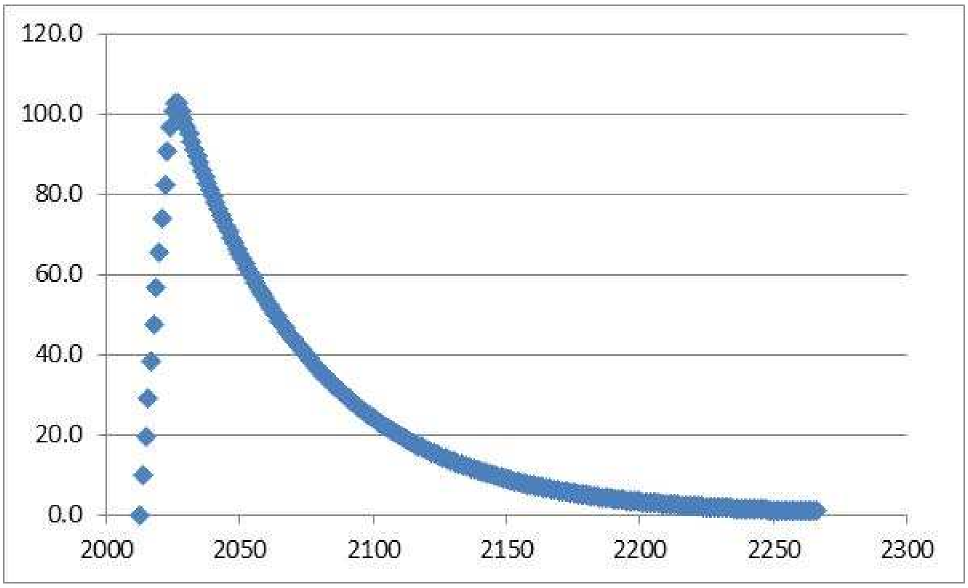

Figure 12 Carbon storage (kg) over time in case 10 kg carbon is stored in wood panels annually for a period of 10 years.

The carbon stock calculation of the EC starts in 1900 as to estimate the current carbon stock in harvested wood products. In our study we will focus on the additional carbon stored caused by cascading in the wood sector.

5.5 Economic performance

5.5.1 Value added

Value added is a commonly used indicator to measure the contribution of a certain production process to the economy. It is defined as follows[57]:

- Gross Value Added (GVA) at producer prices is output at producer prices minus intermediate consumption at purchaser prices. The producer price is the amount receivable by the producer from the purchaser for a unit of a product minus value added tax (VAT), or similar deductible tax, invoiced to the purchaser. (By subtracting consumption of fixed capital from GVA the corresponding net value added (NVA) is obtained). The sum of values added results in the Gross Domestic Product (GDP) of a country.
- Intermediate consumption is an accounting concept which measures the value of the goods and services consumed as inputs by a process of production. It excludes fixed assets whose consumption is recorded as consumption of fixed capital. The goods and services may be either transformed or used up by the production process.

Value added could be considered a measuring stick to evaluate the contribution of a cascade to the economy. Cascades tend to provide the same services in a more efficient

57 http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Value_added

way with less material consumption. The functional unit can be offered at lower costs and the provider of the functional unit can make a higher margin.

In some situations the costs of the cascade can be higher than in the reference situation. In these cases the other benefits of cascading like CO_2 emission reduction, energy savings, should be higher and “get a price”.

5.5.2 Resource productivity

The “*Roadmap to a resource efficient Europe*”[58] suggests to use Resource Productivity: the ratio of Gross Domestic Product (GDP)[59] to Domestic Material Consumption (DMC) expressed in Euro/tonne as a provisional lead indicator to measure resource efficiency. The higher the ratio, the better the performance. This is an indicator that is easy to communicate to the public, but – as the European Commission states - cannot be used properly for policy making without a “dashboard” of supporting indicators that have a life cycle, or value chain, perspective on water, land, materials and carbon plus indicators that measure environmental impacts and the global aspects of EU consumption and thematic indicators to monitor progress towards existing targets in other sectors.

The indicator resource productivity is designed for use on a national level. Given the importance it is given by the Roadmap, this indicator has been included and formulated on the level of a funtional unit in a cascade resource productivity as: the value added generated per kg of material (which can be compared to a reference cascade or a fossil reference).

5.5.3 Employment generation

A common way to determine employment generation is to divide the increase in value added in a sector by the average value added per employee active in the sector. The latter is available in CBS statistics. This approach will be applied in this evaluation method as well. Since the wood sector has an international supply chain, also employment generated outside the Netherlands will be estimated, if possible. A more in-depth assessment should also take into account the number of jobs that are destroyed in production chains that are outcompeted by the new practices.

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[58] COM (2011) 571

[59] Gross Domestic Product is the market value of all officially recognized final goods and services produced within a country in a given period of time.

6 CASE STUDY: TIMBER FRAME CONSTRUCTION

6.1 Introduction

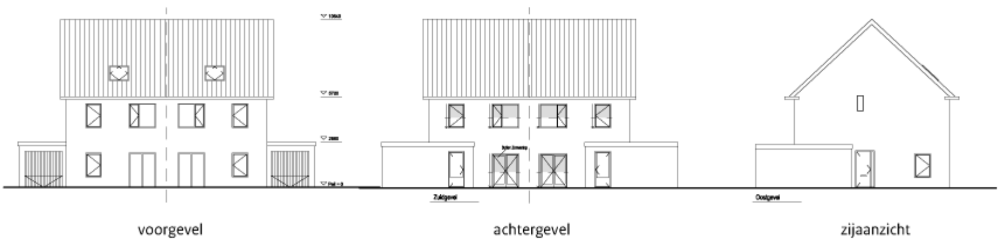
Timber frame construction (in Dutch: houtskeletbouw, further referred to as HSB) is a building method in which houses are assembled using quick fix prefab elements.. These elements have the height of a single storey and often the width of the house itself. The walls consist of softwood HSB elements, the floor and roof elements consist of softwood bars. The elements are filled with insulation material and subsequently covered with particle board and/or oriented strand board (OSB) panels.

Since its introduction about 40 years ago, timber frame construction gained a modest but steady market share of close to 2%. It is estimated that on a total of 7.15 million houses 120,000 houses have been built with timber frame construction. (de Graaf 2013). Also the use of prefab HSB-element in traditional building methods has increased over the years, e.g. houses that are partly constructed with bricks (ground floor) and timber (e.g. first and second floor).

Timber frame construction is very suitable for the realisation of low-energy or even zero energy consuming houses. Furthermore, the energy consumption and carbon emissions during the construction phase are lower than in traditional building. Moreover, a possible increase in the practice of timber based construction would lead to a carbon stock outside the forest. In the next sections the impacts of timber frame construction will be evaluated by applying the cascade evaluation method presented in chapter 5.

6.2 Cascade selection and reference system definition

The <u>functional unit</u> will be a <u>standard duplex house</u> as described in “Referentiewoningen nieuwbouw 2013” published by NL Agency (Agentschap NL 2013). These reference houses are representative state-of-the-art model houses and used to show the impact of measures, changes in standards or law, etc.



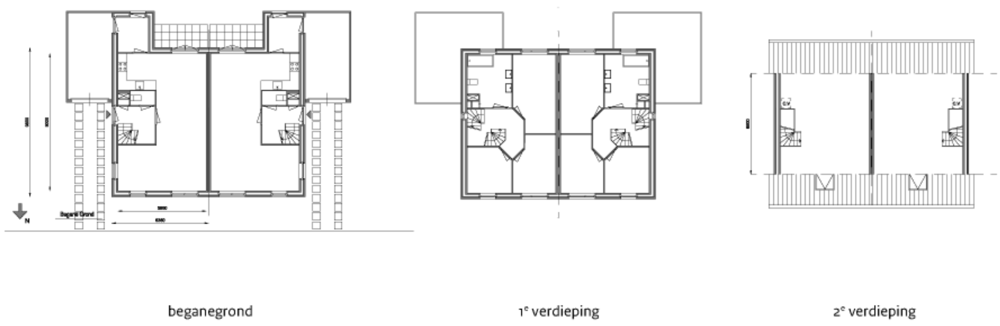


Figure 13 Views of the standard duplex house. Source: Agency NL 2013

Timber frame construction is applied in the private sector (detached houses), building projects (mixture of duplex and terraced houses) and social housing (mainly terraced houses). The duplex house is selected as reference as it is rather average in size.

The reference system is a traditionally built standard duplex house, further referred to as the traditional house. The cascaded system is a standard duplex house, in which timber frame construction is applied, further referred to as the HSB house. Table 5 and Table 6 show the main differences between the traditional and HSB house in terms of materials used. Parts not mentioned in those tables are assumed to be the same for both house types. For instance, both the traditional house and the HSB house have a concrete floor at ground level and a wooden roof construction. Moreover, both house types have the same outer walls made with bricks and tiles. Most Dutch buyers, also those who are interested in wood framed building, prefer a traditional brick style appearance of their house.

6.3 Cascade evaluation

The method for cascade evaluation consists of three groups of indicators related to:

- Resource efficiency
- Carbon emissions
- Economic performance.

The results of the cascade evaluation are presented below.

6.3.1 Resource efficiency

6.3.1.1 Material use

The material use of the parts of the traditional house and the HSB house that are distinct is provided in Table 5 and Table 6, respectively. The surfaces and volumes of materials needed for the traditional and HSB house based on the standard duplex house were obtained with support of the Dutch Joinery Association (NBvT), department of wooden framed timber, and HSB building company VDM, based in Drogeham.

Table 5 Material use of the parts of the HSB that replace materials of the traditional reference house

Part of HSB house	Type of material	Surface m^2	thickness mm	Volume m^3	Mass density kg/m^3	Mass tonnes
Outer cavity walls						
- Façade between the two houses	Softwood			1.18	436	0.5
	gypsum plasterboard	66.4	15	1.00	1100	1.1
	Rock wool	59.7	135	8.06	35	0.3
- Side façade	Softwood			1.39	436	0.6
	DHF-board			0.94	600	0.6
	gypsum plasterboard	62.7	15	0.94	1100	1.0
- Front and back façade	Softwood			1.18	436	0.5
	DHF-board		15	0.66	600	0.4
	gypsum plasterboard	44.1	15	0.66	1100	0.7
Inner walls	Softwood			1.38	436	0.6
	gypsum plasterboard	13.6	15	0.20	1100	0.2
	gypsum plasterboard	121.2	12.5	1.52	1100	1.7
	Rock wool	12.2	135	1.65	35	0.1
Floor first and second floor	Soft wood			3.26	436	1.4
	OSB	104.7	22	2.30	649	1.5
	gypsum plasterboard	104.7	15	1.57	1100	1.7
	Rock wool	94.2	60	5.65	35	0.2
Total				**33.54**		**13.1**

Table 6 Material use of the parts of a traditional reference house that will be replaced by HSB

Part of traditional house	Type of material	surface m2	thickness mm	Volume m3	Mass density kg/m3	Mass tonnes
Outer cavity walls						
- Façade between the two houses	Sand-lime bricks	66.4	120	8.0	1900	15.1
- Side façade	Sand-lime bricks	62.7	120	7.5	1900	14.3
- Front and back façade	Sand-lime bricks	44.1	100	4.4	1900	8.4
Inner walls						
- stability walls	Sand-lime bricks,	12.9	100	1.3	1900	2.5
- walls between bedrooms	Air-entrained concrete	19.4	100	1.9	800	1.6
- other inner walls	Air-entrained concrete	35.1	70	2.5	600	1.5
Floor first floor[b]						
- concrete floor	prefab concrete	52	200	10.4	1515	15.8
Floor second floor						
- concrete floor	prefab concrete	52	200	10.4	1515	15.8
- cement covering	Cement	48.7	50	2.4	2000	4.9
Total				**48.8**		**79.7**

[b)] Please note that both the HSB house and traditional house have a cement covering at the floor of the first floor. That is the reason why it is not listed here.

6.3.1.2 Resource efficiency

Resource efficiency is the material use of a functional unit divided by the material use in the wooden or fossil reference. The parts of the HSB house that are replaced have a mass of 13.1 tonnes compared to 79.7 tonnes of the traditional house, suggesting a resource efficiency factor 0.16, meaning a reduction in material use of 84%, which is considerable. The mass density of traditional materials like sand lime bricks is much higher than that of wood. On volume base the resource efficiency would be 0.69, resulting in a volume reduction of 31%. HSB requires less volume to reach the same insulation level.

6.3.1.3 Resource savings

The resource savings are another way of expressing the resource efficiency, and are provided in Table 7. The useful interpretation of resource efficiency and resource savings remains somewhat ambiguous because the comparison is made with a reference that uses completely different materials, i.e. what is the value of 1 tonne of soft wood compared to 1 tonne of sand-lime brick?

Table 7 Disaggregation of material use into biomass and construction minerals (tonnes material per house)

	Biomass	Construction minerals	Total
HSB	6.1	7.0	13.1
Reference case	0	79.7	79.7
Resource savings	-6.1	72.7	66.6

The EU communication COM(2011)571[60] suggests making a distinction between main categories such as biomass, fossil energy carriers, industrial minerals and ores and construction minerals. This approach has been applied in Table 7. This method provides better information than using a single resource savings value, but the problem of how to value biomass use versus construction minerals use remains. Nonetheless, HSB reaches considerable resource savings compared to traditional building methods.

6.3.1.4 Material recycling rate

In HSB mainly untreated wood is used that can be reused as product or material in different ways. It is difficult to forecast what type of reuse application will be appropriate after the product lifetime of 75-100 years. Conservatively, and based on today's knowledge, it has been assumed that the wood will be used in the particle board industry. For building materials in houses no specific recycling targets have been defined in the Netherlands, mainly because of the long product life time. Instead, recycling policies for untreated waste wood (A-wood) can be followed as described in the national waste management plan.

[60] COM(2011)571 Analysis associated with the roadmap to a Resource Efficient Europe, Part II.

6.3.2 Carbon emissions

6.3.2.1 Absolute carbon emission savings

The carbon emission savings of the timber framed house (HSB house) are related to the difference in materials used during the construction phase. Differences in energy consumption during the use phase of the house are not taken into account, as both houses will meet the same level of insulation and energy use, in the Netherlands expressed by the Energy Performance Coefficient (EPC)[61]. The carbon emissions of parts of the house that are identical in both cases, e.g. roof, ground floor, outer walls are also not taken into account.

Table 8 GHG emissions of parts of traditional house that can be replaced by wood

Part of traditional house	Type of material	Surface m^2	Emission factor[a)] kg CO_2/m^2	Emission kg CO_2
Outer cavity walls				
- Façade between the two houses	Sand-lime bricks, 120 mm	66.4	18.84	1251
- Side façade	Sand-lime bricks, 120 mm	62.7	18.84	1181
- Front and back façade	Sand-lime bricks, 100 mm	44.1	15.7	692
Inner walls				
- stability walls	Sand-lime bricks, 100 mm	12.9	15.7	203
- walls between bedrooms	Air-entrained concrete, 100 mm	19.4	27.6	535
- other inner walls	Air-entrained concrete, 70 mm	35.1	19.32	678
Floor first floor[b]				
- concrete floor	prefab concrete, 200 mm	52.0	49.2	2558
Floor second floor				
- concrete floor	prefab concrete, 200 mm	52.0	49.2	2558
- cement covering	Cement, 50 mm	48.7	25.75	1254
Total				**10912**

[a)] Source: DGBC Materialentool 2.12. Retrieved in Jan 2014.

[b)] Please note that both the HSB house and traditional house have a cement covering at the floor of the first floor. That is the reason why it is not listed here.

The emission factors are derived from DGBC Materialentool 2.11 of the Dutch Green Building Council[62], a software programme using a common set of Life Cycle Inventory data that can be used for environmental performance calculations required for obtaining a building permit for houses with a usage surface of more than 100 m^2. The emissions caused by the production and transport of materials used in the traditional house that are replaced by timber in the HSB house are presented in Table 8.

The emissions of the production and transport of the materials used in the HSB house that replace materials in the traditional house are presented in Table 9.

[61] Energieprestatiecoefficient

[62] More information can be found on www.mileudatabase.nl and http://www.dgbc.nl/wat_doet_dgbc/Materialentool

Table 9 GHG emissions of the parts of the HSB house that can replace traditional materials

Part of HSB house	Type of material	Surface m[2]	Emission factor[a)] kg CO_2/m^2	Emission kg CO_2
Outer cavity walls				
- Façade between the two houses	HSB system wall, structural	66.4	19.5	1294.8
- Side façade	HSB System wall, structural	62.7	19.5	1223
- Front and back façade	HSB System wall, structural	44.1	19.5	860
Inner walls	HSB System wall, not structural	67.4	6.0	404
Floor first floor	HSB floor, cantilevered	52.0	8.6	447
Floor second floor	HSB floor, cantilevered	52.0	8.6	447
				4676

[a)] Source: DGBC Materialentool 2.12. Retrieved in Jan 2014.

The total emission reduction of the timber framed house compared to the traditional house is **6.24 tonnes CO_2/duplex house.** This number is a good first indication of the emissions saving potential of HSB compared to traditional housing.

The emission reduction of the HSB house can be further improved by replacing the mineral insulation by bio-based cellulosic fibres as insulation materials, reaching a total emission reduction of **6.62 tonnes CO_2/duplex house**.

6.3.2.2 Relative carbon emission savings & carbon footprint

Since only emissions of the parts of the HSB house and the traditional house that are distinct have been calculated, it is not possible to calculate the relative carbon emissions savings and carbon footprint on the level of the functional unit, i.e. the standard duplex house as a whole. For the house parts that are substituted an emission reduction in the cradle to product phase of about 57% is achieved.

Comparison with other studies

In Sathre and O'Connor (2010)[63] a displacement factor is defined which quantifies the amount of emission reduction achieved per unit of wood use. Based on a meta-analysis of 21 studies on wood substitution, they concluded that most displacement factors are in the range of 1.0 to 3.0 tonne carbon per tonne carbon contained in the wood product, with 2.1 as the average value. In this case study a displacement factor of 1.6[64] was found, which fits well in the range mentioned by Sathre and O'Connor (2010).

[63] Sathre, R. and J. O'Connor (2010) A synthesis of research on wood products and green house gas Impacts, 2nd edition, FPInnovations.

[64] Based on 1.70 tonnes C emission reduction and 3.16 tonnes C stored divided by 3.16 tonnes C stored.

6.3.2.3 Carbon storage in harvested wood products

The amount of additional carbon stored in the HSB house compared to the traditional house has been calculated according to Draft CEN Standard Fpr EN 16449[65]. The carbon content of the different materials has been taken from relevant literature such as available from the CORRIM project. The amount of additional wood and wood containing board materials were provided by NBvT and HSB company VDM. Table 10 shows that each standard duplex HSB house stores 11.3 tonnes CO_2 more than a traditional house.

Table 10 Additional carbon stored in standard HSB house

Part of HSB house	Unit	Softwood	DHF-board	OSB-board	Total
Additional wood volume in HSB house	**m^3**	8.4	1.6	2.3	12.6
Mass density	kg/m^3	0.44[a)]	0.60[b)]	0.65[d)]	
Total woody mass in HSB house	ton dm	3.7	1.0	1.5	6.1
Percentage (bio)carbon	%	52.4% [c)]	46.7% [c)]	48.0%[d)]	
Totale amount of stored C	ton C	1.9	0.5	0.7	3.1
Total amount of stored CO_2	ton CO_2	**7.0**	**1.9**	**2.6**	**11.3**

[a)] Source: Wagner F., M. Puettmann, L. Johnson (2009) CORRIM: Phase II Final Report, Module B, Life Cycle Inventory of Inland Northwest Softwood Lumber Manufacturing, December 2009.

[b)] Source: EGGER ((2013) EGGER DHF product information brochure.

[c)] MDF was taken for determination of carbon content of DHF. Source: Wilson J.B. (2010), Life-cycle inventory of medium density fibreboard in terms of resources, emissions, energy and carbon, wood and fiber science, March 2010, V. 42(CORRIM special issue).

[b)] Source: Puettmann. M., E. Oneil et al. (2012), Cradle to Gate Life Cycle Assessment of Oriented Strandboard Production from the Southeast.

The development of carbon storage in time can be expressed using the IPCC 2006 method for harvested wood products described in section 5.4.2. Figure 14 shows the additional carbon storage if each year one HSB house is built instead of a traditional house representing storage of 11.3 tonnes carbon dioxide. The HSB houses form a carbon stock that can absorb carbon for more than 250 years before the carbon pool is fully saturated and finds an equilibrium between houses being built and demolished. The increase in carbon stock per additionally built HSB house is the highest in the initial 30-50 years.

[65] FprEN 16449 Wood and wood-based products – calculation of the biogenic carbon content of wood and conversion to carbon dioxide.

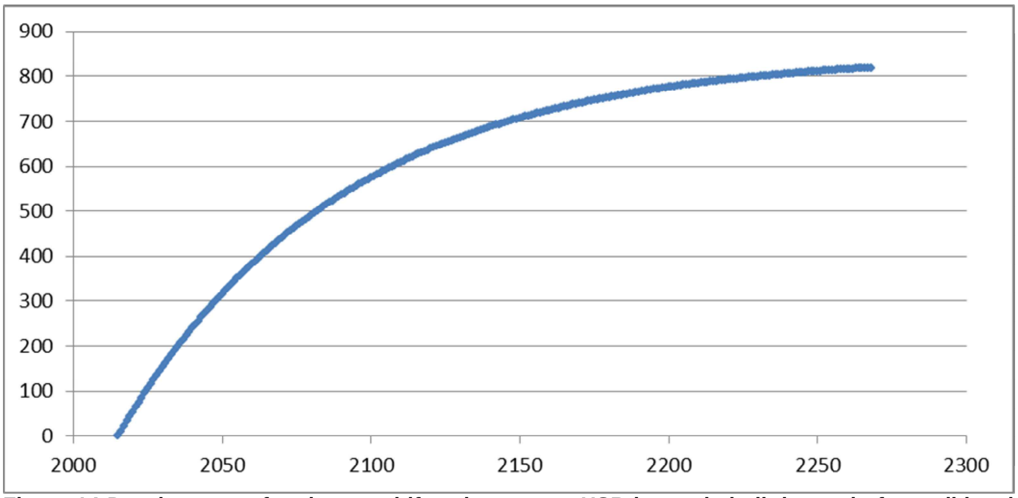


Figure 14 Development of carbon pool if each year one HSB house is built instead of a traditional house (tonnes CO2 stored in year x)

6.3.3 Economic performance

6.3.3.1 Value added

Within the available resources and time frame, and considering the commercial sensitivity of the market information it was not possible to make a full analysis of value added of a traditional versus HSB standard duplex house. Instead some more generic observations have been made. Whether HSB is a cheaper or more expensive building method compared to traditional building is situation dependant. The modular approach of HSB is for instance more cost-effective if a number of similar houses is needed at different locations. Much of the work takes place efficiently at the HSB-factory and less work at the various construction sites.. In case of a large project involving terraced houses, traditional building methods could be more cost-effective. It is concluded that in general HSB is not marketed as a cheap alternative for traditional building, nor regarded as a very expensive option. The value added of both options will be regarded as very similar to each other.

6.3.3.2 Resource productivity

Resource productivity is the value added per kg of material. This indicator is especially useful when the same materials are used and material or product recycling is applied. In case of HSB the same value added is created with different and less materials including biomass. Given that HSB materials are a factor 5-6 lighter than fossil materials, the resource productivity would also increase with the same factor. For the functional unit "HSB house" as a whole the increase in resource productivity would obviously be lower, because similar materials were used for the other parts of the house.

6.3.3.3 Employment generation

Insufficient information was available to draw firm conclusions on the labour intensity of building HSB houses. The systematic approach adopted in constructing HSB houses would suggest that it is more labour efficient than traditional building methods.. In case of

HSB up to 40% of man hours needed to build a house is spent in the HSB-factory, which creates a shift of personnel active at the construction site to the factory. The working conditions inside the factory are easily controlled, leading to e.g. less loss of working time due to frost.

6.3.4 Conclusion cascade evaluation

The cascade evaluation shows that HSB offers excellent carbon emissions savings and carbon storage performance, that could be even improved by the use of biobased insulation materials. In addition, being a prefab building method HSB is very suitable for building passive and energy neutral building.

Given the long lifetime of 75-100 years of houses, on the short and medium term, the options for material and product recycling are limited. After its lifetime, the wood is at least available for particle board production. Furthermore, HSB presents a shift to renewable building materials.

The economic and employment benefits of HSB are similar to traditional building, which means that HSB has positive effects on national income and employment but this is not an additional contribution to economic policy targets compared to traditional building.

HSB has a positive effect on the indicator resource productivity because the same value added is created with less and lighter materials.

6.4 Extrapolation and contribution to policy goals

The cascade evaluation shows that timber framed construction (HSB) can contribute especially to policies targeting climate change mitigation.

Goal scenario

Since its introduction about 40 years ago, timber frame construction gained a modest but steady market share of around 2%. According to Centrum Hout (2005-2013)[66] more than 100,000 timber frame houses have been built to date. This number is based on an inventory of some years ago. The Dutch Joinery Association NBvT estimates that currently some 120,000 HSB houses have been built on a total building stock of 7.15 million houses (de Graaf 2013). Since 2000 on average about 70,000 new houses have been built annually, however the yearly amounts vary considerably as can shown in Figure 15.

[66] Centrum hout (2005-2013), Dossier Houtskeletbouw. A series of currently papers that cover different aspects of timber framed construction.

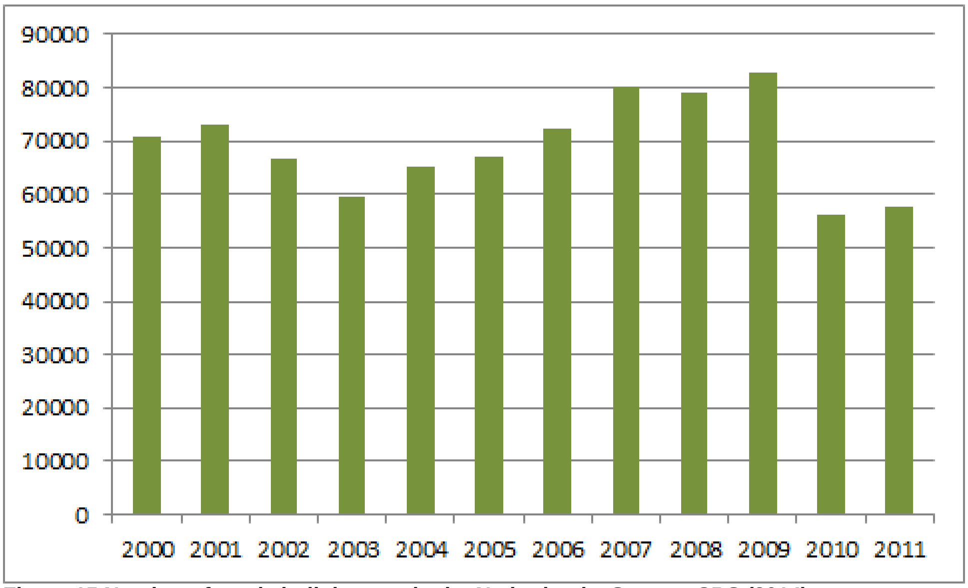


Figure 15 Number of newly built houses in the Netherlands. Source: CBS (2014)

Given the low share of HSB houses in the Netherlands compared to neighbouring countries, as a goal scenario it is assumed that the number of HSB houses built annually could be increased from the current level of 1,500 houses/year to 10,000 houses/year, reaching a market share of about 15%.

Contribution to policy goals

The building of 8,500 additional HSB houses per year above the current level of approximately 1,500 HSB houses per year will lead to a yearly emission reduction of 53,000 tonnes of CO_2 plus the storage of 96,000 tonnes of CO_2, together taking 149,000 tonnes of CO_2 out of the atmosphere. Over time the capacity to absorb additional carbon decreases slowly and the carbon pool of harvested wood products becomes larger as illustrated in Table 11 and Figure 16. This stabilisation takes place because on average after 75 year the HSB houses will be demolished and subtracted from the carbon stock.

Table 11 Emission savings and carbon storage in the scenario where every year 10,000 HSB houses are built instead of traditional houses, starting in 2015 ('1000 tonnes CO_2).

Year	yearly carbon savings	yearly carbon storage[a)]	Total per year	Accumulated carbon stock	Accumulated carbon savings	Total accumulated
2015	53	96	149	96	53	149
2020	53	89	142	554	265	819
2025	53	84	137	983	530	1513
2030	53	78	131	1384	795	2179
2040	53	68	121	2110	1325	3435
2050	53	60	113	2746	1855	4601
2100	53	31	84	4915	4505	9420

[a)] The amount of carbon storage decreases slowly until an equilibrium is reached between newly built HSB houses and demolished HSB houses.

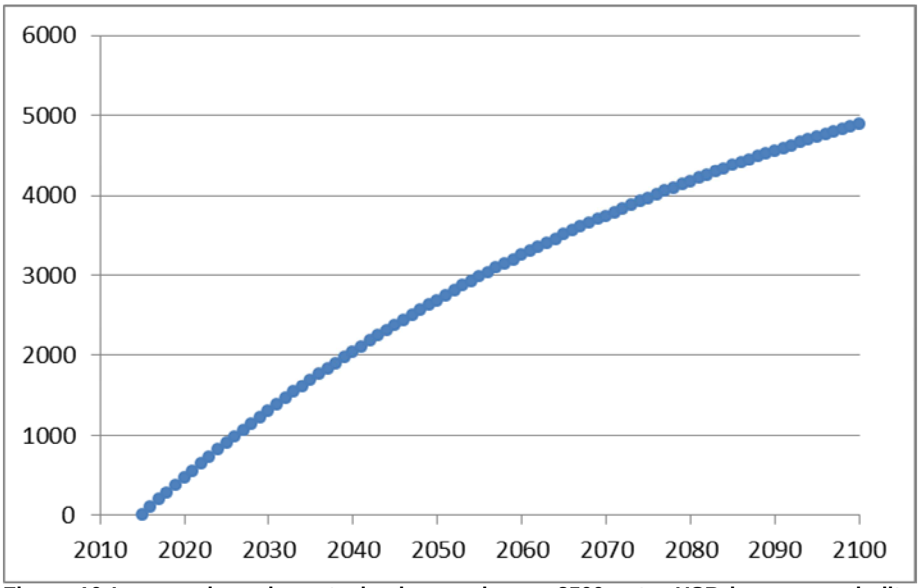


Figure 16 Increase in carbon stock when each year 8500 extra HSB houses are built above the current level of 2000 houses/year ('1000 tonnes of CO_2 stored in year x)

In the year 2050 already 4.6 mln. tonnes of CO_2 will be removed from the air by the combination of carbon emission savings in the construction phase and carbon storage. To give a reference, this result is comparable with the prestigious Rotterdam Opslag en Afvang Demonstratieproject (ROAD), a CCS (carbon capture and storage) project that will store in total 4 mln tonnes CO_2 from an electricity plant in Rotterdam and that will require an investment of around 625 mln Euro[67].

For the year 2020 the Dutch government has a greenhouse gas reduction target of 20% compared to base year 1990. The emission of 1990 was 213.2 mln tonnes CO_2-eq, which means that in 2020 the emission should be reduced to 170 mln tonnes CO_2-eq. In 2012 a greenhouse gas emission level of 193 mln tonnes CO_2-eq was reached, which means that in the period 2013-2020 a further reduction of 23 mln tonnes CO_2-eq is needed (see Figure 17).

[67] Het Financieele dagblad, 3 Feb 2014, p12-13..

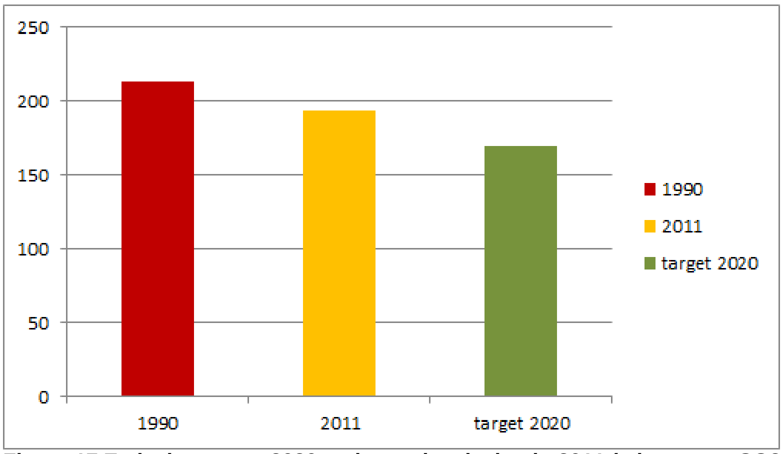


Figure 17 Emission target 2020 and actual emission in 2011 (mln tonnes CO2-eq/year)

Through a combination of carbon emission reduction and carbon storage HSB can remove 149-142 ktonnes CO_2/year from the atmosphere, which is 0.6 % of the additional needed reduction.

In addition to carbon stock increase and emission reductions, HSB can contribute to efficient building targets, leading to emission reductions and energy savings during the use phase of houses. In 2015 the EPC norm for newly built houses will be tightened from 0.6 to 0.4, and the heat resistance value (Rc-value) of the shell of new buildings will be increased from 3.5 to 5 m^2K/W. Both targets can be reached effectively with HSB at reasonable costs.

6.5 Actions for scenario realisation

6.5.1 Identification of barriers

Compared with other countries, HSB is not a widespread building method in the Netherlands. Situated in a river delta, bricks are traditionally the main building element. Table 12 shows that the share of wood in construction of family houses is relatively high in the high-latitude and forest-rich Nordic countries and in North America, but is much lower elsewhere in Europe.

Table 12 Share of wood construction in one and two family house construction in selected countries and regions

Country	Share of wood construction
USA	90-94%
Canada	76-85%
Nordic countries	80-85%
Scotland	60%
UK	20%
Germany	10%
The Netherlands	6-7%[a)]

France	4%

Source: Sathre and Gustavsson (2009)[68]

a) The share of HSB is lower than the share of wood construction in this table because also traditional houses use wood.

The position of HSB as a lesser known building method results in several preconceptions such as poor fire resistance, poor noise insulation, uncertainty about general quality and value stability, etc. Sometimes it is suggested that HSB-houses need air conditioning because they would heat up in summer, however existing HSB-houses simply use night ventilation which is much more energy efficient. These type of preconceptions are difficult to overcome according to HSB building companies and the Dutch Joinery Association.

Buying a new house is often the biggest investment in the life of consumers, which makes buyers conservative and chose easily for the safest choice of a traditional house. The management of social housing organisations often show more interest in the HSB building method.

On the positive side, legislation and building regulations were not reported to be a serious obstacle to the implementation of HSB housing projects. Requirements in the building code are formulated in neutral terms without prescription or exclusion of certain building materials. However, supervisors sometimes tend to be much stricter when checking HSB buildings - that they are less familiar with - sometimes leading to delay in the building process.

The building sector as a whole is facing harsh economic times. Furthermore, Dutch social housing corporations are reluctant to invest as they have to pay a “lessor levy”, a new measure imposed recently by the national government on all social housing organisations. On the positive site, after decreasing for years in a row the interest of private persons to buy houses is on the rise again.

6.5.2 Proposed solutions

The negative image of HSB is largely due to preconceptions and not based on facts. It is crucial that these preconceptions are removed. HSB building companies observe that if there is an opportunity to explain their building method, the preconceptions can be removed. Centrum Hout published a series of brochures on topics like fire safety, health and climate, stability in value, quality, design, renovation and comfort in relation to HSB. This promotion and awareness raising work will remain necessary to counteract negative perceptions about HSB. In addition it could be considered to carry out independent research on (1) customer satisfaction and (2) additional methods to address the negative public perception. Furthermore it is important that all levels of technical education pay attention to efficient building methods like HSB, which will slowly but gradually increase

[68] Sathre. R and L Gustavsson (2009) A state-of-the-art review of energy and climate effects of wood product subsitution, Växjö University, Sweden.

the level of HSB-expertise at social housing organisations, supervisors, architects, builders, etc.

HSB is a very effective building method to produce energy efficient buildings. HSB can indirectly be stimulated by setting strict EPC and Rc-values. This way energy efficient building methods can be promoted with associated benefits of emission reduction and carbon storage in wooden products if HSB is applied. Countries like the UK and Belgium have set ambitious policies and targets for the building construction sector, like the "2016 zero carbon new homes" policy[69] of England and Wales and the Region of Brussels requiring passive building methods for each new building from 2015 onwards. The Dutch government is recommended to set a similar high ambition level in the realisation of low or zero carbon housing in the Netherlands.

The low carbon emissions in the production of HSB are appreciated in the DGBC Materialentool that calculates the lifecycle emissions of buildings, needed for a building permit application for buildings with a surface larger than 100 m^2. It is recommended to the HSB sector to provide as much as possible Life Cycle Inventory (LCI) information on HSB components to the "milieudatabase" in order to make it easy for the users to obtain a good score by using HSB.

Currently carbon storage in harvested wood products is neither measured systematically nor valued in financial terms. The IPCC Good Practice Guidelines provide countries the methods to include carbon storage in "harvested wood products" (HWP) in their national greenhouse gas inventory report that has to be submitted to UNFCCC each year. Most countries including the Netherlands do not consider carbon storage in harvested wood products and simply take the carbon stock change as zero. The European Commission promotes the accounting of harvested wood products by Decision 529/2013/EC[70] that was adopted in 2013 and obliges member states to apply the accounting rules of UNFCCC on harvested wood products, without the obligation to implement them in the national inventory reports. The decision provides standard half-life values for paper, wood panels and sawn wood and allows the use of subdivisions of these categories and country specific half-life factors. The Dutch authorities are recommended to implement the EU decision fully. This way the relevance of carbon storage in wood products can be explored, without direct consequences for the national inventory report.

An important detail is that the carbon stock change in HWP is allocated to the country where the biomass is harvested. Only wood that is harvested in the Netherlands and

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[69] Building A Greener Future: Towards Zero Carbon Development. Department for Communities and Local Government 2006. For an overview of developments see for instance http://www.constructionproducts.org.uk/sustainability/buildings/zero-carbon-homes/ and http://www.ukgbc.org/content/new-build

[70] Decision 529/2013/EU on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities.

processed into wood products either in or outside the Netherlands counts to the Dutch GHG inventory. Given that most HSB houses are built using imported wood, the effort of carbon storage of HSB will appear mainly in the national inventory of other member states. This however, does not eliminate the fact that carbon storage by using timber frame construction is an excellent opportunity to mitigate climate change and achieve carbon emission reduction targets with existing building technology.

7 CASE STUDY: WOODEN PALLETS

7.1 Introduction

The wooden packaging sector involves the production and repair of wooden pallets, crates, boxes, and industrial packaging. All these items are used in the transport of goods. Wooden pallets make up 75% - 80% of the total production volume[71] in the sector. The total amount of wood used annually in the sector is more than 1 million m^3 of softwood (primarily sourced from other European countries, such as Scandinavia and Central and Eastern Europe).

Wooden pallets are commonly used for the transport of goods. Standard European pallets (often referred to as Euro-pallets) are often held in (open and closed) pools. In certain sectors, such as the chemical industry, pallets are also held in non-pools. Furthermore, many types of limited-use pallets (often customer-specific pallets) are produced. 90% of all pallets are made of wood. The wooden packaging sector is well organised, with about 85% of the production volume coming from about 45 suppliers, united in the EPV (Emballage- en Palletindustrievereniging / Wooden packaging and pallet industry association, www.epv.nl). About 70% of the total market volume is produced by four large suppliers that are members of the EPV. The sector employs about 3400 people.

In the wooden packaging sector cascading is practiced in two ways:

- Product reuse, which means re-use of wooden pallets, sometimes after repair.
- Material recycling, which means that the wood is re-used in other products, mostly in the particle board industry.

Product reuse is a key characteristic of the use of wooden pallets. Pallets are recycled in open pools, i.e. free trade in standardised pallets and in closed pools in which the standardised pallet remains owner of the same organisation. Other standardised pallets are recycled in non-pools, such as pallets used in the chemical industry (CP pallets). Another group of pallets are limited use pallets (often customer-specific) of different shapes and forms. Also these pallets are reused but to a somewhat lesser degree than the standardised pallets.

Material recycling is an important issue in the packaging sector. Stichting Kringloop Hout monitors and publishes the material recycling ratio of wooden packaging on a yearly base[72]. The level of material recycling, which was nearly 40% in 2005 and 2006, is currently decreasing and reached a level of 30% in 2011. This is still higher than the current minimum level agreed with the government (25%), and substantially higher than the EU guideline of 15% re-use. However, the downward trend is worrying and the goal

[71] Wageningen UR, "Kansen en barrières voor verduurzaming van houtketens", werkdocument 222, http://edepot.wur.nl/173280, April 2011

[72] http://www.kringloophout.nl/monitoring-recycling

of 45% material recycling by 2022 - agreed between sector and government in the Packaging Agreement ("Raamovereenkomst Verpakkingen 2013 - 2022") - becomes unattainable. According to the wooden packaging sector a prime reason for the decrease in material recycling is the pull for used wood caused by biomass combustion plants, stimulated through the SDE+ subsidy for renewable energy production.

Below the impacts of both material recycling and product reuse are described quantitatively with the developed methology. The results will be extrapolated to sector level and the contribution to policy goals will be determined.

7.2 Cascade selection and reference system definition

Functional unit

Cascades generate one or more products that provide certain services. In the case of wooden pallets the product is wooden pallets and the service is trips in which the wooden pallet is used as packaging material. In the case of the particle boards the product is the particle boards and the service is the use of particle boards in furniture or housing for a certain amount of time. Since the cascade contains both wooden pallets and particle boards, the functional unit is defined as:

One trip in which a wooden pallet is used, combined with a quantity of particle board that can be produced by using the amount of pallet wood from that one trip, with a wooden pallet material recycling percentage of 45%.

Since the goal of this functional unit is to provide a common basis for the calculations, any material recycling percentage is acceptable in this definition. The 45% mentioned above is chosen for convenience as will be shown by calculations elsewhere in this section.

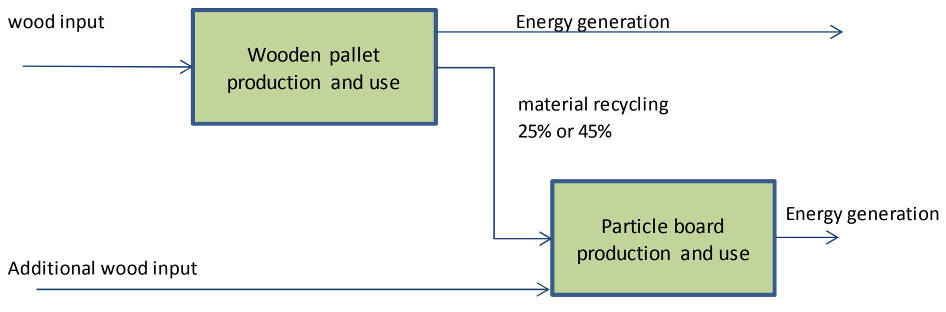

Figure 18: Definition functional unit and wooden packaging cascade for evaluation

In this cascade the primary use as wooden pallets, the re-use as pallets and the subsequent use of part of the wood waste in the particle board industry is included. There are alternative (non-energy) uses for wood from wooden pallets, such as use in pressed pallets and chips production for animal husbandry. The particle board industry is however the largest non-energy consumer of this type of wood waste. In The Netherlands there is no particle board industry, and waste from wooden packaging is for 69% (2011) exported to Belgium and Germany[73]. The remaining 31% is utilised in the Netherlands.

Reference system

Given that 90% of the pallets are made of wood, a wooden pallet has been selected as reference system. The reference system is defined by the weight, the number of trips and the material recycling percentage, as detailed in Table 13. A distinction is made between the number of trips of standard (open and closed) pool and non-pool pallets and limited-use pallets (often customer specific pallets).

Table 13: Data used for determining material flows for the wooden packaging scenarios

Parameter	Value	Unit
Averaged weight of pallet	25[74]	kg/pallet
Percentage wood used for repair	6%[75]	-
Averaged trips per standard pallet	25[76]	trips/pallet
Averaged trips per limited-use pallet	5.5[77]	trips/pallet
Percentage standard pallets	55%[78]	-
Percentage limited-use pallets	45%[78]	-
Averaged trips per pallet	16.2	trips/pallet
Averaged wood content in particle boards	86%[79]	-
Averaged density particle board	640[79]	kg/m3

The average weight of a pallet has been taken to be the averaged weight of a Euro-pallet. The actual average weight of all types of pallets may differ; there is however no data available to determine this actual average weight. During its lifetime a pallet is sometimes repaired. The percentage of wood used for repairing a pallet during its lifetime is listed in the table.

The number of trips that are made on average with standard pallets and limited-use (often customer-specific) pallets has not been independently verified. Especially with respect to customer-specific and open pool pallets the number of trips is difficult to determine since the customer becomes the owner of the pallets, and registration of pallet use is often a low priority.

[73] Nyenrode Business University and Stichting Probos, “Het bevorderen van materiaalhergebruik van houten verpakkingen in de afvalfase”, 18 March 2013.

[74] http://www.palletcentrale.nl/pdfs/Verpakkingsbelasting.pdf

[75] TNO report "Milieugericht Levens-Cyclus-Analyse van meermalige houten pallets en meermalige kunststof pallets", 1994

[76] http://www.epv.nl/images/stories/Europese_houtverordening/Voorbereid_op_houtverordening.pdf

[77] Personal communication EPV, 7 February 2014

[78] Personal communication EPV, 7 February 2014

[79] http://www.wpif.org.uk/uploads/PanelGuide/39_%20Annex%202a%20BRE%20V3%2021_04.pdf

It is known that certain standard pallets, like those used in the chemical industry, are used for a large number of trips. The above data are assumptions based on the industry's own estimates.

7.3 Cascade evaluation - material recycling

7.3.1 Scenario definition

In this chapter the benefits of material recycling of wooden pallets are evaluated. The following two cascade scenarios have been defined (see Figure 19):

- A 'Baseline' scenario with a material recycling level of 25%. This level of material recycling is considered realistic if no policy changes are enacted.
- A 'Goal' scenario with a material recycling level of 45%. This level is equal to the 2022 target for material recycling agreed in the Packaging Agreement ("Raamovereenkomst Verpakkingen 2013 - 2022").

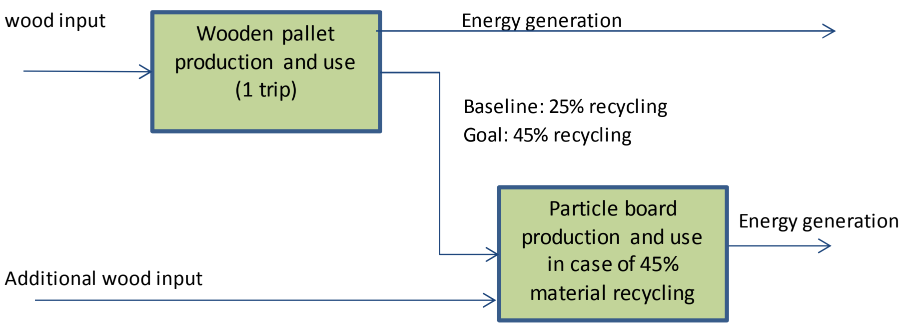

Figure 19: Definition of cascades wooden packaging for evaluation

Figure 19 figure shows that the functional unit is the same for both scenarios. 1 trip with a wooden pallet, and the amount of particle board that can be produced with 45% material recycling.

The Baseline scenario and Goal scenario differ with respect to the amount of material recycling,set at 45% and 25% respectively, which means that in the latter case additional wood input is needed to produce the same amount of particle board. Since the Belgian and German particle board industry use both fresh and used wood, it is considered realistic that they would replace a shortage of wood waste with addition fresh wood.

Waste wood from both the wooden pallet industry and from the particle board industry is used for renewable energy generation. The associated CO_2 emission reduction and energy generated is not taken into account in the evaluation, since it is assumed that all wood will ultimately be used for energy generation (see paragraph 3.3 for a more elaborate discussion).

7.3.2 Resource efficiency

The first set of indicators deal with resource efficiency. Specifically the following indicators are determined:

- Material use;
- Resource efficiency: the amount of materials used per functional unit;
- Recycling rate: tonnage of used materials that is collected for material re-use divided by total amount of material that is discarded;
- Number of product cycles/product lifetime;

Material use

The amount of wood needed per functional unit for the Baseline scenario of 25% and Goal scenario of 45% material recycling are given in Figure 20 and Figure 21, respectively.

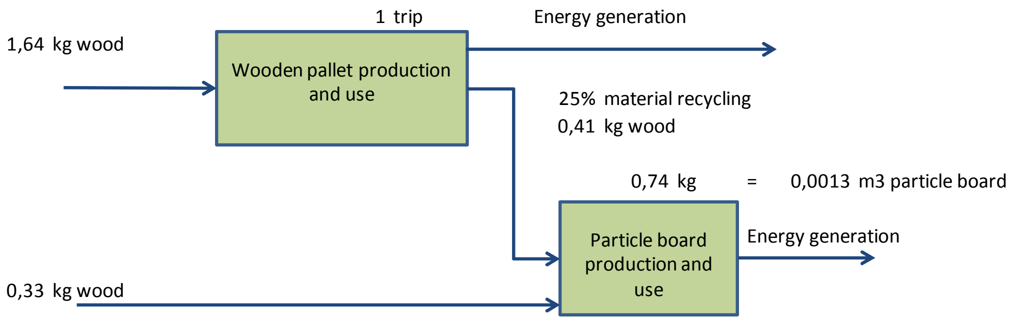

Figure 20: Material flows for the wooden packaging cascade in case of the Baseline scenario (25% material recycling)

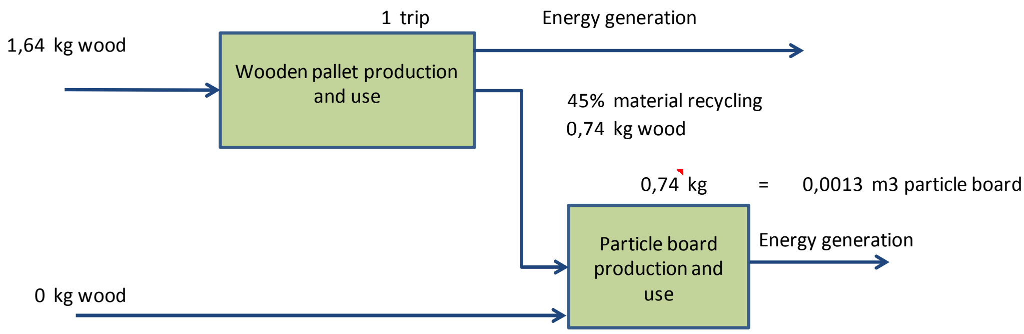

Figure 21: Material flows for the wooden packaging cascade in case of the Goal scenario (45% material recycling)

These figures show that the functional unit in both scenarios is the same, namely one trip and the amount of particle board that can be produced with 45% recycling. The main difference between the scenarios is that in the Goal scenario less wood is needed to produce the same amount of particle board as compared to the Baseline scenario (1.64 kg versus 1.97 kg wood). Based on these figures, it is possible to quantify the other cascade evaluation indicators.

Resource efficiency

The resource efficiency indicators follow from the material flows as determined above. Because the material recycling rate in the Goal scenario is higher, less wood is needed per functional unit. This results in a reduction in material use of 17%.

Material recycling rate

The material recycling rate of 45% compared to 25% in the Baseline scenario is a scenario input parameter, and not a result of the cascade evaluation.

Product reuse rate

The number of product cycles has been determined as the averaged number of pallet trips plus the (assumed one-time) use in particle boards. In the scenario definition the number of trips is the same for both scenarios.

The results of these resource efficiency indicators are summarised in Table 14.

Table 14: Resource efficiency indicators for wooden packaging material recycling scenarios

Indicator	Unit	Baseline scenario	Goal scenario
Material use	kg wood/ functional unit	2.0	1.6
Resource efficiency improvement	%	n.a.	17%
Recycling rate	-	25%	45%
Number of product cycles/product lifetime	-	17.2	17.2

7.3.3 Greenhouse gas emission savings

The second set of indicators detail the greenhouse gas emission savings. The indicators are:

- Carbon footprint: greenhouse emissions per functional unit;
- Relative carbon emission savings (compared to reference case);
- Absolute carbon emission savings (kg CO_2-eq/functional unit);
- Carbon stored in harvested wood products.

Apart from these indicators also the energy expenditure, expressed as MJ (MegaJoule) per functional unit is calculated. The results are given in Table 15.

Table 15: Greenhouse gas emission savings indicators for wooden packaging Baseline and Goal scenario

Indicator	Unit	Baseline scenario	Goal scenario
Carbon footprint	kg CO_2-eq/func. unit	1.064	1.061
Relative carbon emission savings	-	n.a.	0.32%
Absolute carbon emission savings	kg CO_2-eq/func. unit	n.a.	0.003
Carbon stored in harvested wood products	kg C/func. unit	1.19	1.19
Energy expenditure	MJ/func. unit	9.67	9.64

Carbon footprint & carbon emission savings

The greenhouse gas emission savings calculations have been carried out using literature data from various LCA studies such as a study from Anil[80] about the environmental impact of wooden pallets, an LCA study by TNO[81] and a study by CarbonRiver in which the CO_2-equivalent emissions of the particle board industry for various cases were determined[82]. The carbon emission savings are related to the carbon emissions in the Baseline scenario, so the carbon emission savings for that scenario are zero.

The results show a very small of material recycling on carbon emissions. Both as a percentage, and in absolute figures, there is not much difference in carbon emissions whether the material recycling percentage is 25% or 45%. The reason for the small difference is that in the Baseline scenario additional wood needs to be sourced to produce the same amount of particle board (see Figure 20; 0.33 kg additional wood is needed) The harvesting and transport emissions associated with additional wood sourcing are small compared to the CO_2-equivalent emissions from pallet production and particle board production. Otherwise there are no differences in the CO_2-eq emissions of the two scenarios, in both scenarios the same amount of pallets and particle board is produced leading to the same amount of carbon emissions.

Carbon storage

The carbon storage was calculated for both scenarios using the IPCC (2006) model. For both scenarios the amount of wood that is stored in products is the same, meaning that the carbon storage is also the same. In the Baseline scenario the same amount of carbon storage is attained as in the Goal scenario, while utilising more wood because more wood is used for energy generation.

7.3.4 Economic performance

The third set of indicators involves the economic performance. The following indicators have been defined:

- Gross value added: turnover minus costs of raw materials, calculated per functional unit;
- Resource productivity: value added per kg material;
- Employment generation.

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[80] Anil, S.K., "Environmental analysis of pallet types and ISPM treatment methods", Pennsylvania state University, 2010, http://mbao.org/2010/47Anil.pdf

[81] TNO report "Milieugericht Levens-Cyclus-Analyse van meermalige houten pallets en meermalige kunststof pallets", 1994

[82] CarbonRiver, "An analysis of carbon emissions for different end of life scenarios for virgin, recycled and low grade wood fibre", 2009, http://www.makewoodwork.co.uk/GalleryEntries/Manifesto_and_Reports/Documents/WPIF_Project_Subsidy_Report.pdf

Gross value added

The gross value added due to pallet use is determined by combining price information with sector information on the average value added per trip. Because in both scenarios the same service is delivered (same functional unit) the gross value added is the same for both scenarios. In Table 16 the calculation for the value added with respect to the *wooden packaging sector* is explained:

Table 16: Calculation gross value added per function unit (pallet trip part)

Parameter	Value	Unit
Costs pallets new[83]	10	Euro/pallet
Costs pallets used[84]	6.4	Euro/pallet
Trade value pallets used[85]	3.75	Euro/pallet
Value added pallet production[86]	49%	-
Value added repeat use pallets	100%	-
Amount of trips/pallet	16.2	trips/pallet
Amount of pallets used per trip	0.07	pallets/trip
Added value first use pallets	0.32	Euro/func. unit
Value added repeat use pallets	2.61	Euro/func. unit
Total value added pallets	2.93	Euro/func. unit

The value added is generated firstly because a pallet is produced and sold. From statistical data available from CBS it is clear that about half the turnover for the wooden packaging industry concerns value added. Since the wooden packaging sector is a subsector of CBS sector 16.2, and since the CBS data relate to the sector 16 as a whole, the actual value may differ somewhat. The value added per pallet is thus the price of a new pallet (= turnover) times the value added percentage. The amount of value added per functional unit is subsequently determined by multiplying the value added per pallet with the number of pallets used per trip (16.2 trips/pallet, so 0.07 pallets per trip).

Secondly, the value added for repeat use is determined. First the price difference between re-used and new pallets is determined. The percentage value added is set at 100% for repeat-use; the amount of materials needed for repair is considered negligible for this calculation. This difference is multiplied by the number of repeat-uses of one pallet. This total – the value added generated by repeat-use of a single pallet – is subsequently multiplied with the number of pallets per functional unit (0.07). The result is the value added due to repeat-use of pallets per functional unit.

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83 http://www.123pallets.nl/product-europallet-nieuw

84 http://www.kruizinga.nl/pallet/houten+pallet/5884/gebruikt/99-5884gb/?gclid=CPGE3rLZurcCFYWN3godDi4AaQ

85 Various enquiries per telephone

86 CBS data, Sector 16.2 (Hout- kurk en rietwaren industrie), SBI 2008. The wooden packaging sector is a subsector (16.24) of this sector.

The value added due to the use of wood as pallets is the sum of the values added for first use and repeat use.

In Table 17 the value added per functional unit with respect to the particle board use is determined.

Table 17: Calculation gross value added per function unit (particle board part)

Parameter	Value	Unit
Particle board prices in EU in 2012[87]	150	Euro/m^3 PB
Percentage value added[88]	22.8%	-
Amount of particle board per functional unit	0.0013	m^3 PB/func. unit
Value added particle board	0.05	Euro/func. unit

Because the – for these scenarios relevant - particle board industry is located in other European countries, the prices for particle board and the value added have been determined by combining averaged EU prices of particle board with information on the value added of the European panel board industry.

The value added due to use as particle board is then calculated by determining the amount or value added per m^3 particle board (multiplying the figures in the first two rows of the table above). The amount of particle board per functional unit follows from Figure 20. The value added value is determined by multiplying the amount of value added per m^3 particle board with this last figure.

The gross value added per functional unit is determined by the sum of the results of Table 16 and Table 17 (2.98 Euro/func. unit).

Resource productivity

The resource productivity is different for the two scenarios. Since in the Goal scenario less wood is used, the productivity per unit of resource (wood), is higher. This is shown in the calculation (Table 18):

Table 18: Calculation of resource productivity

Indicator	Unit	Baseline scenario	Goal scenario
Gross value added	Euro/func. unit	2.98	2.98
Amount of wood used	kg/func. unit	2.0	1.64
Resource productivity	Euro/kg wood	1.52	1.82

The resource productivity is the quotient of the gross value added and the amount of wood used.

[87] http://www.unece.org/fileadmin/DAM/timber/publications/07.pdf

[88] http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Manufacture_of_wood_and_of_products_of_wood_and_cork,_except_furniture;_manufacture_of_articles_of_straw_and_plaiting_materials_(NA

Employment generation

The same data sources have also been used to determine the employment associated with the cascades. The calculation is shown in Table 19. Just as in the case of the gross value added, the employment generated is the same for both scenarios since the functional unit is the same. Note that the amount of employment generated is given per million functional units.

Table 19: Calculation of employment generated

Parameter	Value	Unit
Value added per employee wooden packaging industry	104,706	Euro/employee
Value added due to pallets	2.93	Euro/func. unit
Employment wooden packaging industry	28.0	employees/mil. func. units
Value added per employee Particle Board industry (EU)	45,064	Euro/employee
Value added due to PB	0.05	Euro/func. unit
Employment PB industry	1.02	employees/mil. func. units
Total employment per million functional units	29.0	employees/mil. func. units

The calculation of the employment generated is divided into employment in the wooden packaging sector and employment in the particle board sector. The employment generated in the wooden packaging sector is far higher than the employment in the particle board sector. Main reason is the relative high value added that is generated due to the wooden packaging use.

Overall results of the economic performance parameters are given in Table 20.

Table 20: Economic indicators for wooden packaging material recycling scenarios

Indicator	Unit	Baseline scenario	Goal scenario
Gross value added	Euro/trip	2.98	2.98
Resource productivity	Euro/kg wood	1.52	1.82
Employment generation	Employee/mln. trips	29	29

7.4 Cascade evaluation - product reuse

7.4.1 Introduction

Besides the previous scenarios in which the amount of *material* recycling is varied, it is also interesting to investigate *product reuse* as cascading alternative, to illustrate its relevance for the sector. Two product reuse alternatives on the Baseline scenario are considered :

1. A decrease of the number of trips per pallet by 40%;
2. An increase in the number of trips per pallet by 10%.

These alternatives are discussed below.

7.4.2 Decreasing the number of trips by 40%

Scenario definition

When the number of trips per pallet decreases (in this case by 40%), the amount of service per pallet also decreases. The following material flows are associated with the first product reuse alternative:

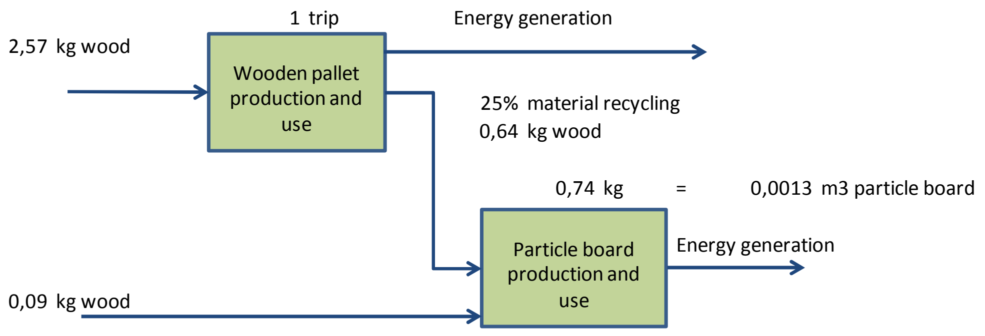

Figure 22: Material flows for the wooden packaging cascade in case of a 40% decrease in trips per pallet

In this scenario it is assumed that no additional wood is needed for repair of wooden pallets. This is consistent with the relatively large reduction in trips per pallet. The material recycling associated with this alternative is set at 25%, the same as with the Baseline scenario. Figure 22 shows that, when compared to the Baseline scenario, the amount of wood needed for the pallets is higher. Therefore more wood needs to be harvested to ensure that the same funcional unit is supplied as in the Baseline scenario.

The indicator levels resulting for this first alternative are presented in Table 21.

Table 21: Indicators for the alternative scenario in which the number of trips per pallet is decreased by 40%, compared to the Baseline scenario results

Indicator	Unit	Baseline scenario	minus 40% product recycling
Material use	kg wood/func. unit	1.96	2.66
Resource efficiency improvement	-	n.a.	-36%
Recycling rate	-	25%	25%
Number of product cycles/product lifetime	-	17.2	11
Carbon footprint	kg CO2-eq/func. unit	1.06	1.44
Relative carbon emission savings	-	n.a.	-25.9%
Absolute carbon emission savings	kg CO2-eq/func. unit	n.a.	-0.37
Carbon stored in harvested wood products	kg C/func. unit	1.19	1.65
Energy expenditure	MJ/func. unit	9.67	13.0
Gross value added	Euro/func. unit	2.98	2.90
Resource productivity	Euro/kg wood	1.52	1.09
Employment generation	Employee/mln func. Unit	29	28

These results show the following:

- The number of trips per pallet is an important factor with respect to resource efficiency and resouce productivity. Both decrease significantly because more wood is needed for the same functionality.
- This has an associated negative effect on the carbon footprint and the energy expenditure, which both increase significantly.
- Other indicators such as gross value added and employment generated only change marginally.
- The carbon stored in harvested wood products increases per functional unit: per functional unit the amount of wood needed for pallet production and use increases, while the amount of wood needed for particle board production and use stays the same. More wood is used for products, which means more carbon storage per trip.

7.4.3 Increasing the number of trips by 10%

When the number of trips per pallet increases (in this case by 10%), the amount of service per pallet increases. The following material flows are associated with the second product recycling alternative:

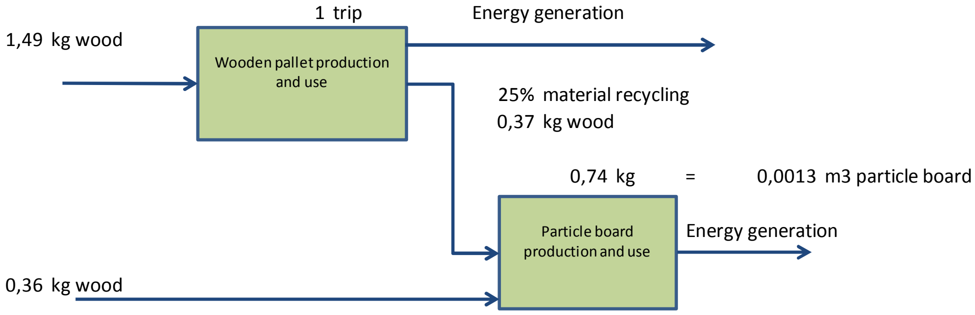

Figure 23: Material flows for the wooden packaging cascade in case of a 10% increase in trips per pallet

The material recycling associated with this alternative is set at 25%, the same as in the Baseline scenario. Figure 23 shows that compared to the Baseline scenario, less wood is used or pallets. Therefore additional wood needs to be harvested to ensure that the same funcional unit is supplied as in the case of the Baseline and the Goal scenarios. The total amount of wood for this cascade remains however below the amount of wood needed in the Baseline scenario.

The indicator levels resulting for this first alternative are presented in Table 22.

Table 22: Indicators for the alternative scenario in which the number of trips per pallet is increased by 10%, compared to the Baseline scenario results

Indicator	Unit	Baseline scenario	+10% product recycling
Resource efficiency	kg wood/func. unit	1.96	1.85
Resource efficiency improvement	-	n.a.	5.7%
Recycling rate		25%	25%
Number of product cycles/product lifetime	-	17.2	18.8
Carbon footprint	kg CO2-eq/func. unit	1.06	1.00
Relative carbon emission savings	-	n.a.	5.9%
Absolute carbon emission savings	kg CO2-eq/func. unit	n.a.	0.060
Carbon stored in harvested wood products	kg C/func. unit	1.19	1.11
Energy expenditure	MJ/func. unit	9.67	9.1
Gross value added	Euro/func. unit	2.98	2.96
Resource productivity	Euro/kg wood	1.52	1.60
Employment generation	Employee/mln func. unit	29	29

These results show the following:

- Resource efficiency and resouce productivity show clear improvements. Increasing the number of trips per pallet has the effect that less wood is needed, which is reflected in these parameters.

- The carbon footprint and the energy expenditure decrease as fewer pallets need to be produced for the same amount of trips, which means that the CO_2-eq emissions and energy requirements associated with production are also less. This effect is more pronounced than when the material recycling is increased.
- Other indicators such as gross value added and employment generated only change marginally.
- The carbon stored in harvested wood products decreases per functional unit: per functional unit the amount of wood needed for pallet production and use decreases, while the amount of wood needed for particle board production and use stays the same. Less wood, used for a longer period of time means in the IPPC (2006) model less carbon storage, since the amount of wood stored in the product decreases over time.

In Table 23 an overview is given of the scores in the three scenarios (Goal scenario, minus 40% product recycling and plus 10% product recycing) compared to the Baseline scenario. The resource efficiency and the resource productivity show the most pronounced changes.

Table 23: Overview table in which the indicators of the three alternative scenarios are listed

Indicator	Unit	Goal scenario	- 40% Product recycling	+10% product recycling
Material use	kg wood/func. unit	1.64	2.66	1.85
Resource efficiency improvement	%	17%	-36%	5.7%
Recycling rate	-	45%	25%	25%
Number of product cycles/ product lifetime	-	17.2	10.74	18.85
Carbon footprint	kg CO_2-eq/func. Unit	1.061	1.44	1.00
Relative carbon emission savings	-	0.32%	-25.9%	5.94%
Absolute carbon emission savings	kg CO_2-eq/func. unit	0.003	-0.37	0.060
Carbon stored in harvested wood products	kg C/func. unit	1.19	1.65	1.11
Energy expenditure	MJ/func. unit	9.64	12.98	9.1
Gross value added	Euro/func. unit	2.98	2.90	2.96
Resource productivity	Euro/kg wood	1.82	1.09	1.60
Employment generation	Employee/million func. unit	29	28	29

7.5 Extrapolation and contribution to policy goals

Now that the effects of the Baseline scenario and the alternatives are available, it is possible to extrapolate the results to the entire sector and determining the contribution that can be made to policy goals. The following themes are included:

- Material efficiency;
- Greenhouse gas emissions, and
- Contribution to the economy.

The results are extrapolated sector-wide using data from the Stichting Kringloop Hout, which show that the yearly wood input in the wooden packaging sector is 400,000 tonne/year[72]. This is in reasonable agreement with data from Wageningen UR[71], which show that the total amount of wood used by the four largest supplies (representing about 65% of the market) is 575,000 m^3/year.

Given this information, the following contributions to policy goals can be expected in the case of the Goal scenario and the two alternative scenarios, when these are compared to the Baseline scenario:

Table 24: Contribution to policy goals of the Goal scenario and the two alternatives

Parameter	Unit	+20% material recycling (goal scenario)	- 40% product recycling	+10% product recycling
Material use (Resource efficiency)	tonne wood/year	66,700	-104,900	24,100
Greenhouse gas emission reduction	tonne CO2-eq/year	831	-55,977	12,873
Carbon storage	tonne C	0	70,000	-16,100
Contribution to the economy				
- based on fresh wood price	million Euro/year	5.3	-8.4	1.9
- based on resource productivity	million Euro/year	101	-114	39

This table shows that when the material reycling rate of wooden packaging increases from 25% to 45% (Goal scenario), substantially less wood is needed (resource efficiency). This has limited effects on the greenhouse gas emissions, but it has a notable effect on the economy. The expected effect on the economy is calculated in two ways, namely based on the fresh wood price and based on the contribution to the economy.

The first (lower) figure is derived by assuming that wood saved is left in the forest Assuming a fresh wood price of 90 Euro/tonne – this is the average price of wood residues with a moisture content of 35% (WG35) in Germany in 2013[89] – the listed figures represents the cost savings associated with that wood price. If it is assumed that this wood is also harvested and put to use in the economy, the contribution to the economy can be determined based on the recource productivity, as derived in the previous paragraphs. This leads to a much higher figure. At this moment there is a considerable

[89] http://www.carmen-ev.de/infothek/preisindizes/hackschnitzel/graphiken

amount of unused biomass potential in European forest, as is shown by Nilssen (2007)[90], which would imply that the first assumption (unused wood is left in the forest) is correct. However, it could be very well possible that in the future the contribution to the economy becomes higher than the costs for the raw wood only, and be closer to the resource productivity figure mentioned in the higher estimate for the economic contribution.

The product recycling alternatives clearly show the positive effects of increased product recycling. Decreasing the number of trips leads to a significant increase in wood use, increased CO_2-eq. emissions and a negative impact on the economy. The single remaining positive effect is the increase in carbon stock. Carbon stock increase represents however a one-time increase in the carbon stock, while the greenhouse gas emission reductions occur every year.

7.6 Actions for scenario realisation

7.6.1 Introduction

In the previous paragraphs several scenarios were investigated: the Baseline scenario, involving 25% material recycling; the Goal scenario, involving 45% material recycling, and two alternatives representing changes to the level of product recycling (-40%/+10%). The evaluation showed that from an environmental perspective both increased material recycling and product recycling are advantageous. Resource efficiency increases while there is not much difference with respect to other parameters, such as CO_2-eq emission reduction and economics/employment.

In this paragraph the barriers to realisation of the various scenarios are analysed, and actions to overcome them. The barriers to increased material recycling and increased product recycling are discussed separately.

7.6.2 Identification of barriers material recycling

Recently Nyenrode Business University and Stichting Probos[73] completed a study in which various policy measures to increase the level of material recycling are discussed, including the current barriers to increased material recycling. From this study – and other sources - the following barriers are identified:

Demand for waste wood in the Netherlands has increased in the last few years, due to the increased use of waste wood for renewable energy generation.

The Nyenrode report concludes that the amount of waste wood used for energy purposes in the Netherlands increased from 169 ktonne in 2007 to 583 ktonne in 2011. At the same time the amount of waste wood exported for energy purposes decreased from 605 ktonne

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90 http://www.unece.org/fileadmin/DAM/timber/workshops/2007/wmw/presentations/wood_resources_Nilsson.pdf

in 2007 to 348 ktonne in 2011, meaning a total increase of waste wood use for energy of 157 ktonne and a shift of the use of waste wood use for energy to the Netherlands.

Utilisation of waste wood from the Netherlands for material recycling is limited to use as input for the particle board industry in Germany and Belgium or use at Presswood for wood-based materials.

According to the Nyenrode study about 69% of the wooden packaging waste that is recycled is used in the particle board industry in Germany and in Belgium, so a large share of this wood waste is exported. The only significant Dutch user of wood waste – apart from energy generation – is the company Presswood in Ermelo. Preswood utilises both A-wood and B-wood to produce pressed pallets and pallet parts. Other uses for clean waste wood are fuel briquettes, garden decoration and animal bedding, represent relatively small quantities of wood (market niches).

The particle board industry pays more for waste wood than wood combustion facilities but transport costs are substantial, specifications are stricter and the amounts needed have decreased

The Belgian and German particle board industry can pay more (up to an extra 25 Euro/tonne) for waste wood than wood combustion facilities, provided that the waste wood meets strict input requirements. Transport costs are however significant and cannot be decreased according to the sector. The production of particle board has decreased significantly (about 20%) in recent years due to the economic crisis, and full recovery is not anticipated any time soon.

Separation of clean and contaminated waste wood is increasingly difficult and often not considered financially attractive

Waste handling companies sometimes separate A-wood and B-wood but this activity is costly and does not generate a lot of additional income. One of the reasons is that there is not much demand for A-wood in the Netherlands.

Regulations on material recycling in existing Dutch law do not yield the desired results

The Dutch Landelijk Afvalbeheerplan 2009 – 2021 (the LAP) includes regulations for wooden packaging. In the sector plan Packaging it is stipulated that the minimum standard for treatment of packaging is material recycling. However as a separate note on *wooden* packaging it is mentioned that if material recycling is not possible (because of contaminations, over-aging, etc.) the minimum standard becomes “useful application”. Useful application is a.o. combustion for the generation of renewable energy.

Furthermore it is observed that sector plan 41 on packaging materials uses material recycling as minimum standard, while sector plan 36 on waste wood uses energy use as minimum standard. If packaging materials are chipped they cannot be distinguished from waste wood anymore. It would make sense if both sector plans use the same minimum standard.

Other relevant regulations concern the separation of non-hazardous waste[91]. By law (Activiteitenbesluit article 2.12) it is required to separate this waste if it can be reasonably achieved. The definition of “reasonable” is also detailed, and standard quantities that can reasonably expected to be separated off are defined in the LAP (article 14.4). For wooden packaging this is 2 pallets per week.

From the above it is clear that material recycling is preferred in the Netherlands. In practice, however, separation into A-wood and B-wood is often not happening, which is illustrated by the fact that the B-wood streams that are combusted in the biomass energy plants contain a large (22%) share of A-wood.

Conclusions on the barriers to material recycling

From the above it is clear that material recycling of wooden packaging decreases because of increased competition from energy applications, in the Netherlands as well as abroad. The higher prices that can in theory be obtained through material recycling do not materialise because of lack of proximity (resulting in high transport costs), lower demand abroad and limited applications in the Netherlands. This leads to a low interest in separating A-wood and B-wood. The existing regulations do not yield the intended results.

7.6.3 Proposed solutions to increase material recycling

In the Nyenrode report a number of possible solutions to increase the amount of material recycling are discussed extensively, including:

1. Terminating future and/or current subsidies for biomass energy plants
2. Introducing subsidies for material recycling of wooden packaging
3. Introducing a ban on the combustion of wooden packaging
4. Creating more demand for material use
5. Introducing new guidelines for sorting companies so that wooden packaging waste is separated more efficiently
6. Modifying the LAP so that the regulations can be enforced better

In the frame of the Nyenrode assignment these possible actions have been discussed in a workshop, involving trade representatives and other persons related to the sector. For a full report on the specific discussions and remarks reference is made to the Nyenrode report. Here the following observations are made.

On the termination of subsidies for biomass energy plants and similar measures

The share of renewable energy production in the Netherlands in 2012 was 4.4%, nearly equal to that in 2011. More than 70% of the renewable energy was generated by biomass. Current renewable energy production is substantially lower than the 14% target for 2020

[91] http://www.rwsleefomgeving.nl/publish/pages/93503/hout.doc.pdf

agreed on EU-level[92]. When compared to other countries in the European Union – using data from 2008 - the share of renewables in the Netherlands is the fourth lowest in the EU out of 27 countries[93]; only the UK, Malta and Luxembourg rank lower. Also more recent data show that the Netherlands is one of the few countries in the EU that falls short of the intermediate renewable energy EU targets[94].

Considering the slow progress to date the Dutch government and stakeholders recently agreed on a plan to rapidly increase the share of renewable energy production and use in the near future. In the national agreement on sustainable energy growth ("Energieakkoord"[95]) many actions are identified to increase i.e. the production of renewable energy from biomass, and the use of the renewable energy support scheme (SDE+) as the primary subsidy mechanism to subsidise the production of renewable energy. This shows that in The Netherlands, as well as in other countries in Europe, there is a broad push to increase the amount of renewable energy, of which a large part is bio-energy. Measures that jeopardise this will therefore face an uphill battle. Furthermore, since the waste wood market is very international, Dutch measures prohibiting the use of waste wood for energy generation could very well lead to increased exports.

On measures to ban the use of clean wood for combustion

In Flanders a measure discouraging combustion of clean wood is currently in effect, issued by the VREG in 2008[96]. Under this measure combustion of wood that can still be used for other industrial uses cannot result in renewable energy premiums. Companies that combust wood in (bio)energy plants need to show via an audit that they comply with this measure.

The effects of this measure are mixed. When looking at price data in 2010 it was determined that the wood waste prices in Belgium had increased just as in the rest of Europe, indicating that wood waste was still combusted in Belgium or abroad. Prices of clean wood were close to those for contaminated wood. According to Mr Jan Dietvorst of Fedustria (a Belgian industry organisation)[97] the Flemish ban has had a positive effect, however, there are still a number of combustion facilities that choose to combust clean wood, even if they do not receive renewable energy premiums. So not receiving renewable energy premiums would appear to be more economic than not operating at all.

The above example shows that it is possible to issue measures to ban the use of clean wood, but too large effects – certainly in the short term – should not be expected due to the existing plants and the international dimension of the problem.

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92 CBS, "Hernieuwbare energie in Nederland", http://www.cbs.nl/NR/rdonlyres/7E4AB783-ABB3-4747-88BA-AF3E66A7ACF1/0/2013c89pub.pdf, 2013

93 http://www.energy.eu/

94 http://www.eea.europa.eu/publications/trends-and-projections-2013

95 http://www.energieakkoordser.nl/

96 http://www.vreg.be/mede-2008-2

97 Telephone conversation 18 November 2013

Proposed actions
Additional actions that could help reaching the goal of a higher percentage of material recycling include:

- Government measures to help develop a wider number and variety of waste wood applications. Examples include using wood fibres as filter material, as absorbents, in adhesives, etc. The government could play a role in this by stimulating the innovation in the development of these applications.
- Measures to facilitate the separation of A-wood and B-would. Innovative solutions for such separation are being researched e.g. in Germany. However, results are not yet commercially applicable[98]. And as long as the applications for clean waste wood are limited, the price difference between clean and contaminated waste wood will remain small, which means that there will be little financial incentive to separate the wood.
  Improved enforcement of existing regulations for waste handling companies. Enforcement can however be problematic since it is difficult to distinguish A-wood from B-wood, especially after handling.

7.6.4 Identification of barriers to increased product reuse

As described above, the wooden packaging industry already practices product reuse to a large extent. For economic reasons repeat-use pallets and limited-use pallets (often customer-specific pallets) are used a number of times before they are discarded.

Several barriers can be identified to the increased product reuse of wooden pallets. These are discussed below.

No policy incentives for product reuse
There are few policy incentives with respect to product reuse, neither in terms of a specific product reuse target nor in terms of instruments stimulating product reuse.

Little knowledge about the amount of product reuse
There is little public data available on the level of product reuse of wooden pallets. The data used in this report is based on industry estimates, but an independent verification has not taken place so far. This also complicates setting policy goals, since it is not possible to measure progress if the data is not available.

The poor information availability (and difficult verification) can be contributed to a large number of wooden pallets being made for specific customers. These pallets do not remain in a closed pallet pool, but may change hands after every trip. There are furthermore a wide variety of pallets produced and used. The product reuse rate of these various pallet types will most probably vary significantly, dependent on pallet characteristics (how

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[98] Probos, "Inzetten op hergebruik van sloophout", http://www.pianoo.nl/sites/default/files/documents/documents/inzettenophergebruiksloophoutbosberichten2013-03.pdf, 2013

heavy or how light), but also on the type of sector they are used in. The chemical industry is for example known to have high product reuse rates, the same may not be true for other sectors.

Little appreciation by the general public of resource efficiency
The general public shows little interest in the environmental advantages of product reuse, and the resulting increased availability of wood for other applications.

7.6.5 Proposed solutions to increase product reuse

Several actions can be undertaken to tackle the barriers to increased product reuse as discussed above.

A first step is investigating the current product reuse level for different types of pallets For example, standard pallets have a higher product reuse rate. Therefore measures to promote the use of standard pallets may be justified. It would furthermore be useful to show the environmental advantages that are associated with product reuse and show the contribution of the sector in this respect. Lastly, it will be easier to compare the use of wooden pallets with other – non-renewable – alternatives.

In a more general sense, increased attention for resource efficiency could lead to a revaluation of product reuse and lessen the focus on material recycling. The EU has made a start with their "*Roadmap to a resource efficiency Europe*", that shows that resource efficiency is key to a number of societal challenges such as climate change and reduced environmental impacts.

Apart from this more general solution, there are a variety of ways in which product reuse can be encouraged. The implications, contribution and practical implementation of these measures should be investigated further before these are actually implemented. Some solutions may be:

- Make product reuse easier than material recycling. One possible way to do this is to have a central registry which needs to give permission for material recycling of wooden pallets. An alternative is to demand that pallet companies register the reasons for not repairing pallets. Benchmarking of pool pallet companies can be a more 'soft' driver towards increase product reuse. This benchmarking could be achieved by prescribing companies to mention their wooden packaging product reuse rate in their annual environmental reports.
- Adopt policies that favour product reuse of pallets in the public sector. One possible way is to encourage that only reusable (standard) pallets from pallet pools and non-pools can be used in public sector projects.
- Encourage the use of standardised pool and non-pool pallets, since increased use of standard-sized pallets may favour product reuse. Whether this will actually be the case should however first be investigated.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Cascading in the wood sector can be described by (a combination of) fossil/mineral product substitution, product reuse and material recycling. Each of these aspects has specific impacts to targets in the field of CO_2-reduction, carbon storage, resource efficiency and resource productivity. This is illustrated in Table 25.

Table 25 Matrix showing the main relations between cascading actions (product substitution, product reuse and material recycling) and policy targets (carbon storage, carbon emission, reduction, resource efficiency)

Cascading action / Target	**Product substitution fossil/mineral materials by wood.**	**Product reuse**	**Material recycling**
Carbon storage	Positive impact (by definition)	Negative impact (by definition)	No impact (by definition)
Carbon emission reduction	Likely positive impact	Positive impact	Likely positive impact
Resource efficiency (and resource productivity)	Not known in advance	Positive impact	Positive impact

If ***carbon storage*** is targeted, woody materials should be applied as much as possible to replace fossil materials like plastics or minerals like bricks. A maybe counterintuitive result is that the level of carbon storage decreases if the level of product reuse increases. This can be easily explained as the amount of (woody) material per functional unit (i.e. the service provided by a product, like a trip with a wooden pallet) decreases when product reuse is applied. Material recycling has no impact on the amount of carbon stored in the product, i.e. if the rate of material recycling is lowered, more biomass is combusted and more fresh wood is harvested, however, the volume of wood stored per functional unit remains unchanged.

If ***carbon emission reduction*** is targeted, all cascading actions could generate positive results. Producing wooden products often costs less energy and emissions than producing the same product with mineral or fossil materials, although this always has to be verified by a life cycle analysis. Product reuse avoids the production of a new product, which will lead to emission reductions unless the emissions of repair become higher than producing a new product. Generally speaking, material recycling has the weakest CO_2-reduction potential as there might not be a big difference in CO_2-emissions of processing a fresh and a used raw material, although emissions of harvest and drying of the fresh materials are avoided.

If ***resource efficiency*** is targeted, both product and material recycling are effective measures. Also product substitution with wood can have resource efficiency impacts, as illustrated in the case of timber frame construction. However, it remains somewhat unusual to compare wood with bricks or metal simply on a mass base.

No pronounced differences in ***value added*** were found by cascading. This can be explained as the total amount of services to be delivered by the cascade in all scenarios was fixed by the definition of functional units. The ***resource productivity***, the added value per unit of material, does increase proportional to the material savings gained by product and material recycling. Next to added value in the case of wooden pallets, another indicator was introduced: the value of the raw materials saved by cascading.

The dynamics of growth of the wood stock in the forest was not taken into account. Instead it was assumed that the wood is produced sustainably and that the carbon pool in the forest is maintained; i.e. the harvest of the forest is fully compensated by the regrowth in that same year. This is the case for most European forests.

The case study on timber frame construction shows a great potential for greening the building sector and creating a substantial carbon pool of wooden products that contribute to mitigate climate change.

The case study on wooden pallets quantifies the potential impact of current material recycling targets. Moreover, it shows the benefits of product reuse that is common practice in the wooden packaging sector.

8.2 Recommendations

Cascading of wood and biomass in general contributes to policy targets in the field of renewable energy, carbon emission reduction and resource efficiency, by reducing material use and carbon emissions. In the near future, with an increasing demand for biomass for biobased products and energy, cascading will become more and more important. Some measures to promote cascading are recommended for consideration by policy makers:

- The minimum standards as formulated in the Dutch Waste Management Plan (LAP2) should be kept in place and enforced. Furthermore, sector plan 41 on packaging materials uses “material recycling” as minimum standard, while sector plan 36 on waste wood uses “energy use” as minimum standard. It would make sense if the same minimum standard would be applied in both sector plans in order to promote material recycling.
- It is worth to explore if selected biomass types, suitable for material recycling, can be excluded from renewable energy subsidies. Given the international character of the biomass trade flows, this type of measure might only be effective if taken on a European level. Furthermore, there should be sufficient demand from the side of material recycling.
- It is recommended not to rigidly prescribe fixed cascades that are valid for all biomass types, but to evaluate the full benefits of cascading by using the evaluation tool developed in the frame of this study.

- It is recommended to investigate the impact of carbon storage in the wood sector together with carbon storage in the forest. This could be combined with the inventory on carbon storage in harvested wood products that all EU member states have to carry out in the frame of the recently adopted Decision 529/2013/EC[99].
- It is recommended not to rigidly prescribe fixed cascades that are valid for all biomass types, but to evaluate the full benefits of cascading by using the evaluation tool developed in the frame of this study.

Furthermore, some specific recommendations are made based on the case studies on timber frame construction and wooden pallets.

Timber frame construction has still a relatively modest market share in the Netherlands, caused by preconceptions that need to be counteracted by continuous promotion and education efforts. In addition it is recommended to carry out independent research on (1) the satisfaction of owners of timber framed houses and on (2) how the negative public perception could be further addressed. Furthermore it is important that all levels of technical education pay sufficient attention to efficient building methods like HSB, which will slowly increase the level of HSB-expertise at social housing organisations, supervisors, architects, builders, etc.

Wooden pallets are a good example of how material recycling and product reuse lead to efficient use of wood resources. It was observed that much attention is paid to material recycling, i.e. in the Packaging Agreement ("Raamovereenkomst Verpakkingen 2013-2022"), but that product reuse is overlooked. It was observed that - besides expert opinions - there is not much data (freely) available on the current level of product reuse of wooden pallets. It may not be easy to determine the average level of product reuse of wooden pallets, but a better understanding of the data may serve to increase the interest for this possible solution. For example, it is expected that standard pallets have a higher product reuse rate than open pools. If this is verified, measures to increase the use of standard pallets may be justified.

[99] Decision 529/2013/EU on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities.