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FOREWORD

In Finland, wood packaging waste and construction wood waste have primarily been utilised in energy production. Some wood packaging waste has also been recycled as dry material for compost, and wood pallets have been repaired for reuse. Using wood waste for energy production has been seen as a prudent course of action in Finnish conditions as the waste can be used to replace fossil fuels while reducing the climate change impacts of energy production. The recycling of wood packacing waste and construction wood waste is challenging in Finland due to the fact that a large volume of clean wood waste is always available to the particle board industry, for example, resulting in low demand for less clean wood waste. The contamination of wood waste (e.g. concrete residue in construction waste) poses its own challenges for recycling.

According to the goal set in the EU Waste Framework Directive, 70% of construction and demolition waste should be recycled or otherwise reused as materials by the year 2020. The current recycling target for wood packaging waste is 15%, but the European Commission is likely to propose a more stringent requirement in the directive amendment proposal presented in conjunction with the Circular Economy Package. These goals are challenging for Finland, a country where the proportion of wood waste in construction and demolition waste is higher than in many other EU countries and where there is little demand for recycled wood.

Since the life cycle environmental impacts of wood packaging waste and construction wood waste have not been previously examined, the Ministry of the Environment ordered an analysis from the Finnish Environment Institute. At the Finnish Environment Institute, the life cycle analysis was conducted by Kaisa Manninen, Jáchym Judl and Tuuli Myllymaa. The process was carried out under the instruction of Riitta Levinen and Sirje Stén of the Ministry of the Environment.

Helsinki 24 November 2015

Ministry of the Environment

TABLE OF CONTENTS

1 Introduction

The recycling targets for wood waste and their feasibility in densely forested countries such as Finland have been a long-standing topic of conversation in the country. Forestry and the forest industry generate plenty of high-quality by-products, which is why there has been little demand for construction wood waste and wood packaging waste as recycling materials. Instead, wood waste has primarily been put to use in energy production. The energy utilisation has been regarded as a justified alternative in order to achieve the goals for increasing the use of renewable energy sources.

Pursuant to the target prescribed in the effective EU Waste Framework Directive, 70% of construction and demolition waste should be recycled or otherwise reused as materials by the year 2020. Reaching this goal will present a challenge in Finland where the proportion of wood in construction and demolition waste is higher than in many other EU countries due to the prevalence of wood construction.

The EU Packaging and Packaging Waste Directive (94/62/EC) sets forth a minimum recycling rate of 15% for wood packaging waste, which Finland has been able to achieve just barely in recent years. However, in the proposal to amend the Waste Management Directive (COM(2014)397) issued in the summer of 2014, the Commission suggested the recycling goal for wood packaging waste be increased to as high as 80% by 2030. The Commission withdrew the proposal at the beginning of 2015 and has promised to provide a new revised proposal by the end of 2015.

The wood waste recycling targets and the suggested changes have given rise to widespread concern in Finland with regard to the possibilities of increasing the recycling of wood waste. In Finnish conditions, using wood waste for energy recovery has been seen as a preferable option in terms of environmental impacts and costs.

The EU Waste Framework Directive (2008/98/EC) lays down a five-tier priority order, which is also referred to as a waste hierarchy. According to this hierarchy, the waste legislation and policy must adhere to the following order: The primary goal is to reduce the quantity and harmfulness of generated waste. However, if waste is generated, the waste holder must prepare the waste for reuse or, in the event that this is not possible, recycle it. If recycling is not possible, the waste holder must utilise the waste in some other fashion, such as energy recovery. If this is not possible, the disposal of the waste must be arranged. However, the directive states that departures from the hierarchy can be made where this is justified by life cycle thinking based on the overall impacts of the generation and management of specific waste. Any such deviations must, first and foremost, take into account achieving the best possible result for the intention of the law. In addition to this, the principle of caution and care in environmental protection must be taken into account, along with the technical and financial capabilities of observing the priority order.

In order to influence the EU negotiations on the upcoming directive amendments, the Ministry of the Environment ordered an analysis from the Finnish Environment Institute, which employed a life cycle assessment method to examine the life cycle impacts of using wood waste for energy recovery, particle board industry purposes and the production of wood composite in order to obtain unambiguous information on the environmental impacts of the various processing alternatives as required by the Waste Framework Directive.

2 Waste statistics and wood waste quantities in Finland

Statistics Finland prepares the official waste statistics in Finland, which report the overall waste volumes by sector and waste type. According to the statistics, some 3.4 million tonnes of wood waste is generated in Finland annually (Statistics Finland 2014, Appendix 1). This amounts to approximately 3.4% of the national waste volume. The statistics indicate that the primary sources of wood waste are paper production, production of sawn goods, energy production and construction (Statistics Finland 2014, Appendix 1).

The national waste statistics are produced using the materials generated by the statutory reporting processes of companies obliged to hold an environmental permit. The companies enter the information in the national environmental protection database (VAHTI), and the appropriate supervisory officials confirm the information in the system. Packaging waste is also represented in the VAHTI database, but the official statistics on it are produced based on information separately reported to the supervisory authority by the producer responsibility organisations. Statistics Finland prepares a summary of the information stored in the national environmental protection database and supplements the data with other materials.

There are some ambiguities in the terminology and statistics regarding construction and demolition wood and wood packaging waste as construction waste may be included in statistics for other waste categories, for example. The following sections present definitions and statistics regarding wood packaging waste and construction wood waste in a concise manner. Wood waste quantities are covered more widely in the Myller (2015) report, which tested miscellaneous wood waste in the production of various end products.

2.1 Wood packaging waste

Wood packaging is one of the waste types covered by producer responsibility. In waste statistics, this waste is included in municipal waste and wood waste reported for each specific sector. The producers of wood packaging waste must annually report waste quantities placed on the market to a national authority, which for producer responsibility waste generated in Finland is the Centre for Economic Development, Transport and the Environment for Pirkanmaa (ELY Centre).

Wood packaging is primarily used in goods transport – examples of such packaging are pallets, cable drums, barrels and crates, the most popular of which is the pallet (Myller, 2015). The ELY Centre for Pirkanmaa prepares and delivers a statistical report on packaging and packaging waste to the European Commission in June each year. Reports have been provided on statistics as of 1997. The statistics are based on information reported annually by producers and producer corporations. There are some uncertainties with regard to the statistics, which are addressed in the Myller (2015) and Jokinen et al. (2015) reports.

The total volume of wood packaging placed on the market in 2013 was approximately 207,000 tonnes, 31,000 tonnes of which was recycled while 176,000 tonnes was used for energy recovery. Of the recycled portion, 9,900 tonnes was utilised for composting and landscaping, whereas 21,000 tonnes of wood packaging was repaired. (Ala-Viikari, e-mail 30 March 2015)

The current recycling rate for wood packaging meets the 15% goal set forth in the Goverment Decree on Waste (179/2012). Currently, the required recycling rate is achieved by recycling wood as dry material for compost and repairing wood pallets. In Finland, wood packaging waste is not used to manufacture particle board, as higher-quality waste from the forest and sawmill industries is available for the same purpose. By the beginning of 2016, the producer of packaging (importer or manufacturer of packaged products) must organise the separate collection and recycling of fibre and wood packaging waste so that the annual volume of packaging waste recycled by the producer in relation to the volume placed on the market by the producer (*recycling rate*) is no less than 17% by weight (Government Decree 518/2014).

2.2
Wood waste generated in construction

All waste material generated in construction, repair and demolition, such as soil and rock materials, wood, glass and paper waste as well as scrap metal, is considered to be construction waste. Most of the construction waste volume consists of mineral materials, primarily soil. Construction wood waste is primarily generated by the construction of buildings. Construction of buildings encompasses new construction, renovation and demolition. Statistics Finland prepares a summary of the wood waste quantities generated by construction and demolition activities and strives to ensure that the same waste batches are not counted at multiple tiers of waste management. (Myller, 2015)

In the waste statistics produced by Statistics Finland, roughly 99% of construction waste consists of heavy soil materials. Excluding soil waste, the volume of other construction waste stood at approximately 224,000 tonnes in 2013, of which 63% i.e. 142,000 tonnes was wood waste (Statistics Finland 2014). Construction wood waste represents 4.2% of wood waste generated by all sectors (Appendix 1).

The EU Waste Framework Directive and the Finnish Government Decree on Waste lay down an obligation to utilise 70% of construction waste as materials by 2020. Since wood accounts for a fairly large percentage of Finnish construction materials, achieving this goal is challenging. Wood contained by construction and demolition waste is often dirty and otherwise unsuitable for recycling purposes. Wood materials originating from construction feature surface treatment and metal fastenings, for example, that hamper their reuse and recycling. The reuse and recycling as construction materials are also limited by the quality requirements set for construction materials. For these reasons, wood waste has been primarily used for energy recovery. This has been seen as a justified option for promoting the use of renewable energy sources and reducing the use of fossil fuels.

3 Life cycle analyses of the processing alternatives for wood waste

3.1

General

Life cycle thinking and life cycle assessment are methods of producing information based on a variety of criteria in order to support decision-making. There are international standards on the implementation of life cycle assessment (ISO 2006), which are based on a broad consensus on the application of the method. In particular, life cycle assessment and thinking are utilised in modern environmental policy and the decision-making of companies in order to find optimally sustainable solutions and steering methods for industrial production and consumption patterns.

Life cycle assessment is a systems analysis method, the purpose of which is to identify all possible impacts of a product or service – both direct process emissions and indirect emissions, i.e. the environmental burden caused by the use of resources in energy production, raw material production and primary production. Comprehensive life cycle assessments of products or services include the indirect spillover effects of the examined activities on other production systems. The effects can either increase or reduce emissions. In the event that the indirect effects on other systems reduce emissions, they are referred to as avoided processes and emissions, and the compared operations are indicated to substitute these bypassed products and emissions.

3.2

Prior studies on the subject

Myllymaa and Dahlbo (2012) have collected and compared results of domestic life cycle assessments. With regard to wood waste, they state that the recycling of high-quality wood is a prudent course of action for the environment if there is a market for the recycled product. By recycling wood, carbon can be tied in long-term storage, which reduces short-term climate impacts. Burning wood waste, on the other hand, is a good way of utilising the energy content of wood as an organic energy source, which is why poor quality wood waste should be incinerated. The study identified only a few domestic recycling concepts for wood waste (use as particle board/fibreboard, dry material for compost, plastic composite material or manure litter), all of which are downcycling solutions, meaning that they are recycled into products that are less valuable than the original product. In addition to this, the researchers stated that there is little research material available from domestic life cycle studies and that more is required. To meet this need, the purpose of this work is to produce more material on wood waste to support decision-making.

The following sections present the basics of life cycle analysis, wood waste processing alternatives included in the examination, and the initial data and data sources used in the calculations. The processing alternatives included in the comparison are wood composite production, particle board production and energy recovery.

3.3
Objectives, methods, scope and functional unit of the study

The assessment of the alternative wood processing methods was conducted using the life cycle assessment method. The environmental impacts of the various wood waste processing methods were calculated along with the possible processes that can be avoided if current production is replaced with reprocessed waste products. The calculation tool used was the SimaPro life cycle modelling program, which enables the examination of various environmental impact classes. The life cycle assessments were conducted according to general criteria used in the life cycle analyses of waste management (Myllymaa & Dahlbo, 2012). The starting point for this study was to answer the question “what are the environmental impacts of wood waste processing methods” and compare the loads and net impacts caused by the processing alternatives. The results will be utilised in the negotiations on the amendment of the EU Waste Directives which address recycling goals for various waste types but also possible national liberties to specify these goals and the opportunities to consider the special characteristics of industrial operations and consumption in the member countries.

Of the environmental impact categories, climate change, acidification and eutrophication were included in the results. These were estimated to be the most important potential impact categories with regard to an organic material such as wood and the indirect effects. In accordance with the generally approved impact model interpretations, CO_2 emissions from organic sources are not considered to cause a climate change impact as the biomass binds carbon dioxide as it grows. For this reason, the climate change impact is not considered for the direct emissions of incineration in the wood waste energy recovery alternative.

The life cycle assessment defines a functional unit for which the results are calculated. In this study, the results are calculated for a single tonne of wood waste delivered for processing, meaning that the functional unit is 1 tonne of wood waste.

3.4
Processing alternative 1: Manufacture of wood composite from wood waste

When two or more materials that have physically or chemically differing properties are combined (usually reinforcement and matrix) and the materials blend to form a functional product, the result is called a composite (Finnish Plastics Industries Federation 2014). Plastics are commonly used in composites due to their lightness. Wood composite refers to a product that is a mix of wood and other material. The other material is usually plastic, and there are numerous producers of wood-plastic composite products on the market, which produce boards for external structures in particular. Wood composites are most commonly used in terrace boards, which is why it has been selected as the alternative examined in this study. Wood composite terrace board is a product that could replace the corresponding product made of impregnated wood.

Alongside plastic, both virgin and recycled wood can be used as the raw material for wood-plastic composite (Myller, 2015). This study assumes that the wood composite consists of 60% recycled wood fibre and 30% plastic, of which 50% is virgin polyethylene and polypropylene and 50% recycled plastic. In addition to this, 10% of the wood composite consists of UV protection agents, pigments and substances that support the production process (UPM Profi, 2014; Findock, 2015). These other substances are not included in the examination.

The environmental impacts of recycled plastic are assessed based on the Väntsi & Kärki (2015) study. According to it, the impacts of the production of virgin plastic are approximately 5%, 42% and 20% lower for climate change, eutrophication and acidification, respectively, than the production of virgin plastic.

The process diagram of wood composite production is shown in Figure 1 while the processes used in the production are presented in Table 1. Wood composite is assumed to replace impregnated terrace board with a thickness of 0.025 m and width of 0.1 m. The density of the impregnated wood is assumed to be 450 kg/m^3. The greenhouse gas inventory data for the production of impregnated wood are presented in Table 2.

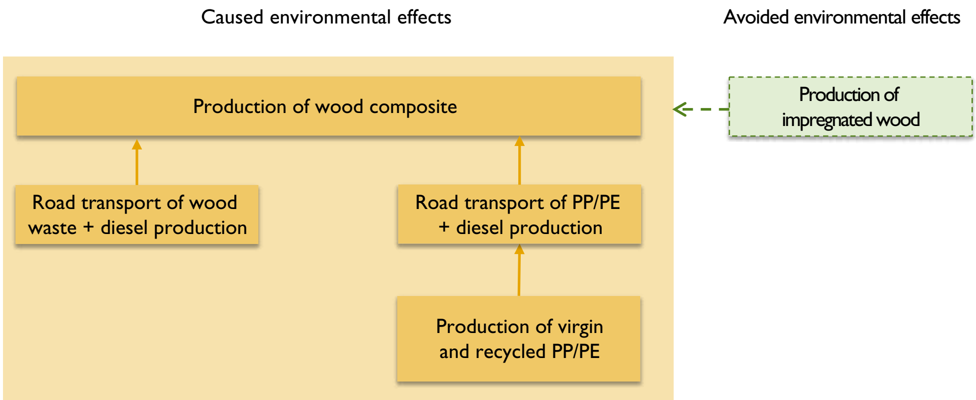

Figure 1. Process description of wood composite production. The process phases outlined in yellow cause environmental effects, while the processes outlined in green represent possible avoidable environmental effects.

Table 1. Processes used in the manufacture of wood composite

Process phase		Quantity/process	Data source
Plastic	polyethylene	Polyethylene, high density, (RER) | production Alloc Def, U	Ecoinvent
	polypropylene	Polypropylene, granulate (RER) | production | Alloc Def, U	Ecoinvent
	recycled plastic	recycled PP/PE	Väntsi & Kärki (2015)
Moulding phase		Extrusion, plastic pipes {RER} | production | Alloc Def, U	Ecoinvent
Wood waste/ plastic transport	plastic transport	full-trailer combination (40 t, full load), 150 km	LIPASTO-database
	transport of wood waste	full-trailer combination (28 t, 70% load), 50 km	LIPASTO-database
	diesel production	Diesel, low-sulphur, Europe without Switzerland, market for | Alloc Def, U	Ecoinvent

Table 2. Impregnated wood inventory data (Korhonen & Dahlbo, 2007).

	Raw material procurement	Production	Waste disposal	Transport	Total
CO_2 [kg/100 m^2]	34,5	333	384	29,5	781
CH_4 [kg/100 m^2]		0,8528	0,0553		0,9082
N_2O [kg/100 m^2]		0,0033	0,0121		0,0154

3.5

Processing alternative 2: Energy recovery of wood

The second processing alternative examined in this study is the use of wood waste for energy recovery. According to Myller (2014), a typical power plant that utilises recycled wood chips is an industrial multi-fuel boiler that burns recycled wood chips in conjunction with other solid fuels, such as forest biomass, peat and coal. By utilising recycled wood chips, power plants can reduce and replace the use of peat and coal.

Power plants that use recycled wood chips are usually fluidised bed boilers that produce electricity, heat and steam, depending on the local energy demand. The process flow of recovering energy from waste wood as well as the resulting and avoided environmental impacts are presented in Figure 2.

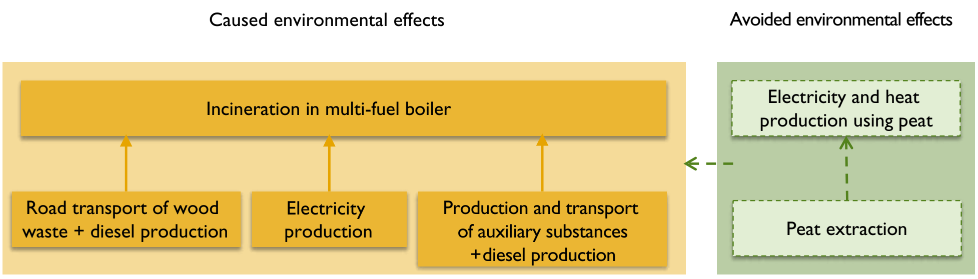

Figure 2. Process description of the energy recovery of waste wood. The process phases outlined in yellow cause environmental effects, while the processes outlined in green represent possible avoidable environmental effects.

When determining the emissions that can be avoided through energy production, we must assess how increasing the use of the new fuel would affect energy production. Wood is incinerated in both large bio fuel plants and small boilers. The energy production of large combustion plants affects the use of marginal fuels, but the effects of small combustion plants connected to district heating networks are normally local and the new fuel typically displaces one of the fuels used at the plant (Myllymaa et al. 20018).

This study used the same suppositions as the Myller (2015) study, and the wood was assumed to be incinerated in a multi-fuel boiler, the primary fuel of which is peat. Therefore, peat was concluded to be the avoided fuel listed in the life cycle assessment. The results are also examined by assessing the total impacts of wood waste incineration in a situation where only some of the thermal energy produced can be utilised.

The inventory data on the emissions and energy generated through wood incineration are based on the information produced by the Myllymaa et al. (2008) study on the incineration of wood in a boiler where the fuel consists of 85% wood and 15% natural gas (Table 3). The inventory data on peat extraction (Table 4) and incineration (Table 5) are also based on the information presented in the Myllymaa et al. (2008) report.

Table 3. Inventory data on energy production from wood in a boiler that uses fuel consisting of 85% wood and 15% natural gas (Myllymaa et al. 2008). Only energy extracted from wood is taken into account.

Input	Quantity	Unit	Output	Quantity	Unit
Wood waste	1	t	Energia	8,6	GJ/t
Energy content	10	GJ/t	CH_4	0,0257	kg
Process electricity	0,0007	GJ/t	N_2O	0,0095	kg
			SO_2	0	kg
			NO_X	0,141	kg
			PM<2,5	0,0018	kg
			2,5<PM<10	0,0045	kg

Table 4. Inventory data used to model the avoided peat extraction emissions (Myllymaa et al. 2008).

Input	Quantity	Unit	Output	Quantity	Unit
Milled peat	1	t	CO_2	87,287	kg
			CH_4	0,138	kg
			N_2O	0,02	kg
			SO_2	0,008	kg
			NO_X	0,086	kg
			P,tot	0,00085	kg
			N,tot	0,024	kg

Table 5. Inventory data used to model the avoided peat incineration emissions in a large multi-fuel plant where peat is used as the fuel (Myllymaa et al. 2008).

Input	Quantity	Unit	Output	Quantity	Unit
Milled peat	1	t	Electricity	1,4	GJ
Energy content	10,1	GJ/t	Heat, utilised	7,5	GJ
Process electricity	0,1	GJ/t	CO_2	1070	kg
			CH_4	0,013	kg
			N_2O	0,112	kg
			SO_2	11,41	kg
			NO_X	7,14	kg
			PM<2,5	0,058	kg

3.6

Processing alternatives 3 A, B and C: Use of wood waste in particle board production

One of the methods of recycling wood waste is the use of recycled wood in the manufacture of particle board. Particle board is wood board manufactured by pressing wood chips and glue together. The boards can be coated or uncoated, and they are available in a variety of strength categories. The boards are used in the cladding of interior walls and ceilings and in floor, exterior wall and partition wall structures. They can also be used in load-bearing structures at the top of T-beams and as webs in I-beams. The carpentry industry utilises particle board in the production of fixtures and furniture. The coated boards can be used as foundation in the watertight covers of wet rooms, roof-covering sheeting, windshield boards and casting moulds. (Building Information 2013)

Wood chips or sawdust generated as by-products in the sawmill industry are used to produce particle board in Finland. Miscellaneous waste wood can also be used as raw material for particle board, but it is not suitable as is and must be processed to match the quality of the sawmill industry by-products. Chip board consists of approximately 90% chipped wood and 10% glue and other binding agents. (Myllymaa et al. 2008)

As regards pretreatment, the life cycle calculation of particle board production is based on the energy consumption information presented in the Myllymaa et al. (2008) report. Production phase energy consumption (minus the energy consumption of pretreatment) as well as the glue and binding agents and their amounts are based on the information in the Ecoinvent database. The inventory data on the particle board production is presented in Table 6.

Three separate production chain comparisons are included in the particle board production process (Figure 3):

A) Particle board production in Finland

B) Ship transport of wood waste to Tallinn and their further road transport to a production facility in Central Europe

C) Ship transport of wood waste to Gdansk and their further road transport to a production facility in Central Europe

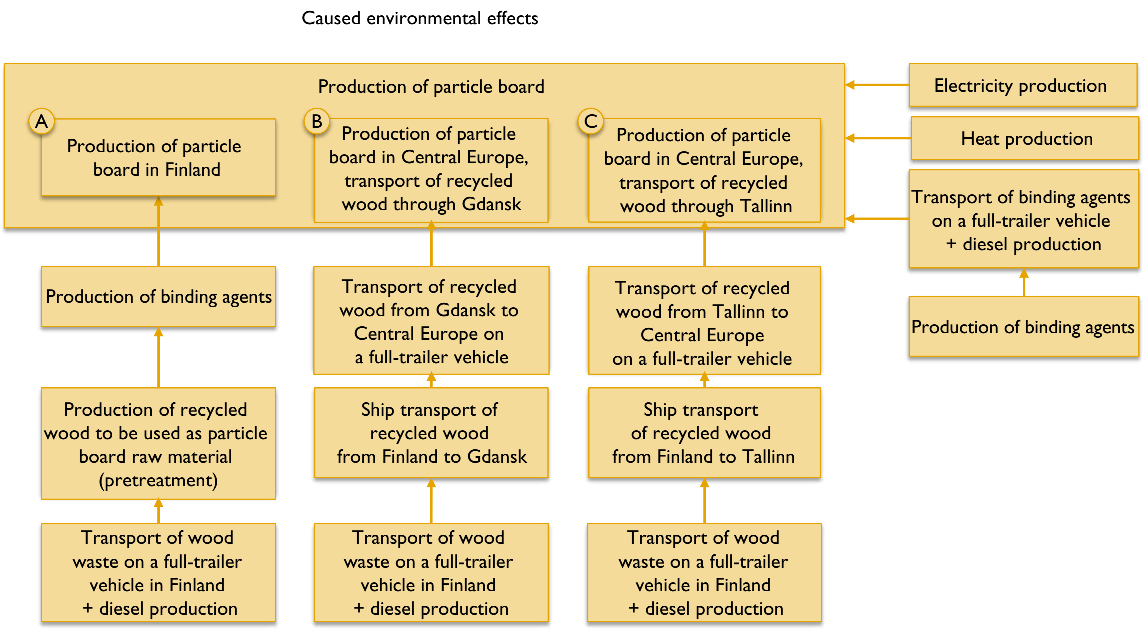

Figure 3. Process description of particle board production. The process phases with a yellow background cause environmental impacts. The examination does not include avoided processes since particle board is not manufactured from virgin wood, meaning that avoided production chains cannot be identified.

Avoided processes are not included in the life cycle assessment of particle board production as particle board continues to be manufactured from sawmill industry by-products/waste. Therefore, particle board produced from wood waste does not replace virgin raw materials in the current market situation. If the market for particle board were to grow in the future in proportion to other building boards, the existing particle board products could replace boards manufactured from other materials. Such growth in the particle board market is unlikely, however. In the event that the market share of particle boards among building board products increases, the life cycle should be supplemented with life cycle information on the manufacture of the avoided building board products.

Table 6. Inventory data on particle board production by data source.

Process phase		Quantity/process	Data source
Pretreatment, electricity consumption		17.6 MJ	Myllymaa et al. (2008)
Production phase	electricity consumption	residual wood, dry (RER) |particle board production, uncoated, average glue mix 13.3 kWh/t, average energy production in Finland	Ecoinvent, SYKE
	heat consumption	0.043 GJ/t, grate boiler	Ecoincent, Judl et al. 2014
	glue/binding agent	0.0736 t/t urea-formaldehyde 0.0162 t/t melamine-formaldehyde resin 0.0052 t/t methylene diphenyl diisocyanate 0.005 t/t paraffin	Ecoincent
Transport of glue/binding agents		full-trailer combination (40 t), 300 km	LIPASTO database
Diesel production		Diesel, low-sulphur, Europe without Switzerland, market for | Alloc Def, U	Ecoinvent
A) Transport (production in Finland)	transport of wood waste in Finland	full-trailer combination (28 t, 70% load), 50 km	LIPASTO database
	diesel production	Diesel, low-sulphur, Europe without Switzerland, market for | Alloc Def, U	Ecoinvent
B) Ship transport to Poland and road transport to production facility	transport of wood waste in Finland	full-trailer combination (28 t, 70% load), 50 km	LIPASTO database
	Helsinki-Gdansk	Ropax, 18 knots, trailer capacity 300, 785 km	LIPASTO database
	diesel production	Diesel, low-sulphur, Europe without Switzerland, market for | Alloc Def, U	Ecoinvent
	production of heavy fuel oil	Heavy fuel oil {Europe without Switzerland}| market for | Alloc Def, U	Ecoinvent
	transport of wood waste to a production facility	semi-trailer combination (17.5 t, 70% load), 300 km	LIPASTO database
C) Ship transport to Estonia and road transport to production facility	transport of wood waste in Finland	full-trailer combination (40 t, 70% load), 50 km	LIPASTO database
	Helsinki-Tallinna	Ropax, 18 knots, trailer capacity 300, 80 km	LIPASTO database
	diesel production	Diesel, low-sulphur, Europe without Switzerland, market for | Alloc Def, U	Ecoinvent
	production of heavy fuel oil	Heavy fuel oil {Europe without Switzerland}| market for | Alloc Def, U	Ecoinvent
	transport of wood waste to a production facility	semi-trailer combination (17.5 t, 70% load), 1,000 km	LIPASTO database

4 Description of the uncertainty assessments prepared on the results

The information used in the modelling of the product systems that utilise wood waste are, as stated above, based on assumptions and estimates, i.e. prior research, literature and databases. Measurement data on actual individual factories and processes was not available, although even such information, as individual data items, would not represent processes that take place partially in Finland and partially abroad. Even if specific processes were examined, the characteristics of the various production facilities would not be considered. If more precise life cycle calculations on an individual facility are required, the calculation should be done using the specific process information of each respective processing facility, where possible.

The data and assumptions based on literature and databases introduce uncertainties to the life cycle calculations, which may significantly affect the end results. Therefore, uncertainty assessments related to the calculations can improve the reliability of the results. The goal is to identify all variables, the values of which have the most impact on the results and, on the other hand, involve the highest amount of uncertainty.

Processes that are uncertain and may change were first identified in the calculations related to the utilisation of wood waste. After this, the processes were analysed based on Monte Carlo simulation using an uncertainty assessment involving 20,000 iteration cycles which alter the values of the variables identified as uncertain in random combinations within the set ranges of variation.

Uncertainty factors identified in the life cycle of wood composite production

As regards the composite, the content of the plastic compounds was found to be uncertain based on the data collection, as the compound can consist of both polyethylene and polypropylene. Therefore, the ratio of the plastic was varied in the analysis. Recycled plastic is also likely to be used in composite production, which is why the ratio of virgin and recycled plastic was also varied. In addition to this, ranges of variation were also set for the transport distances of plastic and wood waste.

Uncertainty factors identified in the life cycle of the energy recovery of wood waste.

Alternative avoided processes were examined as uncertainty factors for the energy recovery alternative. If we assume that recycled wood chips would be used to replace forest biomass instead of peat, the direct emissions caused by the incineration would be at the same level, which means that avoided emissions would not be achieved. However, the harvesting and transport of forest biomass would cause indirect environmental impacts. Since the effect of this alternative processing on the results can be derived from the data, mathematical Monte Carlo modelling was not prepared on this alternative supposition.

If the recycled wood chips would replace coal instead of peat, the direct avoided CO_2 emissions would be slightly lower than with peat. According to the Ecoinvent database, the CO_2 emissions of coal production in Russia (including operations related to coal mines) are approximately 84 kg/t, which is roughly equivalent to the CO_2 emissions of peat production. However, the emissions of coal production vary significantly depending on the country of production. In addition to this, the emissions caused by ship, train and lorry transport should be taken into account in the substitution of coal. The avoided emissions would probably be close to those of peat. Since the result impact of this alternative, too, can be derived from the data, the alternative in which recycled wood chips would replace coal has not been examined using mathematical Monte Carlo modelling.

The proportion of produced heat that can be recovered was selected as the variable in the Monte Carlo simulation. In addition to this, the same assumption as with composite production was applied to the variation in the transport distance of wood waste.

Uncertainty factors identified in the life cycle of particle board production

Transport distances were selected for mathematical analysis in the life cycle of particle board production. Ranges of variation were set for wood waste transport in Finland as well as the travel distances of full-trailer combinations to Central Europe. Table 7 presents the parameters and numerical values varied in the uncertainty assessments.

Table 7. Parameters varied in the uncertainty assessment by process.

Process phase		Min value	Max value	Note
Composite production	polyethylene/ polypropylene ratio in plastic compound	0%	100%	plastic content in composite 30%, with variation in the ratio of polyethylene and polypropylene
	proportion of recycled plastic to virgin plastic	0%	100%	plastic content in composite 30%, with variation in the proportion of recycled plastic
	road transport distance of plastic	100 km	300 km	polyethylene/ polypropylene transport
	wood waste road transport	20 km	300 km	
Energy recovery	wood waste road transport	20 km	300 km	
	avoided heat production with peat-generated heat	0%	100%	the proportion of how much heat produced with peat can be replaced with heat produced with wood waste is varied
Particle board, production in Finland	wood waste road transport	20 km	300 km	
Particle board, production in CE via Tallinn	road transport of wood waste in Finland	20 km	300 km	
	road transport from Tallinn to CE	800 km	1,200 km	
Particle board, production in CE via Gdansk	road transport of wood waste in Finland	20 km	300 km	
	road transport from Gdansk to CE	50 km	500 km	

5 Results of life cycle assessment

5.1

General information on the interpretation of the life cycle assessment results

The results regarding the potential environmental effects of the various wood waste processing alternatives in the impact categories analysed (climate change, acidification and eutrophication) are presented in Figure 4–6.

The results describing the life cycle environmental impacts of the utilisation alternatives examined here are shown as two-part bar charts where the life cycle phases are presented in different colours. The phases are the same as those featured in the process descriptions (Figures 1–3).

The upward bars illustrate the direct environmental effects of the processes. The downward bars, in turn, depict environmental effects that can be avoided if the production in question (wood composite) or raw material (recycled wood chips as fuel) is used to substitute current production. Composite production can be used to replace impregnated wood and thereby avoid the environmental impacts of its production.

The charts indicate that the results for the impact categories are fairly similar and the largest differences can be seen in the processes of avoided emissions.

5.2

Climate change impacts of wood waste processing alternatives

Among the wood waste processing alternatives, the processes that cause the most direct greenhouse gas emissions are the manufacture of plastic used in the production of wood-plastic composite and the manufacture of binding agents for particle board production (Figure 4, upward bars).

The highest amount of emissions can be avoided (Figure 4, downward bars) if wood chips can be used in energy production instead of peat. In Finland, peat is typically used in large heat- and electricity-producing multi-fuel boilers which can burn unprocessed wood chips. As a result, the substitution levels can be clearly identified. Peat is the most environmentally harmful fossil fuel in terms of its greenhouse gas emissions, which means that the levels of avoided emissions are highest when substituting peat use.

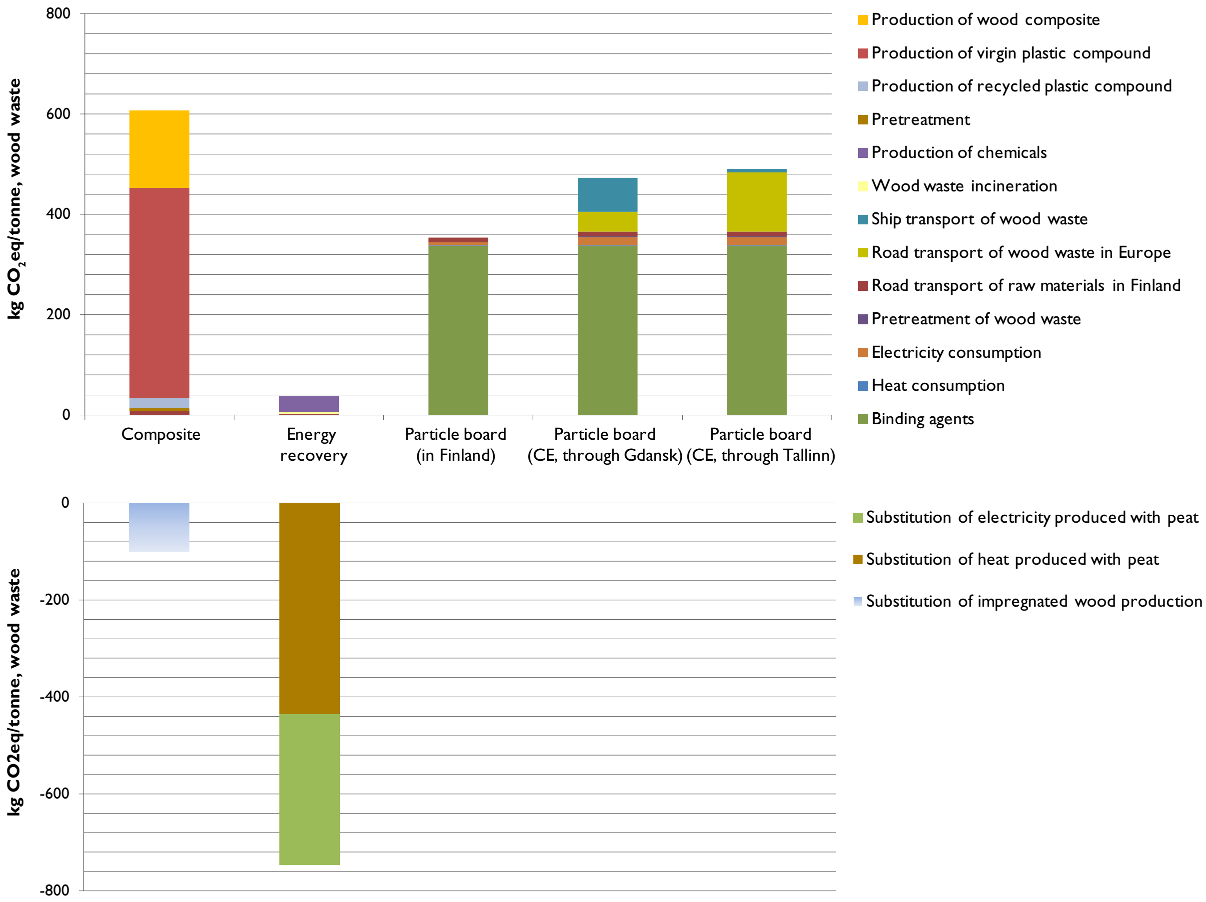

Figure 4. The climate change impacts of wood waste processing chains by life cycle phase.

In wood composite production, the most significant climate change impacts are caused by the production process of the virgin plastic compound and the composite moulding phase which requires a lot of energy. The analysis (Figure 4) is based on the assumption that 50% of the material is virgin plastic and 50% is recycled plastic. The climate change impact of recycled plastic is assumed to be approximately 5% of the impacts of producing virgin plastic (Väntsi & Kärki, 2015). If the proportion of recycled plastic was higher, the lower load caused by the manufacture of virgin plastic would reduce the total impact.

By utilising wood waste in the production of wood composite, production of impregnated wood can be avoided. This is evidenced by the downward climate change bar in the chart.

In energy recovery of wood waste, the most prominent direct climate change impacts are caused by the production of waste gas purification chemicals and direct emissions from combustion plants. However, the emission levels that can be avoided through energy recovery are significantly higher than the direct emissions. Climate change impacts can be avoided by utilising wood waste for energy recovery at facilities where it substitutes the use of peat as an energy source in the production of electricity and heat.

In order to assess the uncertainties related to the substitution of peat, the results have been subjected to a calculated uncertainty assessment, the results of which are presented in the net emission analyses in Section 6. The analysis varies the proportion of substituting peat in heat production with wood waste (cf. Section 4, Table 7).

In particle board production, the most significant climate change impacts are generated from the production of the glue binding agents used in particle boards. The transport emissions also stand out among the results. Among the particle board life cycle alternatives with varying transport routes, production in Finland (A) has by far the lowest environmental impact. The alternatives involving transport to Central Europe (B and C) are very close to one another in terms of their greenhouse gas emissions. Ship transport generates slightly less emissions than road transport, which means that the climate load of transporting goods through Poland is a few percentage points lower than that of transporting them through Estonia. The electricity consumption emissions of particle board manufactured in Central Europe are slightly higher than those of particle board produced in Finland due to the more polluting electricity production profile.

The use of wood waste in the production of particle board is not estimated to prevent climate change impacts, since in Finland particle board is already manufactured as a by-product and from waste wood materials, which means that substitution chains could not be identified.

5.3

Acidification impacts of the wood waste processing alternatives

Among the wood waste processing alternatives, the processes that cause the most direct acidifying emissions are the manufacture of binding agents in particle board production and the manufacture of plastic used in the production of wood-plastic composite (Figure 5).

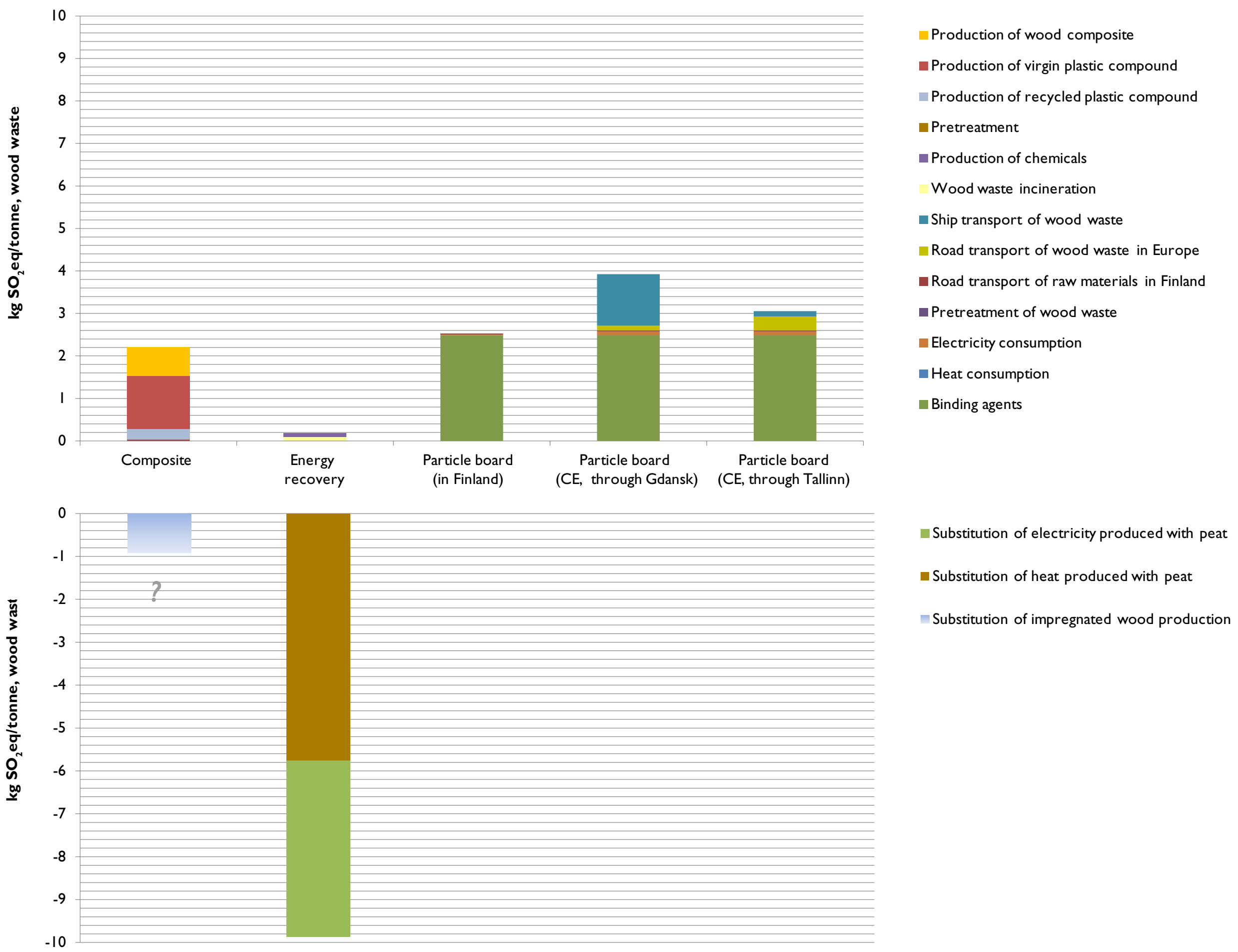

Figure 5. The acidifying impacts of wood waste processing chains by life cycle phase. The question mark indicates the assumed acidifying impacts of impregnated wood.

In context, too, the highest level of emissions can be avoided by utilising wood chips in energy production as a replacement to peat.

In wood composite production, the most significant acidifying impacts are caused by the production process of the virgin plastic compound and the composite moulding phase which requires energy. In the analysis presented in the figure, 50% of the plastic material is virgin plastic and 50% is recycled plastic, but the acidifying impacts of recycled plastic are assumed to be approximately 20% of the impacts caused by the manufacture of virgin plastic (Väntsi & Kärki, 2015).

In the examination of the avoidable acidification impacts of wood composite production, impacts caused by the substitution of impregnated wood were not taken into account as the inventory data used in the analysis only include greenhouse gas emissions. However, it can be assumed that there are other impacts besides greenhouse gas emissions, although background data on them could not be found for this analysis. These impacts are indicated in the bar charts with a question mark. Furthermore, the production of impregnated wood may involve some ecotoxic impacts, which are also not included in the examination.

The energy recovery of wood waste does not cause much acidification at all based on the data sources used in this study. Peat, on the other hand, contains nitrogen, which means that reducing the incineration of peat results in significant reductions in acidifying emissions.

In the manufacture of particle board, the acidifying impacts are primarily caused by the production of the binding agents. In addition to this, acidifying impacts are generated by the road and sea transport of raw materials. This study utilised the LIPASTO database process for Ropax ships using heavy fuel oil (HFO) as the emissions data for ships. The beginning of 2015 saw the institution of the Sulphur Directive (2012/33/EU), which states that the sulphur content of fuel may not exceed 0.1%. This change has not been taken into account in the data sources, which means that the current acidifying impacts of ship transport are actually lower.

5.4

Eutrophication impacts of the wood waste processing alternatives

Among the wood waste processing alternatives, the processes that cause the most direct eutrophying emissions are the manufacture of binding agents in particle board production and the manufacture of plastic used in the production of wood-plastic composite (Figure 6). The data sources used did not assess avoided eutrophying emissions, which is why the alternatives were analysed based on direct emissions alone. However, it can be assumed that eutrophying emissions can also be generated by processes whose inventory data does not include them. These possible impacts are indicated in the figures with a question mark.

The eutrophying impacts of wood composite production are similar to other impact categories since the emissions are energy-related and caused by the production process of virgin plastic compounds and the composite moulding phase, which consumes a large amount of energy. In the analysis presented in the figure, 50% of the plastic material is virgin plastic and 50% is recycled plastic, but the eutrophying impacts of recycled plastic are assumed to be approximately 42% of the impacts caused by the manufacture of virgin plastic (Väntsi & Kärki, 2015). As regards avoided emissions, the effects that substituting impregnated wood has on eutrophication are not evident in the results as the inventory data only covers greenhouse gas emissions.

In the context of energy recovery from wood waste, the eutrophying emissions are primarily caused by the manufacture of waste gas purification chemicals.

In the production of particle board, eutrophying emissions are, once again, primarily generated by the manufacture of binding agents and the energy consumption of the process.

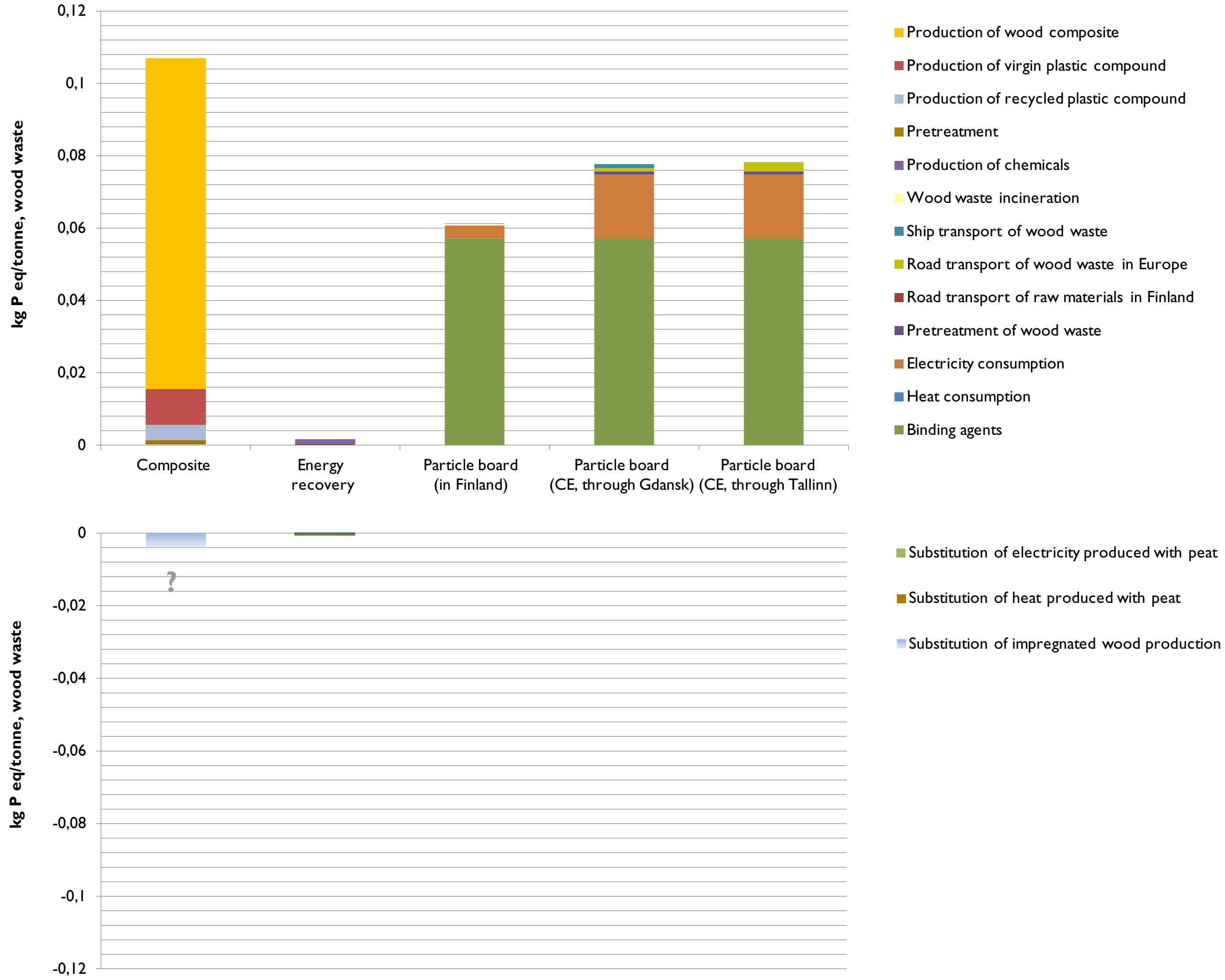

Figure 6. Eutrophying impacts of wood waste processing chains by life cycle phase. The question mark indicates the assumed eutrophying impacts of impregnated wood.

5.5

Net environmental impacts of the wood waste processing alternatives and the results of the uncertainty assessment

The net environmental impacts of the wood waste processing alternatives are presented in figures 7–9. The net environmental impacts have been gained by summing up the impacts caused by each measure presented in figures 4–6 and the avoided impacts. In addition to this, a range of variation has been added to the figures to illustrate uncertainty, or in other words how the results can vary based on the uncertainty assessment (Monte Carlo analysis) when using the alternative processes in Table 7 or the utilisation processes for avoidable processes.

The environmental impacts of composite production are very similar in the various impact categories and the results indicate that more emissions are generated than avoided across all categories, as a result of which the net emission bars point upwards. However, the uncertainty analysis indicates that the composite production results are fairly uncertain. The significant variation indicated by the uncertainty analysis is related to uncertainty as to the ratios of virgin and recycled plastic used in the manufacturing process. The analysis does not take into account the quality differences between wood composite made from recycled wood and virgin materials, but according to Myller (2015) it is possible for wood composite manufactured from recycled materials to be of a lesser quality than a product made using virgin wood and plastic raw materials.

The environmental impacts of particle board production are very similar across all environmental impact categories: production in Finland generates a lower environmental load than transport abroad. However, the differences between the net impacts of transport chains abroad are so minor that they provide no scientific grounds. As regards the calculations produced through uncertainty assessments, the result reliability seems good and very little differences can be seen in the ranges of variation since the only parameter changed is the transport distance.

The net impacts of energy recovery of wood waste vary between the different impact categories. The climate change impacts and acidifying impacts of wood waste incineration are lower than those of the substituted processes, which means that savings are achieved and the net bars point downwards. However, the uncertainty assessment indicates that the incineration process results are fairly uncertain and the net impact is heavily dependent on what percentage of the thermal energy produced from the waste can be actually utilised. The range of variation does not include an assessment of other alternative energy sources (e.g. coal, forest biomass), but as regards other fossil fuels, it can be roughly estimated that replacing energy produced with coal would result in avoided emissions almost to the same degree as with peat – the level of avoided emissions would be lower when replacing energy produced with oil and lowest for energy produced with natural gas (Myllymaa et al. 2008). Even if we take into account the extreme values of the net results of the uncertainty assessment, the incineration of wood waste emerges as the strongest alternative. The result is in line with the guidelines published by the European Commission which state that incineration is the preferred route for wood, if the material can be easily separated and the energy production can be maximised (European Commission JRC 2011). Since Finland has use for thermal energy, too, the maximisation requirement will most likely be met regardless of the region.

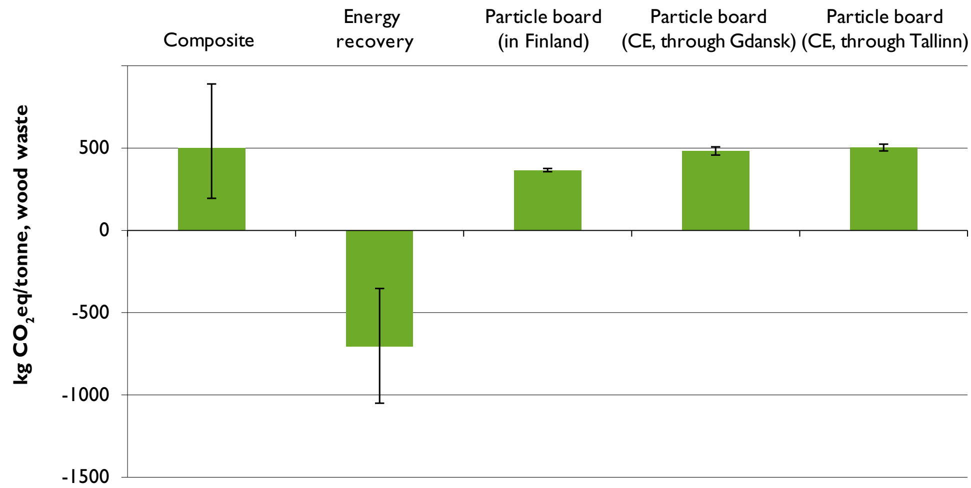

Figure 7. The net climate change impacts of wood waste processing alternatives and the range of result variation identified based on the uncertainty assessment.

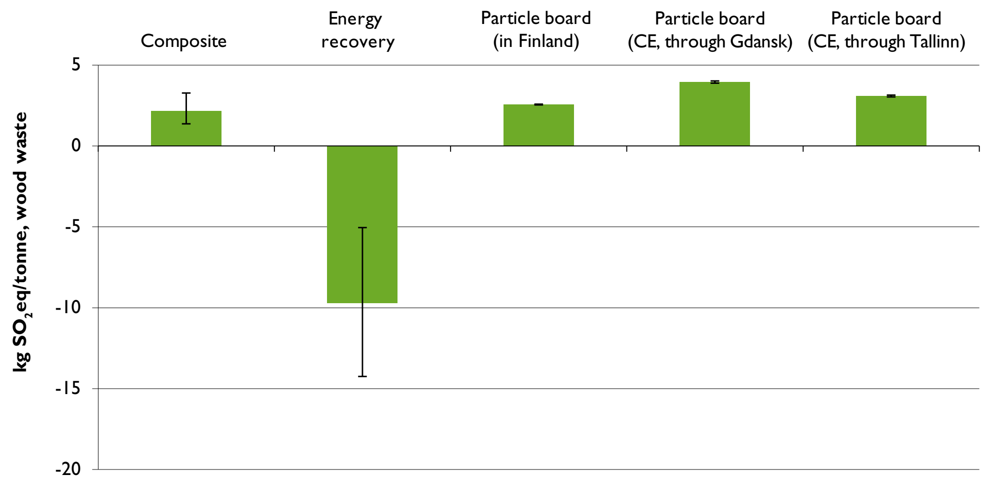

Figure 8. The net acidification impacts of wood waste processing alternatives and the range of result variation identified based on the uncertainty assessment.

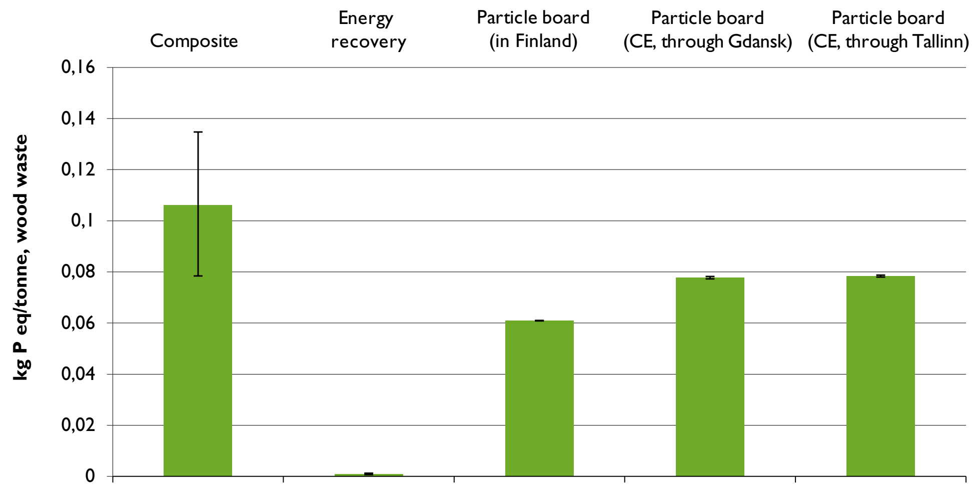

Figure 9. The net eutrophication impacts of wood waste processing alternatives and the range of result variation identified based on the uncertainty assessment.

6 Summary and conclusions

This study compared the life cycle environmental impacts of different wood waste processing methods in three impact categories: climate impact, acidifying impacts and eutrophying impacts. The wood waste recovery methods examined were the use of wood waste in wood composite terrace boards which replace the corresponding product made of impregnated wood, the use of wood waste for energy recovery in a multi-fuel boiler instead of peat and the use of wood waste in the production of particle board in either Finland or Central Europe. The results of the life cycle assessment are based on source materials derived from literature, previous Finnish life cycle assessments and database inventory materials. As such, the results do not directly illustrate the impacts of any individual processing facility.

The life cycle of the energy recovery of wood waste was defined under the assumption that it would substitute peat incinerated in a multi-fuel boiler. The net impacts of wood incineration vary between the impact categories: the climate change impacts and acidifying impacts of wood waste incineration are lower than those of peat incineration, whereas the net impacts of eutrophying emissions are close to zero. The uncertainty assessment indicates that the incineration process results are fairly uncertain and the net impact is heavily dependent on what percentage of the thermal energy produced from the waste can be actually utilised. The uncertainty assessment does not include an analysis of replacing other alternative energy sources (e.g. coal, forest biomass) instead of peat. Even if we take into account the extreme values of the net result variation in the uncertainty assessment of all processing alternatives, the incineration of wood waste emerges as the strongest alternative from the perspective of the environment.

The net life cycle emissions of wood composite were positive in all impact classes, meaning that the emissions were higher than the emissions bypassed in the production of the replaced impregnated wood. The uncertainty assessments of the environmental impacts show that results are strongly dependent on whether the plastic used in production is virgin or recycled plastic. The production of virgin plastic is an energy-intensive process, and the production-phase emissions of recycled plastic are lower than those of virgin plastic in all of the examined impact categories. In other words, the environmental load of wood composite production is inversely proportional to the share of recycled plastic used to produce the composite. The assessment works under the assumption that products manufactured from recycled wood and plastic have an equally long service life than products made from impregnated wood. No inventory data was available on the acidifying impacts and eutrophication impacts of the production of impregnated wood. The climate change impact of wood composite production is lower than that of particle board production but higher than that of energy recovery, so long as the plastic used in production consists primarily of recycled plastic.

High-quality wood waste is suitable for the production of particle board. In fact, in the current market situation all particle boards are produced from industrial wood side streams and waste. Since increased use of wood waste in the production of particle board does not therefore replace virgin raw materials, no processes are avoided and the results consist only of direct emissions. In the event that the particle board markets were to grow, particle board could possibly be used to replace other building board products, in which case the avoided processes would have to be re-examined. However, a change of this kind is unlikely. The use of packaging or construction wood waste in the Finnish particle board industry is not currently a realistic alternative for waste processing, and it is unlikely to become one in the future. This is due to the fact that a sufficient amount of high-quality waste generated by the forest industry is available for the purpose in Finland. The markets of packaging waste and construction wood waste in Central Europe were not examined in the scope of this study.

The energy recovery of wood waste was found to be the best option in Finland with regard to net environmental impacts in all examined environmental impact categories. Using wood waste to replace fossil fuels in energy production can reduce the carbon dioxide emissions resulting from energy production and facilitate the realisation of set climate objectives. According to the EU's Waste Framework Directive, reuse and material recycling should be preferred to energy recovery from waste. However, according to the Directive reaching the best overall environmental outcome may require specific waste streams departing from the hierarchy where this is justified by life cycle thinking on the overall impacts of the generation and management of such waste. Based on this study, the energy recovery of wood waste is a justified option in Finland and results in an overall better environmental outcome in regard to life cycle impacts compared to the other recycling methods examined. This should be taken into consideration in the setting of recycling targets based on the EU's waste directives.

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Appendix

Appendix 1. (Statistics Finland 2014)	Waste type		
Waste amounts by sector (Statistics Finland 2014)	Wood waste	Proportion of wood waste in sector waste	Proportion of sector wood waste in the entire wood waste volume
A Agriculture, forestry and fishing sector	25	36%	0.00%
B Mining activities and quarrying	-	0.00%	0%
10–12 Production of foodstuffs, drinks and tobacco products	1,918	0.30%	0.06%
13–15 Production of textiles, clothes, leather and leather products	50	0.60%	0.00%
16 Production of sawn timber as well as wood and cork products (excl. furniture), production of straw and wickerwork products.	273,523	92.60%	8.10%
17–18 Production of paper, paper and paperboard products, printing and reproduction of recordings	2,515,077	64.10%	74.50%
19 Production of coke and refined oil products	62	1.00%	0.00%
20–22 Production of chemicals and chemical products, pharmaceuticals and drugs as well as rubber and plastic products	4,591	0.20%	0.14%
23 Manufacture of other non-metal mineral products	880	0.10%	0.03%
24–25 Metal refining and manufacture of metal products (excl. machines and equipment)	4,944	0.20%	0.15%
26–30 Manufacture of computers, electronic and optical products, electronic devices, other machines and devices, motor vehicles, trailers, semi-trailers and other vehicles	5,586	7.80%	0.17%
31–33 Manufacture of furniture and other products as well as repair, maintenance and installation of machines and equipment	989	3.40%	0.03%
D Electrical, gas, heat and AC maintenance	286,273	24.30%	8.48%
36, 37 and 39 Intake, treatment and distribution of water, sewer and waste water management, reconditioning of soil and water systems as well as other environmental management services	94,592	4.20%	2.80%
38 Collection, processing and disposal of waste, material recycling	408	0.30%	0.01%
F Construction	141,585	0.90%	4.20%
46.77 Wholesale of waste and scrap	2,067	1.90%	0.06%
Services and households	43,795	1.50%	1.30%
Total	3,376,365		

DOCUMENTATION PAGE

Publisher	Ministry of the Environment Environmental Protection Department		*Date* February 2016
Author(s)	Kaisa Manninen, Jáchym Judl and Tuuli Myllymaa		
Title of publication	**Life cycle environmental impacts of different construction wood waste and wood packaging waste processing methods**		
Publication series and number	Reports of the Ministry of the Environment 29en/2015		
Abstract	This study compared the life cycle environmental impacts of different wood waste processing methods in three impact categories: climate impact, acidification impacts and eutrophication impacts. The wood waste recovery methods examined were the use of wood waste in terrace boards made out of wood composite which replace impregnated terrace boards, incineration of wood waste in a multi-fuel boiler instead of peat and the use of wood waste in the production of particleboard in either Finland or Central Europe. The results of the life cycle analysis are based on source materials derived from literature, previous Finnish life cycle assessments and database inventory materials. As such, the results do not directly illustrate the impacts of any individual processing facility. The net life cycle emissions of wood composite were positive in all impact categories, meaning that the emissions were higher than the emissions avoided in the production of the replaced impregnated wood. The uncertainty assessments of the environmental impacts show that results are strongly dependent on whether the plastic used in production is virgin or recycled plastic. In other words, the environmental load of wood composite production is inversely proportional to the share of recycled plastic used to produce the composite. No inventory data was available on the acidification impacts and eutrophication impacts of the production of impregnated wood. The climate impact of wood composite production is lower than that of particleboard production but higher than that of energy recovery, as long as the plastic used in production consists primarily of recycled plastic. High-quality wood waste is suitable for the production of particleboard. In fact, in the current market situation all particleboards are produced from industrial wood side streams and waste. Since using wood waste in the production of particleboard does not therefore replace virgin raw materials, no processes are avoided and the results consist only of direct emissions. The energy recovery of wood waste was found to be the best option in Finland in regard to net environmental impacts in all environmental impact categories. Using wood waste to replace fossil fuels in energy production can also reduce the carbon-dioxide emissions resulting from energy production and facilitate the realisation of set climate objectives. According to the EU's Waste Framework Directive, re-use and material recycling should be preferred to energy recovery from waste. However, according to the Directive reaching the best overall environmental outcome may require specific waste streams departing from the hierarchy where this is justified by life cycle thinking on the overall impacts of the generation and management of such waste. Based on this study, the energy recovery of wood waste is a justified option in Finland and results in an overall better environmental outcome in regard to life cycle impacts compared to the other recycling methods examined. This should be taken into consideration in the setting of recycling targets based on the EU's waste directives and in the definition of calculation methods for the recycling rate of wood.		
Keywords	construction waste, wood waste, packaging waste, life cycle analysis, waste, environmental impacts		
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KUVAILULEHTI

Julkaisija	Ympäristöministeriö Ympäristönsuojeluosasto	*Julkaisuaika* Helmikuu 2016
Tekijä(t)	Kaisa Manninen, Jáchym Judl ja Tuuli Myllymaa	
Julkaisun nimi	**Life cycle environmental impacts of different construction wood waste and wood packaging waste processing methods** (Rakentamisen puujätteiden ja puupakkausjätteiden käsittelyvaihtoehtojen elinkaarenaikaiset ympäristövaikutukset)	
Julkaisusarjan nimi ja numero	Ympäristöministeriön raportteja 29en/2015	
Tiivistelmä	Työssä on verrattu puujätteiden käsittelyvaihtoehtojen elinkaaren aikaisia vaikutuksia kolmessa eri vaikutusluokassa: ilmastomuutosvaikutus, happamoittavat vaikutukset ja rehevöittävät vaikutukset. Tarkastellut puujätteen hyödyntämisvaihtoehdot ovat puujätteen käyttö puukomposiitista valmistetuissa terassilaudoissa, jotka korvaavat kyllästettyä terassilautaa, puujätteen polttaminen monipolttoainekattilassa turpeen sijaan ja puujätteen hyödyntäminen lastulevyn valmistuksessa joko Suomessa tai Keski-Euroopassa. Elinkaariarvioinnin tulokset perustuvat kirjallisuudesta, aiemmista kotimaisista elinkaaritarkasteluista ja tietokantojen inventaarioaineistoista saatuihin lähtöaineistoihin. Tulokset eivät siten kuvaa suoraan minkään yksittäisen käsittelylaitoksen vaikutuksia. Puukomposiitin elinkaarenaikaiset nettopäästöt kaikissa vaikutusluokissa ovat positiiviset eli suuremmat kuin korvatun kyllästetyn puun tuotannon vältetyt päästöt. Ympäristövaikutusten epävarmuustarkastelut osoittivat, että tulokset riippuvat voimakkaasti siitä, käytetäänkö valmistuksen raaka-aineena neitseellistä vai kierrätettyä muovia Puukomposiitin valmistuksen kuormitus on sitä pienempi, mitä suurempi osa komposiittiin käytetystä muovista on kierrätettyä. Kyllästetyn puun valmistuksen happamoittavista ja rehevöittävistä päästöistä ei ollut käytettävissä inventaariotietoja. Ilmastonmuutoksen osalta puukomposiitin valmistus asettuu lastulevyn valmistuksen edelle mutta energiahyödyntämisen jälkeen, jos suurin osa käytetystä muovista on kierrätettyä. Hyvälaatuiset puujätteet soveltuvat lastulevyn valmistukseen. Vallitseva markkinatilanne onkin jo se, että kaikki lastulevy valmistetaan teollisuuden puuperäisistä sivuvirroista ja jätteistä. Koska puujätteiden käyttäminen lastulevyn valmistuksessa ei siten korvaa neitseellisiä raaka-aineita, lastulevyn valmistukseen ei kytkeydy vältettyjä prosesseja ja tulokset koostuvat ainoastaan suorista päästöistä. Jätepuun energiahyödyntäminen todettiin nettoympäristövaikutuksiltaan parhaimmaksi vaihtoehdoksi Suomessa kaikissa tutkituissa ympäristövaikutusluokissa. Korvaamalla puujätteellä fossiilisia polttoaineita energiantuotannossa voidaan myös vähentää energiatuotannon fossiilisia hiilidioksidi-päästöjä ja päästä lähemmäs annettuja ilmastotavoitteita. EU:n jätedirektiivin jätehierarkian mukaan jätteen kierrätys on ensisijaista jätteen energiana hyödyntämiseen nähden. Ympäristön kannalta parhaaseen lopputulokseen pääseminen voi kuitenkin direktiivin mukaan edellyttää poikkeamista tästä järjestyksestä, jos tämä on elinkaariajattelun mukaisesti perusteltua jätteen syntymistä ja jätehuoltoa koskevien kokonaisvaikutusten osalta. Selvityksen perusteella voidaan arvioida, että energiahyödyntäminen Suomessa on puujätteelle perusteltu vaihtoehto ja se tuottaa elinkaarivaikutuksiltaan paremman lopputuloksen selvityksessä tarkasteluihin kierrätysvaihtoehtoihin nähden. Tämä tulisi ottaa huomioon EU:n jätedirektiivien kierrätystavoitteiden asettamisessa ja puun kierrätysasteen laskentamenetelmiä määriteltäessä.	
Asiasanat	rakennusjätteet, puujäte, pakkausjätteet, elinkaarianalyysi, jätteet, ympäristövaikutukset	
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PRESENTATIONSBLAD

<table>
<tr><td>Utgivare</td><td colspan="3">Miljöministeriet
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<tr><td>Författare</td><td colspan="4">Kaisa Manninen, Jáchym Judl och Tuuli Myllymaa</td></tr>
<tr><td>Publikationens titel</td><td colspan="4">Life cycle environmental impacts of different construction wood waste and wood packaging waste processing methods
(Livscykelanalys av olika sätt att behandla träavfall från byggande och avfall från träförpackningar)</td></tr>
<tr><td>Publikationsserie och nummer</td><td colspan="4">Miljöministeriets rapporter 29en/2015</td></tr>
<tr><td>Sammandrag</td><td colspan="4">I detta arbete jämförs alternativa sätt att behandla träavfall och deras miljöpåverkan under hela livscykeln. Påverkan har indelats i tre kategorier: påverkan på klimatförändringen, försurningspåverkan och övergödningspåverkan. De studerade alternativen för återvinning av träavfall är användning av träavfall i trallar av träkomposit för altaner, som ersätter impregnerat altanvirke, förbränning av träavfall i flerbränslepanna i stället för förbränning av torv samt återvinning av träavfall vid framställning av spånplattor antingen i Finland eller i Centraleuropa. Resultaten av livscykelanalysen baserar sig på de källmaterial man fått via litteraturen, tidigare finländska livscykelstudier och inventeringsmaterial i olika databaser. Resultaten beskriver därför inte direkt vilka verkningar enskilda behandlingsanläggningar har.

Nettoutsläppen under träkompositens hela livscykel är i samtliga kategorier positiva, dvs. större än utsläppen från produktionen av det impregnerade trä man ersätter. Studier av osäkerhetsfaktorerna när det gäller miljöpåverkan visade att resultaten i hög grad är beroende av om man i framställningen använder jungfrulig eller återvunnen plast som råvara. Ju större andel återvunnen plast man använder i kompositen, desto mindre är belastningen av kompositframställningen. Det fanns inte några inventarieuppgifter att tillgå om de försurande och övergödande utsläpp som uppkommer vid framställning av impregnerat trä. I fråga om påverkan på klimatförändringen placerar sig framställningen av träkomposit före framställningen av spånskivor, men efter energiåtervinning, om största delen av den plast som används är återvunnen.

Träavfall av god kvalitet lämpar sig för framställning av spånskivor. I det rådande marknadsläget tillverkas de facto alla spånskivor av träbaserade sidoströmmar och avfall från industrin. Eftersom det träavfall som används vid framställning av spånskivor därmed inte ersätter jungfruliga råvaror, är framställningen av spånskivor inte kopplad till processer som undviks, och resultaten inbegriper endast direkta utsläpp.

Vad nettomiljöpåverkan beträffar konstaterades energiåtervinning av avfallsvirke vara det bästa alternativet i alla de undersökta kategorierna av miljöpåverkan i Finland. Genom att ersätta fossila bränslen med träavfall i energiproduktionen kan man även minska de fossila koldioxidutsläppen i energiproduktionen och närma sig de klimatmål som ställts upp. Enligt avfallshierarkin i EU:s avfallsdirektiv är materialåtervinning primär i förhållande till energiåtervinning av avfall. För att nå det bästa slutresultatet ur miljösynpunkt kan det dock enligt direktivet krävas avvikelser från hierarkin, när det är motiverat med hänsyn till livscykeltänkandet avseende den allmänna påverkan av generering och hantering av avfall. Med stöd i en utredning kan det bedömas att energiåtervinning är ett motiverat alternativ när det gäller träavfall i Finland och att den i fråga om livscykelpåverkan ger bättre slutresultat jämfört med de återvinningsalternativ som studerats i utredningen. Detta bör beaktas när det ställs upp återvinningsmål i de EU-direktiv som rör avfallsbranschen och när metoderna för beräkning av virkets återvinningsgrad fastställs.</td></tr>
<tr><td>Nyckelord</td><td colspan="4">byggavfall, träavfall, förpackningsavfall, livscykelanalys, avfall, miljöpåverkan</td></tr>
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This study compared the life cycle environmental impacts of different wood waste processing methods in three impact categories: climate impact, acidifying impacts and eutrophying impacts. The wood waste recovery methods examined were the use of wood waste in wood composite terrace boards which replace the corresponding product made of impregnated wood, the use of wood waste for energy recovery in a multi-fuel boiler instead of peat and the use of wood waste in the production of particle board in either Finland or Central Europe.

The energy recovery of wood waste was found to be the best option in Finland with regard to net environmental impacts in all examined environmental impact categories. Using wood waste to replace fossil fuels in energy production can reduce the carbon dioxide emissions resulting from energy production and facilitate the realisation of set climate objectives. According to the EU's Waste Framework Directive, reuse and material recycling should be preferred to energy recovery from waste. However, according to the Directive reaching the best overall environmental outcome may require specific waste streams departing from the hierarchy where this is justified by life cycle thinking on the overall impacts of the generation and management of such waste. Based on this study, the energy recovery of wood waste is a justified option in Finland and results in an overall better environmental outcome in regard to life cycle impacts compared to the other recycling methods examined. This should be taken into consideration in the setting of recycling targets based on the EU's waste directives and in the definition of calculation methods for the recycling rate of wood.

LIFE CYCLE ENVIRONMENTAL IMPACTS OF DIFFERENT CONSTRUCTION WOOD WASTE AND WOOD PACKAGING WASTE PROCESSING METHODS

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