Transboundary flows of woody biomass waste streams in Europe

Picture: VITO

IEA Bioenergy

IEA Bioenergy: Task 40: 2018: 12

Transboundary flows of woody biomass waste streams in Europe

Authors: Prof. Dr. Martin Junginger, Utrecht University; Dr. Mika Järvinen from Aalto University; Dr. Olle Olsson, Swedish Environmental Institute; Christiane Hennig, German Biomass Research Centre; Pranav Dadhich, Aalto University.

Edited by Martin Junginger, Thuy Mai-Moulin, Mar Edo and Inge Johansson

Published by IEA Bioenergy

Acknowledgements:

This report is based on the MSc thesis of Pranav Dadhich, published in September 2017. It was then updated with data from 2016 in September-October 2018 and further extended. We thank all persons who supported this work with providing information through interviews and databases.

This report project was sponsored by Task 40 under the IEA Bioenergy Agreement entitled: 'Sustainable International Bioenergy trade; securing supply and demand' and by IEA Bioenergy Task 36, led by Tech. Lic. Inge Johansson. The project was also a part of the master's thesis of Mr. Pranav Dadhich at Aalto University and supervised by Dr. Mika Järvinen.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AbFG	Abfallbeseitigungsgesetz (German national waste disposal act)
AltholzV	Altholz Verordnung (Ordinance on the management of wood waste)
AT	Austria
AVV	Abfallverzeichnis-Verordnung (German waste regulation)
BE	Belgium
BImschV	Bundes-Immissionsschutzverordnung (Ordinance on emissions of a.o. incineration plants)
CCA	Chromo-Copper-Arsenate
CEWEP	Confederation for European Waste to Energy Plants
CH	Switzerland
CHP	Combined Heat and Power
CN	Combined Nomenclature
CSTB	Centre Scientifique et Technique du Bâtiment
DE	Germany
DIY	Do It Yourself
DK	Denmark
EC	European Commission
EEG	Erneuerbare-EnergienGesetz (Renewable energy law)
EJ	Exajoules
EU	European Union
EUTR	European Union Timber Regulation
EWC	European Waste Catalogue
FI	Finland
FR	France
HS	Harmonized System
IEA	International Energy Agency
INERIS	National Institute for the Industrial Environment and Risks
ISWA	International Solid Waste Association
KrWG	Kreislaufwirtschaftsgesetz (German Circular Economy Act)
KT	Metric Kilo Tons
kWh	Kilo Watt Hour
MDF	Medium Density Fibreboard
MJ/kg	Megajoules/Kilogram
MSW	Municipal Solid Waste
MW	Megawatt
NL	The Netherlands
NO	Norway
NWMP	National Waste Management Plans
OSB	Oriented Strand Board
PJ	Petajoules
SE	Sweden
UK	United Kingdom
US	United States
WFD	Waste Framework Directive
WID	Waste Incineration Directive
WRA	Waste Recycling Association
WW	Wood Waste

EXECUTIVE SUMMARY

The world is facing one of its major waste management problem in the 21st century. According to International Solid Waste Association (ISWA), the global urban waste generation levels are increasing every year estimating at 7 to 10 billion tons per year. The maturity of the waste management systems differs significantly between different countries, where some countries lack collection and treatment of waste at the same time as others have moved ahead from the traditional waste management systems to consider a transition towards a circular economy. In a circular economy the aim is to reduce and ultimately eliminate the concept of waste and keep all materials as much in a closed-loop as possible. That concept though will take time to implement and it needs drastic changes throughout the value chain- converting the chain into a cycle/loop. For the time being, the combustion of waste with energy recovery remains an important end-of-life option, also contributing to the production of renewable energy. Strong legislative bodies and regulations are also helping to curb the problem related to waste generation, especially in the European Union (EU).

An important factor in a sound and secure waste management system is proper quantification of data regarding the generation, trade as well as disposal methods of the waste. The Basel Convention requires the member countries to provide yearly national reports for the trans boundary shipment of waste. Despite that, there lacks a consolidated approach towards a holistic picture of shipment of waste in the world. Especially wood waste is being increasingly used as a feedstock for energy purposes, next to traditional fuel types as well as other biomass sources. Hence, a proper quantification of solid biomass waste would be beneficial for industries as well as countries to assess the potential for renewable energy (currently heat and electricity, but in the future possibly also transport fuels) and recycling options for proper and faster disposal. This report aims at quantifying the existing data on the trans boundary shipment of solid woody biomass waste in Northwestern Europe during the years 2010 till 2016 in the form of trade maps and analyze the underlying key drivers behind the shipment of waste.

The report focuses on trans boundary shipment flows of solid biomass waste, particularly wood waste (hazardous and non-hazardous), in the north-western part of Europe in the years 2010-2016. Non-hazardous wood waste is a rather cheap fuel in comparison to other solid biomass resources and hence is used in some countries for bioenergy production on a significant scale. Also, large amounts of hazardous wood waste are traded, but an overview of these trade flows is so far lacking in literature. An analysis of its trans boundary shipment can be helpful for the national plans of the countries involved as well as the industries and organizations. The study chose the European Waste Codes (EWC) to shortlist the type of wood waste. The EWC were narrowed down to mainly 191206* (hazardous wood waste) and 191207 (non-hazardous wood waste) which have considerable trade flows in Europe. Next to the valorisation as material, wood waste is being used for producing energy in modern bioenergy plants in Germany, The Netherlands and Sweden. The main importers of both hazardous and non-hazardous wood waste are Germany and Sweden with a yearly import of 600+ kilotonnes (KT). The Netherlands also imports non-hazardous wood waste from UK and Belgium for the feedstock of its bioenergy plants. The main exporters of non-hazardous wood waste are UK, The Netherlands and Norway. The combined exports exceed 1200 KT in recent years. The major exporter for hazardous wood waste is The Netherlands with a yearly average of 100 KT to Germany.

The general trend of total shipment of non-hazardous wood waste is increasing every year since 2010. The non-hazardous wood waste is in demand because of its industrial grade nature and cheaper price than other biomass resources. The hazardous wood waste shipments are generally declining since 2010 due to stricter legislation that requires the countries to take responsibility of the hazardous waste that it is producing.

The key driver for both hazardous and non-hazardous wood waste utilization is legislation and policies, which differ between the countries investigated in this report. The support provided by legislation and policies of a country can pave way for a better capacity to deal with hazardous as well as non-hazardous wood waste. This is the case in Germany, where a detailed legislation regarding waste management was setup in 1990 regarding waste management. In the following years additional legislation and policies were introduced on the subjects of trans boundary shipment of waste, the circular economy of waste and management of wood waste as well as supporting the use of biomass including wood waste for energy purposes. The latter induced the installation of bioenergy plants.

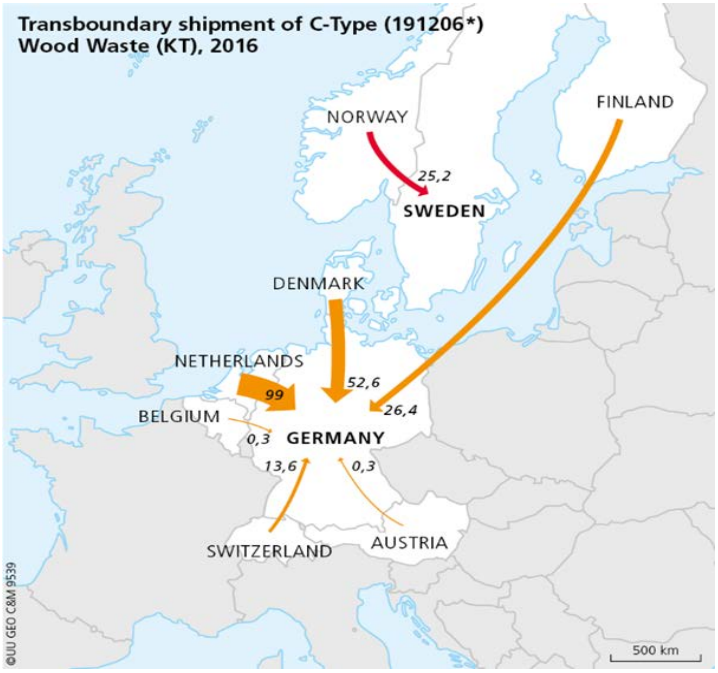


Figure ES1: Transboundary shipments of hazardous wood waste in Northwestern Europe in 2016

In 2015, 700 solid biomass-fired combined heat and power plants dedicated to wood waste were in place with an installed electric capacity of 1510 MWel1 requiring a considerable amount of wood waste (DBFZ, 2015). This demand largely drives the trans boundary shipment of wood waste in Europe.

The non-hazardous (B type) wood waste trans boundary flow occurs extensively in Northwestern Europe (see figure ES.2). Germany and Sweden are the two major importers and UK and The Netherlands are the two major exporters of non-hazardous wood waste. A total of 1522 KT of wood waste was traded in 2016, with Germany importing 664 KT and Sweden importing 668 KT.

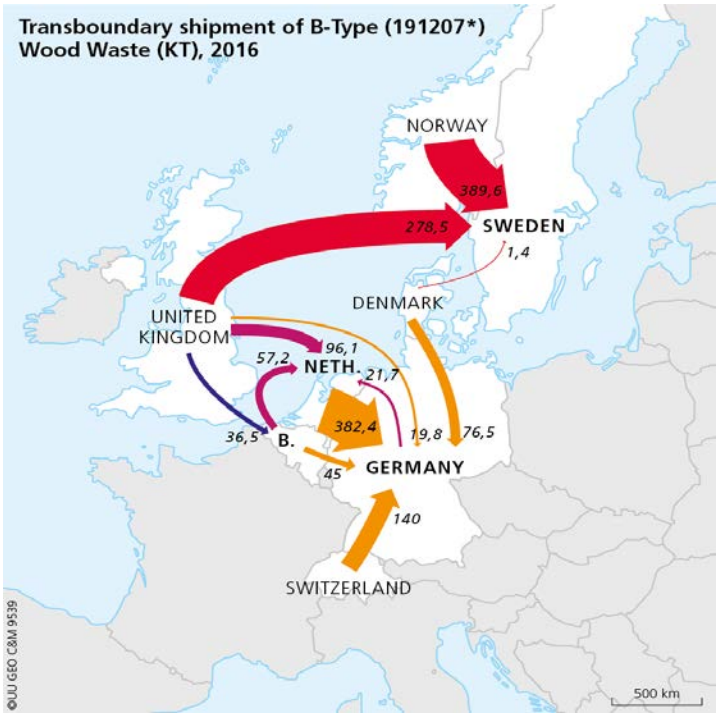


Figure ES2: Transboundary shipments of non-hazardous wood waste in Northwestern Europe in 2016

[1] Note that many of these plants are combined heat and power plants, so the combined output of useful energy is higher than the electrical capacity reported here.

The trade of non-hazardous wood waste is mainly driven by the installed wood waste combustion capacity in Germany and Sweden. These trade flows also looked very similar in the years before 2016.

While trade flows especially from the UK and to Germany can be in the order of several hundred kilotons, the overall contribution of traded wood waste to national bioenergy production is very small to negligible in the countries investigated, typically between 1-3% of total bioenergy production. This is also likely to remain this way, as it is not expected that wood waste volumes will suddenly strongly increase in coming years.

1. INTRODUCTION

In the recent times, the world is facing some major problems ranging from ever increasing population, energy poverty, climate change to increase in global waste generation every year. The waste management issues started with the age of industrialization around the world. It aggravated due to the sudden increase in the population and consumerism. According to the report by International Solid Waste Association (ISWA), the global urban waste generation stands at 7-10 billion tons per year out of which only 30-40% is collected properly, which can lead to many health and environmental problems (ISWA, 2014). Clearly, waste generation has been a persistent worldwide problem. Absence of waste management leads to public health issues and environmental degradation. Even with waste management you will see negative effects on environment since there are a lot of limitations imposed on the waste management by both lack of proper technologies for recycling as well as economic barriers. An increase of waste generation will naturally make the effects larger. In order to tackle these negative effects, various rules and regulations are set up all around the world, especially in the EU. The EU regulations aim to give a minimum requirement regarding waste management in the member states, but the implementation has not progressed equally rapidly in all countries.

In 2012, the EU generated 2514 million tons of total waste out of economic and household activities. From 2004 till 2012, the EU had a 10% increase in the hazardous waste estimated at 99.9 million tons in 2012(Eurostat, 2016). The EU realized there could be a huge issue due to the increasing waste, especially hazardous. Hence, the EU laid down waste directives and regulations over the years, amongst which the directive 2008/98/EC holds a lot of relevance. It establishes the basic concepts of waste, which includes various definitions of waste, generation, recovery and disposal as well as the waste hierarchy. According to the directive, waste is any substance or object a user discards (The European Union, 2008). Nowadays, the major objective of the European Union is to turn the waste into a resource as a part of circular economy. This has become a key driver to stimulate better waste management and development of new materials as well as energy recovery from waste in the EU. This led to sustainable usage of waste along with reduced use of natural resources as well as reduced health and environmental issues.

Since waste is a very broad term, it can be classified in many ways. A general classification which can differentiate between the waste is its hazardousness level. The waste can be divided into hazardous and non-hazardous waste. Hazardous waste is a waste that contains high quantity of elements which fall under the list of dangerous items and hence has to be reported with proper details to relevant authorities if it is being transported between countries. (European Commission, 2008) A non-hazardous waste does not contain dangerous elements and can be transported between countries without notification. In the past the world was facing a huge problem of hazardous waste generation estimated around 400 million tons per year and its inappropriate trans boundary shipment across countries. (Buff. L. Rev., 1991) Hence, the Basel Convention was formed to avoid any illegal disposal of hazardous waste to developing or poor countries. The convention was signed by the EU and 184 countries ensuring a better approach towards a controlled trans-shipment of hazardous waste across countries. Still, one of the major problems with the waste transportation was the quantification of data which was improved under the convention's national reporting database system, which required to submit specific details on import and export of various waste substances of all the member countries.

In the EU, hazardous waste is primarily shipped between the member states. The hazardous waste shipments peaked in 2007 in the EU at around 8.1 million tons. Even though there has been a 23% decrease in shipment of hazardous waste in the EU, due to the financial crisis of 2008, generally the hazardous waste generation is increasing in the EU. (European Environment Agency, 2012) A majority of hazardous waste shipment leads to reclamation of metal compounds or incineration with or without energy recovery in the EU. 93% of the hazardous waste exports was

shipped between the member states of the EU. Some of the major hazardous waste streams are soil and stones containing dangerous substances, solid waste from gas treatment, lead batteries and hazardous wood waste. Hazardous wood waste was one of the top five transported waste streams in the EU standing at 203 KT in 2013. (EUROSTAT, 2013)

One of the foci of the EU is to increase the share of renewables in the energy system and biomass contributes fairly to the energy share of many countries in the EU. Industries and traders are highly dependent on different types of biomass feedstocks . Wood chips are predominantly used in many industries, but with the increase in the shipment of wood waste, industries recovering energy from wood waste are emerging in countries like the UK, The Netherlands, Germany and Sweden. Traders are also interested in the shipment of wood waste, primarily because of its low prices which gives it a better edge over the conventional biomass like wood chips. On the other hand, the type of wood (waste) used as a fuel for an incineration plant cannot be switched easily. Permits are very specific with regard to contamination type. For example, the Bio Golden Raand plant in Delfzijl, the Netherlands, is allowed to use wood waste type B (non-hazardous) but cannot use the lower type C (hazardous) (Hol, 2018). Typically, using “lower grade” wood (i.e. more contaminated) as an alternative fuel is not allowed.

Since there is a general interest developing in energy recovery from waste, this report essentially focuses on the quantification of the data in the form of trade maps for solid biomass waste stream such as the hazardous wood waste as well as the non-hazardous wood waste in Europe during the years 2010 – 2016, hence fulfilling the knowledge gap that exists in the area of wood waste market in Europe. Even though, there have been individual country reports, a specific study on the wood waste flow in Europe would be helpful to the waste management stakeholders, energy markets, energy industry and governmental bodies for a concise documentation of the European wood waste market.

The major objective of this report is to quantify the trans boundary shipment data for the solid biomass waste streams in Europe for the years 2010 – 2016. It discusses the major importers and exporters of hazardous and non-hazardous wood waste in Europe, the current as well as future trends in this sector, the trade maps and key drivers of the import and export. It also details the legislations surrounding the trans boundary shipment of waste in the EU and its individual member states. Finally, it analyzes the primary energy supply of the imported wood waste in every country and its contribution in the bioenergy supply in the energy share of a country. The scope of the report is based on various factors such as time, location and type of waste. The time period of the study is from 2010 till 2016. The countries which are actively participating in the shipment of the solid biomass waste are chosen and are examined as individual cases. The type of waste is chosen on the basis of availability of data.

2. METHODOLOGY AND DEFINITIONS

2.1 Methodological approach

The study has chosen a bottom up approach of research methodology. The study started with research on The Netherlands and its import and export of solid biomass waste and the same methodology of data collection and research was then applied to the other major countries identified as the importers and exporters of hazardous and non-hazardous wood waste. The research methodology is explained in detail in the following chapter.

Initially, a literature overview of research on the subject was performed. Articles based on the trans boundary shipment of waste on an international level as well as European level were studied in detail. The overview also considered the research done on the types of wood waste and municipal solid waste and its physical and chemical properties as well as the key drivers involved in the import and export of waste in general. This helped in laying down a basis for the study and understanding important concepts regarding trans boundary shipment of waste. Since, the research was performed at Utrecht University, The Netherlands was chosen as the first country for identifying the trade routes of solid biomass waste streams in Europe.

In the beginning of the study, two waste streams were chosen, municipal solid waste and post-consumer wood waste. As the study progressed, it was narrowed down to wood waste. The major reason to choose wood waste was to have a proper quantification of data in the form of trade maps since there were fewer studies related to wood waste. Also, wood waste as a fuel has grown interest in a lot of countries like UK, The Netherlands, Germany as well as Sweden and it competes directly with the conventional biomass fuels like clean wood chips because it is a cheaper fuel, hence a better understanding of the trade routes would enable greater acceptance in other countries as well as countries dealing with the trade of wood waste in a huge quantity.

Online databases were recognized for the statistics available for the solid biomass waste streams of The Netherlands. The statistics were obtained from individual countries national databases, traders, industries as well as international databases like EUROSTAT and Basel International National Reports. Once the major importer and exporter countries were identified for The Netherlands, the next logical step was to identify a code system that represented the waste streams for easy identification and availability of data. The code system varies widely in Europe and on an international level. The various code systems encountered during the data collection were as follows:

Combined Nomenclature (CN) Codes: The CN codes are a tool for classifying goods for intra EU trade which is maintained by Eurostat. It is an 8-digit code number which has layers of explanation and detail of products being traded. (European Union, 2016)

European Waste Codes (EWC): CN codes are not specifically designed for waste products and hence, an increasing attention towards the waste products led to EWC list. EWC list is a reference nomenclature specifically for providing a common terminology for the different types of waste. (European Union, 2000)

Y – Codes: The Basel Convention defined different types of waste, hazardous as well as non-hazardous waste in the form of Y – Codes which is provided in detail in the Annex I of Basel Convention. (UNEP, 1992)

Initially, the data was collected corresponding to the CN codes of wood waste and MSW for The Netherlands. The EWC is also being used extensively by European countries and though Harmonized System (HS) and CN codes are also used by the European countries, they are not updated as regularly as EWC. The Basel Convention reports demand the information in Basel

Codes or Y – codes. The definitions of the waste streams are very general for the Y – codes and hence it is not reliable. (Christian Fischer, 2012) The presence of different code systems made it difficult to choose a single and uniform system for data collection. In the end, the European Waste Code (EWC) list was chosen as the common code due to better reliability of the data sources.

After the data was collected from online databases and sources for wood waste, multiple interviews were held with ministries, traders and industries for co-relating data between them and getting a reliable dataset for The Netherlands. A basic outlay of trade routes of The Netherlands was generated on a map and then the same methodology was used for other key countries involved in the export and import of hazardous as well as non-hazardous wood waste in Europe.

All the countries examined for the purpose of this study submitted EWC along with the Y – codes in the national reports of Basel convention and it made the data collection process easier and straight forward. Hence, Basel Convention National Reports were ultimately used extensively.

To identify major key drivers of trade of wood waste, an intensive questionnaire was designed for IEA Bioenergy Task 36 and Task 40 which can be referred to in the annex. The feedback to the questionnaire was helpful to narrow down the key drivers for trans boundary shipment of wood waste in Europe.

2.2 Data collection

Primary data used is from national reports and official statistics to maintain a level of relevance in the study. If the official data was not available, data from reports or publications was used. Data was confirmed from various conversations with experts in the field of wood waste trade.

The main sources were:

- National reports: These statistics were provided by the ministries with data on production, trans boundary shipment and end use. The data was also obtained from Basel International's national reports of every member country of the Basel convention. These two data sources were supposed to be of prime importance and relevance since the data in Basel Conventions' reports was updated with EWC as well as Y codes. Basel Codes or Y – codes were not a reliable source, but since every country that has been examined also provided the data with corresponding EWC, the data collection became easier and straight forward.

- EUROSTAT and European Commission: The data available on the EUROSTAT was available in the form of Combined Nomenclature (CN Codes) and there was slight co-relation between EWC and CN codes data. The CN codes are used for the intra EU trade and have an elaborate description for every commodity that is traded. The EWC list is specifically designed for waste in the EU and it provides as better statistical dataset than a general coding system applicable to every traded commodity.

- Statistics from consultancy companies: Data was also provided by various consultancy companies in different parts of Europe in the form of published reports in their national language. Consultancies in The Netherlands has published multiple reports on the wood waste market and the drivers responsible for it. UK based consultancies like Anthesis and Pöyry have also been publishing reports regarding the wood waste market in the UK.

- National Waste Management Plans: The national waste management plans were consulted for the legislations and regulations applied in the individual countries. Every country has a dedicated waste management plan which ultimately gives a good guidance of future plans

for the different type of waste generated and traded.

The scope of this report is as follows:

- Countries: The countries selected are the Netherlands, Germany, Sweden and UK, since the majority of wood waste trade is encountered by them.
- Wood waste occurs in different formats. The study is concerned majorly with the post-consumer wood waste. These are the waste streams investigated in this report (especially the first two):
  - 191206*: The mechanically treated wood waste that is also known as hazardous wood waste
  - 191207: Wood waste other than 191206*.
  - 171201: Wood waste from Construction and Demolition Waste
  - 200137*: Hazardous wood waste from household waste
  - 200138: Wood waste other than 200137*
- Time Period: The time period of the study is chosen to be 2010 – 2016. The main reason being the changes in legislation in 2008 and hence a more defined statistics structure for the trans boundary shipment of waste. The contribution of traded wood waste to the national bioenergy supply is presented in Annex 2 between 2010-2015 (no update was made for 2016 due to time limitations).
- End use: The biomass waste streams were also chosen on the basis of its end use. The biomass waste stream with its end use in incineration with energy recovery is preferred and is of main interest in this report as compared to material recovery or recycling.

2.3 Background

This section is about the basic definitions of the wood waste and its origins, and the different EWC present in the database which refer to the hazardous as well as the non-hazardous wood waste.

Wood waste can be formed during many processes such as wood harvesting, wood processing, and also at the end of final use like post-consumer waste. Wood waste from harvesting or wood processing is relatively clean and falls under the EU Timber regulations. It contains more than 50% wood and is also known as industrial wood waste. On the other hand, post-consumer wood waste refers to the used wood (i.e. end-of- life wood waste). Both types of wood are subjected to either recycling or energy recovery. Post-consumer wood waste accounts for around 22% of the total market volume of wood waste, being 9% used for industrial purposes and over 12% for energy use. (Mantau, 2012)

The wood waste can originate from different sectors and hence are divided accordingly in the EWC list. The different types of wood waste that are present in the EWC are:

Table 1: EWC of types of wood waste (European Commission , 2000)

EWC	Category	Description
171201	Construction and Demolition Waste	Wood - Furniture - Hardboard - Railway Sleepers - Untreated Timber - Wood Cuttings
191206*	Materials from Mechanical Treatment of Waste (Sorting, Crushing, Pelletizing)	Wood containing hazardous substances - Treated Timber - Wood - Wood Cuttings
191207		Wood other than 191206* - Furniture - Pencils - Timber - untreated - Wood - Wood cuttings
200137*	Municipal and Household Waste	Wood containing dangerous substances - Civic amenity waste - Timber - treated - Wood - Wood cuttings
200138		Wood other than that mentioned in 20 01 37 - Civic amenity waste - Cork - Pencils - Timber - untreated

As it is evident in Table 1, wood waste can be categorized on the basis of hazardousness. In some cases, the wood must be preserved for longer periods of time and hence chemical preservatives are used to prolong the lifetime of the wood. This also makes the wood and the wood waste occurring from the same, hazardous in nature. There are two major practices for increasing the quality and lifetime of the wood (CSTB, 2005):

Basic treatment of the surface with substances which do not penetrate the wooden body such as gluing or coating of paint.

Proper preservation treatments wherein the wood is treated with chemicals to make the wood inert to its surrounding.

Table 2 describes different type of treatments that can be done for wood preservation:

Table 2: Different methods of wood treatment and their hazardousness levels (INERIS, 2006) (CSTB, 2005)

Treatment	Function	Preservatives/ Chemicals used	Hazardousness of the Preservative/ Chemical
Thermal Treatment	Protection	None	None
Coating	Protection and beautification	Nonmetallic varnish or paints	None

		Metallic varnish or paints	Toxic, if concentration is high
Gluing	Assembling	Mineral Glue, Animal Glue	None
		Synthetic Resins	Toxic, Noxious
Fire Proofing	Fire Protection	Metallic Salts, Isopropanol	Toxic, if concentration is high
Preservation by Soaking	Resistant to medium biological attacks	Boron and other heavy metals	Toxic, if concentration is high
		Diazole, Pyrethroide, IPBC	Irritating, hazardous for reproduction
Preservation by Impregnation	Resistant to high biological attacks	CCA, Arsenic, Organic Copper, Creosote	Carcinogenic, irritating, highly hazardous

Based on the hazardousness described above, the wood waste can be further categorized as:

- Clean Wood Waste
- Moderately Treated Wood Waste
- Highly Treated Wood Waste

2.3.1 Clean Wood Waste

Clean wood waste can be classified as wood waste that has not been subjected to any sort of chemical treatment. However, it might have received a mechanical or thermal treatment. They are graded as non-hazardous wood waste and can be used as biomass with proper licensing. For example, in the case of waste from construction and demolition, the wooden packaging is clean wood waste and can be used for energy as well as material recovery. (WRAP (Waste & Resources Action Programme, 2012)). The example of EWC that is prevalently used for clean wood waste is 150103 (wooden packaging).

Figure 1:Clean Wood Waste (Source: RPS)

2.3.2 Moderately Treated Wood Waste

These wood waste have a slight concentration of preservatives in them. It can be wood material that has a coating or glue on them. Since, the layer of preservatives on the wood is still dangerous, a certain threshold is mentioned in the regulations to make sure that it does not cross over to highly treated wood waste, in which case the end use of the wood would differ a lot. The EWC such as 191207, 170201 and 200138 can be categorized as moderately treated wood waste.

The wood waste in this category is a mix of hazardous as well as non-hazardous waste. Due to the lack of systems that allow a rapid determination the concentration of hazardous substances on large quantities of this wood waste that is being produced, it is difficult to sort this type of wood correctly. Hence, better regulations are needed to get a clear demarcation between hazardous wood waste and clean wood waste. (CSTB, 2005).

Figure 2: Moderately Treated Wood Waste

2.3.3 Highly Treated Wood Waste

Highly treated wood waste generally arise from wood that is subjected to heavy outdoor usage and hence needs to be heavily protected from the surroundings. The wood is coated and impregnated with chemical preservatives which are ultimately ingrained and bounded to the wood (Kurata, 2005). Due to the high level of hazardous substance, treatment is limited to incineration or hazardous landfill sites, if proper licenses are acquired. The EWC with an asterisk indicate hazardous wood waste and hence 191206* and 200137* are both considered harmful and highly treated wood waste.

Figure 3: Treated Wood Waste

2.4 Legislation

In the section below, all relevant EU legislation is described. Additional legislation in the Netherlands, Germany, Sweden and the UK is presented in Annex 3.

2.4.1 EU Legislation

The European Union establishes directives and regulations for the member states involved. A directive is not directly applicable in the member states as a regulation, but is to be incorporated in the national legislation within a certain timeframe. The directives aim to form a common minimum expectation from each country and by that create a more even playing field Depending on the area of the directive, individual members of EU can impose stricter rules than the directive stipulates. The WFD generated a waste hierarchy as a visualization/guideline about the end use of waste.

On the other hand, a regulation has a binding legal force that every member state has to follow, and it is put into force on a particular date all across the EU. An example of a regulation relevant for this study is the EC 1013/2006 regulation on shipments of waste.

Apart from the EU directives and regulations, there are international treaties such as Basel Convention that helps to reduce the trans boundary shipment of hazardous waste around the world, especially preventing the flow from developed nations to less developed and developing nations. The Lisbon treaty also promotes sustainable development in Europe and works mainly on the “polluter pays price” principle.

2.4.2 EU Directives and Regulations

- Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste

  This directive was introduced to regulate the landfilling of waste in EU. Its major aim was to reduce or prevent the landfilling in the EU and thereby reducing the negative impacts associated with it. The directive also defined different categories of waste such as municipal waste, hazardous waste, non-hazardous waste and inert waste. The landfills were also categorized in three different categories: landfill for hazardous waste, landfill for non-hazardous waste and landfill for inert waste. It also makes it mandatory for the member states to reduce their biodegradable waste going in the landfill to maximum 75% by 2006 and maximum 35% by 2016 and to be treated before disposal. The directive ensures which waste can be disposed of in landfills. This directive is part of the process that the EU is going through towards a circular economy regarding waste. The directive came into full force by 16 August 2009 (European Commission , 1999). In line with higher ambitions regarding the circular economy, the directive was amended with stricter targets in 2018 (European Commission, 2018). The member states shall by 2035 landfill less than 10% of the generated municipal solid waste.

- Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control, IED) (European Commission 2010)
  The IED replaced the Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste (WID). The directive dealt with the incineration or co – incineration of waste in the EU. It imposes strict regulations on the emission limits of the pollutants being released in the air or water after incineration of the waste. It also states the operating conditions and technical requirements of a waste incineration plant. These two directives have aimed at reducing the pollution from the waste incineration plants and pushing the market for a more sustainable and clean energy recovery from waste scenario in the EU. (European Commission, 2000)
- Regulation (EC) No 2150/2002 of the European Parliament and of the Council of 25 November 2002 on waste statistics

  This regulation is responsible for creating and maintaining waste management statistics at the EU level. This helps the EU with regular monitoring of the generation, recovery and disposal of waste across its member states. (European Commission, 2002)

- Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste

  The regulation aimed at simplifying the shipment of waste between member states. It laid down specific procedures in order to improve environmental protection. It monitors the movement of waste between the member states. The regulation specifies the documentation that is needed to report, and the security measures required during transportation. The regulation considers every kind of waste except radioactive waste and is based on the International Basel Convention. (European Commission, 2006)

- Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain directives:

  The directive sets up a legal framework for the treatment of waste in the European Union. It also defines many terms used in the waste management area like ‘waste’, ‘hazardous waste’, ‘waste management’, ‘recycling’, ‘disposal’ to name a few. The directive is also responsible for introducing to the concept of waste hierarchy and polluters pay price in the EU along with various

legislations related to waste management. It is an important directive which lays the groundwork for upcoming directives in the EU regarding waste. The directive came into force from 12th December 2010. (European Commission, 2008)

Focus on the End of Waste status

The sixth article in the 2008/98/EC directive discusses the product status of waste. It simply means whether the waste that is being used has reached its final stage to be called a waste or if it can achieve a product status, in which case different regulations would be applied. The aim is to promote recyclability. According to the directive, the criteria required to achieve product status are (Alejandro Villanueva, 2010):

- "The substance or object is commonly used for specific purposes and market or demand exists for such a substance or object;
- The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products;
- The use of the substance or object will not lead to overall adverse environmental or human health impacts."

Definitions of waste treatment operations

In the Waste Framework Directive (2008/98/EC) basic waste treatment operations are defined as follows:

Recycling

Operation by which waste materials are reprocessed into products, materials or substances whether for the original purpose or for any other purpose, including the reprocessing of organic waste and excluding energy recovery and the reprocessing into materials that are to be used as a fuel or as a filling material. These are the general recycling end use nomenclature that is used (European Commission, 2008):

- R3: Recycling of organic substances that are not used as solvents.
- R4: Recycling of metals and metallic compounds.
- R5: Recycling of inorganic material.

Reuse

Any act by which products or components again are used for the same purpose for which they were intended.

Recovery

"Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfil that function". The included actions that are part of this are listed in Annex II to the Waste Framework Directive (2008/98/EC). The general recovery nomenclature are as follows (European Commission, 2008):

- R1: Use of waste principally as a fuel or other means to generate energy.
- R2: Solvent reclamation/regeneration

- R6: Regeneration of acids or bases
- R7: Recovery of components used for pollution abatement.
- R8: Recovery of components from catalysts.
- R9: Oil re-refining or other reuses of oil
- R10: Land treatment resulting in benefit to agriculture or ecological improvement
- R11: Use of wastes obtained from any of the operations numbered R1 to R10
- R12: Exchange of wastes for submission to any of the operations numbered R1 to R11
- R13: Storage of wastes pending any of the operations numbered R1 to R12 (excluding temporary storage, pending collection, on the site where it is produced)

Disposal

According to the WFD, disposal is "any operation whose ultimate aim is not recovery even though there can be a reclamation of substances or energy". The nomenclature generally used for disposal is as follows (European Commission, 2008):

- D1: Deposit into or onto land, e.g. landfill
- D2: Land treatment, e.g. biodegradation of liquid or sludgy discards in soils
- D3: Deep injection, e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories
- D4: Surface impoundment, e.g. placement of liquid or sludgy discards into pits, ponds or lagoons
- D5: Specially engineered landfill, e.g. placement into lined discrete cells which are capped and isolated from one another and the environment
- D6: Release into a water body, except seas/oceans
- D7: Release into seas/oceans, including sea-bed insertion
- D8: Biological treatment resulting in final compounds or mixtures which are discarded by any of the operations numbered D1 to D12
- D9: Physico-chemical treatment resulting in final compounds or mixtures which are discarded by any of the operations numbered D1 to D12, e.g. evaporation, drying, calcination
- D10: Incineration on land
- D11: Incineration at sea
- D12: Permanent storage, e.g. emplacement of containers in a mine
- D13: Blending or mixing prior to submission to any of the operations numbered D1 to D12
- D14: Repackaging prior to submission to any of the operations numbered D1 to D13
- D15: Storage pending any of the operations numbered D1 to D14 (excluding temporary storage, pending collection, on the site where it is produced)

EU Timber Regulation (EUTR – Regulation (EU) No 995/2010

All timber and wood products are subjected to this regulation so as to avoid any illegal trans-shipment of timber in the EU. Only waste is exempt from this regulation. Wood waste or post-consumer wood waste is a material that has completed its life cycle or would have otherwise been discarded. Primary and secondary wood residues do not fall under the waste category and have to be transported under the EUTR Regulation. Although, post-consumer wood waste does not fall under the regulation. (European Commission, 2010)

Basel Convention

The Basel Convention was introduced to control the trans boundary shipment of hazardous waste and their disposal. It was introduced on 22nd March 1989 after a public outcry by Africa in the 1980's, after it was found out that many developed nations were disposing their hazardous waste in Africa. The convention major aim is to promote better health and living conditions of people around the world against the ill effects of hazardous waste. The convention entered into full force by 1992. (UNEP, 1992) The convention covers a varied list of hazardous wastes, based on their composition, origin and characteristics.

The convention focuses on these principal goals (UNEP, 1992):

1. Reducing the hazardous waste generation and promoting the sustainable management of hazardous waste.
2. Restricting the trans boundary shipment of hazardous waste to countries where it is illegal to dispose and ensuring the movement is to countries that have environmentally sound waste management systems.
3. A regulatory system for the countries that can deal with hazardous waste.

The EU has ratified and adopted the Basel Convention whereas US has only adopted the convention, but not ratified it yet. The regulation applies to:

- Within the EU member states.
- Imported to the EU from Third World countries.
- Exported from the EU to Third World countries.
- In transit

The transported waste is classified into two further categories: the ones with a hazardous nature are part of the 'Amber list'; the ones of a non-hazardous nature are generally part of 'Green list'. But even if a green listed waste is transported for energy recovery purpose in any member state of EU, it has to be recorded under the Basel Convention.

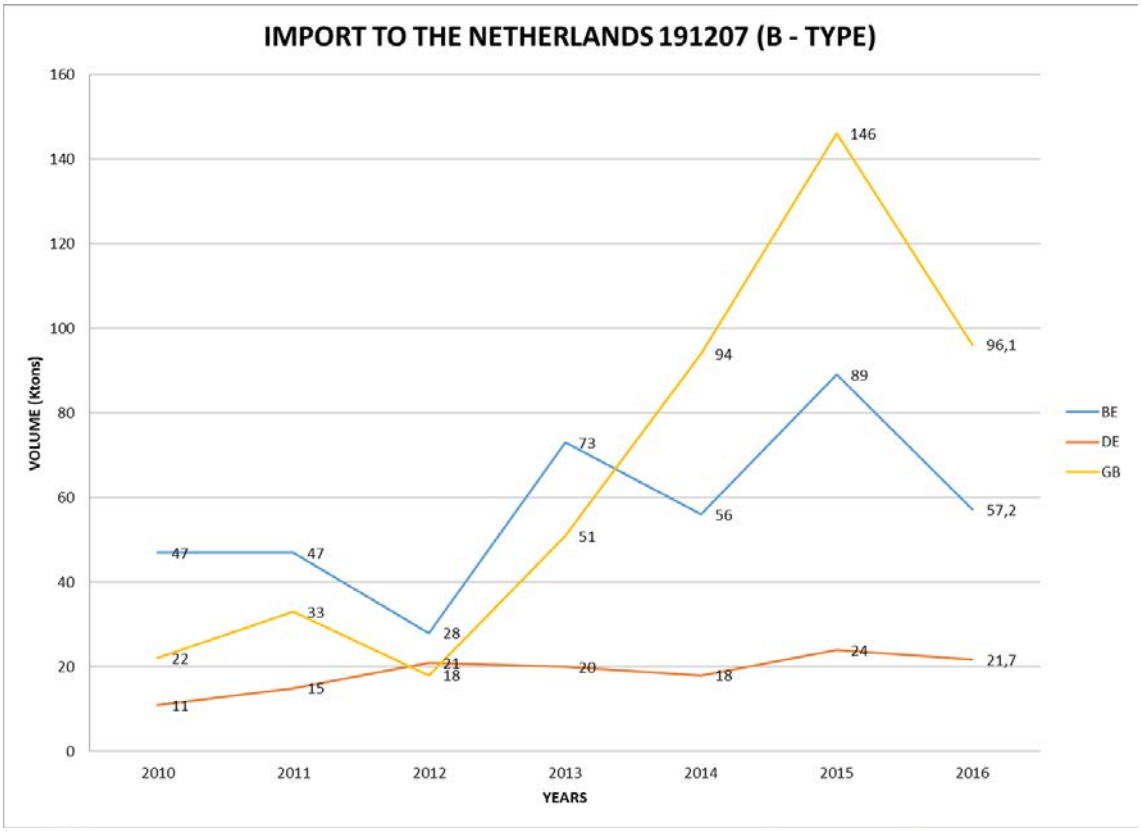
3. RESULTS

3.1 The Netherlands

3.1.1 Trends in Import and Export of Wood Wood waste

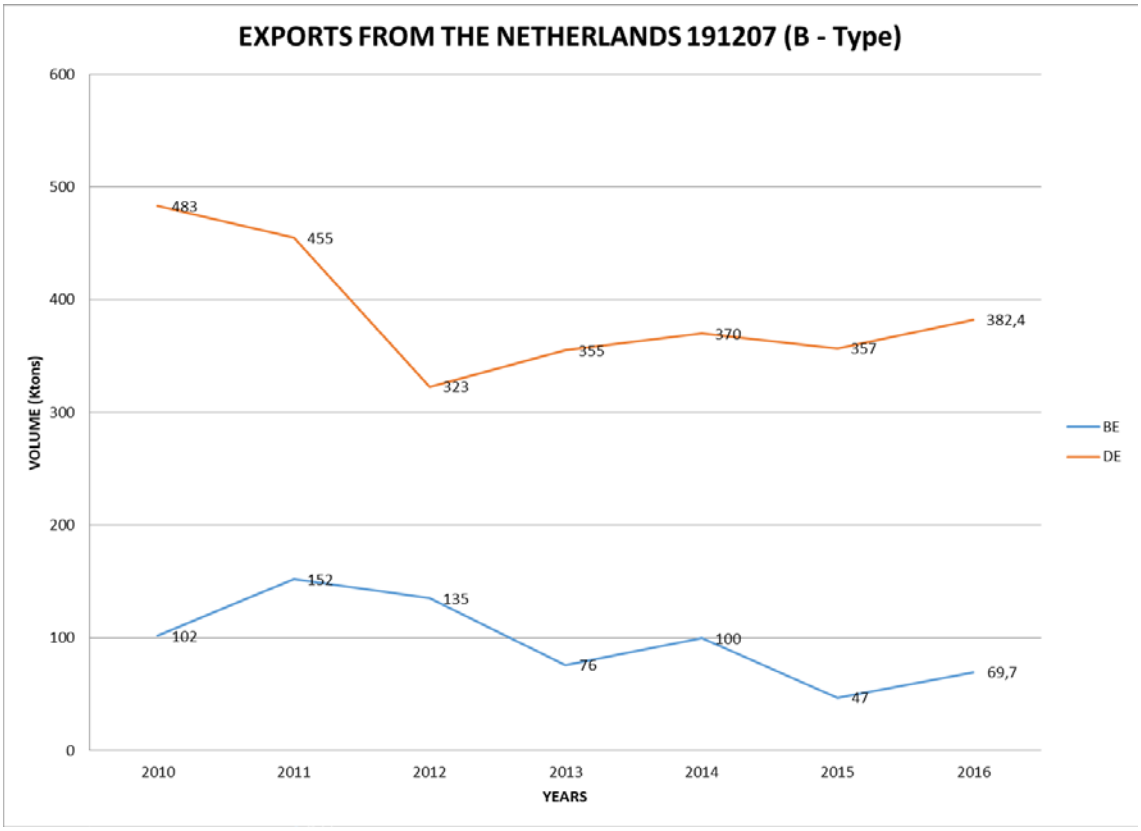
The Netherlands deals with a considerable amount of wood waste in Europe and is a major exporter as well as importer of both hazardous as well as non-hazardous wood waste. The Netherlands has four major bioenergy plants that use wood waste and partly import non-hazardous wood waste as feedstock for their plants: Bioenergie Centrale gouden Raand (Delfzijl), Twence, HVC Groep and AVR Afvalverwerking. In 2015, the bioenergy plants imported around 260 KT of wood waste as fuel. The wood waste imported for bioenergy plants is majorly B – Type which corresponds to the 191207 on the EWC list. The three major exporters of wood waste to the Netherlands are the United Kingdom, Belgium and Germany. The United Kingdom is the primary exporter of wood waste for energy recovery purposes in the Netherlands. The Netherlands had a sudden increase of wood waste from the end of 2012, when majority of its bioenergy plants were established including Eneco, which is the largest wood waste bioenergy plant in the Netherlands. According to the information collected through various interviews from waste stakeholders, Eneco used to import 80,000 tons from the United Kingdom itself for maintaining a consistent supply of its wood waste but the supply has been constantly decreasing ever since the UK has decided to use the wood waste for energy recovery in their country.

Figure 4: Import to The Netherlands EWC 191207



The Netherlands also exported the B-type wood waste to Germany and Belgium in large quantities in the years 2010 - 2015. Germany had a steady bioenergy market which was already established due to the renewable energy friendly policies. In Belgium, the demand for wood waste is majorly for material recovery in the chipboard industry. (NL Agency, NL Energy and Climate Change, 2013).

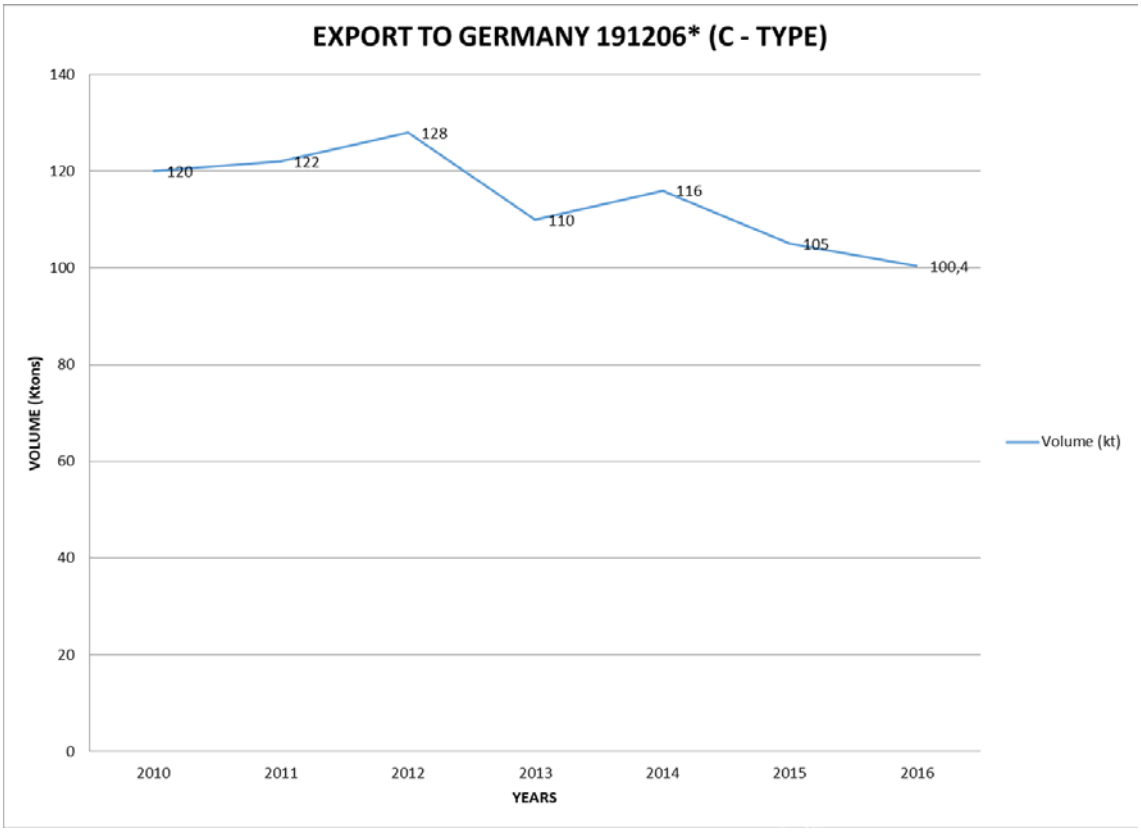
Figure 5: Export from The Netherlands EWC 191207



The Netherlands produces hazardous wood waste on a large scale and most of it is exported to other countries. The major importer of C-type wood waste or 191206* according to the EWC list, from the Netherlands is Germany. The exported volume is used mainly for energy recovery. It has consistently exported 100+ KT to Germany for its wood waste-based bioenergy plants. It is costly in the Netherlands to incinerate the hazardous wood waste for energy recovery purposes, hence it is majorly exported to Germany (Mark van Benthem, 2005). Also, there is no provision in the legislation of the Netherlands to take care of hazardous wood waste by landfilling. Landfilling of hazardous wood waste is illegal and hence it is shipped to Germany (VROM, The Netherlands, 2004).

However, despite the official ban of hazardous wood waste landfilling, in 2017, there was a massive oversupply of contaminated wood waste in the Netherlands, which led to exceptional permitting of landfilling this material (Huet 2018). While the exact reasons behind this oversupply remain unclear, it is an indication that waste incineration capacity may become scarce, and disposal of contaminated wood waste may become an issue in the future.

Figure 6: Export from Netherlands to Germany EWC 191206*



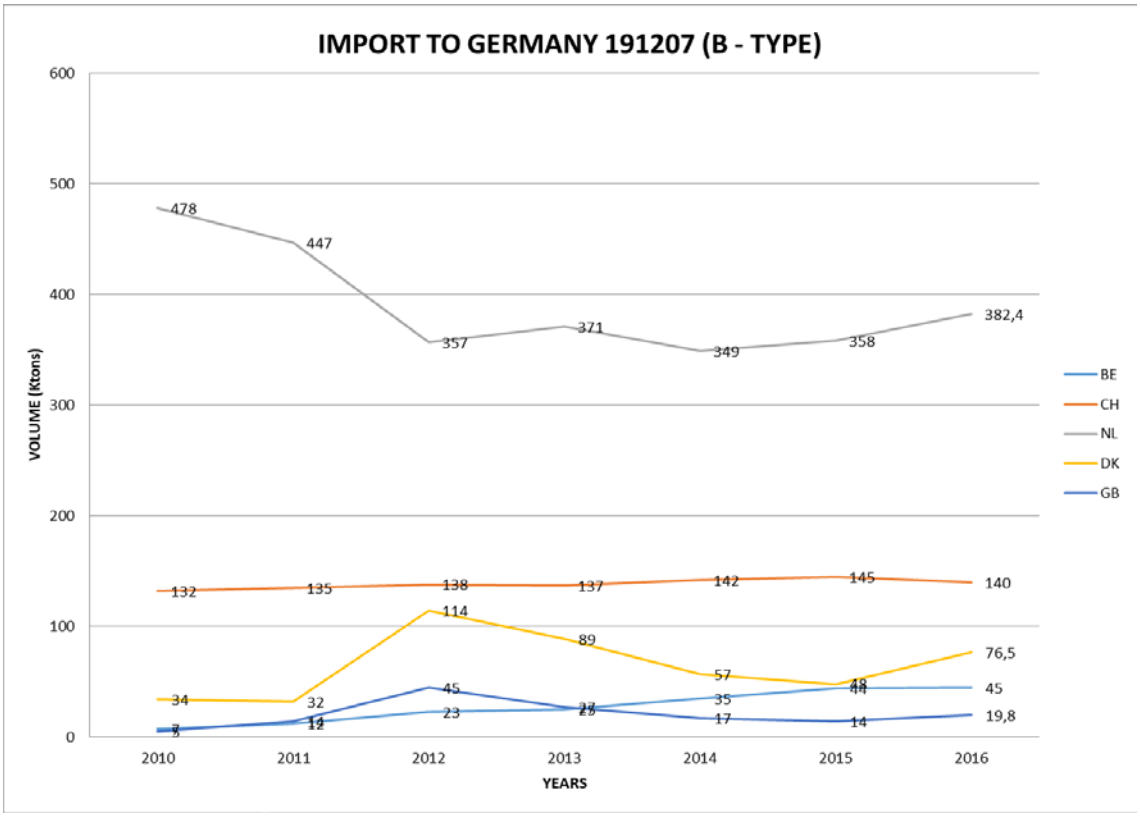
3.2 Germany

3.2.1 Trends in import and export of wood waste

Germany is the main importer of wood waste in the EU. It imports the largest amount of wood waste which rounded off to 780 KT, both hazardous and non-hazardous.

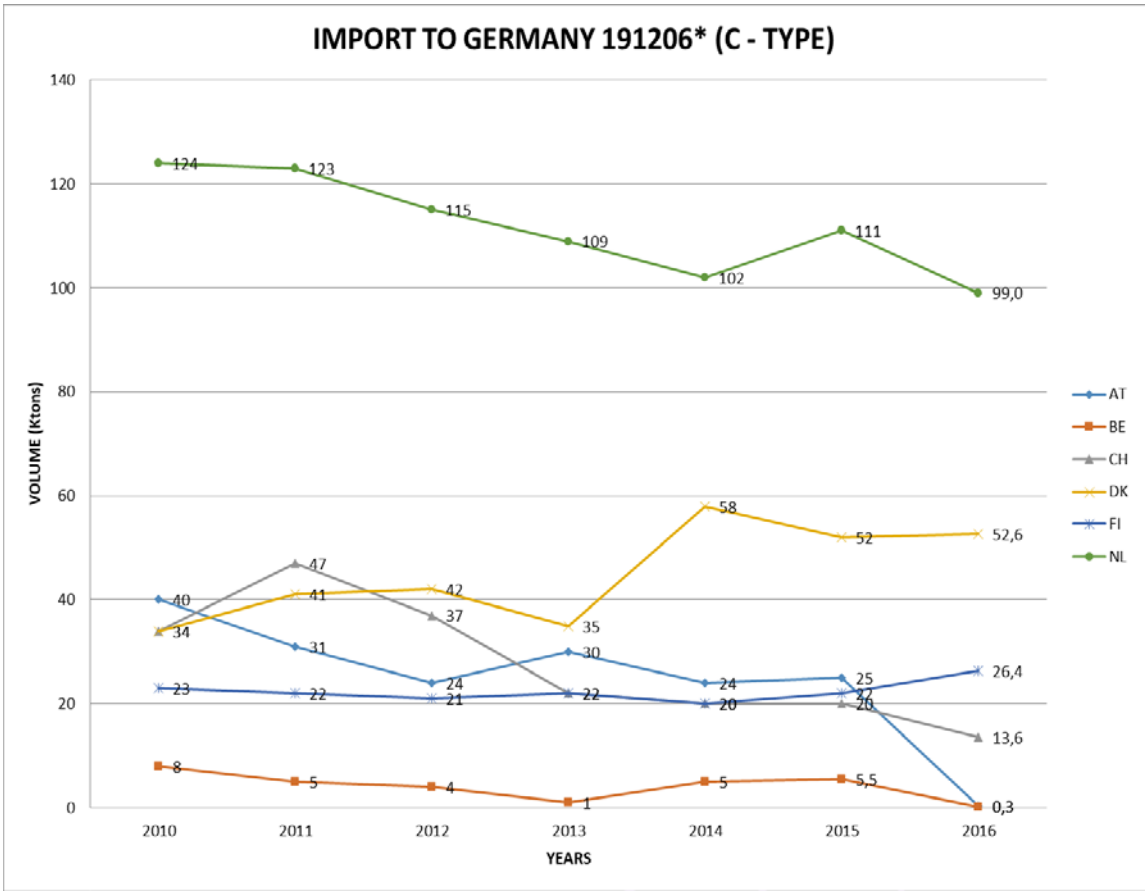
Germany is a net importer of B-type wood waste or 191207 from the EWC list. The major exporters to Germany are the Netherlands and Switzerland. As seen in the section above, the Netherlands supplies a large volume of B-type wood waste to Germany as feedstock for CHP-plants based on solid biofuels. Import of wood waste from the Netherlands peaked in 2010 with 480 KT, since then it has decreased. The sudden decrease in imports from the Netherlands in 2012 is because of the increase of bioenergy plants that use wood waste as feedstock in the Netherlands. The Netherlands used the wood waste to produce energy in its own country rather than shipping it to Germany.

Figure 7: Import to Germany EWC 191207



The C – type wood waste is imported from all over Europe, majorly from the Netherlands (100+KT/yr) and Denmark (50 KT/yr). Finland, Switzerland and Austria have a consistent supply of 20 KT. Germany has the capacity as well as proper legislations and policies to support the energy recovery process of hazardous wood waste which are discussed in detail in further sections. Hence, it is a net importer in Europe during the years 2010-2015.

Figure 8: Import to Germany EWC 191206*

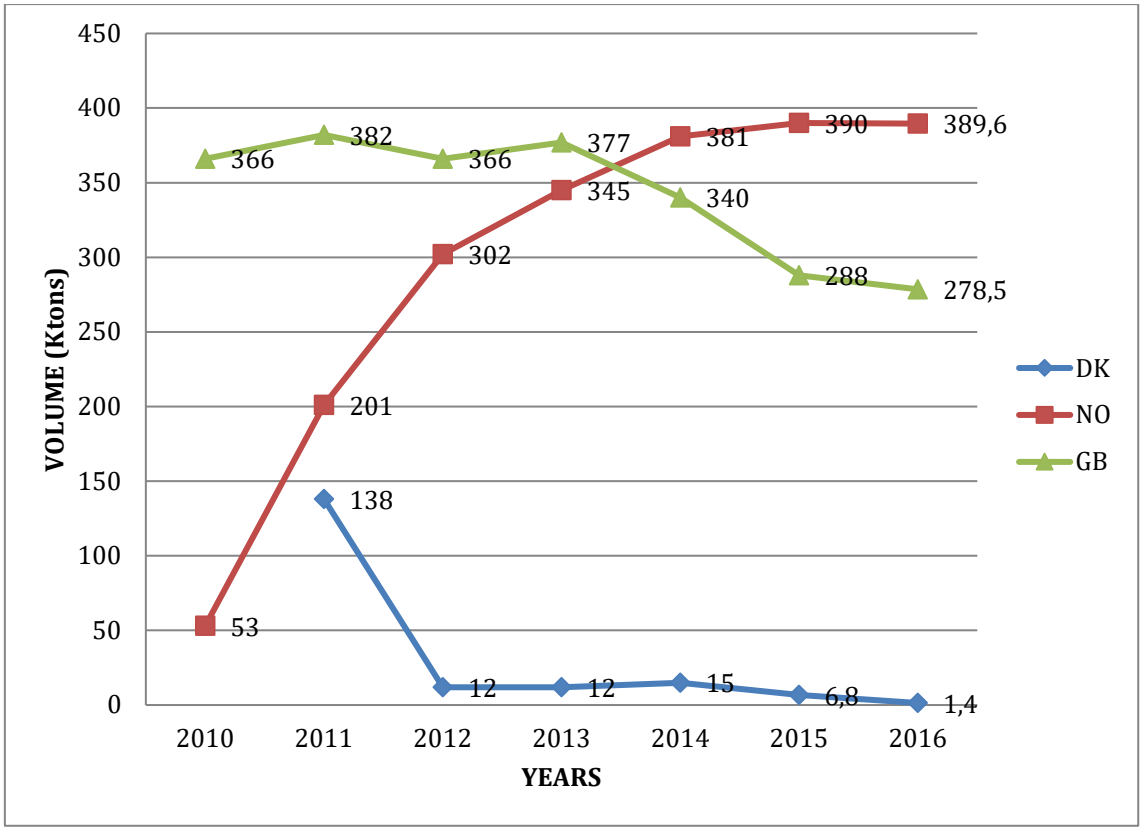


3.3 Sweden

3.3.1 Trends in Import and Export of Wood waste

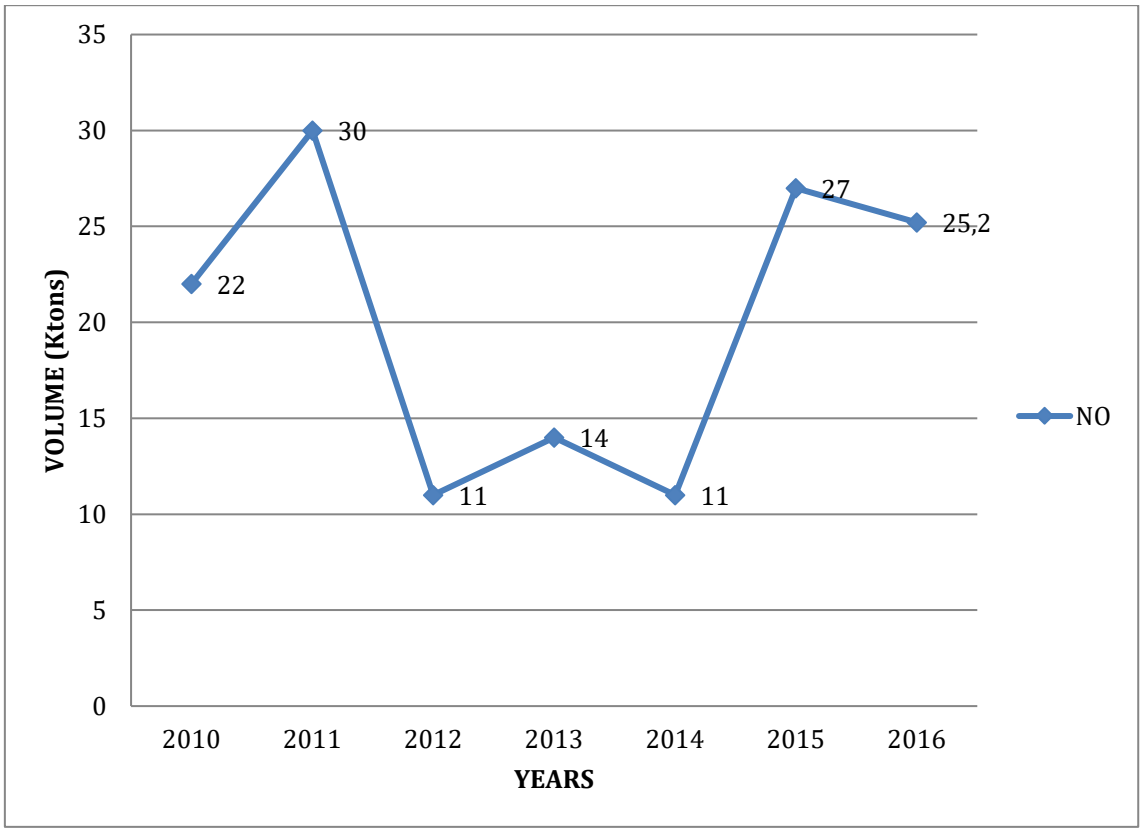
Sweden is the second largest net importer of wood waste in the EU. It imports around 681 KT per year, of both hazardous and non-hazardous waste. Sweden is a net importer of B-type wood waste. The major exporters to Sweden are United Kingdom and Norway. Sweden highly depends on the wood waste supply from these countries for maintaining a supply of feedstock for its CHP plants. The UK supplied more than 300 KT annually up until 2014. After 2014, these volumes decreased as the UK started new bioenergy plants whose feedstock is wood waste.

Figure 9: Import to Sweden EWC 191207



The C – type wood waste is imported from Norway depending upon the generation of hazardous wood waste. Norway lacks the facilities to dispose of the hazardous waste, whereas Sweden has the capacity as well as proper legislations and policies to support the energy recovery process of hazardous wood waste and hence it is a net importer in Europe during 2010-2016.

Figure 10: Import to Sweden EWC 191206*



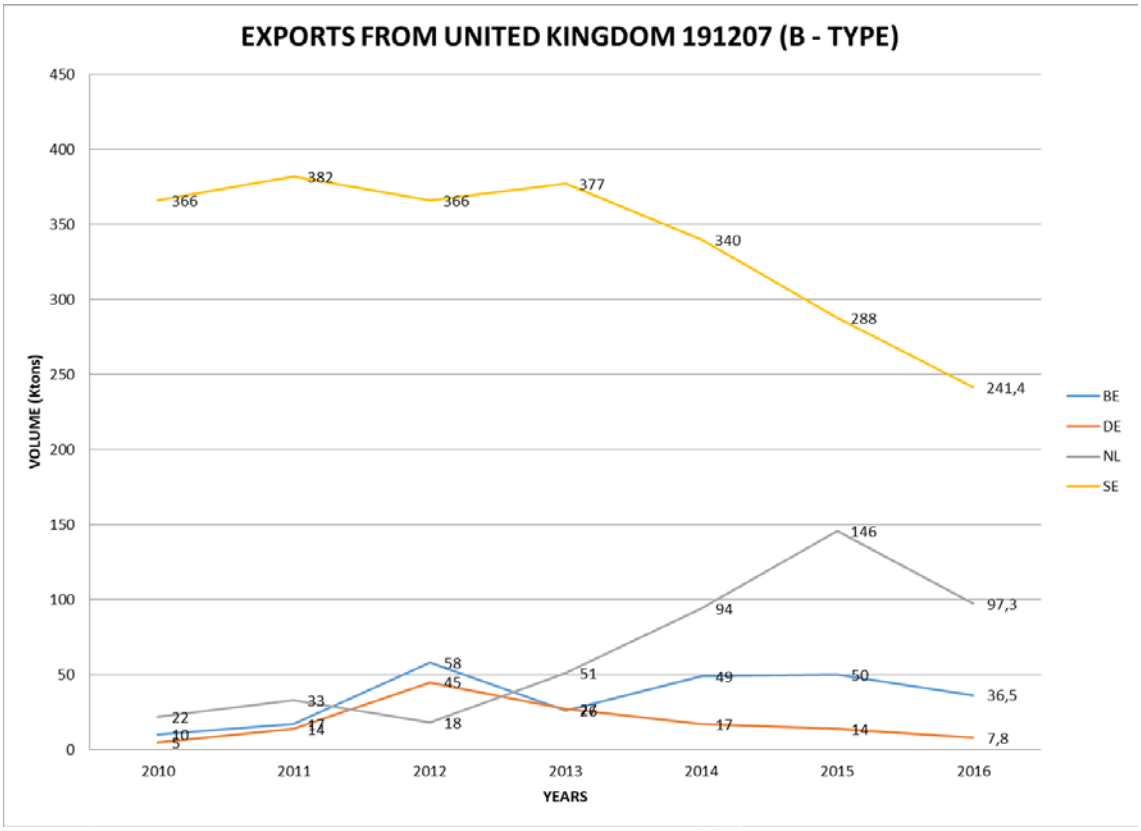
3.4 United Kingdom

3.4.1 Trends in Import and Export of Wood waste

United Kingdom is a net exporter of wood waste in the EU. It is one of the most prominent exporters of non-hazardous wood waste. The United Kingdom requires permission for transboundary shipment of hazardous waste, which is costly for many traders and industries and hence majority of the hazardous waste is dumped in landfills. The total export of non-hazardous wood waste was approximately around 500 KT in 2015.

The B– type wood waste is exported majorly to the Netherlands and Sweden. Belgium and Germany also import wood waste from the United Kingdom, but the quantities are not high (10-50 KT/yr).

Figure 11: Exports from United Kingdom EWC 191207



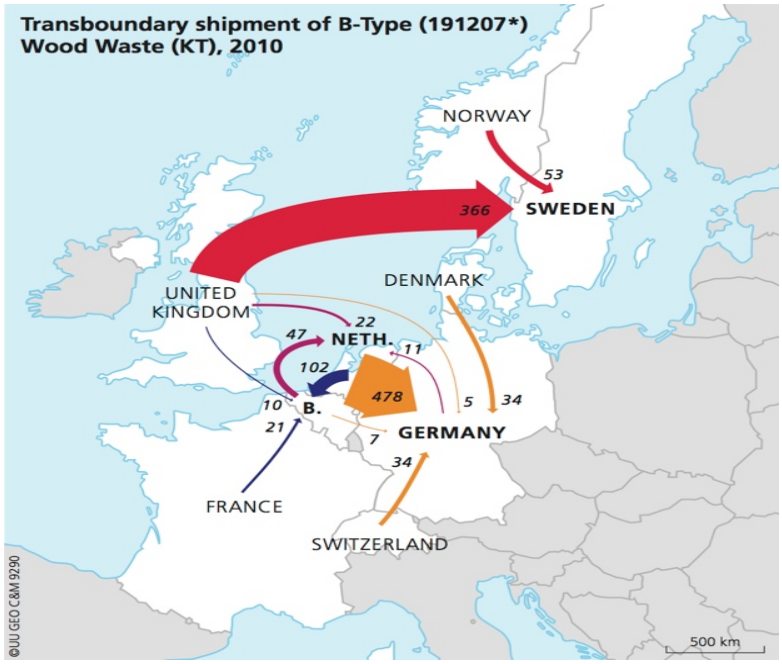
3.5 Europe

3.5.1 NON-HAZARDOUS WOOD WASTE (191207)

B – Type Wood Waste (also known as the non-hazardous wood waste) is mainly imported by Germany and Sweden in Europe. The main countries involved in the trade are situated in the Northwestern part of Europe. The total volume of B-type wood waste transported in 2010 was 1190 KT. The B-type wood is majorly used for R1 and R3 recovery paths since the EU regulations does not allow to ship the waste if it is being disposed of in a landfill.

As seen in the figure, the major importer of wood waste in 2010 was Germany with a trade of 558 KT which is 47% of the imported wood waste in Northwestern Europe. The German laws and legislations made it easier for the biomass industry to set up successfully in the country. The increase in the number of biomass plants using wood waste as fuel resulted in import flows of wood waste, mainly from neighboring countries.

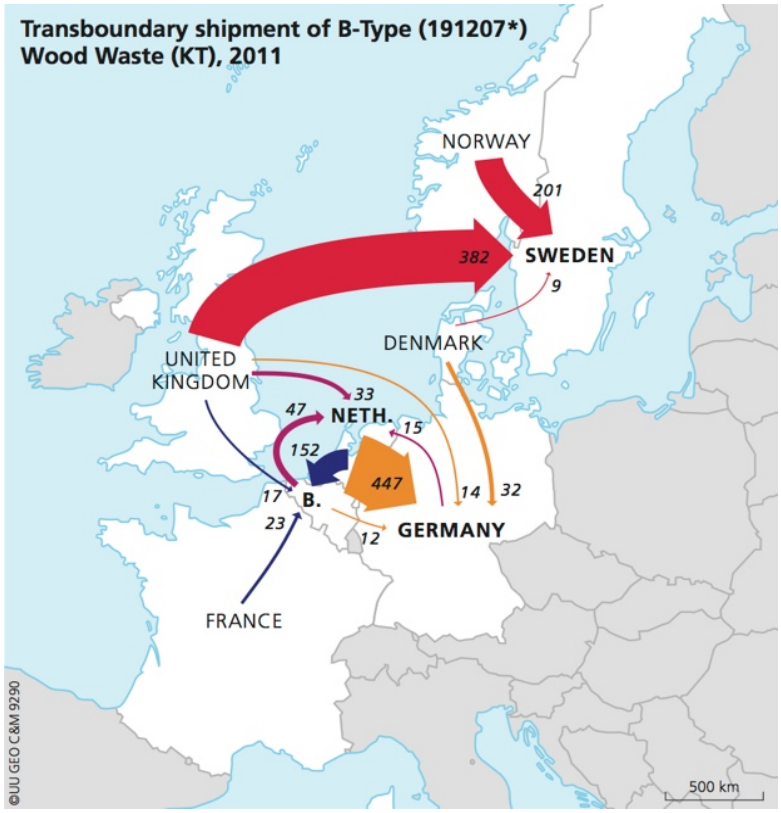
Figure 12: Transboundary shipment of B type Wood Waste, 2010



Sweden is another major net importer of Northern Europe. It had major imports from Norway and the UK. One of the key drivers of high imports of wood waste to Sweden is the energy system infrastructure present in the country which made a sound environment for high energy recovery from waste. The early bans on landfilling in Norway in combination with abundant Swedish wood waste combustion capacity led to high exports of waste from the country to Sweden.

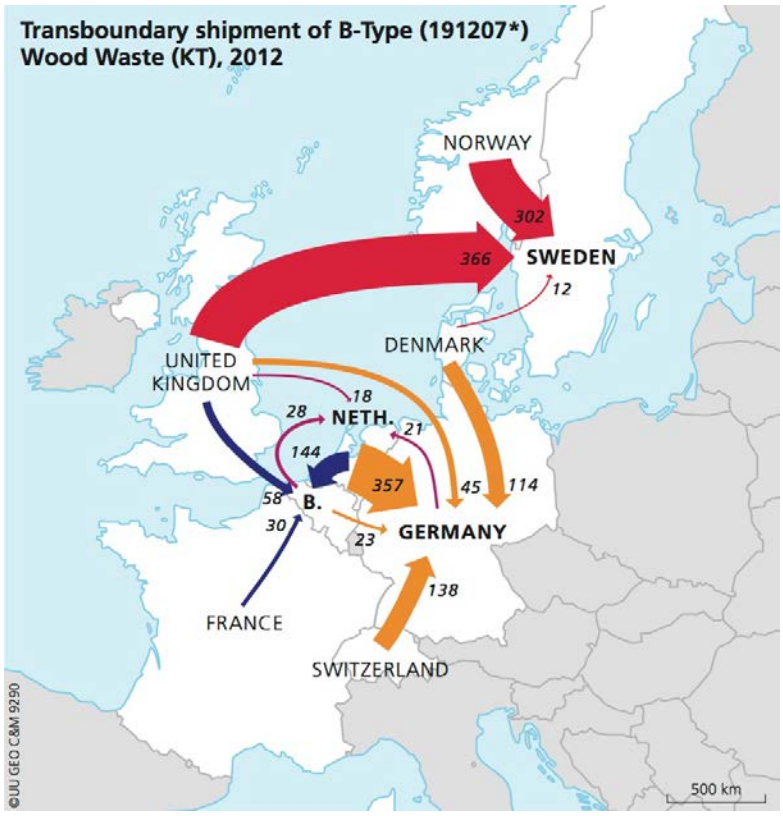
In 2011, the total shipment of B-type waste increased to 1384 KT in Northwestern Europe. Sweden surpassed Germany becoming the largest importer of wood waste standing at 592 KT which is 43% of the total shipment of wood waste in the area. Germany was the second largest importer with 505 KT of wood waste trade. Since, the capacity in the Netherlands was not high enough, it increased its export of wood waste to Belgium. Belgium used the wood waste majorly in chipboard industry.

Figure 13: Transboundary shipment of B type Wood Waste, 2011



In 2012, the total shipment of B-type wood waste increased to 1656 KT. Sweden and Germany both imported 690 KT of wood waste. The Netherlands had an interesting development with installation of the new Eneco wood waste fueled biomass plant, it reduced its export to Germany and Belgium. This led to an increase in exports from Denmark, the UK and Switzerland to Germany for fulfilling the feedstock demand of biomass plants.

Figure 14: Transboundary shipment of B type Wood Waste, 2012



The net trade in 2013 increased to 1677 KT. The trend of Sweden and Germany being the top importers continued. Sweden imported 734 KT and Germany imported 649 KT of B-type wood waste. The Netherlands also imported 144 KT of wood waste which is a 115% increase of imports due to new biomass plants running in the country. It became highly dependent on the imports from the UK, Belgium as well as Germany. It also reduced the exports to Belgium since the demand for wood waste increased in their own country.

Figure 15: Transboundary shipment of B type Wood Waste, 2013

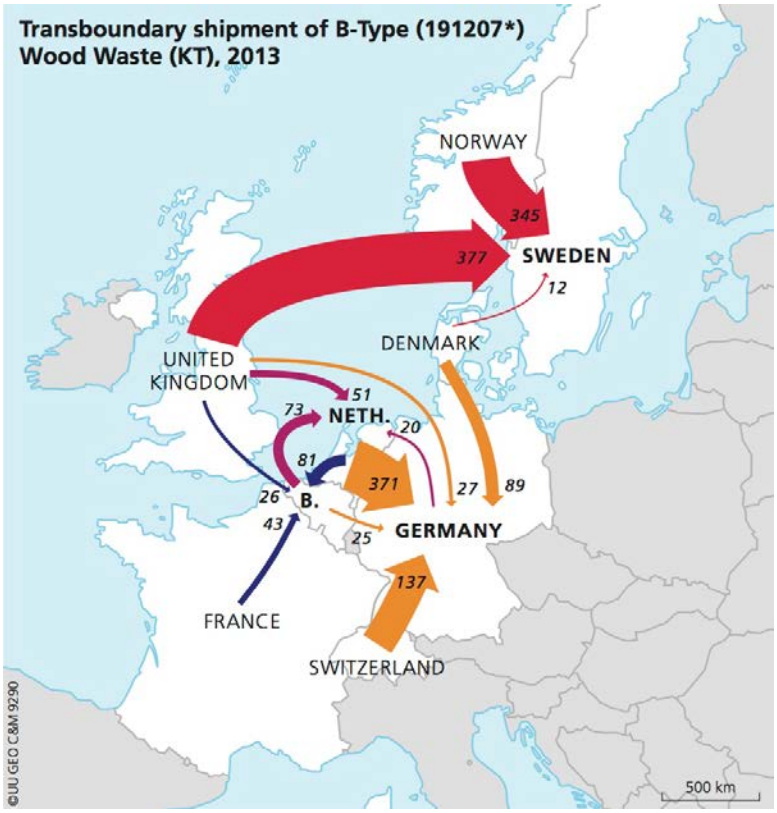


Figure 16: Transboundary shipment of B type Wood Waste, 2014

The total trade of B-type wood waste increased to 1721 KT in 2014. Sweden was the top importer with 736 KT of wood waste imports and Germany imported 600 KT of wood waste. As seen in the map for 2014, UK has started reducing the wood waste exports to Sweden as well as Germany. UK planned to start new biomass plants from 2015 and hence the capacity for wood waste energy recovery increased in the country. The wood waste is going to be used for energy recovery purposes in UK.

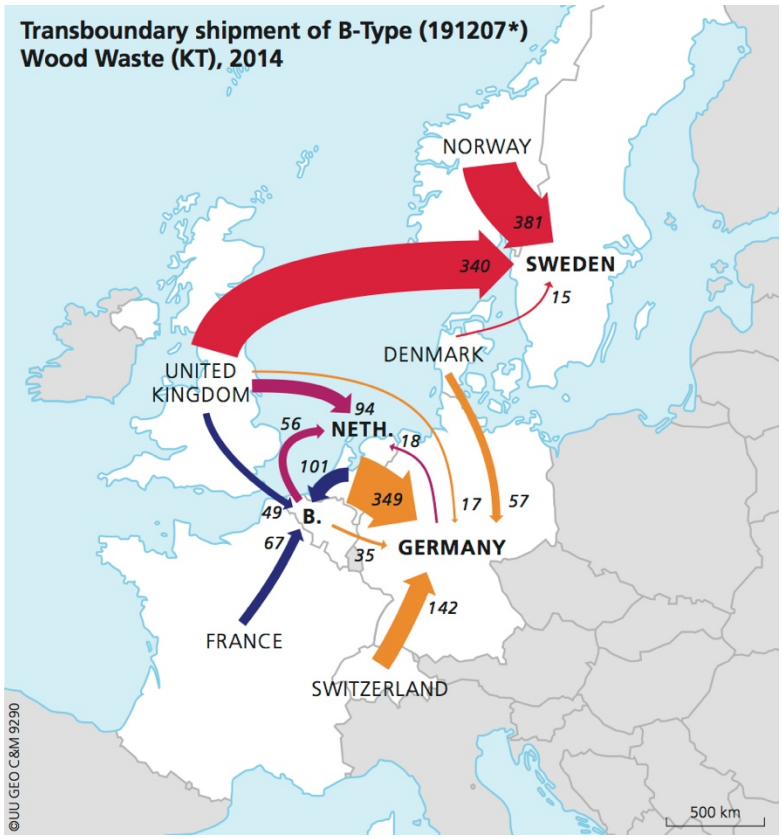
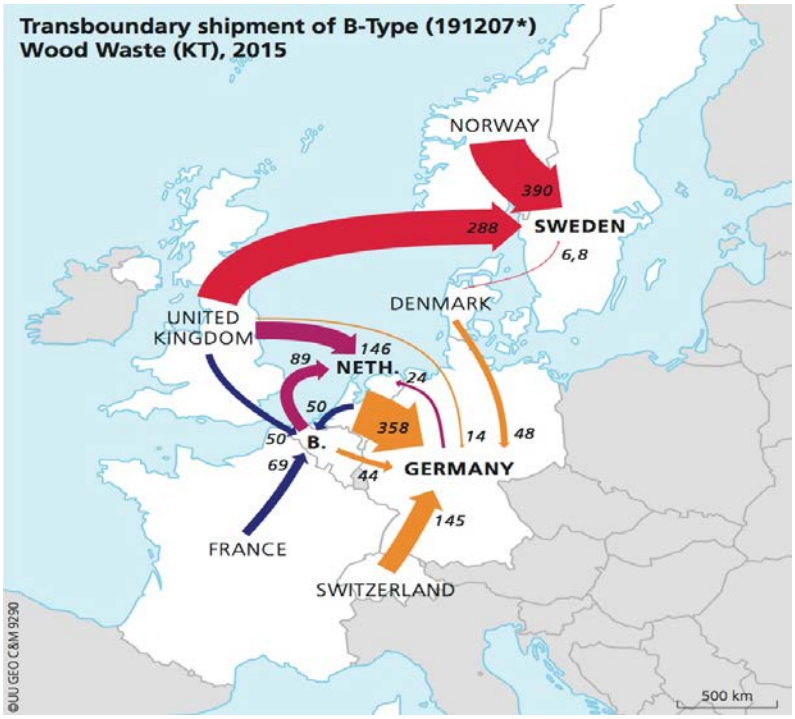


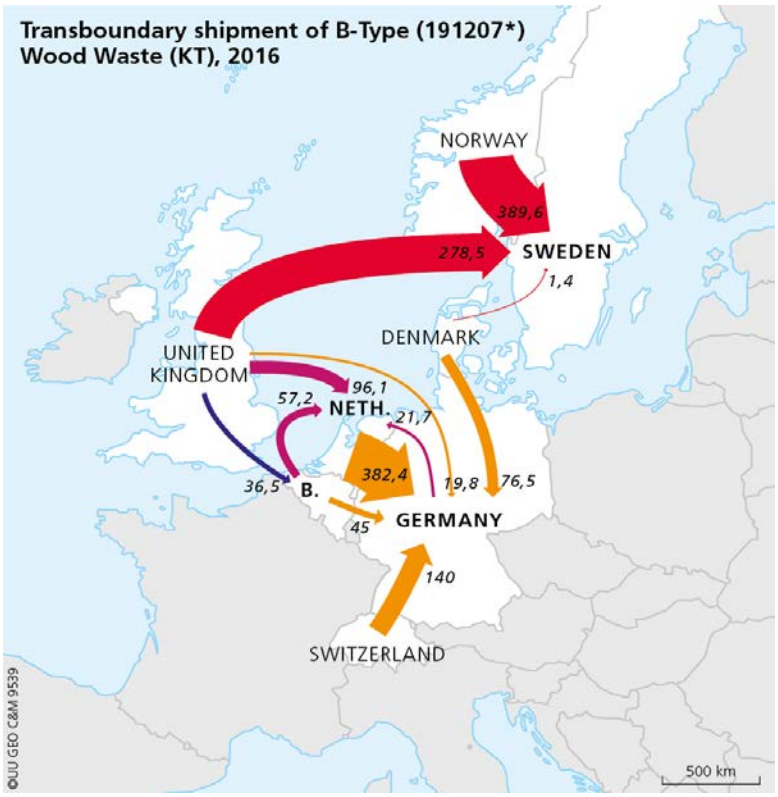
Figure 17: Transboundary shipment of B type Wood Waste, 2015

The trade of B-type wood waste remained constant in 2015 at 1722 KT. There are major factors for this constant supply of wood waste in 2015. In Germany, no additional power plants using wood waste as fuel have been built. Hence, the supply of wood waste in Germany has been nearly constant at 609 KT. The supply of wood waste to Sweden reduced drastically to 685 KT because of reduction of imports from the UK. The reason for reduction is the installation of new bioenergy plants in UK.



In 2016, the situation barely changed compared to 2015, with negligible variations in most trade flows. Note: no data was available on imports by Belgium from other countries than the UK.

Figure 18: Transboundary shipment of B type Wood Waste, 2016



3.5.2 HAZARDOUS WOOD WASTE (191206*)

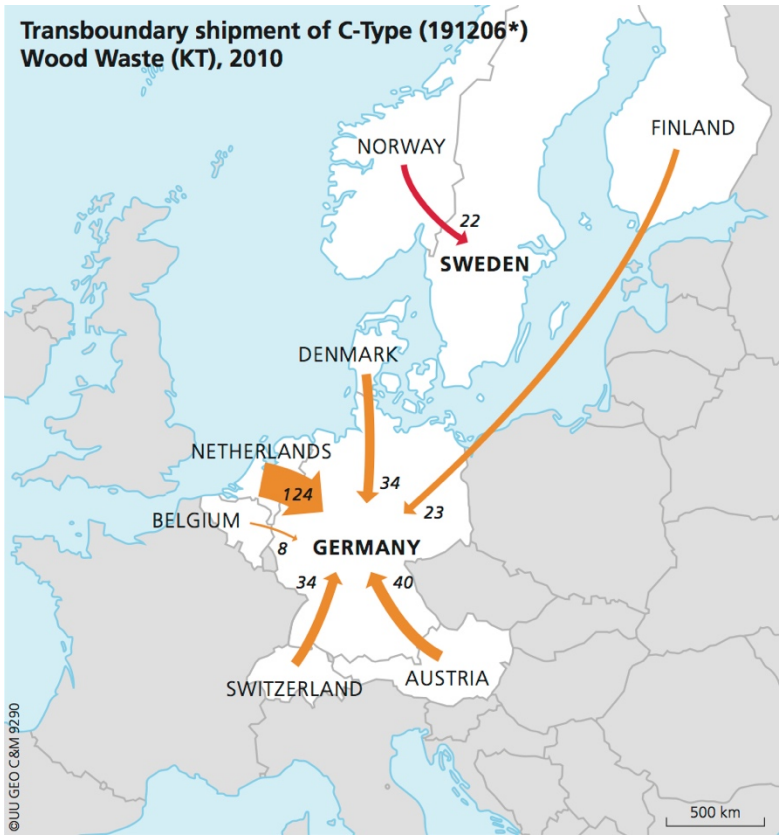
According to the EU directives and regulations, hazardous wood waste can only be disposed of by incineration or hazardous waste landfills. However, some countries in the EU, such as Sweden, have bans on landfilling of combustible waste, in which hazardous wood waste would be included, and therefore incineration is the only alternative. The general trend of shipment of hazardous waste is decreasing over the years because of stricter rules and policies in every country.

Hazardous wood waste with EWC 191206* is transported mainly to Germany in Europe. Germany has a robust legislation system which helped in developing a strong biomass industry.

Furthermore, Germany has provisions for incineration of hazardous wood waste. Therefore, Germany is one of the countries in Europe which accepts hazardous wood waste and can incinerate it whether for energy or non-energy recovery purposes, and it has become the largest importer of hazardous wood waste in Europe. Sweden is another net importer of hazardous wood waste. The most important driver of trans boundary shipment of hazardous wood waste is legislation. In UK, there is no provision for shipment of hazardous wood waste and hence majority of it is landfilled with the consequent negative impact on the environment. One of the largest exporters of hazardous wood waste is the Netherlands which has no provisions in its legislation for landfilling of most hazardous wood waste. However, it does to incinerate hazardous waste, but it should follow proper protocol and hence the whole process becomes costlier. Therefore, it is cheaper for the Netherlands to export its hazardous waste to the neighboring country, Germany.

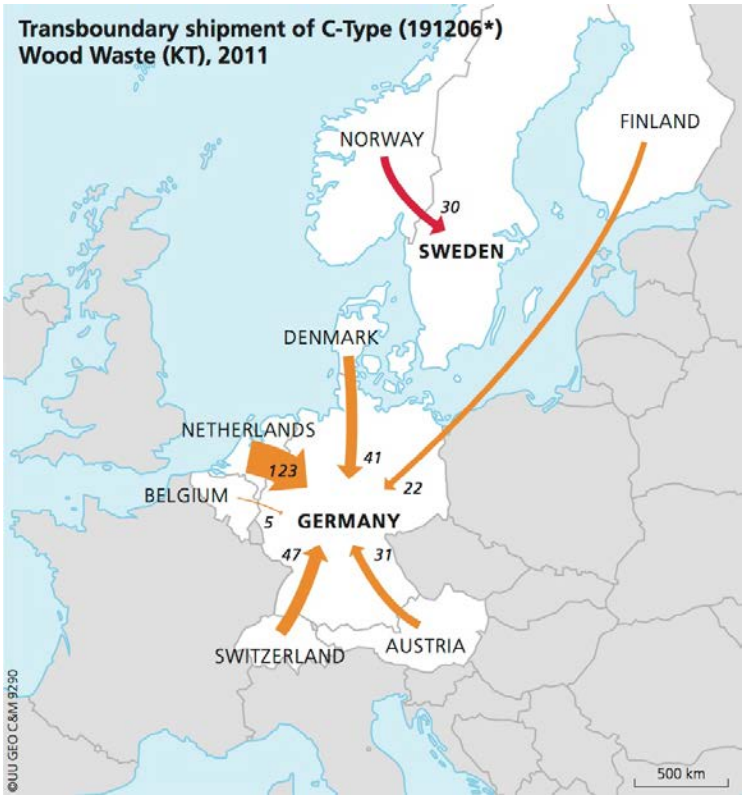
In 2010, 285 KT of hazardous wood waste was transported in Europe out of which 263 KT were imported to Germany. Sweden imports hazardous wood waste mainly from Norway. Norway lacks the capacity to handle the hazardous wood waste and implemented a landfilling ban of biodegradable waste in 2009 (EIONET, 2018). Hence it exports the majority of its hazardous wood waste to Sweden.

Figure 19: Transboundary shipment of C type Wood Waste, 2010



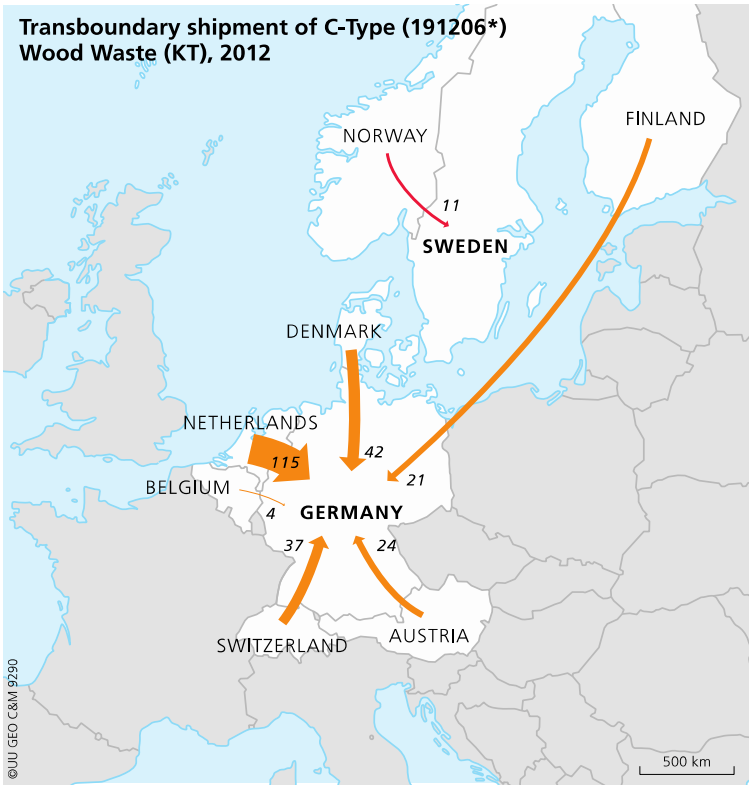
In 2011, 299 KT of hazardous wood waste was transported in Europe out of which 269 KT was imported to Germany. Germany acts as a one of the key players in driving the hazardous wood waste trans boundary shipment. It imports hazardous wood waste from all the neighboring countries including Switzerland and Austria.

Figure 20:Transboundary shipment of C type Wood Waste, 2011



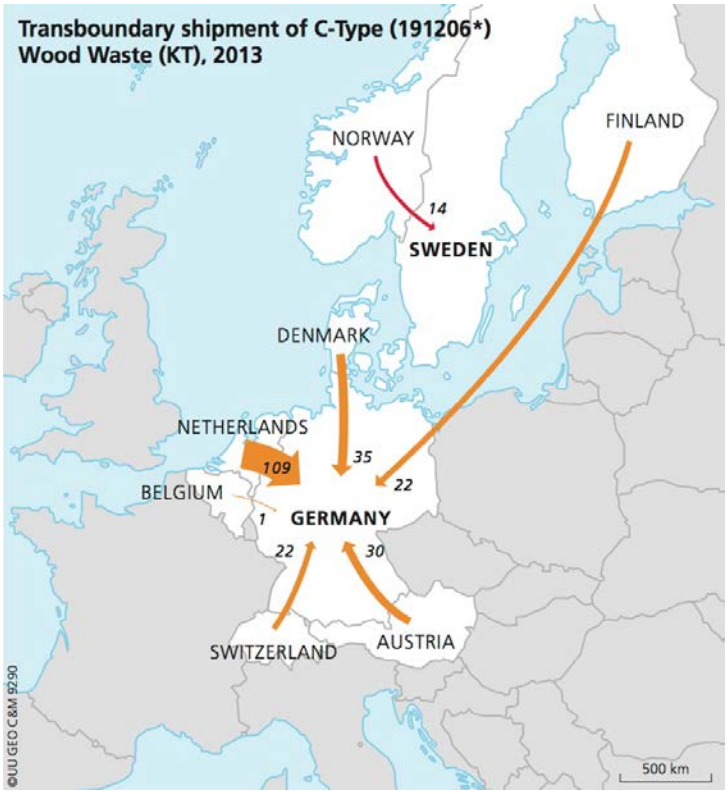
In 2012, 254 KT of hazardous wood waste was transported in Europe with more than 90% being imported to Germany.

Figure 21: Transboundary shipment of C type Wood Waste, 2012



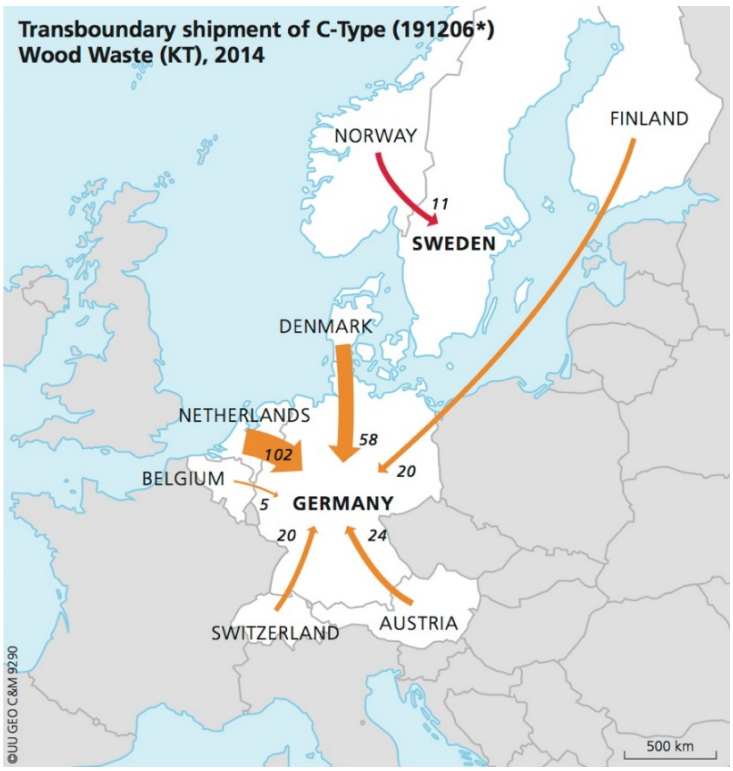
In 2013, 233 KT of hazardous wood waste was transported in Europe.

Figure 22: Transboundary shipment of C type Wood Waste, 2013



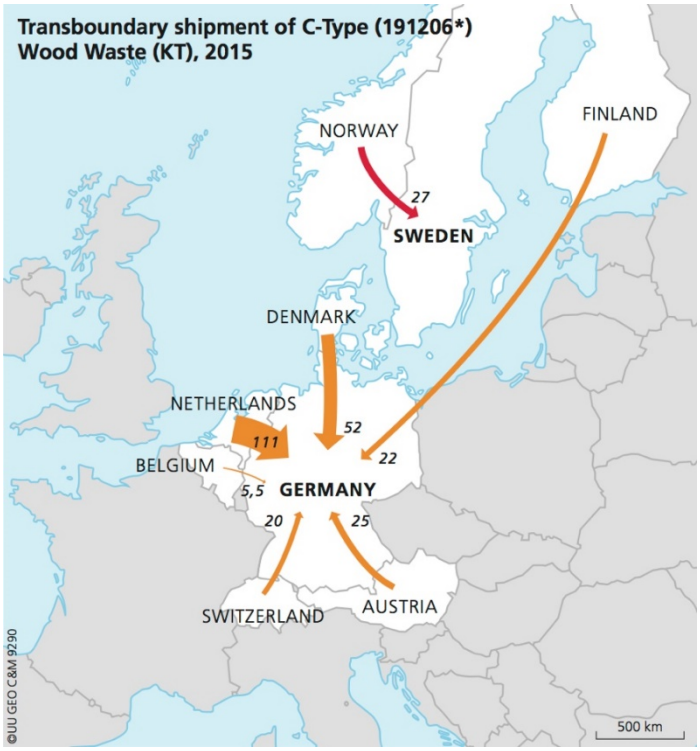
In 2014, 240 KT of hazardous wood waste was transported in Europe.

Figure 23: Transboundary shipment of C type Wood Waste, 2014



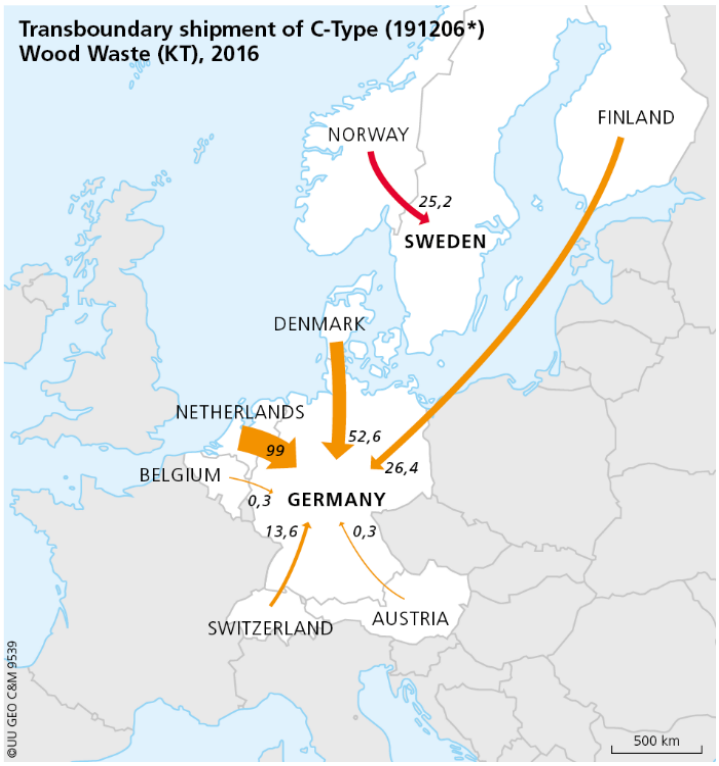
In 2015, 262 KT of hazardous wood waste was transported in Europe. The slight increase compared to 2014 was caused by a slight increase in hazardous wood generation in The Netherlands and the lack of domestic incineration capacity. Norway has landfill bans but lacks the capacity to deal with the upsurge of hazardous wood waste and hence it has to be transported to Sweden, which is cheaper than hazardous waste incineration in Norway.

Figure 24: Transboundary shipment of B type Wood Waste, 2015



In 2016, this situation hardly changed. Trade flows vary marginally compared to previous years; Germany remains the central importer for most neighboring countries.

Figure 25: Transboundary shipment of B type Wood Waste, 2016



4. DISCUSSION

4.1 Drivers of transboundary shipment of wood waste

4.1.1 HAZARDOUS WOOD WASTE

There has been a constant demand and supply for hazardous wood waste across the EU. There are various factors that are driving the trans boundary shipment of wood waste. The major drivers are as follows:

1. Legislations and Policies: One of the most important drivers is the legislation and the policies that a country imposes on the recovery options of hazardous wood waste. As it can be seen in the section above, Germany is the highest importer of hazardous wood waste and it acts like a sink for Europe's hazardous wood waste. It has been made possible because of the detailed policies that have been adopted by the federal as well as state governments over the years. Germany was one of the first countries to have a hazardous waste ordinance. It also implemented the renewable energy sources act supporting the combustion of wood waste for electricity and heat generation It has a special wood waste management ordinance which takes care of the recovered and used wood exclusively. Hence, promoting better ecological standards

2. Installed capacity: The lack of capacity for handling wood waste of the exporting countries combined with the constant need of feedstock of existing treatment plants in the importing countries can drive the trade of hazardous wood waste. For example, The Netherlands does not have the legislation or the installed capacity to deal with the hazardous wood waste and hence is mainly exporting it to Germany for its disposal. On the other hand, Germany has a constant demand for wood waste. There are about 700 bioenergy plants based on (partly hazardous) solid fuels with an installed capacity of 1500 MW_{el} in place producing electricity and heat. (DBFZ, 2015) The technology is also a key driver for hazardous wood waste trade. Even though The Netherlands might have the capacity,it is still lacking the best technology possible to use hazardous wood waste for energy recovery purposes which is in accordance with the strict Dutch legislation. (VROM, The Netherlands, 2004)
3. Economics: In many countries, it is costlier to landfill waste rather than trade it to another country. Except UK, The Netherlands, Germany and Sweden have a landfill tax. In some cases, depending on the type of waste, landfilling is totally prohibited. These cost restrictions drive the trans boundary shipment of hazardous wood waste. Also, sometimes the wood waste is a cheaper fuel than the wood pellets or regular fuel in the market. Therefore, the demand for wood waste as a fuel increases and a market of wood waste drives the trans boundary shipment of hazardous wood waste.

Table 2: Landfilling Tax in European Countries (Source: (CEWEP, 2017))

Country	Landfill Tax	Landfill Ban Implemented
Germany	-	Landfill ban for untreated MSW since 1.6.2005 Landfill ban for wood waste since 1.3.2003
Sweden	Average net fee for landfilling: €50-75/t Landfill tax: €55/t (increased from €45/t in 2015) Total price for landfilling: €120-170/t Landfill tax increased more than 50% from 2001 to 2010	1.1.2002: Sorted combustible waste 1.1.2005: Organic waste
The Netherlands	17 €/t (2014) Average net price: 40 – 50 €/t	For 64 categories of waste
UK	2.65 – 84.4 £/t Gate fees: 9-25£/t (10.40-29 €/t)	NO

4. Transportation: The transport to neighboring countries is another added factor. As seen in the maps, the waste is being traded with the neighboring countries, indicating that the transportation costs also matter. Sometimes, the facilities in another country might be closer to reach than the facilities in their own country. On the other hand, transportation will also have an impact on the environmental and this should also be considered. According to a study by Olofsson et al. (2005), it can cost 40 €/ ton to transport mixed waste in Germany while it costs 52 €/ton to transport mixed waste in Denmark. This difference is because of variation in type of transport used for shipment of waste, like a truck and a boat. Transportation by boat costs lesser than a truck. (Mattias Olofsson, 2005)

4.1.2 NON – HAZARDOUS WOOD WASTE

1. Legislation and Policies: For non-hazardous waste, the legislation becomes a very important driver. As mentioned in the EU WFD, non-hazardous wood waste can either go for material or energy recovery. Hence, one more market of recycling industry opens for non-hazardous wood waste along with the biomass plants. In the Netherlands, the government has planned to consider a mandate which makes co – firing compulsory for the coal plants and wood waste is generally used as a feedstock. (Pellcert, 2012)

2. In UK, the government provides financial support in the form of Renewable Obligation Certificates, similarly in Sweden wood waste has been included in the fuels eligible for green certificates from electricity production. In Germany, the detailed legislation is already discussed in chapters above which made the market for non – hazardous wood waste favorable. Hence, the legislation is an important driver for the trans boundary flow of wood waste. (NL Agency, NL Energy and Climate Change, 2013)

3. Capacity Factor: The capacity factor also plays an important role. As seen in the case of Germany as well as The Netherlands, the higher the number of wood waste biomass plants are, the higher the imports increase. The Netherlands did not import B-type wood waste until 2012 when it opened the highest capacity wood waste biomass plant, Eneco and the imports eventually increased in the upcoming years from the UK as well as other countries and decreased to the neighboring countries since it was being used for national energy production. The high capacity factor of Germany and Sweden drives a B – type wood waste from neighboring countries.

4. Price of Wood waste: In UK, the wood waste market is highly dependent on the cost of the wood waste. The lower grade wood waste has a lot of cost associated with it such as cleaning. High grade wood waste, or non-hazardous wood waste do not face such issues. (NL Agency, NL Energy and Climate Change, 2013). Still it should be pointed out that although landfilling tax is a price-component, in general, there is a market for wood waste and the price is dependent on basic economics such as demand versus supply. Markets however are only bilateral; there are no exchanges or price-hubs active. Thus, this market is not transparent (Hol, 2018)

Table 3: Cost of disposal of wood (Source: (DEFRA, 2008))

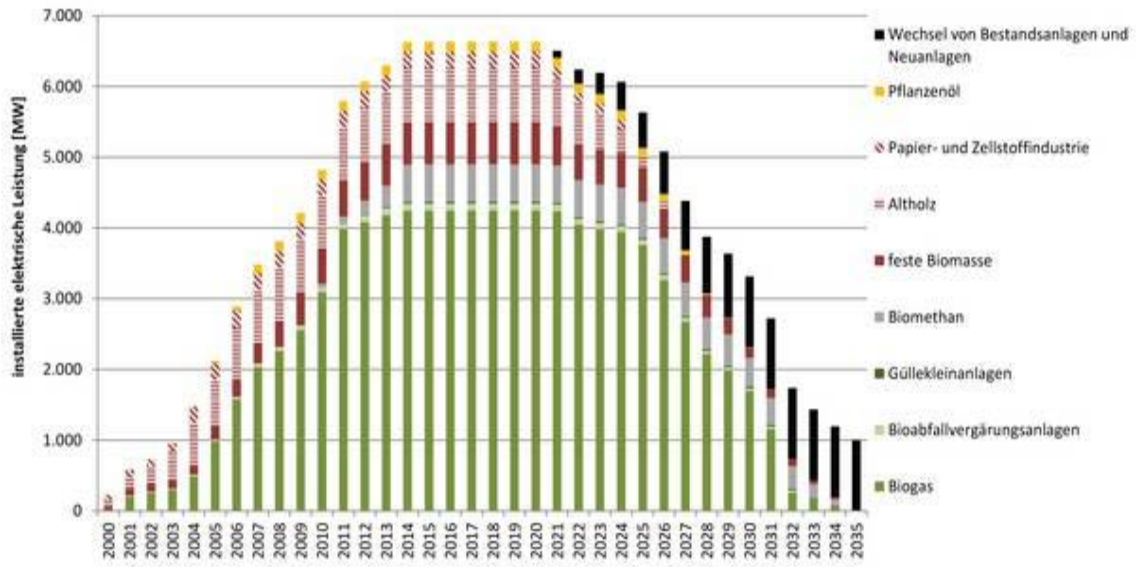
GRADE	RECOVERY METHODS	RECOVERY COST
GRADE A	Animal Bedding, Mulches, Panel board	Potential income of £150
GRADE B and C	Energy or Panel Board	Cost to £5 to £30
GRADE D	Landfilling	£35 to £45

4.2 FUTURE TRENDS

Future trends in the import and export of wood waste is obtained from interviews from experts in UK, The Netherlands, Germany and Sweden. The UK has decided to increase the bioenergy capacity in the upcoming years and the main feedstock for the bioenergy plants would be industrial grade wood waste. Considering the fact that it is currently a major exporter of wood waste to countries like Sweden, The Netherlands and Germany, UK aims to reduce the exports in the upcoming years. While Sweden may manage the feedstock supply from different sources of biomass, The Netherlands and Germany must look for new exporters of B-type wood waste to keep its bioenergy plants like Eneco supplied with a constant feedstock. According to multiple experts from UK and other countries, the Brexit will likely not affect the shipment flows of wood waste in the upcoming years,

Germany has around 1500 MWel bioenergy plants based on solid fuels and wood waste installed and working currently, but for many plants the financial support under the EEG guaranteed over 20 years is phasing out soon. Besides, with the amendment of the EEG in 2017 there has been a switch from a feed-in tariff system to an auction system under which a cap is applied for bioenergy plants and they are likely to struggle more to be competitive. In case existing and new bioenergy plants are not successful in the bidding rounds or in finding other business models, existing plants are going to gradually phase out from 2020 onwards and/or new capacities will not be installed. The capacity would then drastically reduce in the upcoming years (compare with Figure 26 Installed capacity in Germany over the years. Source: DBFZ 2016).

Figure 26: Installed capacity in Germany over the years. Source: DBFZ 2016



Along with the amendments of the EEG also the biomass ordinance (BiomasseV) has been amended defining which type of biomass is eligible for support under the EEG. Here wood waste is already no longer eligible for support since 2012. There also has not been any change in that when switching to the auction system implying that neither existing nor new wood waste plants can receive support under the current EEG. These aspects may lead to a capacity reduction of wood waste installation from 2020 onwards having an immediate effect on the hazardous wood waste of Europe since Germany is currently the sink for most hazardous wood waste in Europe. The Netherlands would be affected strongly, since it is constantly exporting 100+ KT of hazardous wood waste every year to Germany along with 350+ KT of non-hazardous wood waste/year.

The Netherlands has to find new sources for maintaining a constant feedstock for its bioenergy plants in the upcoming years. It has started facing problems currently when UK reduced the exports of 191207 wood waste to The Netherlands. It also may have to look for new importers for its hazardous wood waste generation since Germany may reduce its imports in the years to come.

4.3 UNCERTAINTIES AND METHODOLOGICAL CHALLENGES

The national reports on the Basel International website provides a great deal of insight on the production, import and export of different kinds of hazardous as well as non-hazardous waste. But still, there were considerable variability in certain data sets available. The following sources of uncertainties have been identified during the study:

(a) Lack of availability of data: Apart from the national reports on the trans boundary shipment of waste by Basel International, the sources of data available online are limited. The data provided by Eurostat has shown variation (e.g. between exported volumes of country A to country B be reported by country A, compared to imported volumes of the same flow reported by country B) and is thus considered unreliable, as was also confirmed by ministry/agency officials of The Netherlands and Sweden. The data for CN Code system is not up to date. There is a lack of an online statistical dataset solely based on the European Waste Codes. An EWC list centric dataset could be beneficial for a better and faster approach to the trans boundary flow studies in the future.

(b) Inconsistency in different codes: This was one of the major issues while collecting statistics for the study. As mentioned in the data collection part, the study encountered multiple code systems in Europe. For example, the Dutch wood waste “type B” is equal to the German wood waste “types II and III” (Hol, 2018). The description of the trade commodities was different in different code systems. This led to difficulty in selecting a common and uniform code system. The EC has addressed the issue and is working on co relating the code systems which can be a huge help for the future studies.

(c) Redundancy of data: Since the data was procured from more than one source, this led to varied datasets that overlapped. The datasets were thoroughly checked for redundancy and double data.

(d) Difference in data from different countries: There is a slight difference in the import and export values of different countries. The value that is being exported is minutely different than the value that is being imported. Since the difference is not huge it has been a positive characteristic of the dataset being accurate.

5. CONCLUSIONS

Significant amounts of hazardous and non-hazardous wood waste are shipped between countries in Northwestern Europe. Germany and Sweden are the most important countries driving the transboundary flows of wood waste in Europe.

The major exporters for hazardous wood waste are The Netherlands and Norway. The main importers for the hazardous waste are Sweden and Germany. Germany acts like a sink for hazardous wood waste in Europe. Every year it imports average 230 KT of hazardous wood waste to incinerate at its bioenergy facilities. Sweden imports from Norway at an average rate of 25 KT a year. From 2010 till 2015, there is a general declining trend of shipment of hazardous waste, mainly because of new and stricter legislations and policies in every country regarding landfilling of hazardous waste. This trend is likely going to continue in the upcoming years. This means that in coming years, especially the Netherlands will have to find alternative destinations for its hazardous wood waste if dedicated combustion capacity in Germany diminishes.

Non-hazardous wood waste is an ideal industrial grade feedstock for bioenergy plants in Europe. It is being traded extensively throughout Europe but the major countries to participate in the trade are situated in the Northwestern area. UK, The Netherlands and Norway are main exporters of non-hazardous wood waste with an average export of 300+ KT every year whereas Sweden, Germany and The Netherlands are main importers with and average imports of 600+ KT every year.

While trade flows especially from the UK and to Germany can be in the order of several hundred kilotons, the overall contribution of traded wood waste to national bioenergy production is very small to negligible in the countries investigated, typically between 1-3% of total bioenergy production. This is also likely to remain this way, as it is not expected that wood waste volumes will suddenly strongly increase in coming years.

The key drivers identified in both the cases are a strong legislation and a robust capacity to handle the incoming wood waste for energy recovery purposes. The countries with huge imports have these key drivers in common. In Germany, the legislation is detailed and promotes the installation of bioenergy plants, hence giving platform for better capacity. In Sweden, the capacity is in the form of CHP plants and it is accepting wood waste as a feedstock from neighboring countries.

6. REFERENCES

Alejandro Villanueva, L. D. (2010). Study on the selection of waste streams for end-of-waste assessment.

BMUB. (1990). Seventeenth Ordinance on the Implementation of the federal Emission Control Act).

BMUB. (2003). Ordinance on the Management of Waste Wood.

Buff. L. Rev. (1991). Trashing Developing Nations: The Global Hazardous Waste Trade.

Bundesgesetzblatt (1972). Abfallbeseitigungsgesetz.

CEWEP (2017). Landfill Taxes and Ban.

Christian Fischer, H. J. (2012). Transboundary shipments of waste in the European Union Reflections on data, environmental impacts and drivers.

CSTB (2005). Caractérisation des déchets de bois de chantier, recommandations de tri et approches de valorisation.

DBFZ (2015). Stromerzeugung aus Biomasse (Vorhaben IIa Biomasse). Zwischenbericht Mai 2015.

DBFZ (2016). Biomasse im EEG 2016. Hintergrundpapier zur Situation der Bestandsanlagen in den verschiedenen Bundesländern.

DEFRA (2008). Waste Wood as a biomass fuel

Department for Environment, Food And Rural Affairs. (2013). Wood Waste Landfill Restrictions in England: Call for Evidence .

EEG (2000/ various years). Erneuerbare-EnergienGesetz; EEG. German renewable energy law, updated in several years after 2000, available at: https://www.erneuerbare-energien.de/EE/Redaktion/DE/Dossier/eeg.html?cms_docId=71110

EIONET (2018) European Topic Centre on Sustainable Consumption and Production, Factsheet for Norway. Available at: https://scp.eionet.europa.eu/facts/factsheets_waste/2009_edition/factsheet?country=NO

European Commission (1999). COUNCIL DIRECTIVE 1999/31/EC of 26 April 1999 on the landfill of waste.

European Commission (2000). COMMISSION DECISION of 3 May 2000 replacingDecision 94/3/EC establishinga list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishinga list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste.

European Commission (2000). Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste (WID) .

European Commission (2002). Regulation (EC) No 2150/2002 of the European Parliament and of the Council of 25 November 2002 on waste statistics.

European Commission (2006). Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste.

European Commission. (2008). Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain directives.

European Commission. (2010) EU Timber Regulation (EUTR – Regulation (EU) No 995/2010.

European Commission (2010) DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 November 2010 on industrial emissions (integrated pollution prevention and control) Official Journal of the European Union, 17.12.2010, L334/17-119

European Commission (2018) DIRECTIVE (EU) 2018/850 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 1999/31/EC on the landfill of waste. Published in the official journal of the European Union 14.6.2018 , L150/100-108

European Environment Agency (2012). Movements of waste across the EU's internal and external borders.

European Union (2000). Commission Decision 2000/532/EC.

European Union. (2016). Commission Implementing Regulation (EU) 2016/1821 of 6 October 2016 amending Annex I to Council Regulation (EEC) No 2658/87 on the tariff and statistical nomenclature and on the Common Customs Tariff 1.

European Union. (n.d.). Retrieved 07 25, 2017, from http://ec.europa.eu/environment/waste/index.htm

Eurostat(2013). Top 10 types of hazardous wastes shipped from EU MS, 2013. Retrieved 2017, from http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Top_10_types_of_hazardous_wastes_shipped_from_EU_MS,2013.png

Eurostat (2016). Energy, Transport and Environment Indicators.

Eurostat (n.d.). Waste Shipment Statistics. Retrieved 7 20, 2017, from http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_shipment_statistics

Hol, M. (2018) Personal communication with Marcel Hol, Business Analyst Biomass desk, Eneco, The Netherlands, October 2018.

Van Huet, B (2018) Personal communication with Bas van Huet, Rijkswaterstaat, The Netherlands, October 2018.

INERIS. (2006). Les réglementations relatives aux déchets industriels dangereux. Programme DCE-05 "propriéte des produits.

Institute for Energy and Environment (2007). Monitoring zur Wirkung der Biomasseverordnung. Forschungs- und Entwicklungsvorhaben (FKZ 204 41 133)

ISWA. (2014). ISWA REPORT 2014. Vienna: ISWA.

Kurata, Y. W. (2005). Concentration of organic wood preservatives in wood chips produced from wood wastes. Journal of Maer Cycles Waste Management .

Mantau, U. (2012). Wood Flows in Europe. CEPI.

Mark van Benthem, N. L. (2005). MARKETS FOR RECOVERED WOOD IN EUROPE: CASE STUDIES FOR THE NETHERLANDS AND GERMANY BASED ON THE BIOXCHANGE PROJECT.

Mattias Olofsson, J. S. (2005). Driving forces for import of waste for energy recovery in Sweden.

Ministry of Environment, Sweden. (1999). The Swedish Environmental Code, A résumé of the text of the Code and related Ordinances.

NL Agency, NL Energy and Climate Change. (2013). Competition in wood waste: inventory of policies and markets.

Peek, R. (2004). EU Directives and National Regulations for the Recycling and Disposal of Waste Wood.

PellCert. (2012). European Pellet Report.

Rijkswaterstaat Environment. (2009). National Waste Management Plan.

SEPA. (2004). Naturvårdsverkets föreskrifter om deponering, kriterier och förfaranden för mottagning av avfall vid anläggningar för deponering av avfall (Regulations on landfilling, criteria and procedures for the acceptance of waste at landfills).

Tolvik Consulting (2011). The UK Waste Wood Market .

UNEP. (1992). Basel Convention ON THE CONTROL OF TRANSBOUNDARY MOVEMENTS OF HAZARDOUS WASTES AND THEIR DISPOSAL.

VROM, The Netherlands. (2004). ENVIRONMENTAL MANAGEMENT ACT.

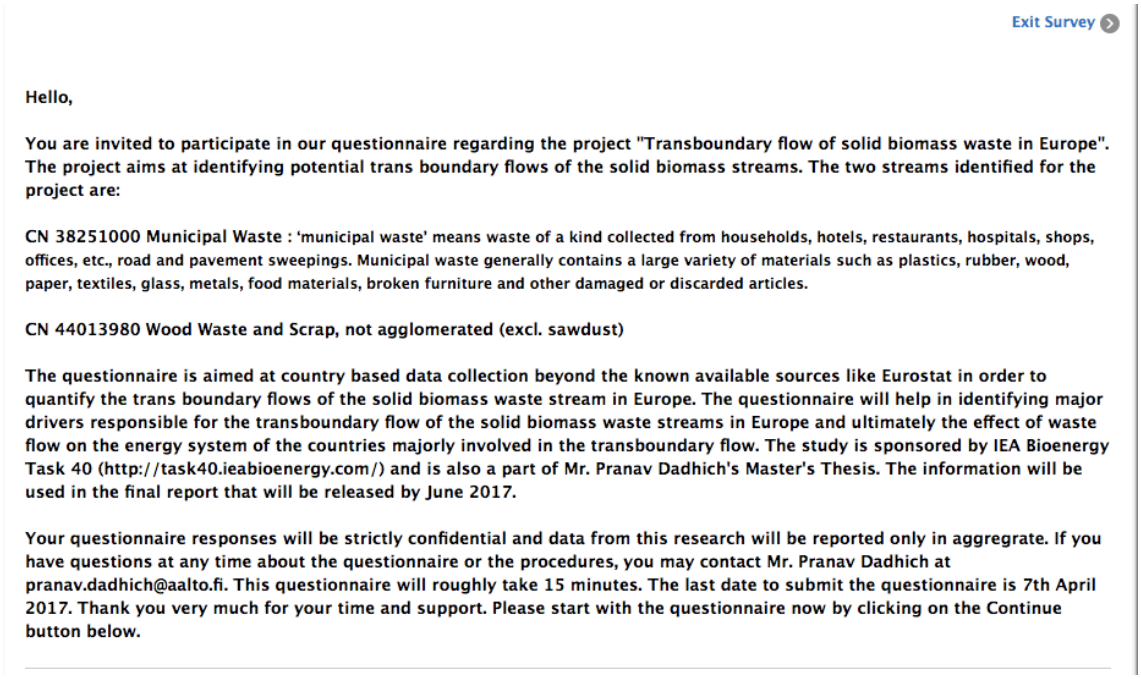
WRAP (Waste & Resources Action Programme. (2012). Specification for the requirements and test methods for processing waste wood.

WRAP (2011). Realising the value of recovered wood.

ANNEX 1

Questionnaire for IEA Task 36 and 40 members

Link to the survey : http://ieabioenergytask40.questionpro.com/



Exit Survey

Hello,

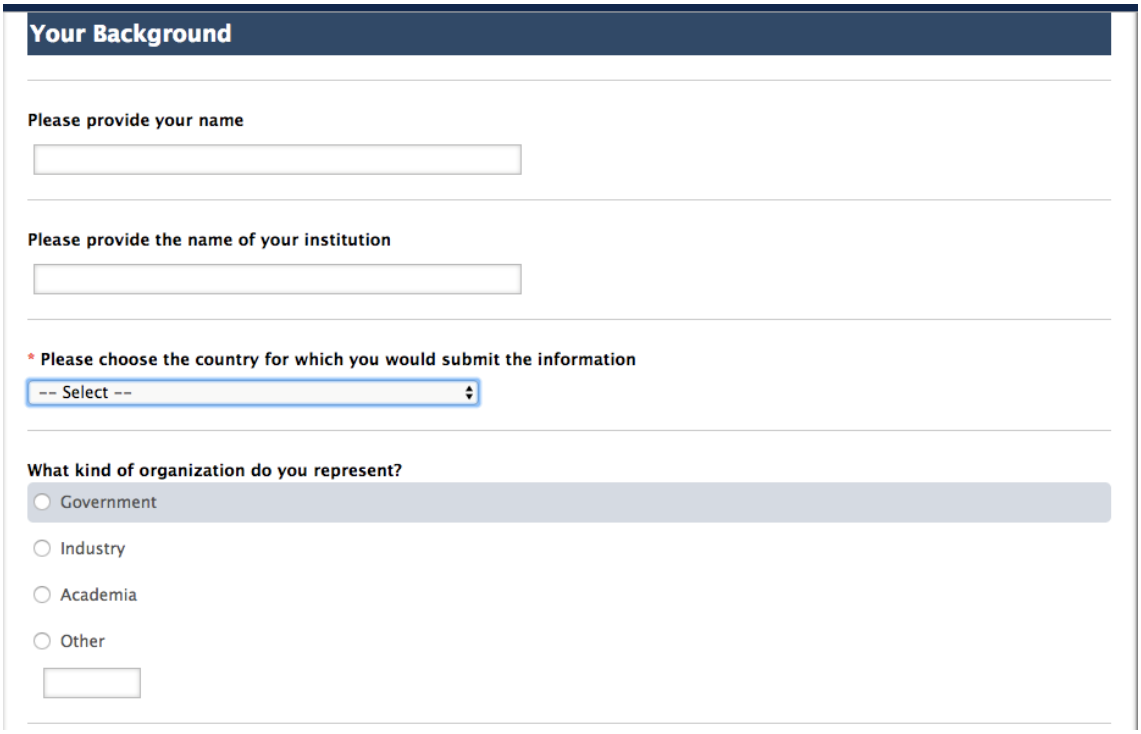
You are invited to participate in our questionnaire regarding the project "Transboundary flow of solid biomass waste in Europe". The project aims at identifying potential trans boundary flows of the solid biomass streams. The two streams identified for the project are:

CN 38251000 Municipal Waste : 'municipal waste' means waste of a kind collected from households, hotels, restaurants, hospitals, shops, offices, etc., road and pavement sweepings. Municipal waste generally contains a large variety of materials such as plastics, rubber, wood, paper, textiles, glass, metals, food materials, broken furniture and other damaged or discarded articles.

CN 44013980 Wood Waste and Scrap, not agglomerated (excl. sawdust)

The questionnaire is aimed at country based data collection beyond the known available sources like Eurostat in order to quantify the trans boundary flows of the solid biomass waste stream in Europe. The questionnaire will help in identifying major drivers responsible for the transboundary flow of the solid biomass waste streams in Europe and ultimately the effect of waste flow on the energy system of the countries majorly involved in the transboundary flow. The study is sponsored by IEA Bioenergy Task 40 (http://task40.ieabioenergy.com/) and is also a part of Mr. Pranav Dadhich's Master's Thesis. The information will be used in the final report that will be released by June 2017.

Your questionnaire responses will be strictly confidential and data from this research will be reported only in aggregrate. If you have questions at any time about the questionnaire or the procedures, you may contact Mr. Pranav Dadhich at pranav.dadhich@aalto.fi. This questionnaire will roughly take 15 minutes. The last date to submit the questionnaire is 7th April 2017. Thank you very much for your time and support. Please start with the questionnaire now by clicking on the Continue button below.



Your Background

Please provide your name

Please provide the name of your institution

* Please choose the country for which you would submit the information

-- Select --

What kind of organization do you represent?

Government

Industry

Academia

Other

Trans Boundary Flow Information

This section of the questionnaire aims at collecting country specific information on the trans boundary flow of solid biomass waste streams. You can submit relevant links to papers or organizations responsible wherever necessary.

*** Is there any national database/publications on trans boundary flow of waste in the national language or English?**

- ○ Yes
- ○ No
- ○ Don't Know

According to the response of this question, the further questionnaire will be set. Which field would you like to answer the questions about?

- ○ MSW
- ○ Wood Waste
- ○ Both of the above
- ○ General Expertise

Were there any changes in legislation regarding trans boundary flow of wood waste in the years 2010-2015 in your country?

- ○ Yes
- ○ No
- ○ Don't Know

Were there any subsidies/government benefits regarding wood waste related energy activities in your country in the years 2010-2015?

- ○ Yes
- ○ No
- ○ Maybe

Were there any recent developments in the technology sector of energy recovery from wood waste in your country in the years 2010-2015?

- ○ Yes
- ○ No
- ○ Don't Know

Was there any reform in waste management sector especially regarding wood waste in your country in the years 2010-2015 regarding wood waste?

- ○ Yes
- ○ No
- ○ Don't Know

What is the end use of wood waste?

- ○ Energy Recovery
- ○ Disposal
- ○ Recycling
- ○ Other

Drivers of transboundary flow of waste

According to you, which is the most important driver for the growing trans boundary flow of waste in Europe? You can choose more than one driver.

Please select the most important driver for trans boundary flow of waste in Europe:

	Wood Waste
Gate fees	☐
Disposal costs	☐
Legislations and Policies	☐
Capacity Factor	☐
Governmental Incentives	☐
Technology	☐

Apart from all the drivers listed above, what other drivers do you feel can be responsible for the trans boundary flow of wood waste in Europe?

Thank you for your feedback

Would you like to receive the result of this questionnaire?

- ○ Yes
- ○ No

Can you give contact details of any experts in the field of Trans Boundary flows of Wood Waste or MSW from your country?

- ○ Yes
- ○ No

Can we approach you by email for follow up questions?

- ○ Yes
- ○ No

ANNEX 2 ESTIMATED CONTRIBUTIONS OF WOOD WASTE TO NATIONAL BIOENERGY PRODUCTION

Disclaimer: In this annex, an attempt was made to quantify the share of traded wood waste to the bioenergy supply and overall energy supply in the Netherlands, Germany, Sweden and the UK between 2010-2014. However, two major disclaimers apply:

1) Lightly contaminated wood can also be recycled and used for e.g. panel boards. Form anecdotal, it is known that these shares can be significant, e.g. out of 70 ktons of exports form the Netherlands to Belgium,55 ktons were destined for recycling. In the graphs below, this was however assumed all to be for bioenergy. These numbers should thus be regarded as a theoretical upper boundary. The only country where this data was available, was Sweden, for which also data was available until 2016.
2) The graphs do not include the use of domestic wood waste, i.e. they only show the amount of bioenergy produced from imported feedstocks. Thus, the total amount of bioenergy produced from wood waste may again be higher.

In any case, the main message from these statistics is that while trade flows especially from the UK and to Germany can be in the order of several hundred kilotons, **the overall contribution of traded wood waste to national bioenergy production is very small to negligible in the countries investigated, typically between 1-3% of total bioenergy production**. This is also likely to remain this way, as it is not expected that wood waste volumes will suddenly strongly increase in coming years.

Netherlands

According to the IEA Energy Statistics, the Netherlands had a primary energy supply of 3.05 EJ in 2014 from every energy source. Out of the 3.05 EJ, bioenergy and waste supplied around 0.15 EJ, roughly around 5% of total primary energy supply. This gives an insight that the Netherlands is a country which has a prominent share of bioenergy in their energy system. The primary energy supply of only bioenergy is 81 PJ. The wood waste being used for the energy recovery purpose has a calorific value of 14 MJ/kg. The amount of wood waste imported in 2014 is 168 KT. The primary energy supplied from the imported wood waste is 2.35 PJ which is 2.9% of the bioenergy share.

Figure 27: Primary Energy Supply from imported wood waste and share in total bioenergy

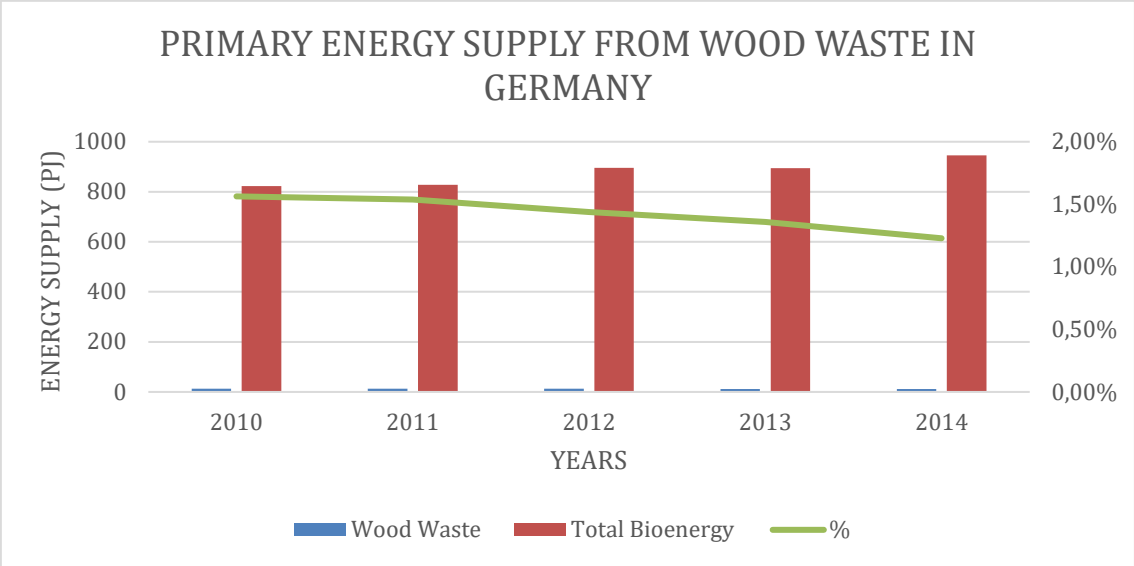
The end use of wood waste with EWC 191207 is energy recovery in the various energy industries setup on the basis of wood waste. The hazardous wood waste can end up in landfill after proper treatment, hence it is mainly exported to Germany where it is used for energy recovery purposes. The export to Belgium is majorly for its particle and chipboard industry.

Germany

According to the IEA Energy Statistics, Germany had a primary energy supply of 12 EJ in 2014 from every energy source. Out of the 12 EJ, bioenergy and waste supplied 1.22 EJ, which is roughly around 10% of total primary energy supply. Due to the renewable energy, friendly legislation such as the renewable energy sources act reflects in the 10% share of biomass in Germany's primary energy supply. The primary energy supply of only bioenergy is 945 PJ. The wood waste being used for the energy recovery purpose has a calorific value of 14 MJ/kg. The amount of wood waste imported in 2014 is 829 KT. The primary energy supplied from the imported wood waste is 11.61 PJ which is 1.23% of the bioenergy share.

The end use in Germany is majorly energy recovery both for hazardous as well as non-hazardous wood waste. As mentioned earlier, Germany has 700 bioenergy CHP-plants based on solid biofuels and requires a constant feedstock for energy production.

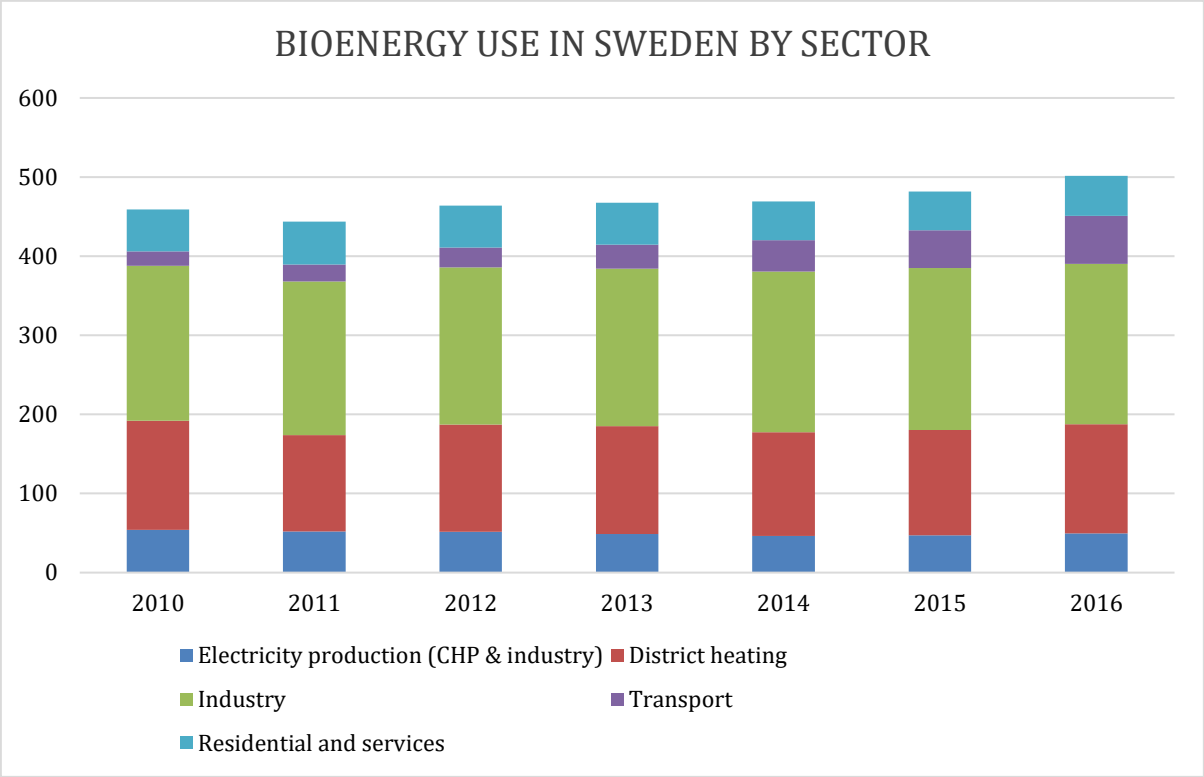
Figure 28: Primary energy supply from wood waste and share in total bioenergy



Sweden

Sweden had a total primary energy supply of 2.1 EJ in 2014. Out of the 2.1 EJ, bioenergy and waste supplied 0.48 EJ, which is roughly 22.85% of total primary energy supply. Bioenergy use in Sweden is dominated by two sectors: a) the forest industry which uses large volumes of internal by-products and residues primarily for process heat) and b) the district heating sector (including combined heat and power). These two sectors together use roughly 80% of all bioenergy in Sweden, split fairly evenly among the two. Firewood etc. for residential heating makes up about 10% and the transport sector (biobased diesel fuels, bioethanol and biomethane) made up about 4% in 2010. This latter share has however grown substantially as Swedish transport biofuel consumption tripled 2010-2016.

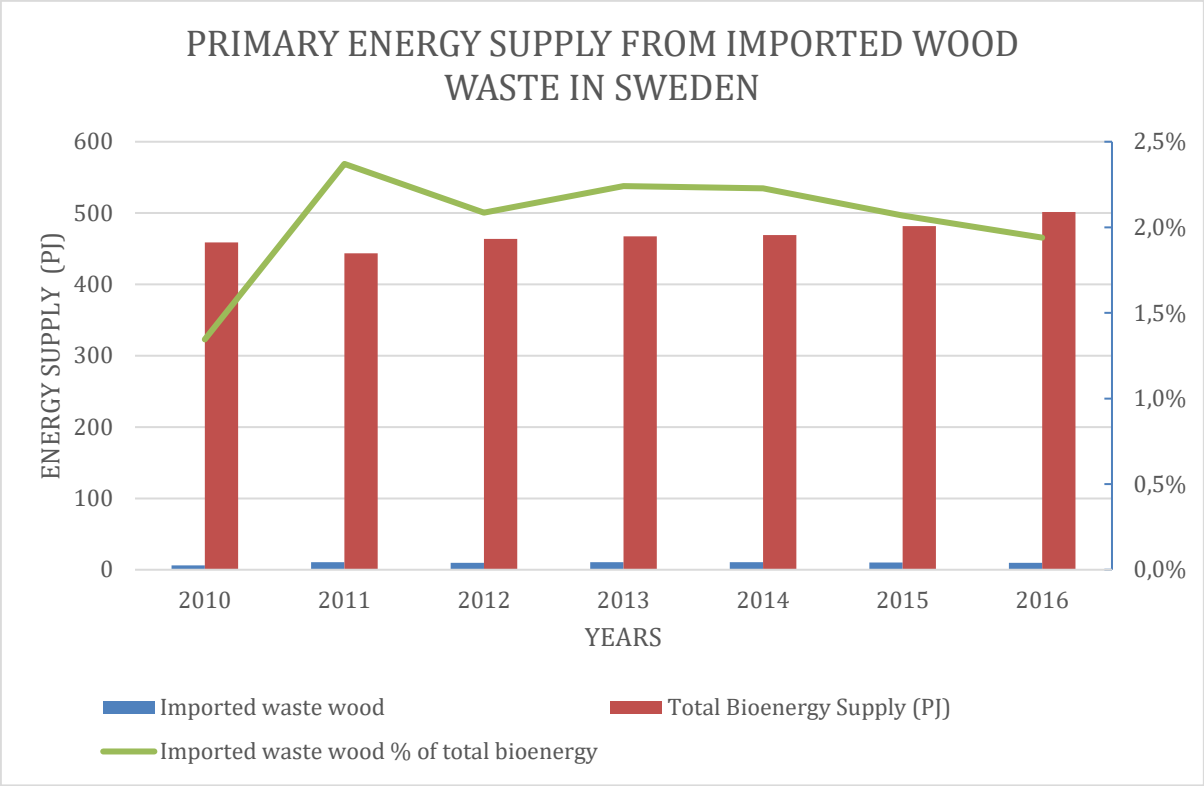
Figure 29:Bioenergy use in PJ by sector in Sweden 2010-2016 (Data source: Swedish Energy Agency)



Although some (post-consumer) wood waste volumes are used by the forest industry for process heat, its use in Sweden is primarily in the district heating (DH) sector for production of district heat, electricity and district cooling. DH networks are found in almost every Swedish settlement with population above 3000 and there are several hundred DH generation plants that use a wide variety of fuels. Most commonly, different forms of by-products and residues from the forest sector are used as fuel, but the share of wood waste and municipal solid waste in the fuel mix has increased significantly in the 2000s. Wood waste made up about 7% of the fuel mix in the Swedish DH sector (including CHP) in 2014.

The amount of wood waste imported to Sweden in 2014 was 747 KT or approximately 10.5 PJ (using a conversion factor of 14 GJ/ton), which would amount to slightly more than 2% of total bioenergy use in Sweden over the time period 2010-2016.

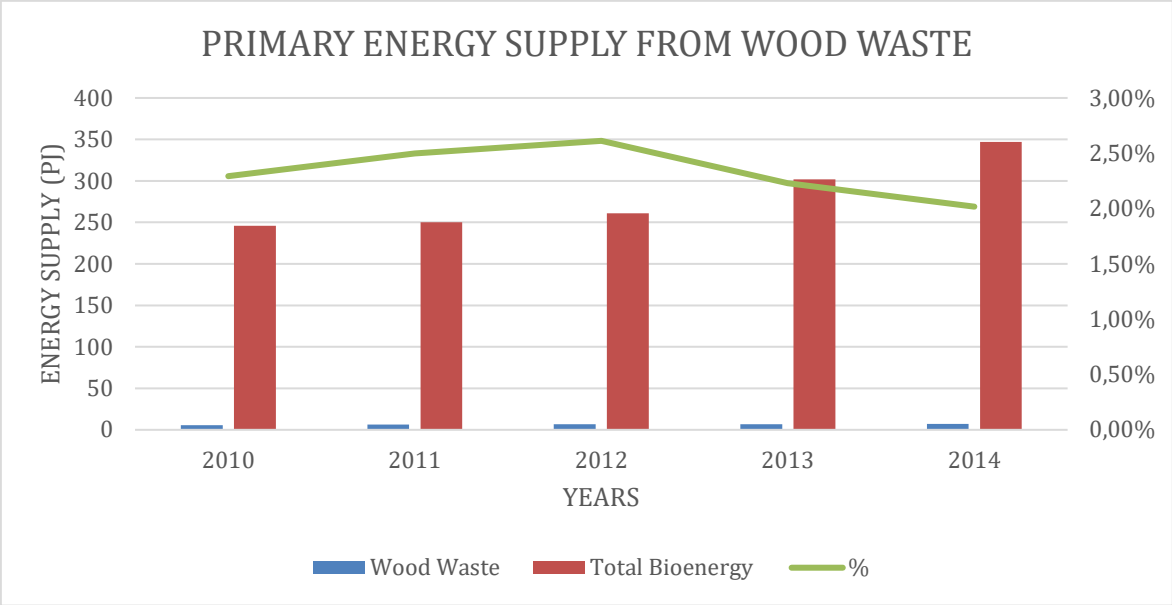
Figure 30: Imported wood wood wasteand total bioenergy use in Sweden in PJ 2010-2016.



UNITED KINGDOM

According to the IEA Energy Statistics, United Kingdom had a primary energy supply of 7.5 EJ in 2014 from every energy source. Out of the 7.5 EJ, bioenergy and waste supplied 0.38 EJ, which is roughly around 5.1% of total primary energy supply. The primary energy supply of only bioenergy is 347 PJ. The wood waste being used for the energy recovery purpose has a calorific value of 14 MJ/kg. Since, the wood waste is being primarily being exported from the United Kingdom, the graph showcases the amount of primary energy it could have supplied to the country's energy share. The amount of wood waste exported in 2014 is 500 KT. The primary energy that could have been supplied from the exported wood waste is 7 PJ which is 2.02% of the bioenergy share.

Figure 31: Primary Energy Supply from wood waste and share in total bioenergy



The end use of wood waste in UK is divided into a lot of sectors. Majority of the wood waste ends up in landfills as well as the panel board industry. Other recycling sectors include animal bedding and mulches. The remaining wood waste goes to wood waste to energy industries. (Anthesis, 2017)

ANNEX 3 OVERVIEW OF RELEVANT NATIONAL LEGISLATIONS

THE NETHERLANDS

The Netherlands has been actively involved in waste management planning. It came up with a National Waste Management Plan (NWMP) for 2009 – 2021 which provides a great deal of insight on different types of wastes, their definitions, the import and export laws and the end use of the waste. The NWMP has individual chapters for different kinds of waste with Section 36 for wood. Section 36 discusses wood waste in detail. The wood waste is divided in three types (Rijkswaterstaat Environment, 2009):

- A – type wood waste: Clean wood waste with no paint or hazardous substance.
- B – type wood waste: Wood waste with some paint or glue which can be easily cleaned.
- C – type wood waste: Wood waste with hazardous substance impregnated or treated for extending the lifetime of the product.

The NWMP also suggests the end use of each type of wood waste. For A and B type, the wood waste should be recovered, either material recycling or energy recovery, and is not allowed to be landfilled. For C – wood, there are two options: if it is heavily contaminated (e.g. with arsenic or chrome), landfilling is still allowed; otherwise, it needs to be combusted, as recycling is typically not possible.

Shipments of treated wood waste to the Netherlands are prohibited under national self-sufficiency, if it is purposed for disposal in landfills. The shipments of treated wood are only allowed if there is permission to incinerate according to Dutch minimum standards. (Rijkswaterstaat Environment, 2009) It strictly follows the EU Waste Framework Directives and regulations. The major issue is to identify whether the product is waste or not, and it is determined by the province or the municipality, case by case. In either case, whether the product is waste or not, the energy plants must have appropriate license to utilize it for energy recovery (NL Agency, NL Energy and Climate Change, 2013).

GERMANY

European Laws

Germany, being a member state of the EU follows all the directives and regulations. The basis of its waste policies is the waste framework directive (2008/98/EC).

German Federal Law

Germany launched its first nationwide waste disposal act, the Abfallbeseitigungsgesetz (AbfG) in 1972. (Bundesgesetzblatt, 1972) Since the implementation, a number of other policies have also been introduced to protect mankind and the environment when producing and managing waste. The latest waste disposal law is called the Circular Economy Act (Kreislaufwirtschaftsgesetz - KrWG) which takes its roots from the previous circular economy and waste act (KrW-/AbfG) from 1994. The aim of this act is to promote circular economy in Germany and conserve the natural resources. It came into force on 1st June 2012. The Circular Economy Act (KrWG) is intended to strengthen resource, climate and environmental protection. Moreover, in 2002, a dedicated wood waste ordinance (Ordinance on requirements for the recovery and disposal of wood waste –AltholzV) was

passed. It became effective on 1st of March 2003 and governs in practice how wood waste has to be treated.

The most important laws and ordinances which helped the cause of recovered wood in Germany are: The Circular Economy Act (KrWG), the ordinance on incineration plants (BImschV), the ordinance on the management of wood waste (AltholzV), the act on granting priority to renewable energy sources (StromEinspG/EEG), and the ordinance on the list of waste (AVV).

German Ordinance on Incineration Plants

The German ordinance on incineration plants majorly focuses on the emission limits of the pollutants from the incineration plants. It was first proposed on 23rd November 1990. It was amended again on 14th August 2003, because Germany had to align its national laws to the European directive of waste incineration plants, 2000/76/EC released on 4th December 2000. It lists different solid and liquid fuels used in incineration plants apart from regular fuels and also places stringent rules and regulations, in case the fuel is hazardous in nature. In case of co–incineration plants using wood waste, rules and regulations applied are based on the fraction of wood waste being used and the emission limits changes accordingly. (BMUB, 1990)

Ordinance on the Management of Wood waste - (Altholzverordnung - AltholzV)

The circular economy and waste act (KrW-/AbfG) from 1994 was an important step ahead in particular promoting a more environmentally friendly waste recovery in Germany, but the scope was vast at the same time and the disposal methods were not consistent at federal state level. By then the disposal took place either via waste incineration plants or in a landfill. A separate ordinance regarding management of waste and recovered wood would guarantee a better standard for wood waste throughout the country. This would then lead to better material and energy recovery. The ordinance came into full force from 1st March 2003. This ordinance was a trial ordinance for different material specific ordinances in Germany. The reasons to choose wood waste are (BMUB, 2003):

- It is a significant volume flow for energy and material recovery.
- The recovery options of wood waste in Germany were of questionable standards.
- There was a need of a common nationwide rule regarding wood waste in Germany.

The ordinance includes all the authorized methods to be applied for wood waste management. There are only two recovery paths identified in the ordinance: energy recovery or recycling. Landfilling of wood waste is no longer permitted. In order to take out hazardous substances from the cycle, wood waste categories have been defined and corresponding treatment methods assigned.

Wood waste Categories

For determining the type of treatment wood waste categories have been defined. Wood waste (except for wood waste with PCB) is assigned to one of four of the following wood waste categories depending on the level of contamination.

- Wood waste category A I: Wood waste in its natural state with no contamination.
- Wood waste category A II: Painted, lacquered or otherwise treated without any halogenated organic chemicals and no wood preservatives.
- Wood waste category A III: Wood waste with halogenated chemicals but no preservatives.
- Wood waste category A IV: Wood waste impregnated with wood preservatives.

Different ways exist in which the wood can be recycled. The different recycling methods of the wood waste are discussed in the table below with the following aspects that must be considered (AltholzV), annex I):

Table 4: Recovery Methods of Wood waste Categories (Source: (Peek, 2004))

Recovery Method	Permissible wood waste categories				Special Requirements
	A I	A II	A III	A IV	
Processing of wood waste to wood chips for secondary timber products	Yes	Yes	Yes*	-	The processing of A III is only permissible if the wood has gone through pre-treatment process and wood varnish and coatings have been removed.
Production of synthetic gas for chemical use	Yes	Yes	Yes	Yes	Recycling is only permitted in installations that have proper licensing.
Manufacturing of active carbon / industrial charcoal	Yes	Yes	Yes	Yes	Recycling is only permitted in installations that have proper licensing.

For energy recovery purposes, priority is given to those type of wood wastes which cannot be recycled to produce derived secondary timber products. Generally, wood waste with preservatives or treatment are used for energy recovery. The energy recovery for hazardous wood waste is highly regulated.

The A I wood waste can be processed in furnaces with thermal capacity of <50 kW. Furnaces with a thermal capacity ≥ 1 MW which can control the emissions of harmful substances in the wood processing industry can use group A II. Group A III-IV can only be used in larger installations. (compare Table 4) The requirements are covered via the fourth and seventeenth ordinance of federal emission control act (4.BImSchV, 17.BImSchV).

Table 5: Use of wood waste in furnaces by plant size in Germany (Source: Institute for Energy and Environment 2007)

wood Waste category	Plant size (thermal capacity)			
	< 50 kW	<1 MW	< 50 MW	≥ 50 MW
A I	permitted	permitted	permitted	permitted
A II	not permitted	permitted in the wood processing industry	permitted	permitted
A III	not permitted	not permitted	permitted	permitted
A IV	not permitted	not permitted	permitted	permitted

Other regulations

Apart from the KrWG, there are various regulations in Germany, such as the Abfallverzeichnis-Verordnung (AVV) which is responsible for classification of waste into hazardous and non-hazardous waste. It aims at monitoring the type of waste that is present in Germany.

German Act of Granting Priority to Renewable Energy Sources

The act was a successor to the Electricity Feed-in Act (StrEG, 1991). The act was a decisive breakthrough in providing support to sustainable energy systems in Germany. The Renewable Energy Sources Act (Erneuerbare-EnergienGesetz; EEG, 2000) regulates the prioritization of grid supplied electricity from renewable sources. It specifies mechanisms for implementing the option of granting priority to renewable power generation envisaged in the EU Directive on the internal market in electricity. Energy producers benefit from the compensation for supplying the grid with electricity from renewable sources. (Erneuerbare-EnergienGesetz;EEG, 2000)

The act guaranteed compensatory payment down to the last kWh making a secure environment for investing in renewable energy. The section 5 of the act from 2000 includes the compensation provided for the electricity produced from biomass. According to the act, it states the following compensation:

1. At least 10.23 cent per kilowatt-hour in the case of installations with an installed electrical capacity of up to 500 kilowatts.
2. At least 9.21 cent per kilowatt-hour in the case of installations with an installed electrical capacity of up to 5 megawatts.
3. At least 8.70 cent per kilowatt-hour in the case of installations with an installed effective electrical capacity of over 5 megawatts.

The level of compensation has been regularly revised since then (2004, 2009, 2012, 2014) With the amendment in 2004, the compensation payment has been significantly reduced to 3.9 Eurocent per kilowatt-hour for new installations using wood waste and being commissioned after 30.6.2006. (Erneuerbare Energien Gesetz, EEG, 2004) As a result there has not been a significant number of new wood waste plants installed in Germany since mid of 2006 (DBFZ, 2015). Since 2012, new wood waste installations are not eligible for a compensation payment anymore (Erneuerbare Energien Gesetz, EEG, 2012; BiomasseV 2012).

SWEDEN

European Laws

Sweden is also a member state of the EU. Therefore, it must follow all the directives and regulations already discussed in the Waste Framework Directive.

The Environmental Code of Sweden

The purpose of the Environmental Code is to promote sustainable development which will ensure a healthy and sound environment for present and future generations. To achieve this, the code is to be applied so that (Ministry of Environment, Sweden, 1999):

- Human health and the environment are protected against damage and detriment, whether caused by pollutants or other impacts

- Valuable natural and cultural environments are protected and preserved
- Biodiversity is preserved
- The use of land, water and the physical environment in general is such as to secure long-term good management in ecological, social, cultural and economic terms
- Re-use and recycling, as well as other management of materials, raw materials and energy are encouraged so that natural cycles are established and maintained.

Waste ordinance

The waste ordinance was released on 1st January 2002. Two major ordinances, Waste collection and disposal (1998:902) and Hazardous Waste Ordinance (1996:971) were merged to form the Waste Ordinance. This was designed to simplify the waste laws and legislation in Sweden and to implement the EU Waste List. The permit procedures for hazardous waste were simplified in this ordinance and double permits were removed because the ordinances were merged into one.

Ordinance on Landfilling of Waste

Since 2002, it has been prohibited by the Ordinance on Landfilling of Waste to dispose of unsorted combustible waste at a landfill site. In 2005, the ban was extended to cover all organic waste with certain exceptions. Sweden also introduced a landfill tax to further prohibit the disposal of waste in landfills. (SEPA, 2004)

UNITED KINGDOM

European Laws

The United Kingdom is a member state of the EU. Therefore, it must follow all the directives and regulations already discussed in the Waste Framework Directive.

National Laws, Policies and Legislations:

The legislations and policies regarding waste differs a lot in the UK than the rest of the Europe. Wood waste has different definitions and hence the policies applied also vary according to the definitions. The wood waste is divided into 4 grades as follows:

Table 6: Grades of Wood Waste in the United Kingdom (Source: (WRAP, 2011))

GRADE	SOURCE OF RAW MATERIAL	CONSTITUENTS
Grade A – Clean Recycled Wood Waste	Distribution, Packaging, Retail, Secondary Manufacturing	Solid softwood and hardwood. Packaging waste, scrap pallets, packing cases, and cable drums. Process off-cuts from manufacture of untreated products.
Grade B – Industrial Feedstock	Grade A but with construction and demolition waste	Contains approximately 60% of Grade A waste with wood waste from construction and demolition sector.
Grade C – Fuel Grade	Grade A and B with Municipal and Civic waste	All of the above plus fencing products, flat pack furniture made from board products and DIY materials High content of panel products such as chipboard, MDF, plywood, OSB and fiberboard.
Grade D – Hazardous Waste	All of the above plus the fencing, track work and transmission poles.	Fencing Transmission Poles Railway sleepers Cooling towers

Landfilling Bans

In 2011, the review of waste policy in England announced the Government's intention to consult on the ban on landfilling of wood waste in 2012. The board invited suggestions from academicians and experts from all over the country and it received 37 written suggestions. It decided on the basis of all the suggestion to not go forward with the ban on landfilling of wood waste, which has affected the wood waste market in the UK.

The landfilling tax was seen as a key driver to divert the wood waste from landfilling to proper recycling and recovery. There were many benefits of the landfilling bans such as improved recycling infrastructure, innovation in the wood waste recovery sector, better producer responsibility and moving wood waste up in the waste hierarchy. But the restriction was denied based on the reasons below (Department for Environment, Food And Rural Affairs, 2013):

- Lack of collecting and sorting infrastructure.
- Proper identification of wood waste treatments and its effect on the end markets.
- Enforcement of the legal restriction on a nationwide level.
- Lack of storage capacity and segregation space.
- Sudden increase in the costs.

Export and Import of Wood Waste

The trans boundary shipment of wood waste in the United Kingdom is based on the EU Waste Shipment Regulations (1013/2006). Under this regulation, the waste can be shipped under three categories:

- Green List: The waste that has the minimum effect on the environment fall under this list. These are mostly recyclable waste and can be transported without any prior permissions.
- Recovery: The waste that can be recovered has to be notified to the proper authorities prior to the shipment.
- Disposal: The export for disposal of waste is not permitted in the UK but only under extreme circumstances.

Wood waste does not fall under the ambit of green list waste and hence it can only be exported if it can be recovered. The wood waste requires minimal environmental permits by the environmental agency, since the wood wood wasteis regarded as 'low waste risk' activity. (Tolvik Consulting, 2011)

Further Information

IEA Bioenergy Website
www.ieabioenergy.com

Contact us:
www.ieabioenergy.com/contact-us/