GREENHOUSE GAS ASSESSMENT OF NOKIAN TYRES

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ABSTRACT

Tampereen ammattikorkeakoulu
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Greenhouse Gas Assessment of Nokian Tyres

Bachelor's thesis 60 pages, appendices 11 pages
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This thesis was done for Nokian Tyres Plc in order to define the greenhouse gas emissions of Nokia factory. The study was carried out as a greenhouse gas assessment with “cradle-to-gate” framing by following PAS 2050 guidelines. The work included data collection and emission calculations. In addition to the assessment, the thesis work included creating a tool that could be used for calculating emission on a yearly level. The calculator was done by using Microsoft Excel -software.

In 2011, the total greenhouse gas emissions of Nokia factory were 3 582 kilograms of carbon dioxide equivalents per tonne of tyres produced. 81% of the emissions were formed by raw material acquisition, 18% by production process at the factory, from which purchased energy composes 17%, and less than one per cent by offices and work trips. Since most of the emissions are caused by raw material acquisition and are therefore difficult to control, the focus should be put on developing the procedure into more energy efficient.

The results of the study cannot be directly compared to other assessments without familiarising oneself with the used methods. The reliability of the comparison is dependent on the chosen standard because there are differences in the defining methods between standards. Some problems were also encountered when determining the emission factors and therefore their accuracy should be taken with reserve. The background data about raw materials is not published in the thesis. Also the calculator and its calculation sheets for partial processes will remain confidential. Thus, appendices 2-5 are not published.

Key words: greenhouse gas assessment, greenhouse gas, CO_2e, PAS 2050

TIIVISTELMÄ

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Degree Programme in Environmental Engineering

MARKKANEN, NOORA
Selvitys Nokian Renkaiden kasvihuonekaasujen päästöistä

Opinnäytetyö 60 sivua, joista liitteitä 11 sivua
Helmikuu 2013

Tämä opinnäytetyö on tehty Nokian Renkaat Oyj:n toimeksiannosta Nokian tehtaan kasvihuonekaasupäästöjen määrittämiseksi. Tutkimus on tehty noudattaen PAS 2050 ohjeistusta, jonka perusteella kasvihuonekaasupäästöselvitys on rajattu koskemaan ”kehdosta portille” -rajaukseen kuuluvia prosesseja. Työ piti sisällään tiedon keräämistä sekä hiilidioksidilaskelmien tekoa. Kasvihuonekaasupäästöselvityksen lisäksi tavoitteena oli luoda laskuri, jolla kasvihuonekaasupäästöt voitaisiin laskea vuosittain. Päästölaskuri tehtiin Microsoft Excel -ohjelmaa käyttäen.

Vuonna 2011 Nokian tehtaan kasvihuonekaasupäästöt olivat yhteensä 3 582 kilogrammaa hiilidioksidiekvivalenttia yhtä tuotettua rengastonnia kohden. Kokonaispäästöistä 81 % koostui raaka-aineiden hankinnasta, 18 % tehtaan tuotantoprosesseista, joista jopa 17 % oli ostetun energian aiheuttamia, ja alle yksi prosentti oli toimistoista ja työmatkoista aiheutuneita päästöjä. Raaka-aineiden hankinnasta aiheutuneiden kasvihuonekaasupäästöjen pienentäminen on vaikeaa, koska valtaosa päästöistä on raaka-ainetuottajien omista prosesseista johtuvia. Näin ollen huomio tulisikin keskittää ostetun energian päästöihin energiatehokkuutta parantamalla.

Kasvihuonekaasupäästöselvityksen tuloksia ei tulisi suoraan verrata muihin selvityksiin tutustumatta niiden käyttämiin ohjeistuksiin. Koska ohjeistukset eroavat toisistaan joissakin yksityiskohdissa, eri perustein lasketut kasvihuonekaasupäästöt eivät ole luotettavasti verrattavissa keskenään. Päästökertoimia on jouduttu määrittämään eri lähteitä käyttäen ja näin ollen myös niiden verrattavuuteen tulisi suhtautua varauksella. Opinnäytetyössä käytetty tausta-aineisto sekä muodostettu laskuri jäävät luottamukselliseksi. Täten liitteitä 2-5 ei ole julkaistu opinnäytetyössä.

Asiasanat: kasvihuonekaasupäästöselvitys, kasvihuonekaasu, CO_2e, PAS 2050

CONTENTS

ABBREVIATIONS AND TERMS

CO_2e	carbon dioxide equivalent
ETRMA	European Tyre & Rubber Manufacturers’ Association
EU	the European Union
GHG	greenhouse gas, a gas that absorbs and emits infrared radiation in the atmosphere
GRG	general rubber goods
GWh	gigawatt hour
IPCC	International Panel on Climate Change
ISO	International Organization for Standardization
ISO 14 040	standard for life cycle assessment; Principles and Framework
ISO 14 044	standard for life cycle assessment; Requirements and Guidelines
ISO 14 067	standard for carbon footprint of products; Requirements and Guidelines for Quantification and Communication
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LIPASTO	a calculation system covering emissions and energy consumption of all traffic modes in Finland
PAS 2050	greenhouse gas assessment method
pkm	passenger kilometre
TEU	twenty-foot equivalent unit, a ship size definer
VOC	volatile organic compound
VTT	Technical Research Centre of Finland

1 INTRODUCTION

Nokian Tyres Plc (later Nokian Tyres) is a Finnish tyre manufacturer operating mostly in Europe, Russia and North America. As sustainability and environmental friendliness are important parts of research and development section, Nokian Tyres wanted to carry out a greenhouse gas assessment in order to determine its own greenhouse gas (GHG) emissions. The aim of this thesis is to carry out a study where the greenhouse gas emissions of Nokian Tyres plant in Nokia are assessed and calculated. Even though, Nokian Tyres has two factories, one at Nokia and the other one at Russia, Vsevolozhsk, this greenhouse gas assessment is done for Nokia plant.

The assessment is done by following the instructions given by PAS 2050 Standard, which is a method for assessing the life cycle greenhouse gas emissions of goods and services (British Standards Institution 2011, 1). The system boundary is set to be “cradle-to-gate”, which means that assessment includes emissions that are emitted before leaving the company property. Thus, raw material production and transportation, procedure at Nokia, purchased energy and work transportation are included into assessment. Greenhouse gas assessment should not be regarded as total “cradle-to-grave assessment” because it does not include retail, usage or neither final disposal. However, in this case “cradle-to-gate” is more appropriate in order to define the GHG emissions of Nokian Tyres factory itself.

Another part of the work process consists of creating a tool for calculating GHG emissions on a yearly level. The calculator is created by using Microsoft Excel software. In the future, emissions can be calculated by entering production data of a certain year into the calculator.

2 NOKIAN TYRES

2.1 Company Basics

Nokian Tyres was founded in 1988 and went public in 1995. However, Nokian Tyres has its history in Suomen Gummitehdas Oy that was founded already in 1898. Nokian Tyres manufactures passenger car tyres and heavy tyres that are used in trucks and harbour, forest and mine vehicles. Besides tyre production, Nokian Tyres manufactures also truck tyre treads that enable reuse of tyres. (Nokian Tyres 2011a.)

As mentioned earlier, Nokian Tyres has two factories that are at Nokia, Finland and Vsevolozhsk, Russia. Some of the products (approximately 5%) are however made in other contract factories that meet the quality requirements of Nokian Tyres. The company has sales offices in Sweden, Norway, Germany, Switzerland, Russia, Ukraine, Kazakhstan, Czech Republic, the United States and Belarus. In other countries, the sales are taken care of by importers. Tyre chain Vianor is a member of Nokian Tyres group and operates as a wholesaler and a retailer in the core market of Nokian Tyres. (Nokian Tyres 2011a.)

According to Nokian Tyres Annual Report, (Will to win 2011) in year 2011, the net sales were 1 456,8 million Euros and average number of personnel was 3 866. Annual production capacity was approximately five million passenger car tyres and 15 thousand tonnes of heavy tyres at Nokia factory whereas at Vsevolozhsk, there were 11 million passenger car tyres produced. As much as 80% of passenger car tyre net sales are formed by winter tyre sales. Winter tyres, most precisely Nokian Hakkapeliitta, are the key products of Nokian Tyres. For example, in the autumn 2012, Nokian Hakkapeliitta was chosen to be the winner in winter tyre tests of several car magazines, such as Finnish Tuulilasi (13/2012), Swedish Vi Bilägare (14/2012) and Norwegian Motor (7/2012). In order to ensure the high quality of tyres, Nokian Tyres puts effort on research and development. As an example, Nokian Tyres has a test centre in Ivalo, Lapland, where tyres can be tested in extreme winter conditions.

2.2 Part of Rubber Industry

Tyre production is only a part of rubber industry. According to Kumiteollisuus Oy (Kumiteollisuus Oy, 2013), rubber products are divided into three categories in Finland: tyres, technical rubber products and rubber boots. However, ETRMA (European Tyre & Rubber Manufacturers' Association) classifies rubber industry into two sections that are tyres and general rubber goods (GRG) (ETRMA, 2011a).

General rubber goods consist of many different rubber applications. However, as much as 65% of GRG is covered by automotive area. The automotive products are different parts and components, such as window seals and fan belts. The rest of GRG consists of pharmaceutical and mining products that are for example medical probes and mining components. (ETRMA, 2011a.)

Tyre production has many operators but the biggest tyre companies are Bridgestone, Continental, Goodyear, Michelin and Pirelli. Even though Nokian Tyres is well-known in Finland, it is a minor manufacturer in global markets. Nokian Tyres is a member of Kumiteollisuus Oy, which is a coalition of rubber manufacturers in Finland. Moreover, Nokian Tyres is a member of ETRMA, which represents the rubber industry of the European Union (EU) district in Brussels and controls international and EU level projects. (Kumiteollisuus Oy, 2013; ETRMA, 2011a.)

2.3 Certificates of Nokian Tyres

Nokian Tyres has several certificates that are supposed to guarantee the high level of performance. Environmental certificate ISO 14 001 and quality certificate ISO 9 001 are given to both factories and also to the Swedish sales company Nokian Däck. Furthermore, Nokia plant has also EMAS (the Eco-Management and Audit Scheme) regulation, which consists of environmental report and environmental management system that is in accordance with ISO 14 001 standard. Through EMAS regulation, Nokian Tyres is obligated to report about its actions. (Responsible Development 2010, 14.)

2.4 Environmental Communications of Nokian Tyres

Environmental communications is essential for showing your products or functions to be environmentally friendly. It is almost impossible to see environmental actions straight from the product. Therefore, also Nokian Tyres is paying attention to environmental communications, which is supposed to inform about all environmental issues and also about environmental risks and responsibilities.

According to Kärkkäinen (2006, 23), environmental communications of companies and organisations can be divided into five sections, which are environmental reporting, environmental communication, environmental information, environmental marketing and investor information (Lovio 2004). The environmental reporting of Nokian Tyres consists of environmental reports, society responsibility reports and special processes, such as greenhouse gas assessments. Nokian Tyres has published many environmental reports during past years – wider EMAS (The Eco-Management and Audit Scheme) reports every three years and smaller EMAS reports in all other years (Nokian Tyres, 2011b).

Environmental communication includes presenting environmental issues in company's internal and external magazines without forgetting the participation in public discussions (Kärkkäinen 2006, 23, according to Lovio 2004, 351). Nokian Tyres has an internal communication tools, such as internal magazine and info-TV, in Nokia factory. Nokian Tyres is also taking part of public conversation via its decisions on using non-hazardous substances. In fact, Nokian Tyres is the first tyre manufacturer that discontinued using high-aromatic oils in rubber compounds in 2005. By that decision, Nokian Tyres put pressure on other tyre producers in Europe, which lead into prohibition of importing and selling high-aromatic tyres inside the European Union in 2010. (Will to Win 2011.)

Nokian Tyres advertises its products as green (figure 1) and emphasises product development as a key for more environmentally friendly tyres (Nokian Tyres 2011c). For example, via product development Nokian Tyres has invented new techniques for producing more silent tyres, which again decreases environmental noise.

FIGURE 1. Birch leaf symbol of Nokian Tyres (Nokian Tyres 2011c)

Final part of environmental information is investor information that is aimed at investors. It is essential to provide comprehensive and systematic information for investors in order to secure confidence towards company's actions (Kärkkäinen 2006, 35, according to Kurki 1999, 171). Furthermore, environmental information might function as a positive impulse in investors' actions.

3 GREENHOUSE GAS ASSESSMENT

3.1 Greenhouse Gases

Greenhouse gases (GHGs) are gaseous constituents in the atmosphere that are released either by natural or anthropogenic sources. Greenhouse gases emit and absorb radiation at specific wavelengths within the thermal infrared range. This property causes the greenhouse effect, which means that the temperature is rising on the surface level because of radiation.

According to IPCC, there are 63 greenhouse gases determined (Forster et al. 2007, 211), which are also presented in appendix 1. The most common ones are carbon dioxide, nitrous oxide, methane, perfluorocarbons, hydrofluorocarbons and sulphur hexafluoride. Water vapour and ozone are not included in the GHG list of IPCC, because they are indirect pollutants. Moreover, water vapour is mostly not human-made gas and therefore categorised differently. (Forster et al. 2007, 152.)

Due to the impact that greenhouse gases have on the climate, several actions have been made in order to decrease the amount of released GHGs. In 1992, United Nations (UN) signed an international treaty, the United Nations Framework Convention on Climate Change, in order to settle the greenhouse gases on the level, which is not hazardous on the environment. In 1997, the treaty was expanded with Kyoto Protocol, which is legally binding the parties to reduce their emissions. Kyoto Protocol for example defines discharge limits that cannot be exceeded for the countries. (Kokko 2012, 12.)

3.2 Meaning of GHG Assessment

Greenhouse gas assessment is a method for assessing the greenhouse gas emissions of a product or service. GHG assessment includes only greenhouse gases, not any other air pollutants. GHG assessment is a part of life cycle assessment (LCA), which takes into account all environmental effects within a life cycle. GHG assessment is done by using some of the work phases of LCA, such as life cycle inventory (LCI), which is the data collection phase and life cycle impact assessment (LCIA), which means calculating emissions in order to determine environmental impacts. (Kokko 2012, 16-19.)

Greenhouse gas emissions can also be referred to carbon footprint. The meaning of GHG assessment is to find out the hotspots of the process in order to develop them into a more efficient direction. At the same time, processes have to be monitored, which helps common reporting and measuring progress and capacity in the long run. (Kokko 2012, 11.)

GHG emissions have a meaning for external relations, as well. While people's interest and awareness towards environmental issues has risen, the amount of emissions is more often a reason behind a decision. Policymakers are often validating their decisions based on environmental friendliness. Therefore, low-emission products get a competitive advantage. The same happens with consumers – greener products are preferred when choosing from two equal items. Thus, representing GHG emissions of a product gives an opportunity to influence the purchasing behaviour of people. (Kokko 2012, 11.)

Emission accounting is still quite new branch of science and therefore there are some problems involved. Assessments are incomparable and reporting is inadequate. There are several guidelines and standards that are used for making GHG assessments. Thus, results may not be comparable between two assessments if they are done by using different guidelines. For example, determining system boundary differently will result in incomparable results. However, development has been made for harmonising instructions by creating international standards for LCA, such as ISO 14 040, ISO 14 044, PAS 2050 and GHG Protocol. In addition to these standards, ISO 14 067 for carbon footprint accounting is under development. (Kokko 2012, 11-12.)

3.3 Different Standards

As mentioned earlier, there are different standards used in the field of environmental assessments. Many of the standards are applicable for several fields and therefore they give non-specific instructions, which leads into incomparable results. However, some of the standards utilise Product Category Rules (PGRs), which help to take account all relevant matters. On the other hand, the usage of PGRs is questionable because the rules are created by different countries and by different methods. Due to the high number of standards, this report is representing the four standards mentioned earlier. (Kokko 2012, 22.)

3.3.1 ISO Standards

ISO (International Organization for Standardization) published the very first standards for LCA in 1997, which were ISO 14 040 and ISO 14 044. Both standards have been updated later. ISO 14 040 represents the principles and framework of life cycle analysis whereas ISO 14 044 determines the requirements and guidelines. (Kokko 2012, 22-23.)

The standard for making a carbon footprint of products (ISO 14 067) is under development. According to ISO, the purpose of ISO 14 067 is to “provide requirements for the quantification and communication of greenhouse gases (GHGs) associated with products” (ISO, 2009). The first part of standard quantifies the carbon footprint, whereas the second part is used for guiding the communication. ISO 14 067 will take account land-use changes and usage of renewable energy as PAS 2050 does already. (ISO 2009; Kokko 2012, 23.)

3.3.2 PAS 2050

PAS 2050 was introduced in 2008 by the British Standards Institution (BSI). The standard was mainly funded by Carbontrust, which is an English non-profit organisation and by UK government department DEFRA (Department for Environment, Food and Rural Affairs). PAS 2050 was the first international standard for quantifying a carbon footprint and it has been used as a basis for developing other carbon footprint standards. (Kokko 2012, 23; GHG Protocol 2012c.)

3.3.3 GHG Protocol

The Greenhouse Gas Protocol (GHG Protocol) is a collaboration of the World Resources Institute (WRI) and the World Business Council for Sustainable Development

(WBCSD). GHG Protocol provides instructions for governments and organisations in order to understand, quantify and control their GHG emissions. GHG Protocol was founded in 1998. (Kokko 2012, 24.)

GHG Protocol has published calculation tools for different fields of industries, which are either general or concentrate on a specific process. Sector specific tools are available for some industry sectors, such as aluminium, pulp and paper, lime, iron and steel. In addition to calculation tools, GHG Protocol has released standards for quantifying GHG emissions. Standards are divided into two main groups, from which the first one is directed to companies and organisations and the second group for climate change mitigation projects. GHG Protocol Product Standard was released in 2011 for quantifying the GHG emissions. In addition to requirements for determining emissions, it also includes requirements for public reporting. (GHG Protocol 2012a; GHG Protocol 2012b; GHG Protocol 2012c; Kokko 2012, 24.)

4 MAKING THE GREENHOUSE GAS ASSESSMENT OF NOKIAN TYRES

4.1 Definitions

As mentioned earlier, this GHG assessment includes only Nokia factory and from now on Nokian Tyres is referring to Nokian Tyres Nokia plant. The assessment is done by using PAS 2050 method (British Standards Institution 2011). According to PAS 2050, all the 63 greenhouse gases listed by IPCC (International Panel on Climate Change) have to be taken account (appendixes 1). However, most emission factors used in this assessment only include carbon dioxide, methane, nitrous oxide and different fluorocarbons. Even though water vapour has a remarkable effect on climate change, IPCC does not include it to the greenhouse gas list, because water vapour is mostly non-human-made gas (Forster et al. 2007, 152). Therefore, it is also excluded from the greenhouse gas assessment.

4.1.1 Functional Unit

According to PAS 2050 (British Standards Institution 2011, 5-6), GHG assessment needs to have a functional unit as a reference, to which all other inputs and outputs are related. Functional unit helps to ensure that all flows are consistent and comparable with each other.

Before determining the functional unit of Nokian Tyres, other tyre companies and their reports were studied. For example, Michelin reports its emissions as tonne of tyre produced (Michelin 2012, 61). Therefore, the functional unit in this assessment was set to be “one tonne (1000 kg) of tyre produced” in order to ease comparability.

4.1.2 System Boundary

System boundary of GHG assessment can either be “cradle-to-gate” or “cradle-to-grave”. The difference between the boundaries is that “cradle-to-grave” includes everything from raw material extraction to end of life activities whereas “cradle-to-gate” includes all emissions up to the gate of the organisation undertaking the assessment. Therefore, “cradle-to-gate” is more appropriate framing for the GHG assessment of Nokian Tyres (figure 2). According to PAS 2050, also raw material acquisition is included into calculations. However, society infrastructure, such as using roads, and land usage are excluded. (British Standards Institution 2011, 9-10, 35.)

According to PAS 2050, capital goods like machines and buildings having lifespan over one year should be excluded. Therefore, office furniture and work clothes are also excluded from the assessment. However, consumables having lifespan less than one year should be taken account. Therefore, for example printing paper is included in the GHG assessment. Moreover, the basic rule for excluding is that “components or materials contributing less than 1 per cent of the dry mass of a product can be excluded, as they are likely to be immaterial” (British Standards Institution 2011, 10). Thus, minor factors can be left out at the same time ensuring that at least 95% of emissions are taken into account. (British Standards Institution 2011, 10-11.)

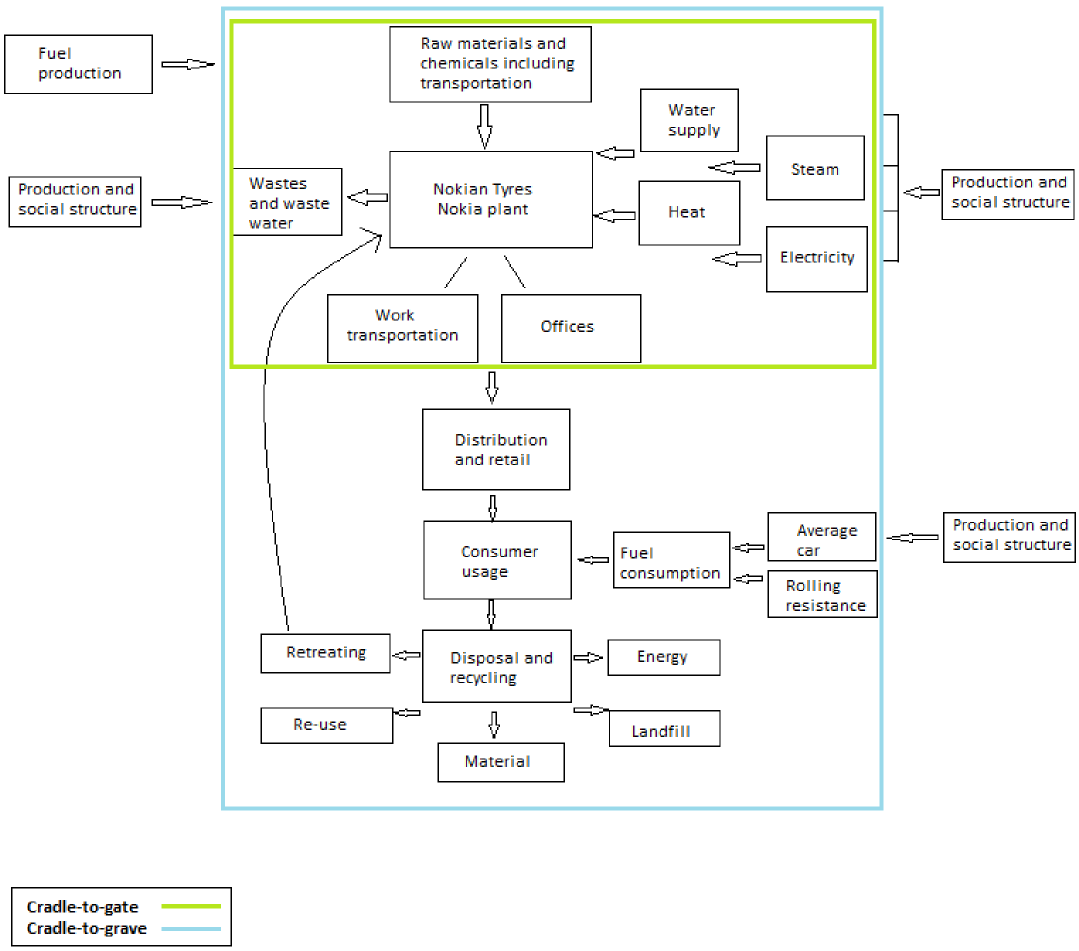

FIGURE 2. System boundaries for Nokian Tyres. Cradle to gate framing used in this assessment presented with green colour.

4.1.3 Allocation

Some processes generate more than one useful output. In that case, PAS 2050 guides to divide, or in other words to allocate, input and output flows between the product and co-products. In this assessment, no allocation has been made because resources are given as a total. In addition, the aim is to define the greenhouse gases for the whole factory, not only to some production line of it. Therefore, all inputs and outputs refer to determined functional unit, tonne of tyres produced, and no allocation is needed. (British Standards Institution 2011, 27.)

4.1.4 Data Collection

In order to make the assessment variety of information is needed and collected from different sources. Primary data is provided by Nokian Tyres and it includes for example energy usage and production information. It is either collected by Nokian Tyres or by its suppliers. By following the guidelines of PAS 2050, resource flows were gathered together into an Excel sheet based on the partial processes. Then flows were balanced to reflect the functional unit, which enabled further calculations. The balancing was done by following three golden rules of PAS 2050 (British Standards Institution 2011, 24), which are

- “always consider waste in the process
- make calculations as transparent as possible, so they can be traced backwards
- record all assumptions and data concerns”.

Secondary data is mostly used either for filling gaps in primary activity date or for defining emission factors for different products or processes. Secondary data can be divided into two categories, which are “aggregated” and “disaggregated”. By aggregated data is meant previously calculated emission factors that can be found from technical reports and other studies. Disaggregated data mean details about specific raw materials and individual emissions that are mostly found in life-cycle inventory (LCI) databases. (British Standards Institution 2011, 16.)

Most of the secondary data used in this assessment is aggregated. The challenge of using aggregated data is to make sure that emission factors are consistent with PAS 2050. Problems can arise if the system boundaries are set differently or the emission factor should be location-specific (British Standards Institution 2011, 17). For example, grid electricity manufacture differs significantly between countries and therefore an emission factor determined in Russia is not valid in Finland. Also, exhaust gases of cars differ between countries. A newer car pool has more and better catalytic converters than an older car pool. Therefore, an emission factor determined for a new car should not be regarded as valid in Eastern Europe.

4.1.5 Calculation Methods

GHG emissions can be calculated by two ways, which are using either an emission factor or global warming potential (GWP). The usage of an emission factor enables calculating GHG emissions for a function or a material (formula 1). Emission factor means a measure of a pollutant discharged into atmosphere. Emission factor is announced as carbon dioxide equivalent kilograms (kg CO_2e) per a certain unit.

$$A \times E = GHG\ Emissions \qquad \text{(FORMULA 1)}$$

A = activity data (kg/litres/kWh/tkm etc.)
E = emission factor (kg CO_2e per kg/litres/kWh/tkm etc.)
GHG Emissions = kg CO_2e

Global warming potential is defined as “the time integrated commitment to climate forcing from the instantaneous release of 1 kg of a trace gas expressed relative to that from 1 kg of carbon dioxide” (Shine, Derwent, Wuebbles & Morcrette, 1990, 58). In other words, GWP states the ratio of warming potential relative to carbon dioxide and considered time period. Thus, other greenhouse gases can be converted to be consistent with carbon dioxide, which helps calculation and comparing. GWP can be used when calculating direct emissions of a certain gas (formula 2) (British Standards Institution 2011, 27.) Direct emissions of individual gases can then be combined in order to get total emissions of a certain source. Hence, GWP can be used when handling disaggregated data.

$$M \times GWP = GHG\ Emissions \qquad \text{(FORMULA 2)}$$

M = mass of GHG
GWP = global warming potential
GHG Emissions = kg CO_2e

GHG emissions are calculated individually for each emission source and then combined based on the division of partial processes. In the end, all the emissions are calculated together in order to get the total number of GHG emissions.

4.2 Raw Material Production and Transportation

According to PAS 2050, GHG assessment includes raw materials that form over one per cent of tyre composition (British Standards Institution 2011, 10). However, some other materials forming less than one per cent are also included when information available. Due to a tight schedule, no questionnaires were sent to raw material producers for getting information for calculating their emissions. Instead, emissions for raw material production are determined by using an earlier research report of WSP (Tiri, Anton & Käpynen, 2011), from which original emission factors for the production of raw materials can be solved (appendix 2).

GHG emissions of raw material acquisition are calculated by adding transportation emissions to production emissions. In order to calculate them, the tyre composition has to be known as well as the production locations of different raw materials. Also, transportation type is needed for calculating the transportation emissions that are included in raw material acquisition. Tyre composition, production location and transportation types are provided by Nokian Tyres (appendix 3).

Whereas GHG emissions for raw material production are calculated by using emission factors defined based on WSP report, transportation emissions are calculated by using transportation type together with the distance between origin and destination. Some simplifying assumptions are made when determining distances and choosing right emission classes for transportation types. Also, some grouping is done according PAS 2050 for certain raw materials, such as “protective agents”, in order to simplify the calculation process (British Standards Institution 2011, 27).

4.2.1 Raw Materials

A tyre consists of many different materials. In addition to rubber compound, it also has steel and textiles as reinforcing materials. The composition of rubber compounds can be seen from figure 3 (Nokian Tyres 2011d). Approximately, 40% of tyre is composed of carbon black and natural rubber, which are the main components of tyre. Other two material groups having a higher content in tyre are synthetic rubber and steel plies and wire. These four materials are further explained in the following sections. Other material groups in tyre are protective agents, booster chemicals that are also known as activators, vulcanising agents and plasticisers (appendix 3). (Nokian Tyres 2011d.)

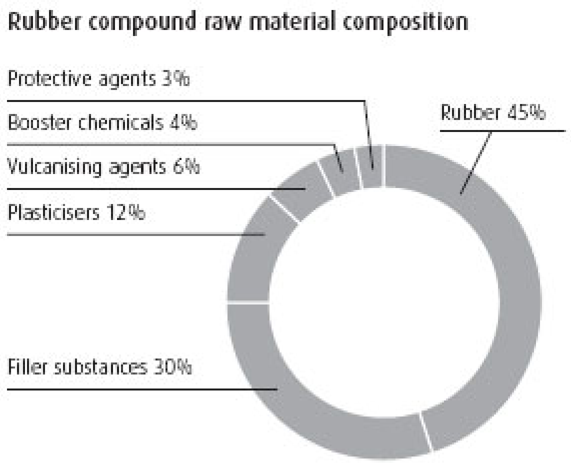

FIGURE 3. The raw material composition of rubber compounds used at Nokian Tyres (Nokian Tyres 2011d)

Carbon Black

Carbon black is made by burning hydrocarbons in a limited air. Burning process forms black smoke, which contains small particles that can be separated in order to get carbon black powder, which is also known as carbon black. Approximately 70% of all carbon black is used as a reinforcing agent in tyre manufacturing. Other usages are industrial rubber products, paints, paper, plastics, ceramics and other automotive parts, such as belts. (Crump 2000, 1-2.) Further information about the origin and the amount of carbon black used at Nokian Tyres is provided in appendix 3.

Natural Rubber

Natural rubber is made from the latex of rubber trees that are grown in warm areas, such as South-East Asia, Middle and South America and Africa. Most of natural rubber is used for car tyres but some technical rubber products, such as seals, are also produced. Natural rubber production forms roughly 40% of all rubber raw materials. The beneficial characteristics of natural rubber are high wear resistance and cold tolerance. However, in hot conditions it has weaker properties than synthetic rubbers. (Kumiteollisuus Oy, 2013.) The origin of natural rubber used at Nokian Tyres and its amount are presented in appendix 3.

Synthetic Rubber

Synthetic rubber is produced by mixing butadiene and styrene in a reactor that contains soapsuds. As a result, liquid latex is formed for further processing. There are several different synthetic rubbers produced, which all have different characteristics. For example, other synthetic rubbers have a high wear resistance whereas others have a high elasticity. Based on the properties, synthetic rubbers can be used for different purposes. (ETRMA, 2011b.) Even though tyres contain many different synthetic rubbers, this assessment concentrates on the four biggest that are presented more precisely in appendix 3. Also, production locations and percentage amounts per production tonne are provided in appendix 3.

Steel Plies and Wire

Steel plies and wire are used in tyre as reinforcing materials. Approximately 70% of used steel material is formed by steel ply and 30% by steel wire. Steel plies and wire are produced in different countries, as can be seen from appendix 3. The total amount of steel materials in production tonne is presented in appendix 2.

Other Raw Materials and Chemicals

According to PAS 2050, materials forming at minimum one per cent of production tonne have to be included (British Standards Institution 2011, 10). However, due to confidentiality agreement, rest of the raw materials are discussed in appendix 2 and 3.

4.2.2 Transportation Summary

There are 19 raw materials (appendix 2) taken account when calculating emissions from raw material acquisition. Based on those 19 materials, 17 raw material groups are created in order to simplify calculations when similar materials in question (British Standards Institution 2011, 27). Closest material comes from Finland whereas the furthest material is transported from Indonesia. Transportation type and route are chosen based on the place of departure. Transportation of raw materials can be summarised in the following way

- Raw materials produced in Central Europe are transported by truck first to Rostock, from which freighted to Helsinki with ocean freight ship. Third part of transportation consists of freight truck from Helsinki to Nokia.
- Raw materials from England are shipped by oceanic freight ship to Helsinki. In addition to ship transport, materials are transported by truck to Nokia. Due to short distances inside England, the transportation from production sites to harbour is excluded.
- Raw materials produced in Russia are transported by truck to Nokia.
- Raw materials from Asia are shipped by transoceanic freight ship to Helsinki, from which onwards to Nokia by truck. Due the long distance from Asia, the transportation to harbour in departure country is excluded.

Transportation emissions are calculated by using a calculation system called LIPASTO, which is created by VTT (Technical Research Centre of Finland) for calculating emissions and energy consumption of all traffic modes in Finland. Transportation emissions include only direct emissions. Therefore infrastructure and for example road abrasion are left out from the emission calculations. (LIPASTO 2012.)

Road Transportation

In this assessment, the truck used for calculations is supposed to be a semi trailer combination. The carrying capacity is 25 tonnes and the route is supposed to contain only highway driving. Naturally, there is also urban driving involved but the calculation process is simplified by using only highway emission information. Emissions are calculated for a full load (25 tonnes) by using tonne-kilometres, which refers to transporting one tonne of material for a distance of 1 kilometre. Instead of determining a specific emission standard, by which are meant EURO emission classes determined by EU, the average is used in order to enable using the same emission information also for transportation abroad. Average classification is chosen because there is no reliable information available for determining country-specific truck emissions. (British Standards Institution 2011, 38; LIPASTO 2012.)

Oceanic Freight Ship Transportation

Freight ships are divided based on their size and purpose. Ocean freight ship used in the assessment is container ship 1 TEU, which means a twenty-foot equivalent unit container. LIPASTO supposes the load to be 65% of the maximum. Emissions are calculated by using tonne-kilometres presented by LIPASTO. Ocean freight ship is used for Baltic Sea shipping. (LIPASTO 2012.)

Transoceanic Freight Ship Transportation

As explained earlier, TEU means a twenty-foot equivalent unit. Therefore, transoceanic freight ship 2 TEU used in the assessment refers to a 40 feet equivalent unit container. Also, for transoceanic freight ship the load is set to be 65% of maximum and the emissions are calculated by using tonne-kilometres. (LIPASTO 2012.) Transoceanic freight ship is used for global shipping. Even though 2 TEU ships do not operate in the Baltic Sea, the same emission factor is used for the whole distance instead of using 2 TEU until Rotterdam and then adding shipping with 1 TEU from there to Finland.

4.3 Operations of Nokian Tyres

In addition to raw material acquisition, this GHG assessment also includes operations that are related to Nokia factory property. Those elements are the production process itself, offices, purchased energy, water usage and created wastes. According to PAS 2050, also work trips are included when differing from the normal trip between home and workplace (British Standards Institution 2011, 11).

There are three main production lines in Nokia factory – passenger car tyres (PC1), heavy tyres (PC2) and re-treading (PC4). In addition to these production lines, rubber adhesives are also produced, from which a portion is sold forward. (Ympäristö-lupapäätös 2007, 3.) Information given about energy usage and other figures is not divided between different processes. Therefore, for example the amount of waste is not divided between production, offices and cafeterias. That is why also results about GHG emissions are given as a total for the whole Nokian Tyres plant. Emissions are calculated based on the functional unit, one tonne of tyre produced. According to PAS 2050, social structure of resources, for example electrical network, is left out of the assessment (British Standards Institution 2011, 11). Some simplifying assumptions are made when needed.

4.3.1 Production Process

There are six main phases in tyre manufacturing process, which are presented in figure 4. First step is to receive raw materials. As mentioned earlier, the raw materials used at Nokian Tyres are non-toxic. Before taking into use, every batch of raw material is tested in a laboratory in order to ensure the required quality. After passing laboratory test, raw materials are used for different rubber compounds. Mixing department produces compounds according to precise recipes. The recipe depends on the needed characteristics of the tyre. Main components are carbon black, natural rubber, synthetic rubber and oil. Finished rubber compounds are then used in component manufacturing. (Ympäristölupapäätös 2007, 4; Responsible Development 2010, 11.)

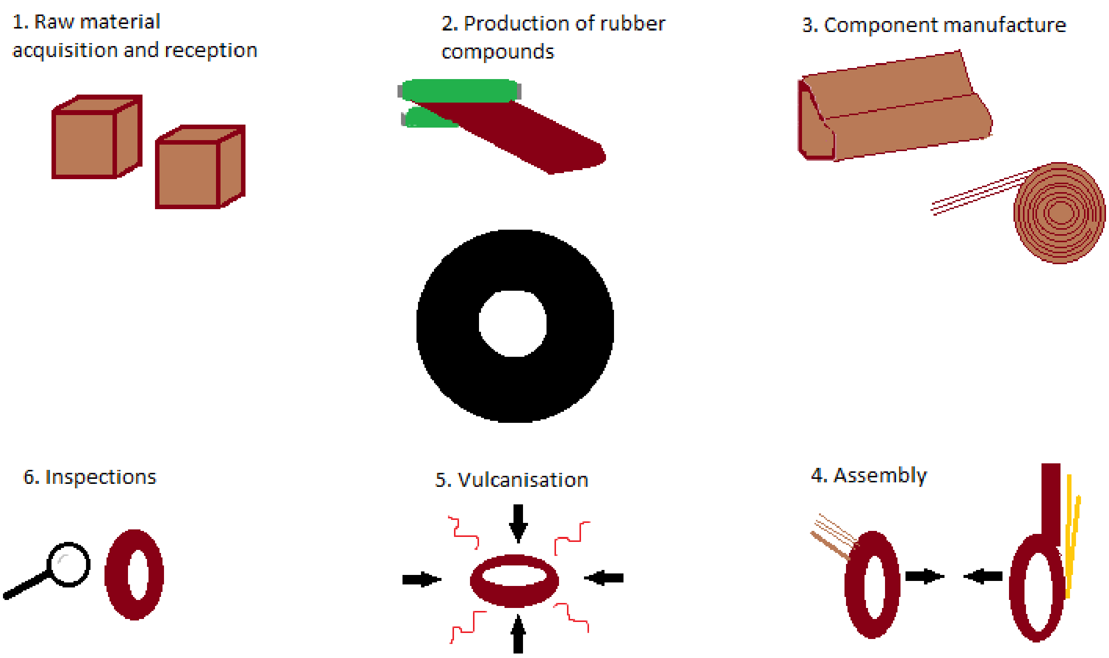

FIGURE 4. Process chart of Nokian Tyres

Third phase of tyre manufacturing is component manufacture (figure 4), which means producing several tread components from rubber compounds, textile materials and metal cords. Treads include for example body plies, inner linings, beads, cores, sidewalls, sidewall wedge inserts, triangular fillers and steel belts. One tyre consists of 10-30 components, from which most are reinforcing elements. (Responsible Development 2010, 11.)

Fourth phase in manufacturing process is assembly, as presented in figure 4. Tyre-building machine combines components together in order to create a so called “green tyre”. In passenger car tyre line, there are two main parts in the machine, body side and belt side. Body side runs inners and sidewalls together with a suitable amount of reinforcing materials while belt side forms a tread package that consists of steel belts and surface rubber. Then machine adds cables, turns sidewalls and rolls the tread package on. Heavy tyres, however, are assembled in a different way. Rubber and reinforcing materials are assembled on preform. This operation needs adhesives and solvents in order to increase the adherence of components. (Ympäristölupapäätös 2007, 5; Responsible Development 2010, 11.)

Green tyres are soft and malleable. Therefore, the next phase in manufacturing process is vulcanisation (figure 4). Before vulcanisation inner surface of preform tyre is treated with chemical liquid in order to avoid curing cushion to adhere tyre. Then green tyre is vulcanised in a curing press under right temperature and pressure in order to make it solid and flexible. Also tyre’s final shape, tread pattern and sidewall markings are given in the curing press. Curing time depends on tyre; passenger car tyres are cured for 7-15 minutes, whereas heavy tyres for 35 minutes up to 5 and half hours. (Ympäristölupapäätös 2007, 5.)

After vulcanisation, every tyre is inspected both visually and manually (figure 4). Visual inspection concentrates on appearance, whereas mechanical inspection measures roundness, force difference and radial throw. Then tyres are labelled, packed and transported to logistics centre, from which they are sent forward to retailers. Based on the chosen system boundary, the logistics centre is excluded from the assessment because it is located outside the factory property. Therefore, also transportation between the factory and the logistics centre is left out. (Responsible Development 2010, 11; British Standards Institution 2011, 9.)

In addition to passenger car tyre and heavy tyre production, there is also re-treading production line (PC4). Tread manufacturing processes are extrusion, pre-vulcanising and roughening of surface. Then bottom is treated with rubber adhesive. The main difference compared to tyre production is the high amount of solvents used, which is supposed to ensure the adherence of components. Finished treads are used in tyre re-treading sites. (Ympäristölupapäätös 2007, 5.)

4.3.2 Energy

Energy used at Nokian Tyres is either steam, industrial water (heat) or electricity (Ympäristölupapäätös 2007, 12). In 2011, the total amount of used energy was 187 693 MWh. As can be seen from table 1, almost half (47%) of the total energy was electricity (87 595 MWh) and the rest 32% steam (60 397 MWh) and 21% heat (39 701MWh).

TABLE 1. Energy usage at Nokian Tyres in 2011

	Electricity	**Steam**	**Heat**	**Total**
Total (MWh/year)	87 595	60 397	39 701	187 693
kWh/production tonne	1,22	0,84	0,55	2,62
%	47	32	21	100

Electricity

According to electricity supplier of Nokian Tyres, the electricity production is based on Nord Pool Spot power market, which is the leading power market in Europe having 370 companies from 20 different countries trading (Nord Pool Spot 2013). Nord Pool Spot releases a report yearly about the distribution of power production types. Since report discusses fossil fuels as a one category, fossil fuels are further divided by using a division graph released by Finnish Energy Industries, which is an industrial policy and labour market policy association of electricity and district heating industry (Finnish Energy Industries, 2012).

After clarifying the division of different electricity types, the amounts of certain electricity used can be calculated. For example, the amount of hydropower is announced to be 0,7% of the total, which gives 613 MWh (87 595*0,007=613). When electricity sources are known, GHG emissions for electricity types can be calculated with formula 1 by using emission factors determined by International Panel for Climate Change (Garg et al. 2006, 23-24). Since nuclear power, wind power and hydropower are so called green energy, their emission factor is zero.

Steam and Heat

Steam and heat (industrial water) are used for production and heating. They are purchased from Nokian Lämpövoima Oy, which uses natural gas as fuel. GHG emissions are calculated by using the environmental report of Nokian Lämpövoima Oy (Lupapäätös 2007, 6, 10) together with production information of Nokian Tyres.

Emission factors for steam and heat are calculated by using table 2. It combines production information and emission information of Nokian Lämpövoima Oy during years 2004-2006 (Lupapäätös 2007, 6, 10). Since information is for earlier years, instead of using the base year 2011, following calculations are done by using the information of year 2006 because it is the latest year presented.

TABLE 2. Production and emission information of Nokian Lämpövoima Oy during years 2004-2006

	Production Information 2004-2006			**Emission Information 2006**			
	Production, GWh/a				**CO2 emissions (tonnes)**		
	Electricity	**Steam**	**Heat**	**Total**	**Electricity**	**Steam**	**Heat**
2004	365	273	95				
2005	303	259	91				
2006	388	266	101	**218 589**	112334,5	77012,81	29241,71
2006 %	51,39 %	35,23 %	13,38 %	**2006 %**	51,39 %	35,23 %	13,38 %

According to Nokian Tyres, in 2006 there were approximately 65 GWh of steam and 43 GWh of heat used. Thus, the percentage value of Nokian Tyres from total Nokian Lämpövoima production can be calculated by using table 2. For steam it is approximately 24% and for heat 43%. Since it is known that Nokian Tyres uses 24% of all produced steam, it is assumed that also 24% of carbon dioxide emissions of heat are caused by Nokian Tyres. Based on the initial emissions announced in table 2, carbon dioxide is calculated to be 18 483 tonnes. Then CO_2 emissions are divided by the used amount of heat in order to define the emission factor of heat production. The same calculation process is conducted for determining the emission factor for steam production.

4.3.3 Water Usage

Water usage consists of both water intake and wastewater. The water supplies of Nokian Tyres are municipal water system and river Nokianvirta. Tap water is used for drinking and cooking whereas river water is used as cooling water in the production process. Nokian Tyres has its own water plant next to Nokianvirta, through which the river water is taken and treated. Cooling water is circulated in a way that it does not have a contact with chemicals. Therefore, it stays clean and can be lead back to Nokianvirta. However, 0,1% of taken river water is used at washers of mixing machines. Washing water is circulated few times in the washers before it is lead to sewer network. (Ympäristölupapäätös 2007, 11-12.)

In 2011, total water usage was 8 121 771m^3, from which 99% was river water and 1% municipal water. However, since the operations of the water plant are included in energy data, there are no separate emissions calculated for river water. Thus, this assessment focuses on municipal water in more detail. Clean water emission factor includes water production and water system, whereas wastewater emission factor includes sewer network and wastewater treatment.

Since there are no emission factors available for clean water and wastewater, they are determined by few calculations. In order to get the emission factor for input water, emission factors for water production and water system have to be determined. The same holds true with output water: the emission factor is defined based on the emission factors of wastewater treatment and sewer network.

By using table 3, which is formed based on the information provided by Seppälä & Vilkas (2008, 5) and Aamulehti (Tampereen Vesi: Asiakkaat ovat tyytyväisiä 2012, Pirkanmaa), the emission factors for each water phase can be calculated. The amounts of carbon dioxide equivalent tonnes are divided by the amount of cubic meters in order to define the emission factors. Then water production and water system factors are combined together, which results the clean water emission factor to be 8,34. The same way sewer network and wastewater treatment factors are unified in order to define the wastewater emission factor, which is 11,89. These emission factors are used when determining the GHG emissions of water usage.

TABLE 3. Water figures of water supply service in 2007

	GWh	t CO_2e	mill. m^3	kg CO_2e / m^3	kg CO_2e / m^3
Water Production	240	77311	10	7,73	8,34
Water System	19	6 120	10	0,61	
Sewer Network	25	8850	10	0,89	11,89
Wastewater Treatment	340	110000	10	11,00	
Total	624	202281	20	20,23	20,23

4.3.4 Wastes

In 2011, the total waste amount produced by Nokian Tyres was 8 190 tonnes of kilograms. As can be seen from figure 5, largest waste types based on the weight were unvulcanised rubber waste, waste tyres and wood. Section “landfill” includes both mixed waste and hazardous waste, whereas “other recyclables” means plastics, energy waste, iron and steel, paper, cardboard, waste oil, biowaste and class.

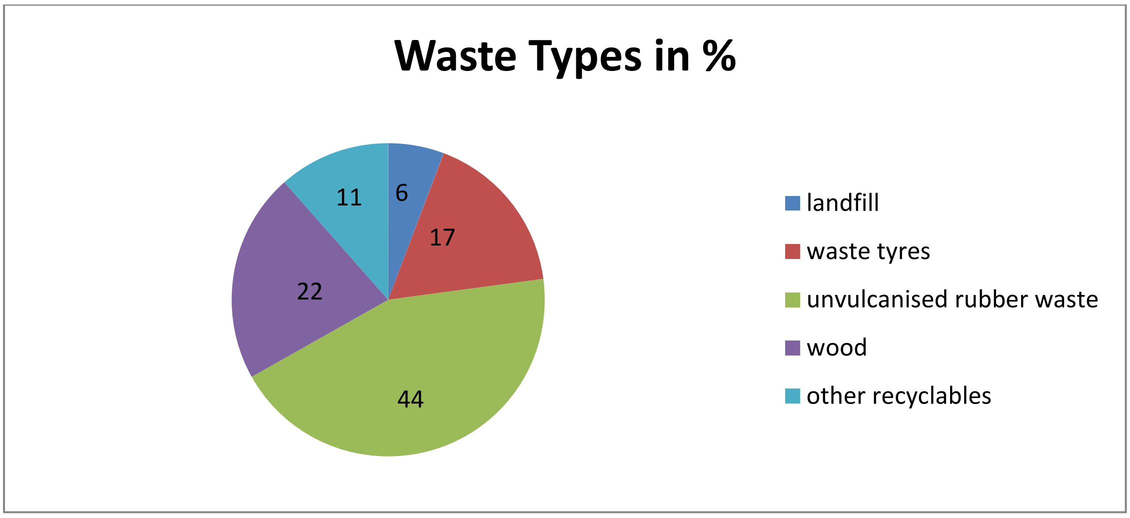

FIGURE 5. Distribution of waste types in year 2011

According to PAS 2050, emissions of recycled waste that is used as a raw material for some new product should be excluded from the assessment (British Standards Institution 2011, 39). Therefore, emission factors for each waste type are determined in a way that only waste treatment is included and further processing into new material is left out and allocated to new product. As an example, recycling of paper produces 1050 kg CO_2 equivalents per paper tonne, from which waste disposal of paper forms 10 kg CO_2 equivalents and utilisation as a raw material creates 1040 kg CO_2 equivalents. By following the guidelines of PAS 2050, only waste treatment is taken account and thus, the emission factor for paper recycling is 10 kg CO_2 equivalents per waste tonne. The recycling rate of Nokian Tyres is quite high and therefore, also the waste emissions are rather low (appendix 4).

Emission factors for waste types are determined by using several different sources because there is no compatible document with PAS 2050 available, which would combine emission factors for all needed waste types. Some of the factors that are used in this assessment are redefined by calculating only waste transportation emissions. The reason for that procedure is that factors initially included also the processing into new raw material, which is incompatible with PAS 2050 regulations. This calculation method is however only used, when no comparable information is available in order to ensure that waste emissions are equal. Otherwise, the transportation of wastes is included in waste treatment emission factors.

4.3.5 VOC Emissions

Volatile organic compounds (VOCs) are released into atmosphere by natural and anthropogenic sources. VOCs have relatively short atmospheric lifetime and small direct effect on radiative forcing. In fact, the indirect influence on climate is formed when VOCs produce organic aerosols and ozone in the presence of nitrous oxides and sunlight. The largest source of VOC emissions is natural and caused by vegetation. Anthropogenic sources of VOCs are mostly transportation and industrial emissions, more precisely emissions caused by the usage of solvents. (Ehhalt & Prather 2001, 257.)

It is controversial whether VOCs are seen as greenhouse gases. IPPC does not include VOCs into the list of 63 greenhouse gases (appendix 1) because VOCs are indirect GHGs. Despite of PAS 2050 guidelines, VOCs are discussed in this assessment because the role of VOCs is altogether remarkable from Nokian Tyres point of view (British Standards Institution 2011, 7). Controlling VOC emissions is an important part of the environmental actions taken by Nokian Tyres and therefore also VOCs were decided to be included in this assessment.

As explained earlier, the production processes of Nokian Tyres require using some solvents. Most of the solvents are used in re-treating line (PC4) for cluing and increasing the adherence of components. Also heavy tyre production (PC2) and adhesive production use solvents. Adhesive production, however, is a closed process and therefore it does not create any VOC emissions. VOCs released at PC4 are lead into combustion plant, which is on the roof of the factory. In addition to those emissions, there are also spread emissions in the factory. For example, vulcanisation fumes contain VOC emissions and different work phases in heavy tyre production are connected to solvent usage. (Ympäristölupapäätös 2007, 16-17.)

There are two main solvents that are used at Nokian Tyres. Those solvents are used for calculating the VOC emissions of Nokian Tyres. As can be seen from appendix 5, the calculation is carried out by using the 100-years GWP (greenhouse warming potential) for non-methane volatile organic compounds (NMVOCs) determined by IPCC (Ilmasto.org, according to IPCC 2001).

4.3.6 Offices

Since Nokian Tyres has its headquarters at Nokia, there are many offices in the building. As PAS 2050 states, emissions related to the production of capital goods should be excluded from the assessment. Thus, offices themselves are not included but the consumables used in those offices are taken into account. However, not all of the consumables are included in the assessment according to PAS 2050 regulation. As mentioned earlier, consumables having a lifespan less than a year should be included, whereas goods with a lifespan more than a year should be excluded. (British Standards Institution 2011, 11.) As an example, office furniture is left out because it lasts more than a year, whereas copying paper is included because the lifespan is supposedly less than year.

Emission factors for office-related goods are provided by WWF in co-operation with Eco-support Activity –project (WWF 2011). Even though WWF gives emission factors for many equipments and consumables, only printing paper, copying paper and letter carriage are covered in the end. The reason for it is that for example emissions of electronic devices should be included only to acquisition or waste disposal in order to avoid double-counting. Since waste data does not analyse data types so clearly, it is simpler to allocate the emissions from electronic devices directly to waste disposal.

There is one exception in office emission counting. Even though lamps are consumables having a lifespan less than a year, the emissions that should be taken account are considered in energy and waste data. According to Oksanen (Oksanen 2009, 9-10), lamp production and waste disposal forms only a minor part of lamp's carbon footprint. Almost all emissions are caused by the usage and therefore included in energy figures.

4.3.7 Work Trips

According to PAS 2050, travelling to normal work place is not included in the assessment (British Standards Institution 2011, 11). However, work trips to other locations should be included. Work trips can be divided into three categories; flying, driving and train travelling. Travelling distances are gathered from transportation companies and driving compensation expenses and calculated together. In 2011, the workers of Nokian Tyres flew 13 985 640 kilometres, drove 734 227 kilometres and used train for 466 772 kilometres (figure 6).

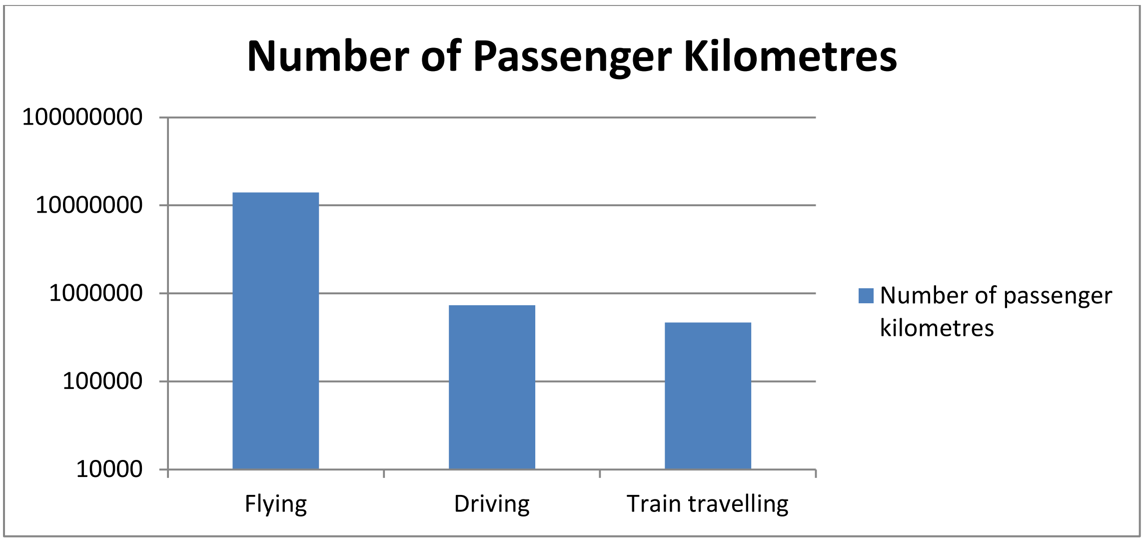

FIGURE 6. Work trip transportation in passenger kilometres according to transportation types

Work trips are presented in passenger kilometres (pkm), which is a measure of transportation informing the distance travelled by a person in a vehicle. Emission factors for driving and train travelling are defined by using the LIPASTO calculation system. Flight emissions are calculated by using the information given by Defra (Department for Environment, Food and Rural Affairs).

Driving

Emission factor for driving is defined by using an average passenger car with 1,7 persons load. Instead of choosing a specific EURO emission class, the average class is used in order to simplify the calculation method. The emission factor is chosen based on the assumption that 35% of the journey is composed of street driving and the rest 65% of highway driving. (LIPASTO 2012.) The driving emission factor is then used together with the gathered kilometre number in order to calculate the driving emissions of work trips (appendix 5).

Train Travelling

Train emissions are calculated based on the emission factors defined by LIPASTO and personal notification given by VR’s employee Markku Markkanen (LIPASTO 2012; Markkanen 2012). LIPASTO provides emission information about the following train types: Pendolino, InterCity, commuter railway and rail bus. Since the transportation data is not categorised based on the train type, the emissions have to be calculated by using an average value. However, LIPASTO does not have any average values for train emissions unlike it has for other vehicles. Thus, the average emission factor is calculated based on the personal notification of Markku Markkanen about the average distribution of used train types and their fuel type. When it is known, how many percentages each train types compose, the average emission factor can be calculated. Then the factor is further used for calculating the train travelling emissions (appendix 5).

Flying

In order to calculate flight emissions, flight data have to be transformed into passenger kilometres because many companies present the work trip information in distances. For example, three roundtrips between Helsinki and London forms 10 938 passenger kilometres, (3 x 2 x 1 823), whereas the initial information is presented to be 1 823 kilometres. Many airlines also present their own information about GHG emissions. However, in order to ensure the comparability of results, the GHG emissions are calculated separately for all journeys of each airline.

Defra provides information about flying emission factors (Defra 2011, 57). Domestic flights, short-haul flights and long-haul flights have different emission factors. Since the information provided by the airlines does not inform about the percentage values of different flight types, the emission factor for flying is supposed to be the average value of given emission factors. That emission factor is then used for calculating the emissions of work trips comprised of flying (appendix 5).

5 CREATING THE CALCULATOR

As explained earlier, another part of the thesis process is to create a GHG emission calculator for Nokian Tyres. The calculator is done by using Microsoft Excel software. The aim of the calculator is to provide a tool, which can be used for calculating the GHG emissions also in coming years. The calculator is built in a way that by filling out new information, it gives the total amount of produced GHG emissions in carbon dioxide equivalents (CO_2e).

The calculator (appendix 4) consists of 11 different sections, which are general information, summary and procedure information including all nine partial processes explained earlier. There is a blank column in the main page that is reserved for filling in the quantities of procedure information. Also, the section “general information” has blank cells, to which the production information is entered. By filling in the information about production and different procedures, the calculator gives the total GHG emission amounts to each partial process as well as combines all those totals into a summary. The summary presents the totals of each partial process and also the total of all GHG emissions of Nokian Tyres.

In addition to the main page, there are several sheets that are used for calculating the emissions (appendix 5). The sheets are named after each partial process and for example “work trips” sheet includes information about driving, flying and train travelling. There are several columns including data about the transportation type in question. By using the references from the main page, the cells can calculate the quantity per production tonne, which is then multiplied with the emission factor in order to get the GHG emissions. The cell giving the answer is then used as a reference to the main page, which enables presenting the amount of GHG emissions of that certain transportation type on the main page.

All the sheets have a same function, which ensures that the only updating procedure needed in the future is to fill in the production and partial process information into the main page. The emission factors stay the same and the quantities per production tonne are automatically updated by the calculator when new production information is filled in. The quantities of partial processes and production information are easily gathered from internal sources annually. However, the only information that should be edited before entering is the amount of used fossil fuels. The reason behind is that the Nord Pool Spot presents the fossil fuels as a one category without further dividing it into different energy sources, as explained in the section 4.3.2 Energy. In order to have reliable GHG emissions, it is preferred to calculate the emissions by using emission factors of precise energy sources. Therefore, the fossil fuels are further divided into natural gas, coal, oil and peat according to Finnish Energy Industries (2012).

6 GREENHOUSE GAS EMISSIONS OF NOKIAN TYRES

6.1 Total GHG Emissions

According to appendix 5, in 2011 the total amount of greenhouse gas emissions of Nokian Tyres was 3 582 kg CO_2e per tonne of tyres produced. As can be seen from table 4, the biggest portion of GHG emissions is clearly created by raw material acquisition with 2 888 kg CO_2e. Lowest emissions are caused by offices and wastes.

TABLE 4. Summary of the total GHG emissions according to the sources in 2011

Emission Source	Emissions [kg CO_2e/production (t)]
Raw Materials	2888
Electricity	204
Steam	244
Heat (water)	160
Water Usage	23
Waste	3
Offices	2
Work Trips	26
VOC	31
Total Emissions	**3582**

Raw material acquisition consists of raw material production and transportation. As appendix 5 states, approximately 9% of the raw material acquisition emissions are caused by transportation whereas 91% are released due to raw material production. The proportions of raw material production and transportation are presented in figure 7. If combining the emissions released by the production process at Nokian Tyres itself, which includes electricity, steam, heat, water usage, wastes and VOCs, the amount of their emissions is 665 kg CO_2e (figure 7).

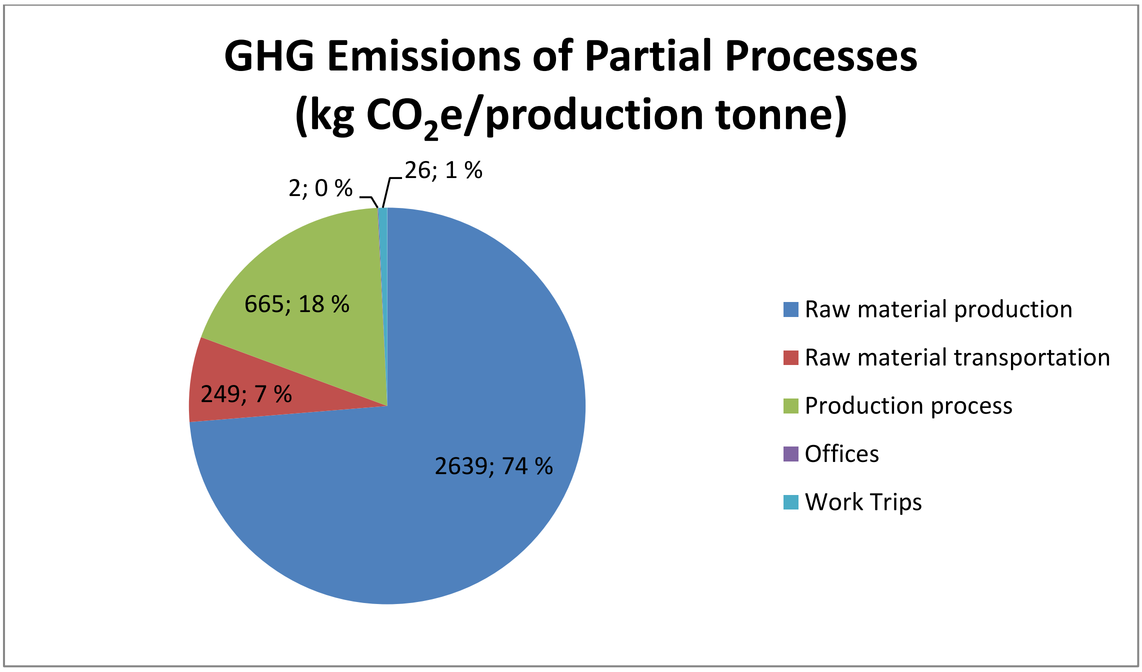

FIGURE 7. Greenhouse gas emissions of partial processes, from which production process includes energy, water usage, wastes and VOC emissions

6.2 Raw Material Emissions

As presented earlier, there are 19 raw materials taken account in this assessment. The GHG emissions of raw materials are not directly comparable to the used amounts because the emission factors are different for each material. Figure 8 presents the greenhouse gas emissions of raw materials. The explanations for raw material symbols can be seen from appendix 3. As figure 8 demonstrates, biggest pollutants are material L with 34%, material A with 22%, material M with 17%, material O with 14% and material N with 8%. Rest of the raw materials clearly form only a minority of the GHG emissions. Moreover, six of those 14 minor pollutants create less than one per cent of the functional unit and also less than one per cent of all raw material emissions and therefore are according to PAS 2050 excluded from the results (British Standards Institution 2011, 10).

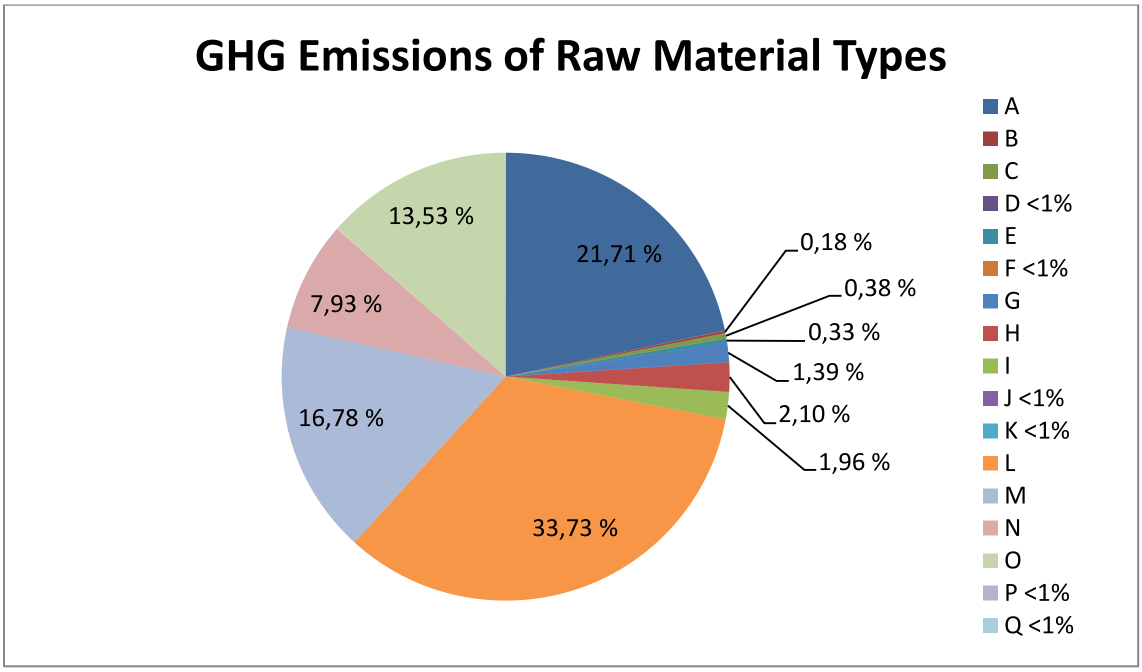

FIGURE 8. Greenhouse gas emissions of each raw material type

6.3 Waste Emissions

Greenhouse gas emissions of wastes are extremely low. As can be seen from table 4, waste emissions are 3 kg CO_2e per production tonne forming only 0,008% of the total GHG emissions. The reason behind is supposedly the high recycling rate of Nokian Tyres. Figure 9 presents the emission percentages of each waste type. As can be seen from the figure, most of the waste emissions are caused by so called unrecyclable waste that includes mixed waste (34%) and hazardous waste (48%). Rest of the emissions are formed by recyclable wastes. Zero percentages in the figure 9 refer to emissions being below 1%. Wood is left out from the figure because the GHG emissions of wood are defined to be zero due to renewability.

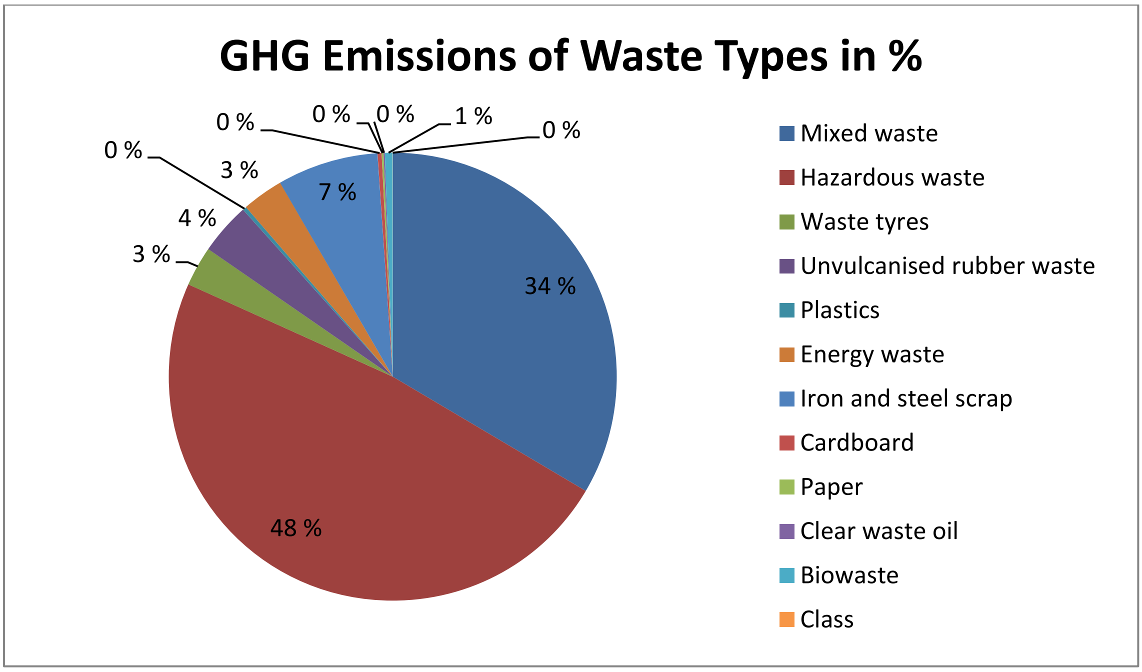

FIGURE 9. Greenhouse gas emissions of waste types in percentages

6.4 GHG Emissions of Energy, Water Usage and Work Trips

As can be seen from table 4, electricity, steam and heat form together 608 kg CO_2e per production tonne. The GHG emissions between energy types are quite even. Figure 10 illustrates the distribution of emissions between energy types. Steam produces most of the emissions by contributing 40%, whereas electricity forms 34% and heat 26%.

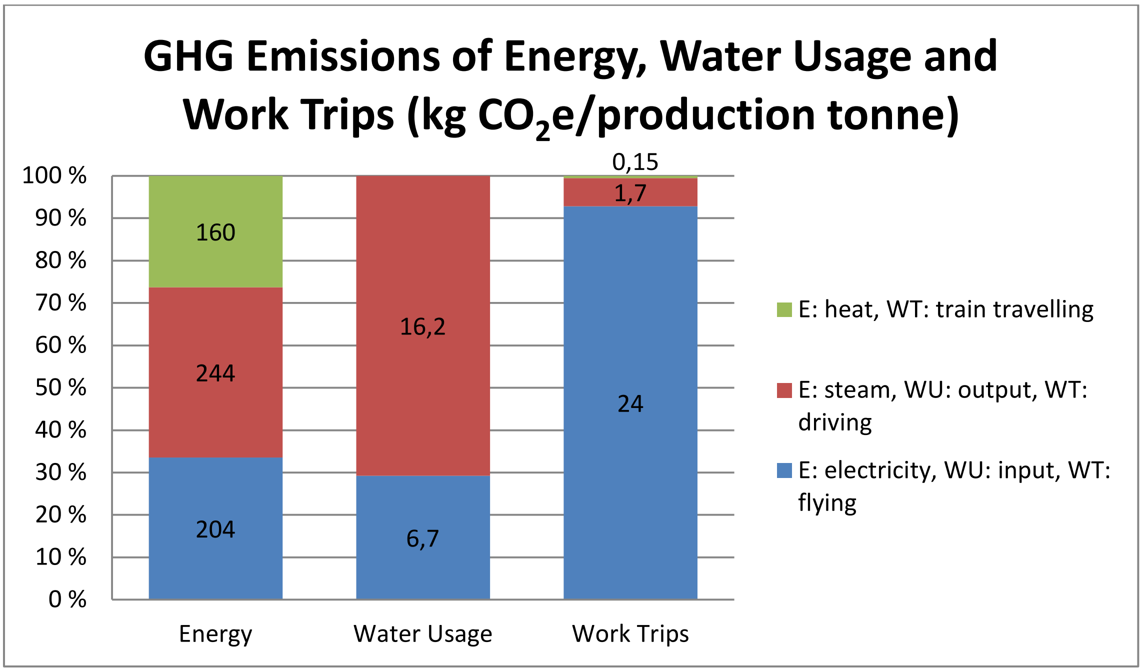

FIGURE 10. Greenhouse gas emissions of energy, water usage and work trips

Water usage emissions are mostly formed by wastewaters, which can be seen from figure 10. 70% of the emissions are caused by output operations whereas 30% are due to input operations. The reasons behind are first of all the higher amount of output water (appendix 4), which is resulting from the usage of river water that is partly feed into the sewage system. Another reason is the higher emission factor of wastewater compared to the clean water emission factor (table 3). Water emission factors are further discussed in section 4.3.3 Water Usage.

As can be seen from figure 10, most of the work trip emissions (93%) are caused by flying. Driving creates approximately 7% of the GHG emissions and train travelling only less than one per cent. The emission factors for work trip transportation presented in appendix 5 do not have a high variation. Therefore, the reason behind incomparable emissions of flying against other transportation types is the great number of total flying kilometers due to long distances.

7 DISCUSSION

The aim of the thesis was to carry out a greenhouse gas assessment of Nokian Tyres and create a calculator for further emission counting. The GHG assessment was done by following the guidelines of PAS 2050 (British Standards Institution 2011) and thus the results should be in accordance with the given instructions. However, it has to be stated that there might be some deviation involved.

First of all, choosing the standard was quite complicated and done by acquainting myself with different guidelines, such as ISO standards, GHG Protocol and PAS 2050. Even though the purpose of the standards is to harmonise the GHG assessment procedure, there are differences between different standards. Therefore, standards are not functional indicators for ensuring the comparability of the results. PAS 2050 was chosen because it has clear instructions for reporting.

The second problem concerns of defining the system boundary. Even though PAS 2050 gives instructions for choosing the right boundary, which in this case is “cradle-to-gate”, there are still decisions to be made. For example, the logistics centre of Nokian Tyres was left out because it is located elsewhere and therefore is not a part of the factory property. Thus, also the transportation to the logistics centre is excluded. The decision is in accordance with PAS 2050 regulation, which states that the system boundary can vary depending on the location of the gate (British Standards Institution 2011, 9). Despite the accordance, the comparability of the results towards other assessments can decrease because of the decided system boundary.

The biggest challenge on making the assessment relates to emission factors. It was extremely difficult to find emission factors, since there were no functional databases available. As an example, free ELCD (European Reference Life Cycle Data System) is a core database, which would need LCA software in order to be useful. Therefore the emission factors were gathered from different sources, such as reports and researches. Thus, all the emission factors may not be defined in a same way, which affects on the reliability of the results. In order to avoid underestimations in the results, the emission factors were defined in a way, that if choosing between two factors, the factor stating higher emissions was chosen.

As mentioned already in the results, the waste emissions are extremely low. High recycling rate has influence on the results but also the emission factors have an important role. As explained, the emission factors do not include further processing into new raw materials, which decreases the emission factors evidently. Therefore, also the calculated GHG emissions are really low. Some questioning arises about the waste emission factors in general: are other assessments done by using waste factors, which include also further processing? This kind of differences in GHG assessment guidelines can produce results that are not comparable. As an example, the carbon footprint calculated for WR 205 tyre (Tiri et al. 2011) gives a lot higher waste emissions than this assessment. The only reasonable explanation is that the waste emissions are calculated by using higher emission factors that include also processing. Consequently, the waste emission results of this assessment should not be considered to be comparable with other assessments without verifying the method used for defining the emission factors. The same holds true also with other partial process emissions and the total emissions of the factory. Moreover, it is quite challenging to compare these results to the results of other tyre manufacturers because only Michelin presents some figures about its greenhouse gas emissions, which were 1210 kilograms of CO_2 per production tonne in year 2011 (Michelin 2012, 61). However, the methods used are not provided and therefore the emissions should not be compared directly to the emissions of Nokian Tyres.

As figure 7 illustrates, raw material acquisition causes most of the GHG emissions (81%) of Nokian Tyres. In order to decrease the emissions, attention should theoretically be paid on raw material production and their transportation. In reality, managing emissions that are released by some other authors is rather difficult. The emissions of raw material production can be tried to be decreased by making supply contracts with sustainability requirements and choosing new suppliers based on the sustainability of their operations. Transportation emissions can be affected most efficiently by using closer suppliers. However, some raw materials, such as natural rubber, are only produced in distant lands and thus their transportation emissions are impossible to control. Also, the biggest pollutant, material L, is already produced quite near but the reason for high emissions is the production process itself (appendix 3). One method for decreasing raw material emissions could be a new innovation for tyre recipe produced by research and development department, which could enable using more sustainable materials for tyres. For example, creating a tyre recipe with less material L would result in lower emissions.

Since the development of raw material acquisition is quite challenging, the attention should be put into energy efficiency. At the moment, energy forms second-largest part of the GHG emissions with 17%. Decreasing the emissions of energy production and distribution is almost impossible - if not taking account changing energy into renewable energy, such as hydropower - and therefore the solution is to highlight energy efficiency. Energy savings have to be made in all actions, which is possible by training employees and investing into more energy efficient machines. Employee training can develop the attitudes towards energy issues to be more positive and thus help to make energy savings for example via switching off lights. Also water usage can be decreased by changing the attitudes.

Another way to decrease energy usage is to invest on new machines that consume less energy. In addition to bigger machines, also smaller investments are important. Nokian Tyres has already for example lamps that are automatically switched off when nobody is moving on the area. One possible improvement could be done in the switching off the machines. When shifts are changing, there is a period of time, when nobody is using the machines but they still are running. It should be studied, whether it is worthwhile to put the machines onto standby state or stop them during the sift change. In order to clarify that issue and other possible energy improvement targets, another study would have to be made about the function of the process chain as well as about determining the possible causes of energy losses.

The calculator was done in order to estimate the greenhouse gas emissions on a yearly level. The function of the calculator is designed to be as simple as possible. By filling out little information, it calculates the emissions of a certain procedure. In the end, it combines all the partial process emissions together in order to define the total emissions of the year. Another design criterion was to keep the information as transparent as possible. Therefore, the calculation sheets (appendix 5) of the calculator are done by following the same pattern, which has several calculation phases. However, it would have been better to have also sources presented for each emission factor on those calculation sheets. Thus, the calculator would have been even more transparent, which would have helped the people who are using the calculator in the future. Despite that fact, the calculator should work well for the purpose of Nokian Tyres because all needed information already exists on their internal database.

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APPENDICES

Appendix 1. List of greenhouse gases including their lifetimes, radiative efficiencies and global warming potentials relative to CO_2 (Forster et al. 2007, 158)

(1/2)

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency ($W m^{-2} ppb^{-1}$)	Global Warming Potential for Given Time Horizon			
				SAR‡ (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b]1.4×10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7×10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03×10^{-3}	310	289	298	153
Substances controlled by the Montreal Protocol							
CFC-11	CCl_3F	45	0.25	3,800	6,730	4,750	1,620
CFC-12	CCl_2F_2	100	0.32	8,100	11,000	10,900	5,200
CFC-13	$CClF_3$	640	0.25		10,800	14,400	16,400
CFC-113	CCl_2FCClF_2	85	0.3	4,800	6,540	6,130	2,700
CFC-114	$CClF_2CClF_2$	300	0.31		8,040	10,000	8,730
CFC-115	$CClF_2CF_3$	1,700	0.18		5,310	7,370	9,990
Halon-1301	$CBrF_3$	65	0.32	5,400	8,480	7,140	2,760
Halon-1211	$CBrClF_2$	16	0.3		4,750	1,890	575
Halon-2402	$CBrF_2CBrF_2$	20	0.33		3,680	1,640	503
Carbon tetrachloride	CCl_4	26	0.13	1,400	2,700	1,400	435
Methyl bromide	CH_3Br	0.7	0.01		17	5	1
Methyl chloroform	CH_3CCl_3	5	0.06		506	146	45
HCFC-22	$CHClF_2$	12	0.2	1,500	5,160	1,810	549
HCFC-123	$CHCl_2CF_3$	1.3	0.14	90	273	77	24
HCFC-124	$CHClFCF_3$	5.8	0.22	470	2,070	609	185
HCFC-141b	CH_3CCl_2F	9.3	0.14		2,250	725	220
HCFC-142b	CH_3CClF_2	17.9	0.2	1,800	5,490	2,310	705
HCFC-225ca	$CHCl_2CF_2CF_3$	1.9	0.2		429	122	37
HCFC-225cb	$CHClFCF_2CClF_2$	5.8	0.32		2,030	595	181
Hydrofluorocarbons							
HFC-23	CHF_3	270	0.19	11,700	12,000	14,800	12,200
HFC-32	CH_2F_2	4.9	0.11	650	2,330	675	205
HFC-125	CHF_2CF_3	29	0.23	2,800	6,350	3,500	1,100
HFC-134a	CH_2FCF_3	14	0.16	1,300	3,830	1,430	435
HFC-143a	CH_3CF_3	52	0.13	3,800	5,890	4,470	1,590
HFC-152a	CH_3CHF_2	1.4	0.09	140	437	124	38
HFC-227ea	CF_3CHFCF_3	34.2	0.26	2,900	5,310	3,220	1,040
HFC-236fa	$CF_3CH_2CF_3$	240	0.28	6,300	8,100	9,810	7,660
HFC-245fa	$CHF_2CH_2CF_3$	7.6	0.28		3,380	1030	314
HFC-365mfc	$CH_3CF_2CH_2CF_3$	8.6	0.21		2,520	794	241
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	15.9	0.4	1,300	4,140	1,640	500
Perfluorinated compounds							
Sulphur hexafluoride	SF_6	3,200	0.52	23,900	16,300	22,800	32,600
Nitrogen trifluoride	NF_3	740	0.21		12,300	17,200	20,700
PFC-14	CF_4	50,000	0.10	6,500	5,210	7,390	11,200
PFC-116	C_2F_6	10,000	0.26	9,200	8,630	12,200	18,200

(2/2)

Perfluorinated compounds *(continued)*							
PFC-218	C_3F_8	2,600	0.26	7,000	6,310	8,830	12,500
PFC-318	c-C_4F_8	3,200	0.32	8,700	7,310	10,300	14,700
PFC-3-1-10	C_4F_{10}	2,600	0.33	7,000	6,330	8,860	12,500
PFC-4-1-12	C_5F_{12}	4,100	0.41		6,510	9,160	13,300
PFC-5-1-14	C_6F_{14}	3,200	0.49	7,400	6,600	9,300	13,300
PFC-9-1-18	$C_{10}F_{18}$	>1,000[d]	0.56		>5,500	>7,500	>9,500
trifluoromethyl sulphur pentafluoride	SF_5CF_3	800	0.57		13,200	17,700	21,200
Fluorinated ethers							
HFE-125	CHF_2OCF_3	136	0.44		13,800	14,900	8,490
HFE-134	CHF_2OCHF_2	26	0.45		12,200	6,320	1,960
HFE-143a	CH_3OCF_3	4.3	0.27		2,630	756	230
HCFE-235da2	$CHF_2OCHClCF_3$	2.6	0.38		1,230	350	106
HFE-245cb2	$CH_3OCF_2CHF_2$	5.1	0.32		2,440	708	215
HFE-245fa2	$CHF_2OCH_2CF_3$	4.9	0.31		2,280	659	200
HFE-254cb2	$CH_3OCF_2CHF_2$	2.6	0.28		1,260	359	109
HFE-347mcc3	$CH_3OCF_2CF_2CF_3$	5.2	0.34		1,980	575	175
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	7.1	0.25		1,900	580	175
HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	0.33	0.93		386	110	33
HFE-449sl (HFE-7100)	$C_4F_9OCH_3$	3.8	0.31		1,040	297	90
HFE-569sf2 (HFE-7200)	$C_4F_9OC_2H_5$	0.77	0.3		207	59	18
HFE-43-10pccc124 (H-Galden 1040x)	$CHF_2OCF_2OC_2F_4OCHF_2$	6.3	1.37		6,320	1,870	569
HFE-236ca12 (HG-10)	$CHF_2OCF_2OCHF_2$	12.1	0.66		8,000	2,800	860
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$	6.2	0.87		5,100	1,500	460
Perfluoropolyethers							
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	800	0.65		7,620	10,300	12,400
Hydrocarbons and other compounds – Direct Effects							
Dimethylether	CH_3OCH_3	0.015	0.02		1	1	<<1
Methylene chloride	CH_2Cl_2	0.38	0.03		31	8.7	2.7
Methyl chloride	CH_3Cl	1.0	0.01		45	13	4