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GREENHOUSE GAS EMISSIONS FROM TYRE PRODUCTION – CASE NOKIAN TYRES

Master of Science Thesis

Examiner: prof. Jukka Rintala
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ABSTRACT

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Climate change is a growing concern. The growing concentrations of greenhouse gases (GHGs) are the main cause for climate change. In order to prevent dangerous changes in the climate system the GHG emissions have to be controlled. GHG assessment can be seen as an important tool in controlling GHG emissions as the emissions and their sources have to be known in order to restrain them.

The goal of this thesis was to determine all relevant GHG emissions from tyre industry with special focus on indirect GHG emissions. As a case study the GHG emissions of Nokian Tyres' operations were assessed. In the study GHG emissions from production and transportation of raw materials, manufacturing of the tyres, distribution and sales operations, use of the tyres, and the end-of-life treatment were included. In the manufacturing emissions the indirect emissions from auxiliary operations such as wastes, commuting, and business travel were also included. To calculate the total GHG emissions the non-CO_2 gases were converted into CO_2 equivalent (CO_2e) using their global warming potentials. All GHG emissions were calculated using activity data and emission factors. In addition a calculator was created to enable easy calculation of the annual GHG emissions from the operations based on activity data only.

Many studies have shown that the use of the tyres creates most of the GHG emissions during the whole lifecycle. In this study the total GHG emissions from all of the operations were 30 364 kg CO_2e/t tyres produced. 87 % of the GHG emissions were formed during the use of the tyres. The manufacturing of the tyres comprised only a small amount of the total GHG emissions (2.1 %). Most of the GHG emissions from manufacturing are caused by energy use. The high usage of carbon neutral energy sources keeps the GHG emissions low however. Emissions from distribution and sales operations mainly comprised of the energy use of the sales facilities. The production of raw materials formed second largest part of all GHG emissions (7.8 %). GHG emissions from end-of-life treatment were insignificant (less than 0.1 %).

The largest GHG emission reduction potential is during the use phase. By lowering the rolling resistance of the tyres the fuel consumption and thus GHG emissions can be reduced. GHG emissions from the use of tyres are however also dependent on car and fuel industries. As the impact on the GHG emissions from raw materials is limited energy use has the second best potential for GHG emission reductions. By substituting more energy sources in the factories and sales facilities by renewable or carbon neutral sources GHG emissions could be reduced.

TIIVISTELMÄ

LAURA KOKKO: Kasvihuonekaasupäästöt rengasteollisuudessa – case Nokian Renkaat
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Huoli ilmastonmuutoksesta on viime aikoina lisääntynyt. Pääsyy ilmastonmuutokselle on kasvihuonekaasujen lisääntyneet konsentraatiot ilmakehässä. Jotta vaaralliset muutokset voidaan estää, on kasvihuonekaasupäästöjä kontrolloitava. Kasvihuonekaasupäästöselvitystä voidaan pitää tärkeänä työkaluna päästöjen hallinnassa, sillä päästöt on tunnettava, jotta niitä voidaan vähentää.

Tämän työn tarkoituksen oli määrittää kaikki oleelliset kasvihuonekaasupäästöt rengasteollisuuteen liittyen. Huomiota kiinnitettiin erityisesti epäsuoriin päästöihin. Esimerkkinä tutkittiin Nokian Renkaiden toimintaan liittyviä kasvihuonekaasupäästöjä. Tutkimukseen sisällytettiin raaka-aineiden valmistuksesta ja kuljetuksesta, renkaiden valmistuksesta, jakelusta ja myyntitoiminnoista, renkaiden käytöstä ja renkaiden loppusijoituksesta aiheutuvat kasvihuonekaasupäästöt. Valmistuksen päästöihin sisällytettiin myös epäsuorat kasvihuonekaasupäästöt toimintaan liittyvistä lisätoimista kuten työmatkoista ja jätteiden käsittelystä. Kokonaiskasvihuonekaasupäästöjen laskemiseksi muut kasvuhuonekaasut kuin hiilidioksidi muutettiin hiilidioksidi-ekvivalenteiksi (CO_2e) käyttäen niiden lämmityspotentiaaleja. Kaikki kasvihuonekaasupäästöt laskettiin käyttäen aktiivisuusdataa ja päästökertoimia. Lisäksi tehtiin laskuri, jonka avulla vuotuisten kasvihuonekaasujen laskenta on helppoa pelkän aktiivisuusdatan avulla.

Useat tutkimukset ovat osoittaneet käytön aikaisten päästöjen muodostavan suurimman osan renkaan kasvihuonekaasupäästöistä. Tässä tutkimuksessa rengastuotannon kokonaiskasvihuonekaasupäästöt olivat 30 364 kg CO_2e/t tuotettuja renkaita. 87 % näistä päästöistä syntyi renkaiden käytöstä. Vain pieni osa päästöistä syntyy renkaiden valmistuksesta (2,1 %). Suurin osa valmistuksen päästöistä tulee energian käytöstä ja suuri hiilineutraalien energialähteiden käyttö piti kasvihuonekaasupäästöt alhaisina. Jakelu ja myyntitoimintojen päästöistä suurin osa syntyi myyntipisteiden energiankäytöstä. Raaka-aineiden kasvihuonekaasupäästöt muodostivat toisiksi suurimman osan kokonaiskasvihuonekaasupäästöistä (7,8 %). Renkaiden loppusijoituksesta syntyvät päästöt olivat merkityksettömät (alle 0,1 %).

Suurin potentiaali kasvihuonekaasupäästövähennyksiin on renkaan käytön aikana. Laskemalla renkaan vierintävastusta voidaan vähentää polttoaineen kulutusta ja samalla päästöjä. Käytön aikaiset päästöt ovat kuitenkin riippuvaisia myös auto- ja polttoaineteollisuudesta. Raaka-aineiden päästöihin voidaan vaikuttaa vain rajallisesti, joten enemmän potentiaalia päästövähennyksiin on energian käytössä. Vaihtamalla tuotantolaitosten ja myynti-pisteiden energialähteitä hiilineutraaleihin vaihtoehtoihin voidaan kasvihuonekaasupäästöjä vähentää.

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LIST OF SYMBOLS AND ABBREVIATIONS

CH_4	methane
CIS	Commonwealth of Independent States; member states: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Uzbekistan; associate states: Turkmenistan, Ukraine
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
GWP	global warming potential
ELT	end-of-life tyre
EU-27	27 Member States of the European Union before 2013: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden and the United Kingdom
GHG	greenhouse gas
IPCC	the Intergovernmental Panel on Climate Change
ISO	the International Organization of Standardization
LCA	life cycle assessment
N_2O	nitrous oxide
NR	natural rubber
OH	hydroxyl
pkm	passenger kilometer
RF	radiative forcing
RR_C	rolling resistance coefficient
TEU	twenty-foot equivalent unit
tkm	tonne kilometre
VOC	volatile organic compound
WTT	well-to-tank

1. INTRODUCTION

Climate change is an ever growing concern and the increasing concentrations of greenhouse gases (GHGs) are the most significant cause for it (IPCC, 2013). GHGs are gaseous compounds that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth’s surface, the atmosphere and the clouds. They can be of natural or anthropogenic origin. (ISO 14064-1, 2012, p. 1) Carbon dioxide is regarded as the most important GHG. Other main gases are methane and nitrous oxide. GHGs are the main cause for the natural greenhouse effect. In the industrial era, however, the amount of GHGs has drastically increased which has led to global warming and climate change. (IPCC, 2007, p. 97) If GHG emissions are not controlled there will be further warming and changes in all components of the climate system. Thus GHG emissions need to be reduced substantially and sustainably in order to limit climate change. (IPCC, 2013, p. 19) The Paris Agreement is the most recent international effort to combat climate change. Its goal is to keep the global temperature rise this century below 2 °C above pre-industrial levels. It also aims to strengthen the ability of countries to deal with the impacts of climate change. Nations who have ratified the Agreement each have their own GHG reduction goals and they are required to report regularly on their emissions and implementation efforts. The Agreement stepped into force in November 2016. (UNFCCC, 2016)

The first step in controlling emissions is knowing them and where they come from. One tool for determining the emissions is GHG assessment. The aim of the assessment is to determine all relevant GHG emissions and their sources. The assessment can be done for an organization or for a product or service. GHG assessment can be done as part of a life cycle assessment (LCA) or it can be its own entity. In LCAs the many different impacts caused by a product or service to the environment are taken into consideration more extensively as where GHG assessment only focuses on the GHG emissions.

Setting the boundaries for the assessment is a crucial phase. By setting the boundaries differently the results can vary tremendously. Thus it is important to incorporate all relevant operations in order to have as accurate and complete GHG assessment as possible.

There are several LCA and carbon footprint studies concerning tyres. However, they are usually focused with only one tyre and its life cycle instead of the whole operations of a tyre factory for instance. The goal of this thesis was to determine all relevant direct and indirect GHG emissions linked to tyre production and the auxiliary activities. Special focus was on the indirect GHG emissions. As a case study emissions of Nokian Tyres were assessed. Nokian Tyres has its own retail chain thus emissions from retail operations could also be included. Emissions were assessed separately for the factories both in Nokia and in Vsevolozhsk, and for the retail chain Vianor. The assessment was done based on the ISO 14064 standard. In addition the GHG Protocols Corporate Value Chain (Scope 3) Accounting and Reporting Standard was followed.

Another goal was to create a calculator that makes assessing the annual GHG emissions easy. By assessing the GHG emissions annually the development of the operations can be evaluated from the GHG emission point of view. Possible reductions can be seen quickly with continuous following of the GHG emissions. Nokian Tyres had earlier a GHG calculator for determining the GHG emissions from the Nokia factory. The calculator was now updated and expanded to apply for the Vsevolozhsk factory and the Vianor chain as well.

In this study the principles and goals of a GHG assessment are explained more thoroughly first. Then the full life cycle of a tyre from cradle to grave and the possible GHG emission sources during the cycle are presented. The information needed for assessing the GHG emissions from tyre production was collected as primary and secondary data. GHG emissions from all operations during the life cycle of tyres were calculated. Based on the results GHG emission reduction possibilities are presented.

2. GREENHOUSE GAS ASSESSMENT

2.1 The Greenhouse Effect

Earth’s climate system is powered by solar radiation. About 30 % of the sunlight reaching the top atmosphere is reflected back to space by clouds, aerosols or light-coloured surfaces of the Earth (e.g. snow, ice and deserts). The radiation that is not reflected back to space is absorbed by the Earth’s surface and atmosphere. The surface then emits energy to the atmosphere and the atmosphere in turn emits energy back to the Earth and out to space (figure 2-1). GHGs absorb and re-emit the longwave radiation keeping it in the atmosphere and thus warming the Earth’s surface. Without the natural greenhouse effect the average temperature on the Earth would be about 30°C colder. (IPCC, 2007, pp. 115-116)

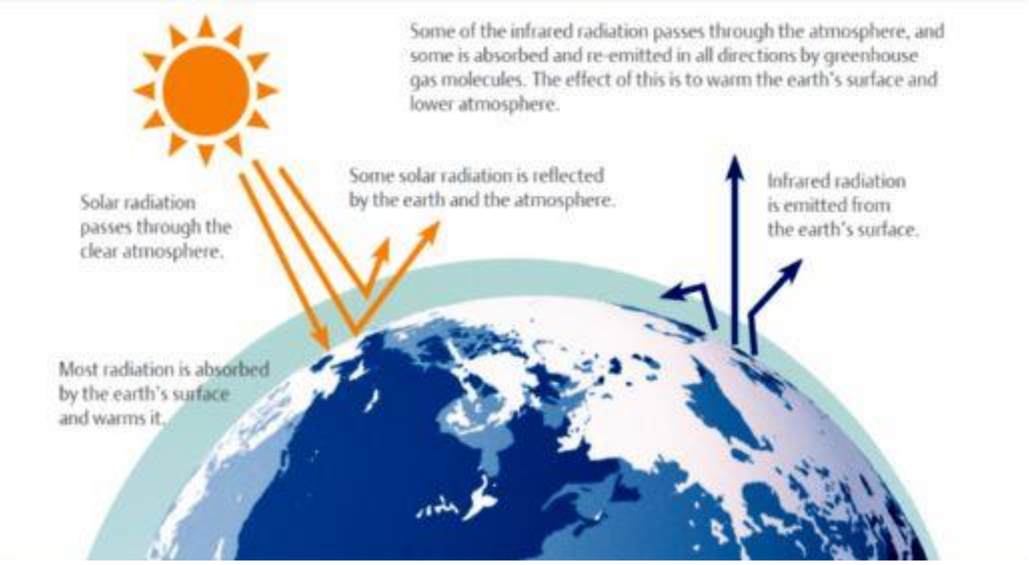


Figure 2-1 An idealized model of the natural greenhouse effect (Emerson, 2016)

The most important GHGs are water vapour and carbon dioxide (CO_2). Other less prevalent, but powerful GHGs are methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (table 2-1). (IPCC, 2007) Water vapour is the largest contributor to the greenhouse effect. However it is mostly of natural origin, anthropogenic emissions through irrigation for example, have only a negligible impact on the global climate. Air temperature controls the amount of water vapour in the atmosphere, not the amount of emissions. Thus water vapour is seen as a feedback agent rather than a forcing to climate change. (IPCC, 2013, pp. 666-667)

Although volatile organic compounds (VOCs) are not usually seen as GHGs they affect the climate as well. Their impact on the atmosphere is mostly indirect. VOCs have a short atmospheric lifetime and their direct effects on radiative forcing are small. They affect the global warming indirectly by producing ozone and aerosols in the presence of nitrous oxides and sunlight. (IPCC, 2001) VOCs also cause methane build-up in the atmosphere. They are oxidized by hydroxyl (OH) radicals which leads to increased competition for the OH radicals thus lowering the oxidation capacity of the troposphere. While methane's build-up is controlled by the oxidation capacity this leads to higher methane concentrations. (Collins, 2002) VOCs are mostly of natural origin caused by vegetation. The largest anthropogenic sources of VOC are motor vehicles through evaporation or incomplete combustion of fuel. (IPCC, 2001)

Human activities have intensified the natural greenhouse effect, causing global warming. Main reasons for the increase in the GHG concentrations are burning of fossil fuels and the change in land-use mostly due to clearing of forests. In the last two centuries the atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen, and this can be linked to the increase of GHGs. (IPCC, 2013, pp. 3,129)

2.2 Global Warming Potential

There are several ways to examine how different drivers affect the climate. One of the most widely used metrics used to provide estimates of the climate impact is radiative forcing (RF). RF is a measure of the influence a factor has in the energy balance of the Earth system. A positive forcing warms the system, while negative forcing cools it. RF values are usually expressed in Watts per square meter (W/m^2). Many other metrics are based on RF. (IPCC, 2013, p. 664) One of these is global warming potential (GWP). The Intergovernmental Panel on Climate Change (IPCC) (2013) defines GWP as the cumulative RF integrated over a period of time from the emission of a gas relative to emission of an equal mass of CO_2. Radiative efficiencies of the various substances and their lifetimes in the atmosphere affect their GWP. GWP has become the default metric for transferring emissions of different gases to a common scale, precisely carbon dioxide equivalent (CO_2e). GHG gases can be converted to CO_2e using equation 1

$$GHG\ emissions\ (kg\ CO_2e) = m \times GWP, \tag{1}$$

where *m* is the mass of the GHG and GWP the global warming potential of the gas. GWPs of carbon dioxide, methane, and nitrous oxide are presented in table 2-1. Although IPCC published new GWP values in 2013 here are presented the values from 2007 while they were used when doing the present GHG assessment.

Table 2-1 Global warming potentials and lifetimes of the most abundant greenhouse gases (based on (IPCC, 2007; IPCC, 2013))

Species	**Chemical formula**	**Lifetime (years)**	**Year**	**Global Warming Potential (Time Horizon)**		
				20 years	100 years	500 years
Carbon dioxide	CO_2	variable*	2007, 2013	1	1	1
Methane	CH_4	12	2007	72	25	7.6
			2013	84	28	
Nitrous oxide	N_2O	114	2007	289	298	153
			2013	264	265	
*Lifetime of CO_2 differs due to carbon cycle						

GWPs can be integrated over different periods of time. The typical periods used are 20, 100, and 500 years with 100 years being the most commonly used. Choosing shorter time period gives more value to the impact of short lived gases whereas longer time period to the impact of long-lived gases. (IPCC, 2013, pp. 710-711)

2.3 Scope 3 Emissions

GHG emissions can be divided into three categories direct emissions, energy indirect emissions and other indirect emissions. GHG Protocol defines the categories as scope 1, 2 and 3 emissions (figure 2-2). Scope 1 emissions are direct emissions from sources owned or controlled by the reporting company. Scope 2 emissions are indirect emissions from purchased electricity, steam or heating and cooling and scope 3 emissions include other indirect emissions. (GHG Protocol, 2004, p. 12) Indirect emissions are emissions that occur at sources not owned or controlled by the reporting company but are result from its activities. (GHG Protocol, 2011, p. 27)

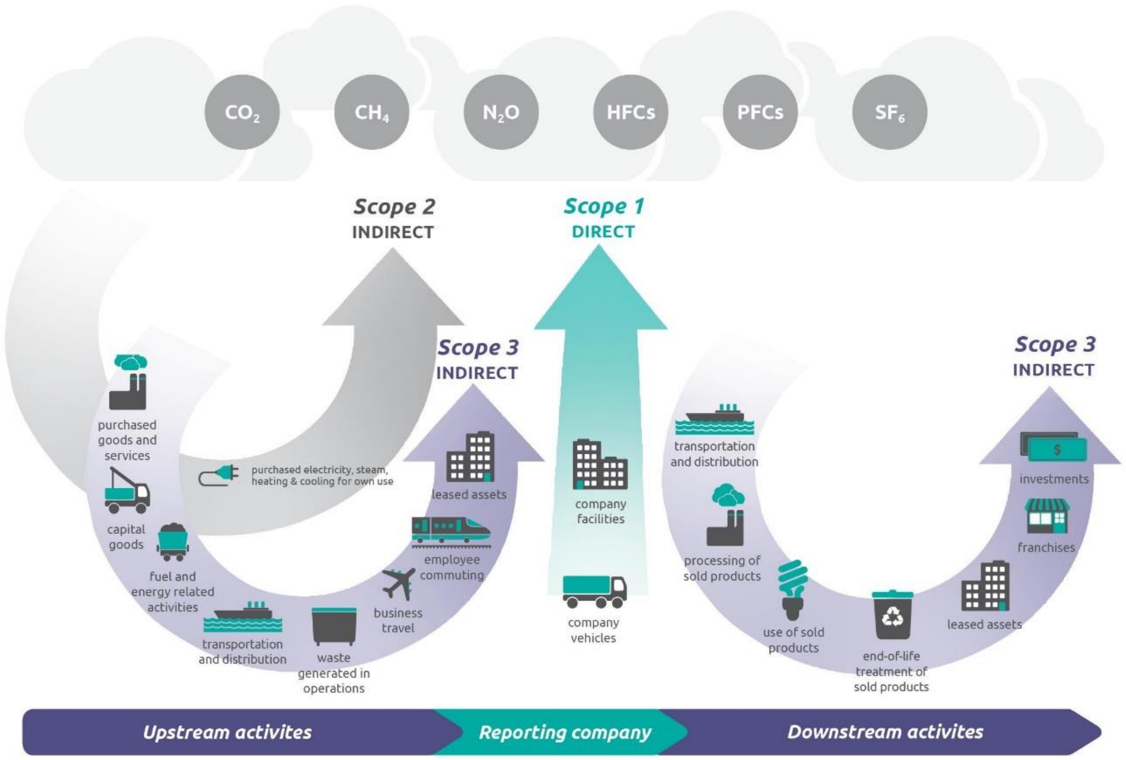


Figure 2-2 Scopes and emissions across value chain (GHG Protocol, 2011, p. 5)

Scope 3 emissions can be from upstream or downstream activities in the value chain. Upstream emissions consist of emissions from purchased goods and services and of indirect emissions that occur before or during the manufacturing process while downstream emissions are indirect emissions that occur after the product leaves the production facility. Scope 3 emissions can represent the largest source of GHG emissions for organizations. Scope 3 emissions can be divided into several categories in order to calculate them and to help define if they are relevant (table 2-2). (GHG Protocol, 2011)

Table 2-2 Division of the scope 3 emissions into different categories (GHG Protocol, 2011)

Scope 3 category	
Upstream emissions	**Downstream emissions**
1. Purchased goods and services	9. Downstream transportation & distribution
2. Capital goods	10. Processing of sold products
3. Fuel- and energy-related activities	11. Use of sold products
4. Upstream transportation & distribution	12. End of life treatment of sold products
5. Waste generated in operations	13. Downstream leased assets
6. Business travel	14. Franchises
7. Employee commuting	15. Investments
8. Upstream leased assets	

Purchased goods and services account for all raw material acquisitions as well as services bought from outside the organization such as cleaning and maintenance. Capital goods include all cradle-to-gate emissions of bought or acquired capital goods such as furniture, office supplies or machinery. Also emissions from building new properties should be accounted in capital goods emissions. Fuel- and energy-related emissions may consist of cradle-to-gate emissions of bought fuels. Upstream transportation and distribution include all purchased transportation services. Also transportation of bought products is included here. Although transportation of raw materials may also be included in the emissions from purchased goods. Waste generated in operations include emissions from treating both wastes and waste water. Business travel and commuting categories both consist of emissions from transportation of employees. Emissions from leased assets where the reporting organization is the lessee are reported in upstream leased assets

Downstream transportation and distribution includes transportations between the reporting organization's operations and the end consumer, if not paid for by the reporting organization. In addition retail and storage are included here when they are not owned or controlled by the reporting organization. Emissions from leased assets where the reporting organization is the lessor are reported in downstream leased assets. Depending on the consolidation approach used to define the organizational boundaries emissions from both upstream and downstream leased assets categories may be reported as scope 1 or 2. When organization sells intermediate products the emissions from further processing are reported in the processing of sold products category. Emissions from the use of the sold products are also reported as scope 3 emissions. The emissions can be direct where the product consumes energy during use (e.g. cars) or indirect where the product indirectly consumes energy (e.g. tyres). Emissions from disposal and treatment of the sold products at the end of their life are also reported. If the reporting organization has franchises their scope 1 and scope 2 emissions occurring during operation should reported in scope 3 emissions as well. Category 15 is primarily meant for investors and companies that provide financial services. In here the scope 1 and 2 emissions of the investee are reported. (GHG Protocol, 2011)

2.4 Objectives and Principles of Greenhouse Gas Assessment

The object of a GHG assessment is to determine GHG emissions of an organization. It is a part of LCA. In LCA all environmental impacts of a product or service are determined throughout its whole lifetime. The GHG assessment can also be known as carbon footprint and it only takes into account the emissions of GHGs. LCA is composed of four basic steps: goal and scope definition, inventory analysis, impact assessment, and interpretation which also apply to some extent when making a GHG assessment. (UNEP, 2016)

Inventorying emissions is the first step to controlling them. When the emissions are determined the emission hotspots can be identified and reduction efforts can be prioritized according to them. GHG inventory can also be used for eco-labelling and certification. Nowadays when the large public is more interested in environmental issues a small carbon footprint can be an asset for a product or service. Organizations can also enhance their reputation by reporting the GHG inventory to stakeholders or by adding the inventory to sustainability reports. (GHG Protocol, 2004, pp. 11-14; GHG Protocol, 2011, p. 13) GHG emissions can be reported in registries administered by for example governments or industry groups. If a mandatory GHG reduction program is established later the earlier reductions may be taken into account as well if they are registered. Usually only direct emissions and indirect emission from purchased energy are required in different GHG programs. (GHG Protocol, 2004, pp. 11-14)

GHG accounting and reporting should be done according to five principles: relevance, completeness, consistency, accuracy and transparency. The object of these principles is to ensure that the GHG assessment is true and fair. The GHG inventory should represent GHG emissions of the company and offer appropriate information to decision-making. All relevant GHG emissions and reductions should be included and specific exclusions justified. The accounting methodologies should be consistent to enable meaningful comparisons over time. Changes in assessment methodologies should be recorded. The assessment should be as accurate as possible. That can be achieved by reducing bias and uncertainties as far as practicable. Sufficient information regarding the assessment and how it is made should be available to users. All relevant assumptions should be brought out and appropriate references to the accounting and calculation methodologies and data sources used should be made. (GHG Protocol, 2004, p. 7; ISO 14064-1, 2012, p. 6)

2.5 Setting Boundaries

The protocols of making GHG assessments can vary widely and often only part of the emissions are estimated. Determining the boundaries is important for the accuracy and completeness of the assessment. Although only scope 1 and 2 emissions are required in different GHG programs often scope 3 emissions make the largest portion of all emissions. In USA on average direct emissions only cover 14% of the total value chain emissions of an industry, while direct emissions and indirect emissions from energy input cover 26% of the total emissions. By leaving scope 3 emissions out of the assessment the GHG inventory may look much better but can actually be far from the truth. (Matthews, 2008) Thus inventorying also scope 3 emissions is important. It can give organizations a better understanding about the impacts of their emissions through the entire value chain. At the same time potential risks can be identified and opportunities to reduce emissions and costs through the value chain can be found. (GHG Protocol, 2011, pp. 11-14) And because organizations usually can influence their supply chains to some degree they can contribute to a better climate change policy. (Matthews, 2008)

Determining an approach for consolidating GHG emissions is important for setting boundaries as well. The selection of a consolidation approach affects the organizational boundaries thus affecting which activities in the value chain are categorized as direct emissions and which as indirect emissions. The GHG emissions can be consolidated by two different approaches: the equity share and the control approaches. When using the equity share approach the reporting company accounts for GHG emissions from operations according to its share of equity in the operation. Emissions from assets the company controls but does not own are reported as indirect emissions while emissions from partially or wholly owned assets are reported as direct emissions. Under control approach 100 percent of the GHG emissions from operations over which the company has control are accounted to it. If company only owns an interest in operations but does not have control it does not account for the emissions from the operations. Control can be defined in financial or operational terms. Depending on the definition of control emissions from financially or operationally controlled assets are inventoried as direct emissions while emissions from assets owned but not controlled by the company are included in the scope 3 category. (GHG Protocol, 2004)

Following a standard when inventorying emissions can give the inventories better comparability to those of other products or services. Standards are documents that provide requirements, specifications, guidelines or characteristics that can be used to ensure quality, safety and efficiency of products, services and systems. (ISO, 2016) Although there are various different standards with varying guidelines and that may make the comparing difficult between results obtained following different standards.

2.6 ISO 14064 Standard

The most known organization that provides standards for many fields and purposes is the International Organization for Standardization (ISO). It is a worldwide federation of national standards bodies. The ISO standards are prepared through ISO technical committees and all member bodies have the right to be represented on the committees. The main task of the committees is to prepare the International Standards. Standard drafts have to be approved by at least 75% of member bodies before publication as International Standard. (ISO, 2016)

The purpose of ISO 14064 is to help organizations, governments, project proponents and stakeholders by providing clarity and consistency for quantification, monitoring, reporting and validating GHG inventories. ISO 14064 consists of three parts. The first part gives guidance for quantification and reporting of GHG emissions and removals at organization level, the second part focuses on projects designed to reduce GHG emissions or increase GHG removals and the third details principles and requirements for verifying GHG inventories and projects. (ISO 14064-1, 2012, p. v)

Quantification of GHG emissions should be done according to the following steps:

1) identification of GHG sources and sinks;
2) selection of quantification methodology;
3) selection and collection of GHG activity data;
4) selection or development of GHG emission or removal factors;
5) calculation of GHG emissions and removals (ISO 14064-1, 2012).

Direct or indirect GHG sources or sinks may be excluded if their contribution to emissions or removals is not significant or their quantification would not be technically feasible or cost effective. The exclusions have to be explained though. Quantification methodologies can be classified into three categories: calculation, measurement, or combination of both. Calculation can be based on activity data multiplied by emission factors, the use of models, facility-specific correlations, or mass balance approach. The measurement of emissions can be either continuous or intermittent. (ISO 14064-1, 2012)

If activity data are used to quantify GHG emissions, the selected and collected data should be consistent with the selected quantification method and the emission factors should be derived from recognized origin and be appropriate for the GHG source or sink. The emission factors should also take account of quantification uncertainty. (ISO 14064-1, 2012) Activity data express the magnitude of human activity resulting in emissions or removals taking place during a given period of time. Emission factors express the average amount of GHG released to the atmosphere relative to selected measure of activity.

The following, where quantified, should be reported separately in the GHG inventories:

1) direct GHG emissions (scope 1);
2) GHG removals;
3) energy direct GHG removals (scope 2);
4) other indirect GHG emissions (scope 3);
5) direct CO_2 emissions from the combustion of biomass (ISO 14064-1, 2012).

ISO 14064 standard does not require organizations to quantify other indirect emissions. Indirect emissions may be determined, however, based on the requirements of applicable GHG programs, internal needs or the intended use of the GHG inventory. (ISO 14064-1, 2012)

2.7 Greenhouse Gas Protocol Standards

Greenhouse Gas Protocol (GHG Protocol) offers organizations standards for accounting GHG emissions in different situations. GHG Protocol also offers calculation tools to help organizations to assess their emissions. In the standards of GHG Protocol there is given more specific guidance on how to account for GHG emissions than in ISO 14064, for instance.

In GHG Protocol’s Corporate Value Chain (Scope 3) Accounting and Reporting Standard (2011) there are specific instructions on what scope 3 emissions to include in the inventory. All of the emission categories presented in table 2-2 should be thought of and if some emissions are excluded the decision should be explained and justified. GHG assessment can be done according to ISO 14064 standard also when GHG Protocol’s Corporate Value Chain (Scope 3) Accounting and Reporting Standard is used as more specific guidance in accounting of GHG emissions.

3. LIFE CYCLE OF A TYRE

The life cycle of a tyre can be seen to consist of five stages: (1) production of raw materials, (2) manufacturing, (3) distribution, (4) use stage and (5) end-of-life treatment. The different stages and emissions related to the stages are explained in this chapter.

3.1 Production of Raw Materials

Typically a tyre consists of about 60 raw materials, of which the most important are polymers. Polymers consist of both natural and synthetic rubbers. Polymers create the backbone for the rubber compounds used in tyres. Fillers make the second largest proportion of rubber compound. Rubber compound also contains plasticisers, booster chemicals and vulcanising and protective agents. (NHTSA, 2006, p. 6) Typical composition of rubber compound in tyres is presented in figure 3-1. A tyre contains several different rubber compounds each with a specific combination of materials to provide the desired attributes for the various parts. For example, the compound used for the inner liner is specifically designed for minimizing air loss, and the tread compound is designed to provide traction and resistance to wear, while minimizing the impact on the vehicles fuel consumption. (ETRMA, 2012)

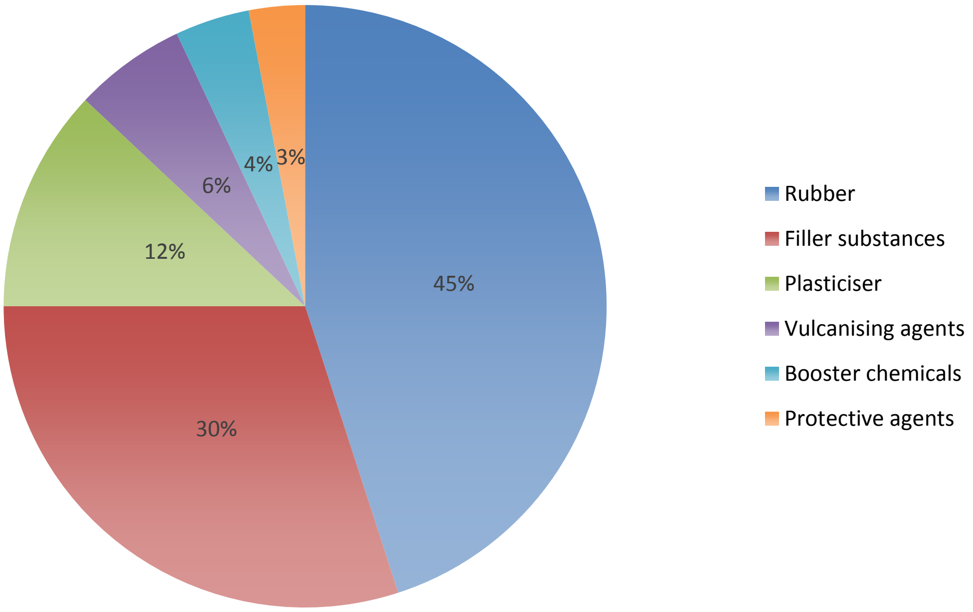


Figure 3-1 Raw material composition of rubber compound (weight-%) (based on Nokian Tyres 2016c)

In addition to the rubber compound tyres also contain reinforcement materials. Steel wires and plies as well as textiles are used in tyres to provide strength and stability. (NHTSA, 2006, p. 6) Of a passenger car tyres weight about 10-15 % consists of steel and 5% of textiles. (WBCSD, 2008, p. 2) Some of the major components of tyres and their production are further described in the following.

3.1.1 Natural Rubber

Natural rubber is made from latex. Liquid latex is extracted by tapping from the rubber trees. Rubber trees are grown on rubber plantation of different sizes. It takes seven years for a rubber tree to start producing latex after which it has 13-18 productive years. (Jawjit, 2010, p. 403) Over 85 percent of the world's natural rubber comes from small plantations that are less than two hectares in size. From the plantations natural rubber is forwarded through wholesalers to processors. (Nokian Tyres, 2016c, p. 39) There the fresh latex can be processed to primary rubber products, which can then be processed to different final rubber products. The most important primary rubber products are concentrated latex, block rubber and ribbed smoked sheet rubber, of which block rubber is the most used in tyre manufacturing. Since most of the natural rubber products are being imported to international markets rubber mills try to focus on pollution reduction and more environment friendly production. (Jawjit, 2010, p. 403) Asia is the biggest producer of natural rubber with Indonesia, Malaysia and Thailand being the largest exporters. Tyre industry uses up to 74% of the natural rubber imported to Europe. (ETRMA 2014)

Emissions from natural rubber production come from rubber plantations and mills. Emissions from plantations consist of CO_2 and N_2O emissions from the production of raw materials, such as fertilizers and fuel, used in the plantation and from the activities on the plantation. Emissions from the plantations include emissions from fertilizer and machinery use. Emissions from plantations cover the entire lifecycle of a rubber tree including soil preparation and the non-productive phase of the trees. Land conversion causes the largest amount of emissions in natural rubber production though. Changing tropical forest into plantations causes carbon loss and cultivation of forest soil takes more fertilizers and energy for tillage of soil. Emissions from rubber mills are relatively low although producing block rubber causes more emissions while the production process is more energy intensive than production of other primary rubber products. (Jawjit, 2010)

3.1.2 Synthetic Rubber

Synthetic rubbers have similar properties as natural. Most synthetic rubbers are produced through polymerization or polycondensation of unsaturated monomers. (TIS (Transportation Information Service), 2016) Butadiene, a by-product of petroleum refining, and styrene, captured either in the coking process or as a petroleum refining by-product, usually form the origin of general purpose synthetic. (RMA, 2016) There are various types of synthetic rubbers with different properties. Co-polymerization of different monomers allows the properties to have a wide range of variations. (TIS

(Transportation Information Service), 2016) Styrene-butadiene rubber, polybutadiene rubber, and butyl rubber are the three most used synthetic rubbers. (Maxxis, 2016) Styrene-butadiene rubber is the most commonly used synthetic rubber in tyre industry (Quantis, 2013).

Because synthetic rubber is petroleum based emissions are mostly produced during the production of its raw materials. Other source for GHG emissions is the energy needed for the polymerization. The polymerization may also lead to some emissions of VOCs. Indirect VOC emissions are however not included in the present assessment.

3.1.3 Filler Substances

Reinforcing fillers are used in tyres to give them more strength, stiffness and resistance to abrasion. Thus resulting in longevity of the tyres, in terms of overall load bearing, durability, and tread wear performance. Carbon black is the most common filler in tyre manufacturing. Amorphous silica is often used as a filler as well. (ETRMA, 2012) Some other materials, such as calcium carbonate and kaolin clay, may also be used to give the rubber compound different properties (Mujkanovic, 2009).

Carbon black is a black, powder or granular substance that is made by burning hydrocarbons such as oil or natural gas in limited supply of air (Crump, 2000). To keep the oxidation incomplete the reaction is controlled by quenching with water. The unburned carbon is collected from the combustion gases as a fine powder. The powder is then pelletized to produce the material used by the tyre industry. (ETRMA, 2012) Carbon black can be produced by five different processes. (Crump, 2000) 95 % of carbon black is produced using the furnace black process (IPCC, 2006).

Amorphous precipitated silica is produced from vitreous silicate. Amorphous silica is precipitated from silicate, dissolved in water, through acidification and under agitation. The precipitated silica is then mechanically processed into micro pearls or granules to ease shipping, handling and use. This form is also used by the tyre industry. (ETRMA, 2012) By substituting part of the carbon black fillers with silica the rolling resistance of the tyre can be reduced thus lowering GHG emissions during the use phase of a tyre.

3.1.4 Textile Plies

Most commonly used textiles in tyres are rayon, nylon and polyester. (NHTSA, 2006, p. 80) Rayon is semisynthetic fibre meaning it is formed of natural polymer, cellulose. Nylon and polyester are true synthetics and they are polymerized from smaller chemical units into long-chain molecular polymers. Fibres are formed by extruding the molten polymer through the small openings of a spinneret and immediately solidifying or precipitating the resulting filaments. After extrusion, fibres can be further processed to meet the required physical or handling properties. (US EPA, 1995, pp. 6.9-1-2) The fibres are then spun into a yarn and several yarns can be further twisted to a cord. The size of a filament, yarn, or cord is usually expressed as decitex which represents the weight of 10 000 metres of the yarn in grams. (NHTSA, 2006, p. 83)

The production of the polymer melt is the most consuming phase of the production of synthetic fibres. Base material for the polymer granulates is usually petroleum based chemicals or petrochemicals. Water, other chemicals and energy are also needed for the polymerization. For extrusion some chemicals may be used to liquefy the polymer but mostly emissions come from energy usage for both extrusion and the spinning of the yarn. Yarn made from recycled fibres produces less GHG emissions while the most consuming phase is avoided.

3.1.5 Steel Plies and Wire

Brass or copper coated high carbon steel is used to produce the steel wires and plies for tyres. (NHTSA, 2006) Steel production is emission and energy intensive. The amount of required energy depends on technology and production route used, and also varies by region. Emission intensity is expressed as a ratio to energy ratio and it depends on the used fuels. Primary steel is produced from iron ore in two stages. First iron oxides of the ore are reduced to pig iron using coal or coke. Pig iron is then purified to make crude steel which can be modified depending on the properties wanted. Steel can also be made in electric-arc furnaces by secondary production route using recycled steel. 70 % of all steel is made using pig iron. (IPCC, 2014) The produced steel is then moulded to the wanted form. To make wire the steel billet is first rolled to rod which is then drawn to wire using dies. Finally the cords are coated with either brass or copper.

Making of pig iron is the most emission intensive part of steel production because of the coal and coke used (IPCC, 2014). In the secondary steel production route no coal or coke is needed thus by using recycled steel as a raw material emissions can be reduced. The energy intensity of primary steel production by blast furnace is on average 21 GJ per tonne of steel as for secondary production route the required energy is only 9.1 to 12.5 GJ per tonne of steel. The moulding of steel into a wire produces a small amount of the emissions of the entire production process. Emissions from the finishing phases are mostly direct or indirect emissions from energy use. (Pardo, 2012)

3.1.6 Other Additives and Chemicals

Besides the earlier mentioned materials tyres contain smaller amounts of several different additives and chemical compounds. Petroleum oils, pine tar, resins and waxes are used as softeners to help processing and to improve the adhesiveness of unvulcanized compounds. Waxes are also used as antidegradents along with antioxidants to protect tires against deterioration. To link the polymer chains and make the rubber strong and elastic the tyres are vulcanized. Sulphur, accelerators and activators are added to the compound to help during vulcanization. (NHTSA, 2006)

3.2 Manufacturing

The tyre manufacture process consists of five main functions after the procurement of raw materials: mixing, component manufacture, assembly, curing and inspection (figure 3-2). First rubber mixtures are made. Composition of the mixture affects the properties of the finished tyre, which is why different mixtures are made for different tyres. Also different components require different kinds of rubber compounds. (Nokian Tyres, 2016c, pp. 116-117) The appropriate blend of rubbers, fillers, oils and pigments are combined to batches of 180 kg to 500 kg. Batches are flattened into slabs or extruded and cut into pellets for storage and later blending with other batches or materials. (NHTSA, 2006, p. 20) Each mixing batch is tested before it is put to use. (Nokian Tyres, 2016c, p. 117)

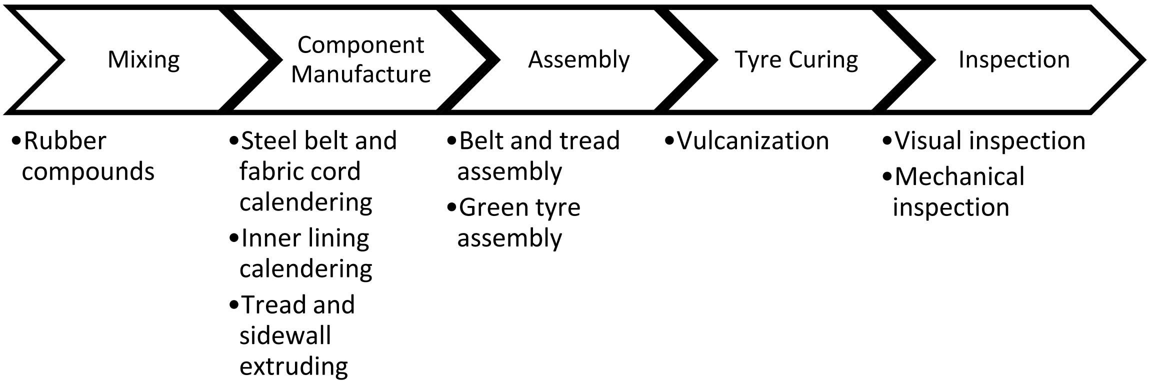


Figure 3-2 Flow chart of the tyre manufacturing process

In component manufacture rubber compounds, textiles and steel wires are used to make various components for the tyres. A tyre may consist of 10 to 30 different components such as body plies, bead, core, steel belt, sidewall and inner lining (figure 3-3). To produce fabric or steel belts the rubber compound is pressed on and into the steel or fabric cords in calenders. The calender is a heavy-duty machine that presses the components between two or more rotating rolls to form thin, flat sheets. (NHTSA, 2006) Also the inner lining of the tyre is calendered to create a thin layer (Maxxis, 2016). Sidewalls and treads are manufactured by extruding (NHTSA, 2006). Most of the components are various kind of reinforcements (Nokian Tyres, 2016c, p. 117).

The finished components are then assembled by assembly machines into carcass and belt packages. Body ply denier, cord style and number of plies affect the tyres body strength and are chosen based on desired characteristics. (NHTSA, 2006) The carcass package consists of the inner surface and the sidewalls of the tyre. Reinforcement ply is used as necessary. Belt package comprises the steel belt and surface rubber. The machine mounts the cables, turns the sidewalls and rolls the belt package on the carcass package. The result is a still soft and shapeable green tyre. (Nokian Tyres, 2016c, p. 118)

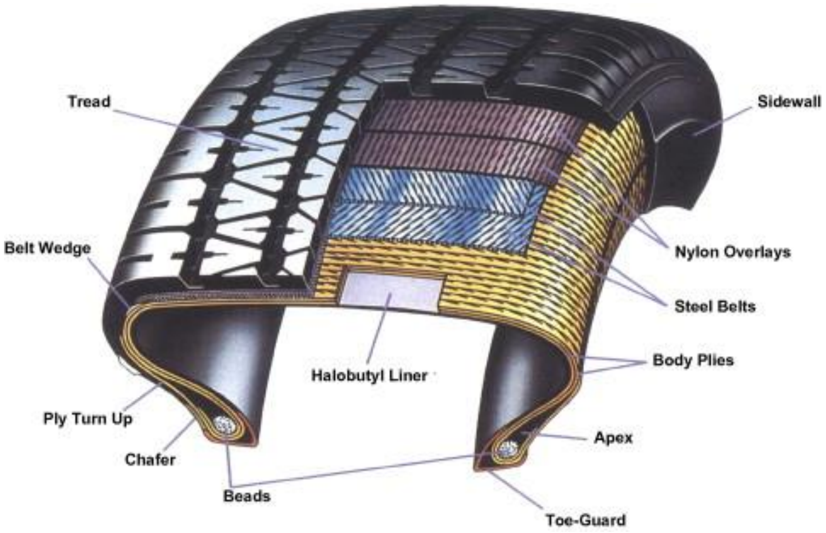


Figure 3-3 Cross-section of a high-performance passenger tyre (Rodgers, 2013)

The green tyre is then placed into a curing press. The tyre is pressed against the curing mould by high steam pressure of the curing pad. Curing vulcanizes the tyre and gives it its final shape and properties including the tread pattern, sidewall markings, airtightness and grip that affects handling. (Nokian Tyres, 2016c, p. 118) The tread pattern of the tyre can affect traction, noise, wear, and the tendency to wear non-uniformly. (NHTSA, 2006, p. 10) Passenger car tyres are cured for 8-20 minutes in about 170 C° depending on size. Heavy tyres need longer curing time. For example mining tyres are cured for over seven hours. Except for the curing time the production of heavy tyres follows similar steps as passenger car tyre production, although they often need more reinforcements. Also solvents are used in heavy tyre manufacturing in order to enhance the adhesion of the components. (Nokian Tyres, 2016c, p. 118)

The cured tyres are inspected both visually and by a machine. First the tyres are inspected for flaws visually and by feel. Machines measure the pattern as well as radial and lateral force variation of the tyre. The tyre is also pressurised and spun for roundness and balance in the inspection. The tyres are also x-rayed to check internal structure. (Maxxis, 2016; Nokian Tyres, 2016c) If a minor imperfection is detected and it cannot be buffed away or repaired, the tire is scrapped (NHTSA, 2006, p. 26). After the inspection the approved tyres are labelled with the basic tyre information, such as name, size and product code, and transported to logistics centres (Nokian Tyres, 2016c, p. 119).

Emissions from manufacturing stage mostly comprise of the emissions from energy use. Electricity, heat and steam are all needed in the manufacturing process. Emissions are of course dependent on the energy sources used. Other emissions are mainly indirect emissions from auxiliary processes such as waste and water management or business travel. The use of solvents in manufacturing may also lead to emissions of VOCs.

3.3 Distribution

Distribution stage covers all transportation between the tyre factory and the end user. Determining the total transportation distance can be difficult while distribution channels may consist of several stages, all of which are not necessarily controlled by the manufacturer. Often the manufacturer only has information regarding the transportation between its own facilities and the delivery to the first customer. Basically there are five main types of first clients, wholesalers, retailers, tyre dealers, vehicle manufacturers, and assembly centres. The first client defines the distribution route, which may involve several different operators. For example, a wholesaler can sell the tyres to a retailer, which then sells the tyres to the end users. (Quantis, 2013) In addition to the transportation, distribution stage also covers the wholesalers and retailers or other distribution routes.

Emissions from distribution may be difficult to determine due to several different route possibilities and several steps in each route. Tyres from the same manufacturing plant can end up all over the world and it is not necessarily feasible to determine every route possible. The first transportation steps are normally large bulk shipments. Thus their emissions are easier to determine. Further down in the distribution chain the shipments become smaller and smaller and determining the emissions becomes more difficult. The smallest shipments can consist of a single tyre. With the production rates being millions of tyres a year the amount of shipments also mounts high.

3.4 Use Stage

Use stage is the most impacting life cycle stage of tyres. It can cause as much as over 90 % of a tyre’s carbon footprint throughout its lifetime. About 20 % to 30 % of passenger cars’ GHG emissions during its use can be allocated to the tyres. Mainly this is caused by the rolling resistance of the tyres. Rolling resistance is defined by rolling resistance coefficient, which is the ratio between the force the tyre creates in resistance to movement on a surface and the load applied to the tyre. It is often expressed as kg force/t of load. (Quantis, 2013) The rolling resistance coefficient of a tyre is measured in a laboratory under controlled conditions. The basis for all tests is the same, the tyre is mounted on a free-rolling spindle, loaded against test drum, turned by the drum to simulate on-road rolling operation, and a measure of rolling loss evaluated. This test procedure is, however, not suitable for studded tyres. (NHTSA, 2009)

The fuel consumption related to rolling resistance is based on the energy needed to overcome the rolling resistance force over a distance. (Quantis, 2013) Thus by lowering the rolling resistance of a tyre the fuel consumption and at the same time the GHG emissions can be reduced. Studies have shown that a 1 kg/t decrease in rolling resistance leads to about a 5 % decrease in fuel consumption. (SEC, 2008)

Emissions from the use phase are difficult to determine accurately while the fuel consumption, and thus the amount of emissions, is dependent on many things other than just the rolling resistance of the tyres. Amongst the affecting factors is weights of the vehicle and the tyres, vehicle's aerodynamics, engine and driveline friction and driving behaviour (Quantis, 2013). Driving style is one of the biggest influencers in the consumption. With economic driving can be achieved over 20 % lower fuel consumption. Maintenance of the tyres also has an influence on the emissions. Driving with under-inflated tyres increases the rolling resistance thus increasing the emissions. (NHTSA, 2009)

Tyres are also a cause for particulate matter emissions. Due to the frictional energy between the road surface and the tyres they both wear releasing small particles into the air. The rate of the abrasion depends on a large number of factors, including driving style, tyre position, vehicle traction configuration, tyre material properties, tyre and road condition, tyre age, road surface age, and the weather. (Ntziachristos, 2013) However particulate matter emissions are not included in this assessment.

3.5 End-of-life Treatment

The worldwide production of tyres is estimated to be 1.7 billion pieces a year, all of which will eventually become end-of-life tyres (ELTs). (ETRMA, 2012) In 2011 in the European Union (EU) about 3.27 million tonnes of used tyres were generated. This included part-worn tyres (0.62 t) that can be reused as they are or by retreading them. 2.3 million tonnes of these tyres were recovered as energy or material while the rest were landfilled. (ETRMA, 2016a)

Recycling rates of tyres are quite high in many countries partly due to legislation and regulation. In 2011 in the EU-27 and Norway and Switzerland the average used tyre recovery rate was 95 % although the rates were heterogeneous in different countries ranging from under 70 % to 100 %. (ETRMA, 2016b) In Japan the recycling rate was 88 % in 2014 for comparison (JATMA, 2015) while in many developing countries recycling is only marginal. Used tyres are often landfilled or left in unmanaged dumping sites. Used tyres can cause serious health hazards when not managed properly. Tyre piles are ideal breeding grounds for rodents and mosquitos, which are known carriers of illnesses. In addition there is a risk of tyre fires in stock piles. (Reschner, 2008) Tyre fires are difficult to extinguish and can release toxic fumes and pyrolytic oil to the environment. (Reschner, 2008; Downard, 2015)

3.5.1 Management of End-of-life Tyres

Tyres have many different recycling possibilities and more are being studied. ELTs can be recycled as material or they can be used as energy. Nowadays only a small proportion of ELTs end up in landfills in Europe. Tyres with an intact body can be retreaded. It is one of the best ways to recycle a tyre. Bus and truck tyres may be retreaded up to 2 - 4 times. (Nokian Tyres, 2016c) In figure 3-4 are presented different management routes for ELTs and their shares of all used tyres in EU-27 in 2011. (ETRMA, 2016a)

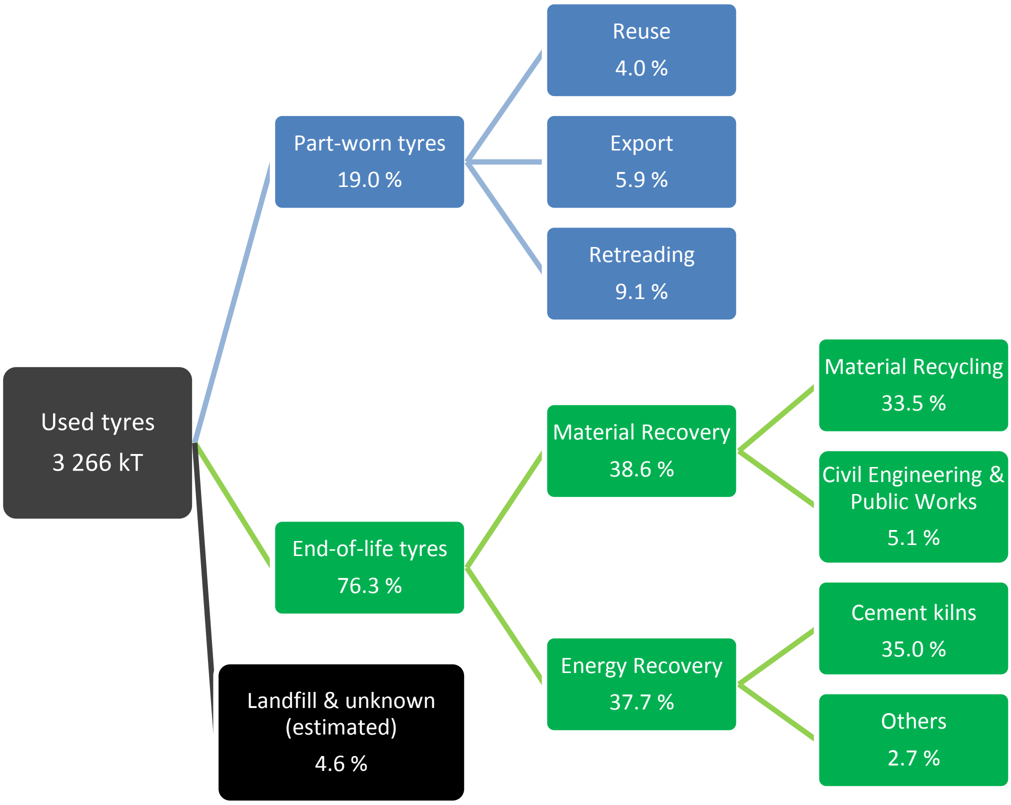


Figure 3-4 Management of end-of-life tyres in Europe in 2011 (based on (ETRMA, 2016a), figures may not add up due to rounding)

In EU energy and material recovery are equally used management routes. In the USA and Japan energy recovery is the most used route for ELTs while in Mexico and Canada most of ELTs are utilised as material (WBCSD, 2008).

3.5.2 Energy Recovery

ELTs have a high energy content thus they are often used for energy recovery. The lower heating value of a tyre is approximately 35.8 MJ/kg while that of oil is 40.4 MJ/kg, for example. (Clauzade, 2010) ELTs can be used to replace part of the fossil fuels in cement kilns, pulp and paper mills, thermal power stations and industrial boilers. They can also be used as a substitute for coal in steel foundries. In energy recovery the tyres can be used as whole or as shredded depending on the recovery route. In cement kilns the tyres can be used as whole but for pulp and paper mills they have to be shredded and the steel removed. (WBCSD, 2008) In cement kilns the steel fraction of the tyres is not removed. Iron is often added to cement kilns to improve the characteristics of the cement thus using scrap tyres as fuel eliminates the need to add iron minerals into the process. (Corti, 2004)

ELTs have lower carbon content as opposed to coal and petroleum coke and thus potential for reductions of GHG emissions. Using ELTs may also reduce nitrogen oxide and sulphur oxide emissions. In addition CO_2 emissions of the biomass fraction (natural rubber) can be regarded as zero, while rubber plantations have sequestered the carbon from the atmosphere. (WBCSD, 2008)

3.5.3 Material Recovery

In material recovery process the tyres are first shredded and textile is separated by aspiration and steel by magnets. (Lo Presti, 2013; WBCSD, 2008) The separated textiles can be burned in cement kilns and steel can be recycled. In passenger car tyres there is about 10-15 % steel and in heavy tyres even more. Rubber is then grinded into smaller particles using different methods. The ground rubber can then be used for several purposes.

One of the most common uses for crumb rubber is road pavements. The recycled rubber can be added to asphalt mixture to create more elastic pavement material which reduces noise level and has a longer lifespan. It can also be mixed with polymers to create moulded goods. Other uses for crumb rubber are synthetic turfs for running tracks and sports fields, ground cover under playgrounds and equestrian floors. When recycled rubber is used as raw material the need for virgin materials decreases also resulting in reduction of emission. (WBCSD, 2008) Although recycled rubber has many applications it has only a little use in production of new tyres. Generally the quality and properties of recycled rubber do not match that of virgin rubber and thus only a small proportion of recycled rubber can be added to tyres without affecting the rolling resistance or other properties. (Zelibor, 2005)

Tyres have also many uses in civil engineering as a whole or as shredded. ELTs have good technical properties for earth construction while they are lightweight, permeable, good thermal insulators, shock and noise absorbent and durable. (WBCSD, 2008) Thus they are used for example as road insulation, embankments and crash or noise barriers (Apila Group Oy, 2015). They can also be used in retention basins to substitute concrete and plastic blocks or in infiltration basins to substitute gravel (Clauzade, 2010).

Use of crumb rubber as the carrier in biofilters in waste water treatment has been studied as one use for ELTs. These filters have been shown to reduce the total nitrogen and ammonium nitrogen content. Also phosphorus was retained by the filter which was thought to be due to the iron in the shredded tyres. Iron can precipitate the phosphorus from its soluble form. (Pisto, 2014) The possibility of using crumb rubber as a filter in subsurface disposal systems in areas of dispersed settlement has also been studied and the results have been promising. In some states of USA the use of crumb rubber as filters in waste water treatment is already allowed. (Matilainen, 2015) Substituting sand and anthracite in filters has shown great promise. It has lighter density and ideal porosity gradient because the top layer of the media is the least compressed and the bottom layer of the media is the most compressed. Crumb rubber filters have also shown to need less water for backwashing. (Xie, 2007)

3.5.4 Environmental Effects

There have been several studies about the environmental effects of the various recovery alternatives for ELTs. By recycling tyres as material or energy there has been showed to have many positive effects for instance in the form of avoided emissions. (Corti, 2004; Clauzade, 2010; Fiksel, 2011)

According to Fiksel et al. (2011) every ton of tyre-derived fuel substituted for coal in cement kilns avoids an estimated 543 kg CO_2e of direct and indirect GHG emissions. If the emissions from the biomass fraction are taken into account the amount of avoided emissions is 613 kg CO_2e per ton of tyres. The use of ground rubber for artificial turfs seems to offer the greatest environmental emission reductions, but it has limited potential for large-scale utilization due to the saturated market for artificial turf. (Fiksel, 2011) According to Schmidt et al. (2009) material recovery is the better recovery option when compared to co-incineration in cement kilns. By using ELTs in the production of asphalt or moulded objects for example production of bitumen and synthetic rubber can be avoided. The separated steel fraction can be used to substitute iron ore. (Schmidt, 2009)

4. MATERIALS AND METHODS

4.1 Nokian Tyres

Nokian Tyres Plc (later Nokian Tyres) is a Finnish tyre manufacturer company founded in 1988. The history of Nokian Tyres traces back as far as to year 1898 when Suomen Gummitehdas Oy (Finnish Rubber Factory) was founded. The main factory of Suomen Gummitehdas was located in Nokia in 1904 and car tyre production was started in 1932. Nowadays Nokian Tyres manufactures passenger car tyres and heavy tyres for various types of heavy machinery such as forest, mining and agricultural machinery. Also treads for truck tyres are manufactured to prolong their lifespan. Products are produced in factories in Nokia, Finland and Vsevolozhsk, Russia. In addition around 3 % of tyres sold are manufactured in other contract factories.

The head quarter is located in Nokia with the factory. Nokian Tyres also has its own retail chain Vianor which operates as wholesaler and retailer in the primary markets of Nokian Tyres. (Nokian Tyres, 2016b) In 2015 the net sales of the company were 1.4 billion euros. Nokian Tyres employees about 4 400 people, approximately 950 of which in Nokia and 1 300 in Vsevolozhsk.

4.2 The factories

In the Nokia factory passenger car tyres, heavy tyres and treads for truck tyres are manufactured. In 2015 the total production was almost 50 000 tonnes of which over half was made up of passenger car tyres. The heavy tyres made up over one third of all the production. The product development is carried out in the head quarter. Also prototypes and test runs are completed there. Nokian Tyres has a test course for the tyres in Nokia. Another test course is located in Ivalo. (Nokian Tyres, 2016c)

The Vsevolozhsk factory manufactures only passenger car tyres. The production capacity of Vsevolozhsk exceeds that of Nokia and in 2015 80 % of the passenger car tyres manufactured came from Vsevolozhsk. The total production rate of both factories, Nokia and Vsevolozhsk, combined was 169 900 t in 2015. (Nokian Tyres, 2016a)

4.3 Base-year

Year 2011 was selected as the base year since it is the first year a GHG assessment was done for Nokian Tyres. The assessment was done for the Nokia factory but emissions for the Vsevolozhsk factory were calculated using the same model. The assessment made in 2011 is less extensive than this assessment thus the total emissions are not directly comparable. Also some of the emission factors and calculation methods have been updated compared to the assessment from 2011.

4.4 Scope

The assessment from 2011 included cradle to gate emissions which included VOC emissions from production, scope 2 emissions from purchased energy used in operations and some upstream scope 3 emissions. Emissions from raw material production and transportation, offices, waste generated in operations, water usage and business travel were included in the scope 3 emissions assessed. (Markkanen, 2013)

In the present assessment the scope was extended to include all relevant emissions from cradle to grave. This includes the procurement and production of the raw materials, manufacturing process, distribution of the tyres, the use of the tyres, and finally the disposal of the used tyres (figure 4-1). The manufacturing process consists of all relevant emission sources from both of the factories, in Nokia and in Vsevolozhsk. These include electricity and steam, disposal of wastes, water supply and wastewater treatment, business travel, commuting, leased and owned vehicles, and emissions of VOCs. In the distribution stage all relevant emissions from the retail chain Vianor were included.

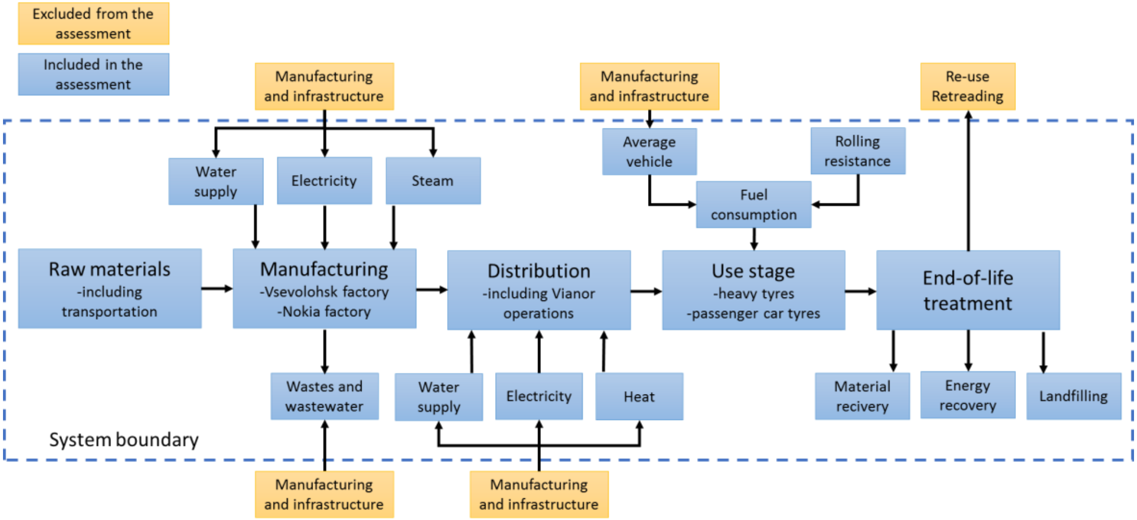


Figure 4-1 The system boundary for the GHG assessment

The operational control approach was chosen for consolidating emissions. Thus only emissions from operations over which Nokian Tyres has control were accounted into scope 1 and 2 emissions. Emissions from the construction of infrastructure and from manufacturing of vehicles were excluded from the study. The production of the fuels for the vehicles was also excluded.

Since the main goal was to enable easy calculation of the annual emissions in the future in this assessment the emissions are calculated based on activity data from 2016 when possible. When needed the data was completed with data from 2015. Since annual fluctuations in the emissions and activity data are minor this should still give a representative picture of the total GHG emissions from the operations.

4.5 Data Collection

Greenhouse gases can be measured by recording emissions at source by continuous emissions monitoring or by estimating the amount emitted using activity data. Here activity data was mostly used and only the VOC emissions are measured. Most of the activity data used was collected as primary data from Nokian Tyres or from its partners and suppliers. Some of the activity data was from year 2015 while some was from 2016.

Emission factors were mostly collected as secondary data from literature or LCA databases. In some cases finding emission factors was difficult and certain assumptions and recalculations were needed. Choosing the emission factors may affect the comparability of this assessment with other assessments while there is no one database where everyone could get all the same factors. In order to make the assessment as representative as possible most recent emission factors were used when possible.

4.6 Calculations

GHGs where calculated using emission factors and activity data. Emissions factors can be presented for different GHGs but usually they are expressed as kg of CO_2 equivalent. When calculating emissions from other GHGs than CO_2 they can be converted to CO_2e using their GWPs. Emissions where mostly calculated using equation 2. Other calculations made are explained in details in the next section.

$$GHG\ emissions = A \times E \tag{2}$$

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

When transforming the non-CO_2 gases to CO_2 equivalents GWP values integrated over 100 years published by IPCC in 2007 were used (table 2-1). Although there are more recent values that may present reality better the 2007 values were used to increase comparability, while they were used when making the GHG assessment for Nokian Tyres in 2011. The IPCC values from 2007 are also currently adopted by the UNFCCC (United Nations Framework Convention on Climate Change) national emissions reporting.

4.7 The Calculator

The existing calculator was created using Microsoft Excel software. The new calculator was created based on the earlier version. The use of the calculator is made as easy as possible. Thus the emission factors and assumptions made are imbedded in the calculator and only activity data is needed to be fed to calculate the GHG emissions from each operation. All operations were presented on their own sheets and the total results were presented in summarizing tables. All GHG emissions were divided between scopes 1, 2 and 3.

4.8 Allocations

Since the assessment is expanded to cover the whole Nokian Tyres' organization instead of just a tyre no allocations inside the factories were needed. Because the product development is done in Nokia all emissions from testing of the tyres were allocated to the Nokia factory. Also emissions from leased vehicles abroad were allocated to the Nokia factory. Since all emissions from the whole operation are added together in the end these allocations are insignificant in the final results.

When calculating emissions from waste disposal recycled content method was used thus allocating emissions from the recycling process to the user of the recycled material and emissions from waste-to-energy operations to the producer of the energy. Vehicle's emissions during the use phase of the tyres were allocated to the tyres based on a model explained in chapter 5.11.

5. MAIN DATA AND ASSUMPTIONS

5.1 Scope 1 Emissions

There are no direct CO_2 emissions from tyre production. Scope 1 emissions consist of energy production in own facilities and of company owned cars' emissions. VOC emissions from Nokia factory were also included although they are not generally regarded as GHGs. While some of the energy used in Nokia and Vsevolozhsk factories comes from outside providers thus being seen as scope 2 emissions all emissions from energy production were covered in their own subsection.

5.1.1 VOC Emissions

Although VOCs are not usually seen as GHGs they were also included in the assessment as they are remarkable for Nokian Tyres. They were also included in the earlier GHG assessment (Markkanen, 2013). Because VOCs are indirect GHGs they don't normally have GWPs. Collins et al. (2002) have, however, calculated indirect GWPs for 10 VOCs based on their effect on tropospheric O_3, CH_4 (through changes in OH) and CO_2 (table 5-1). The weighed GWP for the VOCs is 3.4 kg CO_2e/kg based on the amounts of their emissions. There are, however, significant uncertainties in the calculated GWPs due to the short lifetimes of VOCs and the nonlinear chemistry involved in ozone and OH chemistry. (Collins, 2002)

Table 5-1 Indirect GWPs (100-year) for 10 VOCs (Collins, 2002)

Volatile organic compound	**GWP^{CH4}**	**GWP^{O3}**	**GWP**
Ethane (C_2H_6)	2.9	2.6	5.5
Propane (C_3H_8)	2.7	0.6	3.3
Butane (C_4H_{10})	2.3	1.7	4.0
Ethylene (C_2H_4)	1.5	2.2	3.7
Propylene (C_3H_6)	-2.0	3.8	1.8
Toluene (C_7H_8)	0.2	2.5	2.7
Isoprene (C_5H_8)	1.1	1.6	2.7
Methanol (CH_3OH)	1.6	1.2	2.8
Acetaldehyde (CH_3CHO)	-0.4	1.7	1.3
Acetone (CH_3COCH_3)	0.3	0.2	0.5

All VOCs from tread manufacturing are captured and lead to a catalytic incineration plant. However, there are some VOC emissions from heavy tyre manufacturing. The amount of released VOCs is measured at the factory. In 2015 the VOC emissions were 69 300 kg. Since different solvents are used in the manufacturing process and there were no GWP values for all of the used solvents the weighted average was used to convert the VOC emissions into CO_2 equivalents. Since Nokian Tyres uses solvents only in heavy tyre and tread manufacturing there are no VOC emissions from the Vsevolozhsk factory.

5.1.2 Company Owned Vehicles

Tyres have to be tested for their performance. There are two test tracks, one in Ivalo and one in Nokia, and several different vehicles for testing both heavy and passenger car tyres. In addition some vehicles are needed for maintenance of the tracks. Some of the vehicles are leased but some are owned by Nokian Tyres.

Average annual emissions calculated for the leased test vehicles were used for calculating the emissions from company's own vehicles. The information was received from the leasing company. Calculations of the annual average emissions are explained in detail in chapter 5.9. Average annual emissions were also calculated separately for sport utility vehicles (SUVs) and terrain vehicles while their emissions are normally higher than smaller passenger cars'.

Emissions from the heavy-duty vehicles used on test tracks were calculated based on annual emissions for different heavy vehicle groups reported by LIPASTO. The annual CO_2e emissions are based on typical characteristics of Finnish heavy vehicle population and average power consumption. (LIPASTO, 2011) The reported emissions were divided by the size of the vehicle population to calculate average emissions per vehicle. The average emissions were then multiplied by the amount of the vehicles in use (table 5-2).

For slope machines used in the Ivalo test track the emissions were calculated based on fuel consumption information from a manufacturer and the length of the average snow season in Sodankylä. While the consumption was expressed in litres per hour it was assumed that the machine is operated for an hour on every day of the snow season which is 201 days long on average. (Finnish Meteorological Institute, 2012; Pisten Bully, 2016)

Table 5-2 Number of different vehicle types owned by Nokian Tyres in Finland and their annual average CO2e emissions

Vehicle type	**Number of vehicles**	**Average budgeted emissions per year (t CO_2e/a)**
Passenger car	11	2.16
SUV / Terrain vehicle	5	3.15
Van / Pick-up	6	2.77
Truck	6	7.35
Tractor	2	6.11
Lawnmower	1	0.63
Quad car	2	2.66
Snowmobile	2	5.60
Slope machine	2	8.31

The Vsevolozhsk factory has own passenger vehicles but does not have any leased vehicles. Average annual kilometrage was reported for cars owned by the sales department, Nokian Shina, and by Nokian Tyres (table 5-3). Emissions were calculated based on the emission factor (169 g CO_2e/km) determined by LIPASTO.

Table 5-3 Number of passenger cars owned by Nokian Tyres and Nokian Shina in Russia and their average kilometrage per year

Owner	**Number of vehicles**	**Average distance driven per year (km)**
Nokian Tyres	10	15 000
Nokian Shina	79	27 000

The emission factor used is based on average emissions from passenger cars in Finland in year 2011. Emissions are determined based on the assumptions that 33 % of cars run on diesel and rest on petrol and that 35 % of driving is urban driving and the rest 65 % highway driving. In addition it is assumed that 6 % of the caloric value of both diesel and petrol is bio-based. (LIPASTO, 2011)

5.2 Energy Production

Energy consumption in the factories can basically be divided into electricity and steam. Steam is used for both production and heating. Vsevolozhsk mainly produces its own energy. In the Nokia factory electricity is bought from national grid and steam production was moved to a new partially owned bioenergy plant during year 2016.

5.2.1 Heat and Steam

In 2016 a new bioenergy plant started operation in Nokia. The bioenergy plant is a joint investment of Nokian Tyres, Leppäkosken Sähkö Plc (Leppäkoski Electricity) and SCA Hygiene Products Plc. The new energy plant produces steam and heat for the SCA's paper factory and for Nokian Tyres as well as heat for the city of Nokia. The bioenergy plant uses wood, peat and both bio and deinking sludge from SCA's factory as fuel. Natural gas is used as reserve energy when needed. (Nokianvirran Energia, 2016) Before Nokian Tyres derived heat and steam mainly from natural gas so the change to bioenergy leads to a substantial decrease in GHG emissions. In 2015 the emissions from heat and steam were 24 555 t CO_2e while the estimate of GHG emissions in 2016 from April to December is only 8 709 t CO_2e. When extended to a whole year the emissions would be 11 612 t CO_2e.

The emissions from 2016 had to be calculated partly based on emissions from natural gas and partly from biofuels as the bioenergy plant started its operation in the spring of 2016. Although Nokian Tyres owns 32.3 % of the bioenergy power plant the emissions from heat and steam production were regarded as scope 2 emissions because of the chosen consolidation approach.

The realized CO_2 emissions from April to October where obtained from the operator of the energy plant, Nokianvirran Energia Plc. A prediction of the emissions for the rest of the year was also obtained from the energy provider. Emissions from the beginning of the year were calculated based on the realized amounts of used fuels and the amount of consumed energy both reported by the energy plant. Emission factors used for different fuels were obtained from Statistics Finland's fuel classification 2016 and converted into kg CO_2e / MWh (table 5-4).

Table 5-4 Emission factors (based on (Statistics Finland, 2016a) and the amounts of used fuels between January and March

Fuel	**Emissions factor (kg CO_2e / MWh)**	**Fuel used (MWh)**
Wood (forest fuel wood, industrial wood residue)	394.6	9 530
Biosludge	475.2	8
Deinking sludge	216.0	1 853
Peat	385.2	4
Natural gas	199.8	18 622

Biosludge, deinking sludge and wood are regarded as biogenic fuels thus their GHG emissions are not accounted into scope 2 emissions. Biogenic emissions may, although, be reported separately in the assessment, thus the emissions from sludge and wood were also calculated.

5.2.2 Electricity

In the Nokia factory electricity is bought from the local grid. Finland is part of integrated Nordic power market thus the sources and origin of the energy differs according to supply. Especially the availability of hydro power from Norway and Sweden has a large impact on the use of fossil fuels. The shares of different energy sources in electricity production in Finland in 2015 provided by Finnish Energy were used (table 5-5). (Finnish Energy, 2016)

The Vsevolozhsk factory has its own power plant where it produces the electricity, heat and steam for its own use. The power plant uses natural gas as its energy source. Additional electricity is bought from the local operator when needed. In 2015 about 26 % of the electricity was bought from the grid. Because no accurate information about the energy mix was available from the energy provider the national production mix from 2012 reported by the International Energy Agency (IEA) was used (table 5-5).

Table 5-5 Energy sources and their emission factors

Energy source	**Share of electricity mix in Nokia (%)** (Finnish Energy, 2016)	**Share of electricity mix in Vsevolozhsk (%)** (IEA, 2014)	**Emission factor (t CO_2e/TJ)** (Statistics Finland, 2016a)
Nuclear power	33.7	16.6	0
Hydro power	25.1	15.5	0
Biomass	16.2	-in other renewable	100.0*
Natural gas	7.6	49.1	55.3
Coal	8.3	15.7	93.3
Oil	0.3	2.6	79.2
Peat	4.1	0	107.0
Municipal waste	1.2	0.3	40.0
Other renewable	3.5	0.2	0

*Biogenic, not accounted into GHG assessment

Emissions were calculated based on emission factors from Statistics Finland’s fuel classification (table 5-5) using electricity consumption data and the shares of energy sources. Emissions from biomass were calculated although they were not included in the assessment while they are biogenic and thus seen as carbon neutral. The biogenic fraction of municipal waste, 50 % according to Statistics Finland, is not included in the emission factor. Nuclear and hydro power as well as other renewable sources are regarded as carbon neutral thus their emission factors are zero. The other renewable sources consists of wind power in Finland and of biomass and geothermal energy in Russia. The share of electricity from carbon neutral sources in 2015 was 78.5 % for Nokia factory and 8.5 % for Vsevolozhsk.

According to GHG Protocols scope 3 standard (2011) emissions from production of the fuels used for energy production should also be accounted for. They are also known as well-to-tank (WTT) emissions. Thus emissions from production of natural gas were also calculated as scope 3 emissions for Vsevolozhsk factory. The emission factor used was 26.97 kg CO_2e / MWh (DECC, 2015). This only concerns the fuels used directly by the reporting company thus WTT emissions related to the bought energy are not reported. WTT emissions from biogenic energy sources are not reported as well.

5.3 Raw Material Production

Raw material acquisition is one of the most emission intensive part of tyre production. Emissions were calculated based on the received amounts of materials in 2015. In some cases only one emission factor was used for all materials in the same functional class, for example retarders, vulcanizing agents, and activators. The emission factor was based on the most used compound in that category. Most of the emission factors used are from a LCA study for tyres made by Quantis (2013) and they are modelled using the ecoinvent database v2.2. Emissions from transporting the raw materials were also calculated. The calculations are explained in chapter 5.4 though.

5.3.1 Natural Rubber

Emissions from natural rubber production are calculated based on a study by Jawjit et al. (2010) which is based on natural rubber production in Thailand. In the emission factor the whole lifetime of the trees and all auxiliary functions needed in cultivating are included. Also the final processing of the raw latex into rubber products is included. Emission factor for block rubber production was used while 88 % of the natural rubber used in tyre industry is block rubber (Quantis, 2013). Most of the natural rubber used by Nokian Tyres comes from Malaysia and Indonesia (Nokian Tyres, 2016c, p. 40). Because rubber yield per hectare is lower in Malaysia and Indonesia than in Thailand the emission factor was scaled according to their average yield. Emissions from cultivating a hectare and from processing of the raw latex were assumed to be the same. The yield per hectare for each country is informed as rubber products per hectare and more latex is needed for a ton of rubber products. Jawjit et al. (2010) assumed the latex yield to be 5 640 kg/hectare/year. The latex yields for Malaysia and Indonesia were scaled according to the differences in the rubber yields (table 5-6).

Table 5-6 Yields and emission factors for latex in Thailand, Indonesia and Malaysia

	Yield (kg rubber/ha)	**Yield (kg latex/ha)**	**Emissions, cultivation (kg CO_2/ha)**	**Emissions, latex (kg CO_2/kg latex)**	**Emissions, rubber (kg CO_2/kg rubber)**
Thailand	1 800	5 640	1 128	0.20	0.71
Indonesia	1 080	3 384	1 128	0.33	0.97
Malaysia	1 510	4 731	1 128	0.24	0.78
Average (ID & MY)	1 295	4 058	1 128	0.28	0.86

Jawjit et al. (2010) estimated the amount of fresh latex needed for a tonne of block rubber to be 2 tonnes. The CO_2 emissions from processing the latex into block rubber were calculated to be 0.306 kg/kg rubber. (Jawjit, 2010)

Although Malaysia has the highest deforestation rate (Butler, 2013), land area used for rubber plantations has declined between 1990 and 2010. Rubber plantations have been changed to palm oil plantations in the hope of better productivity. (FAO, 2010) In Indonesia area of rubber plantations has increased by 55.8 % during the same period. The total deforestation rate between 1990 and 2010 excluding the planted forest areas was 20.9 % compared to forestlands in the year 1990. (FAO, 2010) All of the deforestation can't however be allocated to rubber production. Due to the decrease in area of rubber plantations in Malaysia and the fact that most of the rubber comes from Malaysia the emissions for natural rubber were calculated without taking land conversion into account.

5.3.2 Emission Factors for Raw Materials

All emission factors used for calculating emissions from raw material production are collected in table 5-7. The same factors were used for both factories, Nokia and Vsevolozhsk.

Table 5-7 Emission factors for the raw materials used in tyre production

Material	**Emission factor (kg CO_2/kg material)**	**Source**
Natural rubber	0.86	(Jawjit, 2010)
Synthetic rubbers	2.41	(JATMA, 2012)
Carbon Black	2.37	(Quantis, 2013)
Silica	1.77	(Quantis, 2013)
Calcium carbonate	0.040	(ELCD3.2)
Other fillers	2.91	(IPCC, 2006)
Zinc Oxide	2.89	(Quantis, 2013)
Activators	1.90	(Quantis, 2013)
Retarders	1.90	(Quantis, 2013)
Vulcanization agents	0.55	(ELCD3.2)
Accelerators	1.90	(Quantis, 2013)
Antioxidants	1.90	(Quantis, 2013)
Waxes	1.40	(BEIS, 2016)
Plasticizers, mineral	1.40	(BEIS, 2016)
Plasticizers, other	1.04	(Buturca, 2013)
Resins	6.72	(Quantis, 2013)
Cobalt salt	3.16	(Quantis, 2013)
Adhesives and paints	1.52	(ADEME , 2016)
Nylon	11.08	(ELCD3.2)
Polyester (PET)	4.43	(ELCD3.2)
Rayon	4.62	(Dibdiakova, 2014)
Steel cords & wires	2.41	(Pardo, 2012) (Worldsteel, 2015)

Synthetic rubber is petroleum based thus most of the emissions come from refining its raw materials. The emission factor for producing styrene butadiene rubber was used for all synthetic rubber as it is the most commonly used rubber. The majority of the polymers are produced by solution polymerisation technology thus the process for styrene butadiene rubber is a representative process for other synthetic rubbers as well. (Quantis, 2013)

For the production of crude steel emission factor of 1.9 kg CO_2/kg steel was used. The factor is based on the production share of the three normally used production routes, basic oxygen furnace, electric arc furnace and open hearth furnace. The factor is calculated from information of year 2014 by the World Steel Association based on reports from its members. (Worldsteel, 2015) The steel is also further processed into wire. Emissions for the finishing phases of rolling, annealing and coating are obtained from the Strategic

Energy Technologies Information System of the European Commission. (Pardo, 2012) Final emission factor for the steel wires and plies is 2.41 kg CO_2/kg steel wire.

Emission factors for the production of nylon and polyester fibres were calculated with OpenLCA from LCA data acquired from ELCD3.2 database. Viscose and rayon are both polymerized of cellulose so emission factor for viscose fibre was used for rayon fibres. All emission factors are cradle-to-gate thus including the upstream emissions from raw material production and procurement as well as the emissions from extrusion, spinning and processing of the fibres.

5.4 Transportation of Raw Materials

In 2010 transportation accounted for 14 % of all global GHG emissions. This sector primarily consists of road, rail, air, and marine transportation. Petroleum-based fuels make up 95 % of the energy used for transportation thus most of the emissions come from burning fossil fuels. (IPCC, 2014) Transportation of raw materials and of produced goods also contributes to Nokian Tyres' emissions. Nokian Tyres has suppliers in several countries across the world. They also deliver tyres to several locations to warehouses, wholesalers and straight to end customers. All in all the transportation network of Nokian Tyres is broad and complicated. Different ways of transport are needed to carry all goods to their destinations.

Maritime shipping is the most energy-efficient way of mass transporting cargo which is why it is used for longer distances when possible (IMO, 2009). In this study it is assumed that all raw materials coming from Southern Europe, Asia, Africa and North America are transported by freight ships. Shipping is also used to transport produced goods to the same areas. The emissions are calculated based on using container ships. Container ships are freight ships that carry containerized cargo. (IMO, 2009, p. 15) The containers can be used to transport almost anything from light shoes to paper rolls or tyres for example. The size of container ships is usually given as container units. Because containers come in different sizes it is agreed that a container of twenty feet is one container unit TEU (twenty-foot equivalent unit). (LIPASTO, 2009)

When shipping is not possible goods are transported by land. In the next subsections different transportation routes used are explained in detail. All transport emissions are presented in tonne-kilometres (tkm). One tkm describes transporting one tonne of material for a distance of one kilometre.

Some simplifications were needed when calculating emissions from transportation of the raw materials. For each material or group of materials the main supplier was determined based on delivered volumes. To simplify the calculations all transportation emissions for each material group were calculated based on the location of the main supplier.

5.4.1 Shipping

Some of the raw materials come a long way. For example most of the natural rubber used by Nokian Tyres is originated from Malaysia and Indonesia. Raw materials coming from far off countries (Asia, North America) are shipped by trans-oceanic container ships to the big ports in Germany or Netherlands from where they are transported to Finland or Russia by smaller ships. In order to simplify calculations it was assumed that all raw materials are shipped to Lubeck from where they are shipped further to Helsinki port in Finland and St Petersburg in Russia. However also different ports in Finland and in Central Europe may be used. The differences in distances are, however, small. When the distance to Helsinki is compared to other ports in Southern Finland (Turku, Pori, Hanko) the differences are both by land from Nokia and by sea from Lubeck less than 100 km. The difference in the distance from Helsinki port to Lubeck and to Rotterdam is less than 600 km. Using a different port in Central Europe also affects the distance of the trans-oceanic sea fare or the distance travelled by land.

Due to a shift towards larger ships in recent years emissions for the longer routes are calculated by using emission factor for container ships over 8 000 TEU. According to IMO (the International Maritime Organization) 93% of the currently operating ships of 10 000 TEU and over are deployed in the East Asia–Europe route. Larger container ships are also used between Europe and North America. (IMO, 2015, p. 267) To calculate the emissions for the route from Lubeck to Helsinki emission factor for ships of 0-999 TEU was used while most of the container traffic from Finland is so called feeder traffic which uses smaller ships. (LIPASTO, 2009) The same emission factor was also used for the Lubeck-St Petersburg route. Both of the emission factors are obtained from IMO’s Second GHG Study (2009, p. 131).

Due to the long distances (over 15 000 km) by sea, the transportation to harbour in the Asian departure countries was excluded. Also the transportation from St Petersburg to the Vsevolozhsk factory was excluded due to the short distance (less than 40 km). Transportation from Helsinki to Nokia by truck was included though.

Raw materials produced in Central Europe are first transported by truck to Lubeck. From there materials are shipped forward to Helsinki or St Petersburg by ships under 1000 TEU. From Helsinki the materials are transported to Nokia by truck. The transportation from St Petersburg to the Vsevolozhsk plant was excluded.

5.4.2 Land Transportation

Raw materials produced in Finland are transported by truck to Nokia or to Vsevolozhsk. From production sites in Russia raw materials are transported to Vsevolozhsk by truck or by train. Some raw materials from Russia are transported first by train to Vsevolozhsk from where they continue by truck to Nokia. Some raw materials are also transported to Nokia by truck all the way from the supplier in Russia.

The truck used in all road transportation was assumed to be a semi-trailer truck with the carrying capacity of 25 tonnes. Although both highway and urban driving are involved the emissions were calculated only based on highway driving in order to simplify the calculations. Emissions were calculated for 70 % load using tkm. Emissions of a truck are dependent on several factors such as the model and age of the truck and the driving style. Because the truck population used for the transportations was unknown the average emission factor for different truck classes in Finland in 2011 was used. (LIPASTO, 2012)

5.4.3 Emission Factors for Transportation

The emission factors used to calculate GHG emissions for different transportation methods are shown in table 5-8. The transportation mode and country of origin for each raw material is presented in Appendix A.

Table 5-8 CO_2-e emission factors for different means of transportation used.

Transport	**Emission factor (g CO_2-e/tonne-km)**	**Source**
Ship 8000+ TEU	13	(IMO, 2009, p. 131)
Ship 0-999 TEU	36	(IMO, 2009, p. 131)
Semi-trailer truck (25 t capacity)	55	(LIPASTO, 2012)
Train (Russia)	9	(IEA & UIC, 2015)

The emission factors used for calculating the emissions of marine transport are based on emissions from 2007. Since then IMO has tightened emission limits in 2010 and adopted mandatory technical and operational energy efficiency measures in 2013. Energy efficiency measures were expected to significantly reduce the amount of CO_2 emissions. (IMO, 2016) In addition slow steaming, meaning cruising at lower speeds than the ships design speed, has become more common in maritime transport. (IMO, 2015, pp. 53-54) Reducing speed by 10% will result in a 19% reduction in engine power thus resulting in a reduction of GHG emissions. (Faber, 2012) Between 2007 and 2012 ships have reduced their at-sea speed relative to design speed by an average value of 12 % (IMO, 2016). The values of the emission factors are calculated based on average speeds between 17.0 and 25.1 knots but in 2012 the average sailing speed of container ships in 3 000 TEU to 14 500 TEU size categories was between 16 knots and 16.3 knots. This has resulted in an average reduction of daily fuel consumption of approximately 27 % expressed as an average across all ship types and sizes (IMO, 2015, pp. 53-54). Due to these changes the values of the emission factors used for shipping may not fully represent the current emissions. Nonetheless they were used while none more recent values were available.

5.5 Capital Goods

Capital goods should consist of all emissions from machinery procurements for instance. None of the component manufacturers were able to give information regarding their emissions related to machinery production. Best estimates were based purely on emissions from the steel used in manufacturing.

The capital goods were left out of the assessment while at best the calculated emissions would only represent a rough estimate. When more accurate information concerning the emissions from the manufacturing of the machines is available they should however be added to the assessment. The impact of the exclusion is evaluated in chapter 7.3.3.

5.6 Waste Generated in Manufacturing Operations

Wastes from the operations include both waste and waste water treatment. Also usage of clean water is reported here. Only emissions from waste treatment facilities operated by third parties should be included in scope 3 emissions while emissions from waste treated in own facilities should be included in scope 1 emissions. In this category the scope 1 and 2 emissions of the solid waste and waste water treatment facilities are included. (GHG Protocol, 2011)

5.6.1 Water Usage

In the GHG assessment made in 2011 emission factors for water management were calculated based on secondary data of the energy consumption and water volumes of the water treatment facility (Markkanen, 2013). However the emission factors based on the calculations are quite high compared to results from other studies from water management in the United Kingdom and Finland (BEIS, 2016; HSY, 2014; Pöyry Environment Oy, 2009). Emission factors used in the 2011 assessment were 8.34 kg CO_2e/m^3 for water supply and 11.89 kg CO_2e/m^3 for waste water treatment (Markkanen, 2013) as the other emission factors for Finnish water supply range from 0.066 kg CO_2e/m^3 (HSY, 2014) to 0.094 kg CO_2e/m^3 (Pöyry Environment Oy, 2009) and for Finnish waste water treatment from 0.286 kg CO_2e/m^3 (Pöyry Environment Oy, 2009) to 0.593 kg CO_2e/m^3 (HSY, 2014).

The emission factors calculated by Helsinki Region Environmental Services Authority (HSY) in 2013 for its water management operations were used while they represent the average of several water treatment facilities of different sizes in Helsinki region and they have been calculated using information of Finnish energy production. The higher factors (table 5-9) were used for calculating the indirect emissions from water usage. The higher factors include all GHG emissions from the water treatment plants including the GHG emissions from the produced energy that is sold to outside users. (HSY, 2014)

Table 5-9 Emission factors for water usage (HSY, 2014)

	Emission factor (avoided emissions taken into account) (kg CO_2e/m^3)	**Emission factor (Total emissions) (kg CO_2e/m^3)**
Municipal water production	0.066	0.073
Waste water treatment	0.550	0.593

Both emission factors include bought energy, energy derived from own operations and emissions from cars and work machines. The emission factor for production of municipal water also includes emissions from the water supply network and emission factor for waste water treatment includes emissions from composting of the sewage sludge. (HSY, 2014)

Most of the water used on the Nokian plant is derived from river Nokianvirta. River water is used for cooling in the plant. Municipal water is used primarily for drinking and sanitation purposes. The cooling water is circulated in a closed loop so that it doesn't have any contact with chemicals thus keeping it uncontaminated. Only a small amount of river water (1.3 % of the total 7 127 000 m^3 in 2015) is used at washers of mixing machines. Water used for cooling is lead back to river Nokianvirta while the water used for washing the machines is lead to municipal waste water treatment. Nokian Tyres has its own water plant which pumps the water from the river. Emissions from acquiring the water from the river are however not included here while the emissions comprise of the energy used. Thus they are already included in scope 2 emissions. The water lead to municipal waste water treatment is taken into account in the emissions from waste water treatment.

Vsevolozhsk plant uses municipal water also for cooling. All waste water including the water used for cooling is lead to municipal sewerage system. Many waste water treatment plants in Russia are overloaded (UN, 2004), and fitted with outworn equipment that needs renewal, or modernization (Ilyinski, 2012). It is unlikely that their GHG emissions are same as those in Finland. Also the energy mix in Russia differs from that in Finland. However the same factors were used when calculating emissions from Vsevolozhsk plant while no more adequate information was available.

5.6.2 Wastes

GHG Protocol recommends the recycled content method in allocating emissions of recycling process between the user of the recycled material and the disposer of the waste recycled. Thus this method was also used when preparing this GHG assessment. Recycled content method is easy to use and secondary emission factors for recycled material inputs are usually consistent with it. In the method emissions from the recycling process are allocated to the user of the recycled material and emissions from waste-to-energy operations are allocated to the producer of the energy. Also avoided emissions when processing recycled material instead of producing the equivalent virgin material or using recycled material for deriving energy instead of conventional fuels are allocated to the user of the recycled material. While many secondary emission factors may already include the use of recycled materials this way double counting can be avoided. For instance generally combustion of waste for energy is included in the grid average emission factor. When wastes are incinerated without energy recovery the emissions should be however reported in the waste category. In addition emissions from processing the wastes without material recovery are fully allocated to the producer of the waste. (GHG Protocol, 2011)

Nokian Tyres utilizes most of their wastes. For the Nokia factory the utilization rate in 2015 was 99 % while for the Vsevolozhsk factory it was 84 %. The generated waste can be roughly divided into three categories: landfilled or non-recycled waste, utilized waste and hazardous waste. The wastes are then further sorted into different categories which have their own disposal methods. Waste volumes are weighed by waste management companies and logged in yearly reports. All production waste is weighed at the factory and logged in monthly reports. The division of disposal methods for wastes for both factories in 2015 are presented in figures 5-1 and 5-2. (Nokian Tyres, 2016c) In 2016 the utilization rate for Nokia factory is going to be even higher since all hazardous waste is utilized as energy or material as well. Emissions were calculated based on the utilization rates for 2016.

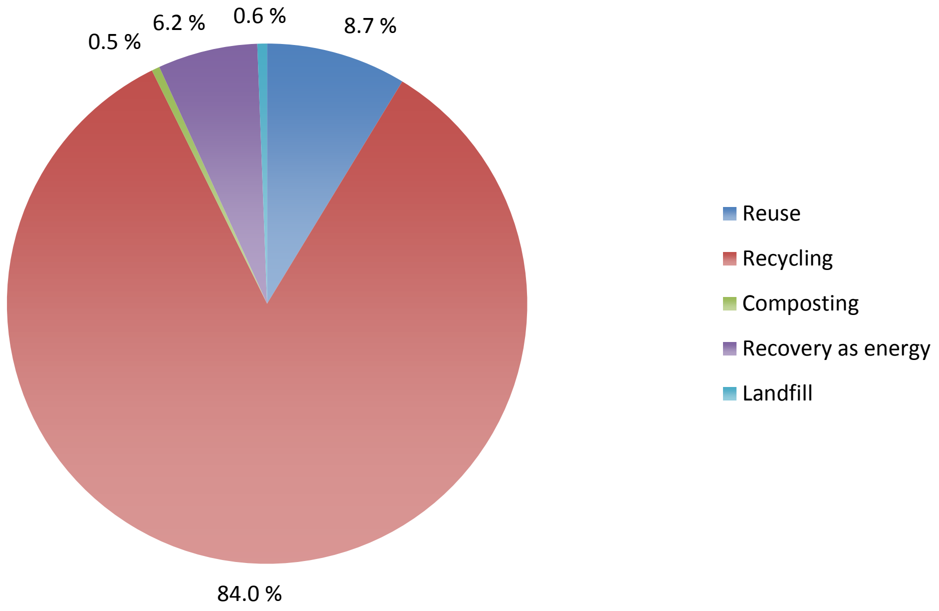


Figure 5-1 Wastes from Nokia factory by disposal method in 2015 (Nokian Tyres, 2016c)

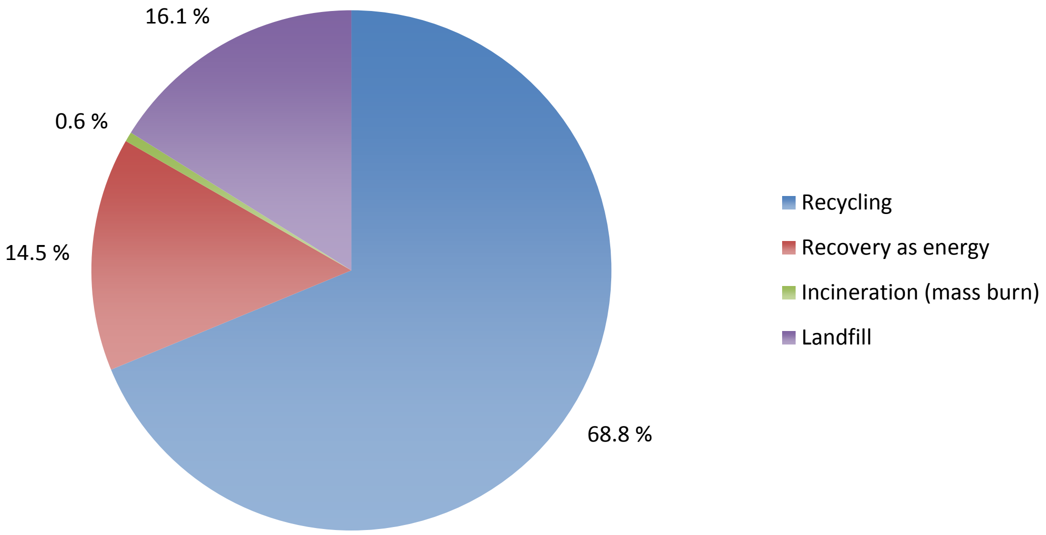


Figure 5-2 Wastes from Vsevolozhsk factory by disposal method in 2015 (Nokian Tyres, 2016c)

In order to calculate GHG emissions from waste management the reported waste volumes were multiplied by the emission factor for the specific waste category and disposal method. When not included already in the emission factor emissions from the transportation of the waste to the treatment facility were added. For the recycled wastes emissions other than from the transportation were allocated to the user of the recycled material as advised in the recycled content method. The same applied for the waste used for energy production.

Because in Nokia the utilization rate is high most of the emissions come from the transportation of the wastes to the treatment facilities. Only mixed waste is landfilled causing emissions. Most of the wastes such as metals, paper and glass are recycled as material. Hazardous wastes consist of blade seal oil from compound mixing machines, oily waste, waste chemicals, waste oil, fluorescent tubes and batteries and they are either incinerated with energy recovery, or utilized as material. Emissions from landfilling the mixed waste (table 5-10) were calculated based on emission factor for commercial and industrial waste. Industrial waste contains a smaller amount of degradable fraction thus releasing less GHGs than municipal waste for example.

In Vsevolozhsk the utilization rate is lower and some of the wastes are transported long distances to treatment facilities. Emissions from mixed waste were calculated using same emission factor as for Nokia. Most of the emissions come from hazardous waste. Hazardous waste is usually treated by incineration. Hazardous waste does not usually contain a high biogenic fraction thus emissions from treating it are higher than for municipal waste. Although not all of the hazardous waste from Vsevolozhsk is incinerated the emissions were calculated based on incineration (table 5-10). Emissions from batteries were calculated based on landfilling though.

Table 5-10 Emission factors for the waste fractions and means of transportation used for collecting the wastes

Emission source	**Emission factor (kg CO_2e/unit)**	**Unit**	**Source**
Industrial waste	199	tonne	(BEIS, 2016)
Hazardous waste	1 410	tonne	(WWF, 2016)
Batteries	76	tonne	(BEIS, 2016)
Transportation, truck empty	0.458	km	(LIPASTO, 2011)
Transportation, truck full	0.559	km	(LIPASTO, 2011)

For both factories the emissions from transporting the wastes were calculated using tkm and assuming that trucks with the load capacity of 9 t were used for all transportation (table 5-10). The truck was assumed to be the average truck in traffic in Finland in 2011 (LIPASTO, 2011). Emissions were calculated assuming the trucks run the trip first empty and then return with full load. The number of trips was calculated based on the mass of the waste and the capacity of the truck. Most of the waste from Nokia factory are treated in the city of Nokia or in the Pirkanmaa area leaving the transportation lengths to under 35 km. Only metal, energy and hazardous wastes are transported longer distances (150-175 km). For the landfilled waste emissions from transportation were not added while the emission factor already includes transportation emissions as well (BEIS, 2016) The emission factors for hazardous waste and batteries also included emissions from transportation. However, some of the hazardous waste from Vsevolozhsk are transported over 1 000 km thus emissions for transportation were also added. It was assumed that the trucks do not return to the factory empty thus only emissions from a one way trip were calculated.

5.7 Business Travel

Business travel can be divided into three categories, air, road and rail transportation. All travel is presented in passenger kilometres (pkm), which measures the distance travelled by a person in a vehicle. Travel information was obtained from Nokian Tyres as passenger km (table 5-11). Kilometrage travelled by car was not available for Vsevolozhsk employees. However some of the business travel emissions are already included in the company owned cars.

Table 5-11 Realized travel distances for employees in 2015 by transportation mode

Transportation mode	Distance travelled in 2015, Nokia (pkm)	Distance travelled in 2015, Vsevolozhsk (pkm)
Air travel	8 459 567	95 000
Road transportation	1 019 116	-No information
Train travel	418 124	190 000

Emission factor for road transportation was obtained from LIPASTO while emissions factor for train travel was from the Finnish railway operator VR Group. Emission factor for flying was obtained from BEIS (Departent for Business, Energy & Industrial Strategy) (table 5-12). BEIS has determined emission factors for domestic (UK), short-haul, long-haul and international flights. The emission factors include emissions of CH_4 and N_2O presented as CO_2e using the GWP factors from IPCC fourth assessment report. In addition a factor of 8% has been added to the distances in order to account for delays, circling and non-direct routes between destinations. (BEIS, 2016) According to IPCC (1999) studies on penalties to air traffic show that an average of 9-10 % is added to the flight track distance of European flights due to air traffic management problems. Analysis for Department for Transport suggest a factor of 8 % is more appropriate for the flights in UK (BEIS, 2016). The average factor for international flights was used while it is based on non-UK flights of different distances.

Table 5-12 Emission factors for different transportation modes used for business travels

Transportation mode	Emission factor (g CO_2e/pkm)	Source
Air travel	95	(BEIS, 2016)
Road transportation	98	(LIPASTO, 2012)
Train travel (Nokia)	1.9	(LIPASTO, 2012)
Train travel (Vsevolozhsk)	27	(IEA & UIC, 2015)

The emission factor for road transport is calculated based on average emissions from passenger cars in Finland in year 2011 (table 5-12). Emissions are based on the assumptions that passenger load is 1.7 persons, 33 % of cars run on diesel and that 35 % of driving is urban driving and the rest 65 % highway driving. In addition it is assumed that 6 % of the caloric value of both diesel and petrol is bio-based. (LIPASTO, 2012) For Nokia emission factor reported by for Finnish passenger railway traffic was used while most of the train travel is domestic or between St. Petersburg and Finland. Most of the trains in Finland are operated by electricity and the electricity mainly comes from renewable sources which explains the low emission factor. (VR, 2015) For business travel of Vsevolozhsk factory’s employees same emission factors were used for air and car travel. The emission factor for train travel was obtained from Handbook Railway 2015 (IEA & UIC, 2015). The emission factor was determined based on emissions from Russian passenger railway traffic in 2012.

5.8 Employee Commuting

Employee commuting was estimated to cause only a small fraction of all emissions thus secondary data was used to calculate the emissions. Average distance travelled daily by a person was obtained from passenger traffic survey of Finnish Transport Agency. The average distance for people with part or full time jobs was used in order to get a more representative figure. The data for the survey was collected in years 2010 and 2011 from 12 000 Finns by telephone interviews. The results are divided between regions of different sizes but because Nokian Tyres has employees coming from several regions the average results for whole Finland were used. Commuting makes about 28 % of the total average distance travelled daily for people with part or full time jobs. The average commuting distance was not directly divided into different means of transportation thus it is assumed that the modal split for commuting is the same as for the total distance travelled daily. The total average distance travelled daily also includes subway and tram which do not apply to Nokia region. It was assumed that instead of the subway other public transportation is used thus the distance travelled by subway was added to the distance travelled by bus. Other means of transportation include taxi fares, air and ferry travel. Air and ferry travel are unlikely means used for commuting thus distance for other means of transportation was added to driving. (Liikennevirasto, 2012) Distances travelled by different means of transportation are presented in table 5-13.

Table 5-13 The total distance and the distance travelled to work by different means of transportation by a person daily in Finland (Liikennevirasto, 2012)

Mean of transportation	**Total average distance travelled daily (km/d/person)**	**Average distance travelled to work daily (km/d/person)**
Bus	2.83	0.79
Train	3.99	1.11
Car	41.03	11.43
Subway	0.33	0.091
Others	6.19	1.72
Bike	0.75	0.21
Walking	1.01	0.28
Total	56.13	15.64

Emission factors for bus and passenger cars were derived from LIPASTO. For train travel the same emissions factor as in and commuting consists of only domestic traffic. All emission factors are presented for passenger km using average utilisation rates (table 5-14).

Table 5-14 Emission factors for different transportation modes

Mean of transportation	**Emission factor (g CO_2e/pkm)**	**Source**
Bus	53	(LIPASTO, 2011)
Train (Nokia)	1.9	(VR, 2015)
Train (Vsevolozhsk)	27	(IEA & UIC, 2015)
Car	98	(LIPASTO, 2011)
Bike, walking	0	-

Emission factor for bus represents average bus using diesel fuel with 6 % biodiesel in Finland in 2011. The final emission factor is calculated for 50 % highway driving and 50 % urban driving. Utilisation rate used for calculating emissions per pkm for bus travel is 22.5 %. (LIPASTO, 2011) Emission factor for passenger cars is calculated on the same bases as in section 4.6. For train travel the same emission factor from the Finnish railway operator VR as for business travel was used. To avoid double counting the amount of leased vehicles was deducted from the amount of employees. Emissions from leased vehicles were calculated separately and it was assumed that all the passenger cars are also used for commuting by an employee.

Emissions from commuting in sales companies were also calculated based on the results of the Finnish passenger traffic survey. Nokian Tyres has sales companies in 11 countries. The distance travelled daily and the modal split vary between different countries. However, the variation does not cause large differences in the total commuting emissions. In addition emissions from commuting are only a small fraction of total emissions thus the same figures were used for all the personnel in the sales companies.

However, the same figures could not be used to calculate emissions from commuting in Vsevolozhsk while Nokian Tyres arranges a bus transportation from St. Petersburg to the plant. The bus has several different routes from St. Petersburg to the plant some of which go through the city of Vsevolozhsk. About 54 % of employees uses the provided bus transportation. The lengths of the routes and the amount of trips made daily by different routes were obtained from Nokian Tyres.

Emissions from the bus transportation where calculated based on the kilometres travelled annually. The buses run 7 days a week with the same schedule except for the summer and Christmas holiday season (about 25 days) when all routes are only driven twice a day. Normally the total distance the buses travel per day is 1 299 km and on holiday seasons

369 km. The emission factor of 590 g CO_2e/km was obtained from LIPASTO. The factor is for highway driving on an average diesel long-haul bus in Finland in 2011 carrying 12 passengers.

Over half of the factory's employees live in St. Petersburg and the rest in Leningrad region, mainly in the Vsevolozhsk district. For the bus routes going through Vsevolozhsk the passengers were assumed to come proportionally from Vsevolozhsk district and St. Petersburg while passengers coming straight from St. Petersburg were all assumed to live there. Based on these assumptions the shares of employees from different areas using own or company provided transportation were calculated (table 5-15).

Table 5-15 Shares of Vsevolozhsk employees living in St. Petersburg and elsewhere in the Leningrad region

Place of residence	**Share of employees using the company bus (%)**	**Share of all employees not using the bus (%)**
St. Petersburg	42	13
Leningrad region	12	33

Emissions from commuting of the employees not using the bus were calculated based on the same shares for different means of transportation as in Finland. The distance travelled daily was based on information about the employees' place of residence. Distance from St. Petersburg to the plant is about 37 km and the distance in the Vsevolozhsk district was assumed to be 15 km on average. When calculating the annual distances travelled vacation time (four weeks) and the five day work week were taken into account. The same emission factors (table 5-14) as for commuting in Finland were used except for train travel. For train travel the same emission factor (27 g/pkm) as for business travel in Russia was used. Emissions from employee teleworking were excluded for both factories.

5.9 Leased Assets

Nokian Tyres has several leased company cars some of which are in company use and some are held by employees. The emissions from the cars were calculated based on information given by the leasing company. In order to make updating of the calculator as easy as possible the emissions were calculated based on the average budgeted emissions per year reported by the leasing company. Budgeted emissions are based on the length of the leasing contract, contract kilometrage and the car's emission factor per km. Nokian Tyres has three different type of cars: passenger cars, vans, and trucks. Annual average emissions were calculated separately for all types (table 5-16). In addition some heavy duty vehicles are leased for test use. Emissions for slope machine and dumper were calculated as explained in chapter 5.1.2. Vsevolozhsk factory does not have any leased vehicles thus emissions from leased assets only apply to the Nokia factory.

Table 5-16 Number of leased vehicle types and their average budgeted emissions

Vehicle type	**Number of vehicles**	**Average budgeted emissions (t CO2/a)**
Passenger car	101	4.68
Van	3	7.35
Truck	2	3.48
Dumper	1	44.55
Slope machine	1	8.31

While some of the leased vehicles are used for testing the tyres they are not always driven in the most fuel economic way. Because of this the emissions from the test cars may exceed the emissions reported by the car manufacturers. The actual emissions of a vehicle can't be determined without measuring them thus the same average budgeted emissions based on the emission factors reported by the car manufacturers were used. Using only the annual average budgeted emissions for calculating emissions may lower the accuracy somewhat. On the other hand calculating emissions separately for every car is not reasonable. In addition accurate kilometrage from every car is not available. Using the average annual emissions may overstate the emissions from the vehicles not in test use based on some calculations made with the actual kilometrage of cars for which it was available. While some cars may exceed their contract kilometrage some stay far below it.

5.10 Distribution

The tyres are stored in logistics centres and warehouses. Distribution of the produced tyres is done from logistics centres in Nokia and Vsevolozhsk. Specific tyres are studded and put on rims in the logistics centres as well. The largest warehouses are located in Nokia, Vsevolozhsk, Czech Republic and North America. All together there are over 30 warehouses in 13 countries. The tyres are distributed from warehouses to whole sellers and retailers from where they are sold to end users. (Nokian Tyres, 2016c) A big part of the tyres are also sold straight to first customers who may then pass the tyres forward. The distribution network is wide and complicated and there is only information about the transportations to warehouses and first customers. Thus several simplifications and assumptions were needed to assess the emissions. Although emissions from Vianor chain are also included in the distribution stage they are presented here separately.

Only emissions from the transportation from the factories to the first customer were included. This consists of the transportations to the warehouses, transportations straight to the first customer, and the transportations from the warehouses to the first customers (figure 5-2). The distribution centre in Nokia is outside of the plant area but because the distance is only a few kilometres the transportation between them was excluded.

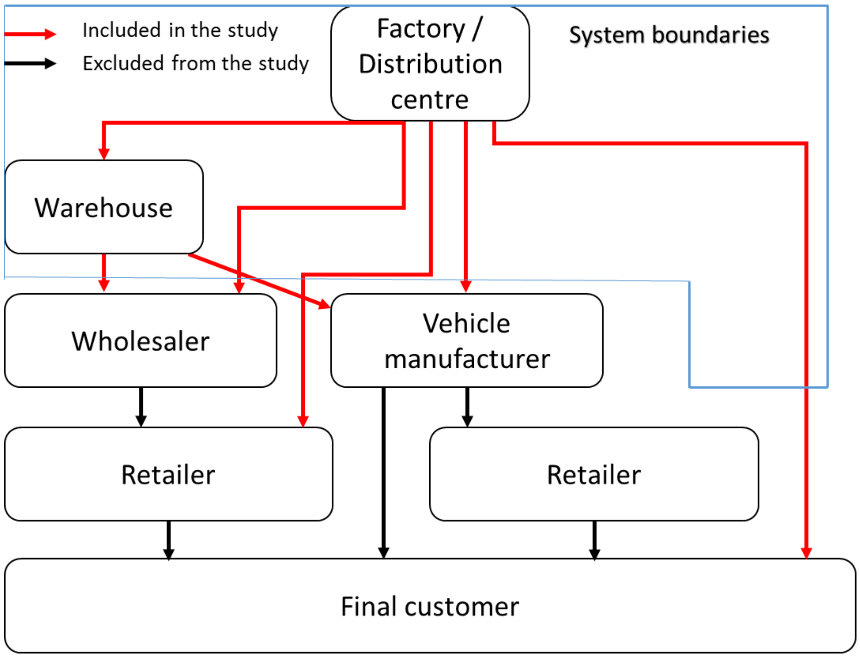


Figure 5-3 System boundaries for the distribution stage of the assessment

Tyres are mainly transported using trucks. From Finland the tyres are first transported by ships to Central Europe and then by trucks to the final destination. From Russia the tyres are transported to Central Europe either first by ship and then by truck or by truck all the way. In this assessment it was assumed that 50 % of the tyres from Russia are transported by land only and 50 % by land and sea. All transportation from Russia to Eastern Europe was assumed to be done by trucks. Almost all transportation in Russia is done by trucks, only less than 2 % of the tyres are transported by train. This has only a small effect on the total emissions thus all transportation in Russia was calculated to be done by trucks. To the far off destinations the tyres were assumed to be transported first by smaller ships to Lubeck from where they are shipped with larger container ships to their destination countries. All emission factors used to calculate the emissions from distribution are shown in table 5-17.

Table 5-17 The emission factors for different means of transportation used for calculating emissions from distribution

Transport	**Emission factor (g CO_2-e/unit)**	**Unit**	**Source**
Ship 8000+ TEU	13	tkm	(IMO, 2009, p. 131)
Ship 0-999 TEU	36	tkm	(IMO, 2009, p. 131)
Semi-trailer truck (25 t capacity)	55	tkm	(LIPASTO, 2012)
Semi-trailer truck (25 t capacity)	959	km	(LIPASTO, 2012)
Deliver lorry, light, (3,5 t capacity)	177	tkm	(LIPASTO, 2012)
Deliver lorry, heavy, (9 t capacity)	113	tkm	(LIPASTO, 2012)

The size of the trucks used for land transportations depend on the first customer and the size of the shipment. The assumptions made regarding the trucks are covered in next sections. All emissions from distribution were calculated based on the estimated delivery volumes in 2016.

5.10.1 Transportation to Warehouses

Information about tyre volumes transported between own warehouses was received from Nokian Tyres. For passenger car tyres the information was in number of tyres and for heavy tyres in kilograms. Passenger car tyres are rather homogeneous in size and one semi-trailer truck takes approximately 900 tyres in Europe. In North America the trucks are smaller thus they only take about 800 tyres. Since the first transportation steps to warehouses are large bulk shipments it was assumed that the trucks are fully loaded (900/800 tyres per truck). Heavy tyres have large variation in sizes and weights thus the emissions were calculated based on tonne km. Since the volume rather than the weight is the restricting factor when filling the trucks, the trucks were assumed to be 70 % loaded based on the mass (table 5-17). For simplification emissions were only calculated based on the distance to the largest warehouse in each country. USA and Russia created an exception while the distances are large there.

For all transportations from the warehouses to the first customers the same distance was assumed. The distance is based on primary data of the average distance from the European tyre manufacturers to the first client collected by ETRMA. The distance was assumed to be 511 km which is the average distance for the transportations of summer and winter tyres. (Quantis, 2013) Although it is the European average it was used for all market areas since the first transportation to a local warehouse was already included.

Since the transportations to the customers are not anymore large bulk shipments the emissions were calculated based on the weights of the transported tyres. The tyre amounts were converted into weights assuming one tyre weighs 8.9 kg. The sizes of the shipments vary but it was assumed that all transportations are done using a light delivery lorry with the maximum load capacity of 3.5 t. The used emission factor was based on 50 % load rate and highway driving (table 5-17).

5.10.2 Transportation Straight to Customers

The volumes of the passenger car tyres delivered from each factory straight to customers were obtained only as pieces of tyres sent to a country or a certain area. The delivery volumes were compared to sales figures from 2014 and 2015 to assess the destinations of the tyres delivered to non-specified areas. In 2015 Russia, Nordic countries and Central Europe accounted for over 85 % of all sales (Nokian Tyres, 2016a). Tyre volumes delivered to other areas are much smaller. Thus the emissions from deliveries to other areas were divided to South and Middle America, Asia, Oceania, Middle East, Africa and

Commonwealth of Independent States (CIS). From the CIS countries were excluded Russia, Kazakhstan and Belarus, since they had individual figures available. And although Georgia no longer is a part of CIS it was included there. For each area the emissions were calculated based on the distance to the country with the largest sales. In Central Europe distances were assumed based on the six countries (Austria, Belgium, France, Germany, Italy, and Poland) with the biggest sales. In addition emissions from deliveries to Iceland and United Kingdom were calculated. North America's deliveries were divided between USA and Canada based on the sales figures. All the distances were assumed to be to the approximate center of the country. For Russia and Finland emissions from distribution were calculated based on the total amount of tyres sold. All emissions from transportations to customers in Russia were allocated to the Vsevolozhsk factory and all transportations to customers in Finland were allocated to the Nokia factory.

The sizes of the shipments straight to customers can vary from full semi-trailers to shipments of only a few tyres. For simplification all emissions were calculated assuming a heavy delivery lorry with the maximum capacity of 9 t and a load rate of 50 % was used. Emission factor for highway driving was used (table 5-17).

5.11 Use Stage

As presented earlier (chapter 3.4) the use stage causes most of the emissions during a tyre's life cycle. Emissions from use may, however, be different for the various tyres with distinct properties. The selection of cars affects the emissions as well. Tyres fitted under an electric car, for instance, have a smaller carbon footprint than tyres of a petrol car (Quantis, 2013). For heavy-duty tyres determining emissions from the use of the tyres is uncertain as there are no studies concerning the allocation of the emissions. In addition information concerning emissions from heavy duty vehicles is less available than for passenger cars.

No emissions from use stage were calculated for the truck tyre treads manufactured. The retreaded truck tyre can be more or less comparable with a new tyre in terms of rolling resistance, however there is no representative data available. (Quantis, 2013) In a way retreading can be seen to result in avoided emissions since instead of manufacturing a new tyre only the tread is manufactured. This results in less resources needed thus resulting in less emissions. Thus the emissions of the use stage of the retreads were excluded.

5.11.1 Passenger Car Tyres

The emissions from the use stage of a passenger car tyre were calculated based on the tyre's rolling resistance. For comparison the emissions were calculated for two different models from Nokian Tyres. The other tyre represented the average tyre (Hakka Blue) produced by Nokian Tyres while the other tyre was so called green tyre (Hakka Green) with very low rolling resistance. Both selected tyres were summer tyres in size 205/55R16 which is the most commonly sold tyre size by ETRMA members in Europe. Rolling resistance for studded tyres can’t be determined the same way as for non-studded tyres thus emissions for all tyres were calculated using the summer tyres’ consumption.

In addition to the tyre’s characteristics its lifespan affects the emissions of the whole use stage. In this assessment the lifespan was assumed to be 40 000 km while it is the average lifespan of a European tyre according to ETRMA (Quantis, 2013). In other LCAs of tyres the lifespan has usually been between 30 000 and 50 000 km which makes the results comparable. (Continental, 1999; JATMA, 2012; Quantis, 2013). To calculate the emissions the fuel consumption related to the tyre was done based on a model developed for a tyre LCA for ETRMA done by Quantis. (Quantis, 2013)

In the model the fuel consumption related to the tyre is dependent of two forces, the acceleration resistance and rolling resistance. The tyre also has a small impact on the air drag of the car but it is seen to have limited effect on the consumption compared to the body of the car thus being excluded.

Acceleration resistance resists the change in the tyre’s velocity and it is related to the translational acceleration (tyre mass), and to the rotational resistance (rotational moment of inertia). In the model the rotational resistance is left out for simplification, though, while the impact of the acceleration resistance in the total fuel consumption is low. Thus the acceleration resistance is based on the marginal fuel consumption due to the tyre weight, the tyre weight and the lifespan of the tyre (equation 3). Tyres wear losing their mass during their life time thus the average weight of the tyre was calculated and used. According to ETRMA the average wear loss for summer tyres is 2.83 g/100 km (Quantis, 2013). Based on this the average weight was calculated using the determined lifespan of the tyre.

Because the fuel consumption related to the rolling resistance is based on the energy needed to overcome, the energy was first calculated. The wear loss of the tyre also has an impact on the rolling resistant coefficient. According to ETRMA the rolling resistance coefficient is decreased on average by 20 % over a tyre’s lifetime though it can be decreased by as much as 40 %. (Quantis, 2013) In this study the reduction was assumed to be 20 % over the whole lifespan of the tyre making the average rolling resistance coefficient 90 % of the reported one. According to the model the rolling resistance energy is dependent on the average rolling resistance coefficient, the load applied to the tyre, calculated from the weight of the vehicle divided by the number of tyres, Earth’s gravity, the lifespan of the tyre, and the efficiency of the vehicle (equation 4). The rolling resistance energy can then be converted into fuel consumption by dividing it with the fuel’s lower heating value and density (equation 5). The total fuel consumption related to the tyres is the sum of the fuel consumption related to the acceleration resistance and to the rolling resistance (equation 6). Finally, the GHG emissions resulted from the tyres lifetime were calculated based on the fuel consumption and the emission factor of the fuel (equation 7).

$$AR_{Cons} = MC * m_{tyre} * LS_{tyre} \tag{3}$$

$$RR_{energy} = RRc_{avg} * \frac{m_{vehicle}}{No\ tyres} * G * LS_{tyre} / Eff_{vehicle} \tag{4}$$

$$RR_{Cons} = \frac{RR_{Energy}}{LHV_{fuel}} / Density_{fuel} \tag{5}$$

$$TyreFuel_{Cons} = RR_{Cons} + AR_{Cons} \tag{6}$$

$$Emissions_{tyre} = TyreFuel_{Cons} * EF_{fuel} \tag{7}$$

AR_{Cons} = *Fuel consumption due to acceleration resistance (l/tyre)*
MC = *Marginal consumption due to weight of the tyre (l/km*kg)*
m_{tyre} =*Average mass of the tyre (kg)*
LS_{tyre} = *Tyre's lifespan (km)*
RR_{energy} = *Energy needed to overcome rolling resistance (MJ/tyre)*
RRc_{avg} = *Average rolling resistance coefficient (kg/t)*
$m_{vehicle}$ = *Mass of the vehicle (t)*
No tyres = *Number of tyres per set*
G = *Gravity* (m/s^2)
$Eff_{vehicle}$ = *Average vehicle efficiency*
RR_{Cons} = *Fuel consumption due to rolling resistance (l/tyre)*
LVH_{fuel} = *Lower heating value of the fuel (MJ/kg)*
$Density_{fuel}$ =*Density of the fuel (kg/l)*
$TyreFuel_{Cons}$ = *Total fuel consumption caused by the tyre (l/tyre)*
$Emissions_{tyre}$ =*Total emissions caused by the tyre* (kg CO_2/tyre)
EF_{fuel} =*Emission factor of the fuel (kg CO2/l)*

The values used for calculating the total GHG emissions caused by the tyre's use are presented in table 5-18 for both of the tyre types. Both the rolling resistance coefficient of a new tyre and the average rolling resistance coefficients (90 % of RRc_{new}) are presented.

Table 5-18 Values used for calculating use phase emissions for Hakka Blue and Hakka Green 2 tyres

	Hakka Blue	**Hakka Green 2**	**Unit**
MC	0.000034	0.000034	l/km*kg
$m_{tyre,new}$	8.4	7.6	kg
m_{tyre}	7.83	6.98	kg
RRc_{new}	7.9	6.3	kg/t
RRc_{avg}	7.11	5.67	kg/t
LS_{tyre}	40 000		km
$m_{vehicle}$	1.3		t
No tyres	4		
g	9.81		m/s^2

GHG emissions from use are dependent on the fuel of the car. Petrol and diesel cars have differing efficiencies and emission factors (table 5-19). The total emissions were calculated based on the average shares of 37 % diesel cars and 63 % petrol cars in EU reported by Eurostat. Shares of alternative fuels and electric cars are small and thus they were excluded in order to simplify the calculations. (Eurostat, 2015)

Table 5-19 Vehicle efficiencies, heating values, densities and emission factors for petrol and diesel (Statistics Finland, 2016a)

	Petrol	**Diesel**	**Unit**
$Eff_{vehicle}$	0,27	0,37	
LVH_{fuel}	42,6	42,9	MJ/kg
$Density_{fuel}$	0,78	0,83	kg/l
EF_{fuel}	2,19	2,18	kg CO_2 /l

The total GHG emissions were calculated from the GHG emissions of a tyre and the total amount of passenger car tyres produced in 2015. The total GHG emissions were calculated based on both tyre’s rolling resistance coefficients for comparison. Only the GHG emissions from the average tyre (RR_C = 7.9 kg/t) were used in the final results.

5.11.2 Heavy-duty Tyres

The emissions from the use of heavy-duty tyres were not calculated based on the same model as passenger car tyres’ because the model is not verified for heavy tyres. Also the range of different tyres is much larger with heavy tyres than with passenger car tyres. For example the weights and the operating environments of the tyres can alter highly. In addition the fuel consumptions of heavy-duty vehicles may alter considerably based on their age. (LIPASTO, 2015) Thus the calculations were based mainly on average figures.

The heavy tyres were divided into four categories based on their operating environment, namely tractors and agriculture, forestry, mining and earthmoving, and harbour and material handling. All these categories consist of a range of different tyres for different kind of machinery. The average emissions were calculated separately for each category and then multiplied by the production rates of the categories.

LIPASTO has reported emissions and fuel consumptions for different vehicle types considering characteristics of the Finnish vehicle fleet such as age distribution and average power consumption. Thus the figures used to calculate the emissions are based on average use of heavy-duty machines in Finland. (LIPASTO, 2015) The fuel consumptions were presented as tonnes per year for all vehicles of a certain vehicle type. First the average consumptions per vehicle type were calculated based on the amount of the vehicles. Because each tyre category consists of different types of vehicles, typical vehicles for which consumption information was available were selected for each category (table 5-20). About 20-40 % of a trucks fuel consumption can be related to the tyres and it was assumed that 30 % of a heavy-duty machine’s consumption is allocated to the tyres. The tyre related consumption was then divided between the amount of tyres in a vehicle. The tyres of trailers and other towed equipment that do not consume fuel on their own were included in the agriculture tyres as well. Thus the amount of tyres for agriculture tractors was calculated to be six.

Table 5-20 Heavy tyre categories, vehicles counted in the categories and their average emissions related to the tyres, the number of tyres per each vehicle and the average emission factor used for the tyre category

Tyre category	Vehicle types included	Average consumption related to tyres (l/tyres/a)	Number of wheels per vehicle	Average emissions related to a tyre (kg CO_2e/tyre /a)
Tractors and agriculture	-Agricultural tractor	473	6	173
	-Combine harvester	321	4	
Forestry	-Felling machine	8 545	6	2 502
	-Forest tractor	4 863	4	
	-Forest tractor	4 863	6	
Mining and earthmoving	-Dump truck	5 115	6	1 316
	-Road grader	3 171	6	
	-Wheel loader	636	4	
	-Backhoe loader	1 881	4	
	-Wheeled excavator	3 626	4	
	-Maintenance tractor	1 318	4	
Harbour and material handling	-Forklift	3 948	4	951
	-Industrial tractor	952	4	
	-Crane	1 682	4	

Emissions for each tyre type were calculated based on the consumption. Heavy-duty vehicles are mostly run by diesel engines thus the emission factor of diesel containing 17 % biodiesel (2.18 kg CO_2/l) was used (Statistics Finland, 2016a). The final emission factor used for each tyre category was then calculated as the average of the emissions from different tyre types included in the category. The tyres' lifespan was assumed to be 7 years. Total emissions were calculated based on the shares of the different tyre categories manufactured in a year and the lifespan of a tyre.

5.12 End-of-life Treatment

Although the recycling rates and the ratios between different recycling paths differ from country to country the values for Europe were used while Nordic countries and Central Europe accounted for approximately 70 % of sales in 2015 (Nokian Tyres, 2016a). In addition there is accurate data available regarding recycling of tyres in the EU. The recycled content method is used for the treatment of ELTs as well as for the waste generated in operations. This means that the benefits of using ELTs instead of virgin raw material are also allocated to the user of the recycled tyres. However transportation of all ELTs to a treatment facility is accounted for. In most of the EU27 countries (64 %) including Finland ELTs are managed through producer responsibility. Generally a not-for-profit company financed by tyre producers is grounded to manage the collection and recovery of the ELTs. Also this may mean that wholesellers of tyres are obligated to take ELTs and organize their transport to a treatment facility. (ETRMA, 2016a)

Reuse, retreading and export were excluded from the assessment. However these tyres will eventually become ELTs too and their amount was included in the average European end-of-life treatments increasing the shares of other treatment routes proportionally (table 5-21). This may not be entirely accurate while most of the tyres are exported outside Europe where legislation regarding ELTs is not as strict. However there aren't necessarily accurate statistics about ELT management thus making tracing the exported tyres impossible. (Quantis, 2013)

Table 5-21 Shares of different treatment methods for end-of-life tyres. (ETRMA, 2016a)

	Part-worn tyres to reuse (export, retreading)	**Material recovery**	**Energy recovery**	**Landfill**
Shares of end-of-life treatments (%)	19.0	38.6	37.7	4.6
Adjusted shares (%)	-	47.7	46.6	5.7

Because the recycled content method was used emissions come only from the landfilled tyres and the transportation of all the ELTs. ETRMA has estimated the average transportation distance for collected tyres to be 77 km and the same was used in this assessment as well. The tyres were assumed to be transported in semi-trailer trucks with the carrying capacity of 25 tonnes with 70 % load rate. The same emission factor of 55 g CO_2e/tkm as for raw material transportation (table 5-8) was used here (LIPASTO, 2011). Emissions from landfilling were calculated based on the emission factor for commercial and industrial waste, 199 kg CO_2e/t (BEIS, 2016). Commercial and industrial waste as well as tyres are more inert than municipal waste for example and they produce less emissions when landfilled.

5.13 Retail Operations

The retail chain Vianor has several facilities in Europe and North America some of which are operated on a franchising principle (table 5-22). In addition there are two retreading facilities in Finland. For the own Vianor stores all related scope 1, 2 and 3 emissions were determined when possible. For the partner stores however only scope 1 and 2 emissions have to be reported in the franchise category of scope 3 emissions. (GHG Protocol, 2011, p. 37) Because there are no scope 1 emissions from the stores only emissions from bought energy were calculated for the partner stores.

Table 5-22 The number of Vianor facilities and employees per region

Location	**Own facilities**	**Partner facilities**	**Employees in own facilities**
Finland	70	33	693
Sweden	62	54	426
Norway	52	61	394
Russia	2	405	15
USA	10	68	52
Central Europe	6	344	33
Baltic	0	35	0
Eastern Europe	0	280	0
Total	202	1 280	1 613

Altogether Vianor has stores in 26 different countries. Although some of the own stores are located in rented premises and some in own properties all emissions from energy use were treated as scope 2 emissions because of the chosen consolidation approach.

5.13.1 Energy Use

The information regarding electricity and heating for Vianor facilities were obtained in realized expenses per year. The average expenses per facility were calculated for both in order to simplify calculations and to expand the figures for the facilities without such information. The expenses were then converted into megawatt hours using the average prices per unit in Finland (table 5-23). Because the information was only available for the Finnish facilities the same average energy consumptions were also used for calculating emissions from the facilities abroad. Also in some facilities electricity or heating was included in rent thus the figures were applied for them too. For the retreading facilities the consumption of electricity and heating were calculated separately as they do not match the consumptions of the stores.

Table 5-23 The average energy expenses and consumptions per facility and the average prices in Finland

	Average expense per facility (€)	**Price in Finland (€/MWh)***	**Average consumption per facility (MWh)**
Electricity	11 340	87.51	130
Heating	11 253	71.88	157

* (Statistics Finland, 2016b)

Emissions from electricity were calculated based on the emission factors of the average electricity consumption mixes in different areas (table 5-24). For Central Europe the emission factor for the European members of the International Energy Agency (IEA) and for Baltic and Eastern Europe the factor for Eastern Europe were used. Distribution losses are included in the factors. (Brander, 2011)

Table 5-24 Emission factors for electricity mix in different areas (Brander, 2011)

Location	**Emission factor (kg CO_2/MWh)**
Finland	209*
Sweden	25
Norway	3
Russia	563
USA	587
Central Europe	502
Baltic & Eastern Europe	910

* (Motiva, 2016) based on Statistics Finland

Some of the facilities had differing heating systems. Most of the places used district heating but a few were heated using oil, gas, electricity or thermal heat. Because the number of other heating systems than oil and district heating was so small they were excluded. The emissions in Finland were calculated based on a 75 % share for district heating and 25 % for oil. For district heating the average emission factor for combined heat and power (183 kg CO_2 / MWh) provided by Finnish Energy was used (Motiva, 2016). Emissions for the facilities abroad were all calculated based on the average fuel consumption in heat production in EU-28 in 2014 (table 5-25). Other sources included heat pumps, electric boilers, chemical sources and other non-specified sources. (Eurostat, 2016) For other sources the emission factor of electricity consumed in the IEA member states was used (Brander, 2011). The final emission factor used for heating was 216 kg CO_2e / MWh. The same factor was used for all the facilities abroad, both own and franchises.

Table 5-25 Energy sources used for heat production in EU-28 in 2014, their emission factors and emissions from production of one MWh of average European heat (Eurostat, 2016)

Energy source	**Share of total heat production**	**Emission factor (kg CO_2/MWh fuel)**	**Emissions (kg CO_2/MWh heat)**
Coal products	25.9	389	100.8
Peat	1.3	371	4.9
Petroleum products	4.6	267	12.2
Natural gas	38.6	199	76.9
Nuclear	0.2	0	0
Renewable	22.2	0	0
Waste	4.5	144	6.4
Other (incl. electricity)	2.7	501	13.6

5.13.2 Water Usage

The information about water usage was obtained in realized expenses per year. First the average expenses for water were calculated and then converted into cubic metres using the average price for water in Finland (table 5-26). The average price is based both on water supply and wastewater treatment. When calculating emissions it was assumed that the average consumption is drawn from the municipal water system and released entirely to the sewage system.

Table 5-26 The average water expenses and consumptions per facility and the average prices in Finland

	Average expense per facility (€)	**Price in Finland (€/m^3)***	**Average consumption per facility (m^3)**
Water supply	1 402	4.48	313

* (Finnish Water Utilities Association (FIWA), 2016)

The emissions were then calculated using the emission factors from HSY (table 5-9) and the average water consumption. The same emission factors were used for both the facilities in Finland and abroad.

5.13.3 Wastes

Generated wastes are not reported as precisely in Vianor stores as in the factories thus the information concerning wastes was limited. The reporting methods and units vary between the stores thus making processing the information laborious. For this reason waste data was only processed for two stores, one large, and on small. From this data average amounts were calculated for different waste fractions and applied for all of the stores. This may lead to inaccuracies in the results. However, to get an estimate of the emissions related to the waste disposal the results were included in the assessment. Since wastes are largely recycled the emissions from waste disposal should remain low in any case.

Only the mixed waste fraction is landfilled entirely. All rubber and tyre waste is recycled. Same was assumed for all wood, card board and metal wastes. For waste oil and solid oily waste it was assumed that 50 % is utilized and the other 50 % is disposed as hazardous waste. The same recycled content method as earlier was applied here and emissions from transportation were included for all waste fractions. For the rubber waste the transportation distance was assumed to be 77 km due to the ETRMA’s estimate for ELTs (Quantis, 2013). For the other waste fractions the transportation distance was assumed to be 40 km based on the transportation distances of the wastes from the factories. Since the waste volumes are much smaller the emissions from transportation were calculated based on tonne kilometres. A truck with maximum load capacity of 9 t and load rate of 50 % was assumed to be used for the transportations. Wood and cardboard formed an exception. They are collected in pallets or containers and their mass was not reported thus emissions were calculated per pallet or container. A truck with the load capacity of 9 t was assumed to be used for the collection here as well. Emissions were calculated assuming the trucks run the trip first empty and then return with full load. Emission factors for mixed and hazardous waste already include transportation (table 5-27).

Table 5-27 Emission factors for waste disposal and collection

Emission source	**Emission factor (kg CO_2e/unit)**	**Unit**	**Source**
Industrial and commercial waste	199	tonne	(BEIS, 2016)
Hazardous waste	1 410	tonne	(WWF, 2016)
Transportation, truck empty	0.458	km	(LIPASTO, 2011)
Transportation, truck full	0.559	km	(LIPASTO, 2011)
Transportation, truck 50 %	0.113	tkm	(LIPASTO, 2011)

The same waste volumes and emission factors were used for the stores in Finland as well as for those abroad. Emissions from waste disposal in the franchise facilities were not included.

5.13.4 Business Travel

Business travels were recorded in paid kilometre allowances for road transportation. The paid allowances were converted into kilometres using the maximum kilometre allowance set by the Finnish Tax Administration. In 2015 the allowance was 44 cents per kilometre (Veronmaksajat, 2014). The emissions were again calculated using the same emission factor of 98 g CO_2e/pkm as earlier (LIPASTO, 2012). In 2015 the total distance driven was 1 074 518 km.

Air mileage was received from a travel agency and it was converted into kilometres. The emissions were then calculated using the same emission factor of 95 g CO_2e/pkm as earlier (BEIS, 2016). In 2015 the total accumulated air kilometrage was 486 798 km. No information about rail transportation was available. However emissions per passenger kilometre are the lowest in rail traffic thus it was assumed they would remain negligible.

5.13.5 Commuting

Emissions from commuting were calculated based on information from national travel surveys (table 5-28). For Finland the travelled distances per a mode of transportation were calculated as explained in chapter 5.8. Because for Russia there was no such information available the same figures as for Finland were used. For Sweden and Norway the emissions were based on the average commuter in Sweden in 2014-2015 and for Central Europe the commuter in Switzerland in 2014.

Table 5-28 Average commuting distance and modal split in different store locations.

Location	**Commute distance (km/d)**	**Walking / cycling (%)**	**Rail traffic (%)**	**Bus (%)**	**Car (%)**	**Source**
Finland	15.6	3.1	7.1	5.6	84.1	(Liikennevirasto, 2012)
Sweden	14.5	3.4	13.8	13.8	69.0	(Traffic Analysis, 2016)
Norway	14.5	3.4	13.8	13.8	69.0	(Traffic Analysis, 2016)
Russia	15.6	3.1	7.1	5.6	84.1	(Liikennevirasto, 2012)
Central Europe	14.5	6.2	17.3	2.1	74.4	(Bundesamt für Statistik, 2016a) (Bundesamt für Statistik, 2016b)
USA	11.0	2.9	1.3	1.3	94.5	(Santos, 2011)

The modal splits are determined based on passenger kilometres. For Finland and Central Europe the modal splits are based on all passenger traffic and for others only on commuter traffic. In the travel surveys of USA and Sweden the public transportation was not divided between rail and road traffic thus it was assumed that it is divided equally between them.

For Finland and Russia the same emission factors as in chapter 5.8 were used. For others the average European emission factors for different means of transportation were used (table 5-29) (EEA, 2014).

Table 5-29 Emission factors for different means of transportation

	Emission factors (g CO_2/pkm)			
Location	**Train**	**Bus**	**Car**	**Source**
Finland	1.9*	53	98	(LIPASTO, 2011) * (VR, 2015)
Russia	27*	53	98	(LIPASTO, 2011) * (IEA & UIC, 2015)
Others	14	68	104	(EEA, 2014)

The number of leased passenger cars was deducted from the amount of employees in order to avoid double counting. It was assumed that all the passenger cars are also used for commuting by an employee. Emissions from leased vehicles are dealt separately in the next chapter.

5.13.6 Leased Assets

The amount and consumptions of the leased vehicles were obtained from the leasing company. The average budgeted emissions were calculated separately for passenger cars leased in Finland and in Sweden and for trucks and vans in Sweden (table 5-30).

Table 5-30 The average budgeted emissions per year for different vehicle types leased by Vianor in Finland and in Sweden

Location	**Car type**	**Number of vehicles**	**Average budgeted emissions per year (t CO2/a)**
Finland	Passenger car	9	5.97
Sweden	Passenger car	51	4.56
	Van	66	7.35
	Truck	4	3.51

The average budgeted emissions were then multiplied by the amount of the vehicles to determine the total emissions produced per year. Other Vianor stores do not have leased vehicles or there is no information about them.

6. RESULTS AND DISCUSSION

The GHG emissions were calculated separately for the Nokia and Vsevolozhsk factories and for Vianor chain using the calculator created. All emissions were calculated as tonnes of CO_2 equivalents and as kg of CO_2 equivalents per tonne of tyres produced. All of the GHG emissions from each category are presented separately for Nokia and Vsevolozhsk factories and for Vianor chain in Appendix B.

The GHG emissions were compared to the GHG emissions reported by other operators in tyre industry. The differences in the results were then analysed. Based on the results of this study opportunities to reducing the GHG emissions are presented.

6.1 Total Greenhouse Gas Emissions from All Operations

The total GHG emissions from the operations of Nokian Tyres were over 5 million t CO_2e (table 6-1). GHG emissions of Nokia factory comprised 37 % and of Vsevolozhsk factory 60 % of the total. Only 3 % of all GHG emissions came from the retail operations. If the GHG emissions from the use and end-of-life treatment of the tyres are excluded the total GHG emissions are almost 8 times lower, only 0.68 million t CO_2e.

Table 6-1 The total GHG emissions separately for Nokia and Vsevolozhsk factories, Vianor chain and the whole corporation. GHG emissions are presented both as tonnes of CO2e and as kg CO_2e/t production. The GHG emissions are also presented without the GHG emissions from use and end-of-life

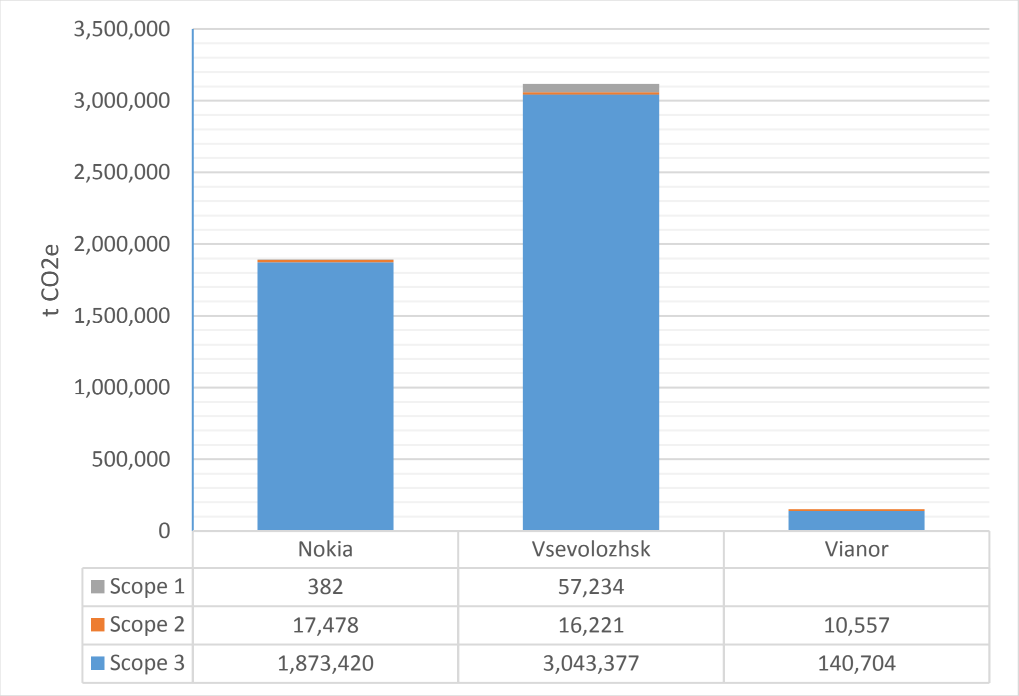
	Total GHG emissions (t CO_2e)	**Total GHG emissions (kg CO_2e/t production)**	**Total GHG emissions from operations* (t CO_2e)**	**Total GHG emissions from operations* (kg CO_2e/t production)**
Nokia	1 891 280	38 698	146 769	3 003
Vsevolozhsk	3 116 883	25 752	382 344	3 159
Vianor	151 261	890	151 261	890
All Nokian Tyres	5 159 645	30 423	680 374	3 189

* Excluding use phase, and end-of-life treatment

The production rate of Vsevolozhsk factory is higher than in Nokia factory thus the total GHG emissions are higher. When the GHG emissions of the use phase are excluded the emissions per tonne of production are similar (table 6-1). The relations between the operations are change when the use phase is not included. Nokia factory, Vsevolozhsk factory, and Vianor comprise 21.6 %, 56.2 %, and 22.2 % of the total GHG emissions, respectively.

6.2 Scope 3 Emissions

Scope 3 emissions formed most of the GHG emissions (figure 6-1). For Nokia factory, Vsevolozhsk factory and Vianor chain scope 3 emissions formed 99.0%, 97.6%, and 93.0% of total GHG emissions, respectively. Because of the own power plant scope 1 emissions of Vsevolozhsk factory are almost 100 times higher than of the Nokia factory's.



	Nokia	Vsevolozhsk	Vianor
■ Scope 1	382	57,234	
■ Scope 2	17,478	16,221	10,557
■ Scope 3	1,873,420	3,043,377	140,704

Figure 6-1 GHG emissions of the Nokia and Vsevolozhsk factories and the Vianor chain divided into scopes 1, 2 and 3

The scope 3 emissions can be further divided by source (table 6-1). The use phase causes most of the emissions. It causes 92.1 % and 89.8 % of all scope 3 emissions for the Nokia and Vsevolozhsk factories, respectively. The GHG emissions from use differ because of the heavy tyres manufactured in Nokia factory. Heavy duty machines have higher fuel consumption than passenger cars thus the GHG emissions from the use of the heavy tyres are also higher.

The second largest source of scope 3 emissions is the production of raw materials. It causes 5.9 % and 8.4 % of the scope 3 emissions for the Nokia and Vsevolozhsk factories, respectively. For Nokia factory the transportation of raw materials is the third largest source as for Vsevolozhsk factory distribution causes more emissions. The difference can be explained by the partly different suppliers. In addition Vsevolozhsk factory is closer to the harbor which can be one reason for the lower GHG emissions. The difference in the GHG emissions from distribution is partly due to the larger amount of road transportations from Vsevolozhsk factory. All direct distribution in Russia is allocated to the Vsevolozhsk factory. Half of the transportation to Central Europe was assumed to be done by trucks. Also most of the transportations to Eastern Europe come from Russia and are done using trucks. GHG emissions from waste are higher in Vsevolozhsk as the recycling rate is lower. Also transportation distances for some waste fractions are long in Russia. The difference in business travel is mostly explained by the smaller amount of flying miles for the employees of Vsevolozhsk factory. In Nokia factory 89 % of the business travel GHG emissions come from air travel. In addition there was no information about road travel.

Table 6-2 The scope 3 emissions of Nokia and Vsevolozhsk factories by emission source

Emission source	**Scope 3 emissions, Nokia (kg CO_2e/t production)**	**Scope 3 emissions, Vsevolozhsk (kg CO_2e/t production)**
Raw materials, production	2 276.6	2 155.4
Raw materials, transportation	169.0	86.5
Well-to-tank (fuel production)	0	63.6
Water Usage	1.3	1.2
Waste	0.6	13.1
Business travel	18.4	0.1
Commuting	12.0	8.1
Leased assets	12.0	0
Distribution	143.0	224.1
Use phase	35 684.2	22 577.7
End-of-life treatment	15.6	15.6
Total	38 293.3	25 145.4
Total excluding use phase emissions	2 648.7	2 567.7

Overall the scope 3 emissions per tonne of production are higher in Nokia factory. The production rate is lower in Nokia factory. Since the head quarter is situated in the Nokia factory there are more auxiliary operations besides the manufacturing. In addition some of the GHG emissions from the sales companies abroad were allocated to the Nokia factory.

For Vianor chain the franchisees generate over 98 % of all the scope 3 emissions. Wastes, water usage, business travel, commuting and leased assets represent a small fraction of all emissions as they do for the factories.

6.3 Greenhouse Gas Emissions from Own Operations

As the GHG emissions from the use of the tyres are so high they may overshadow the other GHG emissions. The relations between the emission sources can be seen more clearly when only the GHG emissions over which there is direct control over are included, and the production and procurement of raw materials, use phase and end-of-life treatment are excluded (figure 6-2). The energy use generates the most of the GHG emissions (approximately 65 %). The second largest source is distribution with a share of approximately 25 %. For Vsevolozhsk factory the production of the natural gas used for energy production forms a big part of the emissions from the factory. In Nokia factory business travel and commuting form a prominent part of the GHG emissions (about 4 %) although they only represent less than 1 % of all the GHG emissions of Nokia factory.

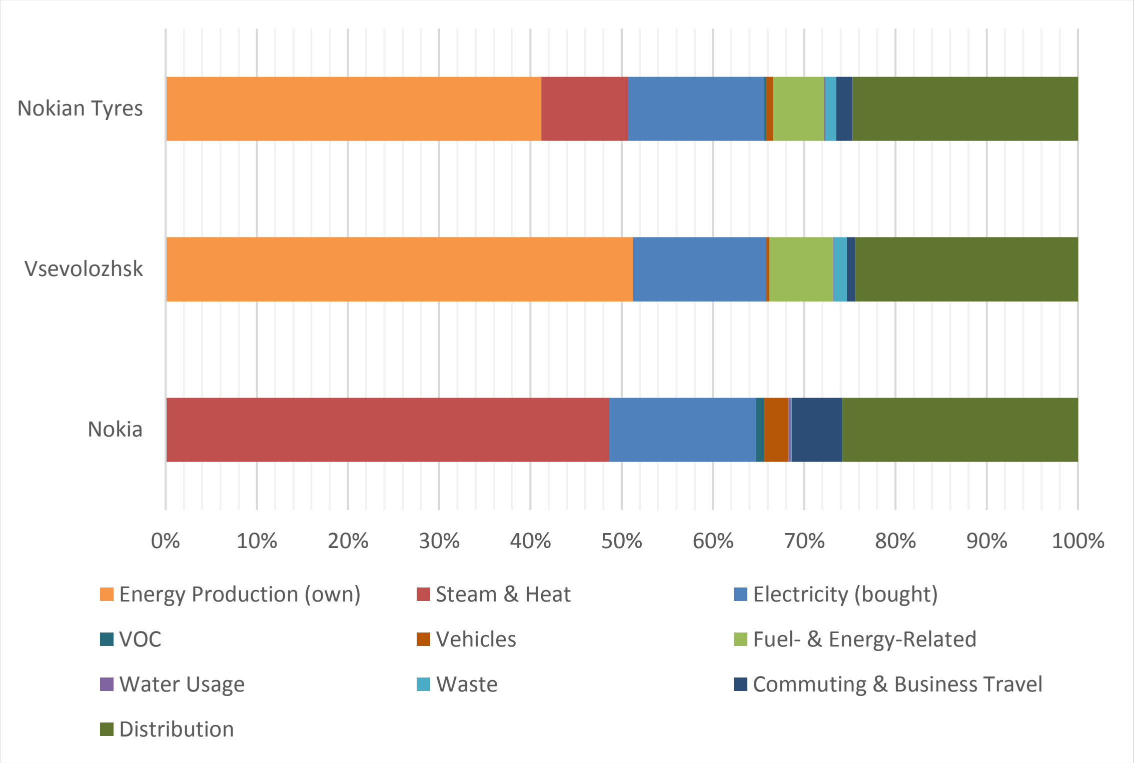


Figure 6-2 The relation of the GHG emission sources of Nokia and Vsevolozhsk factories and of the both factories combined

The shares of GHG emissions from different sources are similar for both factories, Nokia and Vsevolozhsk, when it comes to distribution and energy use. The actual emissions, however are different. The total GHG emissions are higher for Vsevolozhsk factory since the production rate is higher. The GHG emissions per t production are lower for Nokia factory, however (table 6-3).

Table 6-3 The GHG emissions from the own operations of Nokia and Vsevolozhsk factories, Vianor chain and the total combined emissions for whole Nokian Tyres corporation (without emissions from raw materials, use phase, and end-of-life)

	GHG emissions from own operations (t CO_2e)	**GHG emissions from own operations (kg CO_2e/t production)**	**Share of all GHG emissions (%)**
Nokia	27 234	557	18
Vsevolozhsk	110 996	917	74
Vianor	12 747	75	8
All Nokian Tyres	150 977	889	100

Part of the higher GHG emissions are due to the emissions from distribution and wastes in Vsevolozhsk (table 6-2). A large impact, however, is on the energy sources used. The share of renewable or carbon neutral energy sources is high (72 %) in Nokia factory. When only the GHG emissions from energy are taken into account the emissions are 358 kg CO_2e/t production and 604 kg CO_2e/t production from Nokia factory and Vsevolozhsk factory, respectively.

6.4 Comparison to the GHG Assessment from 2011

The present assessment can’t be directly compared to the results from 2011 as the scope is wider. In 2011 the assessment consisted of the GHG emissions from production and procurement of raw materials, electricity, heat and steam, water usage, wastes, business travels, VOCs, and the usage of office paper. (Markkanen, 2013) The results of the GHG assessment made in 2011 are presented in table 6-4. The production rate in 2011 was higher (71 600 t) than in 2015 (48 900 t) which can result in higher GHG emissions. The GHG emissions per t production were used as they have better comparability.

Table 6-4 GHG emissions from Nokia factory in 2011 and in 2016

Emission source	**GHG assessment 2011 (kg CO_2e/t production)** (Markkanen, 2013)	**GHG assessment 2011, updated emission factors* (kg CO_2e/t production)**	**Present GHG assessment (kg CO_2e/t production)**
Raw materials	2 888	2 888	2 446
Electricity	204	204	89
Steam & heat	404	404	269
Water usage	23	1	1
Waste	3	3	1
Business travel	26	26	18
VOC	31	10	9
Offices	2	0	0
Total	3 582	3 536	2 833

*Emissions from water usage and VOCs calculated based on the 2016 emission factors

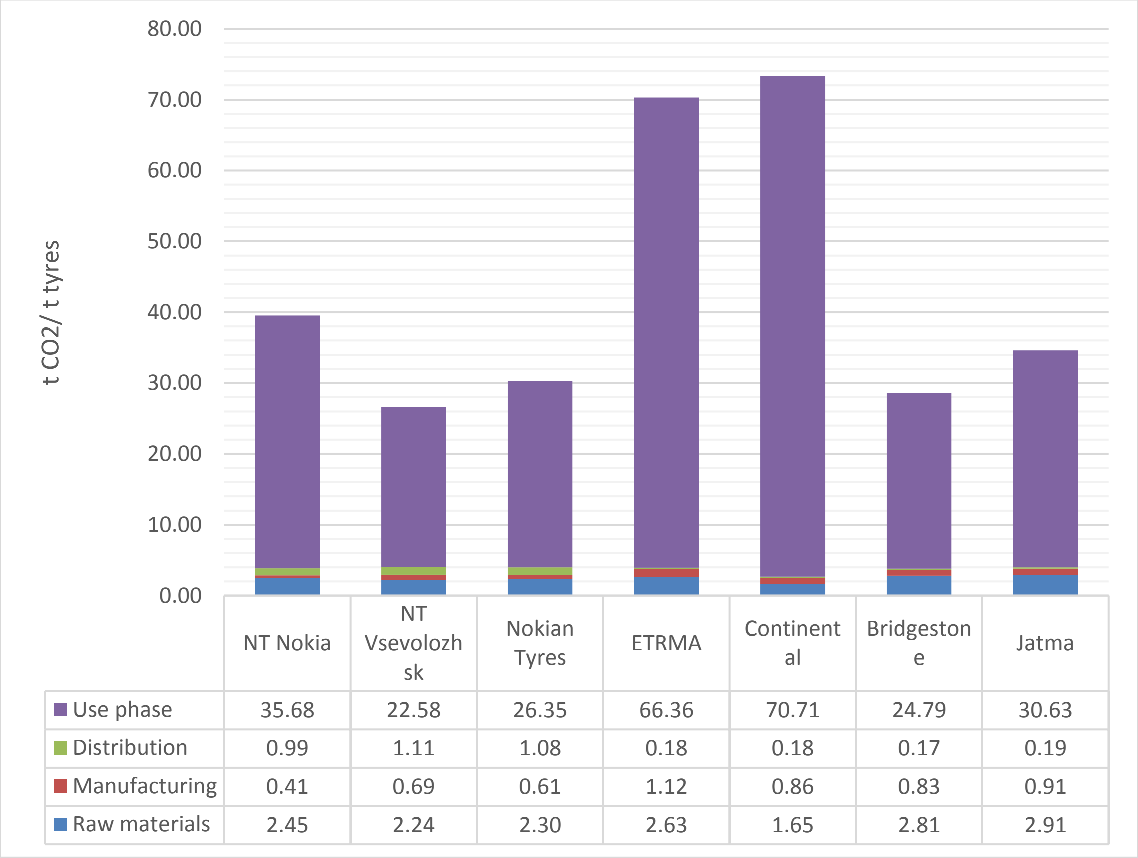
The GHG emissions from Nokia factory are 21 % lower in the present GHG assessment as they were in the assessment from 2011. Even if the emissions from water usage and VOCs were calculated with the updated emission factors and the emissions from office paper were excluded the difference is 20 %. Most of the reductions in the emissions are due to the lower GHG emissions from energy use (-41 %).

The GHG emissions from raw materials have decreased by 15 %. The GHG emissions from raw materials constitutes from transportation and production. The GHG emissions from transportation were 30 % lower in the present assessment. This can be explained by different supplier countries and with the updated emission factors for shipping. Most of the reduction in the GHG emissions of raw materials came from the production though (83 %). There is only little variation in the amounts of the different raw materials. Thus most of the difference in the emissions come from the emission factors used. As the emission factors from 2011 include emissions from the transportation as well (Markkanen, 2013), the comparison of the factors can’t be done accurately however.

Emission factors for air and rail traffic were lower in the present assessment thus lowering the total emissions from business travel. The improvement of the recycling rate reduced the GHG emissions from waste. All in all the carbon footprint of Nokia factory has decreased during the last five years.

6.5 GHG Emissions in Relation to Tyre Industry

The results of this assessment were compared to the results of other GHG studies from tyre industry (figure 6-3). The other GHG emissions were originally presented per one passenger car tyre. As Nokian Tyres also manufactures heavy tyres their emissions could not be presented per a tyre. Thus the results from the other studies were converted into t CO_2/ t tyres using the weight of the tyre from the study or if not announced the average European tyre weight, 8.74 kg (Quantis, 2013). This may result in some errors in the results but it gives better comparability. The tyre in the GHG study for ETRMA represents the average European summer tyre (Quantis, 2013). The tyre in the GHG study by The Japan Automobile Tyre Manufacturers Association (JATMA) is a general passenger car tyre whose characteristics are based on an internal survey (JATMA, 2012). The Bridgestone's study is based on a fuel-efficient tyre (Bridgestone, 2015). The Continental's tyre represents their main line summer tyre (Continental, 1999).



	NT Nokia	NT Vsevolozhsk	Nokian Tyres	ETRMA	Continental	Bridgestone	Jatma
🟪 Use phase	35.68	22.58	26.35	66.36	70.71	24.79	30.63
🟩 Distribution	0.99	1.11	1.08	0.18	0.18	0.17	0.19
🟥 Manufacturing	0.41	0.69	0.61	1.12	0.86	0.83	0.91
🟦 Raw materials	2.45	2.24	2.30	2.63	1.65	2.81	2.91

Figure 6-3 GHG emissions of different tyre producers divided between life cycle stages (Bridgestone, 2015; Continental, 1999; JATMA, 2012; Quantis, 2013)

The emissions from the end-of-life treatment were left out of the comparison while the methods in reporting them are different. Most of the manufacturers reported them as negative because of the avoided emissions. Continental did not report them at all.

For all the manufacturers the GHG emissions from raw materials form the second largest fraction of all GHG emissions. The basic materials for all tyres are the same. The emissions were also similar in all GHG studies. The only exception was Continental whose emissions where lower than the others'.

6.5.1 Emissions from Use

The difference between Nokia and Vsevolozhsk factories in the emissions from the use phase can be explained by the production of heavy tyres in Nokia. If only the GHG emissions from the use of the passenger car tyres were compared to the production rate of them the GHG emissions would be 25.87 t CO_2e/t tyres.

For the passenger car tyres the same method as in the ETRMA’s study (Quantis, 2013) was used in calculating GHG emissions of the use phase. The substantially lower emissions can be explained by the lower consumption related to one tyre. The tyre in the ETRMA study weighted 8.74 kg and had rolling resistance coefficient of 9.76 kg/t as the tyre in the present study weighed 8.4 kg and had rolling resistance coefficient of 7.9 kg/t. Also in the ETRMA study the spare kit was included in the calculations.The GHG emissions from the use of Continental tyres may not be entirely comparable to the others as the study is older (from 1999). The average CO_2e emissions from passenger cars manufactured between years 1997 and 2000 were 170 g CO_2e/km (LIPASTO, 2011) as the average emissions of new passenger cars sold in 2014 were 123 g CO_2e/km (European Commission, 2016) In addition the emissions are calculated assuming the lifespan of the tyre to be 50 000 km (Continental, 1999).

6.5.2 Emissions from Manufacturing

GHG emissions from manufacturing stage mainly consist of the used energy. For the Nokia and Vsevolozhsk factories also emissions from VOCs, water, waste, business travel, commuting and leased and owned vehicles were included in the manufacturing stage. For all others GHG emissions from energy use are included. Also GHG emissions from production of fuels (JATMA), from wastes (ETRMA, Continental), packaging of the tyre, or from transportation of raw materials (ETRMA) could be included (Continental, 1999; JATMA, 2012; Quantis, 2013).

Although there are more emission sources included in the manufacturing phase for the operations of Nokian Tyres the emissions are still lower. Most of the emissions come from the energy production (Vsevolozhsk 87%, Nokia 86%). Thus the lower GHG emissions most likely are a result of the large share of renewable energy sources in the Nokia factory and the use of natural gas in the Vsevolozhsk factory. The emission factor for Finnish grid electricity is 209 kg CO_2e/MWh (Motiva, 2016) as the emission factor for grid electricity in Central Europe is 504 kg CO_2e/MWh (Brander, 2011). Emission factor for natural gas (199 kg CO_2/MWh) is also lower than the factor for the European grid electricity. In Nokia factory the high usage of renewable fuels in steam production also reduces the emissions. In the future as the bioenergy plant will operate around the year the GHG emissions should be even lower.

6.5.3 Emissions from Distribution

Emissions from distribution were higher in this assessment while GHG emissions from the retail operations where included as well. If no GHG emissions from the retail operations were included the GHG emissions would be 0.14 t CO_2e/t tyres for Nokia factory, 0.22 t CO_2e/t tyres for Vsevolozhsk factory and 0.20 t CO_2e/t tyres for the whole operations. At least in the GHG studies for ETRMA, Continental and JATMA the emissions from sales operations were excluded (Continental, 1999; JATMA, 2012; Quantis, 2013).

For all the other tyres the distribution results in the lowest GHG emissions of all life cycle stages. In this assessment the lowest GHG emissions came from the manufacturing however.

6.6 Opportunities to Emission Reductions

Most of the GHG emissions for both Nokia and Vsevolozhsk factories come from raw materials, energy production and the use phase. The other sources contribute only 0.6 % of emissions for Nokia factory and 1.3 % for Vsevolozhsk factory. The use phase causes about 90 % of all GHG emissions. The potential for reducing the total emissions by reducing only the emissions from other sources is low. For Vianor almost all of the GHG emissions consist of the energy use (98.6%). Most of the reduction potential is found in the energy use.

6.6.1 The Use

The use stage is the most emission intensive stage in a tyre’s life cycle. By lowering the rolling resistance coefficient of the tyres these emissions can be reduced. If all tyres produced in the Vsevolozhsk factory would represent the fuel-efficient tyre (rolling resistance coefficient 6.3 kg/t) emissions from the use phase would be 304 494 t CO_2e lower. This would mean a 9.8 % reduction in the total emissions of Vsevolozhsk factory.

Only around 20 % of a passenger car’s emissions can be allocated to the tyres and even those emissions are affected by the vehicle’s properties as well. The tyre industry’s possibilities to impact the GHG emissions during the use of the tyres are limited. The rolling resistance coefficient can’t be reduced to nothing. The reduction of the GHG emissions to a minimum requires efforts from the automotive and fuel industries as well.

6.6.2 Raw Materials

The production and transportation of raw materials is the second largest cause for GHG emissions. The GHG emissions from raw materials form 6.3 % and 8.7 % of all GHG emissions for Nokia and Vsevolozhsk factories, respectively. Most of the emissions come from the production of the raw materials.

Although tyre manufacturers can’t influence the emissions from the raw materials’ production processes directly they can still affect their own emissions. Emission factors between different producers may be different due to the national energy production mix or the technology used. In the choice between suppliers their GHG emissions could be taken into consideration.

Another possibility for controlling the emissions is the choice of raw materials used. For example textiles only compose approximately 5 % of a tyres weight but they can cause as much as 19 % of all the GHG emissions from raw material production. The emission factors are different between the textile materials. Producing nylon causes 11.1 kg CO_2e/ kg and polyester 4.4 kg CO_2e/ kg. If all of the textiles used in Nokia factory would be polyester the total GHG emissions from raw material production would be 8 % smaller. Only emissions can’t however be considered when developing tyres. For example safety is a high priority in the development process.

6.6.3 Energy use

Although GHG emissions from energy use are lower than for most of tyre industry (figure 6-3) they still represents most of the GHG emissions from the factories operations (over 60 %). Reductions could be generated by using more renewable fuels or by making the energy use more efficient.

If 20 % of the natural gas used as fuel in Vsevolozhsk factory would be substituted to renewable fuels the GHG emissions from energy production would decrease by 11 370 t CO_2e. The substitution would also decrease the WTT emissions resulting in an overall decrease of 15 % from the manufacturing emissions in Vsevolozhsk. Although in Nokia factory the use of renewable fuels is already at high level there is always room for improvement. If the use of peat would be lowered from 31 % to 20 % and the use of natural gas from 2.8 % to 0 % the GHG emissions would be decreased by 4 600 t from the projected 11 600 t. This would mean a 29 % decrease in the overall GHG emissions from energy in the Nokia factory when compared to the projected emissions.

For the retail operations energy use comprises over 98 % of all GHG emissions. Most of the energy is consumed by the franchising facilities. In the Nordic countries the use of carbon free energy sources in electricity production is at a good level. Elsewhere in Europe, and in the USA and Russia the emission factors for grid electricity are however much higher (table 5-24). If all the electricity used in the retail facilities outside the Nordic countries would represent the Finnish grid electricity (emission factor 209 kg CO_2e/MWh) the GHG emissions would be 809 t CO_2e smaller for the own facilities (- 22 %) and 63 551 t CO_2e for the franchise facilities (- 67 %).

GHG reductions could be made in the heating energy as well. Many of the facilities in Finland for example are heated with oil. If all of the facilities in Finland would substitute oil with district heating the GHG emissions from the heating in Finland would decrease by 12 %. From all the scope 2 emissions from retail this would mean reduction of 3 %. If the oil was substituted for geothermal heat, which is carbon neutral energy source, the reductions would be even higher.

6.6.4 Distribution

Although distribution's impact on the GHG emissions during a tyre's life cycle is small it contributes to the GHG emissions from Nokian Tyres' operations. If only emissions from the operations of the factories are included distribution represents approximately 25 % of the GHG emissions (figure 6-2).

Most of the emissions come from road transport (74 %). As use of train transport was marginal it was not included. Thus the rest come from sea transport. As ships can carry larger loads than trucks the GHG emissions per tonne km are lower. Even if the transport distances are longer the overall GHG emissions may be lower when ships are used. Rail transport also generates less GHG emissions (9 g/tkm) than road transport (55 g/tkm) As road transport is the main method for transportation potential to decrease the GHG emissions by using more railroads is high. If 50 % of all transportation from Nokia to Russia and inside Russia were substituted to rail transport the overall distribution GHG emissions would be decreased by 8.5 %. In Central Europe sales volumes are high thus substituting some of the road transport with rail transport GHG emissions could be decreased.

6.7 Uncertainty

There are some factors that may cause uncertainties and minor inaccuracies in the results of the assessment. Some of these uncertainties and their impact on the results of the GHG assessment are assessed here.

6.7.1 Double Calculations

Some of the leased vehicles are used for business traveling. Those trips can't be separated from the trips made with employees' own cars thus some emissions may be calculated both in the leased vehicles and in the business travel categories. Other sources for possible double calculations are related to the use stage. Some employees use Nokian Tyres' tyres when commuting or going on business trips. Also the leased and owned vehicles may have these tyres fitted under them. One more source is the testing of the tyres. Thus some of the emissions reported from use stage are already reported in the commuting, business travel, and leased and owned vehicles categories.

Emissions from leased and owned vehicles may be somewhat underestimated since they are calculated based on the emission factors announced by the manufacturers. These emission factors usually represent the fuel consumption in ideal situations and do not necessarily reflect the actual emissions from everyday driving. Especially the emissions from testing the tyres may be substantially higher than the emission factors indicate. In addition the commuting, business travel, and leased and owned vehicles categories represent a small fraction (0.12% for Nokia and 0.04 % for Vsevolozhsk) of all the emissions. Thus it was estimated that these possible double calculations are insignificant in the general view.

6.7.2 Retail Operations

Many uncertainties are related to the retail operations. As data concerning energy, water, and wastes was not available for all the facilities the average values had to be used. Converting the energy and water data into MWh and m^3 from euros causes its own uncertainties in the results. If the energy related GHG emissions from retail operations are decreased or increased by 20 % however the impact on the total GHG emissions of the total operations of Nokian Tyres is less than 1 % (table 6-5). If GHG emissions from use phase and end-of-life treatment are excluded the impact is approximately 4 %.

Table 6-5 Changes in GHG emissions when energy consumption of the retail operations is decreased or increased by 20 %

	Retail operations, original emissions	**Retail operations, -20% of original GHG**	**Retail operations, +20% of original GHG**
Scope 2 emissions (t CO_2e)	10 557	8 446	12 669
Franchise emissions (t CO_2e)	138 514	110 811	166 217
Total GHG emissions from retail (t CO_2e)	151 261	121 447	181 076
Total GHG emissions of Nokian Tyres (t CO_2e)	5 168 895	5 139 081	5 198 710
Change in total GHG emissions (%)	0	-0.6	+0.6
Total GHG emissions of Nokian Tyres (excluding use and end-of-life) (t CO_2e)	689 674	659 860	719 488
Change in total GHG emissions (%)	0	-4.3	+4.3

As the emissions from waste only comprise 0.4 % of the total emissions from retail operations they are insignificant in the overall emissions. Even though there are some uncertainties in the GHG emissions from the retail operations the results give an estimate of the GHG emissions related to them. The results give an evaluation of the relation of the GHG emissions from the retail operations compared to the GHG emissions from other operations also.

6.7.3 Capital Goods

The GHG emissions from capital goods were excluded from the assessment as there was no accurate information about the emissions regarding them. The acquisition of machinery was evaluated to be the main source for GHG emissions in the capital goods category as they are large in size and primarily manufactured of metals. Especially steel generally has high carbon footprint.

The best evaluation for the GHG emissions from manufacturing of the machines used in tyre industry was based on a hydraulic press slider. (Zhang, 2016) According to Zhang et al. (2016) the emission factor for the production of a hydraulic press slider in China is 60 560 kg CO_2e/ 20 000 kg the hydraulic press slider. This can be converted to 3.03 kg CO_2e/ kg the hydraulic press slider. The emission factor includes the production and transportation of raw materials, cutting of steel sheets, weld grooving and welding. For electricity the emission factor of East China Power Grid was used (837 kg CO_2e/MWh). (Zhang, 2016)

The GHG emissions from manufacturing a machine in 3 different sizes were calculated based on the emission factor for the hydraulic press slider (table 6-6). The GHG emissions were then compared to the GHG emissions of the Nokia factory. Emissions were compared to the GHG emissions with and without the GHG emissions from the tyre use phase.

Table 6-6 GHG emissions from the manufacturing of machinery and relation of the emissions to the total GHG emissions of Nokia factory with and without use phase GHG emissions

The size of the manufactured machine	**GHG Emissions (t CO_2e)**	**Share of total GHG emissions (%)**	**Share of total GHG emissions without use phase (%)**
500 t machine	1 515	0.08	1.0
100 t machine	303	0.02	0.2
50 t machine	152	0.008	0.1

The GHG emissions of 500 t of machinery would be less than 0.1 % of the total GHG emissions from Nokia factory. When compared to GHG emissions excluding use phase the GHG emissions from manufacturing of the machinery would be 1 %. The weight of a mixing machine for rubber, for example, may range from 1.5 t to 56 t (Bharaj Machineries, 2016). Thus the impact on the overall GHG emissions would be insignificant. In Vsevolozhsk factory the impact of the machinery would be even smaller as the overall GHG emissions are higher.

The exclusion of the GHG emissions from capital goods does not affect the relevance of the GHG assessment based on this evaluation. When specific information of the GHG emissions from machinery suppliers becomes available the emissions should be added to the GHG assessment.

7. CONCLUSIONS

The goal of this thesis was to assess all the relevant GHG emissions from tyre production and the auxiliary operations related to it. The study met its goals as the most significant emissions sources were assessed. The results of the study showed the most important GHG emission sources from tyre industry. Based on the results potential targets for GHG emission reductions were found. Possibilities for improving the present GHG assessment were also found.

7.1 General conclusions

The use stage causes most of the GHG emissions from tyre industry. The emissions are mainly caused by the rolling resistance. By lowering the rolling resistance coefficient of tyres the GHG emissions can be decreased substantially.

The total carbon footprint of Nokian Tyres is 3 189 kg CO_2e/t production without the GHG emissions from the use and end-of-life treatment of the tyres. When compared to the other operators in the tyre industry the carbon footprint represents the lower range. Major reason for this is the lower GHG emissions from the manufacturing stage due to the low emission energy used. Energy source used is the determining factor when assessing the impact of the manufacturing on climate. Energy use can generate over 80 % of the GHG emissions from manufacturing.

In distribution the largest GHG emission sources are road transportations and the energy use of the retail operations. Although the GHG emissions from distribution are small compared to the total GHG emissions from tyre's life cycle there is potential in decreasing them. By rethinking the energy use of the retail operations and making the transportations more efficient GHG emissions reductions can be made. Decreasing the use of road transportation also leads to GHG emission reductions.

7.2 Recommendations

GHG assessments can and should be improved and expanded whenever possible. Accounting for all GHG emissions at once may not always be feasible. The most significant emission sources should, however, be included from the beginning. The incomplete or inaccurate sections of the GHG assessment should be approached and improved one by one starting with the more significant sections.

7.2.1 Focusing on Retail Operations

The GHG emissions from the retail operations should be defined. The focus should be put first in the energy use as it is the source of almost all of the GHG emissions from retail. The data about energy use should be collected as energy consumption instead of expenses. The data could be grouped on different grounds to make up for the facilities for which no information is available. The ground for the groupings could be for example the size of the facilities, the used heating system, opening hours, or provided services. This way the GHG emissions could be determined more accurately for the facilities where energy consumption is not reported.

By assessing the GHG emissions more accurately for the own retail operations the GHG emissions can be determined more accurately for the franchise facilities as well. For the facilities operated on a franchising principle the energy consumptions are likely not available. Based on available characteristics the GHG emissions could, however, be assessed.

More focus could be put on the waste information although they are a small source of GHG emissions in the retail operations. The collected waste fractions and their amounts should be reported more accurately. With the wastes the same grouping principles as with energy use could be used to assess the wastes and the GHG emissions caused by them better.

7.2.2 Improving Quality of Data

The activity data needed for the calculations was incomplete in some sections. The GHG assessment could be improved by collecting more accurate and complete data from the Vsevolozhsk factory. For example the activity data for business travel and raw materials was incomplete.

The emissions factors should be monitored regularly to keep them up-to-date. It is advisable to check the emission factors for grid electricity in different countries annually. Specific emission factors from suppliers could be acquired to improve the results. The use of national emission factors could be increased when no specific emission factors are available.

7.2.3 Completing the Distribution Chain

For distribution only GHG emissions from the first or the first two transportation steps were included in this assessment. The distribution may however consist of more steps. In the future the assessment should be expanded to cover all the transportation steps at some level. GHG emissions from the transportations directly to customers were based on assumptions only. With better knowledge of the destinies of the sold tyres the GHG emissions could be calculated more accurately.

The quality of the assessment could be improved by collecting information of the specific GHG emissions from the logistics companies handling the distribution. More detailed information of the transportation methods might be useful in improving the GHG assessment as well.

7.2.4 Expanding the Scope

Although the scope of the present assessment was wide there were still some factors left out. The present study did not take into account the production of the studs used in some winter tyres. The production of rims was also excluded. When calculating the GHG emissions from distribution the rims were not taken into account and all weights were only based on the tyres.

The GHG emissions from the sales companies and warehouses were also left unassessed. At least the energy consumptions of the warehouses and the sales companies should be assessed and their GHG emissions compared in relation to the other GHG emissions. Based on the GHG emissions from the energy use other recommendations can be made.

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APPENDIX A: RAW MATERIALS

Table 0-1 The amounts, producer countries, and the means of transportation used for the raw materials used in the Nokia factory

Raw Material	**Quantity (t)**	**Country of origin**	**Transportation mode**
A	10 971	Malaysia	Truck + freight ship
B	12 460	Germany, Singapore, Russia, Belgium	Truck or truck + freight ship
C	11 640	Russia	Train + truck
D	1 450	Germany	Truck + freight ship
E	530	Finland	Truck
F	3	Netherlands	Truck + freight ship
G	899	Germany	Truck + freight ship
H	372	Germany	Truck + freight ship
I	135	China	Truck + freight ship
J	34	China	Truck + freight ship
K	325	Germany	Truck + freight ship
L	383	India	Truck + freight ship
M	473	Russia	Truck
N	163	Italy	Truck + freight ship
O	1 001	Germany	Truck + freight ship
P	550	Finland	Truck
Q	110	South Korea	Truck + freight ship
R	6	South Korea	Truck + freight ship
S	237	Germany	Truck + freight ship
T	1 318	Turkey	Truck + freight ship
U	1 067	China	Truck + freight ship
V	306	Germany	Truck + freight ship
X	3 091	Italy	Truck + freight ship
Y	1 903	South Korea	Truck + freight ship

Table 0-2 The amounts, producer countries, and the means of transportation used for the raw materials used in the Vsevolozhsk factory

Raw Material	**Quantity (kg)**	**Country of origin**	**Transportation mode**
A	10 970	Malaysia	Freight ship
B	20 404	Singapore, Russia, Belgium	Freight ship or truck or truck + freight ship
C	28 504	Russia	Train
D	4 812	France	Truck + freight ship
E	1 560	Russia	Truck
F	0	Netherlands	Truck + freight ship
G	2 198	Russia	Truck
H	904	Germany	Truck + freight ship
I	0	China	Freight ship
J	34	China	Freight ship
K	248	Italy	Truck + freight ship
L	383	India	Freight ship
M	865	Russia	Truck
N	428	Italy	Truck + freight ship
O	4 841	Russia	Truck
Q	579	South Korea	Freight ship
R	6	South Korea	Freight ship
S	237	Germany	Truck + freight ship
T	6334	Czech Republic	Truck + freight ship
X	13 918	Belorussia	Truck

APPENDIX B: TOTAL GHG EMISSIONS

Table 0-3 The total GHG emissions for Nokia and Vsevolozhsk factories, Vianor chain and the whole corporation

Emission source	Vsevolozhsk		Nokia		Vianor		Nokian Tyres	
	Emissions (t CO2e)	Emissions (kg CO2e/t production)	Emissions (t CO2e)	Emissions (kg CO2e/t production)	Emissions (t CO2e)	Emissions (kg CO2e/t production)	Total Emissions (t CO2e)	Total emissions (kg CO2e/t production)
Scope 1	57 234	473	382	8	0	0	57 616	339
Energy Production (own)	56 848	469,7	0	0	0	0	56 848	334,6
VOC	0	0	236	4,8	0	0	236	1,4
Own Vehicles	386	3,2	146	3,0	0	0	532	3,1
Scope 2	16 221	134	17 478	358	10 557	62	44 256	260
Electricity (bought)	16 221	134,0	4 348	89,0	3 685	21,7	24 255	142,8
Steam & Heat	0	0	13 130	268,7	6 872	40,4	20 002	117,7
Scope 3	3 043 377	25 145	1 873 420	38 333	2 190	13	4 918 987	28 952
Raw Materials (production)	260 874	2 155,4	111 277	2 276,9	0	0	372 151	2 190,4
Raw Materials (transportation)	10 474	86,5	8 258	169,0	0	0	18 732	110,3
Fuel- & Energy-Related	7 701	63,6	0	0,0	0	0	7 701	45,3
Water Usage	140	1,2	62	1,3	43	0,25	245	1,4
Waste	1 586	13,1	30	0,6	580	3,4	2 196	12,9
Business Travel	14	0,1	901	18,4	151	0,89	1 067	6,3
Commuting	975	8,1	585	12,0	630	3,7	2 191	12,9
Leased Assets	0	0,0	587	12,0	785	4,6	1 372	8,1
Distribution	27 124	224,1	6 987	143,0	0	0	34 111	200,8
Use Phase	2 732 603	22 577,7	1 743 971	35 684,2	0	0	4 476 574	26 347,8
End-of-Life Treatment	1 885	15,6	761	15,6	0	0	2 647	15,6
Franchises	0	0,0	0	0,0	138 514	815,3	138 514	815,3
Total	3 116 833	25 752	1 891 280	38 698	151 261	890	5 159 374	30 367