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Indirect emissions estimation model for investments in the automobile sector, fossil fuel sector and utilities sector

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Abstract

Indirect emissions estimation model for investments in the automobile sector, fossil fuel sector and utilities sector

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To combat climate change multiple initiatives have been launched to steer the financial market towards a more sustainable and resilient path. For example the Montreal Pledge that have committed over 120 investors to measure and disclose their carbon footprints of their portfolios. ISS-Ethix Climate Solution provides climate change related services to investors. In order to evaluate companies' sustainability ISS-Ethix Climate Solution estimates companies' direct and indirect greenhouse gas emissions. To simplify these estimations, the emissions from corporations are divided into three scopes, where scope 1 and 2 cover the emissions from the combustion of fuels used in the company and electricity generation. Scope 3 corresponds to all other emissions generated upstream and downstream the companies' supply chain.

The aim of this study was to help ISS-Ethix Climate Solution to develop a model that estimates the indirect scope-3-emission intensity for companies in the automobile sector, fossil fuel sector and utility sector. The first objective was to examine if the variations within the sectors could be explained and categorized. To carry this out each sector was defined and their emission sources identified. The emissions could be explained and categorized for the automobile sector and fossil fuel sector. However, the emissions for the utility sector could only partly be explained and categorized. The second objective was to examine which parameters and subcategories were relevant for estimating the emissions. Two methods were investigated to carry out the second objective; correlation analysis and the average-data method. No correlations could be found between any of the sectors and the selected parameters. The estimated emissions using the average-data method were verified to the companies reported emissions. For the automobile and the fossil fuel companies the estimated emissions followed the same trend as the reported data. However, no trend could be found for the utility companies. Estimating emissions using the average-data method requires a certain corporation structure. The method can be used for corporations with a specific output, but does not suit corporations with a more complex structure. The largest limitation with the models was the information shortages from the corporations. Therefore increased transparency from the companies is a necessity in order to develop the models.

Keywords: scope 3, indirect emissions, estimation models, automobile sector , fossil fuel sector, utility sector, sustainable investments

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Referat

Estimering av indirekta emissioner i fordonssektorn, fossila-bränslen-sektorn och energisektorn

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För att minska klimatförändringen har ett flertal initiativ lanserats för att göra finanssektorn mer hållbar. Tillexempel Montreal förbindelsen som har fått över 120 investerare att mäta och publicera klimatutsläppen i sina aktieportföljer. Företaget ISS-Ethix Climate Solution erbjuder klimatrelaterade tjänster för investerare. För att värdera hur hållbart ett företag är estimerar ISS-Ethix deras direkta och indirekta utsläpp av växthusgaser. För att förenkla dessa estimeringar är utsläppen indelade i tre så kallade scopes (områden), där scope 1 och 2 motsvarar emissionerna som genereras av att företaget förbränner fossila bränslen och deras elanvändning. Scope 3 motsvarar alla utsläpp som sker uppströms och nedströms företagens leverantörskedja.

Syftet med denna studie var att hjälpa ISS-Ethix Climate Solution att utveckla en modell som estimerade scope 3 utsläppen från företag inom fordonssektorn, fossila-bränslen-sektorn och energisektorn. Det första målet var att undersöka om variationerna inom sektorerna kunde förklaras och kategoriseras. Detta utfördes genom att varje sektor först definierades och utsläppskällorna identifierades. Emissionerna kunde förklaras och kategoriseras för fordonssektorn och fossila-bränslen-sektorn. Däremot kunde utsläppen från energisektorn bara delvis förklaras och kategoriseras. Det andra målet var att undersöka vilka parametrar och sub-kategorier som var viktiga för att estimera sektorernas emissioner. För att göra detta undersöktes två olika metoder; korrelationsanalys och medelvärdesmetoden. Inga korrelationer kunde hittas mellan någon av sektorerna och de undersökta parametrarna. De estimerade emissionerna när medelvärdesmetoden användes, verifierades mot företagens självrapporterade utsläpp. För fordonssektorn och fossila-bränslen-sektorn följde de estimerade och rapporterade utsläppen samma trend. Däremot påträffades ingen trend för energibolagen. Att estimera växthusgasutsläpp med hjälp av en medelvärdesmetod kräver en viss typ av företagsstruktur. Metoden kan användas för företag med en specifik produkt, men är inte lämplig för företag med en mer komplex struktur. Modellernas största begränsning var informationsbristen från företagen. Därför behövs mer transparens från företagen för att kunna utveckla modellerna.

Nyckelord: scope 3, indirekta emissioner, estimeringsmodeller, fordonssektorn, fossila bränslen sektorn, energisektorn, hållbara investeringar

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Preface

This 30 credits master thesis is the final part of the Master Programme in Environmental and Water Engineering at Uppsala University and the Swedish University of Agricultural Science. The thesis was carried out in corporation with ISS Climate Solution with supervision from Fredrik Lundin. The subject reviewer was senior lecturer Mikael Höök at the Department of Earth Science, Natural resources and Sustainable Development and examiner was Fritjof Fagerlund at the Department of Earth Science, Program for Air, Water and Landscape Science, both at Uppsala University.

I would like to give a special thanks to Fredrik and Mikael for their support and guidance throughout the work. I would also like to thank the whole Climate Solution department at ISS for welcoming me to the team and broadening my understanding for sustainable finance, especially Martin Lind for many well-needed coffee and yoga breaks.

Additionally I would like to thank all the people around me; Patrik for daily support and encouragement, John Granström for valuable inputs about LCA, my beloved family and all my classmates who have pushed me through these five years of studying that reinforced this thesis. Finally I would like to thank Iris and the new generation for invaluable motivation.

Kerstin Thungström
Uppsala, June 2018

Populärvetenskaplig sammanfattning

Estimering av indirekta emissioner i fordonssektorn, fossila-bränslen-sektorn och energisektorn.

Kerstin Thungström

I den här studien har företags koldioxidutsläpp estimerats för att kunna hjälpa investerare att investera mer hållbart. Varför är det här viktigt? Jo, för att hålla den globala uppvärmningen till under 2 grader krävs flera åtgärder. Inte minst måste koldioxidintensiva företag börja minska sitt klimatavtryck. Här kan investerare påverka utvecklingen genom att rösta för hållbara omställningar på bolagstämmor eller genom att helt enkelt sluta investera i vissa företag. Likväl kan det vara svårt för investerare att veta vilka företag som är hållbara på riktigt och vilka som felaktigt uppger sig för att vara miljövänliga. För att hjälpa investerare i den här bedömningen estimerar företaget ISS-Ethix Climate Solution bland annat klimatavtrycket på deras aktieportföljer. För att praktiskt göra detta har utsläppen som ett företag är ansvarigt för under ett år delats upp i tre olika områden, så kallade ”scopes”. Scope 1 täcker utsläppen från fossila bränslen som företaget själva har förbränt, medan scope 2 omfattar de emissioner som bildas vid tillverkningen av den energi som företaget använder. Både scope 1 och scope 2 kan ISS-Ethix Climate Solution estimera med gott resultat, således var målet med denna studie att estimera scope 3, vilket motsvarar de resterande utsläppen som sker uppströms och nedströms företagens logistikkedja. I scope 3 räknas tillexempel alla utsläpp från tillverkningen av de material och produkter som företaget köper in, företagsresor och emissioner som företagens produkter ansvarar för när den ägs av företagets kunder. För att begränsa studien omfattades endast biltillverkare, energiproducenter och företag inom fossila bränslen sektorn, då de ansågs ha ett betydande klimatavtryck.

För både biltillverkare och fossila-bränslen-företag sker mer än tre fjärdedelar av föroreningarna i användarfasen av deras produkter. Detta var troligtvis en bidragande faktor till varför deras klimatavtryck kunde estimeras med någorlunda gott resultat. För att bekräfta om resultaten var goda testades estimerings-modellerna på företag som redan publicerat sitt klimatavtryck. Vid denna jämförelse kunde det konstateras att de estimerade utsläppen följde samma trend som de som företagen rapporterat, samt att resultatet blev bättre när mer detaljerad information från företagen fanns tillgänglig. För energiproducenter var utsläppen inte lika lättidentifierade som för biltillverkare och oljeföretag. Detta var för att utsläppen härstammade från olika källor beroende på vilken energi-mix energiproducenterna producerade, om de sålde gas samt om de köpte och sålde el vidare till konsumenter. Den stora variationen mellan företagen försvårade estimeringarna och en mer komplex modell behövde utvecklas för att ta hänsyn till de olika bidragande faktorerna. När dessa estimeringar jämfördes mot de utsläpp företagen själva rapporterat kunde inga samband ses.

För att utforma modellerna testades två olika metoder, korrelationsanalys och genomsnittsvärdes metoden. Flera olika uppgifter från företagen såsom omsättning, mängd sålda kapitalvaror och antal anställda testades mot företagens rapporterade scope 3 utsläpp för att undersöka om de fanns någon korrelation. Tyvärr påträffades ingen korrelation för någon av parametrarna. Därför baserades modellerna i studien på genomsnittsvärdesmetoden. I den metoden beräknas företagens utsläpp med hjälp av klimatavtrycket av representativa produkter. Tillexempel multiplicerades det mängden växthusgaser från en genomsnittlig bensinbil med det totala antalet bensin bilar som biltillverkarna hade sålt under ett år. Denna metod innebär en hel del förenklingar och antaganden då företagens produkter och förutsättningar såklart inte är likadana. Likväl var den största begränsningen i studien den begränsade tillgången på företagsspecifik information. För att kunna utveckla modellerna ytligare efterfrågas därför en större transparens från företagen.

Abbreviations

BEV – Battery Electric Vehicle

CSP – Concentrating Solar Power

CDP – Climate Disclosure Project (formerly)

GHG – Greenhouse gas

LCA – Life Cycle Assessment

LPG – Liquid Petroleum Gas

PHEV – Plugin Hybrid Electric Vehicle

PV – Photovoltaic

WTT – Well-To-Tank

1 INTRODUCTION

Climate change is affecting communities and countries worldwide with consequences such as increased extreme weathers events, changing weather patterns and raised sea levels and the effects are likely to increase in the future. Therefore climate action is addressed as one of the United Nations seventeen sustainability goals (United Nations, 2018). In December 2015, leaders of the world agreed to combat climate change by keeping the temperature rise to well below 2 degrees through the Paris agreement. It was a powerful statement where over 170 countries decided to move towards a low carbon society. The agreement consists of many different key aspects where one covers the finance flow's consistent with low greenhouse gas emissions (UNFCCC, 2018). To steer the finance market towards a more sustainable and resilient path multiple initiatives have been launched, (see Table 21 in Appendix). For instance the Green Finance Taskforce (GFT) in the UK, the Forth Swedish National Pension Fund (AP4), and the Platform Carbon Accounting Financials (PCAF) in the Netherlands among others (AP4, 2018; GFT, 2018; PCAF, 2018). Also in December 2016 the European commission established the High Level Expert Group on Sustainable Finance (HLEG) that advice the commission how to implement sustainability into the finance market (European Commission, 2018).

Already before the Paris agreement the Montreal Carbon pledge was launched, where investors agreed to measure and publicly disclose the carbon intensity of their portfolios. This is the first step for investors towards decarbonizing actions. Over 120 investors have signed the pledge globally, which corresponds to US$ 10 trillion in assets (Montreal Pledge, 2014). To decarbonize portfolios the investors either can divest from fossil fuel intensive companies or vote against carbon intensive proposals at the companies' shareholder meetings (Modén, 2001). Therefore, investors are dependent of climate information of the corresponding companies when evaluating the portfolios. Over 6300 companies self-reported environmental data are gathered by CDP, which is the largest collection in the world (CDP, 2018a). Unfortunately, not all companies report their emissions since most of the initiatives are not mandatory. This results in information shortages in the investors' decision basis. Moreover, some companies and sectors contribute more than others to the global warming. As much as 70% of the world's industrial greenhouse gases are linked to 100 fossil fuel producing companies alone that are active today (CDP, 2017b). This recently entailed sixty big investors to urge oil and gas companies to take responsibility for the emissions produced by their products, in order to make the Paris agreement successful (Roumpis, 2018). Also Allianz, the world largest insurer, have declared that they will phase out coal from their investments by 2040 (Cheong, 2018).

This advocates the need to identify the carbon footprint for companies who do not report their emissions. International Shareholder Service Ethix-Climate Solutions (ISS-Ethix Climate Solutions) provides climate change related services to investors. Among others they estimate non-reporting companies' carbon intensity according to the Greenhouse Gas Protocol in order to assist investors in their decision-making. The

GHG protocol is an international standard for greenhouse gas accounting developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) and is used by corporations, organizations and cities all over the world (GHG Protocol, 2018). This study aims to update ISS Climate Solution estimation models for indirect emissions, starting with the automobile, fossil fuel, and utility sector.

1.1 OBJECTIVE

The objective of this study is to develop models that estimate the indirect scope 3-emission intensity for corporations associated to the fossil fuel, utility and automobile sectors. Answering the following research questions will carry this out:

- Can the variation of the emissions within the sectors be explained and categorized?
- Which parameters and subcategories are relevant for estimating the emissions and why?

Delimitations

This study was limited to only estimate scope 3 emissions for three sectors. The study followed the GHG protocol Corporate Standard accounting method in the execution of the models but was limited to only estimate the categories with the largest emissions for each sector. The models were only validated to some selected companies reported disclosure data to CDP. The emission intensity was expressed as CO_2 equivalents.

Structure of study

This study is structured as follow: firstly are a background provided. The background includes a basic description of the accounting methodology developed by the GHG Protocol, the companies reported data, common estimation methodologies and previous work within the area. Thereafter the sectors are defined and important categories investigated to limit the setup of the models. To examine the best methodology two methods are studied. First is the possibility of models based on the correlations between the companies reported scope 3 data and company specific information tested. Secondly, models based on the average data methodology are analyzed. In the final step the two methodologies are evaluated and societal implications discussed before recommendations for future work are presented.

1.4 INDIRECT EMISSIONS DEFINED AS SCOPE 3

A carbon footprint refers to the anthropogenic greenhouse gas emissions caused by an organization, a service or product and includes all types of emissions (Mench, 2012). It contains both direct and indirect emissions. For a specific coal-fired-power-plant the direct emissions would be the combustion of coal, while the indirect emissions include the extraction and transportation of coal etcetera. The consumer of the electricity from the coal-fired-power-plant would instead define these emissions as indirect. Depending on a corporation's size and operations their emission sources can vary a lot. To help companies define their emission sources the GHG protocol has divided companies' carbon footprints into three groups, scope 1, scope 2 and scope 3. Scope 1 refers to the direct emissions generated by the usage of fossil fuel owned by the corporations and scope 2 to the indirect emissions generated by the production of the energy used by the corporation. Scope 3 refers to the other indirect emissions, which are divided into fifteen subcategories located upstream and downstream in the supply chain, see Figure 1 (WRI & WBCSD, 2011).

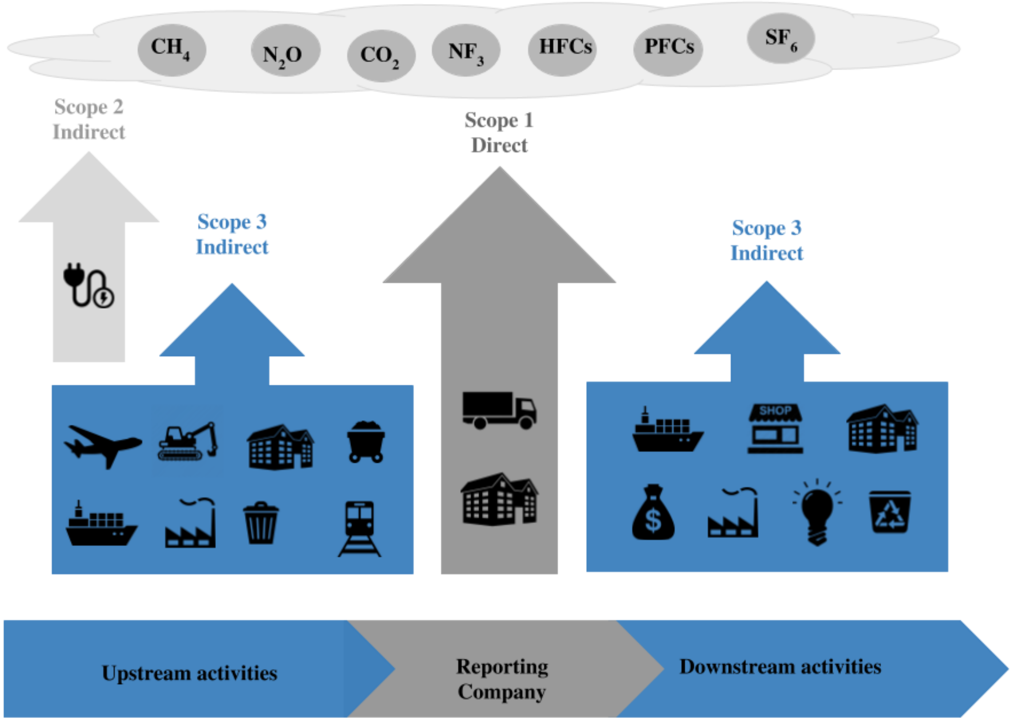

Figure 1 The figure shows the sources of the emissions from a reporting company divided into the three different scopes.

The eight upstream subcategories and the seven downstream subcategories, also called the use phase, are listed in Table 1 below.

Table 1 The fifteen subcategories in scope 3 divided into upstream or downstream (WRI & WBCSD, 2011).

Upstream	Downstream
Transport and distribution	Transport and distribution
Leased assets	Leased assets
Purchased goods and services	Processing of sold products
Capital goods	End-of-life treatment of sold products
Fuel and energy related activities	Usage of sold products
Waste generated by the business	Franchise
Business travels	Investments
Employee commuting	

When a company report their scope 1, scope 2 and scope 3 emissions the sum of these will be equal to the total amount of emissions the company is responsible for throughout their supply chain during the reporting year. The definition of scope 1 and scope 2 ensures that no double counting occurs between two or more companies, which means a company's scope 1 emissions could be another company's scope 2 emissions but not scope 1 and vice versa. This is not the case for scope 3 where double counting may occur in some cases. It is important to keep in mind that some of the scope 3 emissions may already have been generated before the accounting year. Likewise some emissions that are reported have not occurred yet but are expected to happen in the future (WRI & WBCSD, 2013). To better understand the categories accounted for in scope 3 and when the emissions are generated they are all shortly described below.

Category 1: Purchased goods and services
In this category the company reports all emissions generated by their purchased goods and services during the reporting year. It could for example be the generation of electricity used by an upstream supplier, land usage, agricultural processes or the extraction of raw material. Some emissions are production related which include purchased parts and material included in the company's final products, products that are purchased and resold without any modifications or capital goods used to manufacture the final product. Other purchased goods and services are not production related and include furniture, computers and telephones that are used at the company's office and maintenance related products like spare parts or replacement parts (WRI & WBCSD, 2011).

Category 2: Capital goods
The cradle to gate emissions of the companies' capital goods should be reported on the year of acquisition. This includes equipment, machines, buildings and vehicles used by the company. The company have to decide if a certain goods should be counted for in category 1 or 2 based on their own financial accounting process. The emissions corresponding to the usage of the capital goods, like the electricity- or fuel-usage, should be accounted for in scope 1 and scope 2 (WRI & WBCSD, 2011).

Category 3: Fuel- and energy-related activities
This category accounts for the production of fuel and energy that is not reported in scope 1 or scope 2. This applies to all energy that is purchased and resold to an end user by a utility or energy retailer company. Extraction, transportation and distribution of fuel and energy are also reported in this category (WRI & WBCSD, 2011).

Category 4: Upstream transportation and distribution
This category includes all the emissions related to the transportation and distribution of products purchased by the company during the reporting year. Transportation in company owned vehicles is not included as well as transportation and distribution of fuel and energy that is reported in category 3 (WRI & WBCSD, 2011).

Category 5: Waste generated in operations
Emissions corresponding to the waste generated by the company and treated by a third party are included in this category. If the company handles the treatment itself, it is

reported in scope 1 or scope 2. Both solid waste and wastewater is included. Different treatments could for example be landfill disposal, composting, incineration or wastewater treatment (WRI & WBCSD, 2011).

Category 6: Business travel
This category includes business travel emissions in a vehicle owned by a third party. Transportation in company owned vehicles is accounted for in scope 1 or scope 2 and leased vehicles used by the company are accounted for in category 8: upstream leased assets. Also employee commuting is reported in category 7 and not in this category (WRI & WBCSD, 2011).

Category 7: Employee commuting
Includes the emissions generated by the daily transportation of personnel to and from the company. Teleworking where the employee work from home and communicating with the office through email or telephone may be included in scope 1 (WRI & WBCSD, 2011).

Category 8: Upstream leased assets
If the company have leased assets, the corresponding emissions during the reporting year should be reported in category 8. Would the company own the assets and lease it to a third party the emissions should instead be accounted for in category 13: downstream leased assets (WRI & WBCSD, 2011).

Category 9: Downstream transportation and distribution
Downstream transportation and distribution refer to the phase where the product is sold by the reporting company but are not owned by the end user. This could for example be storage in warehouses or retail facilities and transportation by air, land or sea by a third part. All the products that have been sold during the reporting year should be accounted for (WRI & WBCSD, 2011).

Category 10: Processing of sold products
Some companies produce and sell intermediate products. These products are processed into another final product by a third party before it reaches the end user. The emissions generated during the processing are reported in this category, like the processing of wood into paper or petroleum into plastic (WRI & WBCSD, 2011).

Category 11: Use of sold products
Emissions generated by the usage of the sold products or services are accounted for in this category. Some products generate emissions direct throughout its usage, cars or electronics that use fuel and electricity. Other product have an indirect generation of emissions like apparel, where washing and drying require energy, or soap that require hot water when used (WRI & WBCSD, 2011)

Category 12: End-of-life treatment of sold products

There are different end-of-life treatments for the companies' sold products like disposal at a landfill, incineration or recycling. The emissions generated in these processes are reported in this category for all the companies' sold products during the year of disclosure. This means that the emissions may not occur during this year. The companies do also have to assume how the product will be treated (WRI & WBCSD, 2011).

Category 13: Downstream leased assets

This category applies to companies who lease assets to a third party. The emissions, which are generated by the leased product during the reporting year, are accounted for. This could for example be vehicles or buildings (WRI & WBCSD, 2011).

Category 14: Franchises

Emissions generated by the operation of franchises during the reporting year are accounted for in this category (WRI & WBCSD, 2011).

Category 15: Investments

This category applies to companies who have as a purpose to make a profit on investments or provide financial services like banks. Whether or not a company should report their emissions in this category, depend on how they define their organizational boundaries. If a company defines their boundaries according to its equity shares the emissions should already be included in scope 1 and scope 2. If the company instead limit its boundaries to the areas where it has control it should report the emissions from its investments in this category. For instance if the company invests in a long term project, the projects scope 1 and scope 2 emissions during the reporting year should be accounted for in this category (WRI & WBCSD, 2011).

1.5 GHG EMISSION ESTIMATION METHODS

When calculating the emissions related to a product emission factors (EFs) are normally used. The EF corresponds to the average emissions generated by a certain unit of a product. By using Equation 1 the total amount of emissions is calculated.

$$\textit{Total emission} = \textit{Emission per unit} \cdot \textit{number of units} \qquad (1)$$

To estimate company specific emission factors various methods can be used. Some of the common ones are the supplier specific method, the spend-based method and the average-data method. In the supplier specific method, the emission factors corresponding to the companies' products are collected from their suppliers. These emission factors are then multiplied by the amount of products relevant for the company (IPIECA & API, 2016). The spend based method is based on Wassily Leontief's Nobel prize rewarded input ouput approach, which explains the economic flow between sectors (Leontief, 1970). By adding sector specific emission factors to all the companies purchases from other sectors the environmental impacts are estimated. In the spend-based method the emission factors are normalized to the economic value, for example CO_2 equivalents per US$. However, both the supplier specific and spend-based method are limited to cover the emissions upstream in the supply chain (Matthews *et al.*, 2014). Since both fossil fuel companies and automobile companies have considerable emissions in the use phase of their products, these methods are not suitable for this study. The average method takes both upstream and downstream emissions into account; therefore, this approach is one of the methodologies used in this study. In the average method a company's emissions are estimated by multiplying the companies' products with average emission factors from a secondary source (IPIECA & API, 2016). For example from Life Cycle Inventory databases, like the world leading non-profit association Ecoinvent (Ecoinvent, 2018). The databases contain data based on Life Cycle Assessments (LCA) that investigates a products potential environmental impact during its lifetime. Depending on the limitations of the LCA emissions related to the raw material, use and disposal of the product can be included. This approach is called 'cradle-to-gate' although a 'cradle-to-cradle' approach also can be performed (Klöpffer & Grahl, 2014) (Reap *et al.*, 2008). More information about LCA can be found in the book *Life cycle assessment – Quantitative Approaches for Decisions That Matters* (Matthews *et al.*, 2014).

1.6 REPORTED DISCLOSURE DATA

To get an understanding for the sectors scope 3 emissions and validate the models the companies' self-reported disclosure data have been used. This data have been taken from the non-profit organization CDP since they provide the only global collection of self-reported disclosure data. CDP also grade the companies' reported data and in 2013 SustainAbility nominated them to the best ranker out of over 50+ different Enviromental Social and Governance (ESG) scores (CDP, 2018c) (SustainAbility, 2017). The companies who respond to CDP's questionnaires are rated from A to D-. The grade represents the company's overall performance in the four areas disclosure, awareness, management and leadership. To achieve the score A the companies must have verified at least 70% of their reported scope 1 and scope 2 emissions (CDP, 2018b). This study focus on scope 3 emissions and not scope 1 and scope 2. However, companies with a low trustworthiness in their scope 1 and scope 2 emissions are more likely to report fewer scope 3 categories. When comparing ISS Climate Solutions' own trust metric for automobile, fossil fuel and utility companies' number of reported scope 3 categories this was shown, (Figure 2).

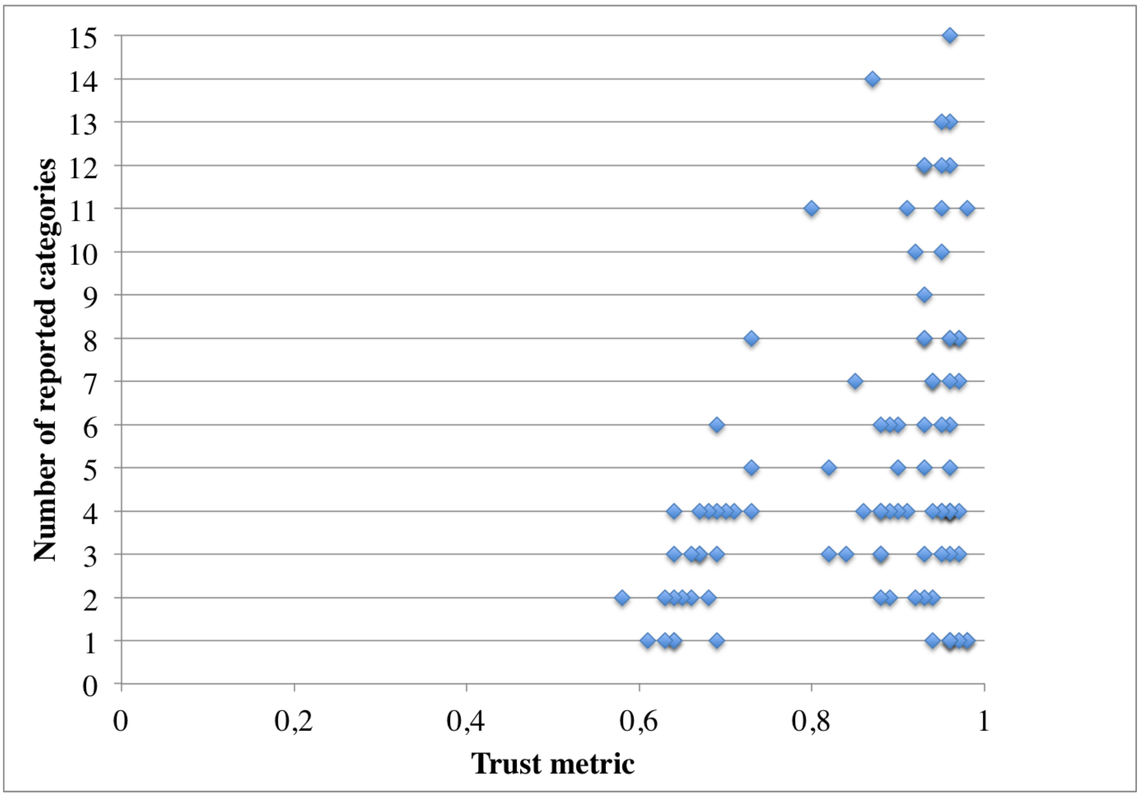

Figure 2 The trust metric for 96 companies and the amount of categories they have reported in scope 3.

The trust metric range between 0 and 1, where a high value indicates a high trustworthiness in the companies reported scope 1 and scope 2 data. A high trust metric on the other hand does not ensure more ambitious reporting of scope 3. As seen in Figure 2, this indicates that a high grade from CDP is not equal to a more ambitious reporting of scope 3, but the likelihood increases with a higher grade. Since this is the best records available it has been used in the study even though there might be a low quality in the reported scope 3 data.

1.7 PREVIOUS STUDIES

To help investors to decarbonize, many different tools have been established. A few of them are presented in this section. Bloomberg, the global provider of financial data, offer the service "The 2D Scenario Analysis Tool" that is developed together with the London based non-profit initiative Carbon Tracker. The service calculates how profitable oil companies would be if the world manages to reach the 2-degree goal. The companies' assets are divided into those who would be profitable despite the reduced demand of fossil fuel and those who are probably not (Bloomberg, 2018a). Carbon Delta also estimates the economic effects related to climate change on a company level. However, they perform their analysis for over thousands of companies and not only for oil companies (Carbon Delta, 2018). A less detailed tool was launched on the 1st of May 2018 by Morningstar together with Sustainalytics. Their Portfolio Carbon Risk Score evaluates portfolios carbon risk exposure and marks funds with a low involvement in fossil fuel, so investors easily can identify them (Morningstar, 2018). The involvement is calculated based on the portfolios over all involvement in fossil fuel in percent. This is defined as the amount of companies who derive at least 5% of their revenue from fossil fuel activities, such as fossil fuel production or energy production from oil, gas and coal (Hale, 2018). Similar to ISS Climate Solution, MCSI carbon footprint index ratios evaluates the companies' scope 1 and scope 2 emissions. MCSI use both companies' reported emissions as well as estimate the emissions when no data is found. They calculate the carbon footprint for 8500 companies monthly, but do not cover scope 3 emissions (MSCI, 2018).

2 DEFINITION AND IMPORTANT CATEGORIES

The economy is divided into different areas called sectors. Each sector consists of companies who work with a similar product for instance food. These food companies can then be divided into smaller more specific sub-sectors like dairy, meat and grains. (Investopedia, 2003). The aim of this study was to develop models for the automobile, utility and fossil fuel sector. Before building the models, each of the sectors had to be divided into more specific sub-sectors, to make sure the companies had their scope 3 emissions from similar sources. First the companies who, according to CDP, are part of the automobile sector, fossil fuel sector and utilities sector were selected. By researching company information from Bloomberg and the company's annual reports an overview of each company within the sectors was made. Then the potential scope 3 emissions between the companies were compared to find commonalities. Based on this information the companies were sorted into subsectors. For example, companies who market and transport fossil fuels and companies who produce and sell fossil fuels were divided into different subcategories. Finally, the subsectors most suitable to model were selected. The scope 3 disclosure data from the selected subsectors were further analyzed to identify which categories that had the largest climate impact. This was carried out by calculating the number of companies who had reported each category, as well as the maximum, minimum, mean and median amount of emissions for each category. Based on this information the categories with the largest contribution to each sector's scope 3 emissions were identified.

2.1 APPLICATIONS IN THIS STUDY

2.1.1 Automobile sector

The automobile sector included companies who produced and sold finished vehicles, for example Volvo, BMW and Toyota. Companies that only produced parts, rented vehicles or repaired vehicles were excluded. The amount of automobile companies who had reported each scope 3 category is shown in Figure 3. A majority of the 15 investigated companies had reported their emissions from purchased goods and services and employees commuting, rather than the emissions from the use of their sold vehicles. Also 13 of the companies had reported their emissions related to business travels and only 12 the emissions related to the end-of-life treatment of the vehicles. The least reported category was upstream leased assets, which only two companies reported.

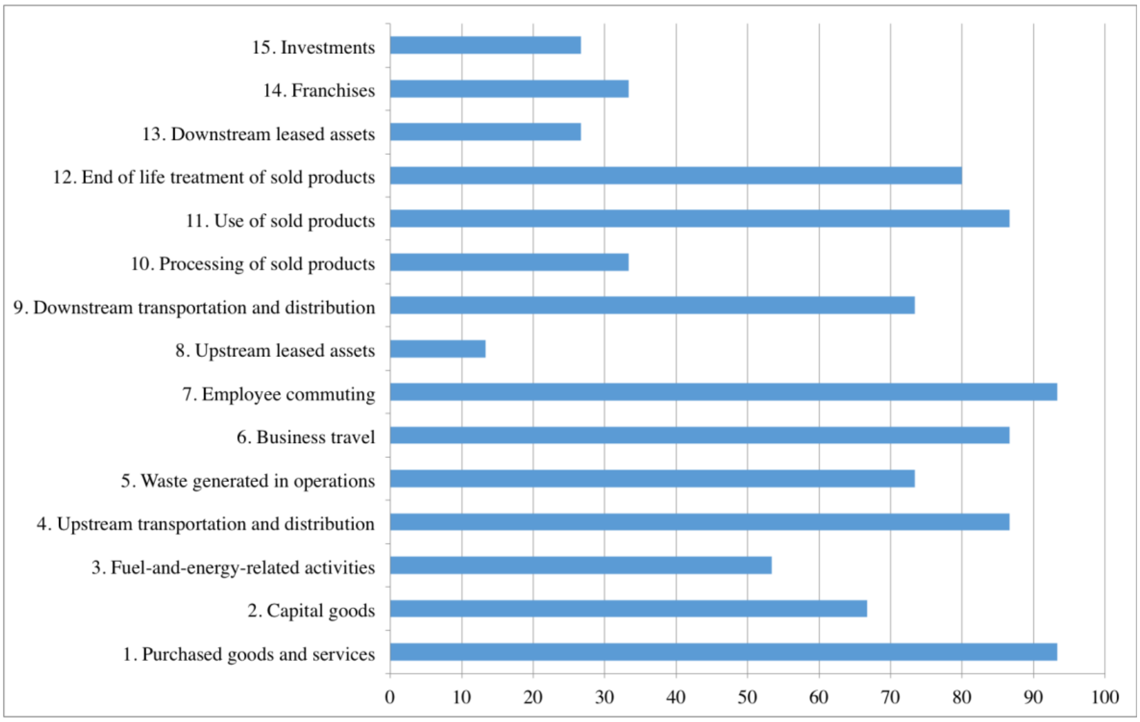

Figure 3 The amount of Automobile companies that had reported each category in percent [%].

The mean proportion of category 11, use of sold products, accounted for 77% of the companies' total emissions, (Figure 4). The second biggest emissions source was from category 1, purchased goods and services with 18%. Emissions from the end-of-life treatment of sold products were 1% and all other categories summed up to 4%. This means that category 1, 11 and 12 together accounted for 96% of the companies' mean emissions. Based on this information these three categories were estimated in the model.

For this calculation the companies who did not reported the emissions related to the usage of their sold vehicles were excluded. As well as those who had only reported one category or had reported a larger amount of emissions related to business travel than to category 11. This excluded 4 companies.

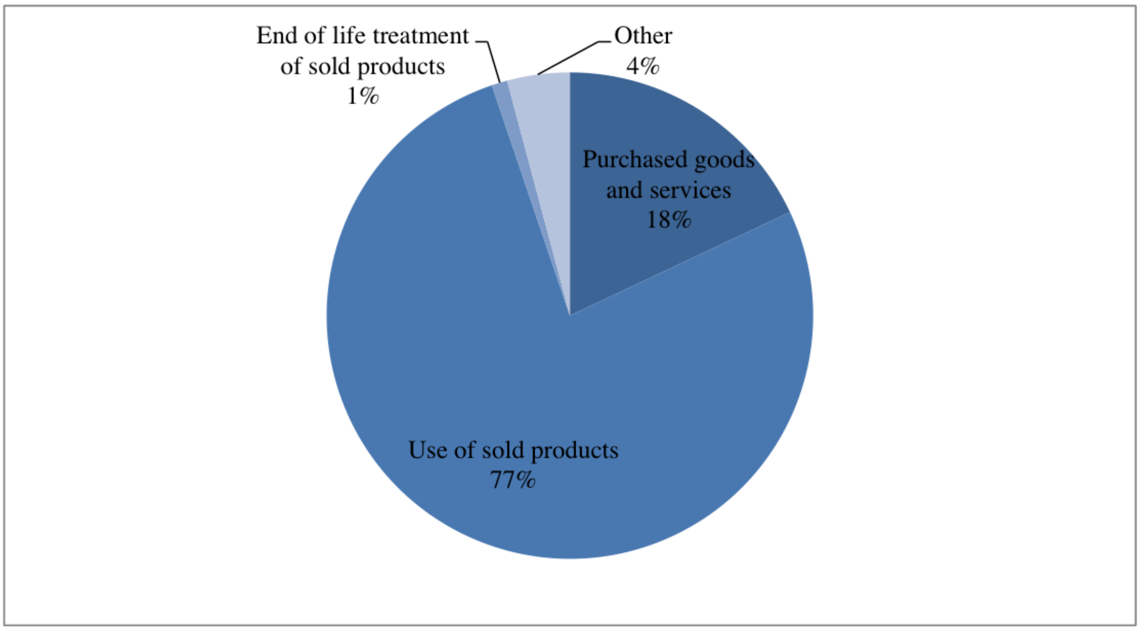

Figure 4 The mean proportion of each category for the automobile companies.

2.1.2. Fossil fuel sector

The fossil fuel sector included the companies that produced and/or sold fossil fuel, for example BP, Shell and Exxon. Companies, which only stored, transported or marketed fossil fuels were excluded. Of 52 investigated companies 75% of them reported their emissions from the usage of their sold fossil fuels, Figure 5. More than 60% had reported their emissions related to business travels and less then 50% had reported all the other categories. End-of-life treatment of their sold products was the least reported category.

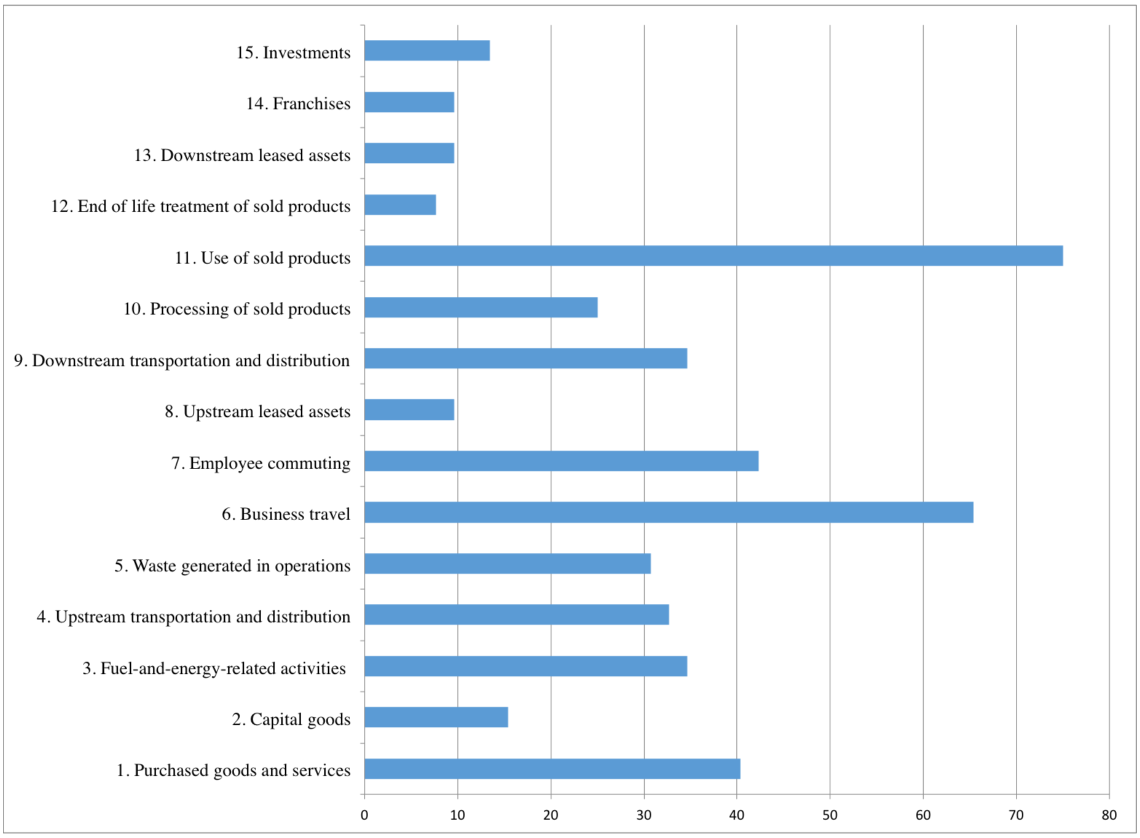

Figure 5 The amount of fossil fuel companies that had reported each category in percent [%].

The mean emission from the combustion of the companies sold fossil fuels accounted for 94% of their total scope 3 emissions. The processing of fossil fuels in refineries was the second biggest source with 4% in category 10, processing of sold products. All other categories summed up to 2%. This means that category 10 and 11 accounted for 98% of the companies' mean scope 3 emissions and therefore vital for the estimation model.

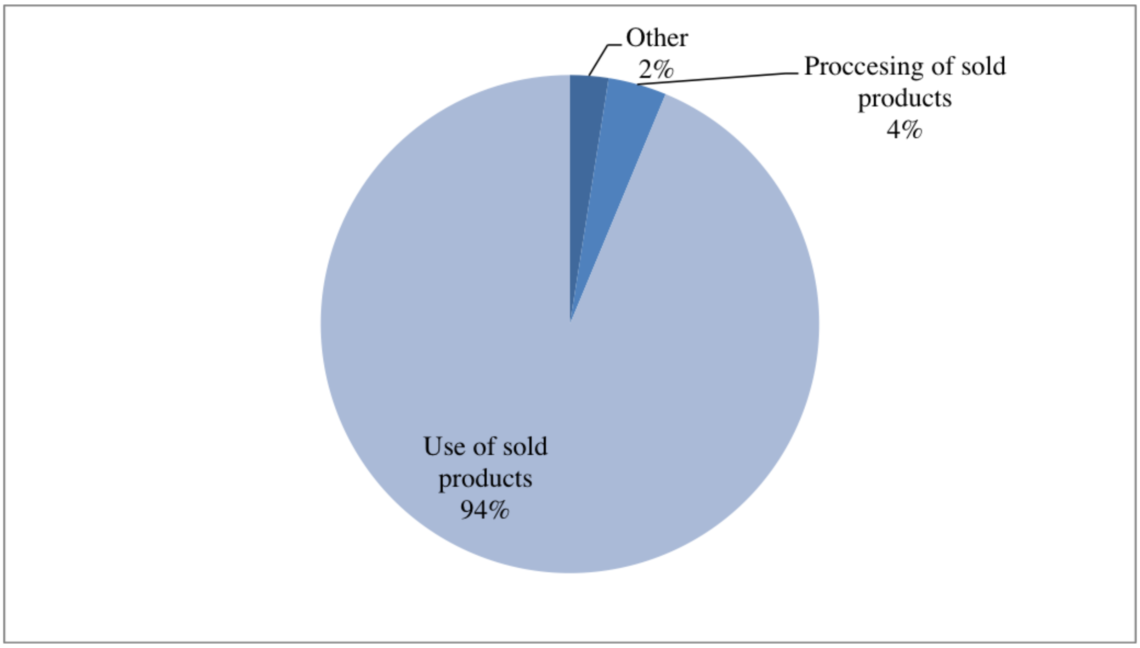

Figure 6 The average proportion of each category for the fossil fuel companies.

2.1.3 Utility sector

The utility sector included the companies that produced and/or sold energy, for example Vattenfall, Engie and Osaka gas. Companies, that only owned the grid or gas pipelines, were excluded as well as water and waste utilities. Of the 42 investigated companies 90% reported their emissions from business travels, Figure 7. The second most reported emission type was from fuel and energy related activities that were not reported in scope 1 or scope 2. Out of all, 67% had reported the emissions generated by employees commuting. Emissions related to the use of sold products, waste generated in operation and purchased goods and services, were reported by more than 50% of the companies. All other categories were reported by less than 40 %.

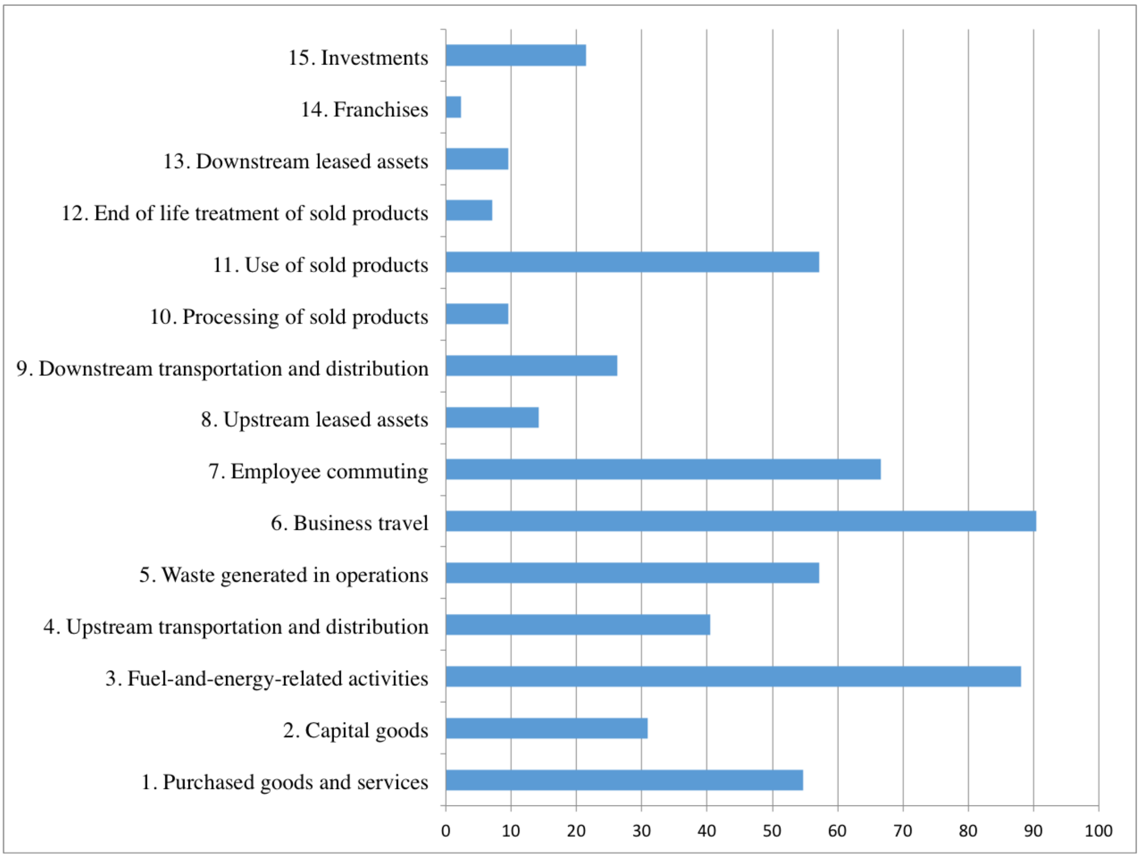

Figure 7 The amount of utility companies that had reported each category in percent [%].

For companies that sold gas a large part of their scope 3 emissions was generated by the combustion of sold gas. Companies that did not sell gas had no emissions in this category. Therefore utility companies were divided into those who sold gas and those who did not. For the companies that did not sell gas the distribution of their scope 3 emissions was distributed as in Figure 8. For them fuel and energy related activities were their largest source of scope 3 emissions with 61%. This category was followed by purchased goods and services with 17%. Investments accounted for 5%, waste generated in the process 4%, and upstream transportation and distribution 5%. All other categories sum up to 8%.

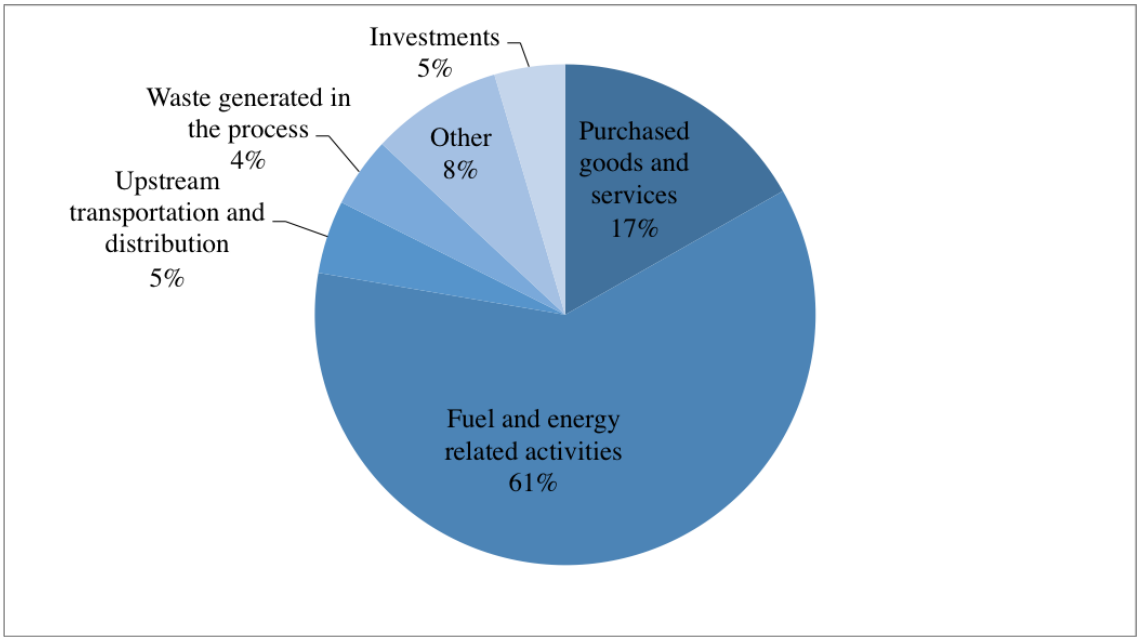

Figure 8 The mean proportion of the categories for utilities that do not sell gas.

For utility companies that sold gas, fuel and energy related activities only accounted for 29%. Instead emissions from the use of sold products were the biggest source with 61%. The third largest source was purchased goods and services with 3%. Emissions from capital goods were 1% and all other categories summed up to 6%.

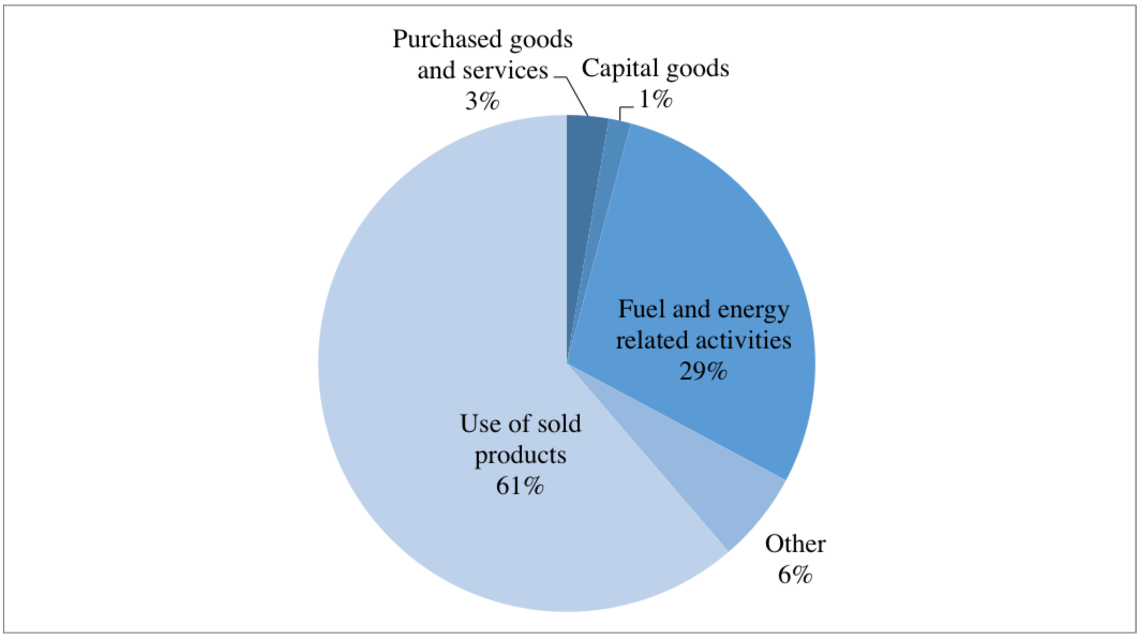

Figure 9 The mean proportion of the categories for utility companies that sell gas.

Figure 8 and Figure 9 show that utility companies scope 3 emissions depend highly on if they sell gas or not and how much energy they have resold to an end user. Therefore, the important categories when estimating the emissions for utility companies are category 3 and 11. The amount of emissions in the other categories seems to depend on what type of energy mix they have. The energy mix varies a lot between companies and every company have their own unique setup, Figure 10. Therefore, no other important category can be determined for utility companies. Each company will have their own set up of important categories depending on their energy mix.

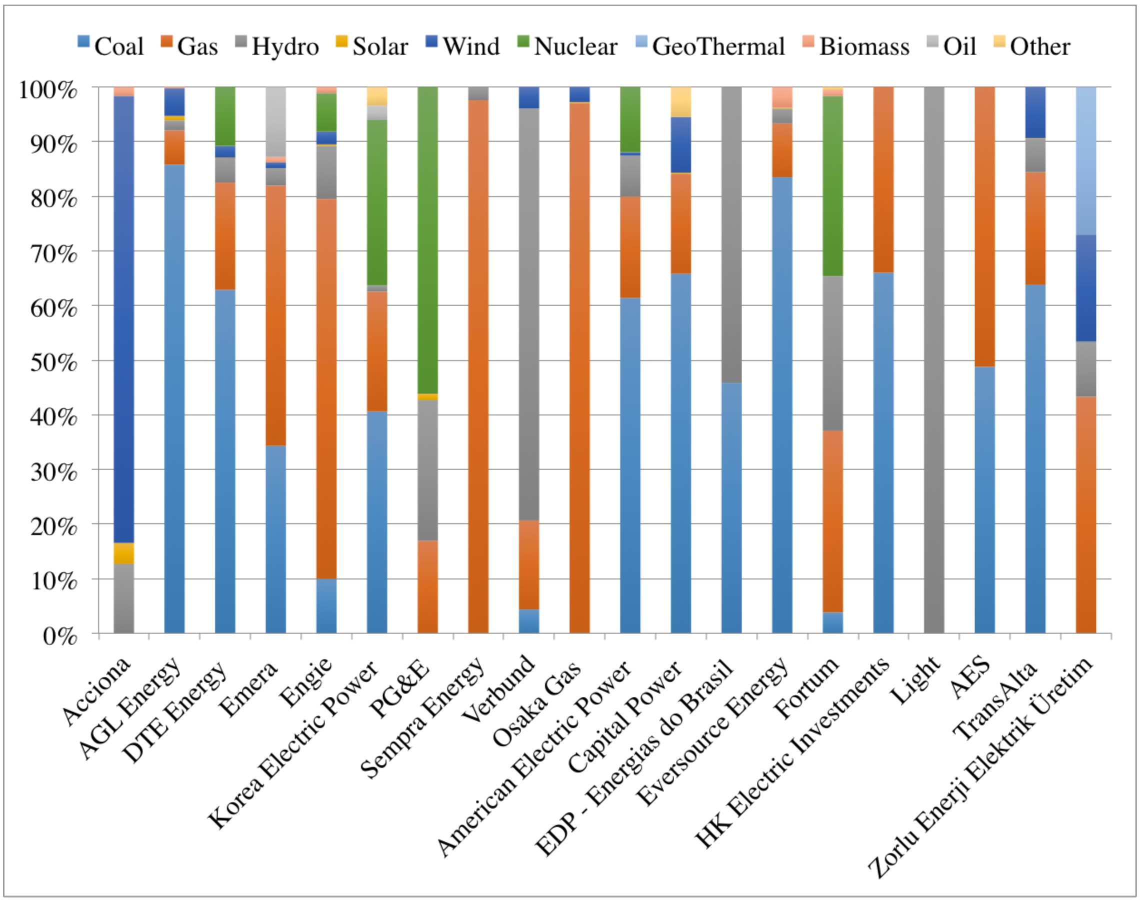

Figure 10 The proportion of energy produced by different types of power plants.

3 METHODOLOGY

In this section the two methodologies used in the study are described. First are the correlation-analysis methodology explained. Then the average-data methodology for each sector are described one by one, starting with the automobile sector, then the fossil fuel sector and finally the utility sector.

3.1 CORRELATION ANALYSIS

The theory that companies' scope 3 emissions could be estimated with the use of some company specific parameters were investigated. The linear correlation between two parameters was investigated by calculating the *proportional reduction in error*, R^2 , as in equation 2.

$$R^2 = \frac{\sum_i (y_i - \bar{y})^2 \cdot \sum_i (y_i - \bar{\mu})^2}{\sum_i (y_i - \bar{y})^2} \tag{2}$$

R^2 ranges from 0 to 1, where 0 to 0.5 indicates no correlation and 1 a perfect correlation. More information about correlations and the proportional reduction in error can be found in the book *functions of linear and generalized linear models* (Agresti, 2015).

The aim was to build the models on the equations of the trend lines if acceptable correlations where found between the reported emissions and a chosen parameter. For example the correlation between the emissions generated in category 7, employee commuting, and the parameter number of employees was investigated. The correlation analyses were performed on each sector's reported scope 3 emissions to CDP. Every sector's total scope 3 emissions as well as the emissions generated by each of the categories were studied. The parameters used for the analysis were:

- Number of employee
- Revenue
- Newest assets
- Newest capital goods sold
- Number of produced vehicles (Automobile sector)
- Generated energy by type (Utility companies)

Different combinations of the parameters like revenue per employee, and revenue per produced vehicle were also tested. The data for each company was collected from Bloomberg (Bloomberg, 2017). The sectors were also divided into subgroups depending on the companies' location e.g. Asia, Europe, North America, South America and Oceania. There were no data from African companies. The utility companies were also divided into two groups, were one included the companies who sold gas and one those who did not.

3.2 AVERAGE DATA METHODOLOGY

The theory that the average data methodology could estimate scope 3 emissions was investigated. The emission factors were limited to only cover the categories who contributed the most to the sectors overall scope 3 emissions, as identified in section

2.1, *applications in this study.* The calculated emissions were compared to some selected companies' reported emissions to validate the models.

3.2.1 Automobile sector

Based on the result from section 2.1.1 the following categories were estimated for the automobile sector:

- Purchased goods and services
- Use of sold products
- End-of-life treatment of sold products

The parameters used for each category is explained in a separate section as well as the input data from the selected companies.

Purchased goods and services

The purchased goods and services category cover all the types of products the company has bought during the year. Companies that are defined as an automobile company might produce other products than vehicles like spare parts. For example Yamaha Motor produces robots and electric power units in addition to their vehicles (Bloomberg, 2018c). To cover the emissions from other types of products than vehicles more company-specific data have to be collected as well as additional emission factors. Therefore, the calculation of the emissions in the *purchased goods and services* category were limited to only cover the emission generated by the manufacturing phase of vehicles. The emission factors for the manufacturing process were collected from Ecoinvent for passenger cars using diesel, petrol and electricity as well as for a bus and a lorry of 28 tonnes (Spielmann *et al.*, 2007). Ecoinvent had no data for motorbikes and thus this emission factor was collected from a LCA study from the university of California (Chester & Horvath, 2009). The data collection was limited to only cover these different types of vehicles. The emission factors for the manufacturing phase included the emissions from the generation of the materials, the transportation and the energy needed in the different processes (Spielmann *et al.*, 2007). This includes the electricity used when assembling the vehicles at the companies' factories, which should be reported in scope 2. To avoid double counting, this contribution was assumed to be negligible. A plugin hybrid car was assumed to have the same emission factor as an electric car in the construction phase, since both vehicle types have a battery. For cars that use other types of fuel then diesel, petrol or electricity the emission factor for a petrol car was used. The emission factors for busses, lorries and motorbikes did not take the used fuel type into consideration. The emission factors used are displayed in Table 2.

Table 2 Emission factors for the construction of one unit.

Type	EF [kg CO_2e/unit]	Reference
Diesel	1741	(Spielmann *et al.*, 2007)
Petrol	4235	(Spielmann *et al.*, 2007)
Electric	5735	(Spielmann *et al.*, 2007)
Bus	36796	(Spielmann *et al.*, 2004)
Lorry 28t	27550	(Spielmann *et al.*, 2007)
Motorbike	9800	(Chester & Horvath, 2009)

Use of sold products

In the use of sold products category all emissions related to the usage of the companies sold products should be reported. For automobile companies, this includes evident emissions like the combustion of fuel from a vehicle and less distinct emissions like the energy used when repairing and washing a vehicle. The evident emissions are required while the less distinct are optional (WRI & WBCSD, 2013). Therefore, this estimation was limited to the direct emissions. The calculations were also limited to only estimate the emissions from vehicles and not from any other products the company may sell. To carry this out two models were developed, model A and model B. This was done since automobile manufacturers constantly are developing the fuel economy technology used in their vehicles. The aim with model A was to reflect the more updated technologies, while model B was based on the average fuel economy for vehicles on the road today. For both models the average lifetime of a vehicle was assumed to be 150 000 km, since it was the most common lifetime in the investigated literature as well as used by the companies in their disclosure reports. The companies' emission where estimated with both model A and model B to see which one estimated the best result.

In model A, the emission from passenger cars using different types of fuels, buses, lorries and motorbikes was estimated. Emission factors for one litre of fuel was taken from the *UK Government GHG Conversion Factors for Company Reporting* for both the combustion of the fuel as well as the generation emissions which includes the extraction, refinery and transportation of the fuel (DEFRA & DBEIS, 2017). Diesel and petrol cars were assumed to have the same fuel economy as the average of the 2016 BMW fleet, which was 0.046 l/km for diesel cars and 0.056 l/km for petrol cars (BMW Group, 2016). Passenger cars using liquid petroleum gas (LPG) was assumed to use 0.099 l/km based on a study from 2016 (Kim *et al.*, 2016). Since the type of fuel used by buses and lorries wasn't found they where all assumed to use diesel. Buses were assumed to use 0.418 l/km which was the lowest fuel economy for a diesel bus in a study from the National Lab of Auto Performance and Emissions Test in China (Guo *et al.*, 2015). The lowest value was chosen since the study was a few years old. The average fuel consumption for lorries was estimated to 0.300 l/km based on figures in the study *Fuel consumption model for heavy duty diesel trucks: Model development and testing* (Wang & Rakha, 2017). Motorbikes was assumed to only use petrol and use 0.057 l/km based on BMW's motorbike K 1600B (BMW, 2018). A battery electric vehicle (BEV) was assumed to use 0.205 kWh/km based on a mean calculated from data presented in a LCA study of electrical vehicles in Italy (Girardi *et al.*, 2015). Since sales data per region was not found for the companies the world average emission factor for electricity were used for all electric vehicles (EIA, 2017). For electric plug in vehicles (PHEV) emission factors for the transportation of one km were from the UK government for both the well-to-tank (WTT) and use phase (combustion) (DEFRA & DBEIS, 2017). The fuel economy for the different types of vehicles is summarized in Table 3.

Table 3 The fuel economy used for the different types of vehicles in model A. The type of vehicle is a passenger car when only the type of fuel is specified.

Type	Fuel economy	Unit	Reference
Diesel	0.046	l/km	(BMW Group, 2016)
Petrol	0.056	l/km	(BMW Group, 2016)
LPG	0.099	l/km	(Kim *et al.*, 2016)
BEV	0.205	kWh/km	(Girardi *et al.*, 2015)
PHEV	0.158	kg CO_2e/km	(DEFRA & DBEIS, 2017)
Bus	0.418	l/km	(Guo *et al.*, 2015)
Lorry	0.300	l/km	(Wang & Rakha, 2017)
Motorbike	0.057	l/km	(BMW, 2018)

In model B the emission factors from the *UK Government GHG Conversion Factors for Company Reporting* were used for all types of vehicles. Both the emission factors for the well–to-tank (WTT) and use phase in CO_2 equivalents per kilometer were taken for an average petrol, diesel, LPG, PHEV and BEV passenger car, as well as for an average loaded lorry and an average motorbike. Furthermore, the emission factor for an average sized car with unknown type of fuel was included. The emission factor for an average bus had another unit, kg CO_2 equivalents per kilometer per passenger. Unfortunately statistical data on the average number of passengers on a bus are difficult to obtain since national bus services often are privatized and therefore rarely publish the data (European Environment Agency, 2015). However, the department of transportation in Colorado define a non-school bus as a vehicle with the minimum of nine seats (Colorado Department of Transportation, 2012). Therefore, a bus was assumed to have nine passengers in the model. The emission factors for the different types of vehicles in model B are summarized in Table 4.

Table 4 The emission factors for the use phase and WTT for the different types of vehicles in model B (DEFRA & DBEIS, 2017).

Type	EF – use phase	Unit	EF - WTT	Unit
Unknown	0.182	kg CO_2e/km	0.043	kg CO_2e/km
Diesel	0.179	kg CO_2e/km	0.043	kg CO_2e/km
Petrol	0.186	kg CO_2e/km	0.051	kg CO_2e/km
LPG	0.201	kg CO_2e/km	0.025	kg CO_2e/km
BEV	0.080	kg CO_2e/km	0.013	kg CO_2e/km
PHEV	0.130	kg CO_2e/km	0.028	kg CO_2e/km
Bus	0.103	kg CO_2e/km /passenger	0.024	kg CO_2e/km /passenger
Lorry	0.870	kg CO_2e/km	0.246	kg CO_2e/km
Motorbike	0.117	kg CO_2e/km	0.031	kg CO_2e/km

End-of-life treatment of sold products

In the category, *end-of-life treatment of sold products,* emissions related to the disposal of the companies' sold products are reported. Also, in this category the calculations were limited to only estimate the emissions from vehicles and not from any other products. The emission factors were collected from Ecoinvent and included the disposal of bulk materials as well as the transportation of tires to cement works. For an electric vehicle the disposal of a Lilo battery was included. (Spielmann *et al.*, 2007). The emission factor for a conventional car was assumed to be representative for all cars who did not use electricity as a fuel. Furthermore, the emission factor for electric vehicles was used for both BEV and PHEV cars. Emission factors were also collected for a bus, a lorry and a scooter, which was assumed to be representative for a motorbike. All emission factors were specific for Europe and are summarized in Table 5.

Table 5 The emissions factors for the disposal of the different types of vehicles in kg CO_2e per unit.

Type	EF [kg CO_2e/unit]	Reference
Conventional	415	(Spielmann *et al.*, 2007)
Electric	706	(Spielmann *et al.*, 2007)
Bus	1390	(Spielmann *et al.*, 2004)
Lorry 28t	1118	(Spielmann *et al.*, 2007)
Scooter	112	(Spielmann *et al.*, 2007)

Input data from companies

The estimations were validated to seven companies' reported scope 3 data. They where selected since they all got rated with the grade A by CDP. All companies except Ford Motor Company had third party verification or assurance that applies to their reported scope 3 emissions. The proportion of the companies reported scope 3 emissions that were verified are summarized in Table 6.

Table 6 The chosen companies and the proportion of scope 3 emissions that have been verified by a third part (CDP, 2017a).

Company	Verified [%]
BMW	99
Daimler	70
Fiat Chrysler Automobile	99
Ford Motor Company	-
General Motors Company	97
Renault	96
Volkswagen	92

To estimate the emissions for each one of the companies their number of produced or sold vehicles during 2016 were collected. When the information was accessible sales data for different types of vehicles was also collected. The difference between sold and produced vehicles was assumed to be negligible. A more detailed description of the data collected from the companies and the assumption made in the estimations can be found in appendix.

3.2.2 Fossil fuel sector

Based on the result in section 2.1.2, the emissions in the following categories were estimated for the fossil fuel sector:

- Processing of sold products
- Use of sold products

The parameters used for each category is explained in a separate section as well as the input data from the selected companies.

Processing of sold products

If a company's fossil fuel products are refined in another company's refinery, the emissions related to the processing should be reported in category 10. If the company refines all their products in their own refinery the generated emissions should be reported in scope 1 and 2. No information was found from the companies about how much of a certain product they had refined, for example diesel or petrol. Therefore, estimations were limited to only cover the generic emission from crude oil in a refinery. A mean was calculated based on the emission factors corresponding to the wellhead-to-refinery phase for 12 different oil fields in 11 different countries (Energy-Redefined LLC, 2010). Emissions generated from flaring and venting as well as fugitive emissions were excluded. This gave an emission factor of 4120 kg CO_2 equivalents per TJ. All the crude oil produced by the companies was assumed to be refined.

Use of sold products

For fossil fuel companies the emissions reported in category 11 are generated by the combustion of their sold fossil fuel. Petroleum products which are used in materials like plastic or asphalt are not combusted and last for a long time and therefore these products do not have to be reported in this category (World Resources Institute, 2015). According to British Plastics Federation 4% of the global oil production goes to plastics (British Plastics Federation, 2008). Therefore 4% of the companies' crude production was excluded from the estimation. Emissions factors for crude oil, natural gas and natural gas liquids were taken from IPCC (Gómez & Watterson, 2006). The global warming potential for 100 years from IPCC's fifth assessment report was used when calculating the carbon dioxide equivalents (Myhre, et. al., 2013). The emission factor for crude oil is used for all types of oil since no more specific information could be found from the companies. When calculating the emissions from coal, CDP recommend to use one emission factor for each one of the five coal ranks lignite, sub-bituminous, bituminous, coking and anthracite (CDP, 2016). The emission factors for the different types of coal were taken from IPCC (Gómez & Watterson, 2006). Since most companies do not report what type of coal they have produced, weighted averages on a regional level were calculated. The production data of coking coal, steam coal, lignite and peat were taken from the International Energy Agency (IEA) for different regions. Steam coal refers to the usage of the coal and includes both bituminous and anthracite, therefore a mean value of their emission factors was used for steam coal (Berdowski *et al.*, 1998). The regions were OECD Americas, OECD Asia Oceania OECD Europe, Australia and all the member countries of IEA. For the U.S production data for bituminous, anthracite, sub-bituminous and lignite were collected from the U.S International Energy Administration (IEA, 2017).

Input data from companies

The selected oil-and-gas-producing companies received the grade A on their climate disclosure report 2016. Also, a third party had verified 90% or more of their reported scope 3 emissions, Table 7. Only a few companies that produce coal reported their emissions and no one had the grade A. Therefore, Exxaro Resources with the grade B and 94% of their emissions verified by a third party was selected. To have a company to compare with Indo Tambangraya Megah was also added, who had the grade C and no third-party verification.

Table 7 The selected companies for the fossil fuel sector, their grade from CDP on their climate disclosure report and the proportion of their reported scope 3 emissions that have been verified by a third party (CDP, 2017a).

Company	Grade	Verified [%]
BP	A-	100
Eni	A-	100
Galp Energia	A	100
Hess Corporation	A-	100
OMW	A	100
Repsol	A-	99
Statoil	A-	100
Total	A-	90
Vermillion Energy	A-	100
Exxaro Resources	B	94
Indo Tambangraya Megah	C	-

According to CDP mining companies generally only report their production data and not their sales data. Furthermore the difference between the sales data and production data are as small as $\pm 2\%$ (CDP, 2016). Therefore, the mining-coal production in million short tonnes was collected from Bloomberg for the coal producing companies. For the oil and gas producing companies no sales data was found and therefore the production data was collected from Bloomberg in million barrels of oil equivalents (boe). One million barrels of oil equivalents was assumed to be equal to 6119 TJ based on BP's conversion factors (BP p.l.c, 2017).

Based on information from Oekom's corporate rating reports the produced amount of oil equivalents was divided into natural gas, natural gas liquids and oil for each company (Oekom, 2017). To determine if a company's products are refined at a refinery owned by a third party annual reports, official websites and company information from Bloomberg were investigated. No information could be found of how much of the companies' produced products that had been refined by a third party. Therefore, companies that owned a refinery were assumed to refine all their products themselves. All selected oil producing companies own refineries except Vermillion Energy where no information that indicates an ownership was found, Table 8.

Table 8 A summary of the companies' ownership of refineries and the reference.

Company	Owns refinery	Reference
BP	Yes	(BP p.l.c, 2016)
Eni	Yes	(Eni SpA, 2016)
Galp Energia	Yes	(Galp Energia, 2016)
Hess Corporation	Yes	(Hess Corporation, 2016)
OMW	Yes	(OMV AG, 2016)
Repsol	Yes	(Bloomberg, 2018b)
Statoil	Yes	(Statoil ASA, 2016)
Total	Yes	(Total S.A, 2016)
Vermillion Energy	No	(Vermillion Energy Inc, 2013)

3.2.3 Utility sector

The emissions related to utility companies as declared in section 2.1.3, depends on the energy mix of the company, if they sell gas and if they resell electricity to end-users. There are many ways to produce energy today for example by using solar, wind, hydro, nuclear, coal, oil, gas and biomass power plants. All these different technologies have their own carbon footprint. Since most companies produce energy by using various technologies and few companies have the same setup, Figure 10, there are no typical similarities between the companies' scope 3 emissions. Therefore, LCA studies for the different technologies were studied and the corresponding emissions categorised according to the GHG protocol. According to the GHG protocol all emissions related to the purchased capital goods should be reported on the year of the acquisition. This mean that all the construction related emissions should be reported the year a new power plant is constructed. This information was not found for the companies and therefore all construction emissions were divided by the power plants expected lifetime and accounted for every year. For the same reason the decommissioning emissions also were reported every year. The emission factors used for each type of power plant is explained in a separate section as well as the input data from the selected companies. Emission factors from the combustion of sold gas are included in the section for natural gas. The estimation of emissions related to resold energy in category 3: fuel and energy related activities, are explained in a separate section.

Resold energy (category 3)

The emissions related to the generation of purchased electricity that is sold to end users are reported in category 3: fuel and energy related activities. To determine the emission factor of the companies purchased electricity the region-specific emission factors were collected. The emission factor for the Nordic countries was taken from Ecoinvent (Frischknecht *et al.*, 2007). The emission factors for all other regions were taken from the U.S International Energy Agency (IEA). The emission factors were a mean based on the years 2013 to 2015 (IEA, 2018). The regions were Africa, Americas, Asia, Asia excluding China, Asia Oceania, Australia, China, Europe, Middle East, Nordic countries, North America and the world. The emission factors ranged from 190690 to 752000 kg CO_2 equivalents per GWh.

Wind

Wind power can be produced onshore or offshore which has been taken into account in a report by Thomson & Harisson (2015). The emissions related to onshore wind power plants range between 3000 – 45000 kg CO_2 equivalents per GWh and for offshore 7000 - 23000 kg CO_2 equivalents per GWh. The emissions were divided into three phases of the power plants lifecycle and the contribution from each phase was reported in percent (Thomson & Harisson, 2015). The three phases were:

1. Manufacturing and installation
2. Operations and maintenance
3. Decommissioning

Based on this information emission factors for each phase were calculated, Table 9. The higher values were used since no mean or median value was stated. The emissions generated by the manufacturing and installation were reported in category 2: capital goods and the decommissioning emissions were reported in category 5: waste generated in operations. The emissions related to the operations and maintenance should be reported in scope 1 and 2 and was therefore excluded. Off shore wind farms takes a longer time to develop and are more expensive then onshore wind farms (Wind Europe, 2018). Therefore the emission factors for onshore wind power plants were used, when the type of wind power plants operated by the company was unknown.

Table 9 Emission factors for onshore and offshore wind as well as each category's total contribution to the overall carbon footprint. (Thomson & Harisson, 2015).

Onshore			
Life cycle category	Scope 3 category	EF [kg CO_2e/GWh]	Contribution to carbon footprint [%]
Manufacturing and installation	2	40500	90
Operation and maintenance	-	2700	6
Decommissioning	5	2700	6
Offshore			
Life cycle category	Scope 3 category	EF [kg CO_2e/GWh]	Contribution to carbon footprint [%]
Manufacturing and installation	2	16100	70
Operation and maintenance	-	4600	20
Decommissioning	5	1400	6

Solar

Solar power can be generated by photovoltaic solar power or by concentrating solar power. In this study both technologies have been investigated. However, photovoltaic solar power is the most commonly installed type (World Energy Council, 2016). Therefore, the emission factors for photovoltaic solar power were used, when no information from the company of which technology they use were available.

The carbon intensity for photovoltaic (PV) solar power was investigated in a study by Nugent and Sovacool (2013). They studied 153 LCA's of solar PVs and sorted them after relevance. Based on the remaining 41 studies mean, median, high and low values as well as standard division were calculated. The emissions were divided into the categories material cultivation and fabrication, construction, operation and decommissioning (Nuget & Sovacool, 2013). Material cultivation and fabrication included all the materials used to build the solar PV and were reported in category 1: purchased goods and services. Construction included the support structures, transport and installation in the construction phase and was accounted for in category 2: capital goods. To avoid double counting with scope 1, the transportations used for installing the solar PV were assumed to be performed by a third party. Emissions generated from the operation of the PV are not included in scope 3 and was therefore excluded. Emissions generated by the decommissioning of the PV were accounted for in category 5: waste generated in operations, since the company have not sold the product and still own it. The investigated LCA studies tended to account the recycling of part as mitigation and therefore these emissions are negative (Nuget & Sovacool, 2013). In this model negative emissions are not accounted for and therefore the emissions were set to zero. The emission factors are summarized in Table 10.

Table 10 The table include the life cycle category for power generation by PV solar power, the corresponding scope 3 category, emission factor and the type of value that was chosen from the study (Nuget & Sovacool, 2013).

Life cycle category	Scope 3 category	EF [kg CO_2e/GWh]	Type of value
Cultivation and fabrication	1	33670	Mean
Construction	2	8980	Mean
Decommissioning	5	0	-

For concentrating solar power (CSP) the emission factors were collected from a study by Kommalapati et al. (2017). In the study twelve different LCA studies were reviewed and the mean emission factor calculated for four different technologies. The emission factors included the manufacturing, construction, operation and maintenance, dismantling of the tower and disposal of the material to a landfill (Kommalapati *et al.*, 2017). To divide the emission factor into different categories the percentage of the impact from each phase was calculated based on data from a report by Burkhardt et al. (2011). This study was chosen since it was the most recent published study used in the review and therefore the emission factor for a parabolic trough was selected as the representative CSP technic. The manufacturing emissions were reported in category 1: purchased goods and services. With the assumption that a third party transport the components and assemble the plant, the emissions generated from the construction were reported in category 2: capital goods. Disposal of the deconstructed parts was reported in category 5: waste generated in operations. An assumption was made that the companies' performed the dismantling, operation and maintenance therefore these emissions was not reported in scope 3. The emission factors and the contribution from each category are displayed in Table 11 as well as the corresponding GHG protocol category.

Table 11 Phase in the life cycle of a CSP power plant, scope 3 categories, emissions factors in kg CO_2 equivalents per GWh and the proportion of the total carbon footprint (Kommalapati *et al.*, 2017; Burkhardt *et al.*, 2011).

Life cycle category	Scope 3 category	EF [kg CO_2e/GWh]	Contribution to carbon footprint [%]
Manufacturing	1	36900	46.3
Construction	2	5200	6.5
Operation	-	31000	38.9
Dismantling	-	300	0.4
Disposal	5	6200	7.8

Hydropower

For hydropower the carbon footprint is generated by the construction of the dams, dikes and power stations. The largest component according to some studies is the emissions related to the flooding of dry land (Lerche Raadal *et al.*, 2011). There is no scope 3 category that takes this type of emissions into account and consequently this contribution was excluded. The largest contribution to the carbon footprint is then the concrete production and transportation of landmasses when building the infrastructure of the hydropower. Therefore, only the emissions generated when building the dams was reported in category 2: capital goods. In a study by Lerche Raadal et al. (2011) 63 LCA's from between 1990 and 2010 were studied and mean values calculated, Table 12. The mean value for reservoir hydropower was approximately 2900 kg CO_2 equivalents per GWh when emissions generated by flooding were excluded. For river-run-off hydropower the mean emissions was 4900 kg CO_2 equivalents per GWh (Lerche Raadal *et al.*, 2011). When the type of hydropower used by the company was unknown the emission factor from a river-runoff hydropower was used.

Table 12 The approximate scope 3 emissions generated by reservoir and river-run-off hydropower (Lerche Raadal *et al.*, 2011).

Type of hydro	Scope 3 category	EF [kg CO_2e/GWh]	Type of value
Reservoir	2	2900	Mean
River-run-off	2	4900	Mean

Geothermal

Geothermal energy can be generated by using the different technologies binary enhanced geothermal system (EGS), hydrothermal (HT) flash system and hydrothermal (HT) binary system. The carbon footprint of a geothermal power plant can be divided into three different phases; the construction, the operational and the end-of-life phase. In a study by Eberle et al. (2017) more than 180 LCAs on geothermal energy production was investigated. The min, median and max values were calculated for the different technologies and life-cycle phases. They also calculated the combined emission factor for all technologies and this median value was selected as the representative emission factor (Eberle *et al.*, 2017). The emissions generated in the construction phase were reported in category 2: capital goods. The operational phase is not reported in scope 3 and was therefore excluded. The end-of-life treatment was assumed to be performed by a third party and was consequently reported in category 5: waste generated in operations.

Table 13 The emission factor for each life cycle category and the corresponding scope 3 category for all technologies (Eberle *et al.*, 2017).

Life cycle category	Scope 3 category	All technologies [kgCO_2e/GWh]
Construction	2	15300
Operation	-	6900
End of life	5	400

Nuclear

The nuclear lifecycle can be divided into five phases:

1. Frontend: includes the mining, milling, conversion and enrichment of the uranium. Including all transportation as well as the final transportation to the nuclear plant.
2. Construction: includes the construction and all material needed to build the nuclear plant.
3. Operation: includes the energy needed during shutdown, maintenance and repairs.
4. Backend: includes the afterlife treatment of the uranium.
5. Decommissioning: includes the reconstruction of the nuclear plant and the uranium mine.

The emissions related to nuclear power production vary a lot between studies. One reason behind the different results is the different technologies used to enrich the uranium. For example, the gas centrifuge method uses 40 times less energy than the gas diffusion method. Another reason behind the variation is the different methodologies used to calculate the carbon footprint (Turconi *et al.*, 2013). In a report by Sovacool (2008), 103 lifecycle assessments of nuclear power were investigated. Only 19 of the studies had submitted their results as detailed as the previous presented lifecycle. Based on these 19 studies min, max and mean values were calculated for each phase in the lifecycle (Sovacool, 2008). The mean values were selected as representative. The emissions generated in the frontend were reported as category 1: purchased goods and services. The construction related emissions are reported in category 2: capital goods. The emissions generated by the operation of the plant are not included in scope 3 and was therefore excluded. Since the afterlife treatment of the uranium and power plant take a long time, the treatment was assumed to be performed by a third party. Therefore, both the backend and decommissioning emissions was reported in category 5: waste generated in the operations, Table 14.

Table 14 The different categories in the lifecycle of a nuclear power plant, the corresponding scope 3 category as well as the emissions factor in kg CO_2 equivalents per GWh (Sovacool, 2008).

Life cycle category	Scope 3 category	EF [kg CO_2e/GWh]
Frontend	1	25090
Construction	2	8200
Operation	-	11580
Backend	5	9200
Decommissioning	5	12010

Biomass

Biomass-fired power plants run on several different types of biomass depending on the region. The lifecycle of a biomass-fired power plant can be divided into five different phases:

1. Procurement including crop management, fertiliser production and fertiliser application.
2. Transport
3. Infrastructure
4. Combustion
5. Ashes disposal

In a study by Turconi et al. (2013) life cycle assessment were investigated and compiled. For combustion of biomass the study found that the carbon footprint ranged between 8500-130000 kg CO_2 equivalents per GWh (Turconi *et al.*, 2013). The highest value was selected and divided into scope 3 categories based on the assumption that the proportion would be the same as for the more detailed study by Sebastián et al (2010).

They investigated both wheat and energy crops and the result for the energy crops were used to divide the emissions into scope 3 categories. The procurement of the biomass was reported in category 1: purchased goods and services, and the transportation in category 3: fuel and energy related activities. The infrastructure of the biomass plant was reported in category 2: capital goods. The combustion of the biomass is not included in scope 3 and was therefore excluded. The ashes disposal was reported in category 5: waste generated in operations, assuming it was performed by a third part, Table 15.

Table 15 The table display the lifecycle category for biomass and the corresponding scope 3 category. The calculated emission factor in kg CO_2 equivalents per GWh was based on the proportion of the category (Turconi *et al.*, 2013; Sebastián *et al.*, 2010).

Life cycle category	Scope 3 category	EF [kgCO_2e/GWh]	Proportion of each category [%]
Procurement	1	106100	81.6
Transportation	3	4800	3.7
Infrastructure	2	400	0.3
Combustion	-	18500	14.2
Ashes disposal	5	200	0.2

Natural gas and natural gas liquid

The life cycle for natural-gas and natural-gas-liquid power plants can be described as:

1. Construction of gas power plant
2. Extraction
3. Transport
4. Combustion
5. Decommissioning

The average emission factor for the material and energy used for the construction of an 300 MW gas power plant as well as the decommissioning was taken from Ecoinvent (Faist Emmenegger, 2007). The unit was kg CO_2 equivalents per unit and the decommissioning was assumed to be up to 10% of the emission factor. The power plant lifetime was assumed to be 30 years with no stops (Spath & Mann, 2000). The contribution from the extraction and transport were taken from a study by May & Brennan (2003) where the climate change impact from natural gas and natural gas liquid power plants were investigated. The study calculated the contribution from the subsystems mining, transport, generation and transmission in percent. Furthermore the carbon intensity range for the three different types of technologies; boiler steam turbine, open-cycle gas turbine and combined-cycle gas turbine were calculated for both natural gas and natural gas liquid (May & Brennan, 2003). To get representative emission factors a mean was calculated based on the higher end of the range for the three different technologies. These emission factors were divided into different categories based on the percentages. The extraction emissions were reported in category 1 and the transportation emissions in category 3.

When gas where sold by the utility companies the combusting of the gas was reported in category 11: use of sold products. Emission factors for natural gas and natural gas liquids were taken from IPCC in kg CO_2 equivalents per TJ (Gómez & Watterson, 2006). The emission factors are summarized in Table 16.

Table 16 The lifecycle categories for natural gas and natural gas liquids and the corresponding scope 3 categories are displayed. (Faist Emmenegger, 2007; May & Brennan, 2003).

Life cycle category	Scope 3 category	EF	Unit
Construction	2	164	kg CO_2e/GWh
Extraction NG	1	85480	kg CO_2e/GWh
Extraction NGL	1	252300	kg CO_2e/GWh
Transport NG	3	10200	kg CO_2e/GWh
Transport NGL	3	41000	kg CO_2e/GWh
Combustion NG	11	56155	kg CO_2e/TJ
Combustion NGL	11	64443	kg CO_2e/TJ
Decommissioning	5	18	kg CO_2e/GWh

Coal

The typical life cycle for a coal-fired power plant can be divided into five phases:

1. Construction of coal power plant
2. Coal mining
3. Transport of coal from mine to power plant
4. Combustion
5. Decommissioning

The carbon footprint from the mining vary a lot depending on the energy used onsite. Furthermore open mines release more methane than mines underground, which affect the carbon footprint as well (Sovacool, 2008). Therefore location specific emission factors for the production of one kg of coal was collected from Ecoinvent for the different regions North America, East Europe, South Africa, West Europe, South America and the Caribbean, Russia and China (Röder *et al.*, 2004; 2007). The extraction emissions were reported in category 1: purchased goods and services. Location specific transportation emission factors were taken from Ecoinvent as well. The emission factors included the transport of one kg coal from the storage in producing countries to a power plant in the specific country. The included countries were Austria, Czech Republic, Poland, China, USA, Slovakia and Portugal (Röder *et al.*, 2007). The transport emissions were reported in category 3: fuel and energy related activities. The construction and decommission emissions are often neglected from LCA's since they only contribute to about 1‰ of the total carbon footprint of a coal power plant. In a study from the UK the contribution from the construction and decommissioning was calculated to 1100 kg CO_2 equivalents per GWh. The assumed time for the construction was 3 years and for the decommissioning 1 year (Odeh & Cockerill, 2007). Based on this a rough assumption was made that the carbon footprint for the construction summed up to 75% of the emission factor and the decommissioning 25 %. The construction related emissions was reported in category 2: capital goods and the decommissioning ones in category 5: waste generated in operations. The combustion are reported in scope 1 and not scope 3 and was therefore excluded. The emissions factors are summarized in Table 17.

Table 17 Life cycle category and the corresponding scope 3 category for a coal power plant. The emission factors are per GWh or per kg (Odeh & Cockerill, 2007; Röder *et al.*, 2004; 2007).

Life cycle category	Scope 3 category	EF [kg CO_2e/GWh]	EF [kgCO_2e/kg]
Construction	2	825	-
Mining	1	-	0.03-0.90
Transport	3	-	0.17-0.97
Combustion	-	-	-
Decommissioning	5	275	-

Oil

The lifecycle for an oil power plant can be divided into six phases:

1. Construction of the power plant
2. Exploration and extraction
3. Refining
4. Transport
5. Combustion
6. Decommissioning

The total carbon footprint for the construction, land usage and decommissioning of a 500 MW power plant were collected from Ecoinvent. The assumed lifetime was 30 years (Jungblunth, 2007). In a study by Kannan et al. (2004) they found that the construction of the plant was responsible for 0.13 % of the total carbon footprint and the decommissioning 0.04 %. This proportion was assumed to be representative and therefore used to calculate the corresponding emissions for the construction phase and the decommissioning phase. The construction phase was reported in category 2: capital goods and the decommissioning in category 5: waste generated in operations.

In the study by Rahman et al. (2015) the recovery emissions for five different crudes was calculated. Emission from the extraction, drilling and land use change accumulated to 79,9 % of the total carbon footprint of the recovery. This proportion was applied on the recovery emission factor for the crude oil using steam injection. These emissions were reported in category 1: purchased goods and services. Both the refinery and transportation emission factors were taken from Ecoinvent as well (Jungblunth, 2007). The refinery emissions were reported in category 1: purchased goods and services. The transport emission factor was for one kg of crude oil from the well to the refinery. The transportation from the refinery to the oil power plant was assumed to be much shorter and therefore neglected. The density 842.7 kg per m^3 was used to convert the emissions factor to carbon dioxide equivalents per thousand square meters. The density was based on a mean calculated from three different kinds of crude oils (Sørheim, 2016). The transportation emissions were reported in category 3: fuel and energy related activities. The emissions generated by the combustion of the fuel oil are not a part of scope 3 and therefore not included. The emission factors are summarized in Table 18.

Table 18 Life cycle category and the corresponding scope 3 category. The emission factors have the units kg CO_2 equivalents per kg and kg CO_2 equivalents per GWh (Jungblunth, 2007; Kannan *et al.*, 2004; Rahman *et al.*, 2015).

Life cycle category	Scope 3 category	EF	Unit
Construction	2	770	kg CO_2e/GWh
Exploration and extraction	1	6876	kg CO_2e/GWh
Refinery	1	502450	kg CO_2e/GWh
Transport	3	0.627	kg CO_2e/kg
Combustion	-	-	
Decommissioning	5	237	kg CO_2e/GWh

Input data from companies

The selected companies received an A on their climate disclosure report from CDP. Also a third party had made a limited or reasonable assurance of their reported scope 3 emissions, Table 19.

Table 19 The selected companies from the utility sector, their grade from CDP and the amount of their reported scope 3 emissions that was verified by a third party (CDP, 2017a).

Company	Grade	Verified [%]
EDF	A-	44
EDP- Energias De Portugal	A-	100
Endesa	A-	100
Engie	A	100
Fortum	A-	100
Gas Natural SDG	A-	100
Korea Electric Power Corporation	A-	95
PG&E Corporation	A-	75
Pinnacle West Capital	A-	25
Sempra Energy	A-	81

The data from the companies were collected from Bloomberg and included the produced energy by type [GWh], amount of sold gas [million therms or 1.055 x 10^{14} joules], coal used [kg], oil used [1000 m^3], total amount of power generated [GWh] and total amount of sold energy [GWh]. The energy production by type was divided into wind, solar, hydro, geothermal, nuclear, biomass, natural gas, biomass, oil, coal, multi (thermal fuel power plants), other renewable and other (not renewable) (Bloomberg, 2017). To convert the amount of sold gas from million therms to TJ conversion factors from BP and American Physical Society were applied (BP p.l.c, 2017; American Physical Society, 2018).

To calculate the emissions from the energy source; other renewable, a mean was calculated based on the emissions factors for all the renewable energy in each category. For example, in category 1 a mean was calculated based on the emission factors for solar CSP, solar PV and biomass. For the energy source; other non-renewable, a mean based on the non-renewable energy sources oil, gas, nuclear and coal were calculated for each category. A thermal fuel power plant generates steam that runs a turbine that generates electricity. The steam can be generated with a solar CSP plant, the burning of fossil fuels or by a nuclear power plant (Hanania *et al.*, 2018). The only companies who had energy generated by thermal fuel power plants were Pinnacle West Capital and Korea Electric Power. In the annual report from Pinnacle West Capital Corporation it could be found that the largest amount of their thermal energy was generated from oil and gas (Pinnacle West Capital Corporation, 2016). For Korea Electric Power Corporation their thermal energy were generated by coal, oil and natural gas liquids (Korea Electric Power Corporation, 2016). Therefore, the emissions generated by thermal energy were calculated using a mean of the emission factors for oil, gas and coal. To estimate the amount of purchased electricity that was resold to an end user the amount of sold energy were subtracted from the produced energy.

4 RESULT

In this section the result from the study is presented. First is the result from the correlation-analysis methodology submitted. Then the results from the average-data methodology are presented for each one of the sectors starting with the automobile sector, the fossil fuel sector and lastly the utility sector.

4.1 CORRELATION ANALYSIS

The correlation between the tested parameters and the companies reported scope 3 emissions could not be proven for any of the sectors' or categories. Most correlations gave a proportional reduction of error below 0.5 and the cases where R^2 where above 0.5 where the dataset too small to be representative for the sector. The correlation between fossil fuel companies' revenue and the emissions from the usage of their products is a representative result from the study, (Figure 11). More representative result can be found in Appendix. The companies seem to be too complex to be explained by one or a few parameters and the companies who report their emissions are too few to get a good correlation.

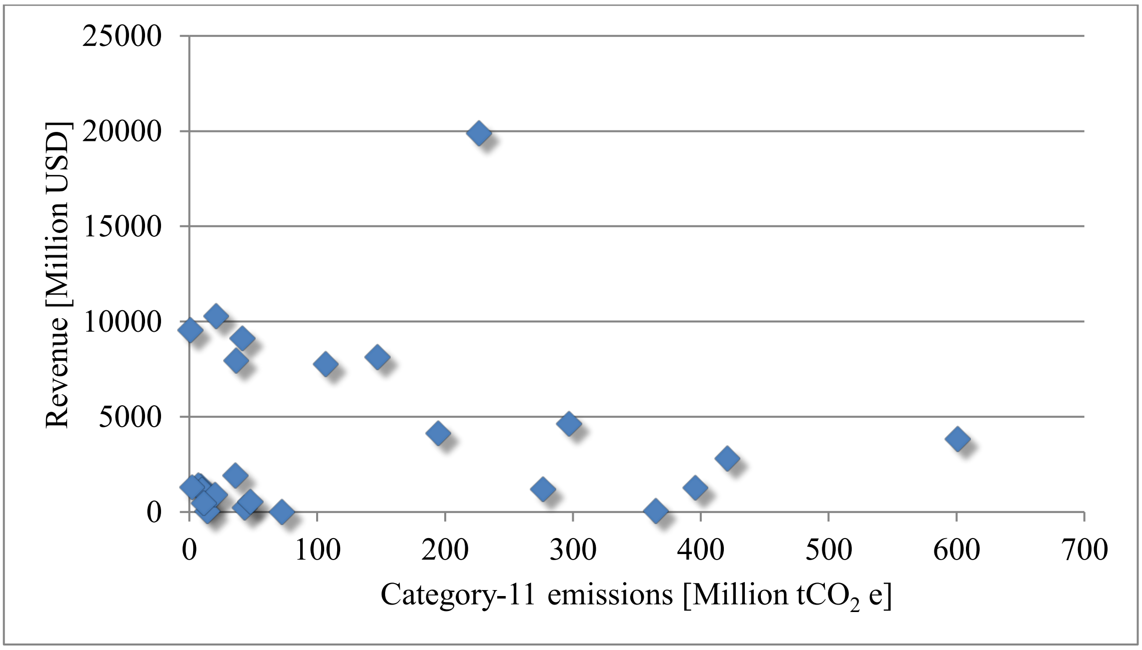

Figure 11 The revenue for the fossil fuel companies and the reported amount of emissions from category 11 in million-ton CO_2 equivalents. No strong correlations were found.

4.2 AVERAGE DATA METHODOLOGY

4.2.1 Automobile sector

The estimated emissions for category 1, 12 and 11 using model A or model B was compared to the companies reported CDP data for the corresponding categories. Figure 12 shows how much the estimated emissions underestimated or overestimated the company's reported amount of CO_2 equivalents in percent. Negative percent indicates an underestimation and positive percentage indicates an overestimation. Ford Motor Company had not reported their emissions in category 12 and therefore this data is missing in Figure 12. Category 1 was underestimated for all the companies except for Ford Motor Company where it was largely overestimated. Ford Motor Company had reported the second smallest amount of emissions in category 1 after Renault. However, Renault's vehicle fleet was less than half the size of Ford Motor Company in 2016. BMW had the third smallest amount of reported emissions in category 1 and had even fewer cars in their fleet than Renault. Category 11 was underestimated by 4% for Daimler when using model A and the same data as they did in their CDP report (buses, lorries and vans was excluded). Volkswagen, BMW, Ford Motor Company, Renault, and Fiat Chrysler Automobile were overestimated by respectively 11%, 14%, 15%, 19% and 33%. General Motor Company was underestimated by 62%. When using model B to estimate category 11 the emissions ranged between negative 13% for General Motors and 110% for Fiat Chrysler Automobile. For category 12 the estimated emission was quite close for BMW, Daimler and Renault with negative 8% to negative 14%. However, for General Motor Company the category was underestimated with 36% and largely overestimated for both Fiat Chrysler Automobile and Volkswagen with 115% and 173%, respectively.

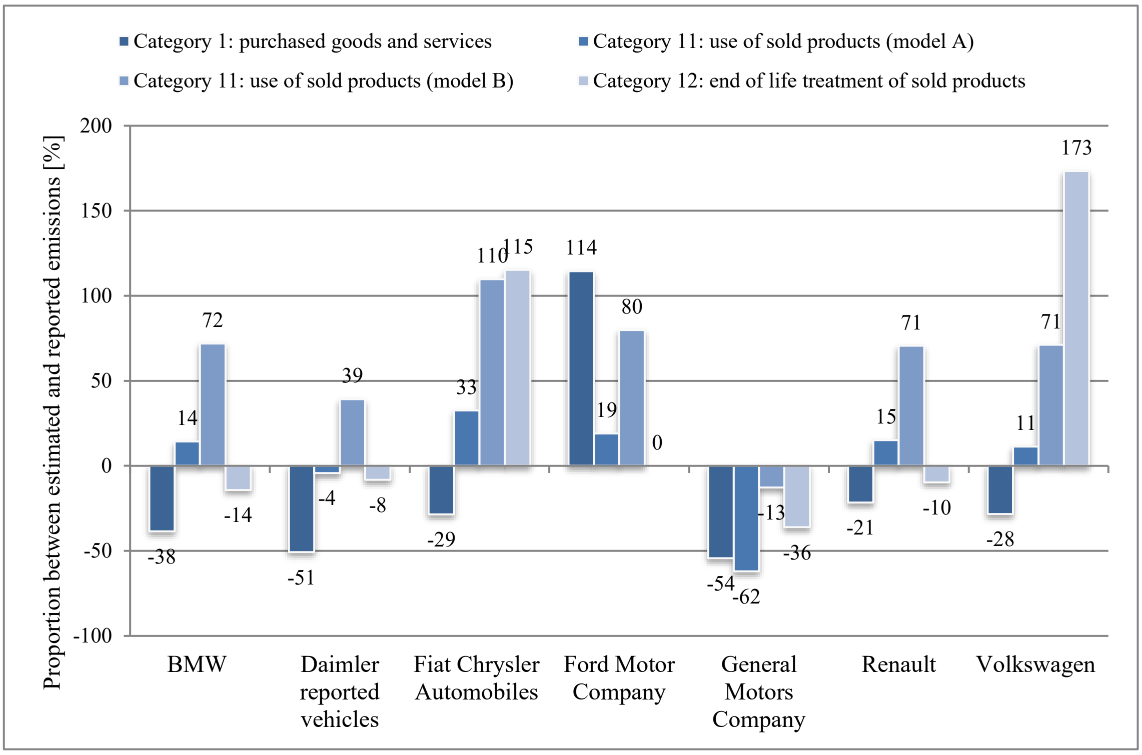

Figure 12 The estimated emission for category 1, 12 and 11 for model A and B compared to the companies reported emissions.

The summarized estimated emissions using model A for category 11 were compared to the reported emissions from category 1, 11 and 12, Figure 13. The estimated results follow the reported trend for all companies except for General Motor Company. For BMW, Volkswagen and Renault the estimation overestimated with 4%, 6% and 11%. For Fiat Chrysler Automobile and Ford Motor Company the overestimation was larger with 19% and 34%. The model underestimated for Daimler and General Motor Company with 14% and 41%.

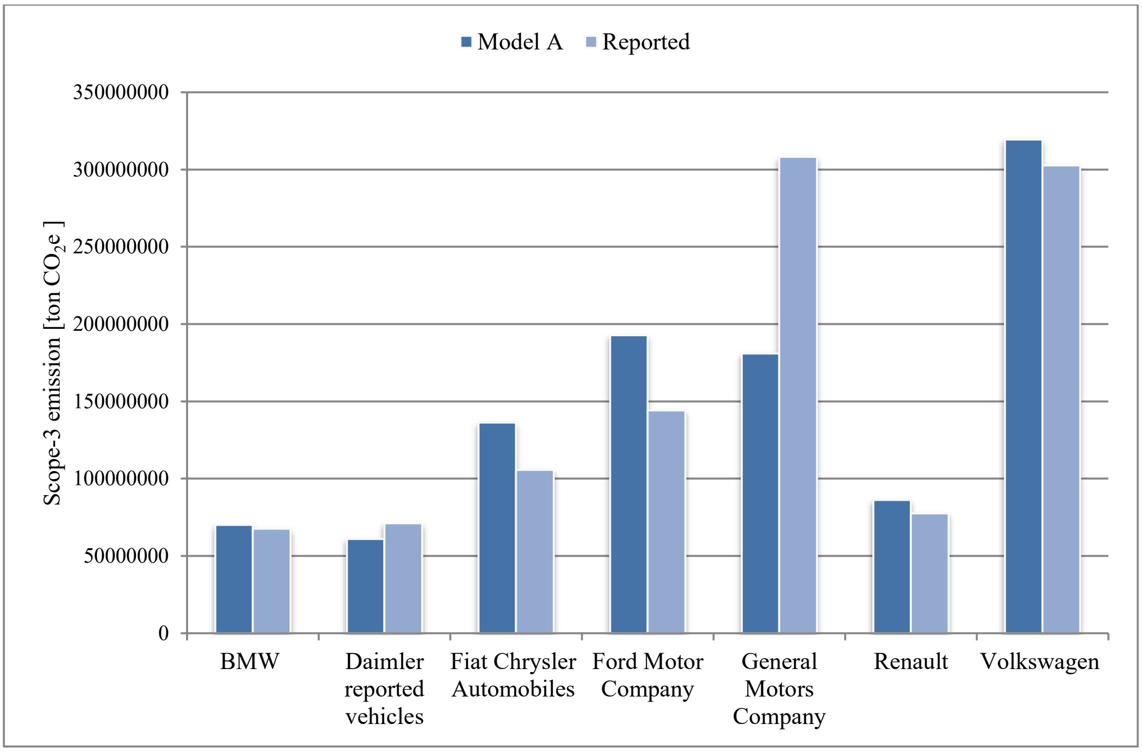

Figure 13 The summarized estimated emissions using model A for category 11 compared to the summarized reported emissions for category 1, 11 and 12.

When model B was used instead of model A all the estimated values were much higher compared to the reported values, Figure 14. For General Motors the underestimation was 20% less than for model A. For the other companies the overestimation were between 19% for Daimler and 85% for Ford Motor Company. For BMW, Renault and Volkswagen the overestimations were between 45% and 55%.

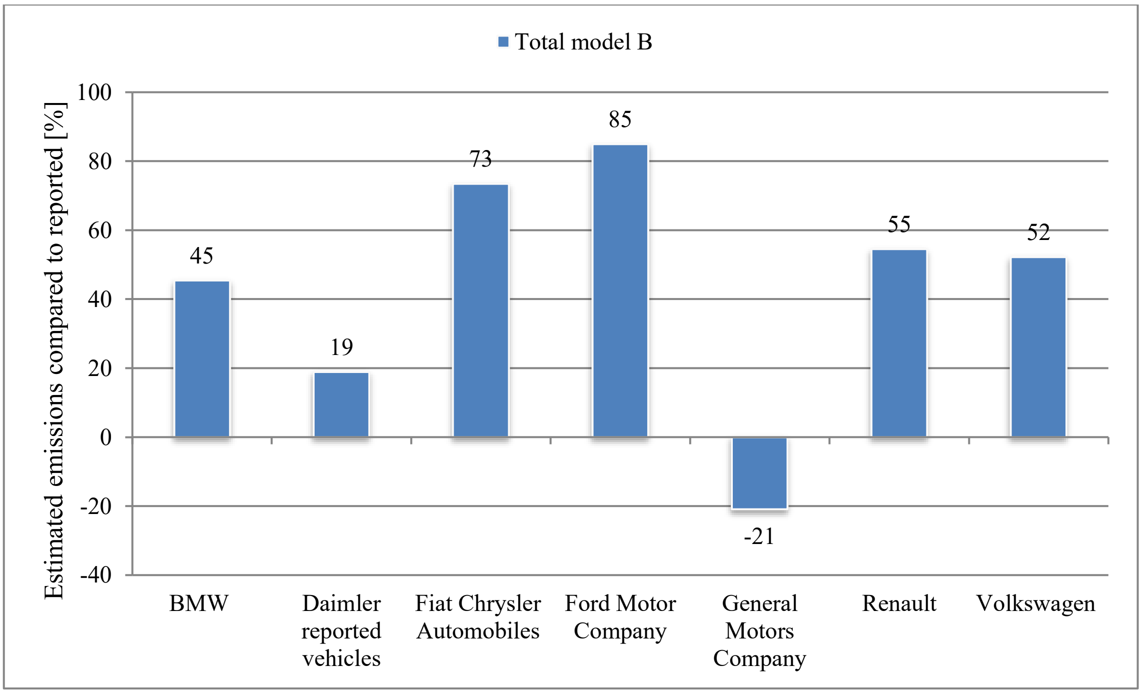

Figure 14 The summarized estimated emissions using model B for category 11 compared to the summarized reported emissions for category 1, 11 and 12.

When the estimated emissions, using model A, were compared with the companies' total reported scope 3 emissions, the difference was reduced for all companies except for Fiat Chrysler Automobile and General Motor Company. For BMW, Renault and Volkswagen the differences were less than 4%, Figure 15.

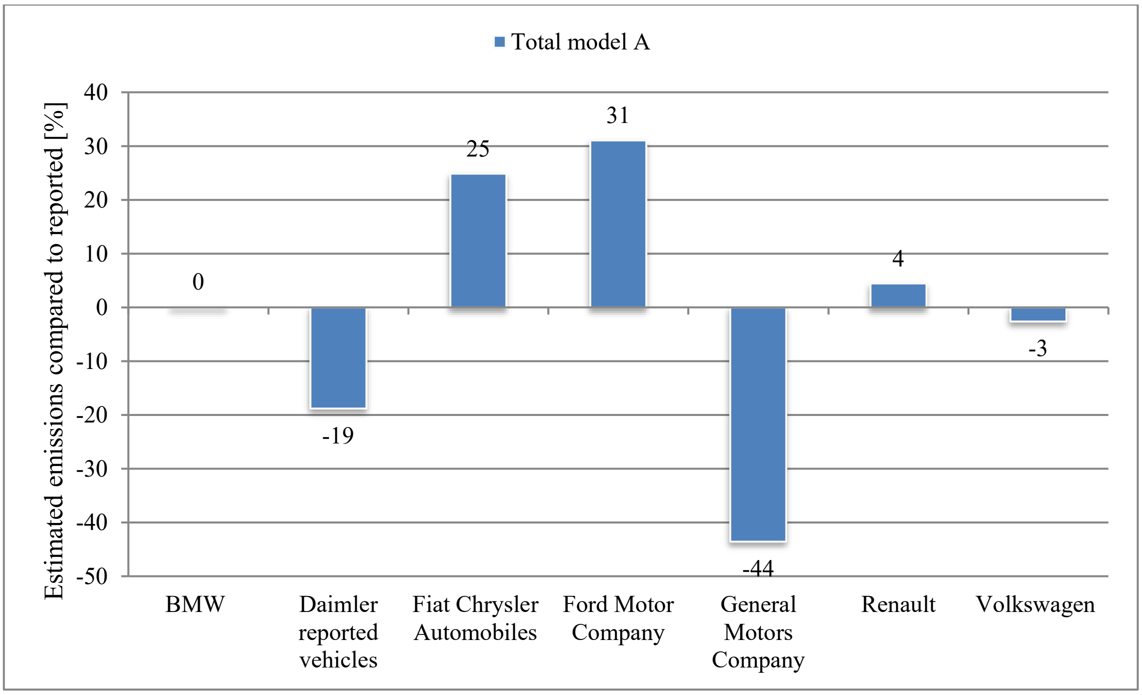

Figure 15 The summarized estimated emissions using model A for category 11 compared to the companies' total reported scope 3.

In Table 20 the result from a comparison between the companies' total reported scope 3 emissions and the estimated emissions are summarized. For Daimler and General Motors Company model B gave the best result compared to their reported data. For the other companies model A gave the best overall result, which ranges between 0% and 31%.

Table 20 Comparison of estimated emissions and total reported scope 3 emissions for the companies. The estimated emissions used model A or model B for category 11. A positive value indicates an overestimation and a negative an underestimation.

Company	Model A [%]	Model B [%]	Best
BMW	0	41	A
Daimler	-19	13	B
Fiat Chrysler Automobiles	25	68	A
Ford Motor Company	31	81	A
General Motors Company	-44	-24	B
Renault	4	45	A
Volkswagen	-3	40	A

Daimler did not report the emissions from all their produced buses, vans and lorries since some of them undergo further processing after leaving the production site. (CDP, 2017a). Therefore the total production of buses, lorries and vans was taken from Bloomberg (Bloomberg, 2017). The vans were added to the diesel car category. To compare the estimated result to the reported CDP data the scope 3 emissions for Daimler was also estimated without the additional information from Bloomberg. Adding the lorries, buses and vans to the input data for Daimler gave an overestimation for all categories compared with their reported CDP data, Figure 16. Category 11 gave an overestimation of 321% when model B was used, which is 264% more than for model A. When the lorries, buses and vans were added model A gave the best overall estimation. Note that in this comparison only the reported emissions for category 1, 11 and 12 are combined and not the total amount of reported scope 3 emissions.

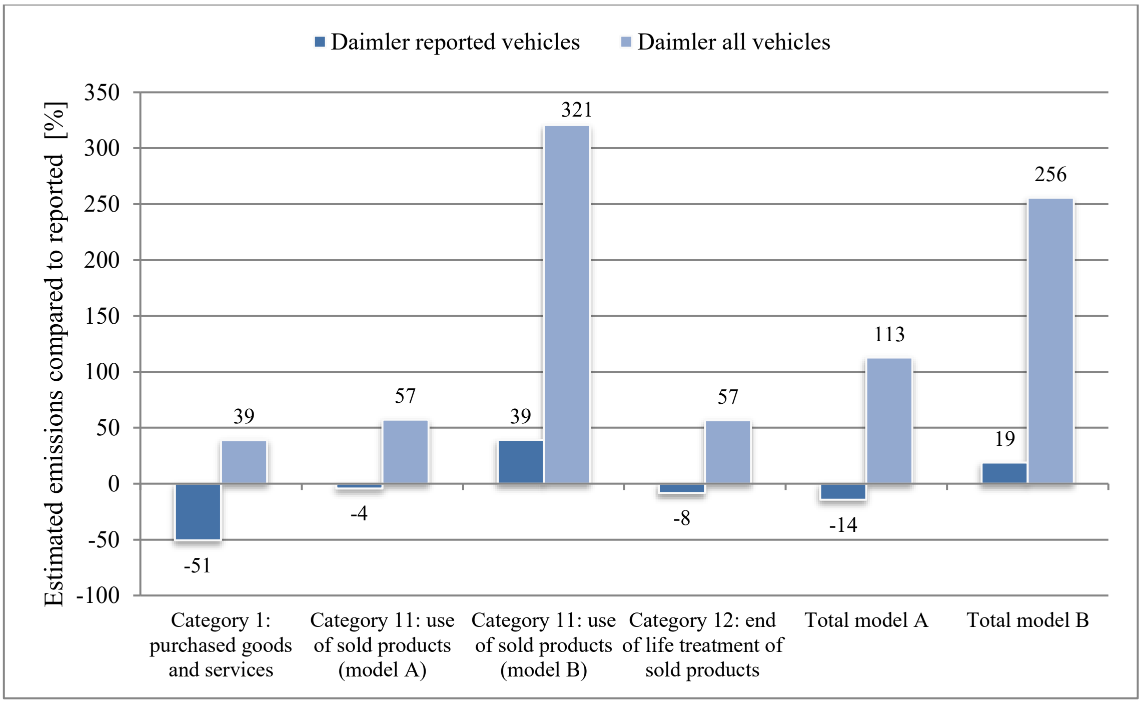

Figure 16 The emissions for Daimler when the same number of vehicles as they used in their CDP report was used in the estimation and when all their lorries, buses and vans are added. Both estimations are compared to their reported CDP data for each category as well as the combined categories when model A and model B are used.

In category 1 emission factors from Ecoinvent were used for all types of vehicles except for motorbikes. Therefore, a sensitivity analysis on category 1 was performed for BMW, which was the only company who had motorbikes in their input data. The emissions factor for motorbikes were decreased by 10 % and increased by 10 % and then compared to the initial value. In category 1 a 10% change of the emission factor had a ±0.02% difference to the overall result of the category. The total amount of estimated emissions for BMW when model A were used, gave a 0.00% difference.

A sensitivity analysis of the fuel economy for petrol cars in model A was also performed on BMW. The fuel economy was increased and decreased by 10% and then compared to the initial value. In category 11 a 10% change gave a difference of ±0.06% and the total result changed ±0.05%, (see Figure 17).

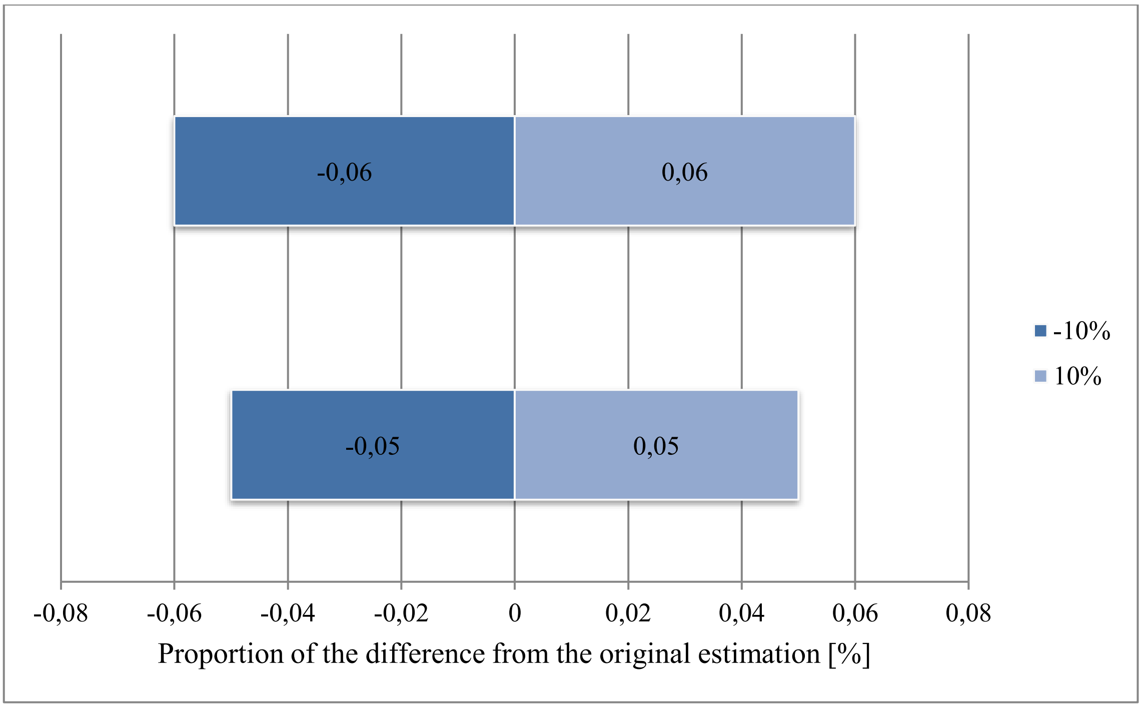

Figure 17 Sensitivity analysis of the fuel economy for petrol car in category 11, model A. The fuel economy was changed with ± 10%. The figure shows the proportion of the difference for category 11 and the total amount of estimated emissions. The company data are from BMW.

The fuel economy for lorries was changed ± 10% for Volkswagen. The difference was then less then 1‰.

4.2.2 Fossil fuel sector

The total amount of emissions estimated by the model follow the same trend as the reported emissions, Figure 18. Both the coal producing companies got overestimated with 20% and 36% respectively. Hess Corporation was overestimated with 280%. They had only reported emissions from natural gas in category 11. However, according to Oekom more than 70% of their production was oil and not natural gas. Also in their annual report was crude oil their biggest source of income (Hess Corporation, 2016). For Galp Energia, OMW and Repsol the model underestimated with 40%-70%. This could indicate that their sales data and production data does not correspond well.

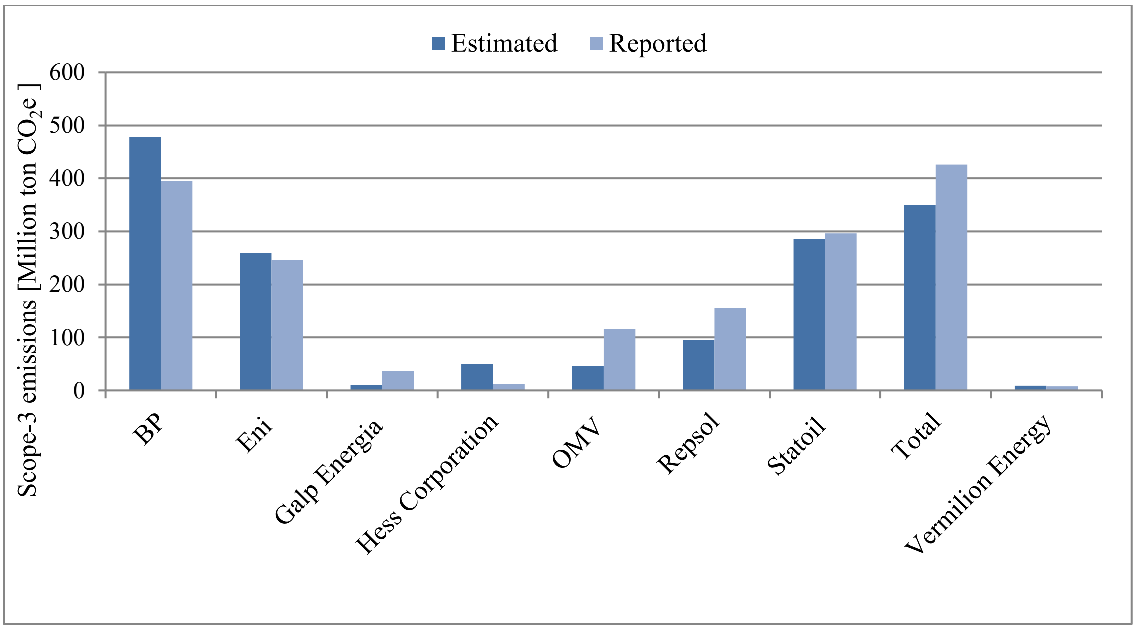

Figure 18 The total amount of estimated emissions compared to the reported emissions in million CO_2e.

The comparison between the estimated and reported emissions in category 11 follows the same pattern, which was expected, Figure 19. The difference in percent were between 0% and 11% for all companies except for Hess Corporation, where the overestimation raised to 426% and is consequently presumed to be an outliner.

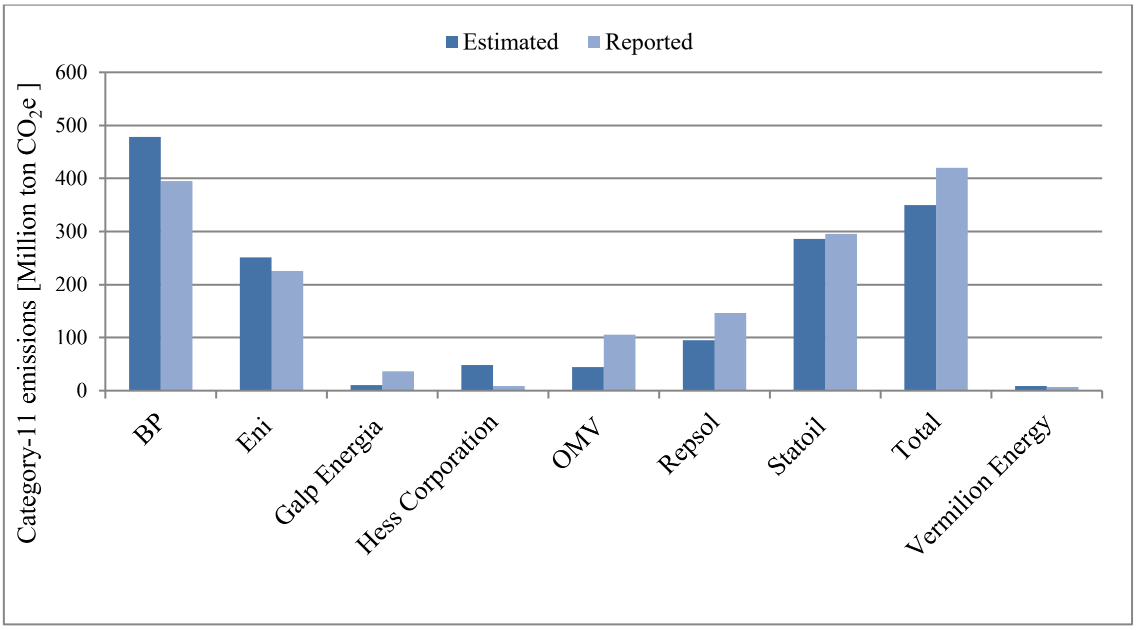

Figure 19 The amount of estimated and reported emissions in category 11 in million CO_2e.

The emission for Vermillion Energy in category 10 was underestimated by 33%. A sensitivity analysis was performed on the refinery emission factor by changing it ±10%. This gave a difference in the total result of less than 3 ‰. When the emission factor for the combustion of crude oil was changed with ±10% the result for category

11 changed much more, Figure 20. Galp Energia had the largest difference of ±9% and Repsol the smallest with ±4%.

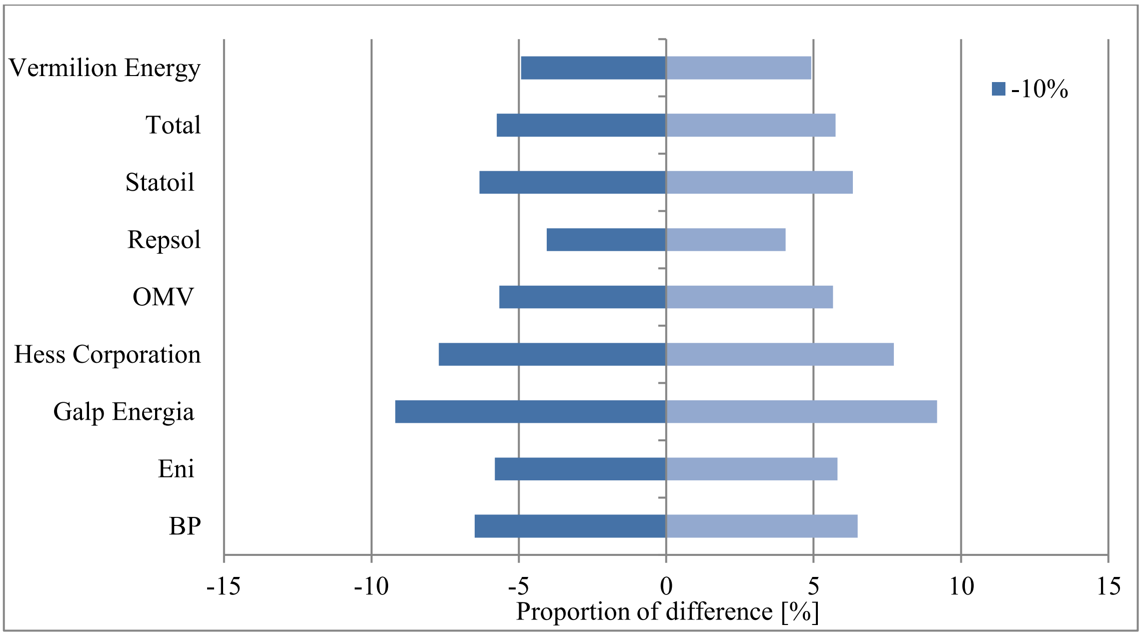

Figure 20 Sensitivity analysis of the emissions factor for the combustion of crude oil.

4.2.3 Utility sector

The total amount of estimated emissions compared to the sum of reported emissions for category 1, 2, 3, 5 and 11 in million CO_2 equivalents are shown in Figure 21. For EDF and Endesa the estimated emissions were 11 and 24 times higher than the reported result. For EDP - Energias de Portugal, and Fortum the estimated and reported emissions correspond well. For all other companies the estimated emissions were underestimated.

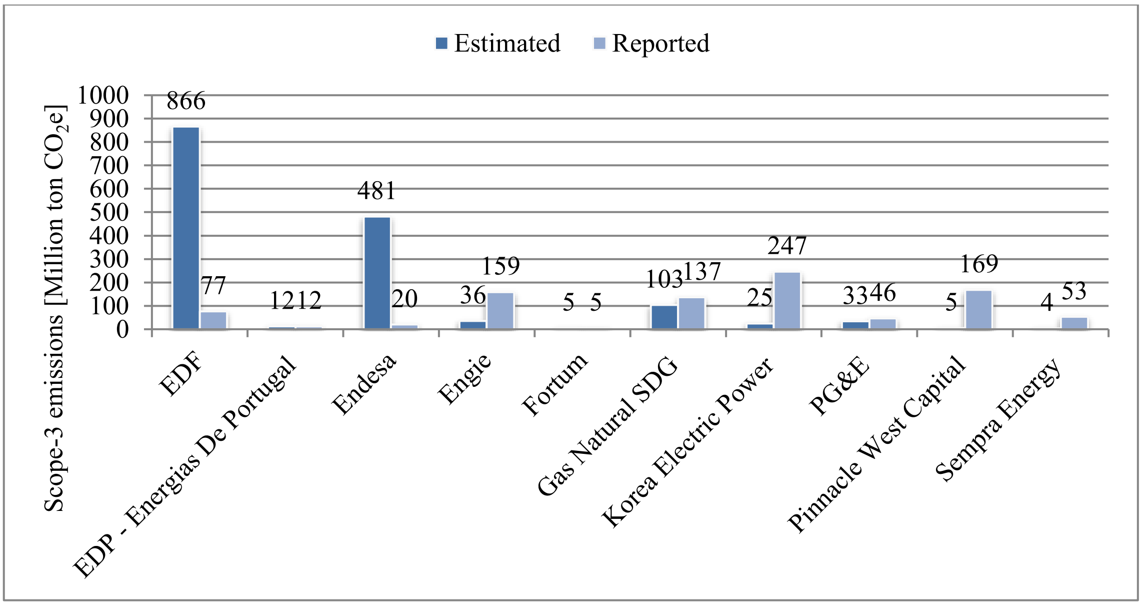

Figure 21 The total amount of estimated emissions for each company in million ton CO_2 equivalents and the combined reported emissions for category 1, 2, 3, 5 and 11.

Figure 22 shows the estimated emissions compared to the total amount of reported scope 3 emissions as well as the sum of the reported emissions in the estimated categories. For PG&E, Pinnacle West Capital and Sempra Energy no percentage difference was between the two comparisons.

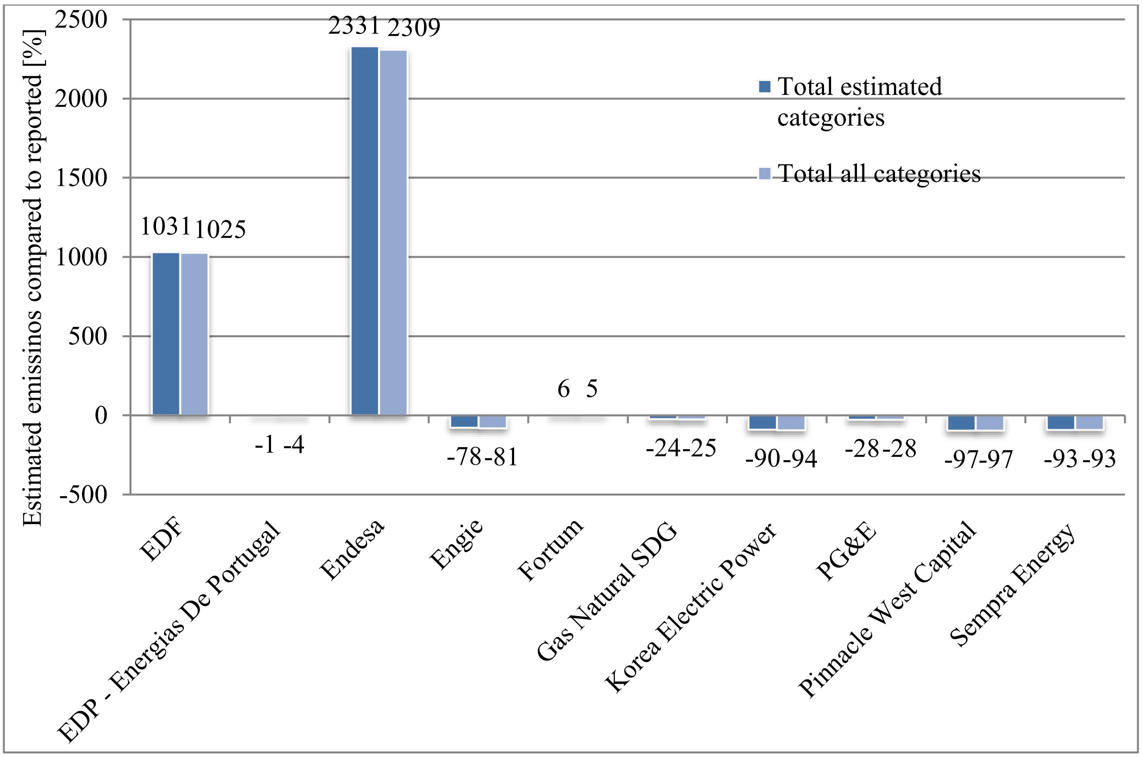

Figure 22 The estimated emissions compared with the sum of the emissions reported in category 1, 2, 3, 5, and 11 as well as the total amount of reported scope 3 emissions in percentage.

In Figure 23 the estimated and reported emissions in category 11, use of sold products, are shown for all the companies that Bloomberg have reported gas sales data for. EDF have in their CDP report stated that they calculated the emission from sold gas. When these emissions were estimated by using their amount of sold gas according to Bloomberg and the emissions factor from IPCC, the result showed that EDF underestimated their emissions with 1658%. They operate in Europe, Americas, Asia, and Africa and only 44% of their estimated scope 3 emissions were verified by a third party, which suggests that they only reported their emission for one or a few regions. This could explain why the emissions they reported do not correspond to their sales data. Endesa have in their disclosure report stated that the emissions from the use of sold products is not relevant for their business since “The emissions derived from the end use of goods and services sold by the Company are not considered as relevant since Endesa's core businesses are electricity generation, distribution and supply”, and therefore excluded this category. However, in the same disclosure report have Endesa stated that they are a “major operator in the natural gas market” (CDP, 2017a). According to Bloomberg the company sold 78,129 million therms of gas in 2016, which is equivalent to 463 million CO_2 equivalents (Bloomberg, 2017). This indicates that the model's overestimation are reasonable due to poor reporting from Endesa.

For the companies Engie, Gas Natural SDG and PG&E the emissions were underestimated compared to the reported emissions. For Gas Natural SDG the result differs with 11%. PG&E calculated their emissions based on their sold gas, still the estimated emissions differ nearly 70%. For Engie the underestimation was as much as 99.8%. In their CDP report they stated that they calculated the emissions based on all the fossil fuels they have sold. They were the biggest gas distributer in Europe 2016, still had they sold the least amount of gas. Endesa had for instance sold 78129 million therms of gas according to Bloomberg compared to Engie's 37 million therms. Naturally, distributing the gas is not the same as selling it. Therefore, one reason to their high reported emissions could be due to transportation losses from the gas they have transported but not sold. On the other hand, Engie did not mention transportation losses in their CDP report. The model assumed that no gas was liquefied natural gas, which has a higher emission factor then natural gas. Nevertheless, a change of the emission factor could not explain the large difference. Another explanation could be that Engie sell other types of fossil fuel then gas, although no information was found that confirm this. This implies that relevant company information is missing or that more emission sources have to be added to the model. All investigated companies except Endesa, Fortum and Pinnacle West capital had reported emissions in category 11.

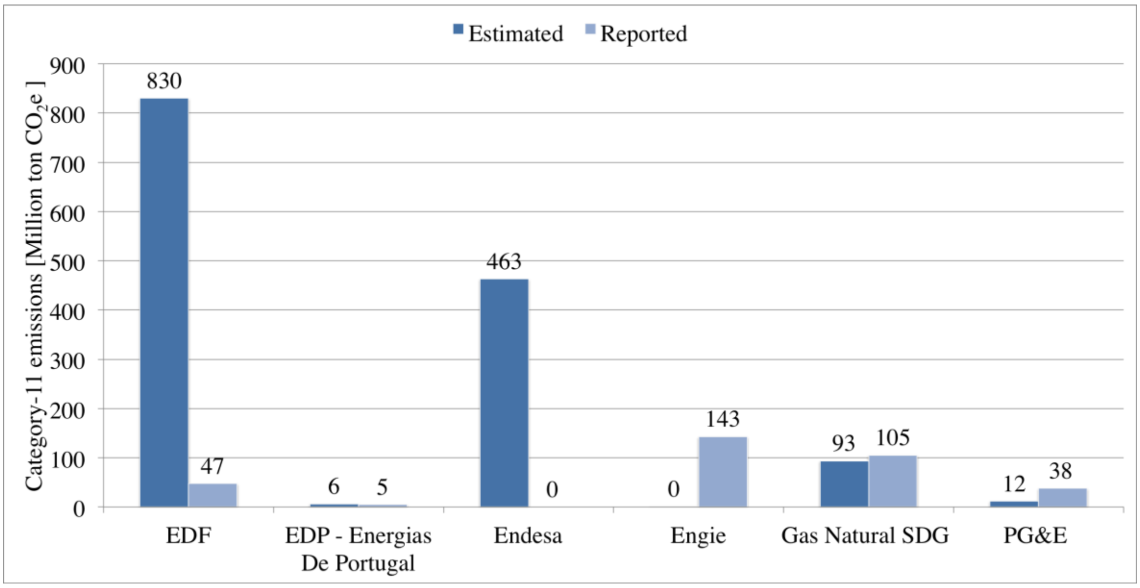

Figure 23 The estimated and reported emissions in category 11: use of sold products, in million CO_2e.

Emissions related to resold energy were not estimated for the companies EDF, EDP – Enegieas de Portugal, Engie and Korea electric power, since they produced more energy than they had sold. Emissions related to the fuel transportation and distribution were estimated for all companies, Figure 24. The estimated emissions for Sempra Energy, Pinnacle West Capital and Fortum gave the best result with 15%, 22% and negative

32%. For Korea Electric power category 3 was widely overestimated with 6744%. The model did not manage to reproduce the reported emission intensity for the majority of the companies. This indicates that the difference between the produced and sold energy might not be equal to the amount of purchased and resold energy, or that emission factors for transportation and distribution vary a lot.

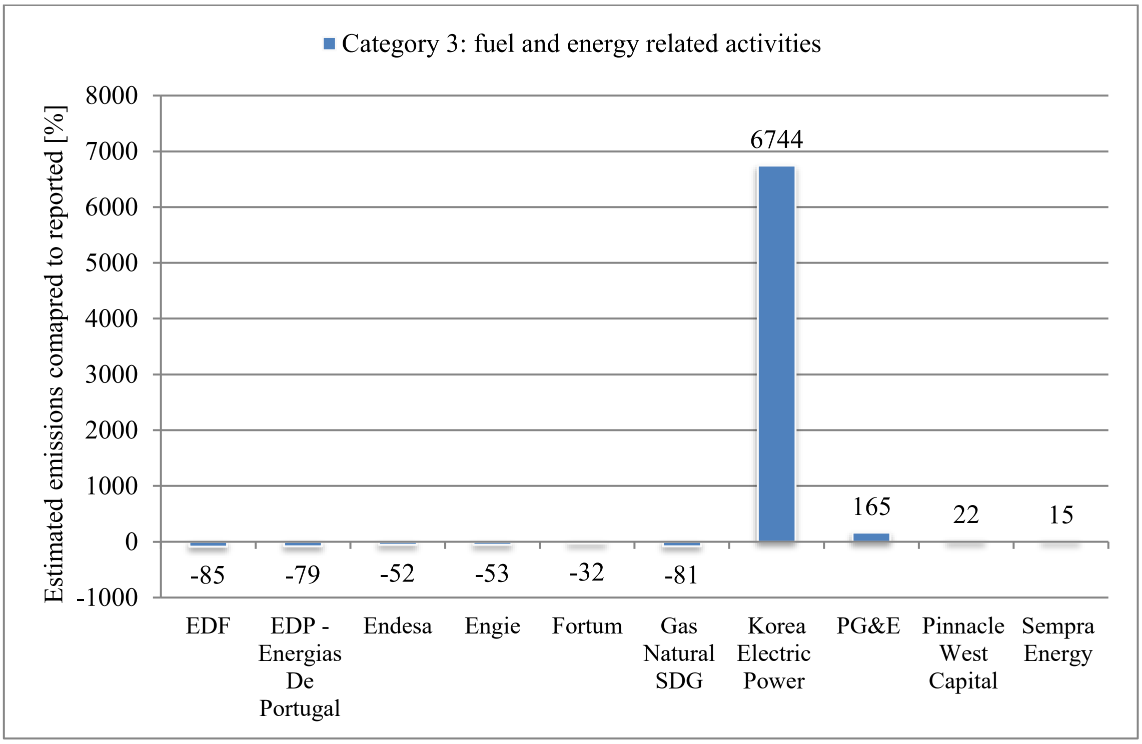

Figure 24 The estimation of the emissions in category 3 compared to the reported emissions in percent.

The proportion of estimated emissions in each category for the investigated companies are displayed in Figure 25. For EDF, Endesa and Gas Natural SDG the emissions from category 11 were responsible for 90% or more of their total emissions. Emissions from category 1: Purchased goods and services, were the biggest source for Engie and Korea Electric Power. For Fortum, PG&E, Pinnacle West capital and Sempra Energy category 3 had the largest impact.

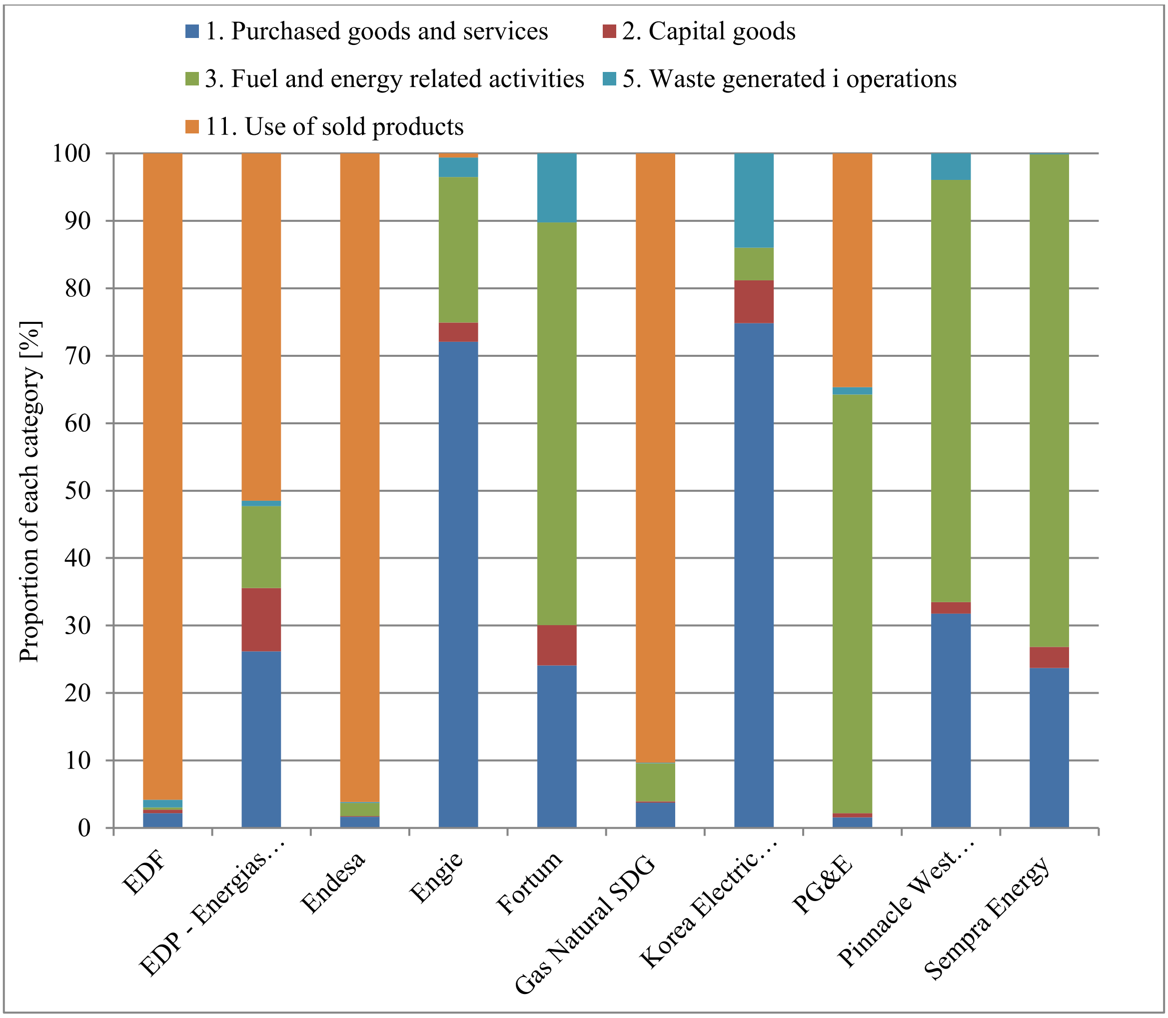

Figure 25 The estimated proportion of the total emissions for each category for the companies in percent.

The same figure for the reported emissions gave a different result, Figure 26. Category 11 were the biggest source for EDF, Engie, Gas Natural SDG, Korea Electric Power, PG&E and Sempra Energy. For Pinnacle West Capital purchased goods and services was the biggest source. Category 3 was the biggest one for Endesa, Fortum and EDP. For Endesa the reported emissions in category 3 only account for 4% of the emissions estimated in category 11 based on the amount of gas they sold.

For Fortum and EDP the model estimated the total amount of emissions quite well. However, when comparing Figure 25 and Figure 26, no similarities are found. The only exception was the proportion of gas for EDP, which differ with about 10%. This signifies that the positive results for Fortum and EDP are most likely coincidental. One of the major factors behind the uncorrelated proportion is the failure to calculate category 3. The proportion of emission from fuel and energy related activities differ for all companies, which could indicate that the difference between produced and sold energy cannot replicate the amount of resold energy to an end user. This could be due to companies producing energy for themselves or a facility the company owns, which would make the proportion of produced energy larger than the sold. Also, this could be due to local aspects affecting the emission factors for the transportation and distribution, which show the limitations in developing this kind of model on a global scale.

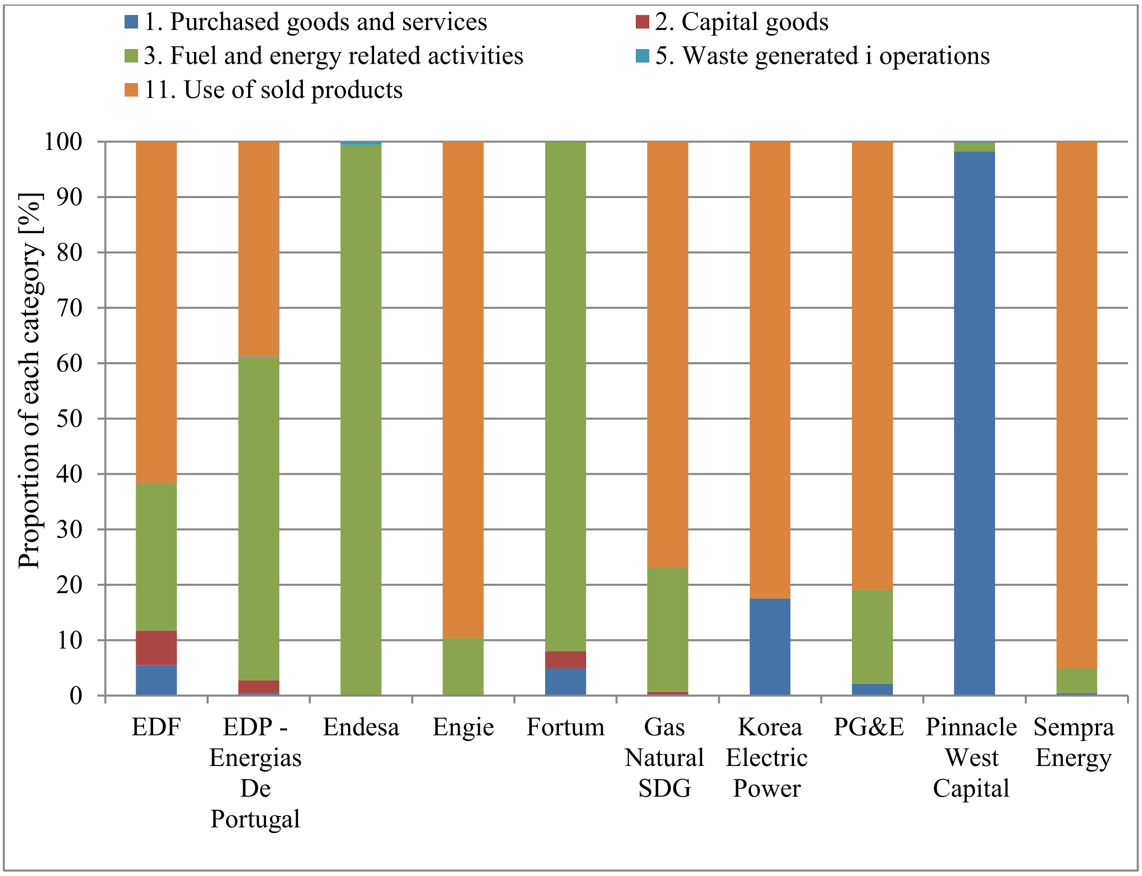

Figure 26 The reported proportion of the total emissions for each category for the companies in percent.

5 DISCUSSION

The aim of this study was to develop a model that estimated the indirect scope-3-emission intensity for companies in the automobile sector, fossil fuel sector and utility sector, as presented in section 1.1. The first objective was to examine if the variations within the sectors could be explained and categorized. To carry this out first each sector was defined and then their emission sources identified in section 2. The emissions could be explained and categorized for the automobile sector and fossil fuel sector. However, for the utility sector the emissions could only partly be explained and categorized. The second objective was to examine which parameters and subcategories that are relevant for estimating the emissions and why. Two methods were investigated to carry out the second objective; correlation analysis (see section 3.1) and the average data methodology (see section 3.2). Between any of the sectors and selected parameters no correlations could be found, (see section 4.1). The estimated emissions of the fossil fuel and automobile sector using the average data method followed the trend of the reported emissions, (see Figure 13 and Figure 18). No trend could be found for the utility companies, (see Figure 21).

5.1 DEFINITION AND IMPORTANT CATEGORIES

The automobile sector was defined in section 2.1.1, the fossil fuel sector in section 2.1.2 and the utility sector in sector 2.1.3. The companies included in the definitions might still have side business that is not related to the specific sectors. For example, companies who run a small-scale production of vehicles would still be included in the automobile sector even if they also were highly involved in steel manufacturing. This entails significant emissions might be left out of the estimation due to the definition and limitations of the models. Some companies in the utility sector could also be part of the fossil fuel sector and vice versa. Therefore, a hybrid sector consisting of both the fossil fuel and utility sector may be suitable for some companies. Unfortunately, the limitations of this study did not enable further research of a hybrid sector.

The important emissions sources were identified for each sector:

- Figure 4 shows that emissions from the use of sold products is the biggest emission source followed by purchased goods and services for automobile companies. The two categories accounted for over 90% of the companies' total scope-3-emission intensity.
- The usage of sold products count for more than 90% of the fossil fuel companies' total scope 3 emissions, Figure 6.
- Scope 3 emission intensity for utility companies depend on if they sell gas, purchase electricity and resell it to end user as well as their energy mix, Figure 8, Figure 9 and Figure 10.

The proportions of each category were based on the companies reported scope 3 data. This data was used since no better data were available. Nevertheless, this data is not scientific and might contain errors. The companies' real scope 3 emissions and reported scope 3 emissions might not correspond. Since the companies are not required to report all categories, considerable emissions could have been left out. For instance, few companies reported their emissions in all categories and no category were reported by 100% of the companies. Category 11, as earlier demonstrated, is the most important category for fossil fuel and automobile companies. Still it was not reported by all companies and not even the most common to report in the automobile sector. The trustworthiness of the companies reported data could therefore be questioned.

According to OECD, (2012), there are several reasons why companies do not report their emissions. The main reason is the difficulty to gather information from different parts of the business. However, this mostly is the case for smaller corporations. Additional reasons are doubtfulness about the advantages of reporting and fear of legal implications that could arise from it, or that the corporation's reputation would be damaged (Kauffmann *et al.*, 2012). The most commonly reported category in the utility sector was business travel, it was also among the most reported category in the fossil fuel and automobile sector. Nevertheless, business travel emissions were not the largest emission sources for any of the companies. One reason could be that the companies travel statistics already were documented for economic purposes, which facilitates the carbon intensity calculations. The connection between transportation and carbon emissions is well known broadly. Reporting the emission intensity of the companies' business travels might therefore give the impression that the company actively work to lower their carbon footprint and care for the climate.

5.2 CORRELATION ANALYSIS

No good correlations could be found between any of the tested parameters and the companies reported scope 3 emissions. To get a statistical approved correlation additional data points are needed. Therefore, more companies were used for the correlation analysis then the validation of the average data method. As previously discussed in section 7.1.1, this data probably contains errors. For some analysis the companies were divided into regional areas. This resulted in too few data points, where the correlations found most likely were a result of two individual groups in a favourable distance. This indicates that the companies are complex and have different structures that cannot be explained by a correlation analysis.

5.3 AVERAGE DATA METHODOLOGY

The results for each sector are summarized and discussed in this section. The estimated results where validated with the companies reported data and not the companies real scope 3 emissions, as previously discussed in section 7.1.1.

Automobile sector

The most significant results:

- Figure 12 shows that category 1, purchased goods and services, is underestimated for all companies except Ford Motor Company.
- Figure 13 shows that the estimations based on LCA data and model A follow the reported trend for all companies except General Motors Company.

- Model A gives the best overall estimation for all companies except Daimler and General Motor Company, Table 20.

The estimations based on LCA data follow the same trend as the reported data. This indicates that the model distinguishes between a company with a large and a small carbon footprint. The company information from Fiat Chrysler Automobile, General Motors Company and Ford Motor Company were the least specific ones. These companies also had the least accurate estimations compared to their reported emissions, Figure 13. This implies the importance of detailed data from the companies. Figure 16 where Daimler's emissions were estimated using their reported data from CDP and their total production also shows the importance of using the right data.

For all categories the same data were used even though category 11 and 12 depend on sales data and category 1 on production data. The assumption that the difference between the sales and production data are negligible might be incorrect. This could be one reason why category 1 was underestimated for all categories. However, the difference between production and sales data was small when it was compared for some selected companies. This suggests that automobile companies have more products than vehicles or that the emission factors from Ecoinvent were lower than the ones used by the companies. The fact that the emission factors from Ecoinvent was over ten years old suggest that more updated emission factors would give more accurate result. The emission factor for the construction of a motorbike came from another newer study and was higher than the emission factor for a car, which insinuate the latter.

Furthermore, Biclho et al. (2017) demonstrated in their study how average industry data (as Ecoinvent) is inadequate for company-specific carbon accounting since the LCA often is performed outside the company's operational context (Bicalho *et al.*, 2017). It is notable that a higher emission factor or the extension of products in category 1 would result in higher overall carbon intensity. Different approaches of LCA might also be the reason why the carbon intensity for Fiat Chrysler Automobile and Volkswagen were largely overestimated in category 12. Both companies calculated their emissions based on all their sold vehicles 2016 as well as the emissions related to different types of vehicles. This shows how sensitive carbon estimations are to the boundaries and assumptions made in the LCA as well as the importance of detailed company information.

The automobile companies are constantly developing their technologies used, and the aim to lower the fuel economy is seen when comparing model A and model B. Model B was built on generic values from running vehicles in the UK, while model A used more updated fuel economy. The difference between the models clearly shows that automobile companies today have advanced their technologies and that model A should be used when estimating their emissions.

Fossil fuel sector
The most significant results for the fossil fuel sector are summarized as follows:

- ♦ The estimated emissions follow the same trend as the reported emissions for all companies except for Hess Corporation, Figure 18, Figure 19.
- ♦ Refinery emissions in category 10 could only be estimated for one company, Vermillion Energy. The model underestimated the emission with 33%, section 6.2.2.
- ♦ The estimation for category 11 change with up to $\pm$9% when the emission factor for crude oil was changed with $\pm$10%, Figure 20.

As for the automobile model, the estimated emissions for the fossil fuel sector followed the same trend as the companies' reported emissions. This was true for all companies except Hess Corporation, whose sales data in their annual report didn't correspond to their presented data in the climate disclosure report. This shows clearly that the overestimation of Hess Corporation more likely is due to poor reporting than limitations in the model. It also demonstrates that the companies' reported scope 3 emissions do not have to be equivalent to their real carbon intensity, as previously discussed in section 7.1.1. Further, the emissions in category 11 were underestimated for three companies. This could indicate that the assumption, that the difference between the companies' production and sales data are negligible, might be incorrect for some companies. Other shortages with the information from the companies regarded the amount of sold crude oil to refineries. Category 10 could only be estimated for one company based on the assumption that companies who own refineries do not sell to others. Nonetheless companies who clearly own refineries had also reported emissions in category 10. This indicates that owning a refinery does not exclude the possibility to sell crude oil to other refineries. Also the emissions associated to the well-to-refinery phase only in China vary with the order of a magnitude, depending on the usage of energy-intensive enhanced oil recovery methods and gas flaring (Höök, 2018). This insinuates the need for location specific emission factors for the refinery emission factors.

Finally, the model was restrained by the breakdown of the companies' products. Crude oil can be derived into several other products with different emission factors. The sensitivity analysis of the emission factor for crude oil in category 11 changed the result with almost 10%, which indicates that more detailed data would give more accurate estimations. Also, company specific instead of region specific emissions factors for coal would probably have an effect on the result. However, the coal companies were too few to draw any conclusions about their result.

Utility sector
The most significant results for the utility sector are summarized:

- ♦ No trend could be found between the estimated and reported emissions, Figure 21.
- ♦ Category 3 cannot be correctly estimated with the data used, Figure 24.

- The companies' amount of sold gas according to Bloomberg and the companies reported emissions in category 11 do not correspond well.

The model for utility companies was built on a large number of parameters since no clear correlations could be found between the companies. This distinguishes the utility model from the other two. While both the automobile and fossil fuel models were able to replicate the same trend as the companies had reported, the utility model did not follow the trend at all. Figure 25 and Figure 26 demonstrate how the model did not distribute the proportion of emissions in each category the same way as the companies had reported. Also, the model both largely underestimated and overestimated the companies' scope 3 emissions. This could depend on several reasons.

Many different studies have been used to gather data. Both emission factors have been collected and assumption made based on the studies. The aim was to get generic data, however, sometimes only a few studies could be found. Furthermore, the definitions of purchased goods and services and capital goods are up to each company to decide, according to the greenhouse gas protocol. This is because capital goods and purchased goods and services might include the same types of products. Except the impact this gives to the proportion of the categories, this also causes a problem in the validation of purchased goods and services as well as capital goods. One can simply not be sure to compare the same things.

On top of this, the companies have used many different methods to calculate their emissions from purchased goods and services. PG&E has for instance used the spend-based method and Pinnacle West Capital has used the supplier specific method. The model underestimated both their emissions in category 1. For PG&E the model covered around 50% of their reported emissions and for Pinnacle West Capital only 1%. However, Pinnacle West had not declared where they had drawn the boundaries for their calculations. If they have accounted all emissions for each supplier, the carbon intensity would be much higher compared to the emissions related to just the purchased products from the supplier. There is therefore a large ambiguity in both the companies' definitions of category 1 as well as the boundaries in the estimations. The challenge with shortcomings in companies' disclosure data and the difficulty to compare them was addressed in a study from 2015 that analyzed third party disclosure data. The study found sever gaps in the companies' disclosure reports and highlighted two main reasons; non compliance with the accounting standards and limiting the number of accounted emission sources (Talbot & Boiral, 2015). The results in this study are in line with the result from Talbot, D and Bioral, O. It is clear that even though the companies in this study had their disclosure reports verified by a third part the trustworthiness is low.

Emissions from the construction in category 2 and decommissioning of power plants in category 5, were not modeled according to the greenhouse gas protocol methodology. Not to follow the recommendations of the greenhouse gas protocol is of course problematic. Nonetheless the constant variation of the companies' structure and holdings, make it hard to gather the needed data. As long as this complex problem is unsolved a correct estimation will not be possible. To exclude these emissions from the estimations would result in actual emissions that no one would be responsible for. Also, on the contrary from what could be expected, did none of these categories have a large effect of the overall result. This motivates the deviation from the greenhouse gas protocol for construction and decommissioning emissions, although this will affect the proportion of these categories.

To summarize, the reported data is not good enough to validate the model for utility companies. Moreover, relevant company information is missing that effects the estimations. There is also a possibility of significant emissions sources that might be left out from the model. However, the model is building on data from scientific reports and for a company who does not report their scope 3 emissions at all, this estimation might be better than nothing.

5.4 COMPARISON WITH RELATED STUDIES

There are a few methodologies on how to estimate companies' or funds' climate impact based on public data as mentioned in section 1.7, *previous studies.* Even if most of them do not market companies' disclosure as their final product, most have probably used some kind of scope 3 estimations in their company analysis. However, the methodologies are confidential to the companies and therefore no comparisons can be done with the results from this study. Nevertheless, all have the same limitations with the shortage of public company specific data, which indicates a high uncertainty for all the different methodologies. Previous research has shown that different types of environmental, social and governance (ESG) scores have a low correlation between each other. This mean that a company can be ranked as sustainable using one score and not sustainable by another (Howard, 2016). Thomä et al. (2018) argue that this suggests that there might be a low correlation between climate impact estimations as well. Given all the assumptions made due to the information shortages this is a valid analysis.

5.5 SOCIETAL IMPLICATIONS

The aim of this study is to broaden the decision basis for investors on companies' climate impact by estimating their carbon footprint. Nevertheless this information alone is not enough to distinguish a "green" company from a ”brown", due to a carbon footprint not taking company specific factors into account. For example, a corporation, which produces emission intensive vehicles like trucks, might also own an automobile manufacturer who specializes in "green" vehicles. In this case the company's more sustainable offering is not detected by just analyzing the carbon footprint. The company would of course still be responsible for all of their emissions, but without further information like amount of sold products, investors might divest from a company that is working on a more sustainable solution. Furthermore, a larger utility company could have larger installed coal power capacity than a smaller one. Even if the smaller company only produce energy from coal and the larger company also produce renewable energy, a carbon footprint would rate the smaller one as better. This implicates the need of adding the companies' size into the analysis and normalizing the companies' emissions. The size of a company can be measured by the revenue, capacity or production. When calculating the impact of a portfolio the companies' carbon footprint is often normalized by revenue. This gives the emission equal to the share owned by the investors.

However, this could also be misleading since companies who sell a more expensive product would get lower emission intensity. For example, Ferrari earn more per sold vehicle compared to BMW, which gives them less kg CO_2 equivalents per US$. For this reason, Ferrari could be considered as a more sustainable corporation even if their cars are not "greener" then BMW's. Another problem with the normalization of emissions is the alteration in prize. This mean that a oil producing company who have the same production intensity for several years would have a change in their emission intensity depending on the oil prize. A low oil prize would give them a high emission intensity in the unit emissions per US$ and a high oil prize would give them a lower emission intensity. (Thomä *et al.*, 2018). To sum this up is all of these parameters necessary when evaluating companies' climate impact in order to avoid incorrect labeling. When estimating the emissions on sector levels the key figures most relevant for each sector/company have to be identified.

The dominating limitation for the models in this study is the shortage of public company specific data. This entails that the companies' own analysts will always be able to provide more detailed and specific estimations of the companies' carbon disclosure. However, to reach the United Nations sustainability goal and the Paris agreement, we do not have time to wait for companies to report correct disclosure reports. It is also important to remember that companies have an interest in appearing sustainable. Robert Engelman, president of Worldwatch Institute, claim that the word sustainability is so commonly used by corporations today that it has lost its meaning and impact (Worldwatch Institute, 2013). This entails the importance of evaluating companies' trustworthiness. How can an investor be sure that a company who claims to be sustainable is telling the truth? To highlight this problem Greenpeace has launched the expression greenwashing, which defines companies who market themselves as environmentally friendly but are not behaving as such. For example, the oil and gas company Shell has been a promoter for sustainable development by supporting the Kyoto protocol and promoting sustainability. Although simultaneously Shell has expanded its fossil fuel activities by exploiting the arctic regions and decreasing their investments in renewable energy. One of their promoted sustainability works have instead been their ban of Styrofoam cups on their Alaskan operating vessels to avoid litter to the sea (Greenpeace, 2012). To get around the problem with greenwashing, third party analysis is necessary to steer the financial market on a truly sustainable path. This is where these models can contribute to estimate how sustainable a company' actually is. Although it is important to remember that this work is only a small piece in the puzzle.

Knowing the companies' climate impact will not alone help us reach the 2-degree goal. Companies still have to take action and reduce their carbon emissions. The common business adage "you cannot manage what you cannot measure", insinuate that estimating companies' carbon disclosure can be seen as a first step towards climate change management. One driving force for corporations to take a sustainable path is the influence from their investors. Nevertheless, this relies on the assumption that investors are willing to stand up for the climate and take action. This might not be material for all investors who prioritize other values or only profitability. Though already in 2014 the first report that indicated a correlation between companies sustainability work on climate change and profitability was published (Confino, 2014). Furthermore, in October 2017 the Responsible Investment Business department at ISS declared that investors were getting more focused on risks related to climate change. One of the presented reasons behind the investors change in interest was the potential introduction of carbon taxes, which would have a negative effect on fossil fuel intense financial portfolios (Skroupa, 2017).

This indicates the importance of political initiatives to push the transition towards a low carbon society. The European Commission confirmed a proposal to such legislatives in the end of May 2018. In addition to define what is "green" an expansion of fiduciary duty for investors was proposed. This means that investors will be requested to include sustainability in their considerations as well as disclose how they do so. Moreover corporations who promote products as sustainable would have to declare how this is performed (Robinson-Tillet, 2018). Several of the HLEG's highest priorities are dignified in this first step towards the implementation of the European Commissions' Action plan for Sustainable Growth (HLEG, 2018). This can be seen as the European Commission taking action against both greenwashing and investors who avoids their climate responsibility. However, the definition and implementation are essential for the legislations success. Vague formulation may result in law gaps easily exploited by corporations.

The failures to manage environmental issues of governments' globally have upset the civil society who pushes towards more rigorous actions. Over 100 organizations sued the EU in May 2018 for not making enough effort to reach the climate agreement. In their point of view the EU goal to lower the carbon emissions with 40% from 1990's levels to 2040 is not ambitious enough (Rindevall, 2018). This is not the first time nations have been sued for their lack of actions against climate change. In April 2018 a group of young Colombians won against their government, who they claimed had failed to constrain deforestation. Also in October this year, a trial against the U.S. nation will commence for not taking enough responsibility for the climate (ETC, 2018). This could contribute to even more aspiring climate regulations, which would increase the risk of fossil fuel investments even further.

Small steps of adaption can be observed among the fossil fuel companies. For example Repsol SA declared that they will no longer seek any growth from their oil and gas business and will focus more on renewable energy (Orihuela, 2018). Furthermore Statoil announced that they will remove “oil” from their name and change it to Equinor (The Local, 2018). Whether their efforts should be called greenwashing or not, still remain to be found out. In the meantime, their sustainability performance should be critically reviewed and estimated to push towards the 2-degree goal.

6 CONCLUDING REMARKS

To use one model to estimate the emissions for a sector on a global scale is consistent with high uncertainties. Despite this the average-data method managed to replicate the same trend as the automobile and fossil fuel companies' disclosed scope 3 emissions. This is most likely due to the large climate impact from their main products in the use-phase. For utility companies where no category or product contributed more to their scope 3 emissions the estimations were not successful. Therefore, estimating emissions using the average-data method requires a certain corporation structure. The method can be used for corporations with a specific output but does not suit corporations with a more complex structure.

Companies' disclosed emissions have a low trustworthiness despite third party verification. Therefore, in order to develop reliable estimation models multiple sources have to be taken into account. Also, when evaluating companies' sustainability several metrics are needed.

The largest limitation in the estimations was the low accessibility to company specific data. The companies' organizational boundaries and global operations contribute further to the complexity. Therefore, more transparency from the corporations is a necessity to enable a better understanding of their climate impact.

6.1 SUGGESTIONS FOR FURTHER RESEARCH

To estimate the emissions for corporations on a global scale more research is needed. Firstly, combinations of the different methods; spend based, supplier based and average-data, could improve the result of the estimations for utility companies. Secondly more detailed data from the companies enable an expansion of the models in the study and more accurate estimations. Parameters that could improve the result but had to be excluded due to information shortage from the companies are as follow:

- Region specific electricity emission factors for electric vehicles.
- Expansion of the vehicles different fuel usage, for example: biodiesel, compressed natural gas (CNG), biogas and hybrids.
- Dividing buses and lorries according to their fuel usage.
- Adding more types of vehicles like scooters, four-wheeler, trains and ships.
- Coal rank emission factors
- Oil products emission factors like diesel, jet fuel and petrochemicals.
- Usage of more then one technic specific emission factors for power plants, for example onshore and offshore wind.
- More types of power plants, for example waste incineration.

Finally models for more sectors are needed to enable the true carbon footprint for financial portfolios. To use the average-data methodology as in this study the companies need a to have a well-defined output. This could for example be apparel companies where the production of the material, transportation and washing would be the main sources. Other interesting sectors are the food-producing, construction and transportation sectors.

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APPENDIX I

Table 21 A summary of different initiatives, their location, their requirement, status and if it was launched before or after the Paris agreement (ISS-Ethix Climate Solution, 2018).

Location	Initiative	Requirement	Status	Pre/post Paris
Global	Task force on Climate-related Financial Disclosure (TCFD)	Voluntary	In place	Post
Global	Portfolio Decarbonization Coalition (PDC)	Voluntary	In place	Pre
Global	Montréal Pledge	Voluntary	In place	Pre
Global	ISO 14097	Voluntary	Expected	Post
Global	Asset Owners Disclosure Project (AODP)	Voluntary	In place	Pre
Europe	Institutions for Occupational Retirement Provision (IORP) II	Mandatory	In place	Post
Europe	High Level Expert Group (HLEG)	TBD	Expected	Post
France	Article 173 of the Energy Transition Law	Mandatory	In place	Post
California	Climate Risk Carbon Initiative	Mandatory	In place	Post
Sweden	National Pension (AP) funds	Voluntary	In place	Post
Switzerland	Ministry of the Environment (FOEN)	Voluntary	Expected	Post
Netherlands	Platform Carbon Accounting Financials (PCAF)	Voluntary	Expected	Post
UK	Green Finance Taskforce (GFT)	TBD	In place	Post
Canada	CSA Staff Notice 51-354 Report on Climate change-related Disclosure Project	Voluntary	In place	Post
China	Carbon emissions data mandated by 2020 for listed companies in China	Mandatory	Expected	Post
Australia	Australian Prudential Regulatory Authority (APRA) climate disclosure action	TBC	Expected	Post

APPENDIX II

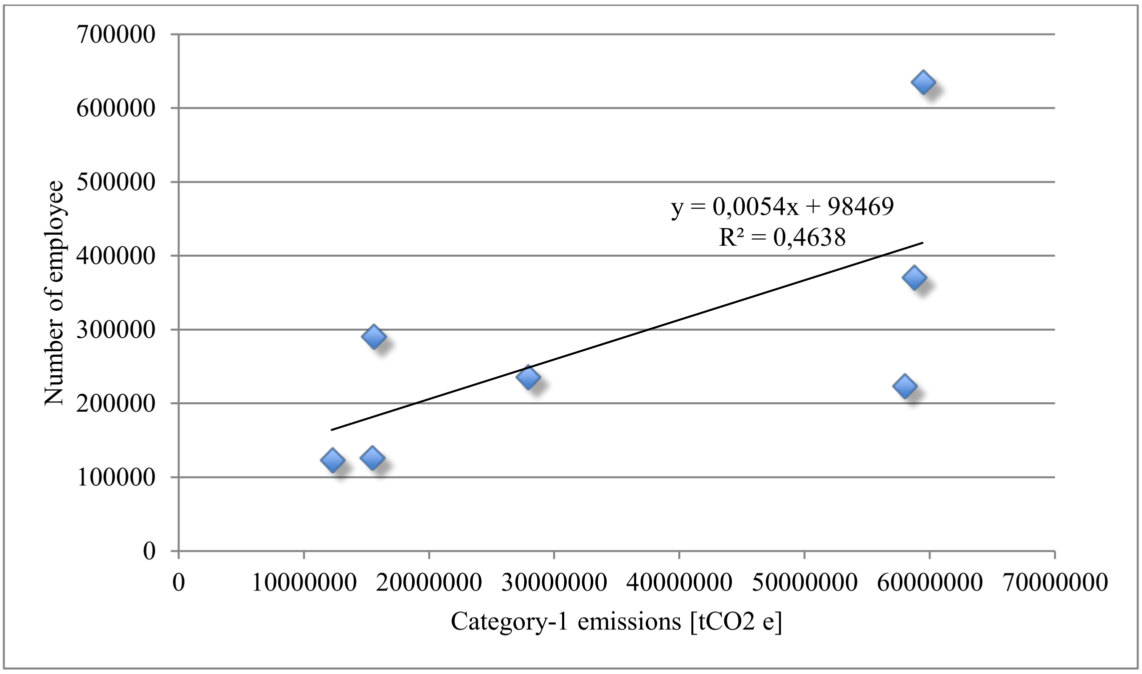

Figure 27 Number of employee and the emissions reported by automobile companies in category 1. The R^2 is below 0.5, which indicates no correlation.

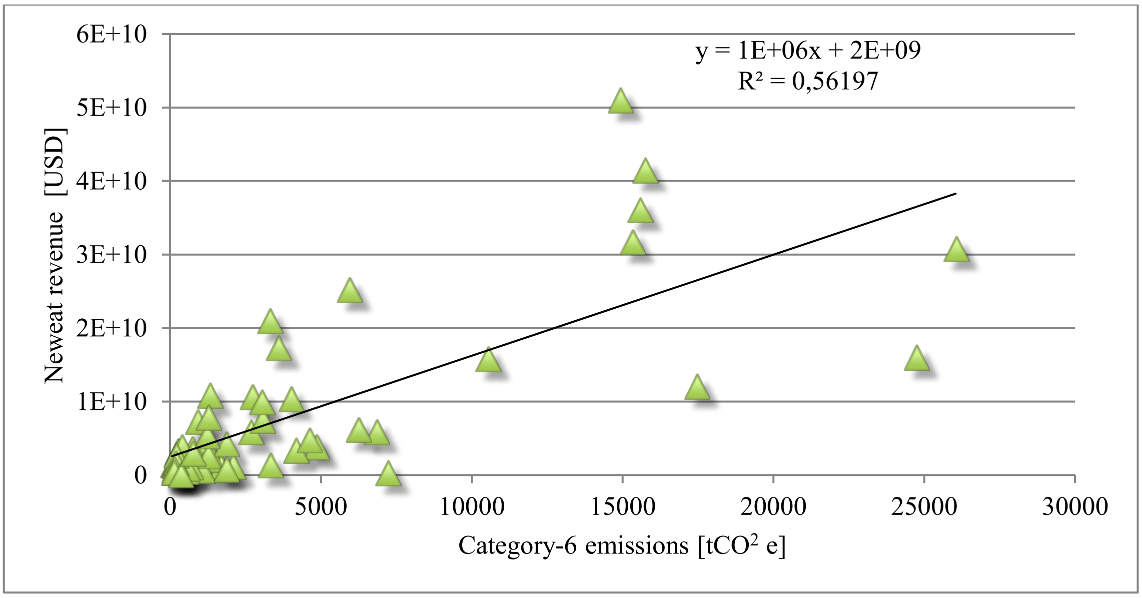

Figure 28 Utility companies newest revenue and the companies reported emission in category 6 (business travel). R^2 is above 0.5 but is still too low to build a model based on the equation of the linear trend line.

APPENDIX III

BMW

The number of sold petrol, diesel, BEV and PHEV vehicles collected from BMW's CDP report and the number of sold motorbikes from their annual report 2016 (BMW Group, 2016). BMW had only reported the emissions from 84% of the vehicles they sold worldwide (CDP, 2017a).

Daimler

The number of sold petrol, diesel, BEV and PHEV vehicles was taken from CDP. However, Daimler did not report the emissions from all their produced buses, vans and lorries since some of them undergo further processing after leaving the production site. (CDP, 2017a). Therefore the total production of buses, lorries and vans was taken from Bloomberg (Bloomberg, 2017). The vans were added to the diesel car category. To compare the estimated result to the reported CDP data the scope 3 emissions for Daimler was also estimated without the additional information from Bloomberg.

Fiat Chrysler Automobiles

For Fiat Chrysler Automobiles the only data found was the total amount of sold vehicles from their annual report (Fiat Chrysler Automobile, 2016). Since no more information was found all the vehicles was assumed to be petrol cars for model A and cars with unknown fuel in model B.

Ford Motor Company

Ford Motor Company had only reported their petrol cars in their CDP report(CDP, 2017a). This was assumed to be all their produced vehicles.

General Motor Company

The only information found from General Motor Company was their total amount of sold vehicles 2016 (General Motors Company, 2016). They were all assumed to be petrol cars in model A and cars with unknown fuel in model B.

Renault

For Renault their reported data for CDP was used. They had reported the number of petrol, diesel, BEV, PHEV and LPG cars (CDP, 2017a).

Volkswagen

For Volkswagen the number of petrol, diesel and BEV was taken from their reported CDP data (CDP, 2017a). From Bloomberg the number of vehicles from each of Volkswagens brands was found (Bloomberg, 2017). The number of vehicles from MAN was assumed to be buses and the number of vehicles from Scania was assumed to be lorries.