Tampere University of Applied Sciences

Research of raw material supply base emissions

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ABSTRACT

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Research of raw material supply base emissions

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The case company has joined Science Based Targets, which is a global initiative to reduce greenhouse gas emissions. The case company needs to publish its emissions reduction targets during 2020, and this thesis provides input to form realistic targets. Emissions are divided into three scopes: emissions of the company's own operations, emissions of the purchased energy and the emissions of the supply base. This thesis focused on the Scope 3 emissions.

The case company hypothesizes that by reallocating the raw material purchasing volumes of each item to the supplier with the lowest emissions, the case company's raw material supply base emissions will become drastically reduced. This was investigated in this thesis by studying the emissions by the raw material suppliers when raw materials are produced for the case company. This investigation entailed a survey sent to all raw material suppliers regarding which sources of energy they use, how much energy they use per product ton and regarding their total carbon footprint per product ton.

An objective of this thesis was to study whether the selected approach is suitable to gather useful information about the raw material supply base emissions, whether this information can be used to create concrete actions towards reducing the emissions and whether realistic emission reduction targets can be created. Most suppliers were not able to answer the question concerning total carbon footprint. Regarding energy usage, the suppliers' reported figures were not comparable during the study, even though it compared suppliers of the same item. The only aspect that could be further investigated was the energy source mix per item-supplier combination. This means that the chosen research approach was not suitable to study these topics.

This thesis created a purchasing volume weighted average gCO2/kWh index for the whole raw material supplier base, and the same index was calculated for different purchasing volume reallocation scenarios. In the realistic scenario, the achieved emissions reductions were only a couple percentage points, which falls within the study's margin of error. This means that the hypothesis is not true and that other actions need to be taken to reduce the raw material supply base emissions.

Key words: emissions, procurement, raw materials

CONTENTS

ABBREVIATIONS AND TERMS

IEA	International Energy Agency
GHG	Greenhouse gas
SBT	Science Based Targets
SBTI	Science Based Targets Initiative
LCA	Life Cycle Analysis
STEPS	Stated Policies Scenario

1 INTRODUCTION

Climate change has regarded a significant global trend during recent decades, and many countries and multinational unions such as the EU have released climate policies and targets to slow climate change. This creates increasing legislation restrictions on companies, and stakeholders, including shareholders, are more interested in businesses' emissions (Eccles & Climenko 2019).

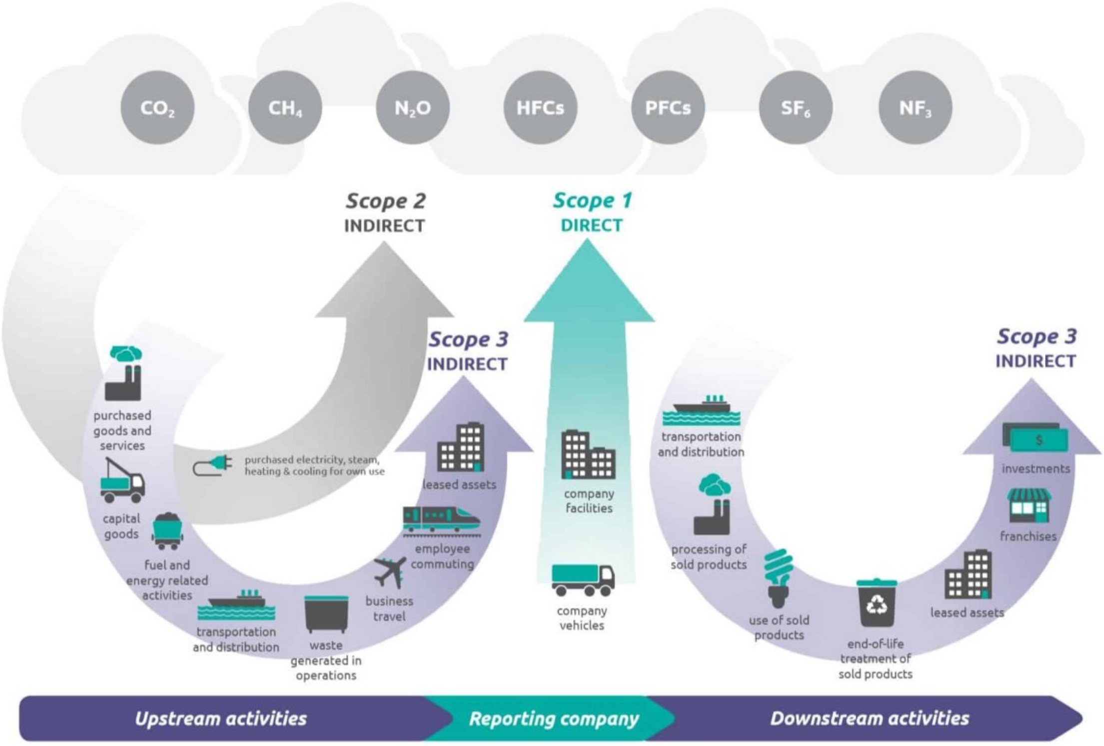
There are also global initiatives created to involve companies to battle climate change together, and one example is the Science Based Targets initiative.

1.1 Science Based Targets (SBT) initiative

Science Based Targets is a global initiative of the Carbon Disclosure Project (CDP), United Nations Global Compact (UNGC), World Resources Institute (WRI) and World Wide Fund for Nature (WWF). This initiative supports companies in setting meaningful targets and showcases companies that have set science-based targets. On 11th April 2020, 854 companies globally are participating in the SBTI. (Science Based Targets 2020):

> Targets adopted by companies to reduce GHG emissions are considered "science-based", if they are in line with what the latest climate science says is necessary to meet the goals of the Paris Agreement – to limit global warming to well-below 2°C above pre-industrial levels and pursue efforts to limit warming to 1.5°C. (Science Based Targets FAQ)

The Greenhouse Gas Protocol has divided GHG emissions into three categories, as illustrated below in PICTURE 1:
Scope 1: Direct emissions from the company's operations.
Scope 2: Indirect emissions from purchased and used electricity.
Scope 3: All other indirect emissions from the activities of the company that are not controlled by the company.



PICTURE 1. Greenhouse Gas Protocol: Technical Guidance for Calculating Scope 3 Emissions (Greenhouse Gas Protocol)

In SBT, all joining companies are required to develop at least Scope 1 and Scope 2 targets. If Scope 3 emissions cover more than 40% of the company's combined Scopes 1, 2, and 3 emissions, then Scope 3 targets also need to be defined. (Science Based Targets FAQ)

The target setting is achieved in 4 steps:

I. Commit: The company officially commits to the SBTI
II. Develop: The company investigates the Scopes 1, 2 and 3 emissions and defines the actions they can take for each scope. There are two goals in SBT target setting criteria. The one with stricter criteria is called 1,5 degrees goal and the less strict is called 2 degrees goal. The company decides to target either to 1,5 degrees or well-below 2 degrees goal and develops the GHG emissions reduction target for each scope.
III. Submit: The company submits the developed emissions reduction targets to the SBTI for evaluation. The SBTI reviews the targets if they meet the set criteria.

IV. Announce: When the targets are accepted by the SBTI, the targets will be published at the SBTI website and the company may use the SBTI logo in communications materials.

1.2 Thesis scope, target and research questions

This thesis has been requested by a case company which has participated in the SBTI in 2018, which requires all participating companies to publish GHG emissions reduction targets within 2 years of participation in the initiative. This means that the case company must publish its SBT targets by 2020.

According to the SBT rules, an internal study of the case company revealed that 90% of their GHG emissions are generated when the case company's products are used by end users. This means that the case company must also publish their Scope 3 target in order to be accepted by the SBTI. According to the case company's internal investigation and the SBT instructions, the minimum emissions reduction target level for the case company's Scope 3 emissions is approximately 15%. The case company's sustainability department will define the targets, and this thesis aims to provide more information about their Scope 3 emissions to increase the target's accuracy.

There is currently no available research regarding Scope 3 emissions in the case company's industry, and therefore this thesis intends to study how the case company's supply base emissions can be evaluated, identify which information is already available, the suppliers' awareness levels of their emissions and energy usage and which tools are useful to collect data from suppliers.

The researcher's current position at the case company is a procurement development specialist, and therefore this thesis is limited to the part of Scope 3 emissions that the purchasing department can study and affect. The case company's internal study revealed that around 8% of the case company's Scope 3 emissions are generated by the case company's suppliers' energy usage when the raw materials for the case company are produced. This thesis is also limited to studying only the CO_2 emissions, which represent around 75% of all greenhouse gases (IPCC 2014).

This research also hypothesizes that reallocating purchasing volumes to lower emissions suppliers will significantly reduce supply base emissions. This thesis investigates the hypothesis and whether the needed Scope 3 emissions reductions are achievable through realistic purchasing volume reallocations.

2 CASE COMPANY

The case company is a global publicly listed company that manufactures products primarily for consumer aftermarkets. The company currently has three manufacturing facilities, and their headquarters is in Finland. Their purchasing department is divided into global procurement and local procurement units.

2.1 Global procurement department

The global procurement department is responsible for managing the raw material suppliers globally, negotiating all the raw material supplier contracts, defining the procurement sustainability framework and measuring the supplier performance. The global procurement department can thus affect the supplier selections and purchasing volume allocations.

2.2 Raw material procurement

Raw material procurement is divided into strategic purchasing and operative purchasing. The strategic raw material purchasing department is located at headquarters while operative purchasing is divided to each manufacturing plant. Raw material procurement is also divided into seven categories according to the type of raw materials purchased, such as synthetic polymers, textiles and steels. Each raw material category has its own manager responsible for selecting their category's suppliers, volume allocations and the suppliers' performance. Raw material procurement in total consists of 100-200 suppliers globally, while there are currently 200-400 different combinations of suppliers and raw materials.

3 CO2 EMISSIONS IN RAW MATERIAL PRODUCTION

The emissions created by energy usage regards three main factors: the energy mix, CO_2 emissions created in electricity production and amount of electricity used.

3.1 Energy mix

In this thesis, energy mix concerns the different electricity production methods for the electricity used by the raw material suppliers in their production facilities. Some of the electricity used can be produced by the suppliers themselves while some can regard purchased electricity. These amounts are calculated together and then divided to determine which proportion of electricity used is produced per different production methods.

This thesis uses the IEA's (IEA 2019, Emissions Factors) separation of different electricity production methods:
Coal – Includes primary and secondary coal, coal gases, peat and oil shale
Oil – Includes oil products
Gas – Represents natural gas
Non-renewable wastes – Includes industrial waste and non-renewable municipal waste
Biofuels – Includes both biofuels and renewable wastes

An additional category is also to represent all the zero-CO_2 emissions methods:
Nuclear, water, wind – Includes nuclear and modern renewables. Modern renewables regard hydropower, solar, wind, geothermal and modern biofuel production (including modern forms of waste-to-biomass conversion) (IEA 2019, Modern renewables).

3.2 CO2 emissions created in electricity production

CO_2 emissions are always emitted in traditional electricity production, and different production methods generate different amounts of emissions depending on the process and feedstock. The IEA has created a document called Emissions Factors (IEA 2019, Emissions Factors), which includes emissions factors for electricity and heat generation. This thesis only focuses on the electricity part of the document.

The document lists emissions factors per electricity production method and per country in the form of grams per kilo watt hours, gCO_2/kWh. This thesis uses the latest figures available in the document, which for most countries regards the 2018 figures.

3.3 Energy used per product ton

The energy mix and CO_2 emissions created in electricity production were defined in 3.1.1 and 3.1.2, but there is a third factor when calculating the CO_2 emissions of raw material production: the amount of energy used per product ton. Many companies currently monitor their energy consumption due to both environmental and economic aspects. Some industries are highly energy intensive and therefore a large share of raw material product prices stems from the electricity used in raw material production.

3.4 Calculating the CO2 emissions

The CO_2 emissions generated in the production of raw materials can be calculated by first determining the energy mix and using the IEA document to check how much CO_2 emissions the energy mix generates in the country where the production facility is located. The result is shown in the form gCO_2/kWh.

The second step is to multiply the previous figure with the amount of kWh used in raw material production. This shows the amount of CO_2 emissions which are generated to produce one ton of raw materials in the example's factory, country and the energy mix used.

4 DATA COLLECTION IN QUANTITATIVE RESEARCH

As previously stated, there is insufficient information available on this topic, and therefore more information needs to be collected in order to continue the study and conclude how the supply base emissions should be studied. This section describes the data collection methods that are used in this thesis.

4.1 Survey

A survey is a tool to collect large amounts of data from a population in a quick and effective manner, and this data can be later analyzed using statistical methods and tools. The downside of surveys is that the information is shallow and there is uncertainty regarding usefulness of the survey from the responders' perspective, the seriousness of the responders' responses or how well informed the responders are about the survey's topic and questions. (Ojasalo, Moilanen & Ritalahti 2018, 121.)

4.2 Survey sampling

Quantitative research systematically describes the researched phenomenon according to observations. Therefore, when conducting a survey, the survey targets and observation units must first be defined. The full quantity of observation units is called a population. (Ojasalo, Moilanen & Ritalahti 2018, 122.)

According to the book *An introduction to Survey Research* (Cowles & Nelson 2015), reliable observations of the population can only be achieved in a survey by asking survey questions from every observation unit and by receiving useful data from everyone. When the population is large, it is expensive and requires significant time to pose the survey questions to all individuals in the population, and in such cases, it is useful to use a representative random sample. With proper sampling, the sample appropriately represents certain characteristic of the population. (Cowles & Nelson 2015, 13.) For example, when free bread samples are given to people at grocery stores the sample needs to be representative by having the same characteristics as the full product when purchased by the customer.

Samples can be divided into probability samples and non-probability samples. There are three main characteristics of a probability sample:

- The sampling frame from all the population units can be created
- All the units have a positive probability of being selected into the sample
- The probability of being selected can be calculated for each sampled unit. (Cowles & Nelson 2015, 15.)

The advantage of probability samples regards the possibility to estimate or calculate the accuracy of the sample's representation of the population. This cannot be calculated in non-probability sampling since the probability of units being selected into the sample is unknown. This means that only probability samples allow making inferences about the whole population and calculating how accurately the inferences describe the whole population. (Cowles & Nelson 2015, 15-16.)

When the sample accurately describes the population, it is called a representative sample. The best possible probability that the sample represents the population is achieved by ensuring that all the population units have an equal likelihood of being selected into the sample. (Cowles & Nelson 2015, 17.)

4.3 Survey error

Every survey inevitably includes some survey error, which is defined as the difference between the population's true value and the survey's obtained value. Survey error cannot be eliminated but can be evaluated and minimized, and it can be either random or systematic depending on the error type and situation. Systematic error occurs due to the error affecting all or significant number of observation units, which is called bias. In probability sampling, the sampling error is random. (Cowles & Nelson 2015, 35.)

There are several types of different errors, and it is important to be aware of the possible errors during the survey design phase as well as when analyzing and presenting the survey results.

4.3.1 Sampling error

Sampling error occurs when the sample is selected from the population, because the sample is always a portion of the population. Whenever same-sized samples are randomly selected from the population, the obtained sample characteristics will slightly diff compared to the chosen samples and compared to the true value of the population. In probability sampling, the sample error can be estimated and can be reduced by increasing the sample size. (Cowles & Nelson 2015, 36-37.)

4.3.2 Coverage error

Coverage error occurs when the sampling frame does not match the population. For example, if the survey aims to determine how many employees of a certain company wish to also work the night shift, then the population must include all the employees of the company, and a list of all company phone numbers is used to send the survey to employees via a text message. This kind of setting would systematically exclude employees without company phones from answering the survey, which would cause a coverage error. Coverage error can be minimized by ensuring that the list covers all observation units in the sample population, does not include units that are not in the study population and includes no duplicates. (Cowles & Nelson 2015, 38-41.)

4.3.3 Nonresponse error

Nonresponse error is caused by some sample units not responding to the survey or rejecting participation. There can be several reasons for not responding. For example, if using email to send the survey, the responders' email firewall can block the email and thus the responder never receives the survey. (Cowles & Nelson 2015, 42-47.)

Nonresponse error can also concern rejection. This can be noticed by receiving no response or by the responders stating being uninterested or unable to respond to the survey or parts of it. (Cowles & Nelson 2015, 42-47.)

Different theories explain nonresponse reasons. According to social exchange theory, people evaluate costs and rewards, and when the rewards exceed the costs, they engage in the social exchange. For example, responding to a survey requires time which can be considered a cost, and sometimes surveys entail a monetary or other incentive to respond, which can be considered a reward. The responder also can think that there will be some reward in the future as a result of engaging in the present social exchange. Therefore, the nonresponse rate can be minimized by reducing the cost to the responder and increasing the reward. (Cowles & Nelson 2015, 42-47.)

There is also the leverage-salience theory, which states that people value different things. For example, if the topic of the survey is valued by the responder, there is higher probability that they will respond. Therefore, to minimize the nonresponse rate, what is important to the responders should be understood and relevant sections highlighted in the survey. (Cowles & Nelson 2015, 42-47.)

Nonresponse bias

Nonresponse bias occurs when the difference between responders and non-responders is systematically related to what the survey's topic. In other words, if the non-responders of a survey would systematically provide different answers compared to the responders, then there is nonresponse bias present. (Cowles & Nelson 2015, 42-47.)

4.3.4 Measurement error

Measurement error regards the error of some survey attribute's received responses difference compared to the actual value. This can be divided into two point of views; measurement error due to the respondent and due to the interviewer. (Cowles & Nelson 2015, 47-58.)

Measurement error due to the respondent means that the respondent has self-interest to non-truthfully respond (Cowles & Nelson 2015, 47-58). For example, when attending amusement parks, usually free of charge. When the age of the children is asked from their parents, there is self-interest to respond ages lower than their true ages.

E. Cowles and E. Nelson state in their book *An introduction to Survey Research* (Cowles & Nelson 2015, 47-58) that there are many reasons that can cause measurement error due to the respondent, such as:

- Question wording: When asking about the same topic using different words, the same responders will provide different answer according to their view on the wording. For example, the expressions welfare and assistance of the poor can be used to mean the same thing, but responders have their own views towards both expressions and respond accordingly.
- Question order: When asking about the same things in different orders, different results are received.
- Satisficing: When people receive many surveys, they tend to reduce the amount of work by answering “don’t know” or “no opinion,” skipping questions, giving one-word responses or randomly selecting the answering values.
- Social desirability: Some behaviors are more socially desirable, which causes measurement error. For example, if asked about recycling, it is socially desirable to respond that the responder recycles all household wastes, and if asked about discrimination, it is not socially desirable to respond as favoring certain age groups in hiring employees. Researchers theorize that if the responder’s response would not be socially acceptable, this can cause also non-response.

Measurement error due to the interviewer means that the interviewer’s age, sex or race can affect the responses’ truthfulness. In addition, the interviewer’s attitude or overall friendliness can affect the responses. (Cowles & Nelson 2015, 47-58.)

4.4 Survey structure and content

The structure and content of the survey are critical concerning the quality of the data received. There should also be sufficient information available before the survey is created to ensure that the right questions are asked and that the responders are able to respond to the questions. There should only be questions that provide information to achieve the target results of the research. (Ojasalo, Moilanen & Ritalahti 2018, 130-133.)

The length of the survey should be suitable for the research, as too-brief questionnaires can miss important questions and too-long questionnaires can result in nonresponses. In addition, the structure of the questionnaire should be easy to read and respond to. In an effective questionnaire, the questions are understood and responded to in the same way by all responders. The best questions are brief and simple and use terms which are familiar to responders. (Ojasalo, Moilanen & Ritalahti 2018, 130-133.)

Detailed response instructions can help all responders to understand the questions and response options in the same way. For successful survey research, a cover letter can be important, which describes the survey, who is conducting the research, how the data collected are used and the deadline for the responses. The cover letter includes a reminder that receiving responses from each responder is essential to the success of the research (Ojasalo, Moilanen & Ritalahti 2018, 130-133.)

To receive a high response rate, it is necessary to send a reminder to non-responders to receive as large a sample as possible. This reminder should inform why it is sent and include a petition to receive the responses and the deadline. It is recommended to send the first reminder immediately after the original deadline (Ojasalo, Moilanen & Ritalahti 2018, 130-133.)

One effective, cheap and quick type of survey is an electrical survey, which can be conducted via survey-focused web-services such as Webropol and Survey-Monkey, surveys sent via email or surveys in social media content. Electrical surveys are currently popular which means that people are receiving several different kinds of surveys. (Ojasalo, Moilanen & Ritalahti 2018, 128-130.) In addition, many companies and personal email boxes use strict firewalls, which can prevent the surveys from reaching the inbox of the responder. These reasons reduce the response rate, which is a downside to electrical surveys.

If the research population is strictly limited to certain types of persons or companies and the survey is available for public response, the responders might not belong to the targeted population of the research. In such cases, a high response rate does not aid the research and it is impossible to make accurate inferences of the research population. (Ojasalo, Moilanen & Ritalahti 2018, 129-130.) It is therefore essential to identify the research population and send the survey only to population units in order to avoid responses from observation units outside the researched population.

5 STATISTICAL DATA ANALYSIS

When performing quantitative research using a survey, it is common to analyze the data using statistical tools (Ojasalo, Moilanen & Ritalahti 2018, 121). Section 4 described the literature definitions of the possible survey errors and that a typical error regards sampling error. There are methods of measuring the sampling error in probability samples, and the terms used to describe how well the sample represents the population are confidence interval and confidence level. The next sections explain these terms, how they can be calculated and how they relate to sample size.

5.1 Confidence interval, confidence level and sample size

In statistics, confidence interval and confidence level are used to determine the sample size. Confidence interval is commonly called the margin of error and communicates the precision of the sample characteristics under study, meaning how close the sample result is to the population's true value. (Cowles & Nelson 2015, 26.) For example, if the poll result is that 49% would vote for president X to become the next president with a confidence interval of +-3%, then the real interval for the result is 46% (49-3) and 52% (49+3).

The confidence level describes the level of certainty that the sample represents the population when repeatedly using the same sampling technique and select similar random samples from the population. A 95% confidence level is commonly used, and in this case if the same survey is repeated infinite times, in 95% of trials the sample results include the population's true value. (Cowles & Nelson 2015, 26.) According to the central limit theorem, if samples are repeatedly taken from the population, the mean of the samples is equal to the population's true value. In addition, the samples' values will be normally distributed around the population's true value (Israel 1992) when the sample size is over 30 and the normal distribution can be used in statistic calculations (Kwak & Kim 2017). The confidence level and confidence intervals allow making claims about the population such as "we can be 95% sure that the population proportion is 43±3%."

A normal distribution is the pre-requisite of using many statistical tools and is the most known distribution model. It is bell shaped and symmetrically proportioned around the mean value (Encyclopaedia Britannica). Normal distribution involves a rule called 68-95-99,7 or the empirical rule, which means that 68% of the data values are approximately within 1 standard deviation (σ), 95% are approximately within 2 standard deviation and 99,7% are within 3 standard deviations (Galarnyk 2018).

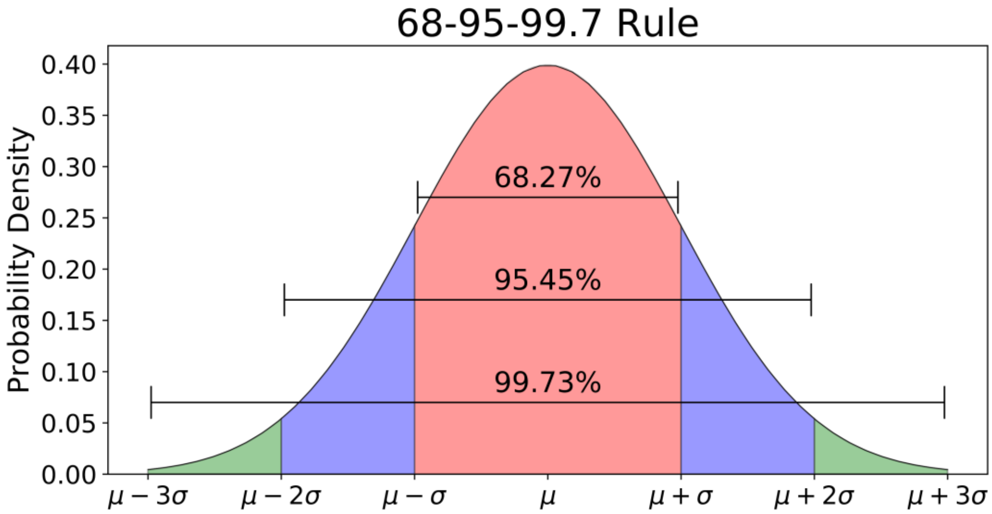
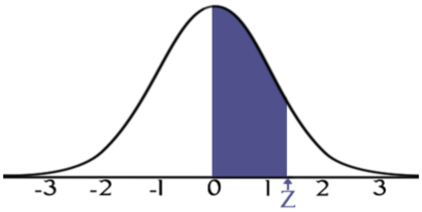


FIGURE 1. Empirical rule (Galarnyk 2018)

In statistics, there is a Z score which represents how many standard deviations the measurement point is from the mean value. When calculating a 95% confidence interval, the formula has a Z score noted as $z_{\alpha/2}$. A Z score table is used to find the Z score value corresponding to the selected confidence level.



STANDARD NORMAL TABLE (Z)

Entries in the table give the area under the curve between the mean and *z* standard deviations above the mean. For example, for *z* = 1.25 the area under the curve between the mean (0) and *z* is 0.3944.

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0190	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2969	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3513	0.3554	0.3577	0.3529	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998

FIGURE 2. Standard normal table and Z score (Statcalculators.com)

To find a Z-score for a 95% confidence level, the above table regards the positive values only, which are half of the whole confidence level. Therefore, half of 95% is 47,5% and that value (0,475) can be found using the table. The corresponding first Z-score decimal can be found in the first column and the second Z-score decimal in the first row. Therefore, the corresponding Z score for a 95% confidence level is 1,96.

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.0…
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0190	0.0239	0.027…
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.067…
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.10…
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.14…
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.18…
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.21…
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.24…
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.27…
0.8	0.2881	0.2910	0.2939	0.2969	0.2995	0.3023	0.3051	0.30…
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.33…
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3513	0.3554	0.35…
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.37…
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.39…
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.41…
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.42…
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.441…
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.45…
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.461…
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.46…
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.47…
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.48…
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.48…

FIGURE 3. 95% confidence level Z score

5.2 Estimating a proportion for a population

One method of studying a population proportion is to take a sample and calculate the confidence interval, which represents how confidently the sample result is the population’s true value. For example, when studying how many employees like working in the company, all the employees represent the population N=389 while a random sample of size n=50 is taken from the population. Employees from the sample are then asked whether they like to work in the company. The result is that 38/50 (76%) like to work in the company. This only shows the opinion of the 50 employees asked, but to estimate the size proportion of all employees who like to work in the company according to the sample result, then the confidence interval for the sample result must be calculated.

Pennsylvania State College course material of STAT 415 Intro Mathematical Statistics Lesson 34 provides two formulas to calculate the confidence interval for a population proportion, including one for large populations (such as all U.S. citizens) and one for small populations (citizens of a small village).

The formula for large populations is:

$$\hat{p} \pm z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \tag{1}$$

Where:
$\hat{p}$ = sample proportion, for example the sample response 76% would be $\hat{p}$ = 0,76.
$z_{\alpha/2}$ = the Z-value of the selected confidence level, for example if calculating 95% confidence interval, the Z score value would be 1,96 according to the Z score table.
n = sample size.

The formula for small populations is:

$$\hat{p} \pm z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n} * \frac{N-n}{N-1}} \tag{2}$$

In the formula for the small populations, the symbols have the same meaning as in the previous formula and there is also the population size N. The corrected formula for small populations can be used when the population size is known. If the sample size is the same as the population n = N, then the small population correction equals zero and the confidence interval is therefore also zero. This is logical because when the sample size is the whole population, there is no margin of error and we can be 100% sure that the sample proportion is the same as the population proportion.

5.3 Calculating sample size using Cochran's formula

In 1977, W. G. Cochran introduced a formula for calculating a sample size for infinite populations (Israel 1992):

$$n_0 = \frac{z^2 pq}{e^2} \tag{3}$$

where

n_0 = sample size

z = Z score value of selected confidence level

p = population degree of variability/sample proportion

q = p – 1

e = is desired level of precision/margin of error

In the population degree of variability, 50% represents the maximum variability since, for example, 20% and 80% show that a significant share of the population has or lacks the attribute of interest. Therefore, if the population degree of variability is not known, a 0,5 value should be used to achieve the maximum variability and most conservative sample size. (Israel 1992.)

5.4 Yamane's formula for calculating sample size

In 1967, a statistician named Taro Yamane introduced a simplified formula for calculating the sample size (Israel 1992):

$$n = \frac{N}{1 + N(e)^2} \tag{4}$$

where

n = sample size

N = population size

e = margin of error

Yamane's formula can be modified to calculate the margin of error e:

$$n(1 + N(e)^2 = N$$

$$n + nN(e)^2 = N$$

$$nN(e)^2 = N - n$$

$$e^2 = \frac{N - n}{nN}$$

$$e = \sqrt{\frac{N - n}{nN}} \qquad (5)$$

6 RESEARCH FRAMEWORK DEFINITION

As described in the scope section, this thesis focuses on the CO_2 emissions generated by the suppliers when producing raw materials for the case company. An aim of this thesis is to investigate how much supply base CO_2 emissions can be reduced by reallocating the purchasing volumes, which entails the following four steps:

1. Determine the current level/baseline
2. Define the possibilities of how the current level can be changed
3. Create a scenario of changed levels and estimate the impacts that the changes can cause
4. Compare the selected scenario emissions figures with the baseline

6.1 Baseline

Investigating the current level of CO_2 emissions generated by the energy usage of raw material production requires the following information:

1. Information from suppliers regarding the energy mix and energy usage per ton of final product
2. Case company’s raw material purchasing volumes

The energy mix and energy usage figures are usually not public information published on companies’ websites, and when they are published, the format is not the same for all companies, which makes it nearly impossible to compare the figures. Therefore, the suppliers’ energy mix and energy usage figures can only be obtained by asking the suppliers, and a survey was thus created for this purpose.

The case company’s purchasing volumes are available from internal IT systems. The volumes that are used in this thesis regard 2018 volumes, because during the calculation of results (November and December 2019) the exact volumes for the full year 2019 were not yet available.

6.1.1 Survey design and sampling in this thesis

As previously stated in Section 4, it is best to use probability samples to make accurate inferences about the population later or at least to calculate the accuracy of the sample. Related to Sections 4 and 5, the traditional method of selecting a probability sample is first to define the sampling frame, decide the acceptable margin of error, calculate the sample size and then select the sample so that each observation unit has an equal probability to be selected for the sample.

In this thesis, the population size is relatively small 200-400 supplier-item combinations (observation units) collected from the raw material supply base of 100-200 suppliers. Selecting the sample size and observation units is difficult since the response rate could not be evaluated before beginning the survey. This is because there are no similar conducted surveys regarding the same topic in the same industry, and the topic can be difficult for suppliers to respond to, which could cause significantly low response rates. If the sample size is pre-determined in this situation, there is no certainty that the sample size is reached, which causes the margin of error to rise.

Due to these reasons and because all the suppliers and supplier-item combinations are known, the sampling approach is to send the survey to all suppliers to include all observation units. The final response rate defines the final sample size, and the margin of error can only then be calculated and not defined beforehand. In this kind of approach, it is also important to design and conduct the survey in a manner that ensures a response rate which is as high as possible. In addition, because the response rate defines the sample size and therefore also the margin of error of the survey, it is essential to evaluate whether there is nonresponse bias, meaning the nonresponse error is caused by systematic reason.

In this sampling setting, the sample frame is defined, and each observation unit has a probability of 1/qty suppliers of being selected for the sample, and therefore the sample can be considered as a probability sample. If no nonresponse bias is found, then the nonresponse rate is considered to be caused by random errors and the sample is considered to be a representative sample of the whole population. The survey coverage error will be minimal since all suppliers and their updated contacts details are known.

As stated in Section 4, one method of mitigating a low response rate is to perform several reminders, however the case company's schedule for the results is brief (two months from sending the survey), and therefore there is no time to perform several reminder rounds. In addition, there will always be observation units which do not respond due to non-specific reasons, and some can reject survey participation due to several reasons, such as claiming the information as confidential.

6.1.2 Creating the survey questionnaire

Before the survey questionnaire was created, definitions were established regarding which information is essential to collect from the suppliers and how it would be later analyzed. The first section of the questionnaire identifies the product that the responses are related to, which regards two main characteristics: the product name and R-code. The R-code describes the case company's raw material item group code, includes a 6-digit code and each R-code has its own specification. This means that if the same R-code raw material is purchased from different suppliers, the raw material is the same material, although there can be different packaging sizes or other differences that do not affect the raw material properties.

As stated in the previous section, the survey data will be later analyzed using the IEA's Emissions Factors document which states the emissions factors per country (IEA 2019, Emissions Factors). This is because the same electricity production method in different countries can create different amounts of CO_2 emissions, and therefore the survey also asked about the production country.

The next three parts discuss the survey questions whose data are analyzed. The first is the energy mix question, where the supplier shares the energy mix used to produce the raw material in the location that they stated in the first section. This section needs to be in the same format as stated in the IEA's Emissions Factors document so that the responses can be analyzed.

The next question is the energy usage per ton of final product. The unit of measure for this is kWh, because in the IEA's Emissions Factors document, all the CO2 emissions values are stated in gCO2/kWh.

One additional question related to the total carbon footprint of the supplied product was added to study whether the suppliers have performed their own Life Cycle Analysis (LCA) studies and could thus answer this question. The hypothesis is that not many suppliers can answer this question since there are many different formats for performing the LCA studies, and they can be difficult and time consuming to perform.

After the main page was created, an instructions page was added to describe what the responder should add to each field and how to interpret the questions. This was done so that all responders would understand the questions the same way and the responses would be completed the same way in order to reduce the measurement error related to question wording.

The questionnaire structure includes up to 10 sheets, representing one per product that the supplier supplies to the case company. The questionnaire was created to be as simple as possible by dividing the sections from each other and color coding the question and response fields. The sheets were also locked so that only response fields are editable, and a summary function was added to help the responder identify whether the energy mix sums to 100% as it should. The outlook of the questionnaire page can be found in Appendix 1.

6.1.3 Sending the questionnaire

The questionnaire was sent via email to all raw material suppliers by the raw material category managers. The questionnaire was sent in the beginning of October 2019 and responses were allowed until the end of October. Category managers were used to send the questionnaire since they are frequently in contact with suppliers and they control the purchasing volumes. For suppliers, this means that a person of high importance to them has sent them a questionnaire, which would likely yield more responses compared to being sent by a procurement development specialist with no business decision power. According to previously mentioned social exchange theory, the relationship between the category manager and supplier representative can create a situation where the responder thinks that responding to the survey will grant them a reward (e.g., more business or better service ratings) in the future. Category managers also have the latest contact information, which ensures that the questionnaire is received by the suppliers and minimizes survey coverage error.

The questionnaire was sent as an attachment to the cover letter email, which stated why the case company is performing the research and identifies the researcher, the research targets, response deadline, how to respond and where to return the completed questionnaire.

6.1.4 Data collecting and recording

In the case company, there are a couple hundred different raw material-supplier combinations, and therefore significant amount of information needs to be recorded from the suppliers' responses. The received data must also be analyzed altogether, and therefore an Excel tool (Appendix 2) was created to record all the suppliers' responses regarding:

- Raw material category
- Supplier name
- Product name
- R-code
- Energy mix
- Energy usage kWh
- Total carbon footprint

The case company's purchasing volumes were also added to the tool. The same Excel tool is used for all the calculations in the analysis section, and therefore functions were created to calculate the needed information while the responses from the suppliers were pending. The tool includes the following information:

- gCO_2 / kWh per R-code, total energy $tonCO_2$ / ton of raw material, total energy $tonCO_2$ with 2018 volumes per R-code
- total CO_2 emissions per category, total CO_2 emissions per full purchase volume of 2018
- the different volume reallocation scenarios
- response rate % from suppliers
- response coverage in terms of supplier-item combinations

6.2 Defining the possibilities to change the current level

This thesis investigates the purchasing volume reallocation and how this affects supply base CO_2 emissions. There are several methods of performing this reallocation, and different scenarios can be derived according to different definitions. The next section lists the different scenarios considered in this thesis, some of which are more idealistic and some more realistic. Several aspects affect the end result and possibilities of the purchase volume reallocation regarding whether the reallocation is wise to execute from a product availability perspective. The cost of the same raw materials from different suppliers is also different, however the cost calculations are not considered in this thesis.

6.2.1 Scenario 1: Full item volume to the lowest emissions supplier

One model is to reallocate 100% of the item purchasing volume to one supplier. There are currently several suppliers for each item, so investigation is needed regarding which suppliers per item have the lowest emissions to then allocate 100% of the purchasing volume to those suppliers. Overall emissions would then be calculated and compared to the original state to observe the CO_2 reductions results.

This model would yield significant emissions reductions, but there are also drawbacks. The purchasing volumes per item are allocated to several suppliers to reduce the supply risk. If one item supplier becomes no longer available, there is still at least one or more suppliers to provide the goods. However, if there is only one supplier that someday becomes no longer available, it would cause immediate supply risk, which can entail serious production and business impacts. This model is therefore not a realistic target since it creates too much supply risk. This model can thus be considered as “the idealistic scenario” and cannot be used for actual purchasing volume reallocation.

6.2.2 Scenario 2: Full item volume to two lowest emissions suppliers

The second model considered is to reallocate the full volume to the two lowest emissions suppliers. There are currently more than two suppliers for many items, and therefore reallocating the volumes to only two of the lowest emissions suppliers per item would reduce the total emissions, where the purchasing volume per item would be split 50/50 between two suppliers.

This model does yields smaller emissions reductions compared to reallocating full volumes to a single supplier per item, but it also creates smaller supply risks since there is always an alternative supply source available. This can thus be considered as “the more realistic scenario.”

6.2.3 Scenario 3: Full item volume to two lowest emissions suppliers - optimal model

This model is similar to the previous, however in this model if there are currently “over-weighted” purchasing volumes to lowest emissions suppliers, they will not be forced to become 50/50 shares between the two lowest emissions suppliers. In these cases, the “over weighting” is left untouched while the rest of that item’s purchasing volume is allocated to the supplier with the second-lowest emissions. An example of the volume allocations in this model is shown in the table below.

TABLE 1: Example volume allocations in Scenario 3.

	Supplier	Emissions	Original Volume allocation %	Adjusted Volume allocation %
Item 1	Supplier 1	50	70%	70%
	Supplier 2	70	10%	30%
	Supplier 3	1000	10%	0%
	Supplier 4	600	10%	0%

This model does not correct the current purchasing volume “over weighting,” which is also not the purpose of this thesis. Commercial reasons can also cause “over weighting,” and therefore it should not be modified without pressing reasons. This model can be considered as “the most realistic scenario.”

7 ANALYSIS OF SUPPLIERS' RESPONSES

This section answers the following research questions:

- How well was the case company's supply base aware of the surveyed topic?
- How well was the case company's supply base able to answer the survey questions?
- How well was the survey designed to gather data from suppliers?

7.1 Suppliers' ability to respond to questions

When analyzing the suppliers' responses, the first item noticed was the suppliers' inability to respond to the additional question regarding total carbon footprint. Only half of the responses included something written in the field and most of these were unrealistic responses. It was clear that this figure could not be further analyzed, which showed that the case company's supplier base is currently unable to respond to this question.

Around 4% of respondents stated that they are unable to provide energy usage figures since they have not investigated their energy consumption.

Around 2% of respondents stated that they are unable to provide the energy mix since their electricity provider is also unable to provide this information.

7% of respondents stated that their company policy is to not share this kind of information. Some of these suppliers would possibly be able to share this information if a Non-Disclosure Agreement (NDA) with suitable content is first signed. Such documents were not signed due to the time needed for negotiating the NDA content.

7.2 Reliability of suppliers' answers

The questionnaire was sent to all raw material suppliers, which means that the responders are from different corporate and country cultures. Because environmental issues are currently a trending topic globally, the suppliers may assume they would benefit by responding with lower-than-actual figures. These considerations might affect the reliability of the responders. Because fact-based responses are not available, it is difficult to evaluate the reliability of the responses, and therefore in this thesis the respondents' answers are considered to be factual.

7.3 Comparable information

This section evaluates the comparability of suppliers' information received from three questions or, in other words, whether different suppliers been able to answer the questions in the same way.

The energy mix question is well structured, and few suppliers had issues answering it, although a couple suppliers requested additional instructions for how to answer. Most companies purchase the energy used in their operations, making it simple to request the energy mix from their energy supplier. Some suppliers produce their own energy in their energy plants near their production plants, in which case the energy mix is known by the supplier. The purchased and produced energy can then be combined and reported in the questionnaire. These gathered data are considered to be comparable between the responses.

A couple suppliers requested additional response instructions for the energy usage section, but overall, the question was similarly understood by different suppliers. The original intention of the energy usage question was to determine the differences between suppliers' energy efficiencies. When suppliers reported these figures, the differences within the same item codes were significant. After investigating this and requesting more detailed information from suppliers, including which process steps were included in the calculation, the reason for the differences became clear: Different suppliers have different numbers of process steps within their production facility. For example, when manufacturing chemical X, supplier 1 has the full scope of production within their plant, including their raw material. For the same (customer's) item, supplier 2 has only a couple final process steps in their plant, none of which are energy intensive. Supplier 2 purchases the nearly final product from their supplier, who purchases the raw material from another company and so on. The energy usage responses of Suppliers 1 and 2 are thus not comparable although both report the same item.

One method of achieving comparable results would regard asking all supplier which process steps they use inside their plants, comparing the answers per item, selecting the least amount of process steps and then again asking suppliers to report their energy usage only from these identified steps. The problem is that this method would require significant time and effort from case company personnel and from the suppliers' side, which was not possible in this research. In addition, this would shift the focus of this study away from the case company's direct suppliers' full production CO2 emissions.

As stated earlier, the total carbon footprint question received responses from about half of the responders, and the figures for the same items were significantly different, and thus this information is not comparable between suppliers of the same items.

It became clear that the energy usage and total carbon footprint figures could not be reliably compared between the suppliers, and therefore they are not further analyzed. This means that the calculation of the real CO2 emissions per item-supplier combination is not possible, and therefore a new approach is needed.

The only remaining comparable information regards the energy mix per item-supplier combination and the IEAs Emissions Factors. Combining (multiplying) these two allows calculating the emissions (gCO2) emitted by kWh used per item-supplier combination. This does not cover all emissions of the item-supplier combination but represents an important factor when calculating the total emissions, and it helps derive an "index" for the whole supply base by calculating the mean of the gCO2/kWh of all reported results.

8 HYPOTHESIS TESTING - PURCHASING VOLUME REALLOCATION SCENARIOS

One research target was to test the hypothesis that reallocating the purchasing volumes to lower emissions item-supplier combinations enables achieving significant CO_2 emissions reductions. This section describes how the hypothesis was tested.

8.1 Current level

Section 7.2 described that the current level for the whole supply base can be calculated by multiplying the energy mix and corresponding emissions factors for each item-supplier combination and then calculating the mean of all results. This model however does not consider the case company's purchasing volume, which is important since some items regard purchases of only a couple thousand kilograms per year while others regard purchases of several hundred thousand kilograms per year. Only calculating the average of gCO_2/kWh figures would therefore give similar weight to each item-supplier combination, which does not model the realistic situation when evaluating emissions.

To account for the purchasing volume of each item-supplier combination, the weighted mean of all responses should be calculated to create the current gCO_2/kWh index value. Each item-supplier combination's purchasing volume is used as the weight in the formula.

The calculation showed that the weighted mean with the current purchasing volume allocations is 706,97 gCO_2/kWh.

8.2 Scenario 1: Idealistic level

Section 6.2.1 explained how the idealistic level is calculated and means reallocating all purchasing volume of a certain item to the supplier whose gCO2/kWh figure is the lowest for that item.

The idealistic level was calculated and showed that the weighted mean for the whole supply base is 635,34 gCO2/kWh.

8.3 Scenarios 2 and 3

In scenario 2, the full purchasing volume of an item is reallocated to two of the lowest gCO2/kWh suppliers for that item without considering the current volume allocation. Scenario 3 is the same except the current volume allocations are considered in that, if there is currently more than 50% item volume allocated to the lowest gCO2/kWh supplier option, this volume is untouched while the remaining volumes are allocated to the second lowest option.

Scenario 2 is not separately calculated, and the scenario 3 weighted mean for the whole supply base is 679,35 gCO2/kWh.

8.4 Emissions reductions with volume reallocations

Evaluating the overall emissions reductions of each scenario versus the baseline allows calculating the sizes of the emissions reductions in percentages:

- Scenario 1 vs baseline: 10,1%
- Scenario 3 vs baseline: 3,91%

As shown in the results above, scenario 1 clearly includes greater emission reductions, but again this scenario cannot be used in a real-life business environment. The emissions reductions are not significant in the optimal and more realistic scenario 3. This means that the original hypothesis that significant CO_2 emissions are achieved via purchasing volume reallocations is true in idealistic scenario 1, but in a more realistic environment the hypothesis is not true.

9 RELIABILITY OF THE EMISSIONS REDUCTIONS VIA PURCHASING VOLUME REALLOCATIONS

9.1 Received response rate and survey sample size

Around 30% of suppliers responded within the deadline, after which several reminders were sent to suppliers who did not respond in time, and this also covered ~30% of supplier-item code combinations. The response rate slowly increased, but the final response rate was 76%. Only supplier responses which included the energy mix were selected, which was about 67% of the total population, with all approved item-supplier combinations representing the whole population.

9.2 Survey sampling – Reliability of survey

As stated in the survey sampling section, the only way for the sample to correctly represent the population is for the sample size to be the whole population with responses received from each unit in the population. In other words, the smaller the sample size, the less accurately the sample represents the population. This research requested information about all item-supplier combinations from suppliers. When conducting the research this way, the margin of error cannot be predetermined but is instead determined by the response rate.

Section 5.1.2 introduced Yamane's formula, which was then modified to calculate the margin of error using the information concerning sample size and population size:

$$e = \sqrt{\frac{N - n}{nN}} \tag{5}$$

The modified Yamane's formula was used to calculate the margin of error: ±4,54%, which can be used together with the results derived from the survey responses. When calculating for example the weighted mean gCO2/kWh in Section 8, first the reported energy mixes are multiplied with the IEA's Emissions

Factors, then each multiplied result is weighted with the purchased volume, and then the average is calculated. The survey margin of error cannot be used to represent the reliability of this figure due to several steps after the survey results which affect the reliability of the results.

9.3 Evaluating the sample representativeness of the population

Due to the low response rate and consequently small sample size, it is essential to evaluate whether there is systematic survey error that causes nonresponse bias in order to determine how well the sample represents the population.

Systematic non-responses can be caused by several reasons, some of which that are related to this survey are listed below along with explanations for why they are not present in this study:

- The relationship of the category manager with suppliers in the category can cause systematic non-response. In this study, the responses were nearly evenly spread between all raw material categories, and therefore the relationship in this setting has not caused non-responses.
- The topic can create non-response bias if the responders' responses would not be socially acceptable. In this study, this could mean that suppliers which use only fossil energy or suppliers from an industry which is known to create significant emissions would not respond to the survey. However, many different energy mixes were reported by the suppliers and most responses included the use of fossil energy. In addition, participants from energy-intensive industries with known high emissions responded to the survey. Therefore, it can be stated that the topic has not caused the non-responses.
- The country of the supplier affects results since the IEA's Emissions Factors are stated per country. In addition, only fossil energies are available in some countries. In this study, suppliers located in countries where only fossil energies are available possibly chose not to respond to the survey, however the responses received were spread in almost every country where the case company's suppliers are located. There was also no in-

stance of a country where many observation units are located yet no responses were received. Therefore, the suppliers' country did not cause non-response bias.

Based on the information above, there is no systematic non-response present and therefore the sample is representative of the whole population.

9.4 Overall energy mix results

This section presents the overall survey results derived from the survey's energy mix responses. The previously calculated survey margin of error can be used with the TABLE 2 results since the averages are calculated using the supplier responses. The following results thus have a margin of error of ±4,54%.

TABLE 2. Average energy mix of the sample.

Coal	16,7%
Oil	7,5%
Gas	46,5%
Non-renewable wastes	5,1%
Biofuels	1,7%
Nuclear, water, wind	22,5%

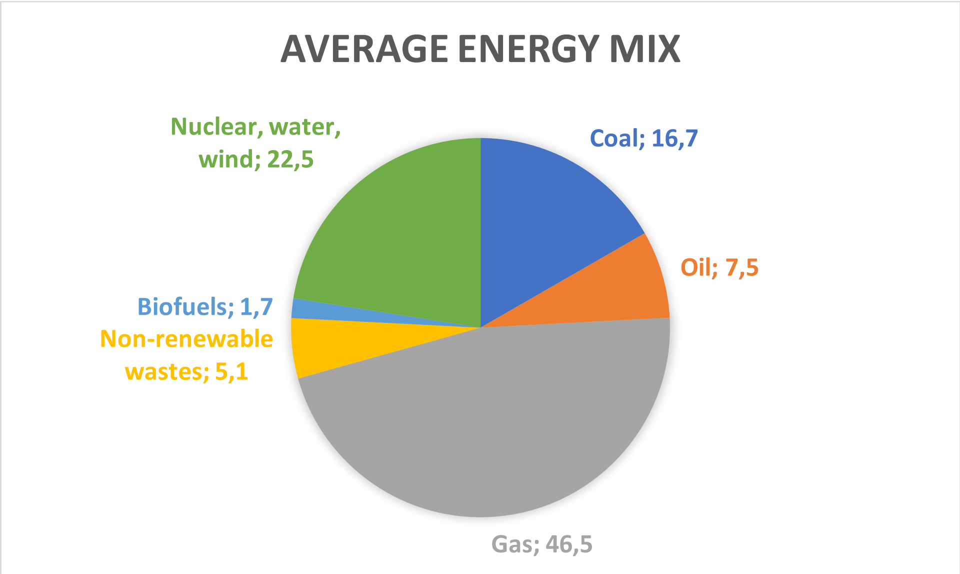


FIGURE 4 Average energy mix

The energy mix proportions of the population can be estimated using the sample results. These results are calculated using the 95% confidence interval which is calculated using the formula for small population proportions (2).

The energy mix results received from the sample are as follows:
50,3% of the item-supplier combinations' energy mix include some zero CO_2 emissions energy sources, meaning nuclear energy, wind energy, water energy etc. With the confidence interval of 4,5%, we can be 95% sure that 50,3±4,5% of the population energy mixes include at some zero CO_2 emissions energy sources.

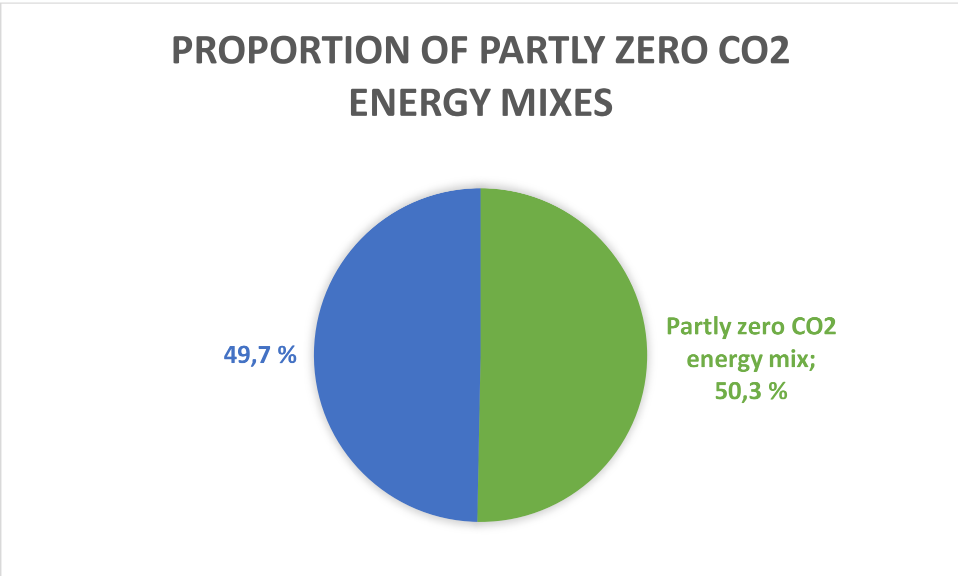


FIGURE 5. Use of zero CO_2 emissions energy

Only 4,3% of the reported energy mixes included fully CO_2-free energy. With the confidence interval of 1,8% we can be 95% sure that 4,3±1,8% of the whole population uses a 100% CO_2-free energy mix.

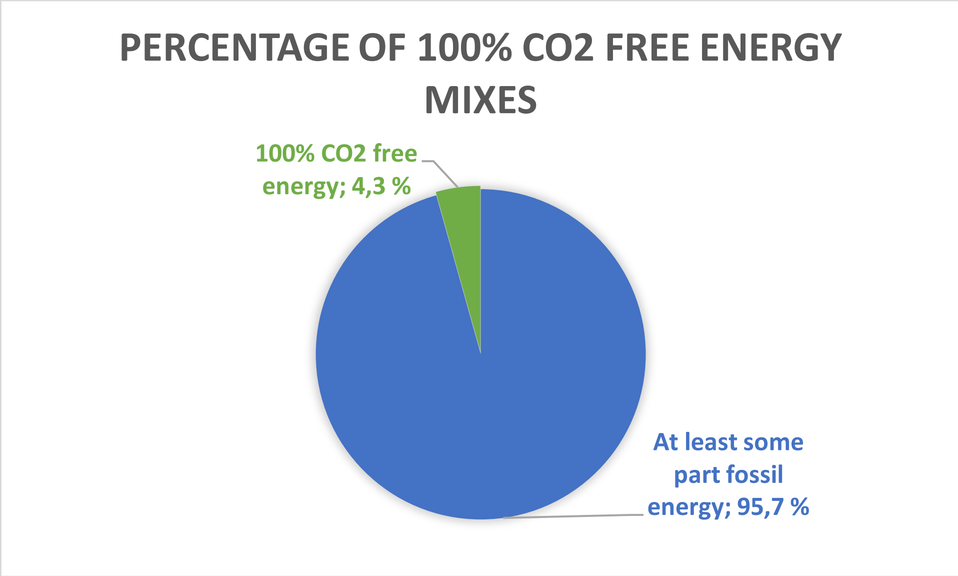


FIGURE 6. Use of 100% CO2-free energy

It is also interesting to note that 37% of the reported energy mixes were fully fossil energy. With the confidence interval of 4,.3%, we can be 95% sure that 37±4,3% of the population's energy mixes are fully fossil energy, meaning energy from coal, oil and gas.

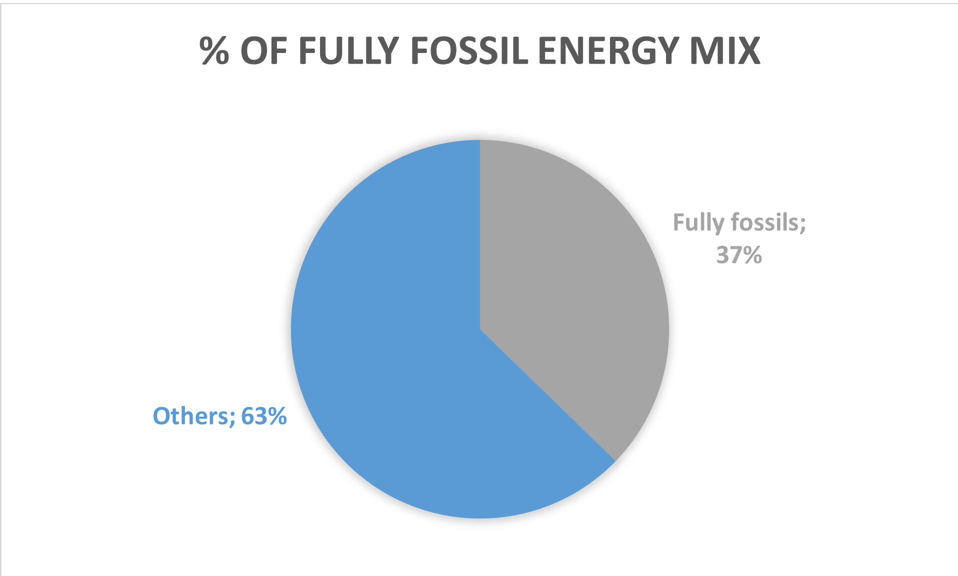


FIGURE 7. Use of fully fossil energy

10 RENEWABLE ENERGY – EMISSIONS REDUCTIONS GLOBALLY

In a UN committee meeting, Emma Åberg from the International Renewable Energy Agency stated that renewable energy and energy efficiency are the key elements to cost-effectively reduce energy-related CO2 emissions (Åberg 2018). This section states how the renewable energy situation is likely to develop in the coming years. This is briefly studied to understand how much the energy mix emissions automatically decrease without the case company's actions.

10.1 RENEWABLE ENERGY

Renewable energy regards energy from natural sources that continuously replenish. The following are considered to be renewable energy sources:

- Solar: This regards energy from sunlight via solar panels, for example, on building roofs or in solar energy farms. Solar energy is considered to be a zero-carbon energy source.
- Wind: Windmills have been used for centuries, however modern windmills for energy creation are massive and a cheap method to produce energy. Wind energy is considered to be a zero-carbon energy source.
- Water: This includes dams in fast-flowing waters such as in rivers or in waterfalls and tidal and wave energy. Harnessing water energy does not cause carbon emissions.
- Biomass: The energy from biomass comes from burning organic material such as trees and crops. The traditional usage of burning biomass creates significant carbon emissions, and therefore biomass is usually falsely considered to be a low emission energy source.
- Geothermal: The core of the earth is extremely hot and warms the surface of the earth. This energy can be captured by drilling a deep well to bring in hot water and use a turbine to create energy. This process does not create carbon emissions. (Shinn 2018.)

10.2 MODERN RENEWABLE ENERGY

There is also modern renewable energy, which means all the renewable energy sources exempting the traditional use of biomass, which is burning fuelwood, charcoal and organic waste (IEA, 2019, Modern renewables). Therefore, modern renewable energy can be considered to be a low or even zero carbon energy.

10.3 FUTURE DEVELOPMENT OF MODERN RENEWABLE ENERGY USAGE GLOBALLY

According to the IEA's Modern renewables report, the growth rate of modern renewable energy exceeds that of energy consumption, which means that the modern renewable energy share of total energy consumption is increasing (IEA 2019, Modern renewables). Many countries have released renewable energy policies, and the IEA has collected these statements to create the Stated Policies Scenario (STEPS). The intention is to provide information on how the currently stated policies would change the energy sector until 2040. (IEA 2019, Stated Policies Scenario.)

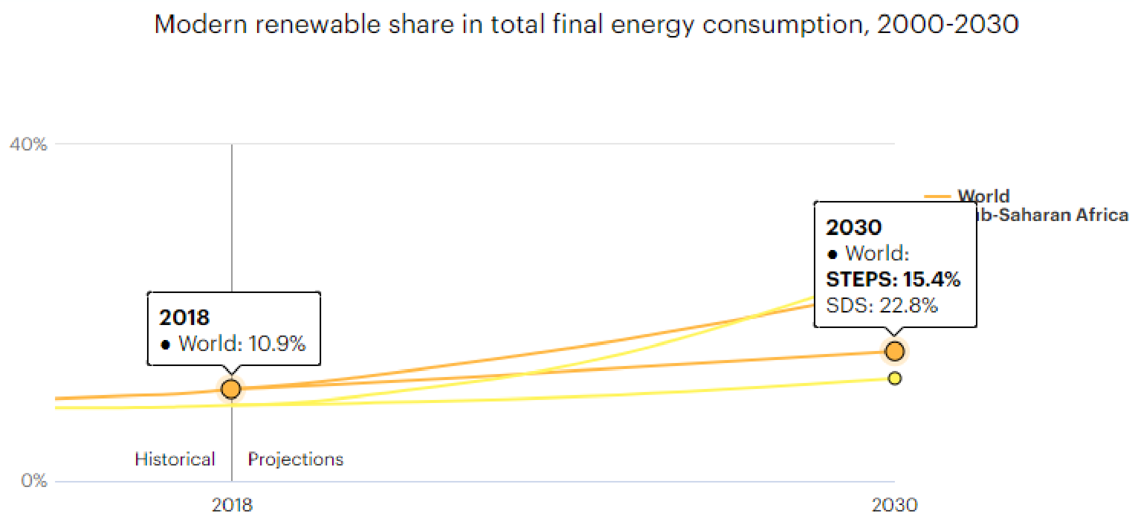


FIGURE 8. Part of modern renewable share in total final energy consumption 2000-2030 (IEA 2019, Modern renewables)

As shown in FIGURE 8, according to STEPS the share of modern renewable energy increases from the 2018 10,9% level to 15,4% in 2030 if global actions are taken according to policies. Because the case company's supply base is global, it can thus be assumed that the case company's suppliers' energy mix will similarly change with emissions decreasing by the same amount (15,4%-10,9% = 4,3%).

11 THESIS RESULTS SUMMARY

This section summarizes the thesis results. There are two main research questions:

1. Does allocating raw material purchasing volumes to lower emissions options cause significant CO2 emissions reductions?
2. Is the selected research approach suitable to study the thesis topic?

Results of testing the hypothesis

This study used a survey to request information from raw material suppliers regarding their energy mix, amount of energy used per product ton and total carbon footprint per product ton. The survey results showed that the reported energy usage figures are not comparable since suppliers included different scopes of production in their response, and most suppliers could not respond to the total carbon footprint question. Only the energy mix figures were analyzed and used to create a weighted average gCO2/kWh index to include all raw materials. Current-state and realistic volume reallocation scenarios were calculated, and their difference represents the received emission reduction: 3,91±4,54%. Although the margin of error is calculated, it does not give a fully realistic level of unreliability since the raw data are weighted twice, first by emission factors and then by purchasing volumes, which causes the results to be more unreliable. This means that significant emissions reductions are not received via realistic raw material purchasing volume reallocations.

Results of evaluating the suitability of the research approach

As stated above, only 1 of 3 sections in the survey yielded useful data, which shows that the selected research approach is not suitable for this topic. The response rate of useful data was also low at 67%. In addition, the calculated index results are not reliable since the raw data are weighted twice. The selected research approach was not suitable to yield useful and reliable data to analyze in further stages. However, the selected approach provided information about the suppliers' awareness of the topic and their energy mixes.

12 DISCUSSION

12.1 Information received from the study

This study's results show that there is a lack of information in the industry since the topic is difficult and is not globally well defined. This was also shown in the suppliers' responses since many did not know their energy mix and they needed to find out before responding to the survey. In addition, many suppliers were not able to respond to the energy usage figures since they had never measured them. Only a few suppliers could provide details about their energy mix and energy usage figures when requested.

The energy usage and total carbon footprint figures could not be further analyzed since it was clear that the received data were not comparable between the observation units. To investigate these figures, definitions are required regarding how to calculate the figures globally in every industry. Such models are currently not available, which makes it difficult to investigate these figures of suppliers.

One way to investigate the total carbon footprint would be to perform an LCA from the emissions perspective, but there is no such global common method. Lifecycle assessment studies are also time consuming, and it would be difficult to require suppliers to perform such studies and inform the results.

Valuable information was received about the case company's raw material suppliers' awareness regarding the studied topics, including that the awareness of their emissions and energy usage significantly differs between suppliers. Some have deeply investigated the topics while some have given them no thought. A couple suppliers stated that other customers have recently asked similar questions, which shows that the topic is becoming increasingly popular and that more information will become available in the future.

12.2 Evaluating the suitability of the research methods to the thesis study

Using a survey for this difficult topic is problematic since the researcher lacks information to appropriately design the survey questionnaire. This can result in the responders being unable to respond to the survey questions and a consequent low response rate, which means the survey results are less reliable than they would be with a high response rate.

This study also showed that when the responders' awareness of the survey topics is not known, too-difficult questions can be asked, which causes the answers' quality to be poor. This means that responders respond to the same question from different perspectives, which makes the collected data incomparable between observation units.

The results show that the two questions about energy usage and total carbon footprint were too difficult and insufficiently defined despite the creation of responding instructions. Such topics should be defined in detail to prevent room for different interpretations. As stated in Section 12.1 however, such models are currently not available, and it would be difficult to define a model to measure the energy usage and total carbon footprint in a comparable manner globally in every industry. Such a model would require so much detailed information that the high "cost" for suppliers to respond would further increase the non-response rate. On the other hand, the results in Section 7.1 show that well-defined instructions are insufficient to enable responses if respondents lack the required data. Therefore, questions regarding the energy usage and total carbon footprint should not be used in this survey. If these topics need to be investigated in greater detail, then other tools and methods need to be selected.

Many suppliers were able to respond to the energy mix question, which was also the best-defined of the three. This shows that this kind of information can be asked in a survey.

The issues regarding responses about energy usage and total carbon footprint also caused problems for the hypothesis since only one out of three main questions could be analyzed. This means that valuable information was not received since this survey is not the best data collection method for these topics. In addition, scheduling the survey research in this thesis was problematic since there were only two months to collect and begin analyzing the responses. This research nonetheless provides valuable information for the case company regarding how to perform survey research on the supply base. This study also yielded valuable information concerning the case company's raw material supply base's overall awareness of the topic.

A survey represents a useful tool for this kind of research given sufficient information about the responders' awareness of the survey topics. In this thesis, the survey would have been more effective if the questions were phrased differently. For example, they could have asked how well respondents are aware of the total carbon footprint of their products and whether they measure their energy usage. Requesting numerical information from responders without knowing their awareness of the topic does not seem to be a suitable method of performing survey research, because the received information depends on how well-informed the responders are regarding the survey topic. This research focused on the numerical data, which caused the research to be quantitative, however the received information could not be fully quantitatively analyzed which caused problems. If the research examines how well the supply base is informed about the topics of energy mix, energy usage and total carbon footprint, then more descriptive and questions could be asked, and the topic could be researched in a qualitative manner.

12.3 Hypothesis of purchasing volume reallocations and CO2 emissions

The results stated in Section 8 show that the hypothesis is partly true. If purchasing volumes are reallocated only to the lowest reported energy mix options, the CO2 emission reductions are significant. This represents an idealistic scenario since dependency on a single supplier would cause too much supply risk and it is not guaranteed that the supplier is able to supply the needed quantities of the raw material.

If the topic is investigated in the more realistic scenario, where purchasing volumes are reallocated to two of the lowest reported emissions energy mixes, the emissions reductions are more conservative. It must be considered that the survey’s margin of error is larger than the calculated emission reductions in this scenario. As stated in Section 9.2, the original data is weighted twice before calculation, which add unknown amount of uncertainty to the results. The emissions reductions in the more realistic scenario are thus small or possibly non-existent.

Before any business actions are taken related to purchasing volume reallocations, it is recommended to study the topic in greater detail to ensure that the emissions reductions are actually achieved. In addition, the SBT-required minimum Scope 3 emissions reductions for the case company are approximately 15%, and if all departments contributing to the scope 3 emissions reduce their emissions this much, then the purchasing volume reallocations will not reach the required level even if the emissions reductions are achieved. Therefore, to reduce the supply base emissions to the required level in a reliable, measurable and systematic manner, other actions need to be utilized.

As stated in Section 10, the current modern renewable policies can globally increase the low carbon energy mix share, including the case company’s supply base. This means that emissions reductions can occur without any actions from the case company. However, this is still insufficient to meet 15% supply base emissions reduction, even with the realistic scenario emission reductions. This emphasizes that the case company should develop other effective actions to reduce the supply base emissions.

12.4 What could be done better?

Performing this survey research with limited starting information was informative for myself and the case company. This section states the points noticed by the researcher that could be improved to achieve more accurate results when performing this type of survey research again.

12.4.1 Research frame

The selected research approach was used to perform quantitative research without knowing how well-informed the responders were regarding the survey questions. This caused problems and could be mitigated for example by performing the research in two stages: The first stage could include qualitative research to investigate the responders' awareness of the topic from different perspectives and the depth of their knowledge. The second stage could include quantitative research to ask only questions that the responders are able to respond to. In addition, the qualitative stage could provide information on how the questions in the quantitative research should be formulated so that the responders understand the questions in the same way. This could increase the quality of the received information.

This would allow the questions to be better defined and easier to respond to, which lowers the responding "cost" to responders. This would result in receiving significantly more information about the responders' awareness of the topics and high-quality data to later analyze during the quantitative stage.

12.4.2 Survey design

Despite the thought invested in creating the survey questionnaire, there is still significant room for improvement. The survey done could be analyzed from qualitative perspective and function as a single-stage research if not performing two-stage research next time. There was not significant starting information, but now there is some to help design the next questionnaire. The two questions about energy usage and total carbon footprint should be omitted since they are too difficult to study with this kind of survey research. The energy mix question provided significant valuable information but could be better defined since there were questions from a couple suppliers. It should be defined regarding whether the research concerns using only electricity or using all energy forms.

12.4.3 Sampling

Successful sampling requires significant planning before beginning. It is recommended to consider the analysis stage when planning the sampling. In statistics, probability sampling is usually desired since it allows calculating the accuracy of the results and making inferences about the population. Simple random sampling represents a common probability sampling method and involves ensuring that each observation unit has equal probability of being chosen into the sample. Simple random sampling:

- defines the population
- defines the desired accuracy level of the research, i.e., margin of error and confidence level
- calculates the required sample size to reach the desired accuracy
- randomly selects the required quantity of observation units

This method ensures that the sample would be randomly selected and is representative of the population according to statistical definitions. In survey research, this is a problematic method to use since it cannot be ensured that the randomly selected observation unit/responder will respond to the survey. However, there are many methods of increasing the response rate and ensuring that the required sample size is reached.

12.4.4 Performing the survey

Performing the survey includes three parts: sending the survey questionnaire to respondents, sending reminders and collecting data.

Sending the survey questionnaire

Several approaches to sending the questionnaire were used in this thesis, such as having the category managers send the survey to their suppliers to grant business importance to the survey, sending the survey to the latest contact details available, creating a survey cover letter, performing reminder rounds, etc. There are nonetheless additional actions that can be taken:

- This study's survey showed that email is not the best platform for sending the questionnaire since it is difficult to establish who has or has not answered. It would thus be better to use a popular internet survey platform such as SurveyMonkey to conduct the survey.
- When the information about responders and non-responders is available, it is easier to send a reminder to non-responders. Sending reminders is crucial when conducting surveys nowadays since people so busy they receive many surveys, to where one survey becomes easily forgotten or buried by other emails. Performing several reminder rounds can significantly affect the response rate. It is therefore important to reserve time to perform several reminder rounds, which need to be planned when designing the survey.
    - The reminders can be performed using forms of communication other than the survey portal, such as by calling non-responders. This could bypass the issue that the responders might not be available via the original survey-sending communication method.
    - The category managers could also be instructed to remind the suppliers to respond every time they are in contact. This makes the suppliers understand that the topic is important to the category manager (i.e., business decision maker) which, according to social exchange theory, creates a feeling that some reward will be received in the future by responding to the survey.
- According to social exchange theory, people think about the "cost" and "reward" when deciding whether to respond to a survey. This should be considered while designing the survey from the responders' perspective to ensure that the reward exceeds the cost. A direct incentive for the responders could be created, or it could be highlighted that responding to the survey is highly appreciated, which gives the responder the feeling that some future reward will be received. One "reward" would be to explain how much responders benefit if they investigate the issue in their company and thereby become more aware of the trending topic and more ready to respond to similar surveys from other customers. An increasing number of companies are joining the SBT initiative, which makes it probable that companies will receive many similar surveys in the future.

- The survey cover page should state how the research data will be used and that they will be treated confidentially, because the response threshold is lower when the supplier is unsure about whether their data is confidential. A pre-signed Non-Disclosure Agreement specific to the survey could also be created so that suppliers would be sure that the data are handled confidentially.

12.5 New research ideas

Volume reallocations also impact total raw material costs. This was also calculated during the study and showed a significant cost increase if the volumes are purely reallocated to lower emissions options without considering other business perspectives. The CO2 emissions reductions achieved via purchasing volume reallocations were rather small and the margin of error of this study exceeds the achieved results, and therefore it is recommended to further investigate the topic before performing any actions.

If the topic is studied in the future with only the energy mix, the supply base CO2 emissions could be reduced by pushing suppliers to use “greener” energy in their operations. More environmentally friendly energies cost more and are unavailable in some countries, but it would be interesting to study how much CO2 emissions would be yielded by such actions and whether there be direct cost effects on raw material prices.

12.6 Final verdict

This thesis yielded significant information about the case company’s supply base awareness regarding their energy usage and related emissions. This thesis did not achieve concrete results about the purchasing volume reallocations’ effect on the raw material suppliers’ emissions, but it provided information that the topic is not simple, and that further research is needed.

In the case company's industry, many companies use the same raw material suppliers and therefore the results can be somewhat useful for other companies investigating the same topic. This thesis provides information regarding how this topic in the case company's industry can and cannot be studied.

For the case company, the most important results from this thesis are that the current supply base is not well informed about their energy usage and emissions. It is also clear that the realistic purchasing volume reallocations are insufficient to reach the intended 15% supply base emissions reduction target. Although the world is changing and the usage of low emissions energy is predicted to increase, it is uncertain whether the predictions will be realized and whether they will be sufficient to reach the 15% target level.

The results in Section 9.4 provide information about the energy mixes of the case company's raw material supply base. The most useful results are that only a few percent of the items are manufactured with fully CO2-free energy mixes, while around 50% of the items are manufactured with energy mixes of partly CO2-free energy sources. This shows that in 50% of cases, the low carbon energy sources are available but are not used, probably because the other energy sources are cheaper. This shows that there is significant potential to improve the supply base energy mixes to include additional CO2-free energy sources.

12.7 What to do next/follow-up measures

If the gCO2/kWh index is used to monitor the emissions reductions in the supply base, similar surveys need to be performed yearly or bi-yearly and their index results compared to the results of this thesis. To achieve decreasing emissions in follow-up studies, some concrete actions are needed to make the supply base energy usage greener. It is up to the case company to select the suitable corrective actions to implement with the supply base. The case company is already planning a more detailed and larger project regarding the topic based on the information received from this thesis.

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APPENDICES

Appendix 1. Supplier CO2 & Energy usage questionnaire

1 (2)

Supplier CO2 Emission & Energy usage Questionnaire

How to fill in information:

All responses to be filled in Product sheets below. Please fill in information of all the products your company is currently supplying to any of [redacted] plants. One product per one Product sheet.

Basic information	Final product name / trade name [redacted] R-code Location where the product is produced
Energy mix	Energy mix means what type of energy is used to produce the product in your plant. There is to be informed percentage how much each energy production type is used. There is a calculator below the green fields to help to have the total sum 100%
Energy usage	If your company has calculated how much energy is used to produce **one ton** of final product in your plant, please fill in per product in Product sheets. Values should be in **kWh**.
Total carbon footprint	If your company has calculated the total carbon footprint per ton of final product (CO2), please fill in per product in Product sheets.

Definitions for energy mix:

Coal	Coal includes primary and secondary coal, and coal gases. Peat and oil shale have also been aggregated with coal.
Oil	Oil includes oil products and crude oil.
Gas	Gas represents natural gas.
Non-Renewable wastes	Non-renewable wastes includes industrial waste and non-renewable municipal waste.
Biofuels	Biofuels includes both biofuels and renewable wastes.
Nuclear, Water, Wind	All different types to produce energy from nuclear, water and wind methods = considered as 0 CO2 emissions

Supplier CO2 Emission & Energy usage Questionnaire

Please fill in the green fields.

Product name:	
[redacted] R-code:	
Production country location:	

Energy mix used in production	Coal		% of total
	Oil		% of total
	Gas		% of total
	Non-renewable wastes		% of total
	Biofuels		% of total
	Nuclear, Water, Wind		% of total
	Total sum	0	%

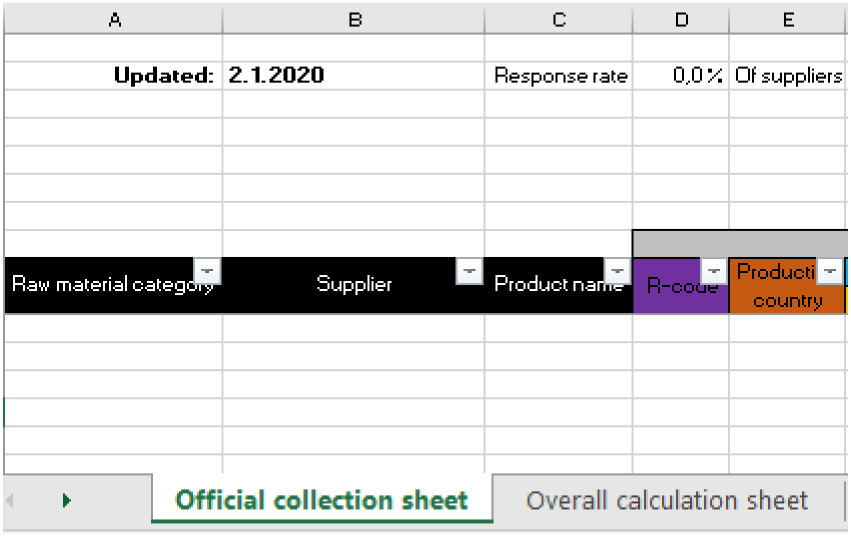
Total energy usage per ton of final product (kWh):	

Total carbon footprint per ton of final product (CO2):	

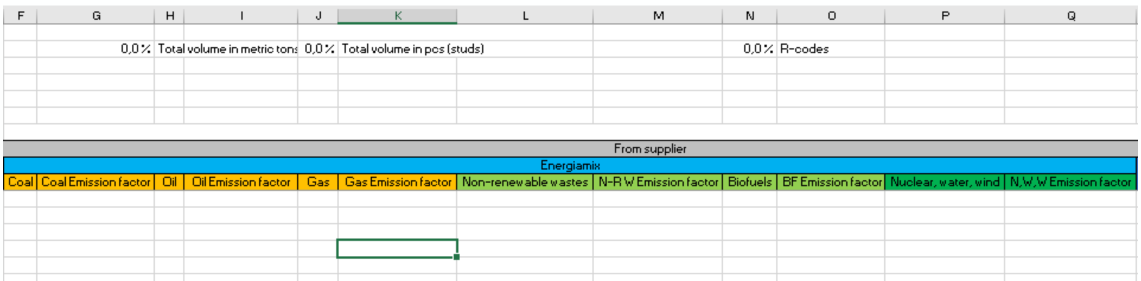
Appendix 2. Survey response recording and results calculation excel

1 (2)

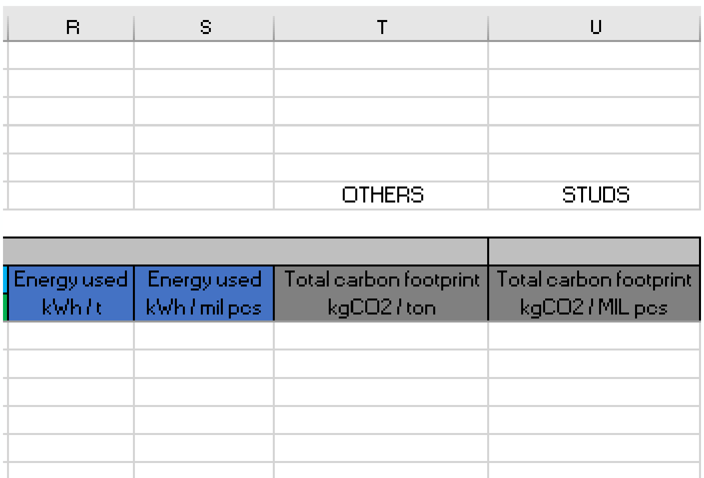
A-E



F-Q



R-U



V-AE

V	X	Y	Z	AB	AC	AD	AE
Calculations							
Total energy gCO2 per	Total energy tonCO2 per product ton	Total energy gCO2 per MIL pcs	Total Energy tonCO2 per MIL pcs	Purchased volume 2018 in tons	Purchased volume 2018 in MIL pcs	Total energy tonCO2 for 2018	Comment