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Organisational LCA (O-LCA) for activities in the Norwegian Defence sector

Håvard Gustafson Jacobsen

Master in Industrial Ecology
Submission date: August 2017
Supervisor: Magnus Sparrevik, IØT
Co-supervisor: Jon Halfdanarson, IØT
Annik Magerholm Fet, IØT

Norwegian University of Science and Technology
Department of Industrial Economics and Technology Management

Problem Description

Organisational LCA (O-LCA) is a compilation and evaluation of the inputs, outputs and potential environmental impacts of the activities associated with the organisation adopting a life cycle perspective (appendix A). By conducting an organisational LCA these indirect assets will be included in the assessment of the organisation's environmental impact. The thesis shall be a case study with the aim to quantify the environmental impacts of the Norwegian Defence sector from a life cycle perspective. In order to not be too comprehensive and avoid security clearance, procurement of military equipment is omitted. LCA tools as Gabi or SimaPro using Ecoinvent inventory database shall be used to calculate impact for the selected input and output streams. The thesis shall also conclude on recommendations for improvements.

The following tasks are will be considered:

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2. Quantify the greenhouse gas emissions in a life cycle perspective (Scope 1-3). A hybrid LCA methodology using both process- and economic data to be used
3. Evaluate the results in light of the placement in the life cycle (production, use or disposal)
4. Discuss the main findings of your work and how these agree with or add to what is available in literature. Discuss strengths and weaknesses in your work, and the main practical/methodological implications, together with recommendations and aspects to follow-up on in later research.

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This Agreement confirms that the topic for the MSc thesisis approved, the supervisory issues are agreed and the parties to this Agreement (student, supervisor and department) understand and accept the guidelines for MSc theses. This Agreement is also subject to Norwegian law, the examination regulations at NTNU, the supplementary provisions and the regulations for the MSc Engineering Education programme.

1. Personal information

Family name, first name: **Jacobsen, Håvard Gustafson**	Date of birth **May 24, 1984**
Email address **haavardgjacobsen@gmail.com**	Phone **98051655**

2. Department and programme of study

Faculty **Faculty of Engineering**	
Department **Department of Energy and Process Engineering**	
Programme of study **Master in Industrial Ecology**	Specialization **Environmental Systems Analysis**

3. Duration of agreement

Starting date **March 7, 2017**	Submission deadline* **August 1, 2017**
If part-time study is approved, state percentage:	

** Including 1 week extra for Easter*

All supervision must be completed within the duration of the agreement.

4. Thesis working title

Organizational LCA (O-LCA) for activities in the Norwegian defence sector

5. Supervision

Supervisor **Magnus Sparrevik**
Co-supervisors: **Jon Halfdanarson** (IØT), **Annik Magerholm Fet** (IØT)

Standardized supervision time is **25 hours** for 30 credits (siv.ing) and **50 hours** for 60 credits (MST) theses.

6. Thematic description

Background and objective

Over the past several years The Defence Research Institute (FFI) have prepared an environmental report of the activities in the Norwegian defence sector. See http://www.ffi.no/no/Rapporter/16-00909.pdf. The emission of greenhouse gases is determined in accordance to requirements in the ISO 14064 Greenhouse gas protocol. The account includes all direct activities as use of fossil fuels, emissions from energy and electricity use and emissions from work travels. Emissions from indirect upstream and downstream activities is not included. For a large organization such as the military, these outputs may be a substantial part of the overall environmental impact.

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7. Other Agreements

Supplementary agreement	**Yes**
Approval required (REK, NSD)	**Not applicable**
Risk assessment (HES) done	**Not applicable**
Comments: * Main supervisor is Magnus Sparrevik, ~~but since he is not listen in the system, Annik Magerholm Fet has been listed as the supervisor. Magnus Sparrevik is the supervisor, while~~ Annik Magerholm Fet and Jon Halfdanarson are both cosupervisors for this master thesis.	

Appendix (list)

Supplementary agreement.

8. Signatures

Conditions	Date	Signatures
I have read and accept the guidelines for MSc theses		Student
I take the responsibility for the supervision of the student in accordance with the guidelines or MSc theses		Supervisor
I take the responsibility for the co-supervision of the student in accordance with the guidelines for MSc theses		Co-supervisors
Department/Faculty approves the plan for the MSc thesis		Department/Faculty

Preface

This master thesis is the last and final work requirement for the Industrial Ecology international master of science program (IndEcol), written for the Department of Industrial Economics and Technology Management (IØT), at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway.

The reason for why I chose to write the thesis on Organisational Life Cycle Assessment (O-LCA) is a strong belief of mine that this topic will become increasingly more important in the future. Organisations will put more efforts into reducing their own carbon footprints, due to legislations, public image, increased environmentally responsible behaviour and so on. O-LCA will be a very lucid method for this work, and therefore I want to learn more about O-LCA, and how to conduct one.

First and foremost, I would like to offer my sincere gratitude to my supervisor, Magnus Sparrevik, who has provided guidance, feedbacks and support like none other. His commitment to this work exceeded my expectations by far, and it has been an exciting and meaningful collaboration.

Furthermore, I would also like to thank Simon Utstøl at FFI, who were a truly easygoing person that provided me with everything I asked for, and more. Data, guidance, patience and engagement came easily to him.

I would like to acknowledge everyone that contributed somehow to my work, in any form. Fellow students at IndEcol that were eager to participate in the discussions, reflects their opinions and share their wisdom. Family and friends (thank you, Ingrid!) that had to sit through my ramblings, and the Norwegian Defence Estate Agency for requesting an O-LCA for the Norwegian Defence sector.

Trondheim 01.08.2017

Håvard Jacobsen

Summary

Over the past several years, The Defence Research Institute (FFI) has prepared annual environmental reports of the activities in the Norwegian Defence sector, for tracking environmental performances. As a continuous step towards this work, the Norwegian Defence sector has expressed the need for conducting an organisational life cycle assessment (O-LCA). An O-LCA includes the indirect greenhouse gas (GHG) emissions for which the environmental report does not, yielding the total carbon footprint (CF) of the organisation.

The O-LCA was conducted for day-to-day operations, using a hybrid LCA approach, by means of both process and economic data. The process data were collected from the environmental report of 2016, while the economic data was collected from Direktoratet for Økonomistyring. The tool SimaPro were used to calculate the process emissions, whereas emissions factors produced by Asplan Viak was used to calculate the economic emissions.

The CF of the process emissions amounted to 421 000 tonnes CO_2-eq, and the economic emissions deduced from the day-to-day operation procurements of 15,4 billion NOKs, accumulated to 379 000 tonnes CO_2-eq. The total carbon footprint of the Norwegian Defence sector for 2016 sums up to 800 000 tonnes CO_2-eq. The largest contribution (44 % of total CF) stems from transportation related activities, while building and construction is the second largest (25 % of total CF).

The total CF is broken down into scope emissions, which dictates direct and indirect categorisation of emissions. Scope 1, Scope 2 and Scope 3 contributed 30 %, 3 % and 67 %, respectably, giving direct emissions a 30 % share, while indirect a 70 % share of the total CF.

Environmental hotpots for the organisation has been identified and presented, giving a good starting point for further research. Recommendations has been given for further work on each one of the hotspots, though it should be noted that these are just suggestions, not guidance.

Norwegian Summary

Forsvarets forskningsinstitutt (FFI) har over flere år produsert og publisert miljø- og klimarapporter over aktiviteter tilknyttet forsvarssektoren til måling av miljøprestasjoner. Som en videreføring av dette arbeidet på miljøfokus, har de nå ytret et ønske og behov for å få utført en organisatorisk livssyklusanalyse (O-LCA). En O-LCA inkluderer de indirekte drivhusgassutslippene, noe miljø- og klimarapportene ikke har gjort. Med de indirekte drivhusgassutslippene vil man kunne se det totale klimafotavtrykket forårsaket av organisasjonen.

Parameterne for O-LCAen er dagligdagse operasjoner og bruk av en hybrid LCA tilnærming, som benytter prosessdata og økonomiske data. Prosessdataen som ble benyttet stammet fra miljø- og klimarapporten for 2016, mens de økonomiske tabellene kom fra Direktoratet for Økonomistyring. Verktøyet SimaPro ble benyttet til å regne ut utslippene for prosess-analysen. For den økonomiske analysen ble utslippsfaktorer produsert av Asplan Viak brukt til å beregne utslippene.

Klimafotavtrykket for prosessbidraget ble beregnet til 421 000 tonn CO_2-eq, mens bidraget fra den økonomiske biten, som utgjorde innkjøp for 15,4 milliarder NOK, ble beregnet til 379 000 tonn CO_2-eq. Organisasjonens totale klimafotavtrykk endte på 800 000 tonn CO_2-eq. Det største bidraget (44 % av det totale klimafotavtrykket) stammer fra transport relaterte aktiviteter, mens det nest største (25 % av det totale klimafotavtrykket) kommer fra bygg, eiendom og anlegg.

Det totale klimafotavtrykket er fordelt mellom «scope» utslipp, noe som dikterer kategorisering av direkte og indirekte utslipp. Scope 1, Scope 2 og Scope 3 har hver et bidrag på 30 %, 3 % og 67 % av det totale. Dette gir direktebidrag en andel på 30 % og indirekte bidrag en andel på 70 %, av det totale klimafotavtrykket.

Såkalte «hotspots» for organisasjonen er blitt avdekket og presentert, noe som gir et godt utgangspunkt for videre arbeid. Anbefalinger er gitt for hver en av disse miljømessige berøringspunktene (hotspots), dog det skal sies at disse er kun forslag, ikke konkrete punkter som skal følges opp.

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Abbreviation

Abbreviation	Description
CF	Carbon Footprint
CH_4	Carbon tetrahydride, commonly referred to as methane
CO_2	Carbon Dioxide
CO_2-eq	Carbon Dioxide Equivalent
EE-IOA	Environmentally-Extended Input Output Analysis
EMAS	Eco-Management and Audit Scheme
EMS	Environmental management system

EPD	Environmental product declaration
FD	Forsvarsdepartementet – The Defence Department
FFI	Forsvarets Forsknings Institutt - The Defence Research Institute
FU	Functional Unit
g	Grams
GHG	Greenhouse Gas
GWP	Global Warming Potential
IndEcol	Industrial Ecology Program
IOA	Input-Output Analysis
ISO	International Organization for Standardization
IØT	Institutt for industriell økonomi og teknologiledelse - Department of Industrial Economics and Technology Management
kg	Kilogram
kWh	Kilowatt-hour
LCA	Life cycle assessment
LCC	Life cycle cost
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCM	Life Cycle Management
LCT	Life Cycle Thinking
MDB	Miljødatabase – Environmental data base
MFA	Material Flow Analysis
N2O	Nitrous Oxide
NTNU	Norges teknisk-naturvitenskapelige universitet - Norwegian University of Science and Technology
O-LCA	Organisational life cycle assessment
t	Metric tons

1 Introduction

One of the major challenges the world is facing today, is global warming. It is a very complex situation, where emissions and pollution connected with production and consumption of goods and services[1] far exceeds what is environmentally sustainable. Resources are being depleted, toxic emissions are contaminating the ground, water and air, and emissions are causing harm/change to the ground surface, ocean PH-value, ozone layer, atmosphere and the very air one is breathing (Stocker et al., 2013).

During the Paris Climate Change Conference in 2015, world leaders agreed to limit the increase of global warming to 1.5°C above pre-industrial levels (Phillips, 2015, The Directorate-General for Climate Action, 2016). To reach this target, the nations of the world need to take drastic steps and immediate action to reduce the environmental strain it is currently causing. The core changes need to focus on a more sustainable production and consumption of current goods and services that are on demand, e.g. cleaner and more renewable production methods, less waste generation, and reduced emissions connected with transport (Edenhofer et al., 2014).

Big, medium and small companies are both producing and consuming goods and services, and thus have a great potential for reducing the environmental impact through focusing on a more sustainable production and consumption within themselves.

For an organisation, such as the Norwegian Defence sector, the impacts caused throughout the value chain will be considerable. Therefore, by looking into what the organisations are directly- and indirectly causing of environmental emissions, potential hotspots can be discovered, which can work as focus areas for the organisation that wish to reduce the environmental strain it is causing.

1.1 Background

The Norwegian defence sector consists of six departments, which are structured in a hierarchical structure, with The Royal Norwegian Ministry of Defence at the top and the remaining five agencies underneath; The Norwegian Armed Forces, The Norwegian Defence Estates Agency, The Norwegian Defence and Research Establishment, The Norwegian Defence materials and The National Security Authority of Norway. The Norwegian defence sector has a total of approximately 28 000 employees, which makes it a big "organisation", and thus a big potential emitter of emissions and pollutions that can cause environmental impacts. Figure 1.1 illustrates the Norwegian defence sector and the structure of it, and how the drawn system boundary defines it to be one system (NSD, 2016, DSS, 2016).

As an organisation, the Norwegian defence sector consumes goods and services on a very large scale. Waste, ammunition, water consumption, chemicals, energy use for military vehicles, airplanes, ships and boats, energy use for buildings and so on. The acquisitions of these goods and services should be focused on, possibly finding and obtaining products that are better for the environment.

For the Norwegian Defence sector, sustainable procurement is now required by law. In 2016 a law on public procurement were put in effect. Its purpose is to facilitate a more sustainable use of the society's resource, through *green* public procurement, meaning a more environmental friendly procurement (Anskaffelsesloven, 2016). One way to make sure that

[1] Goods and services in this thesis are in accordance with the ISO 14044 definition (ISO, 2006)

the procurement is more environmental friendly is by acquire products that are causing less environmental impacts. Products that can offer certified Eco-labelling (GEN, 2017) are causing less strain to the environment, and should therefore be preferred. In addition, companies with certifications are often more environmental friendly than those without, making their products more environmentally friendly. Another aspect is the certificates of products, such as Environmental Product Declaration (EPD).

This focus on the supply chain also facilitates a higher interest for the value chain of an organisation, as acquiring knowledge about better supply chain alternatives often provides information about better alternatives on a value chain perspective. For an organisation, such as the Norwegian Defence sector, the gate-to-gate approach of the value chain - meaning what goes in and out of the organisation, is a good way to get a good and transparent picture of the organisations carbon footprint.

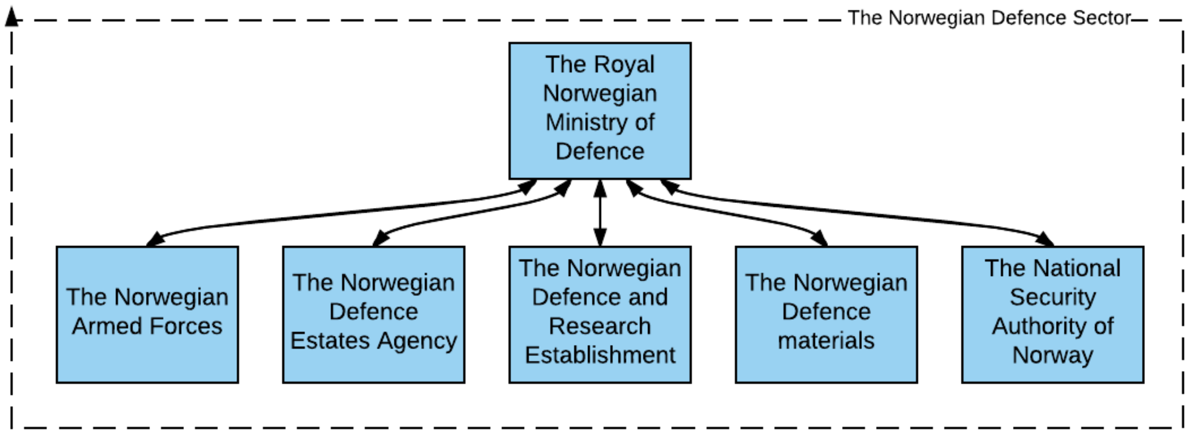

Figure 1.1 Illustrates the 6 departments making up the Norwegian defence sector

The Defence Research Institute has published environmental reports for several years now, containing information about the activities connected with the Norwegian defence sector. These reports look into the direct emissions connected with sources owned or controlled by the organisation, where the aim has been to find potential for reduction of waste, pollution and emissions, as well as efficiency improvements wherever they can be made (Protocol, 2012, Utstøl et al., 2017)

By producing yearly environmental reports, the Norwegian defence sector can present and assess the environmental data, and make comparisons against previous years, as a step for continuous improvements. The Norwegian defence sector has expressed the need for an organisational life cycle assessment (O-LCA), as a continuance to these reports.

By conducting an O-LCA on the Norwegian Defence sector, the organisation can get a much clearer picture of the total amount of emissions caused, directly and indirectly. So far, the annually environmental reports have reported on the direct GHG emissions, indirect GHG emissions from energy production and a few indirect emissions related to work travels. For a large organisation, such as the military, these indirect emissions could make up a substantial part of the overall environmental impact.

In this thesis, the Scope 3[2] emissions will be those related to the day-to-day operations for the sector, giving a transparent overview over emissions caused by the sector. As a natural

[2] Indirect emissions found in upstream and downstream of the organisations value chain. Scope emissions will be addressed in methodology.

continuous to the already existing reports, which is what the sector wants, the thesis' focus will be on the carbon dioxide equivalents (CO_2-eq)[3], also referred to as the carbon footprint. This will allow the sector a much higher resolution on the caused CO_2-eq emissions, and a natural step further in the work on reducing the total carbon footprint of the organisation.

The year 2016 will be the time period for the study, and the physical and monetary inputs and outputs will be presented separate from each other, as the physical aspect is of a much higher resolution than the monetary. The physical data stems from the 2016 environmental report mentioned above, while the monetary (~15,4 billion NOK) stems from publicly available data, *rådata for årsregnskapet 2016*, published by the Directorate of Financial Governing (Direktoratet for økonomistyring, 2017). However, for the Norwegian Defence materials (FMA), the data originate from classified data, which has been declassified and made available. FMA will be included into the yearly reporting from 2017 and onwards. At the end, the physical- and monetary input-output will be combined and presented as one, yielding the total carbon footprint caused by the organisation.

1.2 Goal and Scope

Organisational LCA (O-LCA) is a compilation and evaluation of the inputs, outputs and potential environmental impacts of the activities associated with the organisation adopting a life cycle perspective (appendix A). By conducting an organisational LCA these indirect assets will be included in the assessment of the organisation's environmental impact. The thesis shall be a case study with the aim to quantify the environmental impacts of the Norwegian Defence sector from a life cycle perspective. In order not to be too comprehensive and avoid security clearance, procurement of military equipment is omitted. The LCA tool SimaPro using Ecoinvent inventory database shall be used to calculate impact for the selected input and output streams. The thesis shall also conclude on recommendations for improvements.

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1.3 Case and Limitations

The Norwegian defence sector, which like any other military organisation, operates with classified and none-classified information. All the information regarding the value chain of the organisation must be collected from the different departments. The supervisors from the

[3] CO_2-eq measures the long term global warming potential (GWP100) EPA. 2017. *Understanding Global Warming Potentials* [Online]. Available: https://www.epa.gov/ghgemissions/understanding-global-warming-potentials [Accessed 03.07 2017].

Norwegian defence sector will operate as contact persons for the information requested for this thesis. The information that will be collected is information about the procurement and investment for daily operations, not procured military equipment.

The classified information about the procurement will have to be declassified, because it will be «open» and available to the public. This will cause the information to be less accurate due to less accurate data, as some data on individual levels must be bulked together and presented as a mixed group, as a mean to use classified information. This will result in less accurate data as the calculations will be done with average value of the group, rather than individual level calculation.

Some data will not be provided due to the nature of secrecy, and it could therefore be necessary to make assumptions of some of the inputs or outputs based on the information available. As there exists no complete "map" of the entire value chain, it will be too comprehensive to map it all the way back to the source in a paper of this size. The focus will therefore be on a gate-to-gate approach, yielding a value chain consisting of the upstream suppliers delivering the goods and services to the gate (the Norwegian defence sector) and the downstream activities connected with the goods and services leaving the gate, such as waste. The result of this approach is a less accurate O-LCA for further work, as it only examines emission connected to what goes in and out of the organisation.

1.4 Structure of the thesis

The structure of this thesis is divided into four main parts; introduction, theory and methodology, results and discussion, and recommendations.

Part 1	Introduction (Chapter 1) presents the background on today's environmental challenges, the Norwegian Defence sector, the goal and scope and limitations for this master thesis.
Part 2	Theory and methodology (Chapter 2 and 3) presents the general theory related to the research question, as well as present the methodology which applies to solving the research questions.
Part 3	Results and discussion (Chapter 4) presents and discuss the findings for the physical (process) and monetary (economic) analysis, for which constitutes the O-LCA. Moreover, it presents a sensitivity analysis for the thesis.
Part 4	Recommendations (Chapter 6) presents propositions that may reduce the carbon footprint of the hotspots.

2 Theory

2.1 O-LCA

Like life cycle assessment (LCA, also referred to as *product LCA*), O-LCA aims to identify and quantify the environmental impacts caused by the target of study. It follows the same four-step methodology (figure 2.1) as product LCA, and requires clear definitions, reference unit, defined system boundary, a lot of data with high resolution, allocation procedures, identification of hotspots, etc. O-LCA and LCA are complementary tools that answer different questions. While LCA is used on singular products to answer environmental performance, O-LCA looks at the entire value chain of an organisation, on a much less in-depth way. It provides, for instance, information about the environmental hotspots for the organisation, which the product LCA can be used to assess environmental performance and reductions. If all the products of the organisation were to undergo LCA, or a high enough amount to be representative, with supporting activities accounted for, then the LCAs could serve as an O-LCA. With allocation, a reverse O-LCA to LCA could be presented.

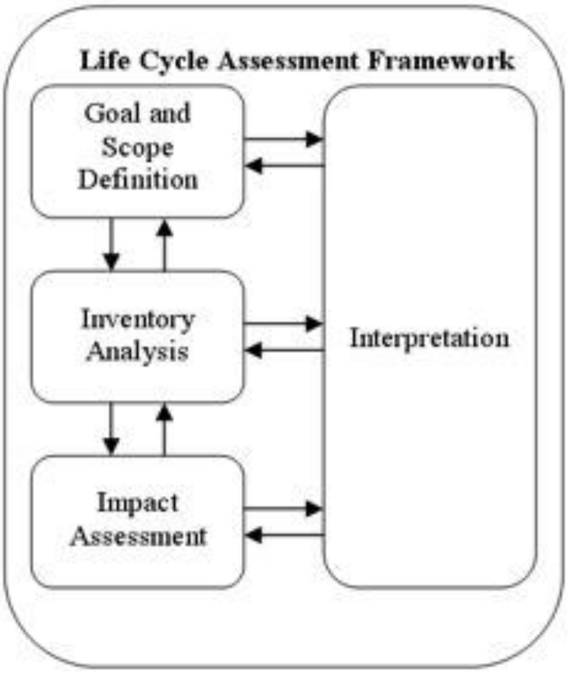

Figure 2.1 illustrates the four steps of LCA (UNEP, 2003)

An O-LCA is an assessment of the environmental performance of the entire value chain of the organisation. The assessment needs to look at the organisation's value chain, as well as the supplier's value chain. All direct and indirect emissions need to be accounted for and then allocated correctly. The result of the O-LCA will show the environmental impact caused by the organisation, where hotspots indicate areas of which the organisation may focus their environmental efforts. The O-LCA is not for comparison between organisations, as each organisation is unique in the structure and value chain. The results could be used to measure the performance over an annual basis, if the organisation takes into account possible alterations.

There are three different kinds of groups that consist of goals for conducting an O-LCA. Martinez-Blanco (Martínez-Blanco et al., 2015) describes these as analytical goals, managerial goals and societal goals. Figure 2.2 illustrates these three groups and the corresponding goals. The analytical group has the following goals: insight in internal operations and value chain, identify environmental hotpots, understanding risk and impact reduction opportunities, and track environmental performance. These are the goals that the Norwegian Defence sector wishes to have answered, with special emphasis on identifying environmental hotspots. This group is perhaps the most sought after group for organisations with high environmental focus.

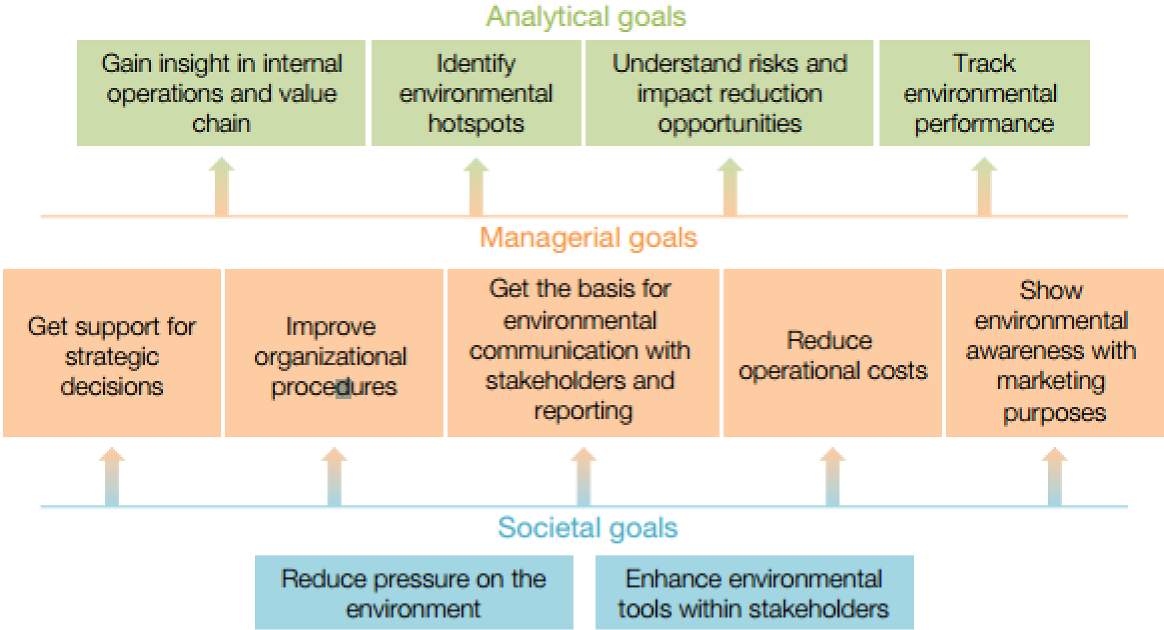

Figure 2.2 Layers of potential goals of an organisation (Martínez-Blanco et al., 2015).

What is also worth noting is the approach an O-LCA takes. For instance, product LCA has a bottom-up approach, were all inputs and emissions need to be collected for all processes related to the product. This approach is very detailed and takes a lot of time and effort. For O-LCA, which rely on environmentally extended input-output analysis (EE-IOT)[4], uses a more top-down approach. The reason for this is related to the national input-output statistics, which requires "digging" for higher resolution. The top-down approach also allows for a better and more complete map of value chain, as the bottom-up approach often is limited by the large effort required by the systematic tracing of the inputs and outputs of the product, and the cut-off parameters set. In fact, Manfred Lenzen (Lenzen, 2000) estimated that the bottom-up approach overlook up to 50 % of the related emissions, giving the assumption of a less accurate method for a total carbon footprint calculation .

An O-LCA can be a combination of a bottom-up and a top-down approach. By combining the more complete approach of top-down with the higher resolution of bottom-up, the result can offer far more accurate emissions data for the organisation. Bo P. Widema explores and presents the advantages of this approach, and concludes:

> *"By integrating the two data sources in one database approach, it is possible to ensure completeness while still providing the necessary detail in process modelling."*

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[4] Input-output analysis is an analytic tool for economic transactions, and by extending it with environmental data, we get EE-IOT. Presented in the methodology chapter

(WEIDEMA, 2003)

This gives the integrated method precedence for being the most fit method for such a calculation. By combining the strengths of product LCA and EE-IOA, the most accurate O-LCA can be conducted and presented.

The life cycle institute[5] has published a guideline on how to conduct an O-LCA (Martínez-Blanco et al., 2015) that is a more explanatory and detailed document than the ISO/TS 14072, from which it strives to align with. It provides additional information and examples for the set framework in the ISO 14072, thus providing a better view of the capabilities and applicability for an O-LCA. This guideline combines the top-down with the bottom-up method.

[5] The life cycle initiative is hosted by the UN Environment, and are a global forum for experts and users of life cycle approaches.

3 Methodology

This chapter will address the methodology used for answering the research questions stated in chapter *1.2 Goal and Scope*.

As this thesis aims to use a hybrid LCA to calculate the total carbon footprint of the Norwegian Defence sector, using both process and economic data, the inventory analysis requires the application of several methods. The process data originates from *Forsvarets miljø- og klimarapport for 2016*, where the reported flows make up the process foundation. For the economic data, the data needs to be available for the public and of high resolution, which is something the Directorate of Financial Governing offer through raw data for the annual accounts 2016. More detailed information about the methods used are found in Appendix D.

3.1 Total carbon footprint

The total carbon footprint is defined as the total sum of greenhouse gas (GHG) emissions triggered by an individual, event, organisation or a product, expressed as carbon dioxide equivalent (CO_2-eq). A carbon footprint consists of direct and indirect emissions. Direct emissions are emissions one is causing directly at a given time and place. Indirect emissions are caused somewhere else, by someone else, due to the goods and/or service one is consuming.

The GHG Protocol (Protocol, 2012, Boles) classifies the carbon footprint into 3 scopes, which are:

Scope 1: Direct GHG emissions
Emissions from sources that are owned or controlled by the organisation. Examples are fossil fuel GHG emissions from heat/electricity production, fossil fuel GHG emissions from use of mobile transportation.

Scope 2: Energy Indirect GHG emissions
Emissions from the purchased electricity, heat or cooling. The emissions occur at the producing facility, upstream of the organisation.

Scope 3: All other indirect GHG emissions
Emissions that are a consequence of the activities of an organisation, but befall from sources not directly owned or controlled by the organisation. Examples of Scope 3 activities are: extraction and productions of purchased goods, third-party transportation, work related travels, emissions from the use of sold products, outsourced activities and waste disposal (Boles, Hogne Nersund Larsen et al., 2016).

Literature research on O-LCA reveals typical shares of Scope 1 and 2 to be 26 %, on average, for the total organisation's carbon footprint, while the Scope 3 emissions average around 74 % of the total carbon footprint (Matthews et al., 2008, Huang et al., 2009). This emphasise the share of contributions Scope 3 emissions have on the organisation's carbon footprint, as it is evident that Scope 3 emissions are by far the largest contributor to the carbon footprint of an organisation.

The separations of direct and indirect emissions into three *Scopes* are done to avoid double-counting of emissions. It also helps to show what can be controlled directly, which are the direct emissions of Scope 1, and what can be influenced in various degrees - Scope 2 and 3.

3.2 Methodology for the physical analysis

The collection of process data was managed by using Material Flow Analysis (MFA), an analytic method for quantifying flows and stocks, as it gives a transparent overview over the stocks and flows. The reported values in the environmental report for 2016 were gathered by reading the report and copying the numbers into excel. Additionally, more detailed data were collected on a product level basis, in order to calculate the contributions for each process making up a flow, which where done by inquires.

After each process were accounted for, the LCA-tool SimaPro was used to calculate the GHG contributions of each process. The reason for why SimaPro were used instead of GaBi or any other LCA software, was because of previous experience with it, and program license issues. For the 8 categories that constitutes the physical analysis, approximately 300 processes were calculated using the SimaPro tool. Some processes did not need to be altered at all, as the processes available in SimaPro were of a near perfect fit, while some others needed to be altered to fit the intended comparison better. The alteration was done by changing some background processes (e.g. from EU mix electricity to Norwegian mix electricity) so it better matched the Norwegian Defence sector's product.

After the contribution data was collected, the analysis began. Each process had contributions to production, use-phase and some end-of-life (EoL). The separation of direct and indirect contributions was conducted by

- Calculation contributions for the background processes, then subtracting the production processes from the in-use processes
- Calculating only *at market* (product at store, ready to be bought) for processes with precalculated use-phase emissions

For the category, *Cars & transportation*, vehicle processes had to have lifetime assumption made, in order to allocate the production emissions. Each vehicle, aircraft and/or sea vessel has had the production emissions divided by life time of the given unit, thus giving the contribution for year 2016.

After the emissions where separated into production, use-phase and EoL for each category, the *Cars & transport* category was merged with the *Fuel* category, in order to present the direct and indirect emissions related to fossil fuel combustion for the mobile fleet of the Norwegian Defence sector. The mobile fleet was then divided into the three groups of vehicles, ships and aircraft.

In the results, the interpretations were done by measuring the emissions in regards to *life cycle stage* contributions and direct and indirect emissions.

3.3 Methodology for the monetary analysis

The economic data was collected from The Directorate of Financial Governing's *Rådata for årsregnskapet 2016*, as it is publicly available and offers a high resolution. This data source offers data for the entire governmental sector, presented in procurement categories (codes). In addition, for the Norwegian Defence materials (an agency as of year 2016) data was collected by means of contact person, and put in the same procurement categories as the rest of the Norwegian Defence sector.

After isolating the data for The Norwegian Defence sector, there were 146 procurement categories connected with daily operations. After removing all none-emissions categories, there were 87 categories left. These 87 procurement categories were all represented by the generic emissions factors published in the Asplan Viak report *The carbon footprint of central government procurement* (Hogne Nersund Larsen et al., 2016). These emissions factors were produced for the very same procurement categorisation as the economic analysis was based upon. The economic procurement categories were then multiplied with the corresponding emissions factors [(NOK) * (kgCO_2-eq/ NOK)], yielding the contributions for that procurement category.

These 87 procurement categories were then allocated into

- five main groups, due to matter of secrecy: *Staff and specialist, Supply and support, Army*, *Navy* and *Airforce.*
- Nine categories: *Transportation, Services, Personnel, Competence, Communications, ICT, Operations, Building and constructions* and *Other*.

3.4 Methodology for combining the two analysis

To avoid double counting, the three categories of *renovation, water and alike, light and heat* and *fuel* were taken out of the monetary analysis, as they were already represented in the physical analysis. This allowed the two carbon footprint results to be combined into one total carbon footprint.

The total carbon footprint was then categorised into direct- and indirect emissions and *Scope* contributions. Moreover, the top 10 contributions were uncovered by analysing the two results, revealing the 10 hotspots for which the organisation may focus more of its efforts into. A literature research was conducted on typical shares of *Scope* 1,2 and 3, as a quality check of the *Scope* results (ref 3.1).

4 Results and discussion

This chapter will present the results from the physical and monetary analysis. The physical results are the results stemming from the environmental report for the Norwegian Defence sector 2016, while the monetary results stem from the data published by Directorate of Financial Governing, *Rådata for årsregnskapet 2016*. The physical and the monetary analysis will be presented separate. In doing so, a good and clear overview of both the physical and monetary can be presented. After presenting the results from each one, the total carbon footprint of the organisation will be presented, where the monetary approach has had an allocation procedure conducted to it, as a mean to avoid double counting on the physical approach. In doing so, the total carbon footprint for the Norwegian Defence sector can be presented.

4.1 Physical inputs and outputs

The basis for the physical inputs and outputs are taken from the environmental report for the Norwegian Defence sector 2016 (Utstøl et al., 2017). The report accounts for all the input and outputs related to Scope 1 and Scope 2 emissions, in addition to some of Scope 3. Figure 4.1 illustrates the inputs and outputs of the Norwegian Defence sector, at a gate-to-gate approach. Figure 4.1 is a simplified environmental account, illustrating how energy and fuel goes into the organisation, based upon reported consumption. CO_2 emissions, chemicals, environmental accidents, air travels, ammunition, water and waste are depicted as outputs. Appendix B offers more details of what makes up the categories depicted by figure 4.1, in addition to an explanation to the figure itself.

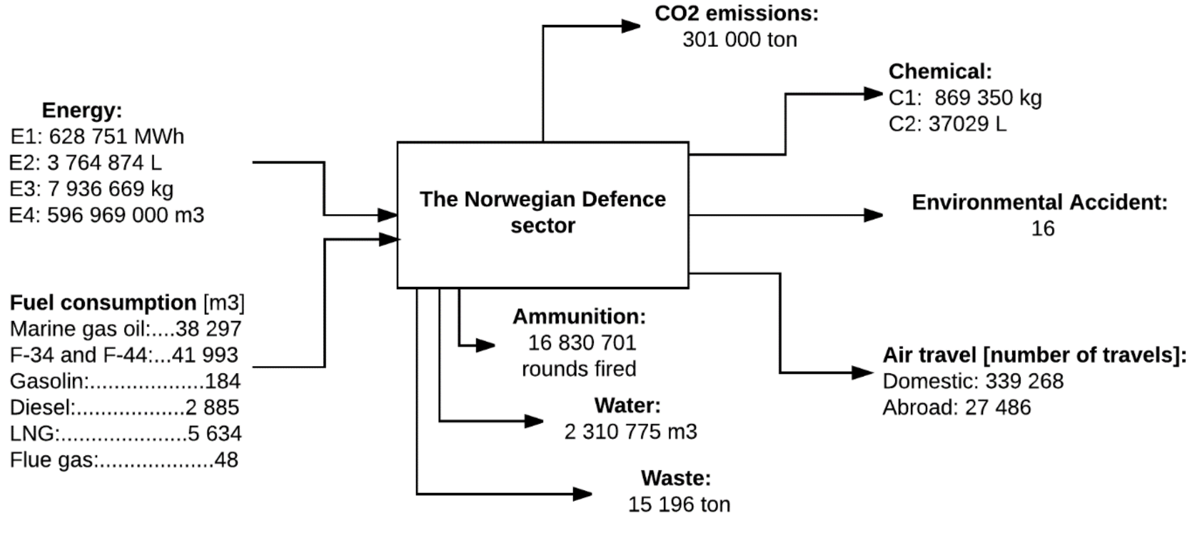

Figure 4.1 illustrates the input and output streams reported in the environmental report produced for and by the Norwegian Defence sector, 2016 (Utstøl et al., 2017).

To make the physical approach more meaningful, process LCA of each contributing process are linked together with categories that are attached directly. This applies for fuel consumption, which are linked together with the vehicle, aircraft or sea craft consuming the fuel. This then require another category, which offers information about the units consuming the fuel.

Figure 4.2 illustrates the share between the three different life cycle categories, production, use phase and end of life for the reported activities in figure 4.1, as well as the category for *Cars & transport*. It accounts for the direct activities, which are found in the use phase, and the indirect activities that are found in the production and EoL. The use phase stands for 68 % of the emissions, which accounts to 286 000 tonnes of CO_2-eq, and are by far the biggest contributor. Production makes up a 4th of the total emissions (111 000 tonnes CO_2-eq), which shows how important it is to account for indirect emissions. End of life only accounts for 6 % (25 000 tonnes CO_2-eq).

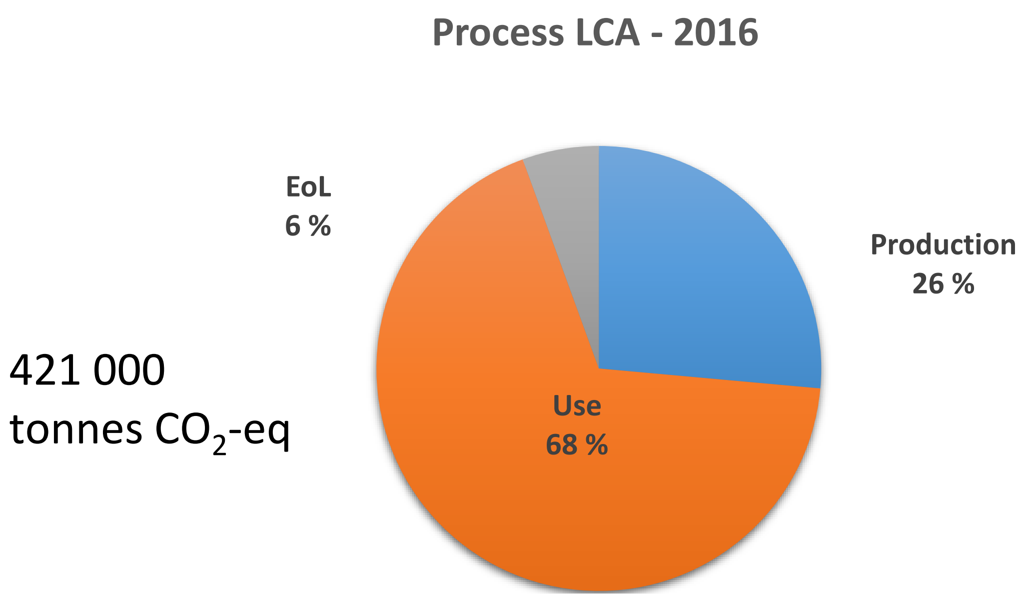

Figure 4.2 illustrates the total emissions related to the reported emissions illustrated by figure 4.1, and the additional category of fuel consuming units. The total emissions are 421 000 tonnes CO_2-eq, and are broken down into the three life cycle stages; production, use and end of life, with respectively share of 26%, 68% and 6%.

Table 4.1 provides information about the process LCA results stemming from the environmental account depicted by figure 4.1, plus the *Cars & transport* category. It gives a little more depth to the results shown in figure 4.2, as it indicates in which stages of the life cycle the emissions stem from for each category. It clearly shows that the biggest contributor to the carbon footprint of the Norwegian Defence sector is fuel consumption, illustrated by use phase of *Fuel*. In fact, the category of *Fuel* stands for 64 % of the total emissions for the process LCA, with 270 000 tonnes out of 421 000 tonnes. Table 4.1 also show that the categories *Air travel* and *Energy* contributes substantial, with respectively 11 % and 10 % of the total carbo footprint. *Fuel*, *Air travels* and *Energy* together amounts to 85 % of the total emissions stemming from the process LCA (physical).

Table 4.1 illustrates the calculated physical CO_2-eq emissions, derived from the environmental report, as well as the vehicle category. Each category is broken down into the life cycle stages, production-, use- and end of life phases. The last column tells the total calculated emissions stemming from each category,

CO2-eq [kg]	Production	Use	EoL	Total
Water	935 738		1 383 153	2 318 891
Chemicals	1 378 033	339 379	1 219	1 718 631
Air travels	10 677 775	37 416 255	1 623	48 095 653
Fuel	38 154 277	231 239 296		269 393 573
Cars & transport	28 211 276		17 061	28 228 337
Waste			23 225 605	23 225 605
Energy	27 668 438	16 560 742		44 229 180
Ammunition	4 058 967	66 404	104 782	4 230 152

As a mean to make the results more meaningful, the *Fuel* category is allocated into what type of unit consumes the fuel. These are, *Vehicles* – vehicles operated on land, *Ships* – watercrafts of all sorts and *Aircrafts* – all units operating airborne.

With this classification of the fossil fuel consuming conveyance, more applicable results is presented, which is illustrated by figure 4.3. The categories of *Fuel* and *Cars & transport* has been merged together and broken up into the three categories of *Vehicle, Ships* and *Aircrafts*, more depth is given to the results, offering an indicator over which agency is causing what when it comes to emissions related to operating the fleet.

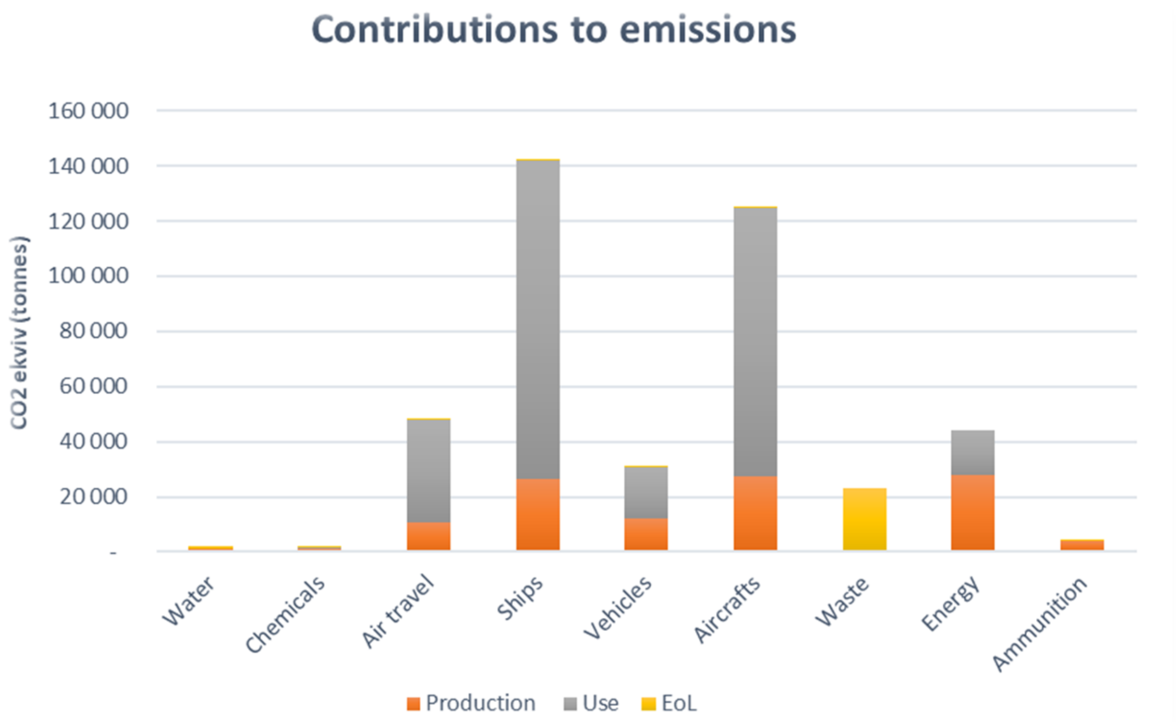

Figure 4.3 illustrates the carbon footprint contributions of all 9 categories, in a life cycle stacking fashion.

The two biggest contributors to carbon emissions in figure 4.3 are ships and aircrafts, with shares of 34 % and 30 % of the total emitted carbon footprint emissions for the physical analysis. That these two are the biggest contributors are somewhat expected, due to the amount of fossil fuels consumed by these vessels. For the vehicle category, the percentage contributions are 7 %. Together, the day-to-day operation of vehicles, aircrafts and ships make up a 71 % share of the total physical contribution to the carbon footprint of the Norwegian Defence sector.

What is worth noting among these three, are the production share emissions of *vehicles*, which accumulates to 40 % of the total CO_2-eq emissions for the life cycle of the category. This illustrates how important it is to be aware of the impact caused by indirect emissions. Furthermore, the *Waste* category is presented to be a solely EoL emissions that contributes to 6 % of the total. The emissions for the *Waste* category is presented as EoL due to it leaving the gate, in the gate-to-gate defined system.

For *Energy*, figure 4.3 demonstrates the production phase to be the largest. In this category, one can find electricity, which has a 0 contribution during use phase, while it is the biggest contributor to the total production of *Energy*, with 14 000 tonnes CO_2-eq. Light fuel oil is the biggest contributor to the use phase, emitting 10 000 tonnes CO_2-eq.

The physical analysis reported on a total carbon footprint of 421 000 tonnes. The number reported in the environmental report for 2016 was 301 000 tonnes CO_2-eq. This demonstrates the importance of adding the indirect emissions when calculating the carbon footprint of an organisation. By examining the same processes as the environmental report does, the carbon footprint is roughly 393 000 tonnes CO_2-eq (when subtracting for *Cars & transport)*, revealing a 92 000 tonnes difference.

Figure 4.4 illustrates the contributions of direct and indirect emissions, defined by the scope definition. The total carbon footprint of 393 000 tonnes CO_2-eq consists of the direct emissions amounting to 247 800 tonnes CO_2-eq (63 %), and the indirect emissions of 145 412 tonnes CO_2-eq (37 %). This is the true contributions of direct and indirect emissions for the same processes presented in the environmental report 2016.

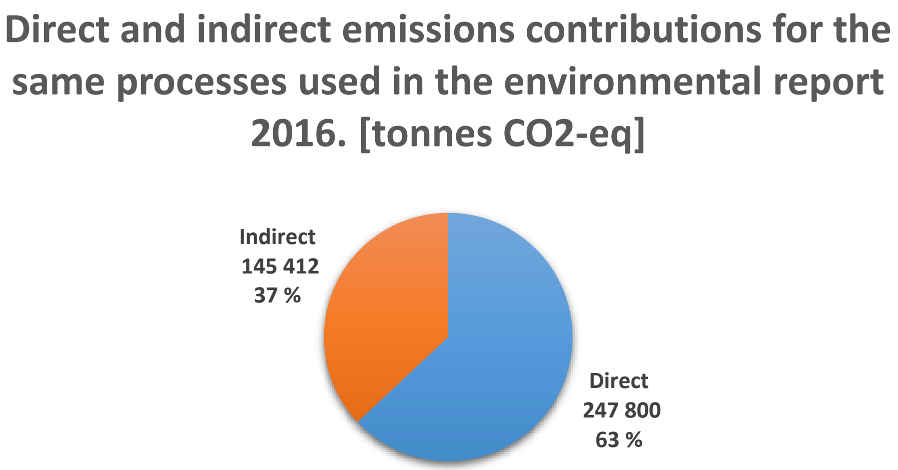

Figure 4.4 illustrates the calculated contributions from the same processes used in the environmental report 2016

4.2 Monetary inputs and outputs

After gathering all the economic data, 146 procurement categories made up the monetary inputs and outputs for the Norwegian Defence sector. The procurement categories are defined as the same for all governmental procurements, which made the factors presented in the report *The carbon footprint of central government procurement b*y Asplan Viak (2016) ideal. Out of these 146 generic categories, 87 of them represented day-to-day operations with environmental impacts (CO_2-eq emissions).

These 87 procurement categories were then allocated into five main groups, due to matter of secrecy, but also due to the interesting findings of the results, and these five groups are:

- *Staff and specialist*: The Royal Norwegian Ministry of Defence, The National Security Agency of Norway and The Norwegian Defence and Research Establishment
- *Supply and support*: The Norwegian Defence Estates Agency, The Norwegian Defence materials and The Norwegian Defence Logistic Organisation
- *Army:* Land-based activates for the Norwegian Armed Forces
- *Navy:* Sea-based activities for the Norwegian Armed Forces
- *Airforce:* Air-based activities for the Norwegian Armed Forces

Together these five groups make up a 15.4 billion budget spread out over the 87 procurement categories, and the total amount of carbon footprint is calculated to be 562 000 tonnes CO_2-eq. What is interesting about these results, is the fact that emissions related to procurement stand out so clearly as it does. Supply and support, which are the purchasing organ, contributes to 36 % of the total, which is 203 000 tonnes CO_2-eq out of 562 000 tonnes CO_2-eq. This illustrates the importance of indirect emissions (Scope 3), which the main part of the *Supply and support* consists of. The *Supply and support* does not consume the majority of the goods and services themselves, but purchase them for the other sectors, and as such, take the contributions for these goods and services. In reality, the share of *Supply and support* should be around the same order of magnitude as *Staff and specialists*. This simply demonstrates the contributions that lay within procurement of goods and services.

Army, *Navy* and *Airforce* are the main consumers of the goods and services acquired by the *Supply and support*. For *Navy* and *Airforce*, the main contributing procurements are related to repairs of fleet and equipment, daily operation requirements, travel and fuel. These five procurements categories make up roughly 80 – 90 % of the shares. For *Army* the same five categories contributes at a more even level of all the other procurement categories, with the exception of light and heat. Light and heat are the main contributor to carbon footprint for *Army*, which adds up to roughly 20 % of the Army emissions with its contribution of 21 000 tonnes CO_2-eq.

Figure 4.5 and figure 6 provides information about the carbon footprint contributions of the five groups making up the Norwegian Defence sector.

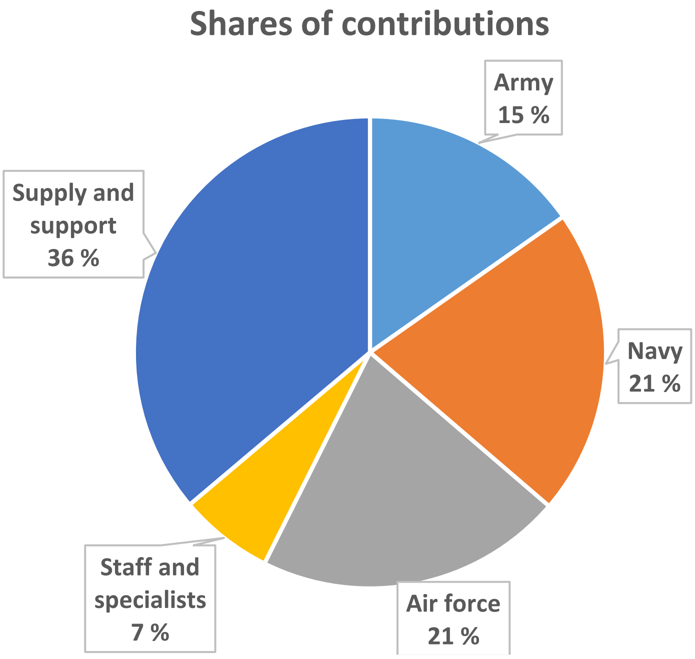

Figure 4.5 illustrates the shares of monetary total carbon footprint of each group that together makes up the Norwegian Defence sector.

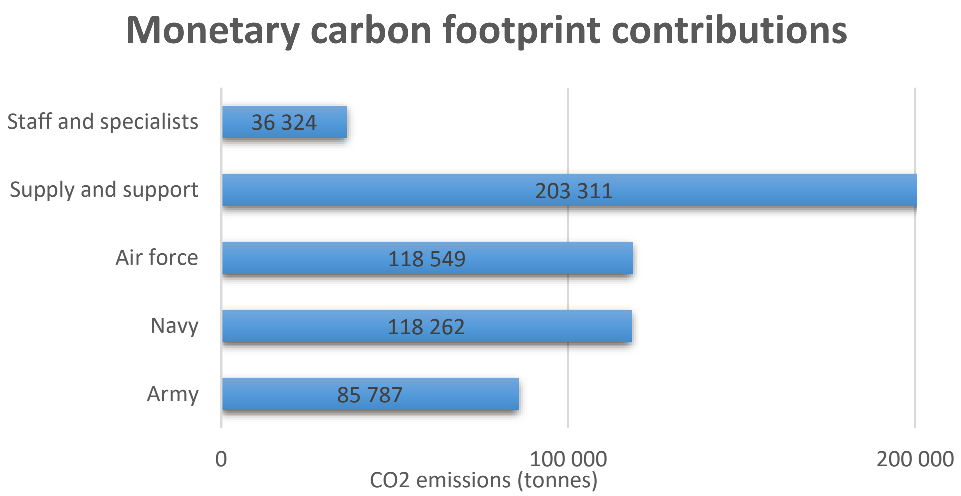

Figure 4.6 illustrates the calculated carbon emissions for each of the five groups that amounts to the Norwegian Defence sector

When measuring the carbon footprint emissions against the procurement expenditures, one can get a better picture of the differences between expenditures and emissions. So far emissions and shares of emissions have been accounted for, but when the expenditures are introduced as a percentage level and measured against the shares of emissions, the results become interesting. In figure 4.7 one can see how *Staff and specialists* is attributed a 13 % share of the total expenditures of the sector, but only 7 % of the carbon footprint of the sector. The reason for this is the internal structure of the Norwegian Defence sector, where for instance the *Staff and specialist's* lessee goods and services from *Supply and support*, which for lessee of buildings gives the hirer the emissions connected with construction, renovation and maintaining the buildings, as well as the energy consumption. One could argue that these emissions should be allocated to whomever is causing them directly, but due to the intricate structure of the sector it would be a too heavy workload for this thesis, and more a matter for further work.

What figure 4.7 also reveals is the almost even share between expenditures and emissions for the *Navy*, *Airforce* and *Army*. As previously mentioned, the emissions contributed by these three are caused by operations on day-to-day basis, and therefore the important Scope 3 emissions of maintenance and renovations related to buildings and constructions are not allocated to this group, but rather to *Supply and support*. However, maintenance and repairs of the vehicles, aircrafts and ships are accounted for, and for *Navy* and *Airforce* the emissions caused by these procurement categories are what makes up the main difference between shares of expenditures and emissions. This applies especially for *Navy*, which has emission intensive fleet maintenance and repairs.

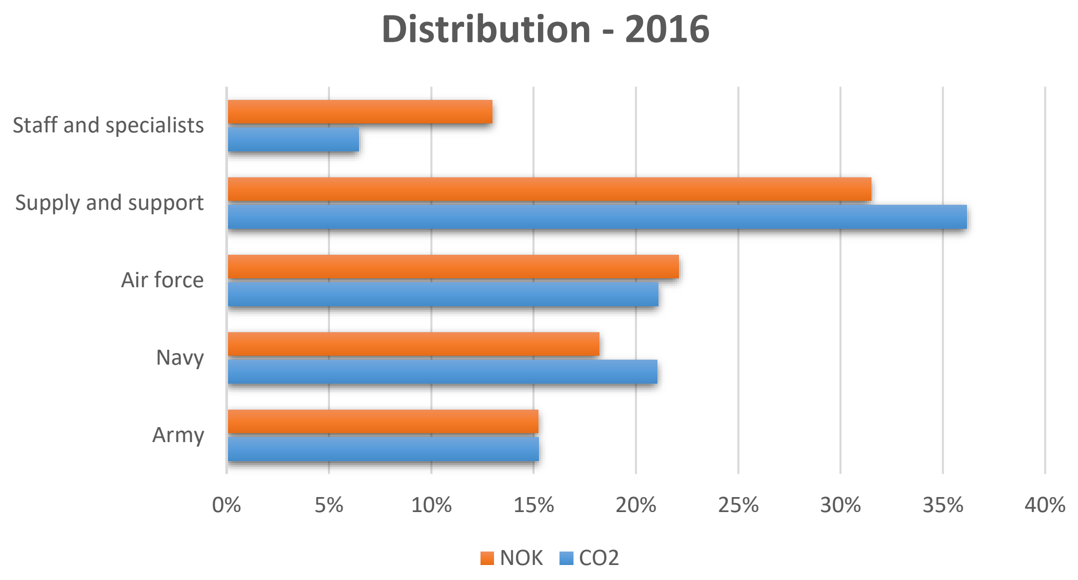

Figure 4.7 illustrates the differences between the share of expenditures and emissions caused by the five groups that constitutes the Norwegian Defence sector.

By breaking down the Norwegian Defence sector in 9 groups, consisting of *Buildings and construction, Other, Operation, ICT (information and communication technology), Communication, Personnel, Competence, Services* and *Transportation*, the carbon footprint for the organisation are presented in a more general way, in accordance with the breakdown of the governmental procurement categories. Figure 4.8 illustrates the shares of both emissions and budget of each one of the 9 categories, with *Transportation, Building and construction* and *Operation* being the top three emission intensive categories, with their respective percentage of 44 %, 25 % and 15 % on the other hand, while the expenditure share of the respective are 28 %, 8 % and 34 % on the other hand. One can clearly see a considerable difference in shares of NOKs vs emissions for the Norwegian Defence sector.

Transportation and *buildings and construction* both have a 16 % share difference between NOK and CO_2-eq. This is particularly interesting for *buildings and construction*, which only has an 8 % share of the budget, while the emissions generated through goods and services demanded by the *buildings and construction* are 25 %. The most emissions intensive subcategories of *buildings and construction* are light and heat, constructions and subcontracts. The indirect emissions of these services are what causes the biggest impacts, and the reason for why there is such a big difference between NOKs and CO_2-eq emissions.

For *Transportation*, the emissions fare higher due to the production and combustions of fuels. These processes are very emissions intensive and therefore generate a high factor for emissions/NOK. The subcategory fuel is causing 50 % of the emissions, while travel cost are the second biggest, with a 25 % share.

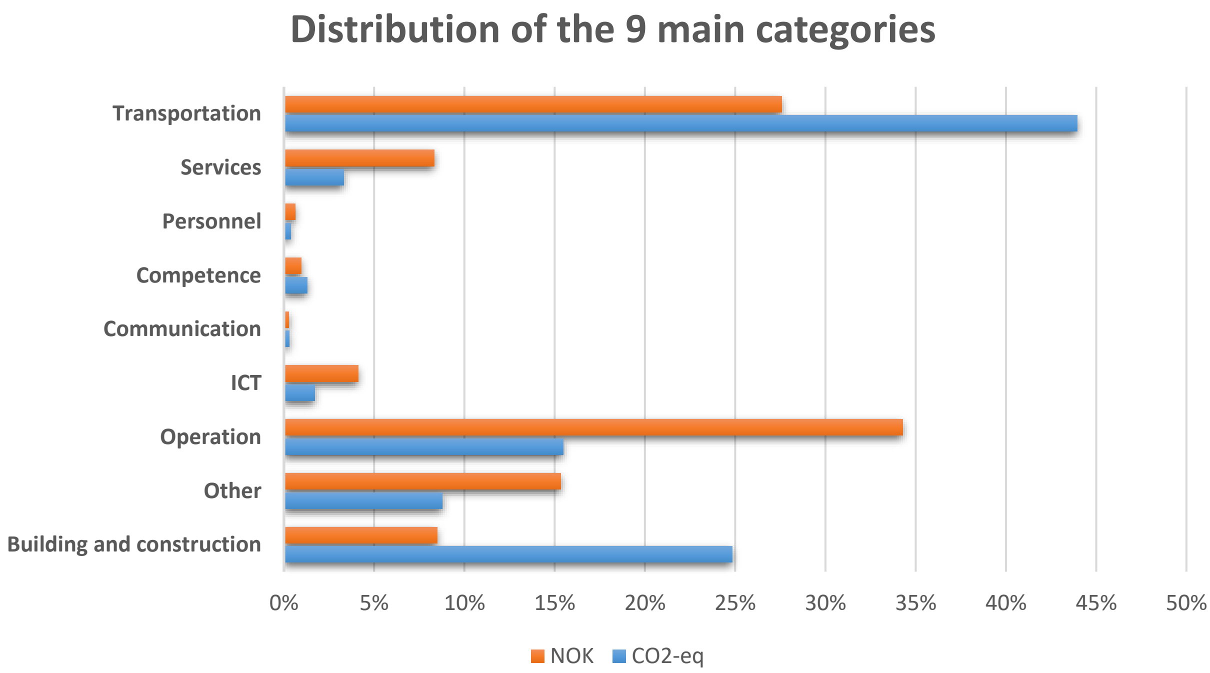

Figure 4.8 illustrates the distribution shares of NOK and CO_2-eq, for the 9 main categories.

Operation is a low emission intensive category, with low factors of CO_2-eq/NOK. What makes up this group is goods and services that are required for daily operations, which are low in emissions but high on demand/cost. This gives the impressions of an environmentally friendly category. This is not necessarily true, as the *operation* category consists of a lot of leased good and services, and therefore as it is not owned by the sector, the sector is only allocated emissions shares based on lifetime of the product. By renting the products, the cost of the products will be higher over time, than it would be if the Norwegian Defence sector purchased it. Therefore, the cost vs. emissions in this case is to-faced. One side, a general low emission intensive category, while the other side is higher NOK cost for a leased service.

4.3 Combining and evaluating the total carbon footprint

By combining chapter 6.1 and 6.2, the total carbon footprint of the Norwegian Defence sector can be presented. The physical analysis revealed 421 440 ton CO_2-eq, while the monetary revealed 562 233ton CO_2-eq. In order to avoid double counting, some of the posts in the monetary analysis were taken out, as it was already present and presented by the physical analysis. These included *renovation*, *water and alike*, *light and heat* and *fuel*. The new monetary account stands to 378 729 tonnes CO_2-eq, and the total of the sector amounts to 800 169 tonnes CO_2-eq**.**

4.3.1 Scope distribution

Out of the 800 169 tonnes CO_2-eq, the direct and indirect emissions are broken down into scope emissions. Figure 4.9 illustrates the scope distribution for the Norwegian Defence sector, with Scope 1 emissions of 247 800 tonnes CO_2-eq and a 30 % share of the total carbon footprint of the sector. Scope 2 amounts to 27 668 tonnes CO_2-eq and a 3 % share, while Scope 3 sums up to 552 369 tonnes of CO_2-eq and a 68 % share.

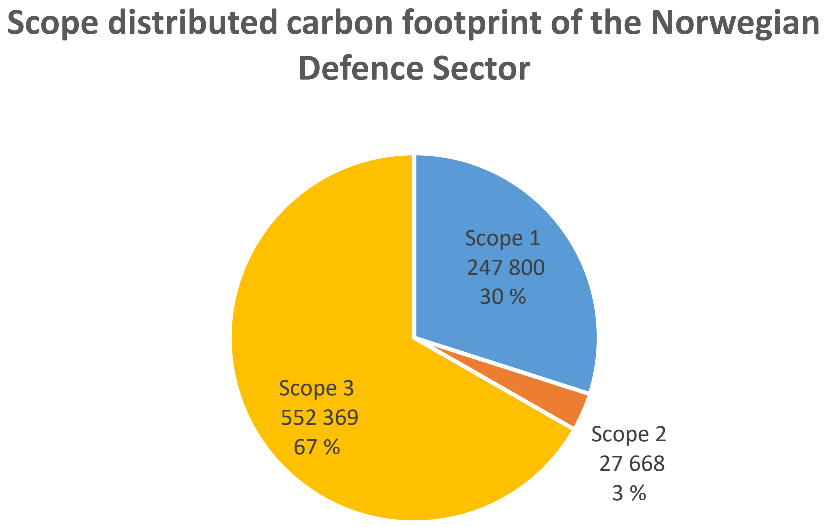

Figure 4.9 illustrates the total carbon footprint of the Norwegian Defence sector, distributed into Scope 1, 2 and 3 emissions.

As figure 4.9 illustrates, the Scope 1 emissions are quite high, which are to be expected for an organisation consuming vast amounts of fossil fuels. For daily operations, an active fleet is important for training, operations and transport, and the contributions stemming from fuel combustion stands for more than 90 % of the Scope 1 emissions. The remaining is fossil fuel used for energy production. For Scope 2, the emissions are lower than expected, but this is due to the Norwegian electricity mix, with an emission factor of 25,6 gCO_2-eq/NOK. The second biggest contributor to Scope 2 is district heating, which is relatively clean, accumulating to 133 gCO_2-eq/kWh. The Scope 3 emissions are roughly as expected, as Scope 3 emissions typically range between 60 - 85 %. Important contributors are air travels, travel costs, subcontractors, renovation, repairs and maintenance; categories that contributes with either high emission intensities or high demand.

4.3.2 Production, Use and End-of-life distribution

Figure 4.2 illustrates the life cycle distribution of the physical analysis, with the use phase as the biggest contributor. The biggest contributor is of course fuel combustion, but what is interesting is the Scope 3 contribution of air travels, contributing 13 % of the use phase emissions. A total carbon footprint breakdown into production, use and end-of-life is not possible due to the simplified monetary analysis – the use of Asplan Viak's emission factors, as well as the lack of EoL processes in SimaPro. However, one could assume that a higher contribution share by production and EoL, as the physical analysis did not have that many Scope 3 emissions included. Scope 3 emissions are not so heavily influenced by use phase emissions, as the use of a commodity such as computer, paper, clothes, food, etc. are often contributing more to production and EoL than use phase. However, it is safe to say that the use phase will be a major contributor to an organisation such as the Norwegian Defence sector.

4.3.3 Main findings (hotspots)

The ten contributions illustrated by table 4.2 are the so-called hotspots for the organisation. Together, these ten contributes to 76 % of the total carbon footprint of the organisation, and therefore, by addressing and prioritising these hotspots, the organisation can reduce the carbon footprint more efficiently. The categories of *Transportation* and *building and construction* are the most intensive categories, contributing to 61 % of the total carbon footprint.

Hotspots are considered to be the starting points for further inquiries of actions, such as process-based LCA. Actions that are meant to release the most significant and cost effective improvements. By investigating and conducting LCA on the subcategories of these ten procurement categories, potential reduction options will be made clear. Some suggestions are presented in chapter 6 for focus areas within the hotspots that may lead towards a reduced carbon footprint.

Table 4.2 illustrates the top 10 contributions to the carbon footprint of the Norwegian Defence sector.

Procurement code	Procurement title	tCO2-eq	Category	[%]
700	Fuel	269 394	Transportation	34 %
713	Travel cost	63 707	Transportation	8 %
658	Other operations materials	55 217	Operation	7 %
634	Light and heat	46 274	Building and construction	6 %
668	Repairs and maintenance ship, rigs, aircrafts	36 905	Transportation	5 %
113	Constructions	36 216	Building and construction	5 %
450	Foreign output and subcontracts	34 403	Building and construction	4 %
779	Other cost	28 427	Other	4 %
400	Procurement of raw materials and semifinished products	20 943	Other	3 %
678	Procurement of other foreign services	16 580	Services	2 %
	Remaining	192 102		24 %
	Total	800 169		100 %

The ten hotspots presented by Table 4.2 are *Fuel, Travel costs, Other operations materials, Light and heat, Repairs and maintenance ship, rigs, aircrafts, Constructions, Foreign output and subcontractors, Other cost, Procurement of raw materials and semi-finished products* and *Procurement of other foreign services*. The hotspots are listed in a contributing order, where *Fuel* is contributing the most, while *Procurement of other foreign services* is contributing the least. By ranging the same 10 hotspots in an emission intensive falling order, the difference between commodities of high demand and commodities of high emissions intensities can be illustrated, as illustrated in table 4.3.

In table 4.3 the posts *Procurement of raw materials and semi-finished products* and *Other operations* materials illustrates the point of high demand vs emissions intensive goods excellent. *Procurement of raw materials and semi-finished products* is a post of higher emissions intensities, and contributes 20 943 tCO_2-eq. *Other operations* materials are a lower emission intensive post with contributions of 55 217 tCO_2-eq. This means that the demand for *Other operations materials* are roughly 8 times higher than the demand for *Procurement of raw materials and semi-finished products*.

Table 4.3illustrates the top 10 contributing posts to the carbon footprint of the Norwegian Defence sector, sorted by high to low emission intensities.

Procurement code	Procurement title	kgCO2-eq/ NOK	tCO2-eq
700	Fuel	0,25	269 394
634	Light and heat	0,18	46 274
713	Travel cost	0,12	63 707
400	Procurement of raw materials and semifinished products	0,07	20 943
668	Repairs and maintenance ship, rigs, aircrafts	0,03	36 905
658	Other operations materials	0,02	55 217
113	Constructions	0,02	36 216
450	Foreign output and subcontracts	0,02	34 403
779	Other cost	0,02	28 427
678	Procurement of other foreign services	0,02	16 580
	Remaining		192 102
	Total		800 169

When addressing the hotspots, the organisation needs to keep in mind how each hotspot is contributing. If it is by high demand, maybe a reduction of demand is the easiest route to take. If it is high emission intensities, then a more “green” product could be the answer.

4.3.4 Harmonising results

The results of this O-LCA, in terms of direct and indirect emissions shares, are coincident with the literature, where Scope 1 and Scope 2 average together a 26 % of total carbon footprint of organisations, while Scope 3 emissions contributes to 74 % of the total carbon footprint.

The literature shows an average for Scope 1 of 14 %, while the Scope 1 emissions for the Norwegian Defence sector is calculated to be 30 %. The difference for the average and this thesis is the vast amount of fossil fuel consumption. The Norwegian Defence sector is an “active” organisation, requiring the combustion of fossil fuel to power the fleet.

The comparison of Scope 3 emissions is perhaps what is most quality informative of this thesis. Scope 3 emissions are averaging to 74 % for organisations, whereas for this thesis the Scope 3 emissions were calculated to be 67 %. This indicates that the results of the indirect emissions connected with procurement of goods and services are on a par with the literature, as the difference is caused by the high contribution of Scope 1 emissions.

4.4 Sensitivity Analysis

The sensitivity is a bit more complex. One analysis method was used for the physical results, while another for the monetary results. This gives different sensitivities between the two, and therefore - for transparency reasons, two sensitivities are presented.

4.4.1 Physical sensitivities

With the physical analysis based upon the inputs and outputs presented in the environmental report (*Forsvarssektorens miljø- og klimeregnskap for 2016)*, the uncertainties connected with the actual flows are low. The SimaPro processes representing each one of the individual flows is more sensitive. The direct contributions for *Airtravels, Fuel* and *Energy* are carefully calculated and presented in the environmental report, with emission data of high quality. The rest of the processes and life cycle contributions stem from the SimaPro calculations, with varied quality. Processes for *Water, Waste* and the none-military vehicles in *Cars&transport* are of good quality, as the SimaPro processes are of European calculations, which are close enough to Norwegian mix.

For the remaining categories, some SimaPro processes reflect good, while others poor. Some of these are related to military vehicles, aircrafts and sea vessels. There are no premade processes in SimaPro that represent military vehicles, thus the processes chosen are based upon assumptions/best fit. The assumptions made were conservative, which then presents carbon footprint results that are lower than they truly are. More can be said about other processes in SimaPro as well, but the fact is that for SimPro processes that are of low representability, they are all conservative.

For the life cycles presented, the use phase is the most accurate, as the quality of data for these are high. The production phases are of good quality, while the end-of-life (EoL) is poor. There are not many SimaPro processes that offers details for EoL, thus one needs to research and create processes for that. With production, use and EoL being of varied quality, the contribution profiling is of poor quality. This also produce a conservative estimation.

For assumptions made, all are based upon information from at least two respected sources, giving a robust supposition.

All in all, for the physical sensitivities, what affects the calculations the most are the SimaPro processes which are fitting poorly. However, these are found mainly in the categories of *Cars & transport* and *ammunition*, which contributes roughly 8 % of the physical carbon footprint, thus resulting in an overall good quality for the physical analysis.

4.4.2 Monetary sensitivities

The economic tables where is good quality, as the Norwegian Defence sector reports the economic data using the standard chart of accounts for governmental activities. However, there are some discrepancies, such as wrongly placed activities in the accounts, which lowers the quality. For this thesis, these activities were only included if there was no doubt of where they belonged in the chart of accounts.

For the emissions factors published in the report *The carbon footprint of central government procurement* by Asplan Viak, the reported uncertainties to the factors are related to the economic background data and the Klimakost model. That being said, the factors are recommended to be used for ministries, agencies and directorates within the government.

The use of the generic GHG emissions factors will not give results that are 100% accurate for the organisation, but rather results of high accuracy. The sensitivities for the monetary analysis are mainly due to the emissions factors, as the wrongly placed activities do not account for that much of the total budget. With the emissions factors being of good quality, the overall for the monetary analysis is of good quality.

4.4.3 Combining sensitivities

When combining the two analysis into one total carbon footprint, the allocations made are critical. For this thesis, the monetary analysis had the activities of renovation, light and heat and fuel removed, as the physical analysis cover these. However, there are some double counting happening, as the activities reported in the standard chart of accounts are often a combination of more than one activity. To avoid double counting all together, an inquire into each reported activity needs to be conducted, which is something this thesis have not done. However, the double counting will most likely not add up to that much, as the physical analysis were mainly Scope 1 and 2, while the allocated monetary analysis was mainly Scope 3.

For this thesis, the combination of physical analysis and monetary analysis offered some challenges. The quality of the direct emissions is very good, while the indirect is of varying quality. The conservative calculations of the physical analysis together with the somewhat underreported account data for the monetary, indicates that the carbon footprint of the Norwegian Defence sector is most likely higher than what this thesis reports. If the physical analysis had SimaPro processes fitting the military activity better, and if some activities/assets were not secluded due to concealment, the total carbon footprint could be over 1 000 000 ton CO_2-eq. However, this is just an assumption.

5 Conclusion

The Norwegian Defence sector is an organisation which takes the environmental impacts seriously. For several years, the Defence Research Institute (FFI) has produced and published annual environmental reports, tracking the environmental performances and calculating the carbon footprint of the organisation. These reports account for the mandatory Scope 1 and Scope 2 emissions, as well as work travel emissions (part of Scope 3). All other indirect emissions related to upstream and downstream activities are not included. For a large organisation, such as the Norwegian Defence sector, the indirect emissions related to Scope 3, emissions from procurement of goods and services, will contribute significantly to the carbon footprint of the organisation.

The results of this O-LCA show that the direct GHG emissions (Scope 1) contributes to 30 % (247 800 tonnes CO2-eq) of the total carbon footprint of the Norwegian Defence sector. Fossil fuel combustion from military vehicles, aircrafts and sea vessels stands for 94 % of the total Scope 1 contributions – mainly aircrafts and sea vessels. The remaining 6 % is caused by energy production, using fossil fuels.

For Scope 2 and 3, the indirect GHG emissions, contributions are 3 % and 67 % (28 000 tonnes CO2-eq and 552 000 tonnes CO2-eq) respectively, adding up to a total of 70 % for indirect emissions. The main contributing activities in Scope 3 are *Transportation* and *Building and construction* related. For work travels, the main contribution activities are the indirect emissions of fossil fuel, while for *Building and constructions* it is subcontractors and renovation. The category of *Transportations* is the most emission heavy category, while the category *Building and construction* stands out as the most emission intensive category when measuring shares of emissions/NOKs.

The total carbon footprint of the Norwegian Defence sector for 2016 calculates to 800 000 tonnes CO2-eq, which is 500 000 tonnes CO2-eq more than what the environmental report of 2016 shows. This illustrates the importance of accounting the indirect emissions of Scope 3, as it adds up to average ~70 % of the total carbon footprint of an organisation.

In the value chain, 10 environmental hotspots have been uncovered, which offers a starting point for further work. For these 10 hotpots, recommendations have been given. The actions taken should be based on strategic, economic and environmental targets.

6 Recommendations

The recommendations listen below are directly related to the 10 hotspots illustrated by table 4.2 in chapter 4.3.3. The recommendations are not presented in full, as they are meant to be suggestions for further inquiries. However, these are recommendations which can reduce the impacts drastically, should be taken sincerely.

6.1 Transportation

The three hotspots *fuel, travel cost* and *repairs and maintenance* belongs in the transport category, and together these three stands for 46 % of the total carbon footprint of the Norwegian Defence sector. The potential within the transportation category is tremendous, as well as challenging.

6.1.1 Fuel

Eco-friendlier fuel based on biofuel technologies

For the vast amounts of fuel that the Norwegian Defence sector consumes, the strongest option for reduction of emissions without it affecting the military activity is by using more environmentally friendly fuel. By putting pressure on the fuel producers for a cleaner production and a cleaner product, the fuel category could change drastically in regards to emissions.

The most consumed fuel is F-34, which is used for aircrafts and vehicles. What makes this fuel type so apt for an introduction to sustainability, is the share market size of it. NATO uses it as standard fuel and the air industry consumes enormous amounts. If the consumers of F-34 put pressure on the producers to produce a more environmentally friendly fuel type, a powerful incentive for a more sustainable production and fuel mix can be introduced. One cannot always wait for authorities to approve and regulate what one should do in regards to environment, so by leading the way for a less emissions intensive consumption of fuel, the Norwegian Defence sector will improve the carbon footprint of the organisation, as well as the image.

In short, the organisation could influence the producers to create an eco-friendlier fuel, based on biofuel technologies. The report *Sustainable jet fuel for aviation* gives information about this, and will give an introduction to the issues connected with the subject (Erik C. Wormslev et al., 2016).

Reducing the fossil fuel demand

Reducing the demand for fossil fuel by alternating towards electricity, hydrogen or biogas.

- For sea vessels, one option is to switch from marine gas oil to LNG for ships, if possible. Another more realistic option is to power the sea vessels in dock by electricity instead of fossil fuel consuming power generation units on board the sea vessels.
  The subject of connecting to "land electricity" is a hot one in Norway nowadays. The installation costs are high, but the emissions reductions justify the monetary cost, if the environment effects are taken into play. More and more ships are adapting and connecting to electricity cables when in dock. Incentives are also given for such

actions. It is highly recommended to connect the sea vessels in dock to the electricity grid, rather than producing its own dirty electricity on board the ship by fossil fuel driven generators.

- Electric fleet
  The battery technology is rapidly improving, in both size, storage, speed and interference. The amount of energy that may be charged and stored in a unit is constantly improving, and already the batteries are ready for ships, cars and even aircrafts.

  Vehicles:
  The Norwegian Defence sector should try to lease electric cars instead of diesel cars, as it would benefit both the organisation, as well as everyone else. In addition, the vehicles owned by the organisation should undergo a mapping of use pattern, revealing which ones that can fit an electric profile, and then adjust future procurement for the results from the survey.

  Sea vessels:
  The number of electric boats are also increasing. Even ferries are fitted with huge battery packs and run on solely electricity, charging the batteries when cars are leaving and entering the ferry. The potentials are huge, and as with vehicles, the organisation should survey the sea vessels and find out which sea vessels could run on electricity, rather by fossil fuel. A hybrid solution would also be recommended.

  Aircrafts:
  The technology for electric powered aircrafts are not far off. The main issue is the weight of the batteries, which as of today, are too heavy. The predictions (Inc., 2017) for when one will see electric aircrafts transporting people are around 15-20 years ahead. Until then, hybrid aircrafts may be the solution. By powering small parts of the plane by battery instead of the turbine in the tale, the fuel consumption decreased. The idea is to let small operations on board an aircraft be powered by electricity stored in a battery, while the rest is powered by the turbine in the tale. As battery technology leaps forward, the usefulness increases, as more energy can be stored, which results in more operations powered by electricity.

- Hydrogen in fleet
  The use areas of hydrogen are constantly increasing, and one of the areas is the use of hydrogen as fuel. The examples for electric fleet also applies to hydrogen fleet.

6.1.2 Travel cost

There is not much one can do about the expenses related to travel directly, except reduce the amount of travels. The emissions stem from food and drinks, rent of cars, use of personal cars, airplane tickets, train tickets and so on.

- The organisation could reduce the high emissions travels and use more low emissions, such as trains, bus or electric vehicles.
- A reduction of travels related to meeting activities can be conducted over Skype (or similar programs).

- The organisation could create incentives for using emissions free travels whenever possible, within reasonable time and cost. For example, using electric (or not) bicycle to close proximity travels.

6.1.3 Repairs and maintenance ships, rigs aircrafts

Emissions from repairs and maintenance could be lowered by using more environmentally friendly products and a "clean and green" power source. This post is restricted in a way that does not allow the user to improve the object of service, thus leaving it strictly to maintaining the same original function. Old ships, rigs and aircraft will have an increasing need for repairs and maintenance, so therefore one option could be to look into acquiring/investing in new products, rather than paying the upkeep of an old one, which is far more emission intensive.

6.2 Buildings and construction

6.2.1 Light and heat

ENØK

With a continuous focus on ENØK, the reduction of energy demands without reducing the level of comfort. By mapping the energy consumption of buildings, one can get an overview over how much energy that can be saved through easy steps, such as:

- Instalment of heat pumps and demand controlled ventilation
- Installing LED-lights
- Instalment of automatic controlling system for light and heat
- Upgrading the buildings by adding extra isolation, windows with higher insolation capacity, reducing thermal bridges, installing sunscreens and so on.

Energy

<u>Electricity</u>: Acquire electricity with *Green Certificates*, which guaranties that the electricity is produced by renewable sources.

<u>District heating</u>: Connect more buildings to the district heating system, which provides heat to buildings. Heat is generated by the incineration of waste, which is an ever-increasing source of *fuel*.

<u>Heat produced by the organisation</u>: Avoid/reduce fuels classified as fossil fuels, and focus on the least emission intensive sources for fuel, starting with renewable sources. Avoid light fuel oil and propane, use more wood chips, bio pellets and LNG. Light fuel oil and propane are quite emissions intensive, with roughly a 100 times that of electricity, and roughly 15 times that of district heating.

Look to renewable technologies, such as:

- Solar PV panels for electricity production
- Small-scaled wind turbines for electricity production
- Solar collectors for heat production
- Geothermal wells for heat production and cooling during summer
- Biomass and biogas for heat production

Zero emission buildings and Energy-plus-house

The organisation could construct new buildings using a higher standard than the current passive house standard (NS 3700 and NS 3701). There already exists a ZEB house at Håkonsvern, which received financial support from ENOVA SF and a lot of positive publicity from within and outside the borders of Norway.

The ZEB buildings are producing as much energy as it "cost" to build it over its lifetime. For energy-plus-houses, the house is producing more energy than it "costs" to build it, over its lifetime. By constructing buildings that produce at least the equal amount of energy it requires from raw resources to finished building, the housing contributes to the supply of energy to the national powergrid, as well as being self-supporting to a much higher degree. It is costly, but so are all good initiatives at the beginning.

6.2.2 Constructions

It is embodied emissions of materials that contributes the most to the construction post, and therefore, it is the material selection that offers the biggest possible impact reduction.

- Wood
  The saturation time of trees are roughly a 100 year, meaning the CO_2 absorption declines and stop at that point. For maximising the potential of trees as a mitigation option for climate change, the use of trees play a vital role. By using more woodwork in construction, the CO_2 is trapped in the woodwork for as long as the wood product is maintained and cared for. Ideally, by exploiting the saturation cycle of trees better, the more CO_2 is taken out of the atmosphere and stored in the woodwork.

  Woodwork is a renewable product, which is naturally recyclable and biodegradable. Of all the competing materials available for construction, it is among one of the lowest in terms of environmental impact (reThink Wood, 2014, Sinha et al., 2012). By building with wood, the construction time is reduced and the indoor climate increases due to better moist balancing (Remen, 2015). Moreover, increasing the wood in construction offers a substantial emissions reduction in regards to the production of the materials due to points made clear over.

- Eco-cement
  Cement, one of the main component of concrete, is causing roughly 60 % of the total emissions of concrete (SINTEF, 2016), while the remaining 40 % are related to fuel consumption for the processes. By introducing eco-cement to the process, the emissions will go down substantially.

  Eco-cement is a type of cement that pollutes far less than regular Portland cement (standard cement), by introducing magnesium into the mix. Essentially, the magnesium allows the mixed cement to absorb CO_2 from the atmosphere, until it saturates. The process of producing the eco-cement is far more environmentally friendly than regular cement, as it allows for lower temperatures, introduction of more alternative filling compounds (for instance, waste like concrete) and less harvesting of raw materials (Mathews, 2012, Harrison).

  Another exciting alternative of eco-cement, is the introduction of blue clay into the mixture. Of the high emissions intensive limestone, 35-50 % (SINTEF, 2016) can be replaced with blue clay, which only requires heat treatment of the raw product. This indicates that the emissions can be reduced by as much as 50 %, if one uses renewable fuel for heat production.

There are some good alternatives to regular Portland cement for concrete production. The listed options are the two most prominent ones, where one absorbs CO_2 while the other heavily reduce the emissions of production. This is worth looking into before choosing materials for constructions.

6.2.3 Foreign output and subcontractors

When the organisation procures services from others, it needs to focus on *green procurement* by putting in place sustainability requirements. This can be done by direct requirements, or influencing the contractors and subcontractors to produce goods and services which are more environmentally friendly. It is recommended that the organisation takes charge and tries to influence subcontractors to act, produce and deliver a more sustainable product.

6.3 Various

6.3.1 Other operations materials

Products with lifetime of less than 3 years and/or maximum cost of 30 000 NOKs makes up this post. This includes products such as computers, smartphones, pads, tools, computer programs and so on. The reduction potential lays at consuming less of these products. It may be a hard post to do something about, as these are everyday operation materials, and are in high demand. Smarter and better mapping of the true consumption is advised, as a mean to reduce the demand.

6.3.2 Other cost

There is not much one can do with this post, as it consists of expenses related to properties, transactions, bank accounts, board meetings, etc. These are expenses required to run the organisation, thus the mitigation options are limited. Avoiding unnecessary properties, transactions, bank accounts, etc. is an option.

6.3.3 Procurement of raw materials and semi-finished products

The new law of green procurement dictates that the public sector needs to acquire more environmentally friendly products than previously and this post will most likely see an effect of that. The organisation should focus on obtaining products with less embodied emissions.

6.3.4 Procurement of other foreign services

By procuring services from contractors/organisations that have a sustainable focus, the reduction of this post can be achieved. It all depends on how environmentally friendly the Foreign Service is, as there are little contributions from the Norwegian Defence sector for this post.

6.4 More recommendations

- Reduce the use of Urea
  Urea is more emission intensive than Aviform. Aviform is fed CO_2 during its production phase and because of this, the emissions stemming from Aviform is not at

high as they seem. The CO_2 that were used during the production phase will need to be deducted out of the total. This makes Aviform a better product than Urea, when measuring it up against the CO_2-eq emissions

- Educate, train and encourage personnel to think more sustainable.
    - Train to operate buildings and equipment more efficiently.
    - Educate and encourage a more sustainable procurement in all levels of the organisation. For instance, acquire products with EPD.
    - Upgrading old equipment. For example, old tanks with old engines are nowhere close to the efficiency of new engines. Upgrading the engines to produce more power by consuming less fuel.
- Aircraft simulators: Use more aircraft simulators for training
- More environmentally friendly ammunitions, both black ammunition and live ammunition
- Eat and drink a more sustainable diet. For instance, one day of eating meat less per week.

7 Further work

There are 3 parts that could be focused on for further work.

Firstly, building up own life cycle assessment processes for military equipment. As there are very few processes in SimaPro that could fit well with military equipment, the analysis was conducted on a conservative level. This was done as a way of showing a minimum organisational carbon footprint with high level of certainty. By building own processes for the entire fleet (land, air and sea) for the organisation, a higher carbon footprint will be proven with a similar high level of certainty. This is time-consuming work, and require a detailed and in-depth view of the value chains. In addition, in time more and more processes will be available on the ecoinvent database, which may match better with the goods and services of the organisation, thus giving a better picture of the organisational carbon footprint.

Secondly, the nature of secrecy forces this analysis not to go as deep as wanted, in order to produce as good data as possible. If the organisation does an analysis including secluded data, a higher carbon footprint will be revealed. This point match well with the previous points about SimaPro processes.

Thirdly, by producing O-LCA for the Norwegian Defence sector annually, the analysis works great as performance tracking. Hotspots can be tracked and followed up. Management can focus efforts into cost/benefit areas, etc. (see figure 2.2). In addition, more detailed data are produced and gathered each year, giving better and more accurate analysis.

Procurement codes: Previously the reporting has been a bit messy. Information needed to be gathered from each agency, which could be challenging to decipher. The 2016 economic reports were of much higher quality, as the individual procurements had been reported in the designated governmental procurement codes (for the most parts). By focusing some efforts on reporting correctly, the foundation for annual O-LCA will be very strong and easy to use. Less investigations and assumptions of oddly reported procurements categories.

Ammunition: The process of ammunition was built on 9mm bullet information using information about materials and energy consumption provided by Carlos Ferrieira's life cycle assessment article about 9mm ammunition (Ferreira et al., 2016). By building additional processes for ammunition, the emission mapping of ammunition will be of far higher quality than it is in this thesis. The life cycle of ammunition should be looked more into.

The life cycle stages: Production, use phase and end-of-life (EoL) are life cycles stages that should be calculated more accurately. In this thesis, the use phase are of high quality, while the production phase is relatively good. However, for EoL, the processes available on SimaPro were of poor quality, as they did not match with military equipment. EoL should therefore be looked more into, as this is an important life cycle of goods and services, and will contain considerable indirect emissions. This applies mainly to the physical analysis. A hybrid EE-OIA will reveal these in the background tables.

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Appendix A – Life cycle perspective

A life cycle perspective is defined by ISO 14001 as:

> *«A systematic approach to environmental management can provide top management with information to build success over the long term and create options for contributing to sustainable development by controlling or influencing the way the organization's products and services are designed, manufactured, distributed, consumed and disposed by using a life cycle perspective that can prevent environmental impacts from being unintentionally shifted elsewhere within the life cycle."*
>
> *(ISO, 2015)*

This means that the organisation should have focus on the environmental effects caused in the upstream and downstream of the organisations (the value chain). For upstream, one will find the productions phase of the life cycle. For the use phase, it is the organisation itself, while for the end-of-life, it is the downstream. Figure 13 illustrates the value chain and the scope emissions. Scope 1 emissions are *use phase* emissions, Scope 2 emissions are indirect purchased energy emissions, while Scope 3 is all other indirect emissions.

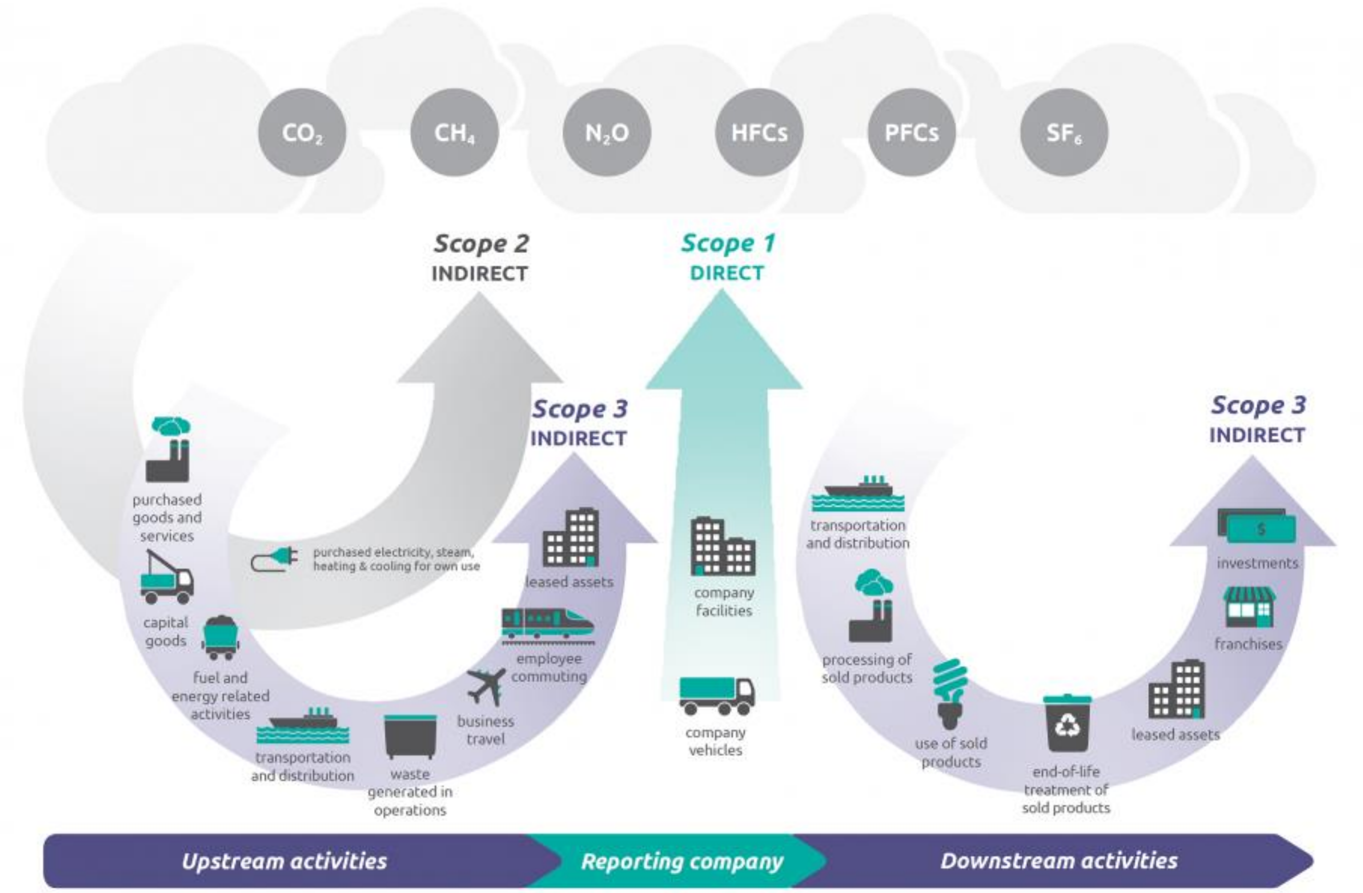

Figure A.1 illustrates the value chain of a reporting organisation. The value chain consists of upstream and downstream activities. The figure also illustrates where the scope emissions lies within the value chain (PROTOCOL, 2011).

Appendix B – Physical analysis

Appendix B presents the background information's for the physical analysis.

Table 0.1explains the figure 4.1

	Explanation
Energy	*E1*: Electricity and heat consumption, given in [kWh] *E2:* Diesel/F34/gasoline, heating oil and paraffin, given in [L] *E3*: Bio pellets, natural gas, propane and wood chip, given in [kg] E4: Natural gas
Waste	Total waste output, given in [ton]
Ammunition	Total rounds of ammunition fired of all sorts [piece]
Water	Consumption of water, [m3]
Chemical	*C1:* Chemicals reported in [kg]. *C2:* Chemicals reported in [L]
Environmental accidents	Spillage to air, land and/or water. Number of accidents.
Fuel	Fuel consumption given in cubic metre [m3]
Transport	Transport by airplanes, domestic and international, given in per travel.

Energy

Table 0.2 illustrates the flows of energy, reported in MWh.

Tabell 3.11 Energiforbruk (MWh) fordelt på energikilde for årene 2012-2016.	
Energikilde [MWh]	**2016**
Elektrisitet	553 063
Fjernvarme	75 688
Fyringsolje	37 862
Propan	15 753
Naturgass	6 208
Biopellets	5 303
Skogsflis	10 995
Sum forbruk	704 872
Sum graddagskorrigert forbruk	726 586

Table 0.3 illustrates the emission factors for Energy.

Energy	**Production**	**Use**	**EoL**
Electricity, kWh	0,0256	-	-
Disctrict heating, kWh	0,1329	0,0163	-
Light fuel oil, kg	0,3205	2,6816	-
Propane (LPG), kg	0,7142	3,0092	-
Natural gas (LNG), m3	0,2636	0,0023	-
Biopellets, kg	-	0,0271	-
wood chips, kg	0,0342	0,0245	-

In *Production* for table B.2, all contributions are CO_2-eq/kWh. The *Use* contributions are listen by the energy source.

Electricity

- has a 0,0153 kgCO_2-eq/kWh contribution from the production, while the infrastructure contributes the remaining 0,0103 kgCO_2-eq.
- SimaPro: Electricity, low voltage (NO)| market for |

District heating:

- The 0,1329 kgCO_2-eq *Production*
    - Consist of the *production* phase emissions of 6 categories: *Waste, wood chip, electricity, heat pumps, LNG* and *light fuel oil.*

Light fuel oil, propane, natural gas, bio pellets and wood chips:

- SimaPro processes for *heat, central heating¸ small scale, at market.* This allows for all the *production* emissions to be accounted for. At market means ready to be used.

Use phase:

- The environmental report 2016 calculated the use phase emissions very detailed. The emission intensities presented in the report was of higher quality than the SimaPro processes allows for, therefore they were used.

End-of-Life (EoL):

- SimaPro did not have any processes for the EoL.

Water

SimaPro processes for *tap water at market (production)* and *treatment, waste water*.

Table 0.4illustrates density, consumption and life cycle emissions for Water

	g/mL	kg/L
Water density	0,997	997,047

	m3	kg
Water consumption 2016	2 310 775	2 303 952 205,735

	CO2 eq	Unit	kg CO2 eq 2016
Production	0,0004061	kg water	935737,7009
Use phase	0		0
End of life	0,5985669	m3 wastewater	1383153,475
Total			2318891,176

Chemicals

Production:

- Urea: Simapro process for *Urea market Nitrogen** 0,46 (share of Nitrogen in Urea used for runway)
- Safewing: Simapro process for *propylene, at market*
  - Safewing I: *propylene* * share of total Safewing * 0,5 (water/chemical)
  - Safewing II: *propylene* * share of total Safewing * 0,8 (water/chemical)
- Aviform: Simapro process for *Potassium, at market* * 0.5 (water/chemical)

Table 0.5illustrates the Production contributions for the three chemicals Urea, Safewing and Aviform

	Consumed in 2016 [kg]	CO2eq/kg	CO2eq [kg]	
Urea	409 553	1,582407038	648079,5496	
Safewing	31 082	3,468141329	107796,7688	
Aviform	407 490	1,52680175	622156,4451	
Total	848 125		1 378 032,76	kg CO2 eq

Use:

Urea: 0,73 (Brentrup and Pallière, 2008)

Safewing: C3H8O2 + 4O2 gir 4H20 + 3CO2 gives 1.7gram CO2 per g C3H8O2

1,7 * 0,8 (type I) + 1,7 * 0,5 (tye II) = 1,2999..

Aviform: Is introduced CO2 in the production phase, which is released in the use phase. Does not contribute to “more” CO2 emissions in the use phase.

EoL:

(share piece per kg chemical) * (total kilo) * (contribution per kg)

Assumed EoL contribution for all three. SimaPro process of *waste handling chemicals*.

Table 0.6 illustrates the emissions intensities and emission contributions for the life cycle of the three chemicals Urea, SafeWing and Aviform

	Production [kg CO2-eq / kg	Use Phase [kg CO2-eq / kg	End of life [kg CO2-eq / kg chemical]		
Urea	1,582407038	0,73	0,001437		
Safewing	3,468141329	1,299973296	0,001437		
Aviform	1,52680175	0	0,001437		
	tot kg CO2-eq prod	tot kg CO2-eq Use	tot kg CO2-eq Waste		
Urea	648 079,5	298 973,7	588,6		
Safewing	107 796,8	40 405,8	44,7		
Aviform	622 156,4	-	585,6		
Total	1 378 032,8	339 379,5	1 218,9	1 718 631,2	kg CO2-eq

Air travel

The air travel category has classified data. What SimaPro processes used for calculating emissions are:

Long hauls, short hauls, large planes, small planes, kerosene, airports.

The *production* and *EoL* where calculated, while the *Use phase* were reported in the environmental report 2016

CO2-eq (regnet for total pkm)	Prod (andel gjennon	Use (Fuel)	Waste (airport)
Innland	6 132 444,3	23 274 038,0	3,2
Utland	2 095 098,7	6 518 632,0	746,7
Charter	2 450 232,3	7 623 585,0	873,3
Total	10 677 775,4	37 416 255,0	1 623,1

Fuel

Table 0.7illustrates the emission intensities and total emissions for each fuel category

	Production [kg CO2-eq/kg fuel]	Production kg CO2-eq/m3 fuel	Use phase [kg CO2-eq/L fuel]
Marine gas oil	0,51357591	441,6752826	2,737
F-34/F-44	0,57717861	467,5146741	2,558
Bensin	0,79574092	586,461058	2,480
Diesel	0,57736764	480,3698765	2,690
LNG	0,00213399	0,96029748	1,892
Avgas	0,79574092		2,275

Consumed in 2016 [m3]	kg CO2eq/kg	kg CO2eq/m3	Density of product [kg/m3]	CO2eq [kg] (market)
38 297	0,51357591		860	16 914 838,3
41 993	0,57717861		810	19 632 343,7
184	0,79574092		737	107 908,8
2 885	0,57736764		832	1 385 867,1
5 634		0,96029748	450	5 410,3
48	0,79574092		737	28 150,1
			SUM Produksjon	38 074 518,4

Density: Values of each product are given on engineering toolbox (ToolBox, 2017)

Direct values are reported in the environmental report 2016.

Cars & transportation

Classified data on amount and detailed type

What can be said about the production emissions are that they are divided on the estimated years of service, so the contribution for 2016 is what it sums up to be. Table B.7 illustrates this. The life times are estimates based on sources. Average lifetime is given by producers, as well as statistical offices. Used producers for sources here. EoL contributions were depicted by the SimaPro processes (very poorly).

Table 0.8 illustrates the fleet of the Norwegian Defence sector, very roughly, with production emissions and life time estimations

Category	Number	Prod.emissic	Lifetime	CO2-eq utslipp for total flåte i kategori, bidrag per år
Big planes	10	7022152	25	2808860,8
Small planes	76	2195180	25	6673347,2
Helicopters	34	8899	20	15128,3
Heavy vehicles	1500	33670	20	2525250
Medium vehicles	4000	13608	20	2721600
Light vehicles	3200	1887	15	402560
Bus	0			
Lorry	1700	24413	20	2075105
Heavy lorry	0			
Delivery truck	0			
Big boats	13	18033743	30	7814621,967
Medium boats	8	1428778,5	30	381007,6
Small boats	37	1187597	30	1464702,967
			SUM	26882183,83

Waste

Table 0.9 illustrates the waste categories for the Norwegian Defence sector

Hovedfraksjon Tabell 3.1, Næringsavfall	2016 [tonn]	CO2-eq fra 1 kg avfall [kg]	kg CO2-eq 2016
Blandet avfall	6 036,91	0,515	3 109 392,243
Bioavfall og slam	3 012,00	0,137	411 670,190
Farlig avfall	2 696,71	2,751	7 419 769,204
Papp, papir og kartong	982,00	1,462	1 435 498,304
Metall	2 202,27	0,829	1 826 060,641
Masser, uorganisk materiale	395,00	0,012	4 754,427
EE-avfall	341,02	0,056	19 041,272
Tekstil, skinn, møbler, inventar	213,00	0,011	2 429,540
Plast	140,00	1,545	216 232,134
Gummi	133,00	2,053	273 087,545
Glass	118,00	0,033	3 877,933
Medisinsk avfall	27,00	2,751	74 288,324
Trevirke	20,72		
Batterier	0,11	1,169	128,636
Total			14 796 101,758

Tabell 3.3 Bygg- og anleggsavfall (kg) knyttet til prosjekter i regi av FB SE c

Avfall FB Utvikling	Mengde (kg) 2016	CO2-eq fra 1 kg avfall [kg]	kg CO2-eq 2016
Bioavfall og slam	509 200	0,137	69 595,771
Papp, papir og kartong	10 000	1,462	14 618,109
Glass	4 000	0,033	131,455
Metall	112 700	0,829	93 447,558
EE-avfall	9 700	0,056	541,615
Masser og uorganisk materiale	605 600	0,012	7 289,319
Plast	11 600	1,545	17 916,377
Farlig avfall	2 157 200	2,751	5 935 361,930
Blandet avfall	456 700	0,515	235 229,363
Medisinsk avfall	456 700	2,751	1 256 573,240
Radioaktivt avfall	3 420 000		-
Sum FB Utvikling	**7 753 400**		7 630 704,737
Sorteringsgrad FB Utvikling (%)	**94**		
Avfall FB Skifte Eiendom			
Bioavfall og slam	140 590	0,137	19 215,376
Metall	199 830	0,829	165 693,217
EE-avfall	9 496	0,056	530,224
Masser og uorganisk materiale	15 402 677	0,012	185 394,691
Farlig avfall	147 726	2,751	406 456,182
Blandet avfall	41 760	0,515	21 509,039
Sum FB Skifte Eiendom	**15 942 079**		798 798,730
Sorteringsgrad FB Skifte Eiendom (%)	**100**		

Ammunition

Production: Created a very basic process in SimaPro for 9 mm ammunition

125kg CO2-eq per 1kg 9mm ammunition

Table 0.10illustrates the production emissions of 1kg 9mm bullets

9 mm	Vekt			1 kg
	0,008			125,00
	Prod	181652,676	98 %	
	Use	1 259,92	1 %	
	EoL	2500	1 %	
		185412,599		

Use: Gun powder without sulfur 10 KNO3 + 2 C7H4O → 5 K2CO3 + 4 CO2 + 5 CO + 4 H2O + 5 N2 gives 0,85 g CO2

EoL:

Table 0.11illustrates the EoL emissions stemming from the revocered and recycled brass casings

Type materiell	Mengde (kg), 2016	CO2-eq fra 1 kg avfall [kg]	kg CO2-eq 2016
Messinghylser	126 370,00	0,83	104 782,32

Table 0.12 illustrates the ammunition emissions caused by the Norwegiand Defence sector

Ammunisjonskategori	Total vekt (kg)	Utslipp til standplass og målområde (kg)	kg CO2-eq use (uten sulfur)	Prod [kg CO2-eq]
		Krutt		
Bombekaster	24 837	615	520,38	165 318,51
Feltartilleri	360 828	36 043	30 497,92	2 401721,14
Fly	34 193	677	572,85	227 593,34
Granatkaster	267	9	7,62	1777,19
Håndgranater	1331	1	0,85	8 859,32
Håndvåpen, 12.7mm	12 207	3 022	2 557,08	81251,48
Håndvåpen, 4.6mm	5 428	1097	928,23	36 129,52
Håndvåpen, 5.56mm	84 658	23372	19 776,31	563 495,37
Håndvåpen, 7.62mm	29 877	4 694	3 971,85	198 865,45
Håndvåpen, 9mm	27 291	1489	1259,92	181652,68
Håndvåpen, hagle	192	9	7,62	1277,98
Markørladn/knallskudd	690	0	-	4 592,74
Mellomkaliber	20 482	3739	3 163,77	136 331,03
PV	103	23	19,46	685,58
RFK	6 457	3687	3 119,77	42 978,69
Røykkasterammunisjon	11	0	-	73,22
Signalbluss	810	0	-	5 391,47
Sprengningsmateriell	146	0	-	971,80
Total	**609 808**	**78477**	**66 403,62**	**4 058 966,51**

Appendix C – Monetary analysis

Table C.0.1illustrates the 87 procurement categories with the emission factors, categorisation, spendings and emissions for 2016

Code	Text	kgCO2-eq/ NOK	Category	mill NOK	tCO2eq
634	Lys, varme	0,18	Bygg, eiendom og anlegg	257 079	46 274
113	Anlegg under utførelse	0,024	Bygg, eiendom og anlegg	1 509 001	36 216
450	Fremmedytelse og underentreprise	0,018	Bygg, eiendom og anlegg	1 911 281	34 403
632	Renovasjon, vann, avløp o.l.	0,069	Bygg, eiendom og anlegg	193 477	13 350
639	Annen kostnad lokaler	0,017	Bygg, eiendom og anlegg	289 218	4 917
636	Renhold, vakthold, vaktmestertjenester	0,017	Bygg, eiendom og anlegg	166 939	2 838
663	Reparasjon og vedlikehold leide lokaler	0,021	Bygg, eiendom og anlegg	38 283	804
664	Reparasjon og vedlikehold infrastruktureiendeler	0,026	Bygg, eiendom og anlegg	17 691	460
126	Fast bygningsinventar med annen avskrivningstid enn bygningen	0,035	Bygg, eiendom og anlegg	5 307	186
660	Reparasjon og vedlikehold egne bygninger	0,021	Bygg, eiendom og anlegg	4 910	103
110	Bygninger	0,024	Bygg, eiendom og anlegg	3 382	81
779	Annen kostnad	0,017	Diverse	1 672 190	28 427
400	Innkjøp av råvarer og halvfabrikater	0,071	Diverse	294 975	20 943
658	Annet driftsmateriale	0,024	Drift	2 300 707	55 217
659	(Annet driftsmateriale - Tas i bruk ved behov for ytterligere underkontoer)	0,024	Drift	657 419	15 778
657	Arbeidsklær og verneutstyr	0,02	Drift	239 885	4 798
669	Reparasjon og vedlikehold annet	0,024	Drift	90 701	2 177
650	Maskiner	0,034	Drift	63 141	2 147
680	Kontorrekvisita	0,046	Drift	23 752	1 093
125	Inventar	0,037	Drift	28 134	1 041
651	Verktøy og lignende	0,038	Drift	22 816	867
654	Inventar	0,023	Drift	35 228	810
689	Annen kontorkostnad	0,031	Drift	25 561	792
127	Verktøy og lignende	0,038	Drift	14 046	534
120	Maskiner og anlegg	0,034	Drift	13 162	447
652	Programvare (anskaffelse)	0,011	Drift	34 079	375
644	Leie av andre kontormaskiner	0,026	Drift	12 078	314
640	Leie maskiner	0,028	Drift	6 678	187
129	Andre driftsmidler	0,029	Drift	6 080	176
694	Porto	0,02	Drift	7 265	145
641	Leie inventar	0,021	Drift	1 513	32
530	Styrer, råd og utvalg	0,024	Drift	513	12
777	Bank- og kortgebyr	0,006	Drift	636	4
750	Forsikringspremie	0,007	Drift	456	3
760	Lisensavgift og royalties (ikke programvarelisenser, jf. 642)	0,014	Drift	11	0

666	Reparasjon og vedlikehold maskiner og anlegg	0,028	IKT	104 667	2 931
642	Leie av datasystemer (årlige lisenser m.m.)	0,016	IKT	171 958	2 751
655	Datamaskiner (PCer, servere m.m.)	0,015	IKT	74 911	1 124
690	Telefoni og datakommunikasjon, samband, internett	0,013	IKT	81 050	1 054
672	Kjøp av tjenester til løpende driftsoppgaver, IKT	0,01	IKT	85 154	852
671	Kjøp av tjenester til utvikling av programvare, IKT-løsninger mv.	0,01	IKT	41 331	413
128	Datamaskiner (PCer, servere m.m.)	0,015	IKT	15 204	228
656	Andre kontormaskiner	0,025	IKT	8 839	221
521	Fri elektronisk kommunikasjon (telefon, mobiltelefon mv.)	0,013	IKT	1 328	17
643	Leie av datamaskiner	0,018	IKT	652	12
686	Møter	0,047	Kommunikasjon	19 872	934
688	Kurs og seminarer for eksterne deltakere	0,033	Kommunikasjon	8 530	281
682	Trykksak	0,032	Kommunikasjon	5 083	163
683	Annonser, kunngjøringer	0,019	Kommunikasjon	4 565	87
732	Reklamekostnad	0,019	Kommunikasjon	2 358	45
735	Representasjon	0,01	Kommunikasjon	4 418	44
730	Salgskostnad	0,015	Kommunikasjon	2 406	36
741	Gave	0,027	Kommunikasjon	294	8
687	Kurs og seminarer for egne ansatte	0,033	Kompetanse	118 662	3 916
877	Tilskudd til statsforvaltningen (Forskning og utvikling)	0,017	Kompetanse	187 631	3 190
684	Aviser, tidsskrifter, bøker o.l.	0,012	Kompetanse	10 273	123
685	Aviser, tidsskrifter, bøker o.l. i bibliotek	0,012	Kompetanse	389	5
522	Fri avis	0,012	Kompetanse	9	0
599	Annen personalkostnad	0,02	Personal	38 533	771
596	Velferdstiltak	0,022	Personal	25 491	561
591	Kantinekostnad	0,105	Personal	3 924	412
592	Gruppelivsforsikring	0,007	Personal	18 837	132
590	Gaver til ansatte	0,027	Personal	4 731	128
740	Kontingent	0,016	Personal	5 571	89
593	Yrkesskadepremie	0,007	Personal	2 118	15
525	Gruppelivsforsikring	0,007	Personal	450	3
678	Kjøp av andre fremmede tjenester	0,017	Prof. Tjenester	975 293	16 580
679	(Kjøp av andre fremmede tjenester - Tas i bruk ved behov for ytterligere underkontoer)	0,017	Prof. Tjenester	56 447	960
674	Innleid personell fra vikarbyrå o.l.	0,008	Prof. Tjenester	91 303	730
670	Regnskaps-, revisjons- og økonomitjenester	0,01	Prof. Tjenester	19 484	195
673	Kjøp av tjenester til organisasjonsutvikling, rekruttering mv.	0,006	Prof. Tjenester	29 995	180
700	Drivstoff	0,25	Transport	482 762	120 690
713	Reisekostnad	0,117	Transport	544 504	63 707
668	Reparasjon og vedlikehold skip, rigger, fly	0,028	Transport	1 318 053	36 905
715	Diettkostnad	0,057	Transport	113 340	6 460
646	Leie av andre transportmidler	0,029	Transport	209 352	6 071
645	Leie av biler	0,033	Transport	158 040	5 215

710	Bilgodtgjørelse	0,079	Transport	38 293	3 025
709	Annen kostnad transportmidler	0,037	Transport	81 607	3 019
702	Vedlikehold	0,028	Transport	41 133	1 152
122	Skip, rigger, fly	0,035	Transport	8 004	280
610	Frakt, transport og forsikring ved vareforsendelse	0,069	Transport	3 395	234
550	Annen kostnadsgodtgjørelse	0,08	Transport	2 371	190
719	Annen kostnadsgodtgjørelse	0,08	Transport	1 087	87
124	Andre transportmidler	0,035	Transport	1 268	44
619	Annen frakt- og transportkostnad ved salg	0,085	Transport	122	10
704	Forsikring	0,007	Transport	91	1
Total				**15 172 774**	**562 233**

Table C.0.2 illustrates the five categories and their spendings and contributions

	CO2 [tonn]	NOK [mill NC	CO2	NOK
Army	85 787	2 346	15 %	15 %
Navy	118 262	2 807	21 %	18 %
Air force	118 549	3 403	21 %	22 %
Supply and suppor	203 311	4 851	36 %	31 %
Staff and specialist	36 324	1 999	6 %	13 %
Sum	562 233	15 406	100 %	100 %

Appendix D – Methods

Material Flow Analysis

In the environmental report *Forsvarssektorens miljø- og klimaregnskap 2016*, which is the environmental report for the Norwegian Defence sector, the information given about the inputs and outputs for the organisation was collected by the use of Material Flow Analysis (MFA). This information consists of the direct emissions that will undergo product life cycle assessment, using the SimaPro tool.

Material Flow Analysis as a tool, is widely used to describe an anthropogenic system quantitatively (Brunner and Rechberger, 2016). It describes a system by flows, stocks and processes, within a system boundary, that is defined in space and time. As MFA is based on the conservation principle, the flows need to go somewhere. They cannot just disappear. This makes the MFA as a tool quite attractive for decision-support in resource-, waste- and environmental- management. MFA provides precise information about the flows and stocks within a system. It describes the input, stock and output by mass balance.

The name, *material flow analysis*, indicates that material is the flow that is studied. However, this is not so. For anthropogenic systems, there are many types of flow and stocks. Material, energy, emissions, information, space and socioeconomic issues all needs to be accounted for. Stocks is described as the accumulative structures, such as infrastructure, buildings, machines, vehicles, fixed capital and consumer products. Flows are what is taking place between the stocks or processes, resulting in maintain, build and operate the stocks (Pauliuk and Hertwich, 2015, Brunner and Rechberger, 2016).

Life Cycle Assessment

Life Cycle Assessment (LCA) has been around for many years. In the 1950s the tool was introduced and put to use, and over the years it has been developed further and further, to which it now can analyse the full life cycle of a product or process (Strømman, 2010). It is a cradle-to-grave perspective, where the three main phases are *production, use phase and disposal*. This is essentially the life cycle, and as figure 2.1 illustrates, the life cycle phases consist of r*aw material extraction, Production/Manufacturing, Distribution, Use and End-of-life (EOL) management.* In the EOL phase, the most preferred options for the smallest amout of emissions connected with the phase, is also illustrated.

Figure D.1 illustrates the life cycle phases of a product(EPA, 2016), and how the EOL phase with the most preferred options for the reducing the amount of environmental emissions connected with the EOL phase.

The life cycle of a product is the value chain, and LCA calculates the total environmental impacts caused by a products' value chain. It will reveal where the environmental loads occur, whether it is choice of energy, material, processes, etc. It can be used develop and to compare products in a competitive way (Strømman, 2010). Advertise products (environmental declaration products (EPD) or environmentally labelled products). To make sure you as a producer follows the rules and regulations related to the production, or to implement a more environmentally friendly corporate image.

The LCA methodology consists of four steps (ISO, 2006).Step 1 is goal and scope, which includes the system boundary, what is to be assessed, level of detail, the reporting flow, cut-off and allocation information. Step 2 is the Life Cycle Inventory Analyse (LCI), and is collecting and presenting the value chain (input and output stream) related to the product or process being studied. Step 3 is the Life Cycle Impact Assessment (LCIA), where further information is presented. Information that will help assessing the products LCI results for better understanding of the environmental impacts. Step 4 is the life cycle interpretation. It presents the results from LCI and LCIA, discusses the results and sensitivity, and ends with a conclusion, limitation and recommendation. Figure 2.2 illustrates the structure of these four stages and how they are interconnected.

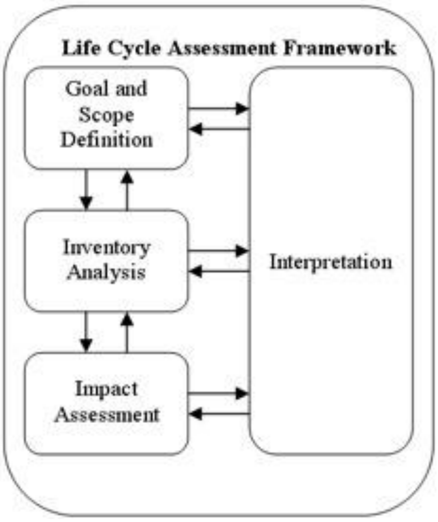

Figure D.2 illustrates the four steps of LCA (UNEP, 2003)

While LCA assess the environmental impact caused by a products' value chain, an organisational life-cycle assessment (O-LCA) studies an organisation rather than a singular product.

Process LCA - SimaPro

The Life Cycle Assessment (LCA) in this thesis are conducted by using the SimaPro tool, on the MFA reported flows, collected from the *Forsvarssektorens miljø- og klimaregnskap 2016.* The SimaPro tool allows the users to build up their own processes for product LCA, providing the level of accuracy linked with the resolution of the data feed to the system. Due to the enormous amount of work hours it would take to map out all inputs and outputs connected with the processes of goods and services acquired by Norwegian Defence sector, this thesis will therefore use already existing processes.

SimaPro has a high number of already existing processes, which vary from very specific processes, to more general and average processes. Processes are built to represent a geographical location as well (e.g. Europe without Switzerland, America, Switzerland, Rest of World etc). Therefore, in this thesis, the SimaPro processes that match as close as possible with the MFA flows, will vary in resolution.

The processes themselves are built up by other processes that represent inputs and outputs into the product. For instance, Kerosene – Europe without Switzerland as a product is presented as a process in SimaPro. The kerosene is built up by ~9000 other processes, which represents all the inputs and outputs of the kerosene process. Simply put, the ~9000 processes represent the "building" blocks of the kerosene process. This process will give detailed and accurate information regarding the CO_2-eq emissions stemming from the process.

For other processes, such as a military tank, existing processes does not exist. For products without existing processes in SimaPro, processes that come as close to the original as possible are chosen. For other processes, some of the inputs are changed, so they can represent the product LCA better. For instance, electricity – Norwegian mix, are one of the inputs changed in processes representing products produced in Norway, but in SimaPro represent European mix instead.

The SimaPro tool allows the user to build its own and alter already existing processes, as the user find preferable. In this thesis it resulted in processes altered to represent the Norwegian Defence sector as best as possible, and some new processes, such as the 9mm bullet.

EE-IOA: factors from Asplan Viak

Input-Output analysis (IOA) is an analytic tool for economic transactions. It provides a systematic quantification of the interrelationships between different sectors, different nations, regions etc. It connects goods, production processes, supply, and demand in both a stationary and a dynamic way. It gives information about what goes in, and what goes out, for all sectors (Hannon, 1995, Brunner and Rechberger, 2016).

By combining IOA with LCA (Brunner and Rechberger, 2016), a hybrid is made, which can be used to trace emissions connected with economy. Input-output tables describe an economy for a given sector/field. These tables can easily be fitted together with the associated emissions data, which is referred to as environmentally extended input-output analysis (Hogne Nersund Larsen et al., 2016). By doing so, emissions factors can be produced, showing emissions per NOK spending (CO2-eq/NOK) Therefore, by obtaining the economic statistics for the Norwegian Defence sector and combining the tables with emissions factors, the emission per NOK can be presented.

Table D.1 presents the emissions factors which Asplan Viak produced by using EE-IOA (environmentally extended input-output analysis) together with their own tool *Klimakost*[6]. For better understanding of the models and methods used to produce the emissions factors, read appendix 3,4 and 5 of the Asplan Viak report *Carbon footprint of central government procurement*.

Table D.0.1illustrates the emission factors Asplan Viak produced and published in the Carbon footprint of central government procurement (Hogne Nersund Larsen et al., 2016).

artkode	artnavn	kategori	kgCO2e./ NOK
400	Innkjøp av råvarer og halvfabrikater	Diverse	0,071
403	(Innkjøp av råvarer og halvfabrikater - Tas i bruk ved	Diverse	0,071
406	Frakt, toll og spedisjon	Diverse	0,02
450	Fremmedytelse og underentreprise	Diverse	0,018
451	(Fremmedytelse og underentreprise - Tas i bruk ved behov	Bygg, anlegg og eiendom	0,018
452	(Fremmedytelse og underentreprise - Tas i bruk ved behov	Bygg, anlegg og eiendom	0,018
453	(Fremmedytelse og underentreprise - Tas i bruk ved behov	Bygg, anlegg og eiendom	0,018
454	(Fremmedytelse og underentreprise - Tas i bruk ved behov	Bygg, anlegg og eiendom	0,018
470	Forskning og utvikling	Kompetanse	0,017
474	Programvarelisenser	IKT	0,011
476	Andre rettigheter	Kompetanse	0,012
480	Bygninger	Bygg, anlegg og eiendom	0,024
481	Beredskapsanskaffelser	Bygg, anlegg og eiendom	0,026
482	Bygningsmessige anlegg	Bygg, anlegg og eiendom	0,026
484	Jord- og skogbrukseiendommer	Bygg, anlegg og eiendom	0,001
485	Tomter og andre grunnarealer	Bygg, anlegg og eiendom	0,012

[6] http://www.klimakost.no

486	Boliger inkl. tomter	Bygg, anlegg og eiendom	0,017
487	Infrastruktureiendeler	Bygg, anlegg og eiendom	0,026
488	Nasjonaleiendom og kulturminner	Bygg, anlegg og eiendom	0,005
489	Andre anleggsmidler	Bygg, anlegg og eiendom	0,029
490	Maskiner og anlegg	Drift	0,034
492	Skip, rigger, fly	Transport	0,035
493	Biler	Transport	0,045
494	Andre transportmidler	Transport	0,035
495	Inventar	Drift	0,037
496	Fast bygningsinventar med annen levetid enn bygningen	Bygg, anlegg og eiendom	0,035
497	Verktøy og lignende	Drift	0,038
498	Datamaskiner (PCer, servere m.m.)	IKT	0,015
499	Andre driftsmidler	Drift	0,029
590	Gaver til ansatte	Personal	0,027
591	Kantinekostnad	Personal	0,105
592	Gruppelivsforsikring	Personal	0,007
593	Yrkesskadepremie	Personal	0,007
596	Velferdstiltak	Personal	0,022
599	Annen personalkostnad	Personal	0,02
610	Frakt, transport og forsikring ved vareforsendelse	Transport	0,069
611	Toll og spedisjon ved vareforsendelse	Diverse	0,029
619	Annen frakt- og transportkostnad ved salg	Transport	0,085
620	Elektrisitet	Bygg, anlegg og eiendom	0,18
621	Gass	Bygg, anlegg og eiendom	0,25
622	Fyringsolje	Bygg, anlegg og eiendom	0,375
624	Ved	Bygg, anlegg og eiendom	0,022
625	Bensin, diesel	Transport	0,25
626	Vann	Bygg, anlegg og eiendom	0,022
629	Annet brensel	Bygg, anlegg og eiendom	0,2
630	Leie lokaler	Bygg, anlegg og eiendom	0,016
631	Leie lokaler fra Statsbygg	Bygg, anlegg og eiendom	0,016
632	Renovasjon, vann, avløp o.l.	Bygg, anlegg og eiendom	0,069
634	Lys, varme	Bygg, anlegg og eiendom	0,18
636	Renhold, vakthold, vaktmestertjenester	Bygg, anlegg og eiendom	0,017
639	Annen kostnad lokaler	Bygg, anlegg og eiendom	0,017
640	Leie maskiner	Drift	0,028
641	Leie inventar	Drift	0,021
642	Leie av datasystemer (årlige lisenser m.m.)	IKT	0,016
643	Leie av datamaskiner	IKT	0,018
644	Leie av andre kontormaskiner	Drift	0,026
645	Leie av biler	Transport	0,033
646	Leie av andre transportmidler	Transport	0,029
649	Annen leiekostnad	Bygg, anlegg og eiendom	0,03
650	Maskiner	Drift	0,034
651	Verktøy og lignende	Drift	0,038
652	Programvare (anskaffelse)	IKT	0,011
654	Inventar	Drift	0,023
655	Datamaskiner (PCer, servere m.m.)	IKT	0,015

656	Andre kontormaskiner	IKT	0,025
657	Arbeidsklær og verneutstyr	Drift	0,02
658	Annet driftsmateriale	Drift	0,024
659	(Annet driftsmateriale - Tas i bruk ved behov)	Drift	0,024
660	Reparasjon og vedlikehold egne bygninger	Bygg, anlegg og eiendom	0,021
661	(Reparasjon og vedlikehold egne bygninger - Tas i bruk ved behov)	Bygg, anlegg og eiendom	0,021
662	(Reparasjon og vedlikehold egne bygninger - Tas i bruk ved behov)	Bygg, anlegg og eiendom	0,021
663	Reparasjon og vedlikehold leide lokaler	Bygg, anlegg og eiendom	0,021
664	Reparasjon og vedlikehold infrastruktureiendeler	Bygg, anlegg og eiendom	0,026
665	(Reparasjon og vedlikehold infrastruktureiendeler - Tas i bruk ved behov)	Bygg, anlegg og eiendom	0,026
666	Reparasjon og vedlikehold maskiner og anlegg	IKT	0,028
667	(Reparasjon og vedlikehold maskiner og anlegg - Tas i bruk ved behov)	Bygg, anlegg og eiendom	0,028
668	Reparasjon og vedlikehold skip, rigger, fly	Transport	0,028
669	Reparasjon og vedlikehold annet	Drift	0,024
670	Regnskaps-, revisjons- og økonomitjenester	Prof. tjenester	0,01
671	Kjøp av tjenester til utvikling av programvare, IKT-løsninger mv.	IKT	0,01
672	Kjøp av tjenester til løpende driftsoppgaver, IKT	IKT	0,01
673	Kjøp av tjenester til organisasjonsutvikling, rekruttering mv.	Prof. tjenester	0,006
674	Innleid personell fra vikarbyrå o.l.	Prof. tjenester	0,008
678	Kjøp av andre fremmede tjenester	Prof. tjenester	0,017
679	(Kjøp av andre fremmede tjenester - Tas i bruk ved behov)	Prof. tjenester	0,017
680	Kontorrekvisita	Drift	0,046
682	Trykksak	Kommunikasjon	0,032
683	Annonser, kunngjøringer	Kommunikasjon	0,019
684	Aviser, tidsskrifter, bøker o.l.	Kompetanse	0,012
685	Aviser, tidsskrifter, bøker o.l. i bibliotek	Kompetanse	0,012
686	Møter	Kommunikasjon	0,047
687	Kurs og seminarer for egne ansatte	Kompetanse	0,033
688	Kurs og seminarer for eksterne deltakere	Kommunikasjon	0,033
689	Annen kontorkostnad	Drift	0,031
690	Telefoni og datakommunikasjon, samband, internett	IKT	0,013
694	Porto	Drift	0,02
700	Drivstoff	Transport	0,25
702	Vedlikehold	Transport	0,028
704	Forsikring	Transport	0,007
709	Annen kostnad transportmidler	Transport	0,037
710	Bilgodtgjørelse	Transport	0,079
713	Reisekostnad	Transport	0,117
714	(Reisekostnad - Tas i bruk ved behov for ytterligere underkontoer)	Transport	0,117
715	Diettkostnad	Transport	0,057
716	(Diettkostnad - Tas i bruk ved behov for ytterligere underkontoer)	Transport	0,057
719	Annen kostnadsgodtgjørelse	Transport	0,08
730	Salgskostnad	Kommunikasjon	0,015
732	Reklamekostnad	Kommunikasjon	0,019
735	Representasjon	Kommunikasjon	0,01
740	Kontingent	Personal	0,016
741	Gave	Kommunikasjon	0,027
750	Forsikringspremie	Drift	0,007

756	Servicekostnad	Drift	0,025
760	Lisensavgift og royalties (ikke programvarelisenser, jf. 642)	Drift	0,014
761	Patentkostnad ved egen patent	Prof. tjenester	0,017
762	Kostnad ved varemerke og lignende	Drift	0,018
771	Styremøter	Drift	0,024
775	Eiendoms- og festeavgift	Bygg, anlegg og eiendom	0,013
777	Bank- og kortgebyr	Drift	0,006
779	Annen kostnad	Diverse	0,017