Acknowledgement

I am so glad that I have had a great opportunity to do my semester project within MiSA AS, which gave me a good initiative to be in close connection within industry sector and learn the rhythm of it.

A lot of challenges were along the way of this project that would have not been achieved without support of persons. I would like to express my gratitude to my co-supervisor Mr. Håvard Begrsdal at MiSA AS for giving me his unstinting guidance. Many thanks are owned to my supervisor Mr. Helge Bratebø at the University of NTNU for giving me high quality guidance through years. I also would like to thank Mr. Thoresen Thor Egil at Jernbaneverket for providing me valuable information, which without the data; such analysis would have not been possible.

In addition, I want to thank my family for their unstinting help through my education, and Linn Martinsen for translation aid.

Abstract

The objective of this project is to define a generic life cycle impact assessment (LCIA) model for electrification of existing railways in Norway. The analysis develops a life cycle inventory (LCI) for a kilometer of infrastructure, which is comprised of four different levels of structures. These structures are divided into design speed alternatives, line sections variants (open section and tunnel), life cycle phases and components. In addition, the life cycle phase in this study covers construction and maintenance.

This project was carried out within MiSA AS (an environmental consulting company in Trondheim, Norway) with utilization of SimaPro and Ecoinvent database to perform an LCA study with Product Category Rules (PCR) for assessment of environmental performance. The results from this work consider signaling, telecommunication, lighting and overhead contact system (OCS) with a functional unit of one kilometer. In addition the results do not consider requirements for installation of new substations and superstructures.

Through the analysis of results, it becomes clear “higher speed leads to more environmental impacts”. Moreover, the total impacts in sections of line for climate change and ozone depletion are greater in open section. However, total impacts from terrestrial acidification and freshwater eutrophication are greater in tunnel section.

Along the way of analysis; high quality steel, copper, cables, aluminum, polycarbonate and transformer oil are critical materials that have the highest share in LCIA. In addition, along with the results, a set of sensitivity analyses for overhead contact systems are applied to achieve recognition of the importance of critical materials. It turns out changing in the type of masts (as one of scenarios for the sensitivity analysis) in open section, which is based on high quality steel contributes the most.

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Abbreviations

AT	Autotransformer
CC	Climate Change
DB	Deutsche Bahn AG (German Railway)
DS	Design Speed
EPD	Environmental Product Declarations
FE	Freshwater Eutrophication
HSR	High Speed Railway
ISO	The International Organization for Standardization
JBV	Jernbaneverket Norge
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact assessment
NTNU	Norwegian University of Science and Technology
OCS	Overhead Contact System
OD	Ozone Depletion
PCR	Product Category Rules
TA	Terrestrial Acidification

Chapter I

1 Introduction

Railways, because of the industrial revolution, led to a massive modification in transportation systems and they have had a major role in this area, in a competition with buses, airplanes, trucks and cars. (Rodrigue, Comtois, and Slack , AREMA 2003) 17th century was the age of development of railways by introduction of steam traction. Steam traction was on the top, up until that time when electric traction equipment found their way to steam powered railways in the late 19th century and represented practicality of electric traction. (AREMA 2003) Norway commenced to electrified their lines with the motto *"Away with the steam"* in 1952 and their plan completed by the late 1960s and through decades 2837 kilometers of lines have been electrified. (Jernbaneverket 2013)

Railways electrification has benefits of reduction in fuel utilization and green operation of trains. (EuropeanCommunities 2008) However, challenges like construction and maintenance of electric traction components are parts of railways electrification that have impacts on the environment.

1.1 Objective and Motivation

Life cycle impact assessments for railways have been done in recent years that most of them have had a focus on high speed railways (HSR) either in Norway or Europe. (Grossrieder 2011) Life cycle assessment of Follobanen (a new double track line Oslo-Ski) is a sample of previous works that has been done by Asplan Viak AS, MiSA AS and etc. The aim of study was to address environmental impacts of the new double track line between Oslo and Ski (Follo Line) for Jernbaneverket infrastructure project. The project has found that the new line emits 671 million (kg CO_2 eq.) in a total lifetime of infrastructure. (AsplanViakAS 2011) Although there were some environmental impact assessments for some specific lines that they were planned to be electrified, there was no interest to assess a generic environmental impact of railways electrification in Norway.

This was a reason and motivation behind this study that push me to evaluate an environmental impact assessment of railways electrification for a kilometer of track to be able to find a generic evaluation.

1.2 Structure of Project

In chapter 2, there is a description of LCA methodology and background theory. Ecoinvent database and Product Category Rules (PCR) guideline are explained.

Chapter 3 provides an overview of railways electrification by means of system and levels descriptions and explains technological components and assumptions that are made during setup the inventory. In addition, relevant detail information is provided in appendixes.

Chapter 4 illustrates the results and sensitivity analyses from impact assessment by means of relative 100% stack bars with brief description of each.

Discussions and give suggestions for future works (from the results) are provided in chapter 5 and chapter 6 is the conclusion.

Chapter II

2 Methodology

2.1 Life Cycle Assessment

The first steps towards environmental assessment with the name of life cycle assessment commenced in the late 1960s. The purpose was to address impacts related to products and to have a better understanding. (ISO 2006a) However, due to a requirement for having a holistic perspective for environmental assessment, the new model of LCA started to form in the early 1990s. (Nes 2012)

LCA presents environmental aspects and impacts through life cycle of a product. The life cycle can be production, use, recycling, end-of-life treatment and disposal. Four steps are in an LCA study that are interpreted and shown in figure 2-1. (ISO 2006a)

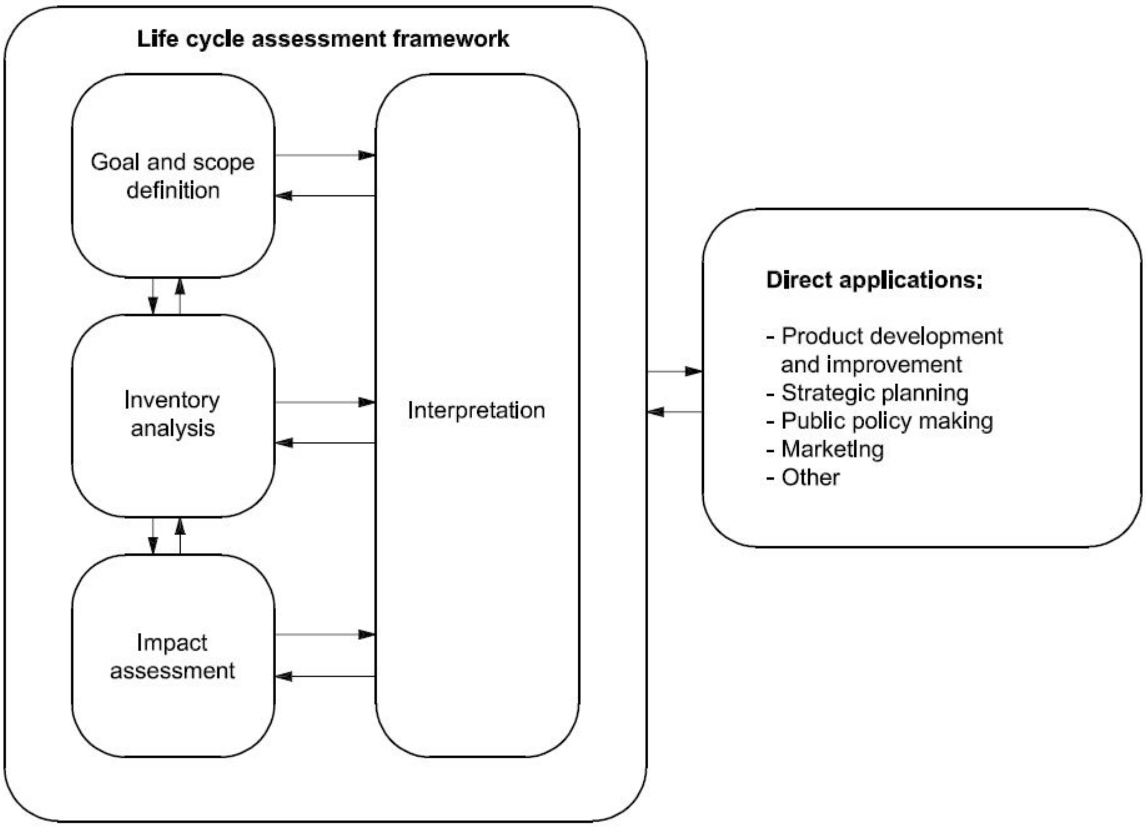

Figure 2-1: Stages of an LCA

- Goal and scope definition

"The goal and scope of an LCA shall be clearly defined and shall be consistent with the intended application. Due to the iterative nature of LCA, the scope may have to be refined during the study." (ISO 2006b)

- Inventory analysis

"Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle." (ISO 2006a)

- Impact assessment

"Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the produce." (ISO 2006a)

- Interpretation

"Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations." (ISO 2006a)

The functional unit is stated in the part of goal and scope and it is defined as "The functional unit is the quantified performance of a product system for use as a reference unit". (ISO 2006b)

2.1.1 Mathematics

Many times the mathematics behind LCA had been explained thoroughly for different LCA studies. This fact was a reason that made me not to describe it here and try to only reflect two LCA studies here for a case that someone is interested in reading more.

"Fission or Fossil: A Comparative Hybrid Life Cycle Assessment of two Different Hydrogen Production Methods" written by Christian Solli at NTNU.

"Life cycle assessment of an offshore electricity grid interconnecting Northern Europe" written by Rasmus Nikolai Nes at NTNU.

2.2 Tools

SimaPro was a software program that is used to assess in the evaluation of environmental impact assessments. *SimaPro* is a software program to carry out life cycle assessments and model life cycle inventory and interpretation. (AsplanViakAS 2011) It allows users to build complex models of products and systems in a systematic and transparent way. (PRéConsultants 2013b) The software tool is developed by PRé Consultants and is continuously updated for the sake of developing inventory databases and characterization methods. (AsplanViakAS 2011)

LCA is a data intensive study that requires high-quality databases. Through decades a lot of processes have been made and collected into various databases. However, it was a great opportunity to have all processes in one database that can fulfill the correct model of industries. (Nes 2012) ***Ecoinvent database*** is a comprehensive database with over 10000 processes that is developed and updated by ecoinvent center in Switzerland. (PRéConsultants 2013a) Processes are in a wide spectrum of fields like materials, energy, transport, chemicals, agriculture etc. The background data in Ecoinvent database is modeled based on average European production data and presented in unit processes and calculated results.(AsplanViakAS 2011, PRéConsultants 2013a)

2.3 Impact Categories

Product Category Rules (PCR) is a guideline for the selection of impact categories in the study of railways electrification that is developed in the framework of the International ***Environmental Product Declarations (EPD)***. The impact categories are climate change, ozone depletion, acidification and eutrophication that are shown in table 2-1. Figure 2-2 shows a system boundary of full life cycle assessment of railways in respect of ***PCR*** to indicate what sub-processes are included or excluded. (AsplanViakAS 2011, International-EPD®-System 2013)

Table 2-1: Environmental impact categories with their units

Environmental impact category	Unit
Climate change	kg CO_2 equivalents
Ozone Depletion	kg CFC-11 equivalents
Acidification	kg SO_2 equivalents
Eutrophication	kg PO_4^{-2} equivalents

More information and details can be found in ReCiPe 2008, which is a good source that describes the implementation of methods for each of these impact categories.

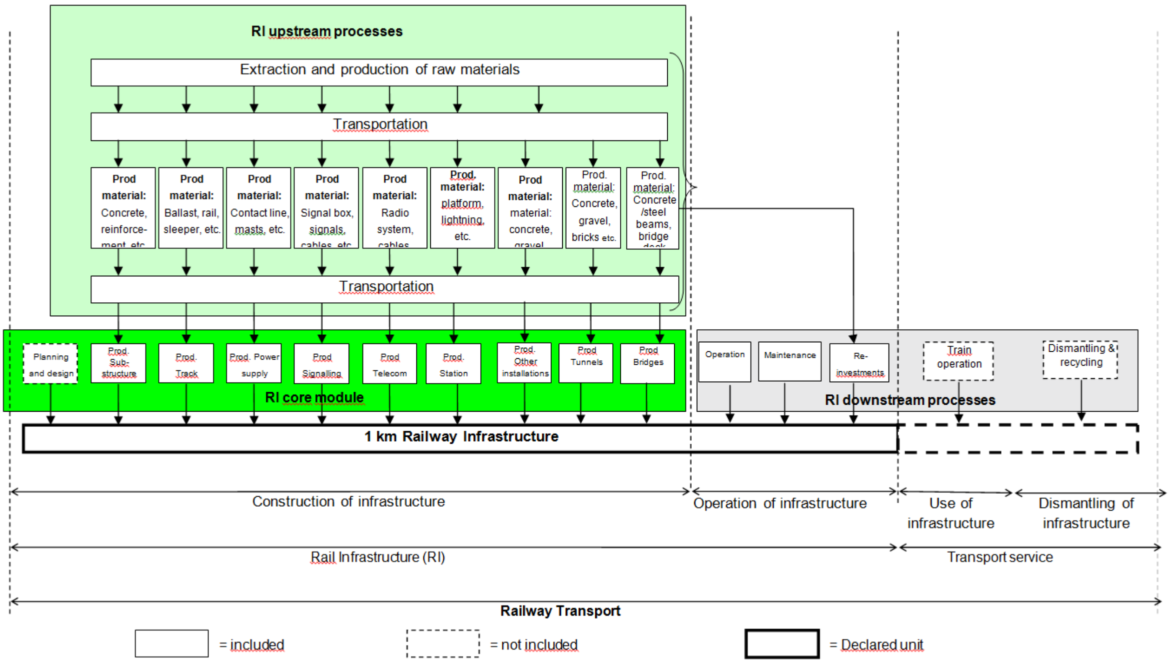

Figure 2-2: Flow chart of the product system for Railway Infrastructure

Chapter III

3 System Description and Inventory Data

3.1 Background

Classification of electrified railways in general is divided into three main factors that are voltage, current and contact system[1]. (Wikipedia 2013g) The origin of the first electrical railways was based on direct current due to hyperbolic/traction speed curve; however, due to the low voltage performance of direct current systems (which is a disadvantage), it necessitates high currents for transmission of power. (Kiessling, Puschmann, and Schmieder 2001) With the objective of reducing current and using the advantage of alternative current which lead to reduction in the number of substations, at the beginning of 20th century an effort on utilization of AC transmission for single phase motors was made. (Kiessling, Puschmann, and Schmieder 2001, Hill 1994)

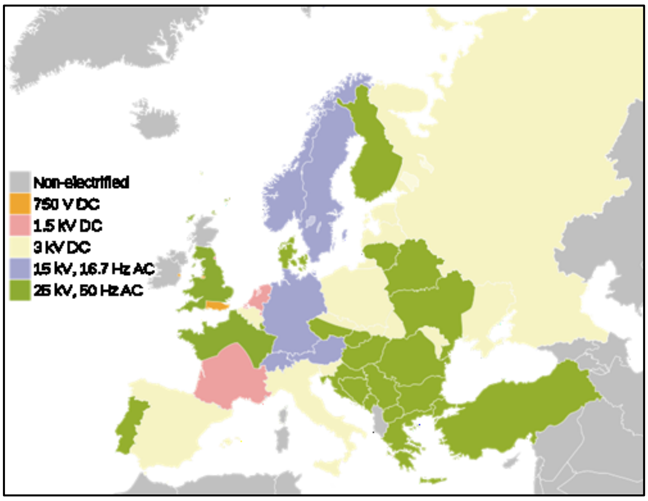

Figure 3-1: Map of traction power systems for European mainline railways

3.1.1 Power Supply

Every year, Norwegian railway consumes 500GWh of electricity that 95% of it is purchased in the open market delivered via local power stations and the rest of it is produced via purpose-built hydropower plants. All the electricity in Norway delivered to the railroad is

[1] Contact systems are divided into three models Overhead Contact System (OCS), three-rail or four-rail, which in here only OCS is taking into consideration.

guaranteed of origin that states of being produced in hydropower plants. (Jernbaneverket 2011)

Jernbaneverket (the Norwegian National rail Administration) was founded as the national railway authority on December 1, 1996. On behalf of the Ministry of Transport and Communication, Jernbabeverket (JBV) is responsible for operation, maintenance and development the national railway network, while Norges Statsbaner As and cargoNet AS are operators for passenger and freight trains, respectively. (Jernbaneverket 2012, Wikipedia 2013d, c)

In 1996, Jernbaneverket established Bane Energi as a separate and concentrated energy supplier. This leads Bane Energi to be an electricity supplier for the entire railroad in Norway and other industrial consumers. Bane Energi purchases 110 kV at 50 Hz electricity from the regional grid and converts it to 16 2/3 Hz via electricity feeding stations. (Wikipedia 2013a) This electricity is produced by power plants connected to national power grid via Nord Pool Spot AS. (Jernbaneverket 2010)

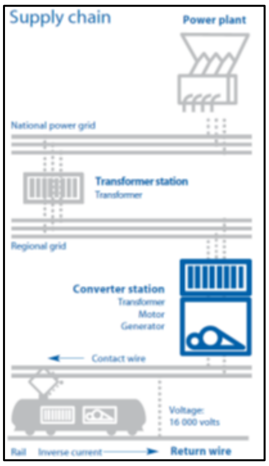

Figure 3-2: Bane Energi, Conversion to 16 2/3 Hz from 50 Hz

The three pillars of electricity feeding stations are power plants, transformer stations and convertor stations. Voltage delivery from feeding stations is normally 16 500 voltages which is higher than nominal voltage (15 kV) to compensate voltage drops that can happen due to distance between trains and feeding stations[2] . The feeding stations are apart from each other and they convert a three-phase to single-phase with rotary and static converters[3] . A typical converter station consists of two to three converter units that work together in order to reach a

[2] On contrary, railway systems in Denmark and Finland have been developed on 50 Hz and 25 000 V.
[3] The development of electrified system goes to more usage of static convertors for modern and advance computer controls and electric power. (Jernbaneverket 2011)

high level of performance and reliability. Moreover, to avoid damages in electricity transmission like short circuits, electrical systems are monitored continuously by auto-protective relays[4] . (Jernbaneverket 2011)

3.2 Description of Electrification of Railways

3.2.1 Structure of LCA

The LCA model of electrification is built base on unit processes, which each process is the smallest building block in an LCA inventory and it can be either linked to or used by other processes. (SimaPro7.3) In this project, the data from background come from Ecoinvent-database whereas some parts of the life cycle inventory for the foreground system are documented by me and the rest is used from the Follobanen report.

3.2.1.1 Structure of Project

In the progression of a better system description in this project, a set of collected data have been utilized from both JBV documents for different design-speeds and Follobanen project.

This project, in accordance with Product Category Rules report for railways, develops an LCA of electrification model for one km of existing single-tracks with a lifetime of 60 years as the base model, and then, tries to model it for different alternatives. (International-EPD®-System 2013) The layout of different alternatives for this project is divided into four levels as it is shown in figure 3-3.

Each level describes how much energy and materials are required for the given system processes and components that are based on unit processes.

The graph below is inspired from project (Grossrieder 2011), which provides a good level of details for a system description. The flows that are drawn in figure 3-3 are an example of one condition for one design speed (DS).

[4] A protective relay is an electromechanical instrument that calculates operation condition in electrical circuits. (Wikipedia 2013f)

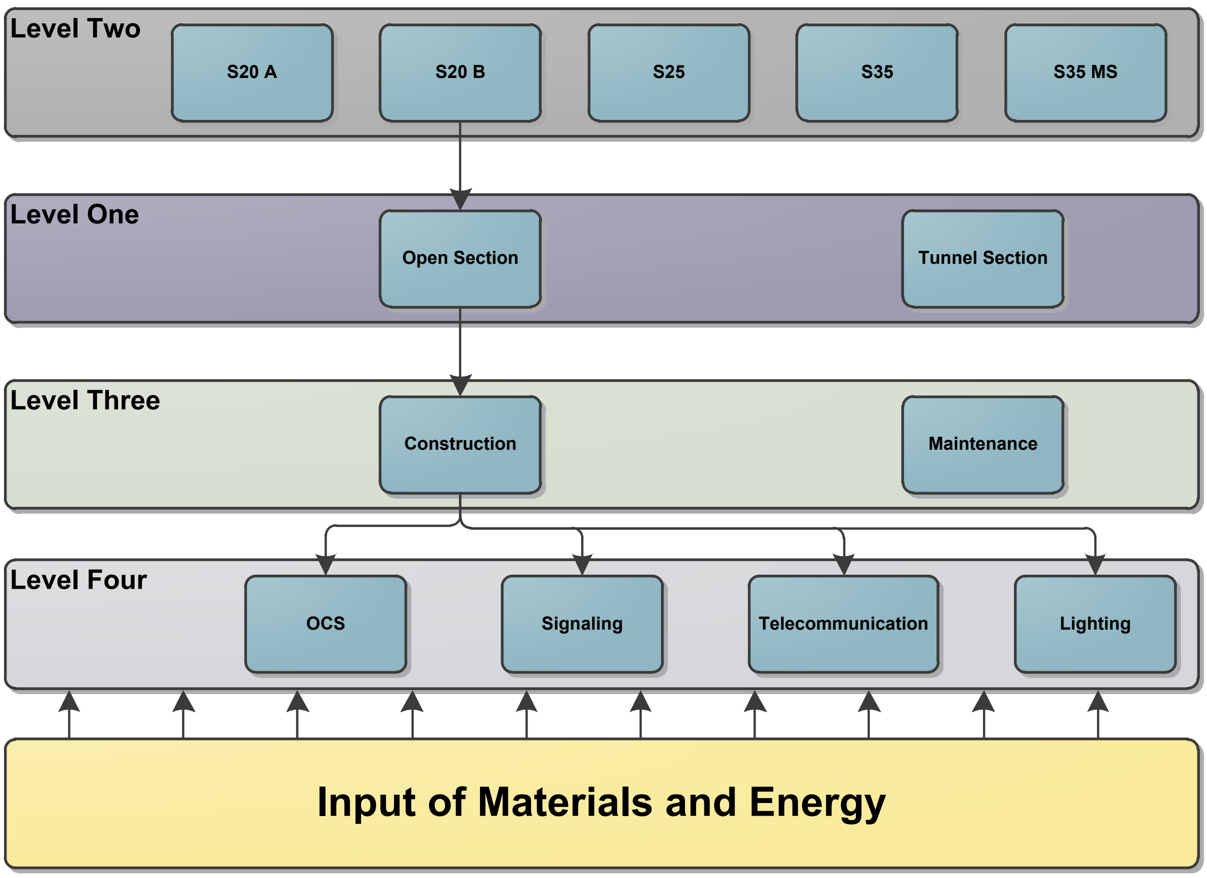

Figure 3-3: Outline of LCA structure for the project

Figure 3-3 is comprised of:

- Design speed alternatives (Level one)
    - S20 A (alternative one)
    - S20 B (alternative two)
    - S25 (alternative three)
    - S35
    - S35 MS
- Sections variants (Level two)
    - Open section
    - Tunnel
- Life cycle phase (Level three)
    - Construction
    - Maintenance
- Components (Level four)
    - Overhead contact system

- Signaling
- Telecommunication
- Lighting (considered only for tunnel alternative)

3.2.2 Description of Design Speed alternatives

In Norway only four systems of DSs exist, which among them only S20 A, S20 B and S25 are utilized for new electrification. The reason is due to this fact that system 35 and 35 MS will be outdated and JBV tries to build minimum system 20 for new railways electrification. A comparison between two systems of 35 (S35 and S35 MS) and the three others (S20 A, S20 B, and S25) are made, but the results are shown in Appendix H.

3.2.3 Description of Sections

The section level covers two variants; open section and tunnel that have different desires in electrification of a line. Information about an open section and a tunnel is provided in Appendix D. In the open section and tunnel section, there will be no evaluation of sleepers due to this fact that the purpose is to define what influences would be relevant to electrification of an existing line. In addition, tunnels in general for railways are made of concrete and have different components such as ventilation fans, pumps, and canals etc., which are not taken into consideration. However, a consideration of installing new LED lighting system in respect of Follobanen project is taken into account.

General speaking, there will be some risks related to tracks, pumps etc. that need to be considered, but it is not the concern of this project.

3.2.4 Description of Life Cycle Phase

To electrify a line either an open section or a tunnel, there is one phase that is construction. Construction is a preliminary part and includes all components for electrification; however, some components have different lifetimes through the lifetime of electrified line. This perspective opens a new study of life cycle that is maintenance. Maintenance due to wear and tear is dissimilar from components to components. Table 3-1 below is a reflection of maintenance framework for different components for this project that is taken from Follobanen project (New Double Track Line Oslo – Ski).

Table 3-1: Lifetime of compoentns and subcomponents in railways electrification

Element	Lifetime (year)
Signaling	20
Telecommunication	15
Mast (open sections and Tunnels)	50
AT	30
Negative and Positive current cables	50
Catenary	30
Insulator	30
Fundament	50
Cantilever	50
Lighting	30

3.2.5 Description of Component

An electrified railway model is comprised of four main components named Substation, Overhead Contact System (OCS), Signaling system, Telecommunication system and other installations. (Tingos and Raposa 1996) In this project, I considered lighting in tunnels, as one extra component due to not being able to find any kinds of mutuality between lighting and the other four main components.

Explanation about components and details of their materials and energy inputs are provided in the following of this chapter.

3.2.5.1 Substation

One of the main components that an electrified railway model is comprised of is substation. Substations are made of transformers, convertors, switchgears, control equipment and signaling facilities that are linked to overhead contact systems by cables can masts. In this project due to complexity of substations, it wasn't easy to make a generic model of them. The reason of complexity of substations is because of different capacity of substations[5], location and distance of substations from OCS. (Kiessling, Puschmann, and Schmieder 2001) This

[5] It is comprised of various design and circuit diagram which can be found in substation design hand book by DB. (Kiessling, Puschmann, and Schmieder 2001)

means, when a new line is needed to be electrified, the results for LCA would vary a lot because of high uncertainty in location and requirement capacity of new substations.

Nevertheless, this does not have a bad reputation about the quality of this project. In fact, this project can be applied for cases that do not require new substations (due to utilization of other lines substations and the distance from a substation to the last *autotransformer* (AT) is not longer than 120km[6]).

3.2.5.2 Overhead Contact System

Overhead contact system (OCS) is a link between subtraction systems and trains that distributes electricity and design of it has been influenced by climate, electrical load, structure limitations, operation speed and train deign. (Tingos and Raposa 1996) OCS consists of catenary[7], power feed and structures. Figure 3-4 shows a flowchart of overhead contact system that embraces subcomponents and sub-subcomponents.

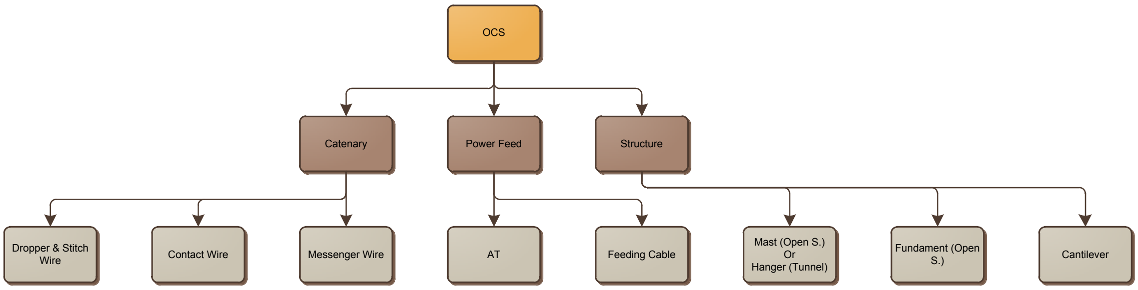

Figure 3-4: Flow chart of overhead contact system

In addition to the flowchart in figure 3-4, a layout of OCS is provided in figure 3-5.

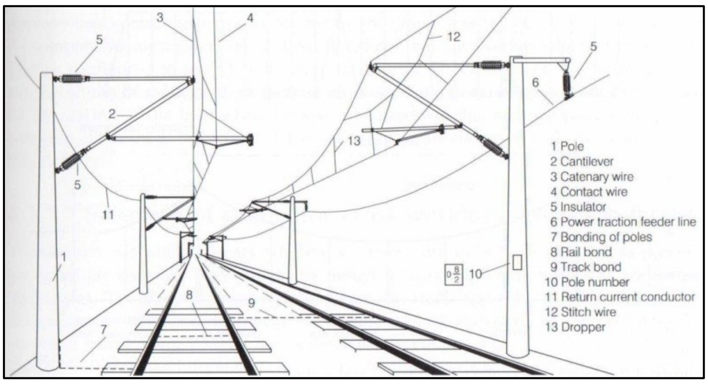

Figure 3-5: Overhead contact system with individual supports (Kiessling, Puschmann, and Schmieder 2001)

[6] More information is provided in this chapter in section 3.2.5.2.2

[7] In this project the utilization of third-rail is not taken into account.

3.2.5.2.1 Catenary

Figure 3-4 indicates, a catenary consists of contact wires, messenger wires, droppers and stitch wires for each system of design speeds in Norway that will be explained more in this chapter. A schematic view of catenary, in addition to figure 3-4, is shown in figure3-6 to give a better illustration for readers.

Properties of a type of catenary need knowledge in operation parameters, which are defined by design and components configurations. (Kiessling, Puschmann, and Schmieder 2001) Table 3-2 demonstrates some features of different systems of design speeds like maximum speed, maximum span length, maximum current-carrying capacities etc.

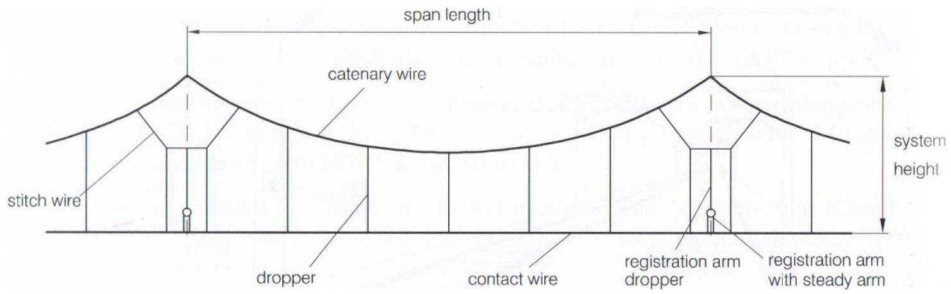

Figure 3-6: Design of a contact line section and span(Kiessling, Puschmann, and Schmieder 2001)

As it mentioned before JBV planned to use system 20 as a base requirement for new electrification projects. By means of table 3-2, the only systems that can be fit into JBV's regulation are S20 A, S20 B and S25. The same table indicates that the minimum speed is 160km and it is owned by system 20 B and the speed goes up to 200km and 250km for S20 A and S25, respectively. Specification details for each system are provided in Appendix A to give a better insight into physical differences of all systems.

Table 3-2: A table of different design speeds features

Systems	Speed design (km/h)	Spanlength (m)[8]		System height (m)[9]		Current-carrying
		Open Section	Tunnel Section	Open Section	Tunnel	capacity (A)
System 35 MS	140	65 ≤	45 ≤	1.55~		600
System 35	150	65 ≤	45 ≤	1.55~		600
System 20 B	160	65 ≤	45 ≤	1.3-1.6	0.7 ≥	600
System 20 A	200	65 ≤	45 ≤	1.3-1.6	0.7 ≥	600
System 25	250	65 ≤	45 ≤	1.6-1.8	1.1 ≥	800

[8] In this project spanlength of 65m and 45m are for open section and tunnel, respectively, for S20 A, S20 B and S25.

[9] In this project only height of 1.55m for S35 and S35 MS, height of 1.6m for S20A and S20 B, and 1.8m for S25 are considered.

3.2.5.2.1.1 Contact Wire

Contact wires are equipment that transmits electricity to collectors (pantographs). The design of a contact wire is twisted to ensure an uninterrupted transmission of electricity to train's pantographs and uniform wear of pantographs strips. The uniform wear of collector refers to a zigzag (to the left and right) arrangement when a contact wire is arranged in alternating angles to the track axis due to avoiding any notches. (Wikipedia 2013e, Kiessling, Puschmann, and Schmieder 2001) The zigzag variation for each system is provided in appendix A and it will be a good illustration if figure 3-10 is looked.

For systems 35 and 35 MS, the model of contact wire is Cu Ri-100. However, for systems 20 (S20 A & S20 B) and 25, the models of contact wires are CuAg0.1 RiS-100 and CuAg0.1 RiS-120, respectively. Adding silver (Ag) alloy (with 1% concentration) for S20 (A & B) and S25 improves mechanical tensioning and thermal properties of copper wires, but nevertheless, it has a reduction in electricity conductivity of contact wires. Figure 3-7 shows the relation of conductivity and additives alloy. (Kiessling, Puschmann, and Schmieder 2001) In this project, assumptions of 100% for copper made wires in S35 and S35 MS are made. Despite of S35 and S35 MS, contact wires with 99% copper and 1% silver are assumed for S20 A, S20 B and S25. (Pupke 2010)

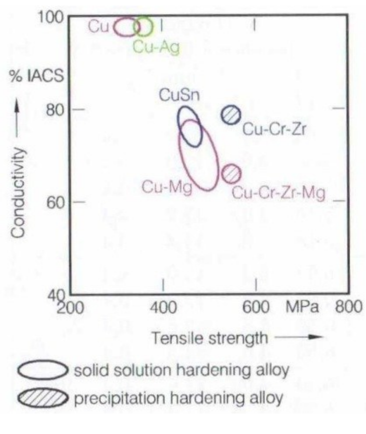

Figure 3-7: relation of conductivity of electrolytic copper with tensile strength

Table below demonstrates the physical properties of contact wires in JBV.

Table 3-3: Dimension with name of contat wires in JBV for different DSs (Egil 2013b)

System	Contact wire	Dimension (mm^2)
S35 & S35 MS	Cu Ri-100	100
S20 A	CuAg0.1 RiS-100	100
S20 B	CuAg0.1 RiS-100	100
S25	CuAg0.1 RiS-120	120

3.2.5.2.1.2 Messenger Wire

Messenger wires are also called catenary wires that are located on top of contact wires. They keep the geometry of contact wires within defined limits by means of *droppers*. Messenger wires have alloy additives of magnesium (Mg) with 0.5% concentration (CuMg0.5), to improve mechanical tensioning and thermal properties like silver alloy contact wires. CuMg0.5 wires are also called BzII and table below tells the physical properties of messenger wires for the DSs.

Table 3-4: Dimension with name of messenger wires in JBV for different DSs (Kiessling, Puschmann, and Schmieder 2001, Egil 2013b)

System	Messenger wire	Dimension (mm^2)
S35 & S35 MS	50 /7 Cu	49.48
S20 A	50/7 BzII	49.48
S20 B	50/7 BzII	49.48
S25	70 BzII	65.81

3.2.5.2.1.3 Dropper and Stitch Wire

Droppers or drop wires are a link between a contact wire and a messenger wire with regular intervals (8 to 12 meters) along the longitudinal span. (Kiessling, Puschmann, and Schmieder 2001, Wikipedia 2013e) In all DSs the model of droppers are the same and it is 10 BzII with the dimension of 10.02 mm^2; however, height of droppers vary due to different parameters such as DS, spanlength, open section, tunnel etc. (Egil 2013b)

Stitch wires are earmarked as a connection wire between messenger and contact wires. The purpose of their designation is to compensate elasticity and height difference at midspans and supports. The usage of stitch wires depends on the specification of a system of catenary. Table below shows a variety of physical properties of stitch wires for the systems that stitch wires are used.

Table 3-5: Dimension with name of stitch wires in JBV for different DSs (Egil 2013b)

System	Contact wire	Dimension (mm^2)
S35	35/7 Cu	34.36
S20 A	25/7 BzII	24.25
S25	35/7 BzII	34.36

As it could be recognized from the table above, no stitch wire is considered for S20 B and S35 MS. The reason of having such action goes to the data package that I got from Mr. Egil that is provided in Appendix A. (Egil 2013b)

3.2.5.2.1.4Layout of Catenaries for Different Design Speeds for Open Section

To be able to make a good data collection in this project for the catenary of the three systems (S20 A, S20 B and S25), there was a requirement to have an access to a software program (Candrop) in JBV[10]. However, due to lack of time for this project, at the end, I made some drawings in a reflection of communication with Mr. Egil and utilization of "Contact lines for electric railways: planning, design, implementation" book. In addition, the models that are provided bellow are drawn by AutoCAD.

S20 A: The layout of system S20 A is shown in figure 3-8 Information for the model of catenary is made based on system Re200 of DB in respect of a communication with Mr. Thoresen Thor Egil. (Egil 2013b)

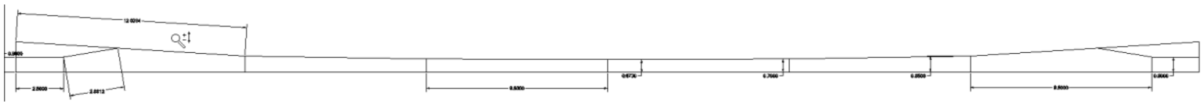

Figure 3-8: Layout of catenary for S20 A

S20 B: The model is taken from a Master Thesis of a student (Jeanette M. Sølvberg) that has been done at the University of Oslo and compensates the requirement in according to Appendix A[11].

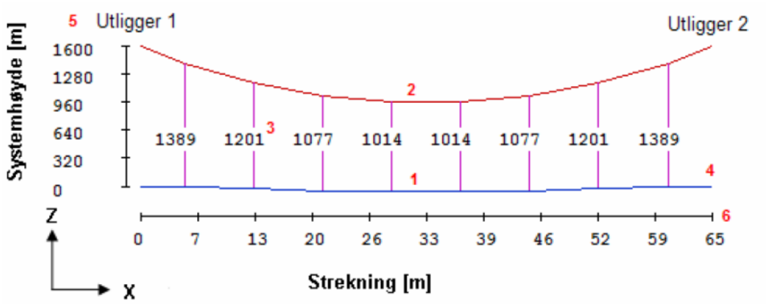

Figure 3-9: Layout of catenary for S20 B

S25: Despite of S20 A, there was some information in the book (Contact lines for electric railways), which is shown in figure 3-10. However, at the end, due to lacking from some key data I made the layout based on system Re250 of DB in respect of a communication with Mr. Thoresen Thor Egil. (Egil 2013b)

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[10] The layout of catenary design for S35 and S35 MS are provided in Appendix H.
[11] The layout of S20 B in accordance with Mr. Egil is without stitch wires.

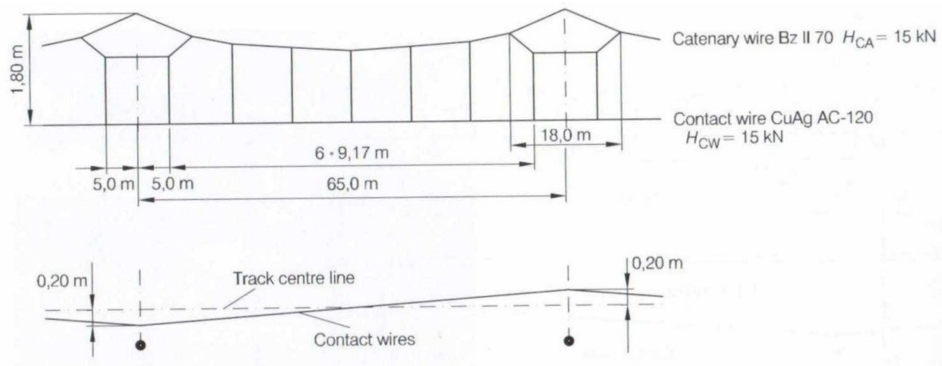

Figure 3-10: Layout of catenary for S25 from "Contact lines for electric railways" (Kiessling, Puschmann, and Schmieder 2001)

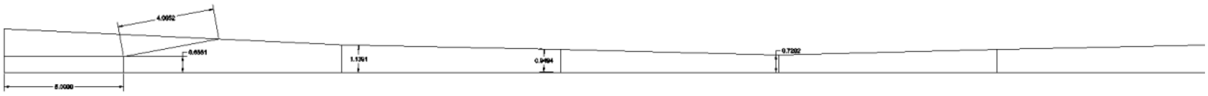

Figure 3-11: Layout of catenary for S25

3.2.5.2.1.5 Layout of Catenaries for different Design Speeds for tunnel Section

The layout for the tunnel section of each DS is done with an assumption that the layout of tunnel section is exactly like the layout of open section but it is adjusted through utilization of some coefficient factors. The coefficients that are used in this project is (0.7/1.6) for systems 20 (A & B) and (1.1/1.8) for S25[12]. These numbers are only multiplied with droppers and stitch wires of respective systems. The reason of having such hypothesis was because of complexity of designing other catenary systems for the tunnel section and in the book (Contact lines for electric railways) that I used all information that was provided was useful for open sections not for tunnel sections.

However, the other wires (contact wires and messenger wires based on the assumption) stayed the same as open section. It could be seen in the table of input materials in Appendix D.

3.2.5.2.2 Power Feed

Power feed makes a link between traction substations and catenaries, which periodically gets electricity in high voltage (110 kV) from traction substations and changes it to the defined voltage for catenary. Power feed consists of autotransformers and cables that are along the right-of-way. (Tingos and Raposa 1996)

[12] The coefficient factors are made out of differences in the height in open section and tunnel. (Check table 3-2)

3.2.5.2.2.1 Autotransformer and Cables

An autotransformer system is utilized where the load and current are high or the distance between locations to contact substations is long. (Kiessling, Puschmann, and Schmieder 2001) To enhance power supply in the future progression and at the same time reduce impedance of railways within JBV, autotransformer systems have been developed. (Egil 2013a) The AT system is a combination of autotransformers (ATs) and two autotransformers conductors (positive and negative conductors). (Jernbaneverket 2011)

In contrary with conventional transformers (booster transformers), autotransformers are made of only one winding and the reason of application of these transformers instead of conventional ones is due to this fact that ATs can maximized the distance between substations (omformerstasjoner) up to 120 km[13]. (Wikipedia 2013b, Jernbaneverket , Egil 2013a) ATs are located with ca. 10 km[14] intervals along the railroads and have connection +15kV on positive conductors, 0kV on return tracks and -15kV on negative conductors. (Jernbaneverket 2011)

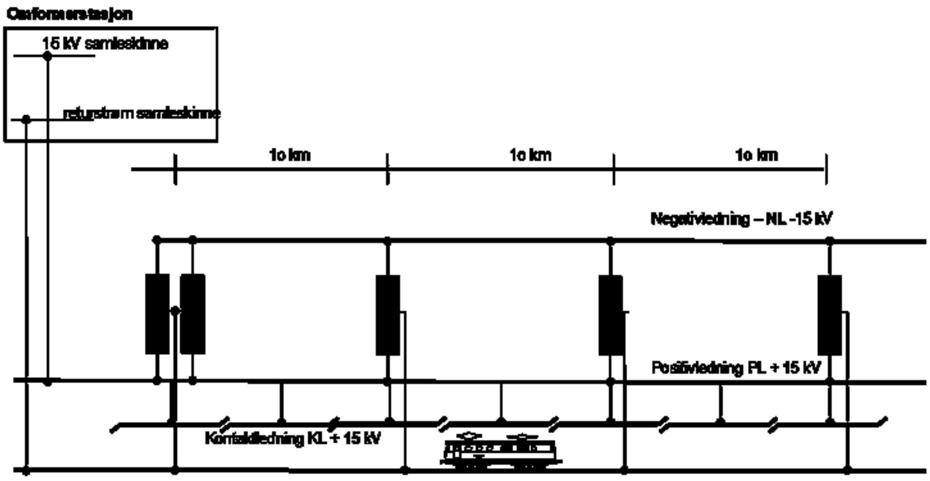

Figure 3-12: AT system with split contact line (Jernbaneverket)

3.2.5.2.2.1.1 Positioning in Open Section

Positive and negative conductors should be mounted on a horizontally symmetrical position on top of OCS poles at the height of approx. minimum 9.5 meters with one-meter gap between them. The dimension of Positive and negative conductors are between 240mm^2 to

[13] In conventional system have a distance of approx. 40 km between feeding stations. (Egil 2013a)
[14] Maximum distance must not exceed 12 km.

400 mm[2][15] and are made of aluminum. Position of positive feeder on the masts must always be on the furthest right side of in the direction of Rising Kilometer. (Jernbaneverket)

3.2.5.2.2.1.2 Positioning in Tunnel

Position of current cables in a tunnel based on a set of data that Mr. Egil provided can be either mounted on the wall or buried in the ground of tunnel that is close to the wall.

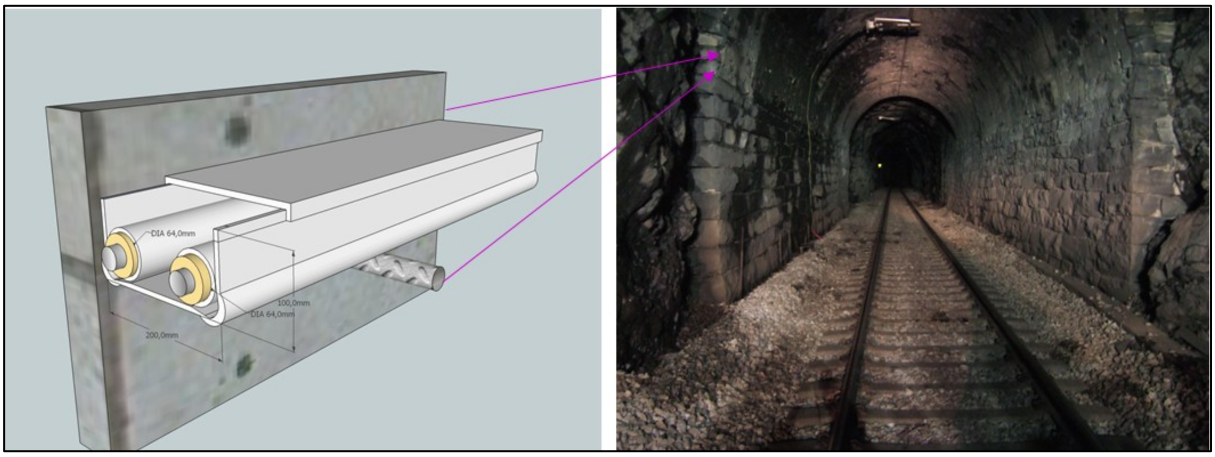

Figure 3-13: Mounting current cables on the wall of tunnel in Bergensbanen (Egil 2013a)

Figure 3-14: Burying current cables in the ground of tunnel (Egil 2013a)

[15] The cross section of feeders should not be greater than 400 mm^2.

As it can be seen from figure 3-13 a box and bolts are used to hang the current cables on the wall. However, concrete and tubes are used to settle the cables in figure 3-14[16]. (Egil 2013a) In this project the model of mounting on the wall is used, but no consideration is done for the usage of bolts and boxes.

Note: In a communication at the end of this project I asked a question about possibility of using AT systems for S35 and S35 MS. Mr. Egil in response mentioned *"Overhead line or contact wire line systems can be used with or without AT-transformers"*. This made it hard for me to calculate new parameters for OCS with boosters instead of AT systems. As a result, this project lacks data for the new scenario as Mr. Egil pointed out.

3.2.5.2.2.2Insulator

Insulators for power feed are placed on top of mast (between current conductors and mast) to avoid short circuit along electricity transition. Insulators here are assumed that are made of porcelain, but with the same weight assumption (3.9kg) as insulators in cantilever (glass insulators). In fact, instead of glass, porcelain is used that has 50% of weight of porcelain insulators. The metal side if insulation is the same as glass insulator, which is lead-antimony and has 50% of weight of porcelain insulators (with 2% antimony per kilogram and the rest is lead)[17]. (Clark 2009) Figure 3-15 is a schematic view of an insulator with aim of providing better insight into the topic of insulators.

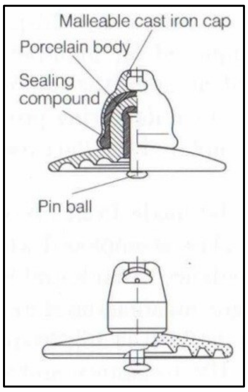

Figure 3-15: Cap and pin insulator. (Kiessling, Puschmann, and Schmieder 2001)

The details about the materials and energy inputs are provided in Appendix D.

[16] The method that is shown in figure 3-14 is called OPI-kanal.
[17] The assumption that is made is that the insulator is made of 50% porcelain and 50% lead-antimony.

3.2.5.2.3 Support Structure

Support structure is the last parameter for OCS that is comprised of cantilevers, insulators, fundaments and masts. Headspans and portals (figures 3-16 and 3-17, respectively) are also part of support structure, but they are not included in this project due to study of LCA of a single-track. (Tingos and Raposa 1996)

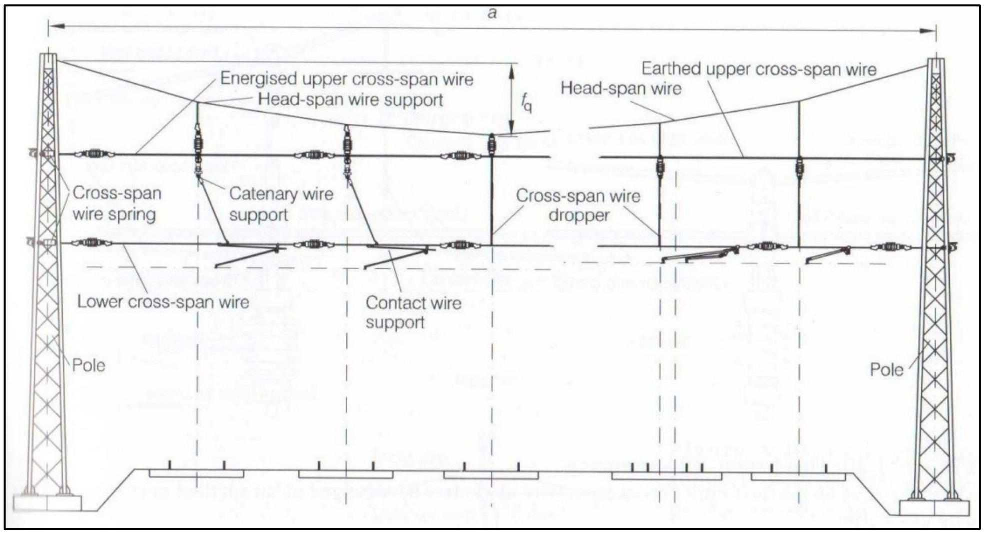

Figure 3-16: Headspan design (Kiessling, Puschmann, and Schmieder 2001)

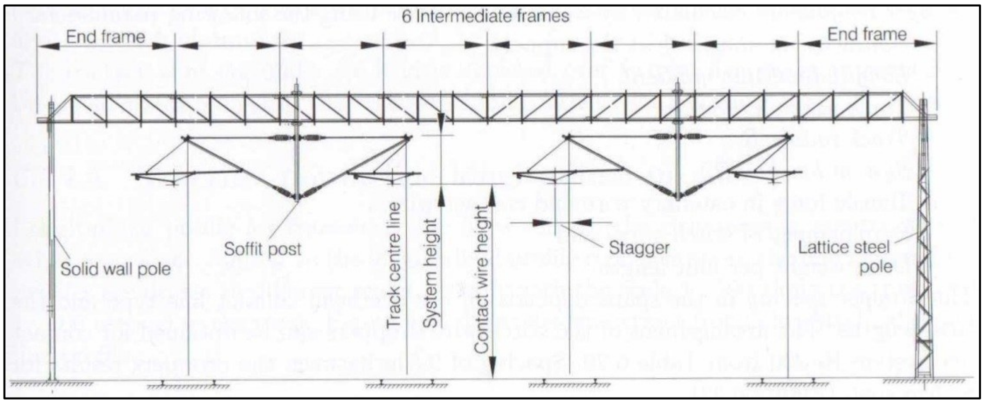

Figure 3-17: A model of portal in JBV (Kiessling, Puschmann, and Schmieder 2001)

3.2.5.2.3.1 Cantilever

Cantilevers are fixtures that carry horizontal and vertical forces. They are divided based on their functionalities into contact wire supports and messenger wire supports and they are connected to *masts* via insulators and swivel brackets. In this project, as it was mentioned before, only three systems of cantilever are taken into consideration. These systems are S20 A, S20 B and S25. A layout of each cantilever is provided in Appendix B to illustrate the differences of designing and material consistencies. The contact wire support shown in figure 3-18 is comprised of the registration arm dropper, the registration, contact wire steady arm, the windstay and the drop bracket. The zigzag mode is applied to contact wire by means of push-off supports and pull-off supports. The catenary wire support includes the cantilever tube, the top anchor and messenger wire support clamp. (Kiessling, Puschmann, and Schmieder 2001)

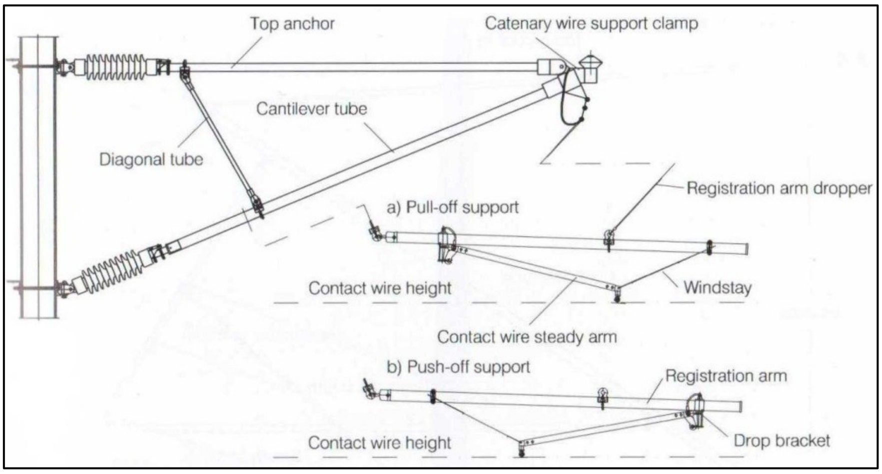

Figure 3-18: A model of cantilever with push-off support and pull-off support

In this project drop brackets, contact wire steady arms, contact wire support clamps and swivels are not taken into consideration due to small amount of materials in comparison with the other components. Appendix B shows the layouts of cantilevers that are used in this project. Moreover, tables are provided in Appendix D to show how calculation is done for both tunnel section and open section.

3.2.5.2.3.2 Insulator

Insulators are barriers for electricity to eliminate the probability of short circuit in electricity transmission and they are placed between cantilevers and masts Utilization of glass insulators for cantilevers are assumed in this project due to observation of a line (Trondheim train station) and images from JBV annual reports. (Jernbaneverket 2012) The model of glass insulator that is made in this project is from EB-elektro and has a weight of 3.9kg. (eb-elektro)

Figure 3-19: Glass insulator (eb-elektro)

The material base of glass insulators are lead-antimony (with 50% of weight of an insulator) and glass (with 50% of weight of an insulator)[18]. The details about the materials and energy inputs are provided in Appendix D.

3.2.5.2.3.3Mast

Masts or poles are vertical structures that their height and design depend on different factors like requirement height for pantographs, design speed etc. In JBV, there are different types of masts such as HEBs, B types and H types. The common types of masts are all types of HEB (200, 220, 240, 260, 280 and 300), B3, B6, H3 and H5. (Jernbaneverket 2002) In this project model of HEB200 with height of 9.5m is assumed.

However, mounting cantilevers by means of masts due to rectangular tunnels is impossible. The solution is soffit posts that cantilevers are mounted on them. Figure 3-20 shows the utilization of soffit posts in a tunnel for Sicat H contact line in Germany. (Kiessling, Puschmann, and Schmieder 2001)

[18] The assumption that is made is that the insulator is made of 50% glass and 50% lead-antimony.

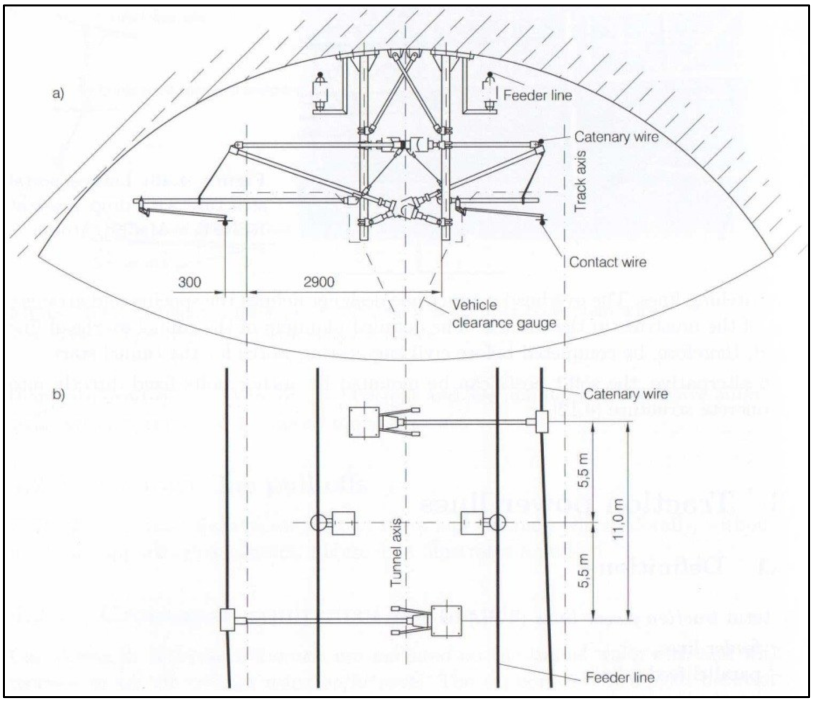

Figure 3-20: Supports in rectangular tunnels with cross section view and view from the top (Kiessling, Puschmann, and Schmieder 2001)

In this project, only one type of support in tunnels is used with and assumption that a support has a height of 2m. Appendix C shows the layouts of masts and a soffit post that are used in this project. Moreover, tables are provided in Appendix C to show how calculation is done.

3.2.5.2.3.4Fundament

Fundaments are concrete blocks that support masts that their types are determined from soil properties and types of poles. In an email from Mr. Egil the model of fundaments are mentioned as cylindrical with a diameter of Ø 555mm and height up to 4.5m. Information about the calculation is provided in Appendix D and the height of 4m is assumed for fundaments.

3.2.5.3 Signaling System

Signaling system introduced to railways with aim of increasing the reliability of system by controlling railway traffic to prevent probability of collision. (Wikipedia 2013h, Kiessling, Puschmann, and Schmieder 2001, Tingos and Raposa 1996) Signaling system is based on LCA of Follobanen – infrastructure report (New Double Track Line Oslo – Ski). In Appendix D, the way that calculation has been done for signaling systems is shown.

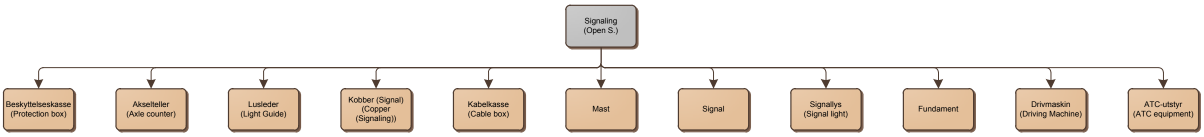

Figure 3-21: Flow chart of signaling system in open section

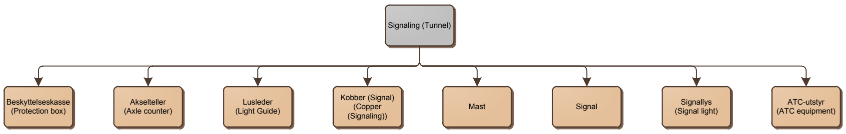

Figure 3-22: Flow chart of signaling system in tunnel section

3.2.5.4 Telecommunication

Telecommunication system includes cables, miscellaneous equipment etc. in accordance with LCA of Follobanen (New Double Track Line Oslo – Ski). In Appendix D, the way that calculation has been done for telecommunication systems is shown.

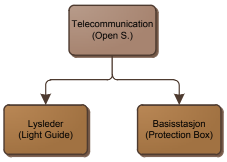

Figure 3-23: Flow chart of telecommunication system in open section

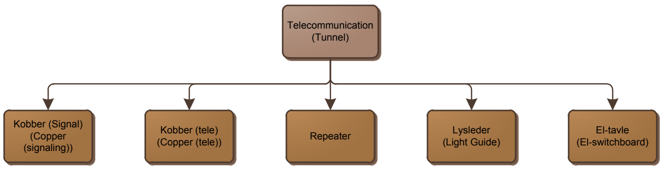

Figure 3-24: Flow chart of telecommunication system in tunnel section

3.2.5.5 Lighting

An assumption is made that considers a replacement of lighting system in tunnels for railways electrification. Thus, lighting system is taken into consideration for electrification of railways in tunnel section. Lighting system consists of LEDs, cables, plastic housing etc. from LCA of Follobanen (New Double Track Line Oslo – Ski). In Appendix D shows how calculation is done for lighting systems.

3.2.6 Assumptions

In this project there are some assumptions that they were not for a particular part or section in this chapter. Hence, I mentioned them here and they are as following.

- In this project, there is an assumption that one kilometer of railways electrification is a straight line[19].
- Spanlength of 65m and 45m are for open section and tunnel section, respectively, for S20 A, S20 B and S25.
- Grounding, tensioning and breaker systems are not considered here for OCS.
- Due to lacking from insulation in tunnels, the same technic as for open section is made for the calculation of insulators

[19] By any case, if the line had been a curve, it would have increased the utilization of support structures and cantilevers due to reduction in the spanlength.

Chapter IV

4 Results

4.1 Results from Life Cycle Assessment

This chapter will indicate the results of railways electrification by means of life cycle impact assessment (LCIA). The life cycle of this study covers life cycle of manufacturing, transportation to regional storage and site, installation, and maintenance. However, it is not taken into consideration substations[20], operation phase of an electrified railroad, dismantling of components after their lifetime, transport dismantled components to a site and waste treatment.

By having results from 18 different impact categories (ReCiPe Midpoint (H) V1.04 / World ReCiPe H), it is hard to define which ones have the highest impotency. To be able to have a better discussion around important impact categories, the description of results here are based on PCR document. This includes impact categories as following

- Climate change (kg CO2 equivalents)
- Ozone depletion (kg CFC-11 equivalents)
- Acidification (kg SO2 equivalents)
- Eutrophication (kg PO4-2 equivalents)

In this chapter first the results from LCA of S20 A, S20 B and S25 for open section and tunnel section is going to be shown and discussed. In continues, sets of sensitivity analyses are applied to these DSs to find out how sensitive the results from our analysis is for critical parameters.

4.2 Main results

General LCA models of railways electrification for a kilometer of an open section and a tunnel of different design speeds is shown in figures 4-1 & 4-3. The figures illustrate the environmental impacts of each system in accordance with PCR.

[20] The reason was due to this fact that in this project assumed a requirement for installation of a new substation is not needed.

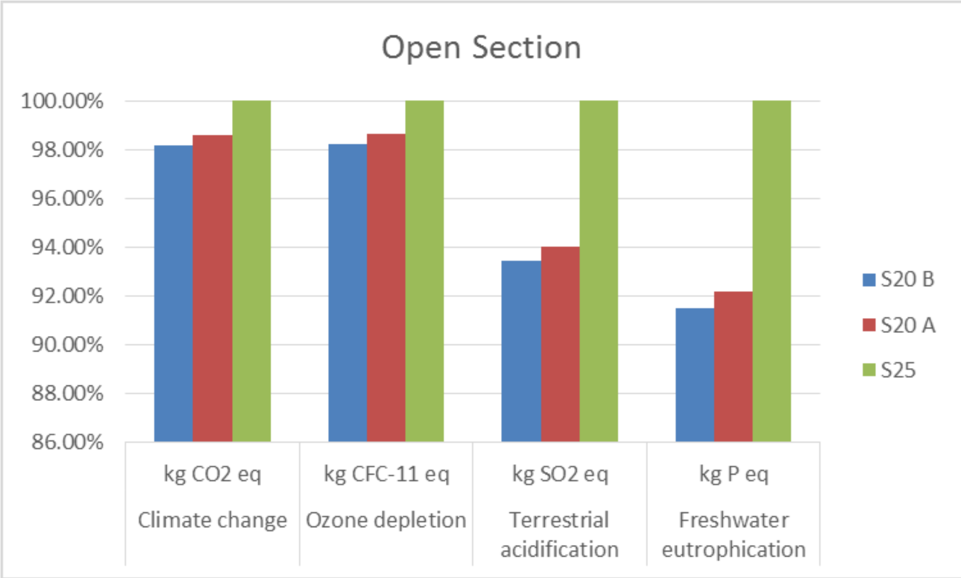

Figure 4-1: Relative environmental impacts for one kilometer of open section

Figure 4-1 shows what the contribution of each system DS is, with respect to four-impact categories. In all four-impact categories, system 25 has the highest impact. The reason of indicating each impact category with 100% stacked column chart is to give a better illustration of one process in compare to the others. The level of dissimilarity with respect to S25 is getting greater as the comparison goes from climate change ($ca.$ 1.5% to 2% for S20 A and S20 B, respectively) on the left side of graph to freshwater eutrophication on the right side ($ca.$ 8% to 8.5% for S20 A and S20 B, respectively). The reason goes to the increase in some components that are critical for each of these impact categories that are demonstrated below. It could be seen (in figure 4-2) high quality steel, cable and copper are the main reason of these behaviors.

The same interpretation can be used for figure 4-3 (Environmental impacts of one kilometer of a tunnel) due to having the same behaviors. However, the three design speeds in a tunnel demonstrate other levels of contrasts for each impact category. This means, the level of dissimilarity with respect to S25 is approx. 2% to 3% for S20 A and S20 B, respectively, in climate change on the left side of graph and it increases to approx. 5% to 5.5% in freshwater eutrophication on the right side.

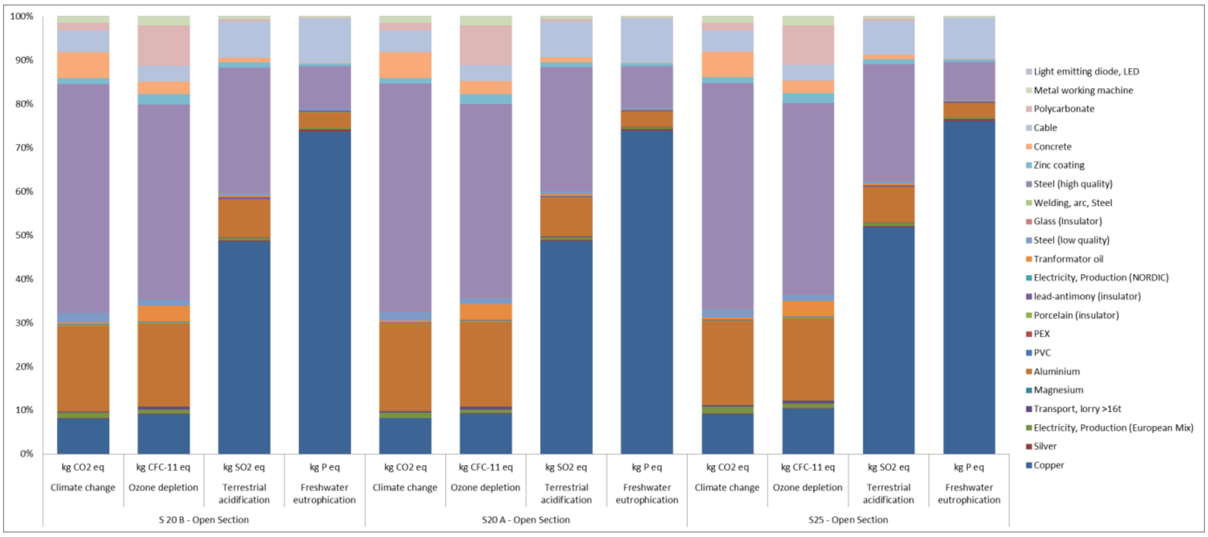

Figure 4-2: Relative environmental impacts of total materials contribution for one kilometer of open section

However, instead of steel in the open section, aluminum (due to replacement of masts with soffit ports in tunnel section) is taking the criticality role for the tunnel. This represents that aluminum, copper and cables are critical components for the LCA of tunnel.

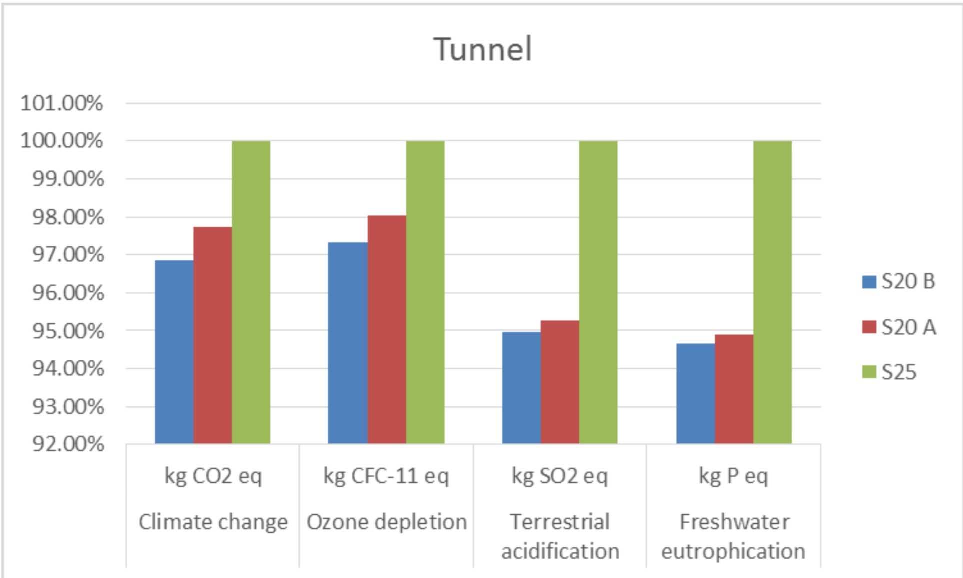

Figure 4-3: Environmental impacts of one kilometer of tunnel

After the first part that was based on giving an indication of level one and two in figure 3-3, it is time to take a step forward and break them down into construction and maintenance.

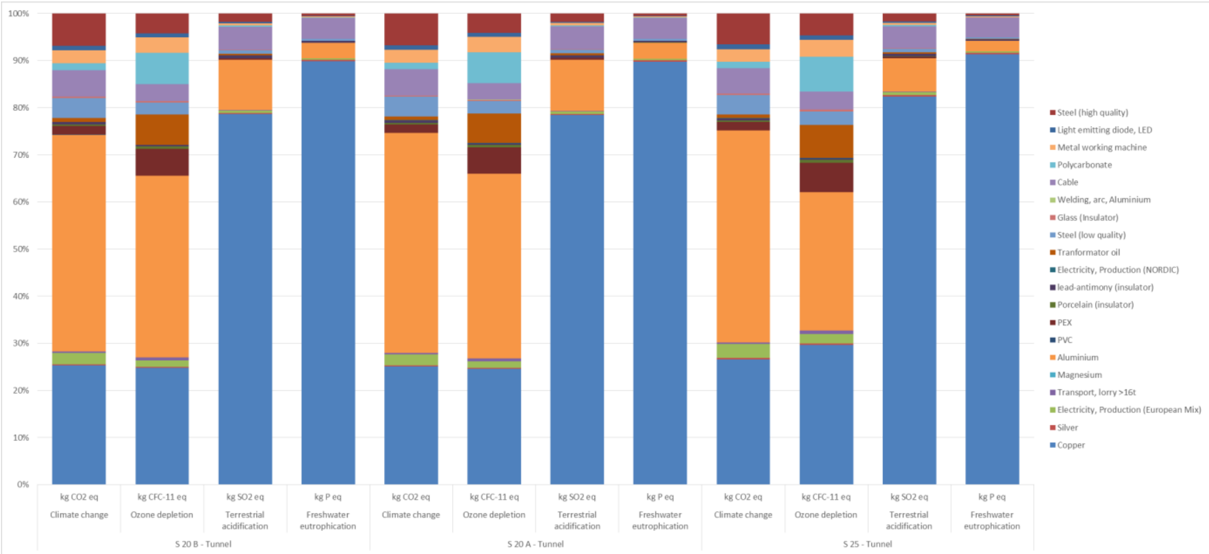

Figure 4-4: Relative environmental impacts of total materials contribution for one kilometer of tunnel

4.3 Open Section

As it could be seen in figure 4-5, the results are slightly different for different DSs when level one, two and three are considered all at once (, but in three separate graphs). Based on the graphs, climate change and ozone depletion are the greatest impact categories for construction, but terrestrial acidification and freshwater eutrophication are the greatest ones for maintenance for all three DSs. By having three 100% stacked column charts, it is difficult to differentiate three DSs. This means a requirement of utilization of additional information is needed to make it possible to find the differences. To do so, a table of quantitative results is provided in Appendix F to facilitate the juxtaposition.

With utilization of the table, it becomes clear that the highest values belong to system 25 due to greater amount of materials.

The differences in according with S25 in construction part are about 1% and 2% for S20 A and S20 B, respectively, for climate change and ozone depletion. However, the differences increase in terrestrial acidification (with respect to S25) around 6% and 7% for S20 A and S20 B, respectively; and 9% for S20 A and 10% for S20 B for freshwater eutrophication.

The pattern will be the same (with a little bit of difference) if maintenance part is take into evaluation. In the appendix part of this project (Appendix F) tables of percentages are provided to see the dissimilarity of two parts with respect to S25.

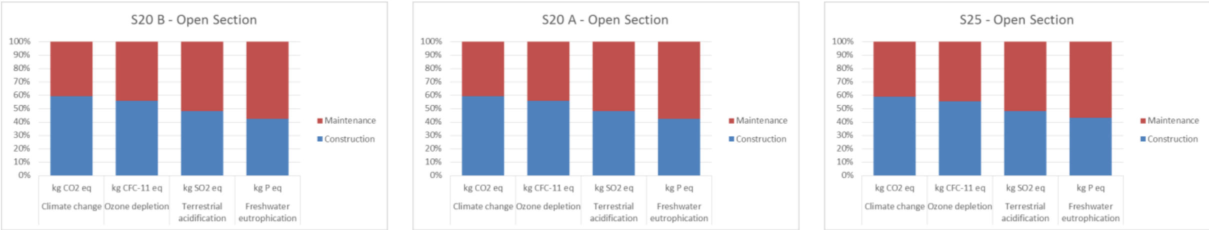

Figure 4-5: Relative environmental impacts of railways electrification for 1km of open section for three DSs

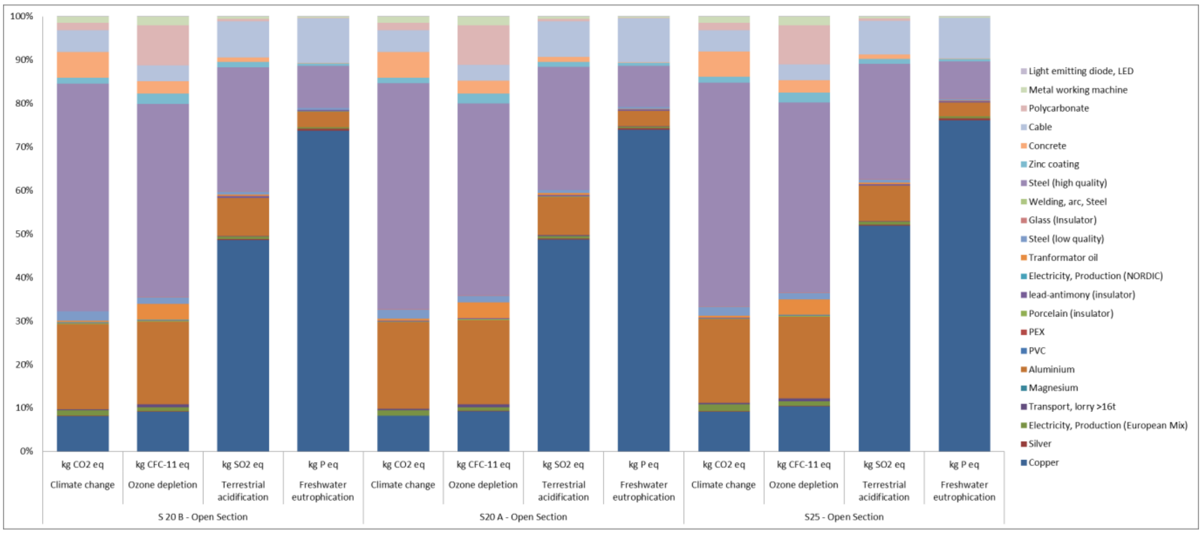

Figure 4-6: Relative environmental impacts of materials contribution for one kilometer of open section-construction for three DSs

Figure 4-6 shows contribution of construction for one kilometer of open section for the three DSs, which high quality steel and aluminum for climate change (CC) and ozone depletion (OD) have the greatest contribution, but for terrestrial acidification (TA) and freshwater eutrophication (FE) copper has a major contribution and it is followed by high quality steel as a second contributor.

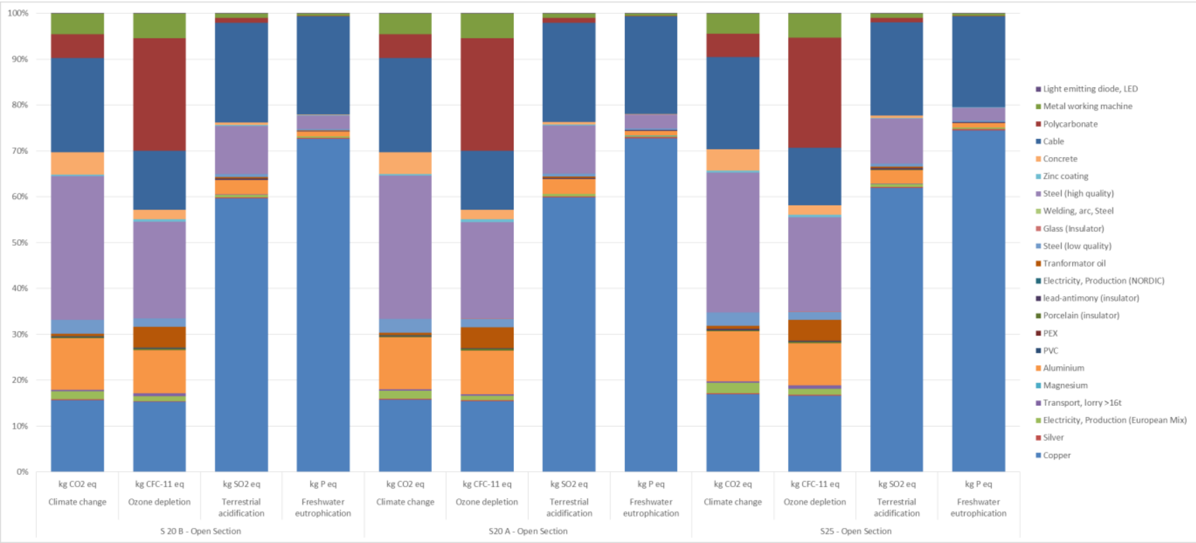

Figure 4-7: Relative environmental impacts of materials contribution for one kilometer of open section-maintenance for three DSs

For maintenance, the effect of high quality steel shrank and cables, PVC, polycarbonate and copper get a bit of contribution on CC and OD in comparison with construction. Copper and cables also have the first and second contributors in the results of TA and FE.

4.3.1 Process of Construction

In this part, the processes of construction are taken into evaluation. This part is the evaluation of all levels in figure 3-3, which is made of OCS, signaling and telecommunication. As it could be seen in figure 4-8, the relative contribution of three DSs are shown. The overhead contact system is the most dominant for the three DSs in all four-impact categories. The reason of this behavior goes back to influence of copper and steel and concrete as it is mentioned in figure 4-9.

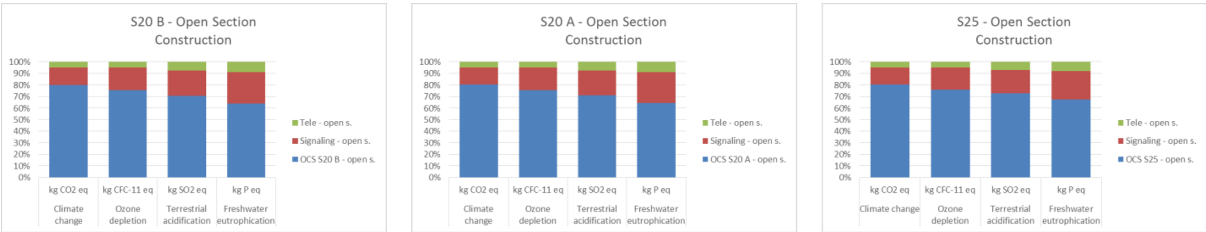

Figure 4-8: Relative environmental impacts of railways electrification for 1km of open section construction for three DSs

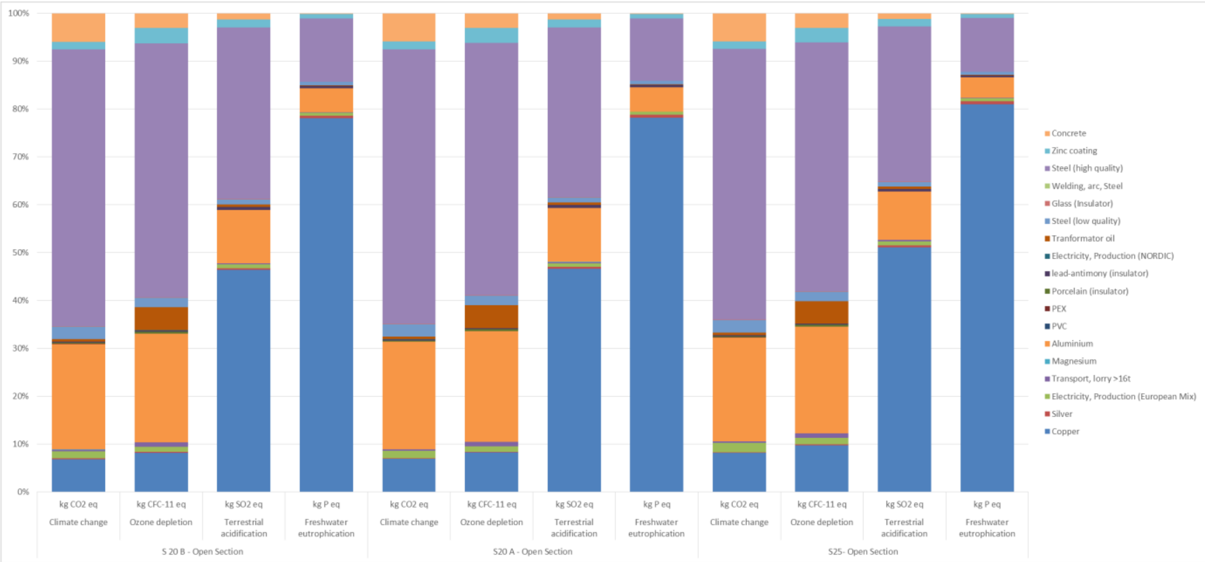

Figure 4-9: Relative environmental impacts of materials contribution for one kilometer of open section-construction-OCS for three DSs

The same bar charts for signaling and telecommunication is representing in figures 4-10 and 4-11. In signaling, as it could be seen aluminum and polycarbonate have the majority impacts for CC and OD. However, copper by far has the most impact in TA and FE.

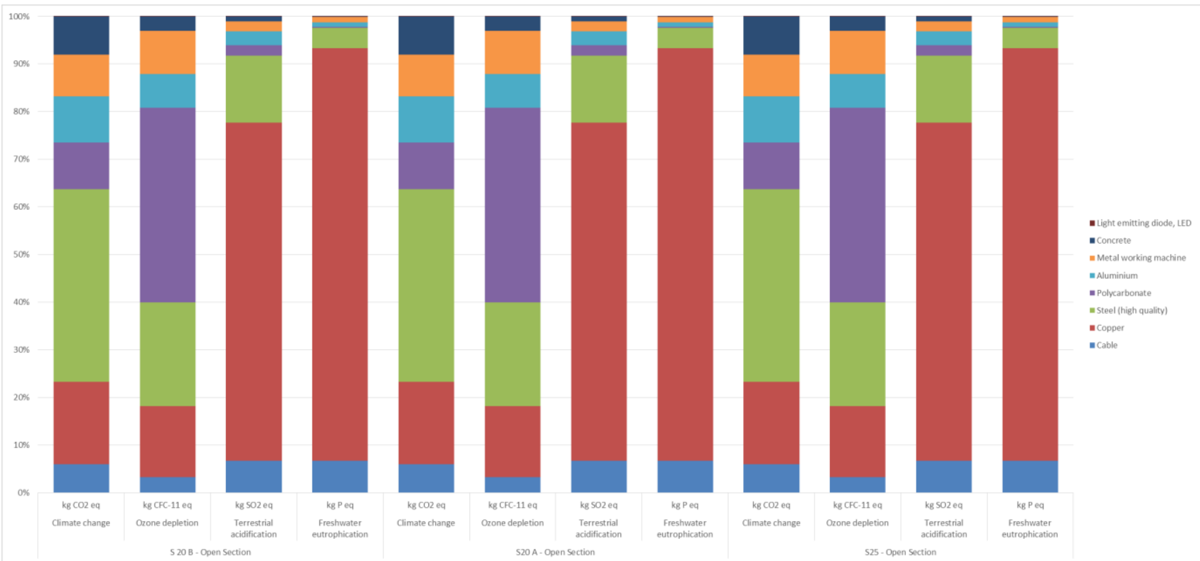

Figure 4-10: Relative environmental impacts of materials contribution for one kilometer of open section-construction-Signaling for three DSs

The story of impact category for telecommunication is so simple and the reason is because of contribution of copper (with more than 80%) in all impact categories except OD (with 60% contribution).

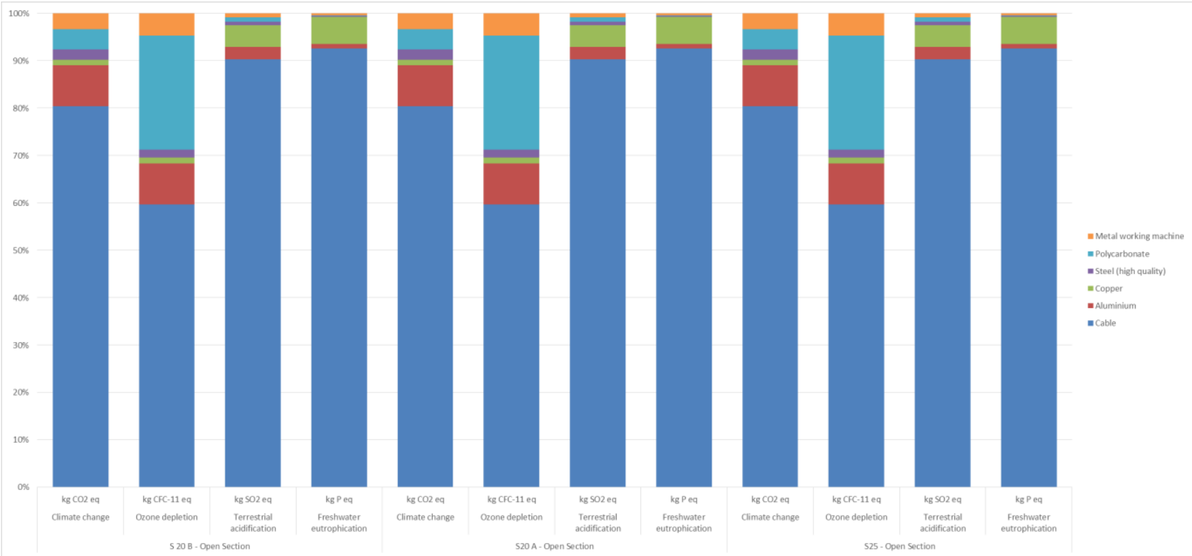

Figure 4-11: Relative environmental impacts of materials contribution for one kilometer of open section-construction-telecommunication for three DSs

To have a better perspective of this differentiation, a table of quantitative for this section is provided to see how big of a difference is between these three DS systems.

The table in Appendix F demonstrates that the highest impact belongs to S25 owing to the fact that more material intense is its processes in compare with S20 A and S20 B. As long as these systems share the same values for signaling and telecommunication, it is easier to say the reason of increase in S25 is overhead contact system. This goes back to the description of the system in chapter three, which is mentioned there would be the same designing system of signaling and telecommunication for the three DS railways.

In appendix G, tables of material impact assessments for the three DS systems are provided that illustrate how much of impact is going from the material of each process to the four-impact categories. According to the table, the highest material contribution is from steel (high quality), aluminum and copper, which all are from overhead contact system process. Despite of OCS, signaling and telecommunication have a bit of contribution from copper, and cable.

4.3.2 Maintenance

Figure 4-12 shows a different figure for the three DS systems in the maintenance part of a kilometer of an open section in comparison with construction. It illustrates that overhead contact systems and signaling have the highest contribution in comparison with telecommunication. Signaling and telecommunication in the maintenance of a kilometer of an open section increase significantly when compare them with construction part. The reason that makes these changes happened is due to lifetime of components for processes.

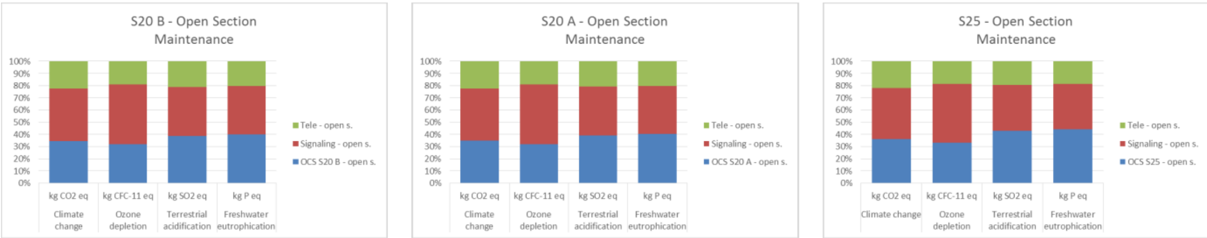

Figure 4-12: Relative environmental impacts of railways electrification for 1km of open section-maintenance for three DSs

In maintenance of OCS[21]; steel, copper, aluminum, and transformer oil (only in OD) are the dominant components in CC and OD. However, like before copper by far has the greatest contribution on TA and FE.

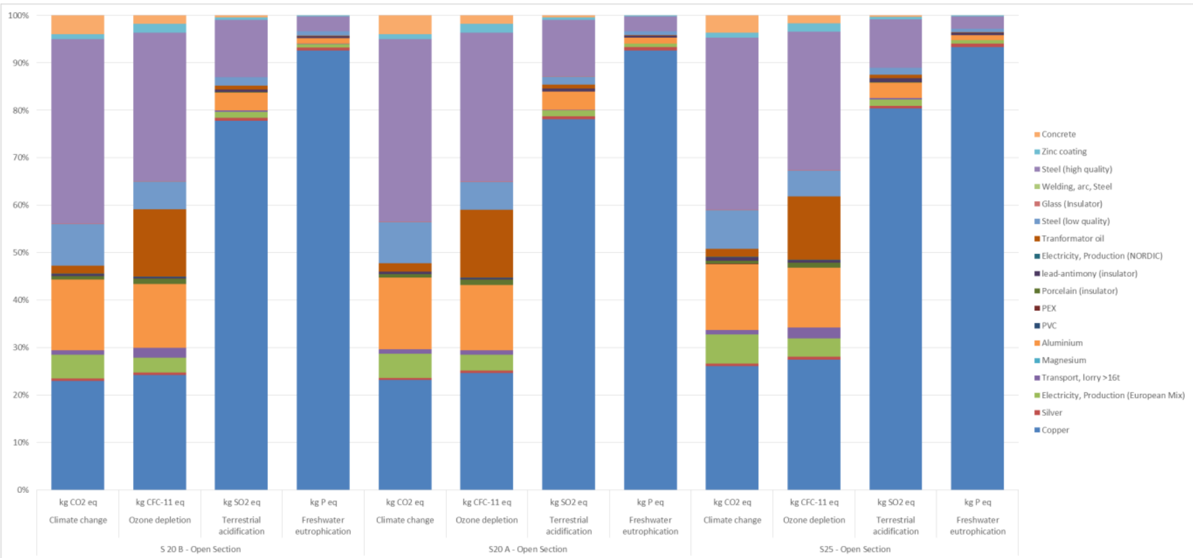

Figure 4-13: Relative environmental impacts of materials contribution for one kilometer of open section-maintenance-OCS for three DSs

The 100% vertical stack bar charts for signaling and telecommunication are exactly the same as construction part in figures 4-10 and 4-11 due to this fact that all components have the same lifetime for the maintenance of each system (signaling or telecommunication). Hence, the relative changes are the same for all components of a given system [22].

[21] The reason of getting different OCS is due to variation of components lifetime in maintenance.

[22] It doesn't mean that the absolute values are not changing. In fact, the absolute values are increasing in maintenance and they are greater than construction (due to lifetime of 15 and 20 years for telecommunication and signaling, respectively), but they increase with the same ratio for their components. Check Appendix G for having a better insight.

4.4 Tunnel

Figure 4-14 gives a generic illustration of maintenance and construction for the three DSs.

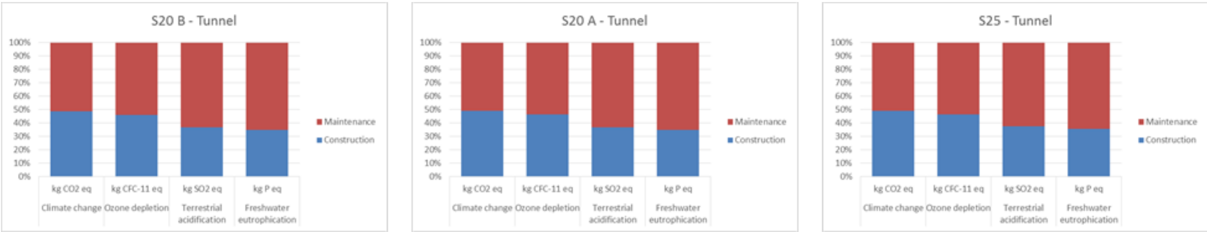

Figure 4-14: Relative environmental impacts of railways electrification for 1km of tunnel for three DSs.

Appendix F makes it possible to find the differences between the DSs. With utilization of the table, it becomes clear that the highest values belong to system 25.

The differences in according with S25 in construction part are about 2% and 3% for S20 A and S20 B, respectively, for climate change and ozone depletion. However, the differences increase in terrestrial acidification (with respect to S25) around 6% and 7% for S20 A and S20 B, respectively; and 7% for S20 A and 7.5% for S20 B for freshwater eutrophication. The discretion will be the same (with a little bit of difference) if maintenance part is take into evaluation (that can be seen in Appendix F).

For climate change and ozone deletion, both maintenance and construction have approx. 50% of influence each (in ozone depletion potential, maintenance has around 55% contribution).

However, maintenance is the dominant parameter in terrestrial acidification and freshwater eutrophication.

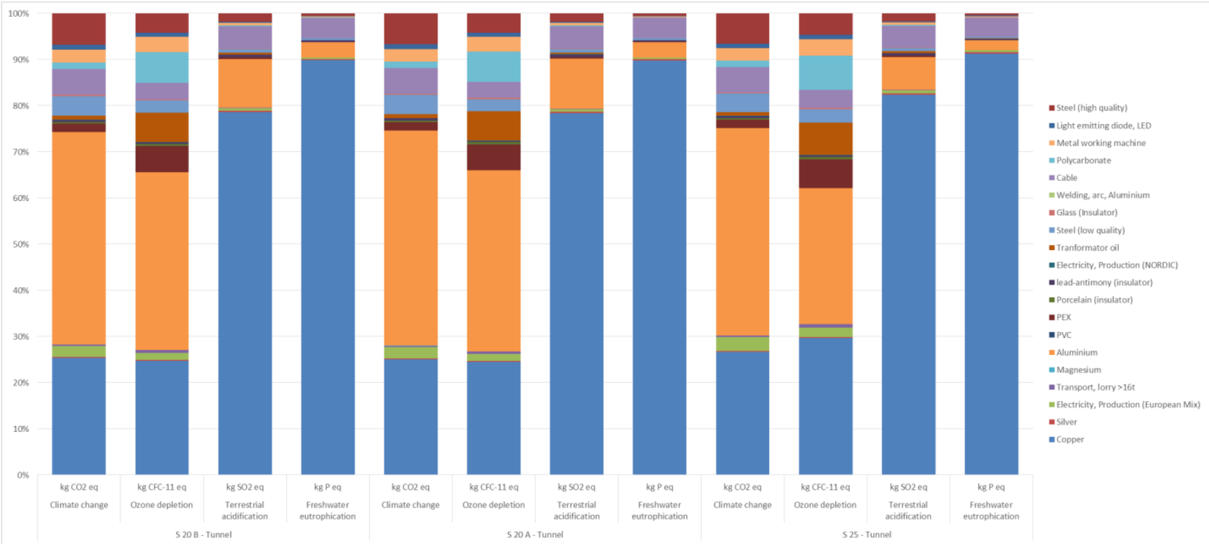

Figure 4-15: Relative environmental impacts of materials contribution for one kilometer of tunnel-construction for three DSs

Figure 4-15 shows contribution of construction for one kilometer of open section for the three DSs, which aluminum and copper for CC and OD have the greatest contribution, but for TA and FE copper has a major contribution and it is followed by aluminum as a second contributor.

For maintenance, the effect of aluminum shrank and cables, PEX and copper get contribution on CC and OD in comparison with construction. Copper and cables also have the first and second contributors in the results of TA and FE (with more than 98% of impacts).

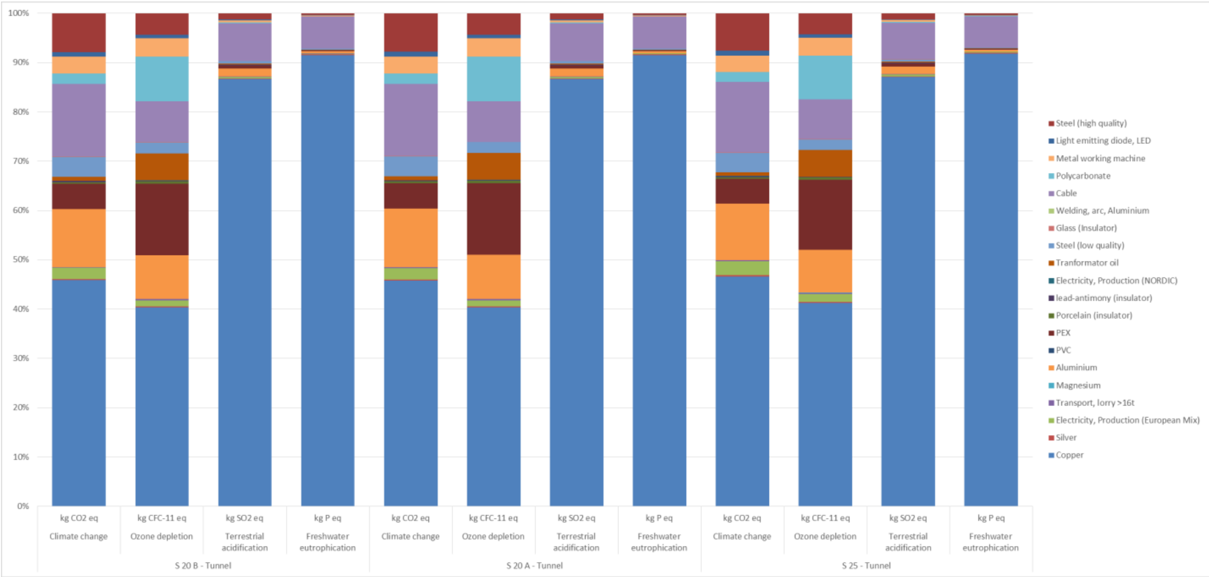

Figure 4-16: Relative environmental impacts of materials contribution for one kilometer of tunnel-maintenance for three DSs

4.4.1 Process of Construction

Overhead contact systems for all three DSs are dominant in climate change and ozone depletion. After Overhead contact system, telecommunication and lighting have about 20% and 10%, respectively.

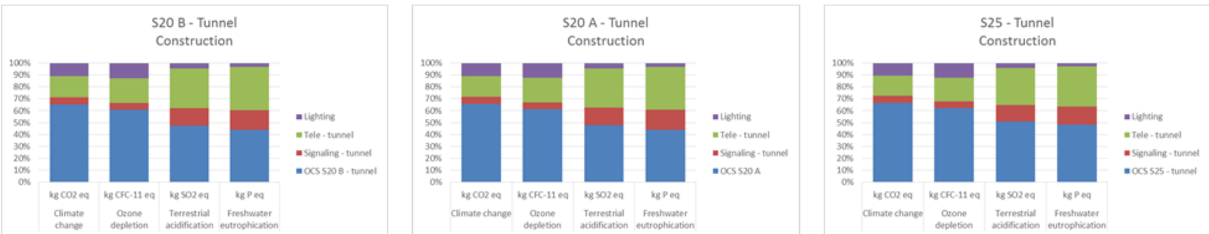

Figure 4-17: Relative environmental impacts of railways electrification for 1km of tunnel-construction for three DSs

Overhead contact systems are still dominant, but with lower impact in comparison with signaling and telecommunication in terrestrial acidification and freshwater eutrophication. Meanwhile the effect of OCS for the three DSs is reduced relatively from CC on the right side to FE on the left side, the impact of telecommunication and signaling increased considerably.

Figure 4-18 shows aluminum has the highest relative contribution for 1km of tunnel construction for the three DSs in climate change and ozone depletion. After aluminum, copper and low quality steel respectively have the second and third level of contribution in climate change. Despite of low quality steel in CC, transformer oil is the third contributor compare to aluminum and copper in ozone depletion.

On the other hand, copper is dominant and it is followed by aluminum as the second contributor in terrestrial acidification and freshwater eutrophication.

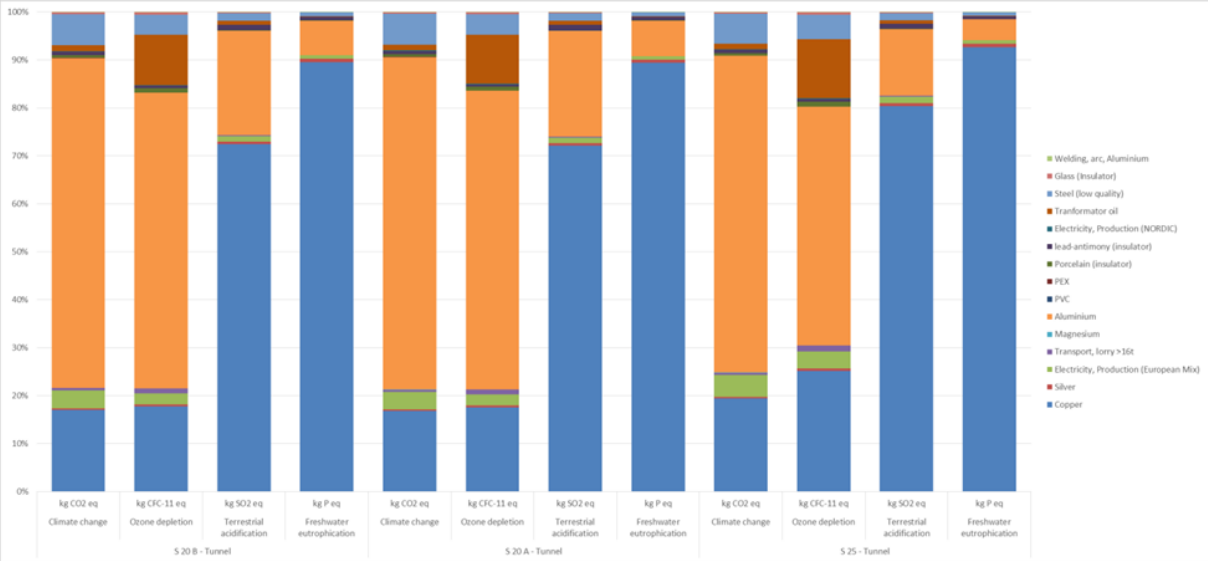

Figure 4-18: Relative environmental impacts of OCS-materials contribution for 1km of tunnel construction for three DSs

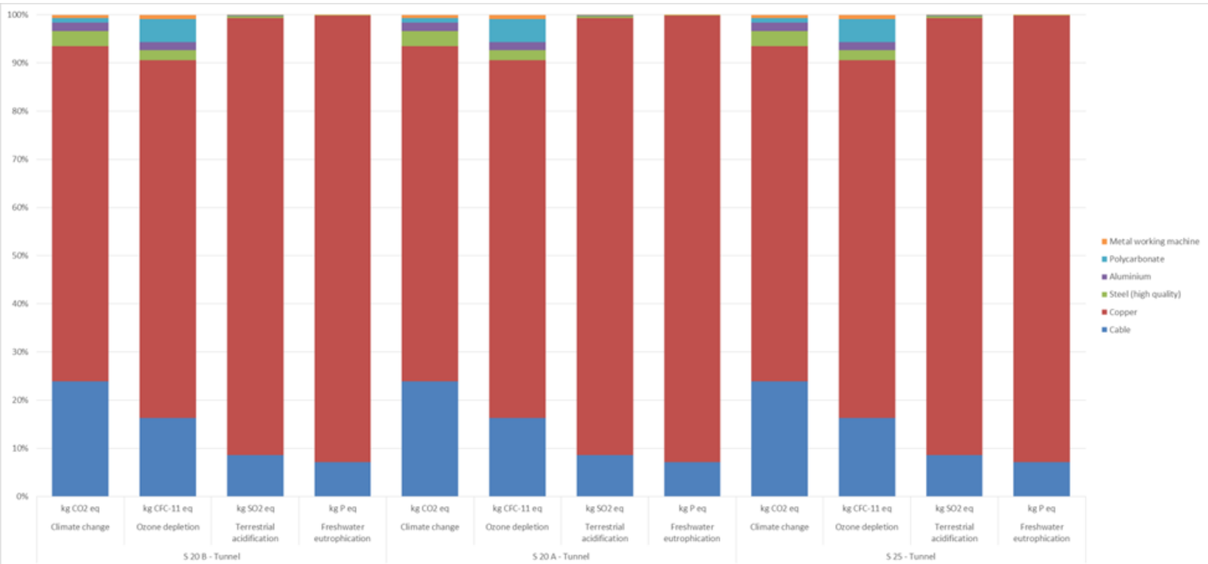

Figure 4-19: Relative environmental impacts of signaling-materials contribution for 1km of tunnel construction for three DSs

Figure 4-19 represents copper is relatively superior in all four-impact categories for signaling and cable is considered as a secondary attributor in the four-impact categories.

Figure 4-20 still shows copper as being a dominant in terrestrial acidification and freshwater eutrophication. However, its relative environmental impacts are influenced by cable and polyethylene (LDPE) with ca. 23% and 10%, respectively in climate change.

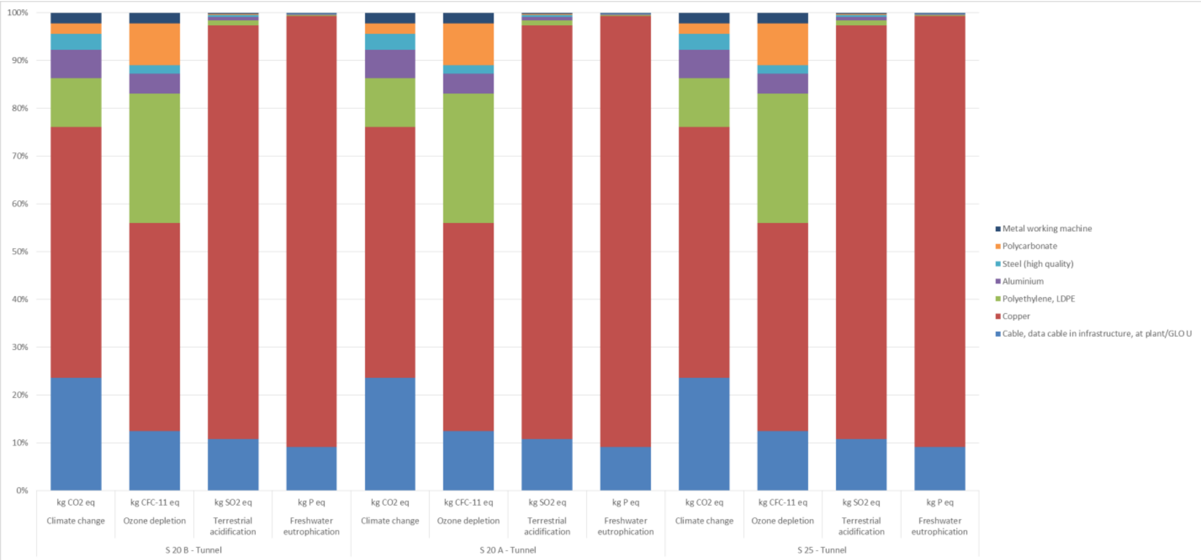

Figure 4-20: Relative environmental impact assessment of telecommunication-materials contribution for 1km of tunnel construction for three DSs

Figure 4-21 demonstrates nearly 50% of impact in climate change is associated with high quality steel and the rest with metal working machine, polycarbonate, LED and copper. High quality steel has a roll in the other three-impact categories, but the level of contribution is not as high as climate change. Copper with high quality steel together have more than 80% of contribution in terrestrial acidification. However, copper is superior all alone with 70% of contribution in freshwater eutrophication.

LEDs and metal working machine to a certain extent contribute to all four-impact categories and their highest level of contribution is in climate change and ozone depletion.

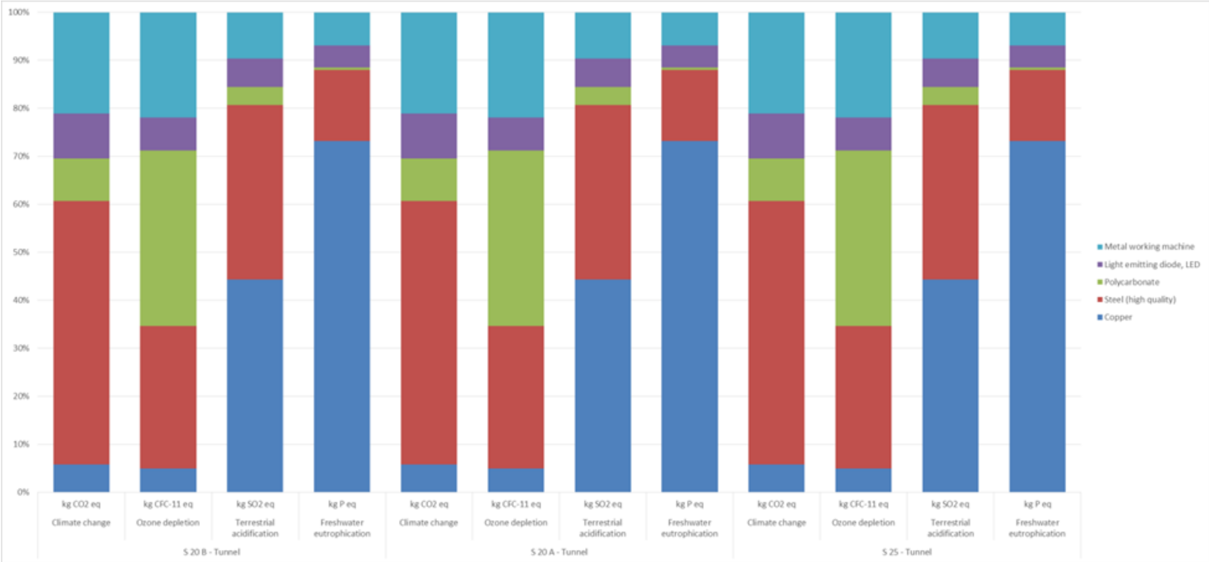

Figure 4-21: Relative environmental impacts of lighting-materials contribution for 1km of tunnel construction for three DSs

4.4.2 Process of Maintenance

Figure 4-22 shows approximately the majority environmental impacts of railways electrification for 1km of tunnel maintenance is based on telecommunication. After telecommunication, overhead contact system and signaling to a certain extent associate to all four-impact categories. The relative contribution of LEDs is greater in climate change and ozone depletion, but they decline to ca. 4% and 2% in terrestrial acidification and freshwater eutrophication, respectively.

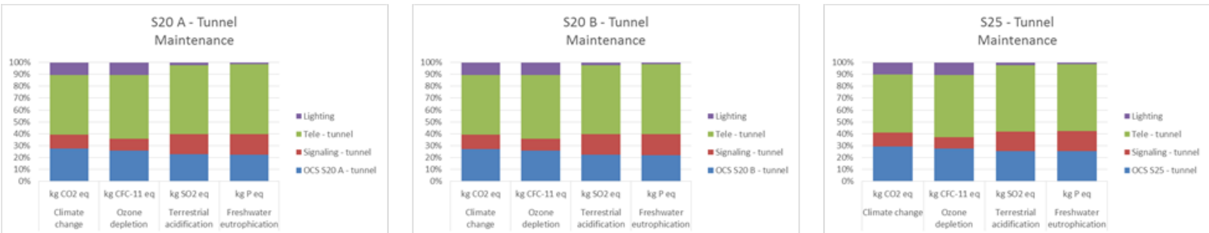

Figure 4-22: Environmental impact assessment of railways electrification for 1km of tunnel maintenance for three DSs

In figure 4-23, copper by far has the highest contribution (with more than 85%) in terrestrial acidification and freshwater eutrophication. Copper also influence the result with more than 30% in climate change and ozone depletion. After copper in climate change and ozone depletion, aluminum is influential.

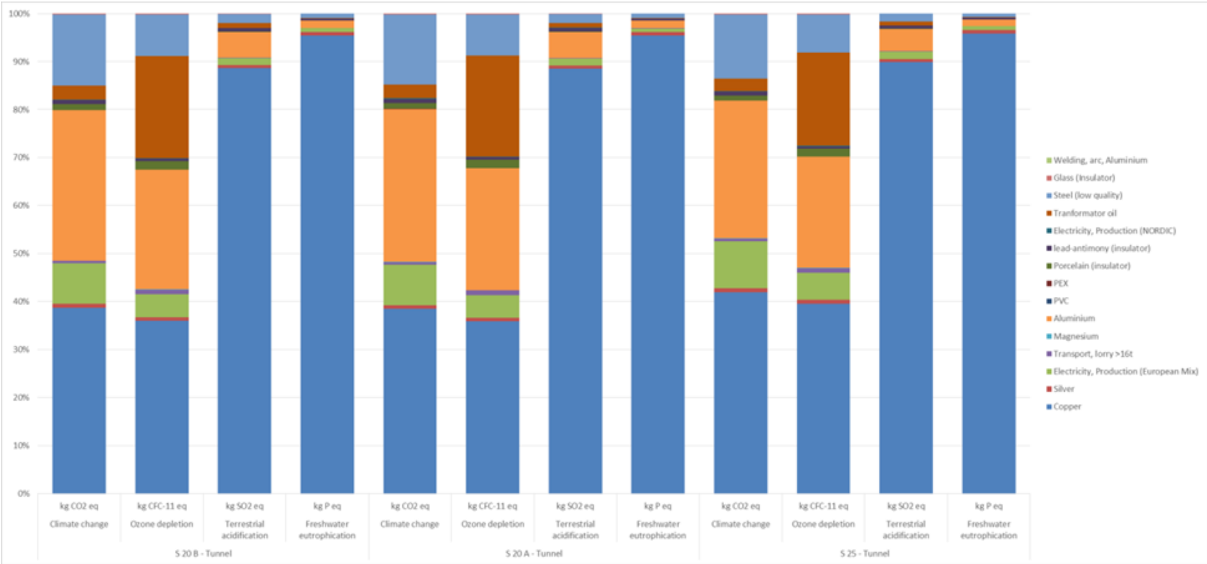

Figure 4-23: Relative environmental impacts of OCS-materials contribution for 1km of tunnel maintenance for three DSs

In climate change, low quality steel and welding of aluminum have the next places in the relative ranking of environmental impact assessment. However, transformer oil after aluminum in ozone depletion is influencing with about 20%.

The 100% vertical stack bar charts for signaling, telecommunication, and lighting are exactly the same as construction in figures 4-19, 4-20, and 4-21 due to this fact that all components have the same lifetime for the maintenance of each system (signaling, telecommunication or lighting). Hence, the relative changes are the same for all components of a given system[23].

4.5 Sensitivity Analysis

In this section, no emphasis is made to do the sensitivity analysis on signaling, telecommunication and lighting. The reason is relying on this fact that the data from signaling, telecommunication and lighting are collected from Follobanen report and if some changes are applied, there will be a level of uncertainty that I cannot support them (due to lacking from thorough information). To be able to make a good sensitivity analysis, an effort has been made to evaluate the quality of the results from OCS data.

In respect of the result that is shown from the first two parts in this chapter and Appendixes F and G, it became obvious that masts are significantly influential on the four-impact categories.

[23] This situation is exactly the same as maintenance in open section, but with one exemption. In fact, there is lighting system in maintenance of tunnel that there was not in maintenance of open section.

Hence, for the first sensitivity analysis a scenario of comparing the preliminary mast (HEB200) with type B (B3 and B6) and type H (H6) is made.

Figure 4-24:Relative environmental impacts of different masts contribution for a kilometer of open section for the three DSs.

In accordance with the relative bar chart, it shows that the highest impact goes to H6 and the lowest is for B3. This analysis shows how sensitive is the analysis with respect to the types of masts in one kilometer of open section. The reason of this behavior is because of material consistency of mast (the mass of steel). As a result, changing in the mass has an influence on getting different numbers. In addition, it was expected to have huge differences in results of climate change and small differences in freshwater eutrophication due to behavior of high quality steel in the open section of this chapter. To be able to see what the differences are in this sensitivity analysis, tables of inputs for the three DSs (in accordance with the types of masts) are provided in Appendix I.

For the second scenario, a decision is made to see how changes on the spanlength of mast in the open section would associate to the result. The spanlength changed from the initial condition (65m) to 60m and 55m.

As it become conspicuous, spanlength is the other influential parameter and shorter spanlength contributes more. However, the effect of spanlength is not as significant as changing types of masts. Technically, the variation in the results is greater for climate change and smaller for FE (for the three DSs). The reason goes back to high quality steel and aluminum that have been found in the previous part (figure 4-9 in part 4.3.1) that showed steel and aluminum contribute more in CC and OD rather than TA and FE.

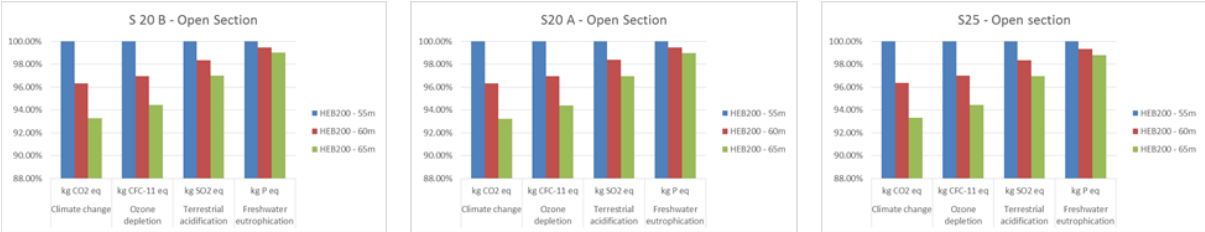

Figure 4-25:Relative environmental impacts of changing intervals for a kilometer of open section for the three DSs.

The third evaluation is made for AT in the open section with this respect, if the materials for all components related to ATs are more than 5% of the initial evaluation in chapter 4.3. Having this way of thinking is because of this fact that in some cases the length of feeding cables or ATs are changing due to not having space for ATs to be close to a track. Hence, more cables and ATs are required.

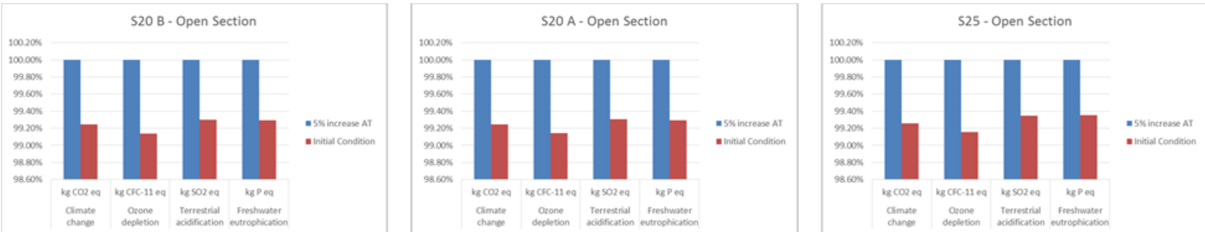

Figure 4-26: Relative environmental impacts of changing intervals of ATs for a kilometer of open section for the three DSs.

As it could be seen from figure 4-26, by having 5% more materials for ATs in one kilometer of open section, the results are not differ more than approximately 0.5%.

The same initiative in the fourth evaluation is taken for ATs in the tunnel section (as it is done for the open section). As it is shown in figure 4-27, the relative changes for one kilometer of tunnel for all three DSs are greater than one kilometer of open section. The differences are varying from 6% in CC and less than 1% in FE for all DSs.

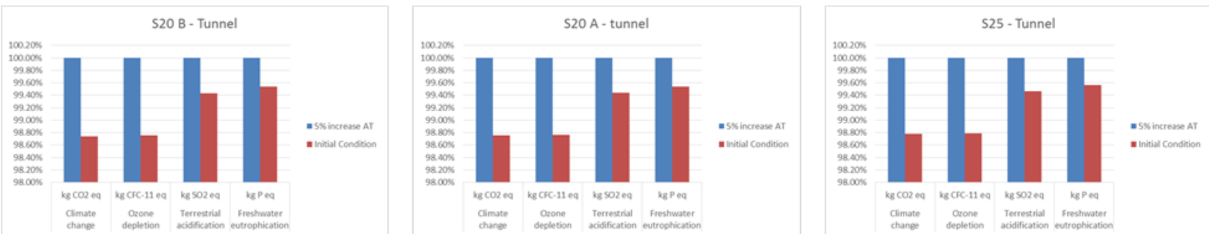

Figure 4-27: Relative environmental impacts of changing intervals of ATs for a kilometer of tunnel for the three DSs.

The last sensitivity is for the tunnel section by changing the intervals of OCS (the same as open section that is done). The comparison is made between 45m (initial evaluation in chapter

4.4) and 40m intervals of overhead contact systems. Figure 4-28 shows the result from the sensitivity analysis. By having a reduction of 5 meters from the initial intervals (45m), the relative increase in the results is 2% in CC and less than 0.2% for FE.

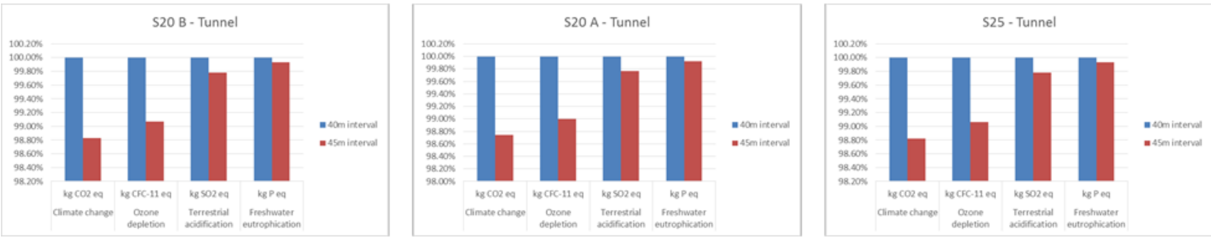

Figure 4-28: Relative environmental impacts of changing intervals for a kilometer of tunnel for the three DSs.

Chapter V

5 Discussion

The provision of the three different design speeds gave a wider range of insight than previous study (Follobanen). Follobanen (New Double Track Line Oslo – Ski) provided information about masts and cantilever together, but it wasn't clear what types of masts and cantilevers (in accordance with different DSs) the project utilized. In fact, based on Jernbaneverket report, there is a variation in usage of distinctive DSs in different sections of Follobanen that is not pointed out in the project. (Jernbaneverket)

Due to a compromise (Klimaforliket) on the 17th of January 2008 in the Norwegian Parliament, all transportation authorities have been told to perform accounting of GHG-emissions when planning the construction of large scale infrastructure projects. (Communication 2009) However, the life cycle impact assessment of this project is in accordance with PCR. This means, only four impact categories are taken into consideration. In a comparison with Follobanen, this project missed one impact category that was photochemical smog which made the perspective become smaller.

Figures 4-2 and 4-4 show how different materials contribute in the four impact categories. Based on material impact assessment, copper, high quality steel, aluminum, cable, autotransformer oil and Polycarbonate are critical materials. However, if contributors are sorted based on the highest percentage, it will be seen copper, high quality steel and aluminum have the highest impacts. Copper has the highest impact in acidification and eutrophication in both open section and tunnel section and high quality steel has the highest impact in climate change and ozone depletion in the open section. Despite the fact that high quality steel in the open section contributes the most, aluminum and copper have the most impact in climate change and ozone depletion in the tunnel.

5.1 Allocation Issues

LCA is a study that is twisted to quality and source of data, which can be so effective in the final results. Hence, it is recommended (ISO 14040) to make a good description of data quality to find out the reliability of the study.

Utilization of alternative materials and processes instead of initial ones was a problem in this project, which can be influential on some levels. This problem happened for PEX, insulators, aluminum (cable), autotransformer oil etc. For instance, for aluminum cable a process of sheet rolling was considered for cable production in accordance with Follobanen report. In addition, a wide allocation happened for both types of insulators (glass and porcelain based). The production of glass based insulator addresses “Flat glass, uncoated, at plant/RER U” and “Tempering, flat glass/RER U” as two parts of glass made insulator. Moreover, the process of “Sanitary ceramics, at regional storage/CH U” is addressed for the porcelain insulator. The same problem happened for autotransformer oil with implication of lubricating oil process.

5.2 Uncertainties Issues

One of the highest uncertainties in this project is the background processes from Ecoinvent. It raises doubts about the age and allocation in some background processes. Actually, some of background processes in this project were published 1990s that might not be a correct reflection of manufacturing of some components in Europe anymore.

The study of railways electrification is a generic LCA case study that does not take into consideration of a specific line in Norway. Thus, there might be some details that can be critical in the final results. Over or underestimation change the actual impacts; such these components that can effect on the final results are transportation, energy, tracks and age of existence line before electrification, system description of LCIA, substations etc.

Transportation and energy in this project addressed a generic model and through building an inventory, a generic model of energy and transportation based on Ecoinvent is utilized. Based on PCR, a lifetime of 60 years is considered for railways electrification that brings, having second thoughts about an existence railway that is going to be electrified. In reality, if the existence line is old enough and is planned to be electrified, it will be needed to consider some key elements like tracks replacement, tunnels evaluation etc.

The other kind of uncertainties that this project was suffering from is the evaluation of LCIA for a kilometer of straight line. This approach is not an idealistic way of evaluation due to having some curves that automatically increase in mass of materials (such as masts, cantilevers and catenaries that all of these three are made of critical components) in this study that are indicated in the sensitivity analysis.

5.3 Future Work

Among a variety of options that are interesting to spend time on, substations were of great importance. Installations of new substations (that this project was lacking from) are assumed to be influential to the final results. Hence, it will be a good initiative to consider this big missing puzzle.

The results from this project evaluate LCA of railways electrification for a kilometer of single track. Evaluation of double tracks and terminals due to direct effect on increase in the mass of OCS, signaling and telecommunication is interesting to look at.

In addition, signaling and telecommunication in this project came directly from Follobanen report without specifying distinctive signaling and telecommunication systems for different DSs. Therefore, having an investigation on mass dissimilarity in signaling and telecommunication for different DSs can address better how speed disparities in two different sections (open sections and tunnels) contribute in the final results of LCIA.

Moreover, in Norway, there are lines that are single-tracks and still not electrified. There will be an interesting study to consider the economics effect of railways electrification on lines traffics. The study can assess alternative cases such as detour lines or closure of lines.

Furthermore, there are three missing parts that are not taken into consideration in this study, which are:

- Maintenance waste and disposal
- Energy requirement for installation and maintenance
- Boosters

Chapter VI

6 Conclusion

This project has performed a life cycle impact assessment for railways electrification of different design speeds in open and tunnel sections in Norway by building a life cycle inventory. The preliminary results have shown how environmental impacts vary for different DSs by means of relative bar charts. However, in the second part a set of sensitivity analyses have been made in accordance with results from primary analyses.

The performance of conclusion in this chapter is in according with highlighting materials, sections and life cycle phases that contribute with the highest impact in the final results.

Based on the relative bar charts in chapter four, the critical materials in LCIA are:

- Steel (high quality)
- Copper
- Cable
- Polycarbonate
- Aluminum
- Transformer oil

In spite of the fact that copper and steel for open section have the greatest share, in a kilometer of tunnel copper and aluminum are the materials that have the most impact.

The environmental impact results of infrastructures for four impact categories are specified in table 6-1. The results are comprised of life cycle impact assessment for a kilometer of open section and tunnel that include maintenance and construction in accordance with PCR.

Table 6-1Quantitative life cycle impact assessment of railways electrification for a kilometre of infrustructure

		Open Section				Tunnel			
		Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication	Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication
		kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq
Construct-ion	S20 B	8.223E+04	5.680E-03	7.499E+02	2.109E+02	4.054E+04	3.239E-03	7.114E+02	2.659E+02
	S20 A	8.270E+04	5.712E-03	7.553E+02	2.128E+02	4.114E+04	3.279E-03	7.154E+02	2.668E+02
	S25	8.354E+04	5.774E-03	8.045E+02	2.340E+02	4.199E+04	3.341E-03	7.630E+02	2.873E+02
Maintena-nce	S20 B	5.655E+04	4.511E-03	8.127E+02	2.855E+02	4.257E+04	3.775E-03	1.228E+03	4.964E+02
	S20 A	5.672E+04	4.522E-03	8.169E+02	2.872E+02	4.272E+04	3.786E-03	1.230E+03	4.972E+02
	S25	5.785E+04	4.604E-03	8.672E+02	3.085E+02	4.383E+04	3.865E-03	1.279E+03	5.178E+02
Total	S20 B	1.388E+05	1.019E-02	1.563E+03	4.965E+02	8.311E+04	7.014E-03	1.939E+03	7.623E+02
	S20 A	1.394E+05	1.023E-02	1.572E+03	5.000E+02	8.386E+04	7.065E-03	1.946E+03	7.640E+02
	S25	1.414E+05	1.038E-02	1.672E+03	5.425E+02	8.582E+04	7.206E-03	2.042E+03	8.052E+02

To begin with the entire system, the total environmental impacts for climate change and ozone depletion for open section are greater (with approx. 59% and 68%, respectively) than tunnel.

On the other hand, the total environmental impacts for terrestrial acidification and freshwater eutrophication are greater (with approx. 80% and 65%, respectively) for tunnel section than open section.

Despite the fact that construction in open section has the highest contribution only in CC and OD, maintenance contributes the most for tunnel and open section. The reason of having such contribution from maintenance is due to greater number of replacements in signaling and telecommunication (as a result of lifetime) that leads to more utilization of materials (especially copper).

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Appendix A: Specifications of Design Speed Systems

A list of specification details for each system is provided in an email from Mr. Egil that gives physical differences of all systems.

Parametre for system 35

Balansearm
Svingbare utliggere
Systemhøyde 1,55 m
Kontakttrådhøyde 5,60 m (5,05 m – 5,60 m)
Bærelinestrekk (50/7 Cu) 7063 N
Kontakttrådstrekk (Ri 100 Cu) 7063 N
Y-linestrekk (35/7 Cu) 1400 N
Spennlengde a <= 66 m
½ maksimal ledningspart 800 m
Spennlengder og siksak se tabell 101
Fixpunkt EK.707064

Parametre for system 35 MS (Modifisert System)

Balansearm
Svingbare utliggere
Systemhøyde 1,60 m
Kontakttrådhøyde 5,60 m (5,05 m – 5,60 m)
Bærelinestrekk (50/7 Cu) 7063 N
Kontakttrådstrekk (Ri 100 Cu) 7063 N
Spennlengde a <= 66 m
½ maksimal ledningspart 800 m
Spennlengder og siksak se tabell 101
Fixpunkt EK.707064

Parametre for system 20 A (200 km/t)

Innspent bæreline
Svingbare utliggere
Systemhøyde 1,60 m
Kontakttrådhøyde 5,60 m (5,05 m – 5,60 m)
Bærelinestrekk (DIN 48201 - 50/7 BzII) 10000 N
Kontakttrådstrekk (RiS 100 Cu/Ag) 10000 N
Y-linestrekk (DIN 40201 - 25/7 BzII) 2300 N
Spennlengde a <= 65 m
½ maksimal ledningspart 750 m
Spennlengder og siksak se tegning EK.800109
R < 800 m uten Y-line se tegning EK.707156
Fixpunkt EK.707195

Parametre for system 20 B (160 km/t)

Innspent bæreline
Svingbare utliggere
Systemhøyde 1,60 m
Kontakttrådhøyde 5,60 m (5,05 m – 5,60 m)
Bærelinestrekk (DIN 48201 - 50/7 BzII) 10000 N
Kontakttrådstrekk (RiS 100 Cu/Ag) 10000 N
Spennlengde a <= 65 m
½ maksimal ledningspart 750 m
Spennlengder og siksak se tegning EK.800109
Fixpunkt EK.707195

Parametre for system 25 (250 km/t)

Innspent bæreline
Svingbare utliggere
Systemhøyde 1,80 m
Kontakttrådhøyde 5,30 m
Bærelinestrekk (DIN 48201 - 50/7 BzII) 15000 N
Kontakttrådstrekk (RiS 100 Cu/Ag) 15000 N
Y-linestrekk (DIN 40201 - 35/7 BzII) 2800 N
Spennlengde a <= 65 m
½ maksimal ledningspart 750 m
Spennlengder og siksak se tegning EK.707397
R < 1200 m uten Y-line se tegning EK.707390
Fixpunkt EK.707195

Parametre for system 25 (250 km/t - tunnel)

Innspent bæreline
Svingbare utliggere
Systemhøyde 1,10 m

Kontakttrådhøyde 5,30 m
Bærelinestrekk (DIN 48201 - 50/7 BzII) 15000
N
Kontakttrådstrekk (RiS 100 Cu/Ag) 15000 N
Y-linestrekk (DIN 40201 - 35/7 BzII) 2800 N
Spennlengde a <= 45 m
½ maksimal ledningspart 450 m
Spennlengder og siksak se tegning EK.707397
R < 1200 m uten Y-line se tegning EK.707390
Fixpunkt EK.707195

Appendix B: Specifications and Layouts of Cantilevers for Systems 20 and 25

Bellow tables of specifications of each system are provided

Table below is made from figure EK.707172-000 for S20 B.

Pos. nr.	Pipe size (mm)	(Weight/lenght) Kg/m	Length (m)	Material	Standard
Pos. 19	Ø55*6	2.494	2.56	Alu	EN AW-6082 T6
Pos. 36	Ø70*6	3.257	2.35	Alu	EN AW-6082 T6
Pos. 20	Ø42*4	1.289	2.6	Alu	EN AW-6082 T6
Pos. 14	Ø26*3.5	0.668	1	Alu	EN AW-6082 T6
Pos. 25	Ø6	0.134	0.98	Steel	3-20.01.01-02

Table below is made from figure EK.707173-000 for S20 A.

Pos. nr.	Pipe size (mm)	(Weight/lenght) Kg/m	Length (m)	Material	Standard
Pos. 19	Ø55*6	2.494	3.33	Alu	EN AW-6082 T6
Pos. 18	Ø55*6	2.494	3	Alu	EN AW-6082 T6
Pos. 20	Ø42*4	1.289	3.2	Alu	EN AW-6082 T6
Pos. 14	Ø26*3.5	0.668	1	Alu	EN AW-6082 T6
Pos. 25	Ø6	0.134	1.3	Steel	3-20.01.01-02

Table below is made from figure E-7191 pos. 2.

Pos. nr.	Pipe size (mm)	(Weight/lenght) Kg/m	Length (m)	Material	Standard
Strekkstag	Ø55*6	2.494	2.7	Alu	EN AW-6082 T6
Trykkstag	Ø70*6	2.494	2.6	Alu	EN AW-6082 T6
Direksjonsstag	Ø42*4	1.289	1.595	Alu	EN AW-6082 T6
Horisontalstag	Ø42*4	0.668	0.72	Alu	EN AW-6082 T6
Steel Wire	Ø6	0.134	0.87	Steel	3-20.01.01-02

$\frac{S}{300} = \frac{12.3}{1.44}$

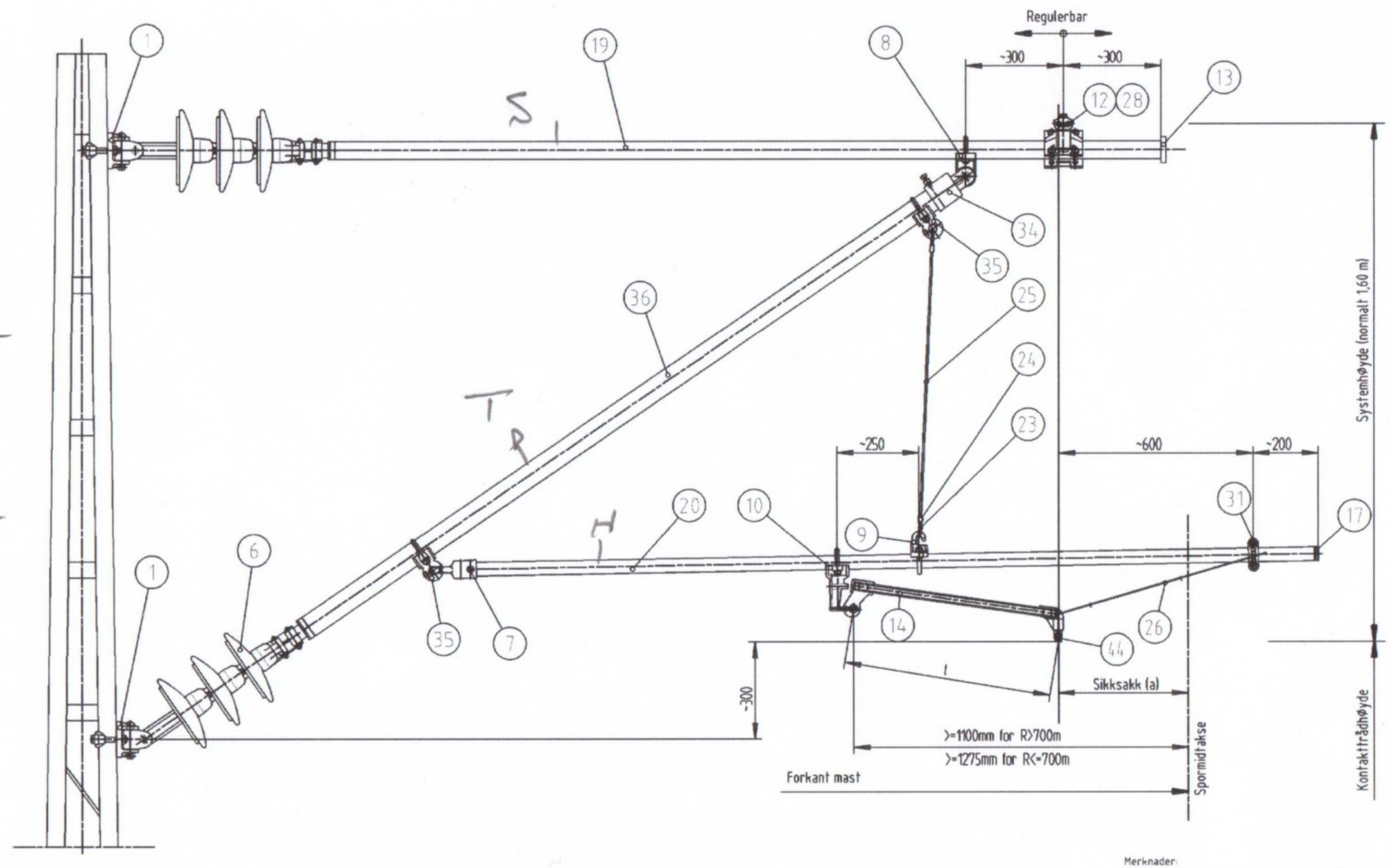
$S = 2562.5$

$\frac{T}{300} = \frac{11.3}{1.44}$

$T = 2,354.2$

$\frac{H}{300} = \frac{12.5}{1.44}$

$H = 2604.2$



$\frac{(25)}{300} = \frac{4.7}{1.44}$

$(25) = 979$

Tabell 1

Rørdimensjoner for utførelse B			
Rørtype	Trykk-stag	Strekk-stag	Horisontal-stag
Rørdiameter	70	55	42

Tiltrekningsmoment:
pos. 6, 8, 10, 12 og 35: 70 Nm.
pos. 9 og 31: 35 Nm.
pos. 7 og 34: 50 Nm.

Tabell 2

Varianter for bærelineholder pos.12		
Tegningsnummer	Tittel	F.nr.
EK.707214-000	Bærelineholder for strekkstag ø55 og ø70	251.405.41
EK.707521-000	Bærelineholder fra Siemens for strekkstag ø55	251.405.47

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F nr. / Anmerkning
1	44	Kontakttrådklemme	EK.707200-000		251.002.50
	36	Trykkstag ø70x6	EK.707291-000		251.401.23
2	35	Øyemuffe med bøyle kompl.f.rør ø70	EK.707314-000		251.405.60
1	34	Endemuffe, trykkstag u/hlr.h. ø70	EK.707206-000		251.405.31
1	31	Vindsikringsh. for ø42 og ø55 r>1200 m	EK.707207-000		251.405.32
1	28	Skive og beskyttelseshylse for 7-trådet 50 mm	EK.707258-000	ALCU	251.405.79
1	26	Vindsikring for lett dir.stag r>1200 m	EK.707315-000	Stålline	251.405.62
	25	Line 6 mm		NRST	250.231.03
2	24	Presshylse 6	EK.707332-000	Al	251.014.69
2	23	Kause 6 for hengetråd av stål	EK.707333-000	NRST	251.018.38
	20	Horisontalstag ø42x4	EK.707291-000		251.401.21
	19	Strekkstag ø55x6	EK.707291-000		251.401.22
1	17	Plasthette ø42 for horisontalstag	EK.707289-000		251.602.14
1	14	Lett direksjonsstag	EK.707198-000		Angi l. ved best.
1	13	Plasthette ø55 for horisontalstag	EK.707289-000		251.602.13
1	12	Bærelineholder for strekkstag ø55			Se tabell. 2
1	10	Holder for lett dir.stag ø42 kompl.	EK.707302-000	G-Al	251.405.54
1	9	Hengelrådholder for horisontalstag ø42	EK.707208-000		251.405.34
1	8	Holder for strekkstag, rør ø55	EK.707202-000		251.405.25
1	7	Endemuffe m/krok for rør ø42	EK.707196-000		251.405.20
2	6	Utliggerisolator	EK.707454-000		249.801.60
2	1	Utl.konsoll m/ledd for norm.utl.B/H-mast	EK.707167-000		Angi. utf. ved best.

Merknader:
Utliggerutførelse er avhengige av kurveradius, utliggerlengde, systemhøyde og sikksakk.
For beregninger av kuttelengder og montasjemål se resultater fra beregningsprogram godkjent av Jernbaneverket.
Konsoller, pos.1, er avhengig av mastetype og størrelse.
Bærelineholdere EK.707214-000 og EK.707521-000, pos. 12, går ikke om hverandre. De kan erstatte hverandre men da må utliggeren beregnes på nytt eller justeres manuelt.
Vindhenger er avhengig av strekkraft, radius og type utligger. Ikke alle utliggere skal ha vindhenger, se kuttetabell.

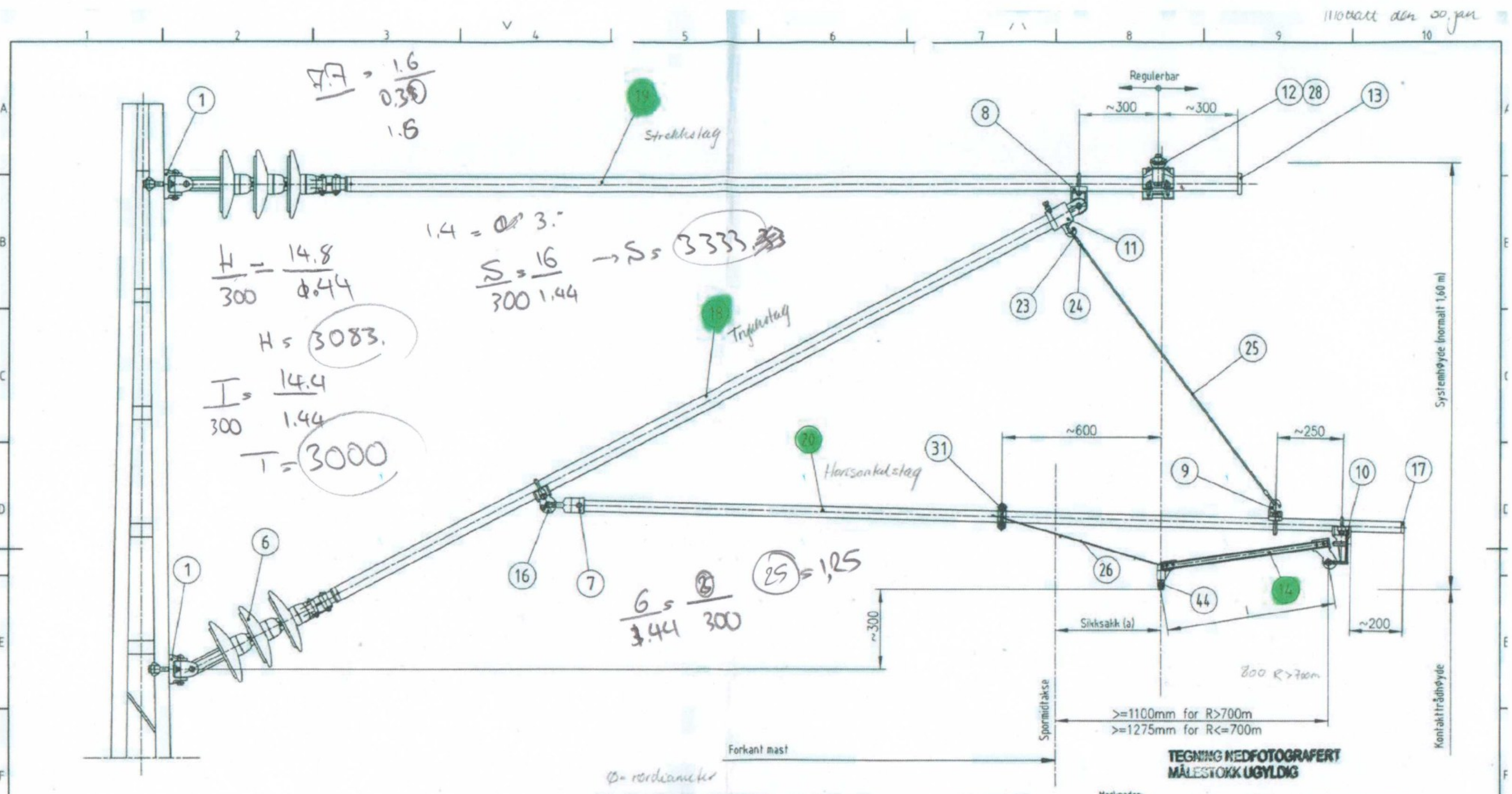
Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
003	Div. tekst/tegningsnr. endret. Pos. 12 oppført med to varianter	04.06.04			
2	Pos.24 f.nr. endret og pos.44 er ny	02.03.99	HMH		
1	Ny stykkliste	23.11.98	HMH		

Normalutligger, strekkbelastet Utførelse B, system 20 Sammenstillingstegning

Målestokk	1:10
Dato	13.11.98
Tegnet av	HMH
Kontrollert av	
Godkjent av	
Arkiv bet.	2-05.05.01-2
Erstatn. for	
Erstattet av	
Tegning nr	EK.707172-000
Rev	003

Jernbaneverket

E-7172.dwg



Tabell 1

Rørdimensjoner for utførelse A			
Rørtype	Trykk-stag	Strekk-stag	Horisontal-stag
Rørdiameter	55	55	42

Tiltrekningsmoment:
pos. 6, 8, 10, 12 og 16: 70 Nm.
pos. 9 og 31: 35 Nm.
pos. 7 og 11: 50 Nm.

Tabell 2

Varianter for bærelineholder pos.12		
Tegningsnummer	Tittel	F.nr.
EK.707214-000	Bærelineholder for strekkstag ø55 og ø70	251.405.41
EK.707521-000	Bærelineholder fra Siemens for strekkstag ø55	251.405.47

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr / Standard	Materiale	F nr. / Anmerkning
1	44	Kontakttrådklemme	EK.707200-000		251.002.50
1	31	Vindsikringsh. for ø42 og ø55 r>1200 m	EK.707207-000		251.405.32
1	28	Skive og beskyttelseshylse for 7-trådet 50	EK.707258-000		251.405.79
1	26	Vindsikring for lett. dir.stag r>1200 m	EK.707315-000	Stålline	251.405.62
	25	Line 6 mm	3-20.01.01-02	NRST	250.231.03
2	24	Presshylse 6	EK.707332-000	Al	251.014.69
2	23	Kause 6 for hengetråd av stål	EK.707333-000	NRST	251.018.38
	20	Horisontalstag ø42x4	EK.707291-000		251.401.21
	19	Strekkstag ø55x6	EK.707291-000		251.401.22
	18	Trykkstag ø55x6	EK.707291-000		251.401.22
1	17	Plasthette ø42 for horisontalstag	EK.707289-000		251.602.14
1	16	Øyemuffe med bøyler, kompl. for rør ø55	EK.707314-000		251.405.61
1	14	Lett direksjonsstag ø45	EK.707198-000		Angi. l. ved best.
1	13	Plasthette ø55 for horisontalstag	EK.707289-000		251.602.13
1	12	Bærelineholder for strekkstag ø55			Se tabell 2.
1	11	Endemuffe for trykkstag ø55 kompl.	EK.707204-000		251.405.29
1	10	Holder for lett dir.stag ø42 komplett	EK.707302-000		251.405.54
1	9	Hengetrådholder for horisontalstag ø42	EK.707208-000		251.405.34
1	8	Holder for trykkstag for rør ø55	EK.707202-000		251.405.25
1	7	Endemuffe m/krok for rør ø42	EK.707196-000		251.405.20
2	6	Utliggerisolator	EK.707454-000		249.801.60
2	1	Utl. konsoll m/lokk for norm.utl.B/H-mast	EK.707167-000		Angi. utf. ved best.

TEGNING NEDFOTOGRAFERT
MÅLESTOKK UGYLDIG

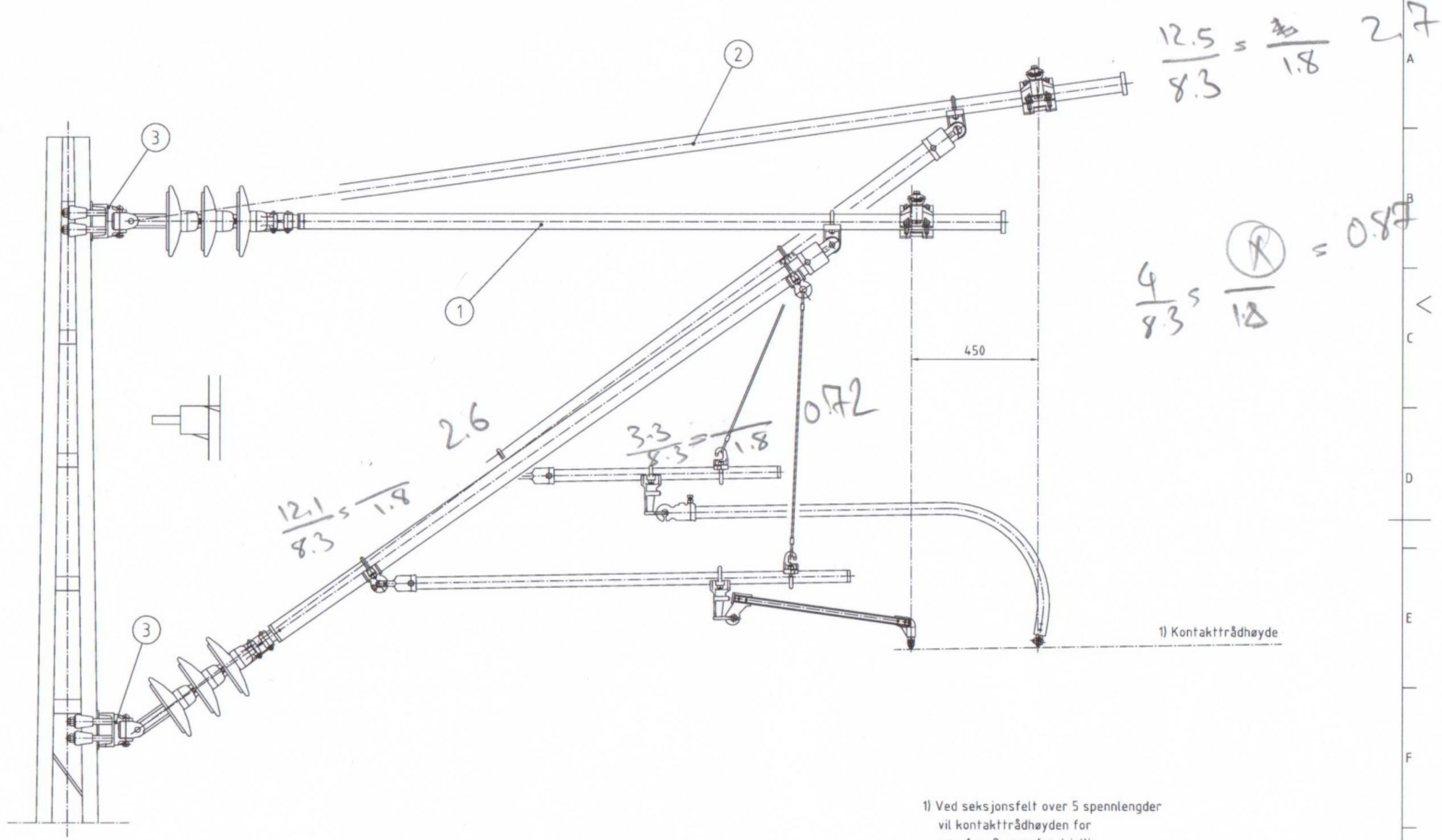
Merknader:
Utliggerutførelse er avhengige av kurveradius, utliggerlengde, systemhøyde og sikksakk.
For beregninger av kuttelengder og montasjemål se resultater fra beregningsprogram godkjent av Jernbaneverket.
Konsoller, pos.1, er avhengig av mastetype og størrelse.
Bærelineholdere EK.707214-000 og EK.707521-000, pos. 12, går ikke om hverandre. De kan erstatte hverandre men da må utliggeren beregnes på nytt eller justeres manuelt.
Vindhenger er avhengig av strekkraft, radius og type utligger. Ikke alle utliggere skal ha vindhenger, se kuttetabell.

Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
003	Div. tekst/tegningsnr. endret. Pos.12 oppført med to varianter	04.06.04	HMH	Top	[illegible]
2	Pos.24 f.nr. endret og pos.44 er ny	02.03.99	HMH		
1	Ny stykkliste	23.11.98	HMH		

Normalutligger, trykkbelastet
Utførelse A, system 20
Sammenstillingstegning

Målestokk	~~1:10~~
Dato	27.04.1992
Tegnet av	HMH
Kontrollert av	
Godkjent av	
Arkiv bet.	2-05.05.01-3
Erstatn. for	
Erstattet av	
Tegning nr	EK.707173-000
Rev	003

Jernbaneverket



1) Ved seksjonsfelt over 5 spennlengder
vil kontakttrådhøyden for
pos. 1 og 2 være forskjellig.
Se resultater fra beregningsprogram.

Merk
Utliggere er avhengige av kurveradius, lengde og siksak.
Rørene i stagene varierer derfor slik;
(Se også kuttetabellene og momentberegningene.)

	Strekkstag	Trykkstag	Horisontalstag
Utf. A (E-7171)	ø55	ø55	ø42
Utf. B (E-7172 / E-7502)	ø55	ø70	ø42

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F nr. / Anmerkning
2	3	Konsoll for dobbelt utligger	E-7168		Angi utf. ved best.
1	2	Utligger ifølge tabell	E-7502		
1	1	Utligger ifølge tabell	E-7171/E-7172		

Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
1	Nye pos. nr., tekst i tittelfelt	23.11.00	ViE		

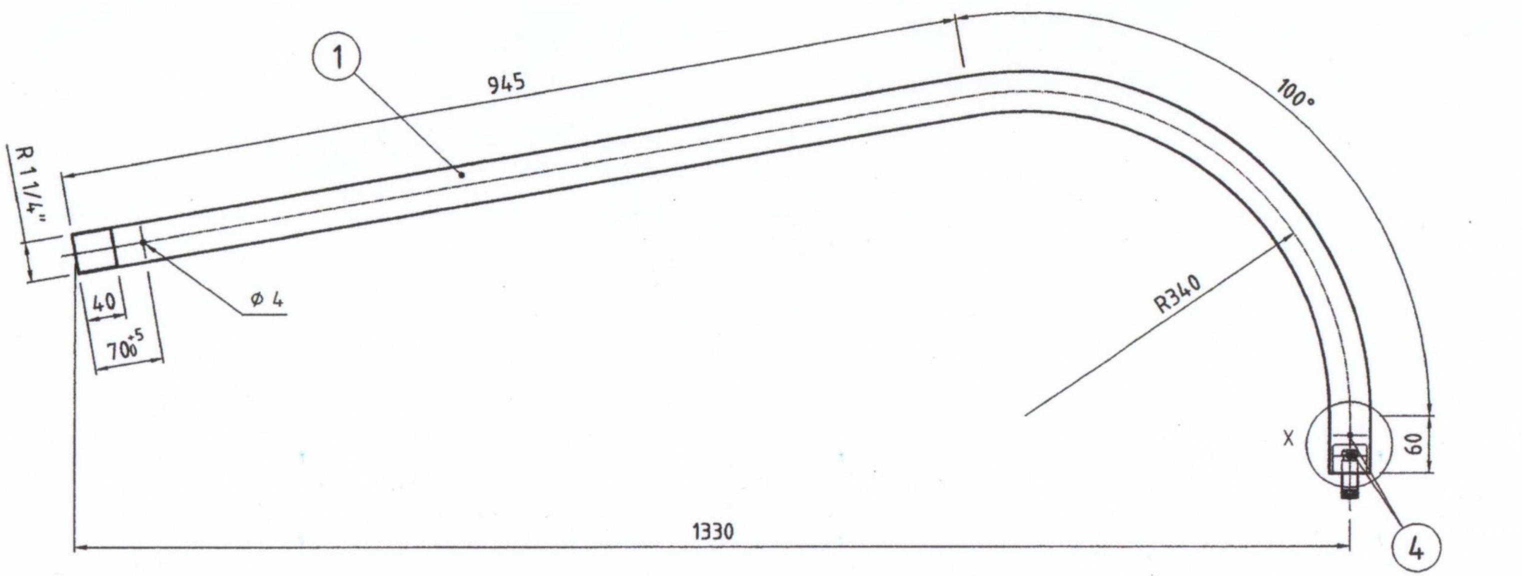
Kontaktledningsanlegg
Seksjonsutligger for seksjons-
felt over 4 og 5 spennlengder.
System 20 A og B

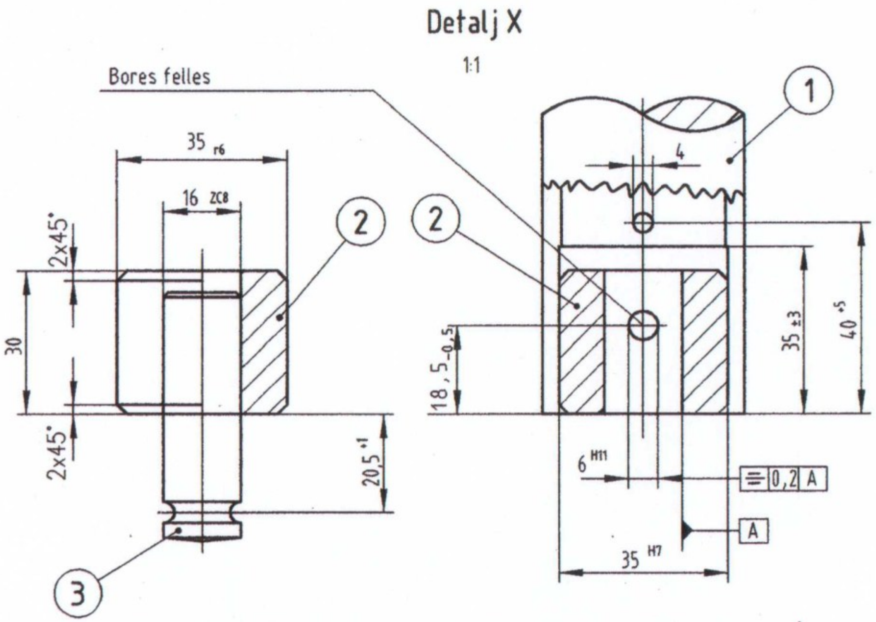
Målestokk: 1:10
Dato: 27.04.92
Tegnet av: ViE
Kontrollert av:
Godkjent av: TET
Arkiv bet.: 2-05.25.02.1
Erstatn. for:
Erstattet av:

Jernbaneverket

Tegning nr: E-7191
Rev: 1

E-7191.dwg





Røret må ikke ha noen knekk !

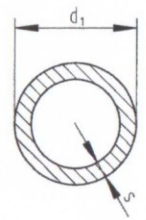
Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F nr. / Anmerkning
1	4	Sylindersplint 6x40	DIN 1473		
1	3	Bolt for kontakttr. klemme i lett dir.stag	E-7312		251.405.57
1	2	Press bøssing		AlMgSi1 T6	
m	1	Rør 42x4	E-7291		251.401.21

Kontaktledningsanlegg Rør for bøyd direksjonsstag System 25	Målestokk 1:5	Dato 02.12.99 Tegnet av ViE Kontrollert av ALR 24/01.00 Godkjent av [signature]
	Arkiv bet.	3-05.98.31
	Erstatn. for	
	Erstattet av	
Jernbaneverket	Tegning nr E-7488	Rev

E-7488.dwg

NS 2400, NS 1402, NS 1415

Pos	Rør $d_1 x s$	Toleranser f.d. $\Delta \bar{d}$ mm	Δd_1 mm	A mm^2	J cm^4	W cm^3	Vekt kg\m	Nyttes som
1	26x3,5	+0,6 -0,1 x)	+1,5 -0,1 x)	247,40	1,603	1,233	0,668	Direksjonsstag, bryterstang, strekkstag, stag.
2	42x4	+0,7 -0,35 x)	+1,8 -0,9 x)	477,52	8,715	4,150	1,289	Horisontalstag, strekkstag, Loddføringsrør.
3	55x6	±0,8	+1 -2	923,63	28,136	10,231	2,494	Trykkstag, strekkstag, horisontalstag.
4	70x6	±0,8	±2	1206,37	62,309	17,803	3,257	Trykkstag
5	80x6	±0,8	±2	1394,87	96,106	24.027	3,766	Trykkstag
6	100x10	±0,9	±2,3	2827,43	289,812	57.962	7,634	Hengemast
7	120x12	±0,9	±2,3	4071,50	600,954	100,159	10,993	Hengemast



Materiale: EN AW-6082 T6, fasthetsegenskaper etter NS-EN 755-2.
Tekniske leveringsbetingelser: NS-EN 755-1.
Mål og tillatte avvik: NS-EN 755-7.
Unntatt verdier som er merket med x):
$\Delta \bar{d}$ =tillatt avvikfra gj. snitt. utvendig diameter.
Δd_1 =tillatt avvik og urundhet.

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F nr. / Anmerkning
m.	7	Aluminiumsrør 120x12		EN AW-6082 T6	251.401.26
m.	6	Aluminiumsrør 100x10		EN AW-6082 T6	251.401.25
m.	5	Aluminiumsrør 80x6		EN AW-6082 T6	251.401.24
m.	4	Aluminiumsrør 70x6		EN AW-6082 T6	251.401.23
m.	3	Aluminiumsrør 55x6		EN AW-6082 T6	251.401.22
m.	2	Aluminiumsrør 42x4		EN AW-6082 T6	251.401.21
m.	1	Aluminiumsrør 26x3,5		EN AW-6082 T6	251.401.20

Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
2	Fra DIN til NS-EN standard	09.10.00	ViE	ALR 10/11.00	TET
1	Ny stykkliste	11.11.98	HMH	ALR	TET

Kontaktledningsanlegg
Ekstruderte aluminiumsrør

Utligger – System 20 og 25

Målestokk	1:1
Dato	02.11.92
Tegnet av	HMH
Kontrollert av	
Godkjent av	TET
Arkiv bet.	4-20.20.16
Erstatn. for	
Erstattet av	
Tegning nr	E-7291
Rev	2

Jernbaneverket

E-7291.dwg

Appendix C: Specifications and Layouts of Masts and a Soffit Post for Systems 20 and 25

Bellow tables of specifications of each system are provided

Table below is made from figure EK.800089-000 for HEB200 mast.

Mast type	Weight (kg/m)	Surface area (m2/m)
HEB200	61.3	1.15

Table below is made from figure EK.800092-000 for B3 mast.

	Area (mm^2)	Length (mm)	Weight	Standard
Pos. 1	42600		40 (kg/m2)	NS-EN 10051
Pos. 3	168000		80 (kg/m2)	NS-EN 10029
Pos. 4	4425		80 (kg/m2)	NS 1903
Pos. 5	259000		240 (kg/m2)	NS-EN 10051
Pos. 6		12203	8 (kg/m)	
Pos. 1		9504.08	20 (kg/m)	

Table below is made from figure EK.800092-000 for B6 mast.

	Area (mm^2)	Length (mm)	Weight	Standard
Pos. 2	33600		40 (kg/m2)	NS-EN 10051
Pos. 3	168000		80 (kg/m2)	NS-EN 10029
Pos. 4	4425		80 (kg/m2)	NS 1903
Pos. 5	259000		360 (kg/m2)	NS-EN 10051
Pos. 6		12203	9.6 (kg/m)	
Pos. 1		9504.08	25.3 (kg/m)	

Table below is made from figure EK.800094-000 for H6 mast.

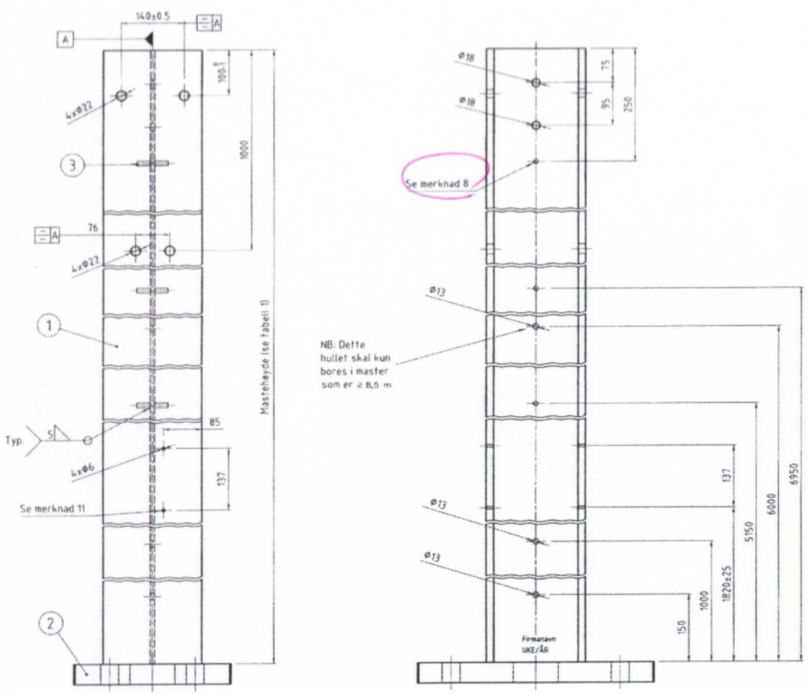
	Area (mm^2)	Length (mm)	Weight	Dimension
Pos. 1		9504.75	11.1 (kg/m)	VINKELSTÅL 75*75*10
Pos. 2		11403	5.42 (kg/m)	VINKELSTÅL 60*60*6
Pos. 3	422500		400 (kg/m2)	650*650*50
Pos. 4	18000		48 (kg/m2)	300*66*6
Pos. 5	86000		80 (kg/m)	200*L*10
Pos. 6		470	11.1 (kg/m)	VINKELSTÅL 75*75*10

Table below is made from figure E.7311 for the soffit post in tunnel for systems 20 and 25.

	Material	weight (kg/m)	Density (kg/m3)	volume (m3)	Weight (kg)
20*450*450	EN AW-6060		2700	0.00405	10.935
12*400*200	EN AW-6060		2700	0.000696	1.8792
Ø 100*10	EN AW-6060	7.92			15.84

Table below is made from figure E.800187-000 for the soffit post in tunnel for systems 35 and 35 MS.

	Material	weight (kg/m)	Density (kg/m3)	volume (m3)	Weight (kg)
HUP 200*100*5	S355NH	22.76			45.52
450*450*20	S355J2G3		7850	0.00405	31.7925
230*40*5	S355J2G3		7850	0.000046	0.3611



Tabell 1:

Maste-profil	Mastehøyde (m)														
	6,0	6,5	7,0	7,5	8,0	8,5	9,0	9,5	10,0	10,5	11,0	11,5	12,0	12,5	13,0
HEB 200	249018010	249018020	249018030	249018040	249018050	249018060	249018070	249018080	-	-	-	-	-	-	-
HEB 220	249018090	249018100	249018110	249018120	249018130	249018140	249018150	249018160	249018170	249018180	249018190	-	-	-	-
HEB 240	249018200	249018210	249018220	249018230	249018240	249018250	249018260	249018270	249018280	249018290	249018300	249018310	249018320	-	-
HEB 260	249018330	249018340	249018350	249018360	249018370	249018380	249018390	249018400	249018410	249018420	249018430	249018440	249018450	249018460	249018470
HEB 280	249018480	249018490	249018500	249018510	249018520	249018530	249018540	249018550	249018560	249018570	249018580	249018590	249018600	249018610	249018620

Pole hight

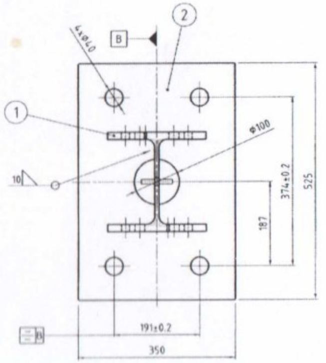
Tabell 1 viser Jernbaneverkets artikkelnummer (F.nr.), masteprofiler og mastehøyder for bjelkemastene. Tabell 2 viser de ulike profilers maksimale moment i foten av masten.

Det er laget et dataprogram for valg av bjelkemaster ved ulike belastninger. Beregning/dimensjonering av bjelkemastene kan utføres ved hjelp av programmet "Kl.fund". Programmet oppgir kreftene i forskjellige grensetilstander og forskyvning i kontakttrådhøyde, samt utnyttelsesgrad. For mer informasjon henvises det til Teknisk regelverk, kontaktledning, prosjektering, kap. 7, vedlegg, "Konstruksjon, beregning av master og fundamenter".

- Table 1 shows JBV ordernumber, mast potiles & mast heights for beam masts.
- Table 2 shows Maximum momentum at the foot of the mast
- It's Created a computer program for the selection of beam mastor at different loads.

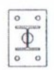
Tabell 2:

Masteprofil	Maksimalt moment i bruddgrense i mastefot (kNm)
HEB 200	120
HEB 220	140
HEB 240	160
HEB 260	180
HEB 280	190



All steel shall be hot-dip galvanized: Fe/Zn EN-ISO 1461
Coating thickness min 115 μm

Masten etableres med "sterk" akse mot spor som vist på skissen.



Spormidt

8. grounding (no. 3) the pin is 20mm in mask. for getting good grounding of the mask.

Merknader:

1. Stålkvalitet : NS-EN 10025 steel quality
2. Stålet skal inneholde 0,15-0,25 % Si steel contains
3. Toleranser : NS-ISO 2768-1-GROV
4. Toleranse for mastehøyde NS-EN ISO 13920-C
5. Sveising : NS 470 KLASSE B, NS-EN 288 og NS-EN 287 welding
6. Hjørner og kanter avrundes/slipes.
7. Alt stål skal varmforsinkes : Fe/Zn NS-EN ISO 1461, beleggtykkelse min 115 μm.
8. Dersom mastene skal pulverlakkers skal alle hull med Ø13 mm maskeres med Ø35 mm maskering før mastene lakkeres. Jordingspunkt pos. 3 stiftens ytterste i 20 mm skal maskeres. Dette for få til god jording av masten.
9. Ved pulverlakkering skal masten forbehandles på en slik måte at masten er godt egnet for pulverlakkering.
10. Merking : Produsentens firmanavn/UKE/ÅR preges inn på angitt sted.
11. Skjøting av masten tillates ikke.
12. Hull for skilt kan erstattes med at hullene markeres med gul lakk eller maling.
13. Minimum 10 % av sveisene skal kontrolleres med MPI.
14. Alle mål er oppgitt i millimeter dersom ikke annet er angitt.

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F. nr. / Anmerkning
6	3	Sylinderstift ø10x30	ISO 2338	Syrefast A4	Se merknad 8
1	2	Stålplate 45x350x525	NS-EN 10029	S355J2G3	
1	1	HEB		S355J2G3	Se tabell 1

Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
001	Krav til maskering påført. Toleranser er endret/presisert.	23.10.09	HMH		
000	Ny godkjent tegning av bjelkemast type HEB, lengde 6,0 – 13,0 m	20.09.06	HMH		

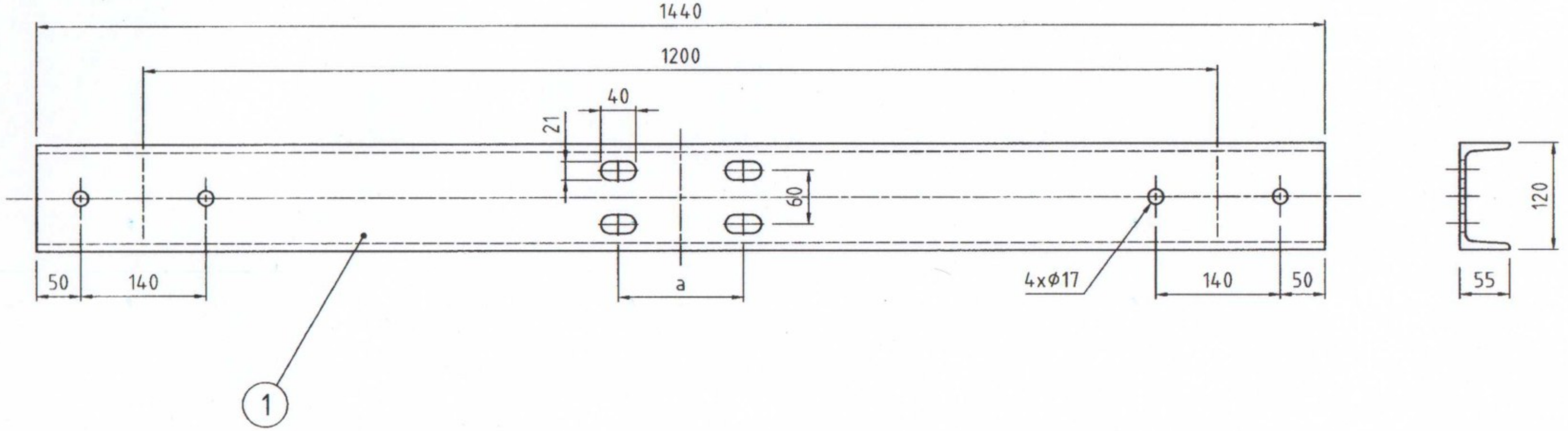
Kontaktledningsanlegg. Bjelkemast, type HEB med fotplate. For fundamenter med avstand R, fra senter fundamenttopp til senter bolt, lik 210 mm. Høyde 6,0 – 13,0 m

Målestokk: 1:5

Fritekst 1
Fritekst 2
Fritekst 3
Produsent
Prod.tegn.nr.
Erstatning for
Erstattet av

Jernbaneverket

Tegningsnummer: EK.800089-000 Rev.: 001



Stålkvalitet : NS-EN 10025
Stålet skal inneholde 0,15-0,25 % Si
Toleranser : NS-ISO 2768-1-GROV
Hjørner og kanter grades.
Alt stål skal varmforsinkes etter : NS-EN ISO 1461, beleggtykkelse min. 115 µm

Mast med vanger av kanaljern (B-mast)	[100 (B1)	[120 (B2)	[140 (B3)	[160 (B4)	[180 (B5)	[200 (B6)
a (mm)	120	140	160	180	200	220
Utf.	1	2	3	4	5	6
F.nr.	251.608.01	251.608.02	251.608.03	251.608.04	251.608.05	251.608.06

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F nr. / Anmerkning
1	1	Kanalstål UNP 120 l=1440	NS 1911	S235JRG2	

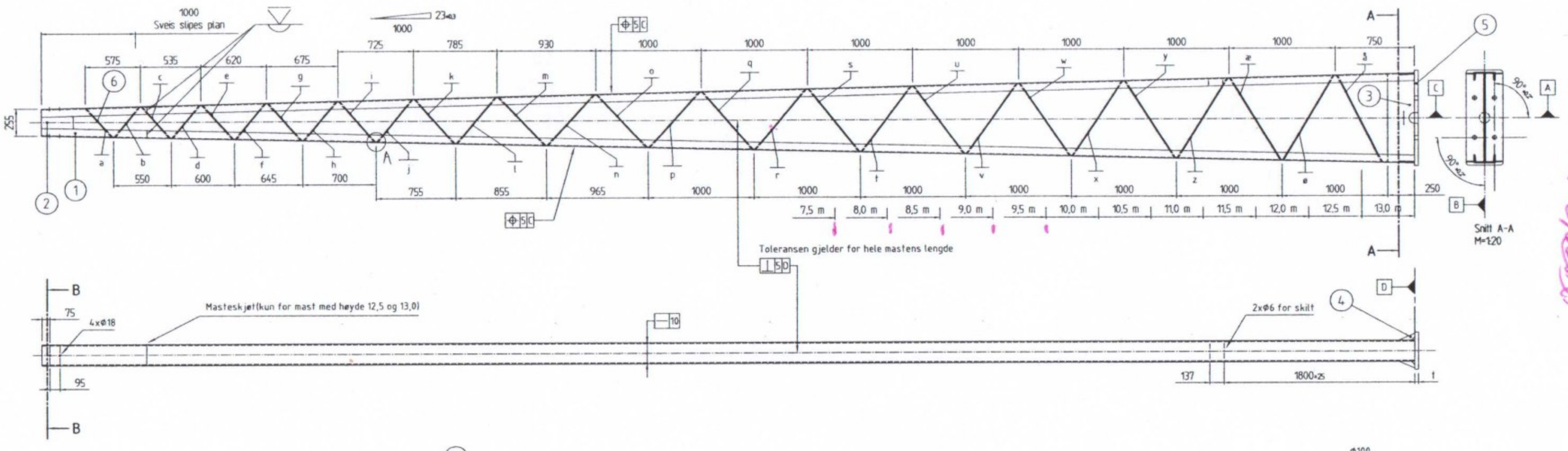
Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
002	Pos.1 i stykklisten, mål endret fra 1200 til 1440.Pos. 2 fjernet.Tegningsnr. oppdat.	07.09.04	HMH	ALR	TcT
1	Stykkliste, tittelfelt, f.nr. påført, tegning delt i bl.nr., NS-EN standard	28.03.00	ViE	ALR	TET

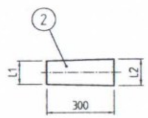
Kontaktledningsanlegg
Seksjonskonsoll på mast av kanalstål (B-mast)
System 20, 25 og 35

Målestokk: 1:5
Dato: 08.92
Tegnet av: Neub./Iske
Kontrollert av:
Godkjent av:
Arkiv bet.: 3-04.54.04
Erstatn. for:
Erstattet av:

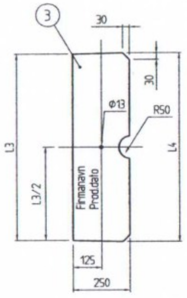
Jernbaneverket

Tegning nr: EK.707165-001 Rev: 002

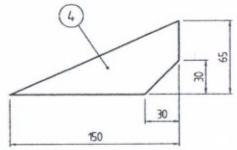




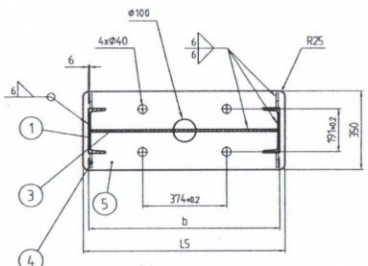
Detalj
M=1:10
Se tabell 2



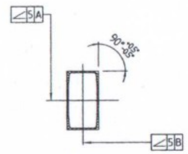
Detalj
M=1:10
Se tabell 5



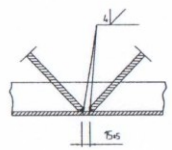
Detalj
M=1:2



Detalj
M=1:10



Snitt B-B
M=1:10



Detalj A
M=1:5

Tabell 1						
Angivelse av lengder og dimensjon for pos. 6 for den enkelte mastetyper						
Pos.	L	Mastetype B2 50x10	Mastetype B3 50x10	Mastetype B4 60x10	Mastetype B5 80x12	Mastetype B6 100x12
a	354	•	•	•	•	•
b	355	•	•	•	•	•
c	383	•	•	•	•	•
d	390	•	•	•	•	•
e	420	•	•	•	•	•
f	425	•	•	•	•	•
g	458	•	•	•	•	•
h	467	•	•	•	•	•
i	499	•	•	•	•	•
j	508	•	•	•	•	•
k	544	•	•	•	•	•
l	555	•	•	•	•	•
m	618	•	•	•	•	•
n	635	•	•	•	•	•
o	674	•	•	•	•	•
p	692	•	•	•	•	•
q	709	•	•	•	•	•
r	427	•	•	•	•	•
s	745	•	•	•	•	•
t	763	•	•	•	•	•
u	782	•	•	•	•	•
v	800	•	•	•	•	•
w	820			•	•	•
x	839			•	•	•
y	858				•	•
z	878				•	•
æ	897				•	•
ø	917				•	•
å	Tilpasses					•

Tabell 2		
Lengder for pos. 2 for den enkelte mastetype		
Mastetype	L1	L2
B2	145	159
B3	135	149
B4	125	139
B5	115	129
B6	105	119

Tabell 3	
Lengde for fotplate pos. 5	
Mastelengder (m)	Lengde (L5) (mm)
7,5-9,5	740
10,0-12,0	850
12,5-13,0	900

Tabell 4		
Dimensjoner for kanaljern pos. 1 og tykkelse på fotplater pos. 5		
Mastetype	Kanaljern pos. 1	Tykkelse på fotplate pos. 5
B2	120	30
B3	140	30
B4	160	45
B5	180	45
B6	200	45

Tabell 5								
Mastelengde (mm)	Avstand (b) mellom yttersidene av pos. 1 i bunnen av masten (mm)	Lengder for pos. 3		F.nr.				
		L3=b-26	L4=b-14	B2	B3	B4	B5	B6
7500	600	574	586	249.021.050	249.021.250	249.021.450	249.021.650	249.021.850
8000	623	597	609	249.021.060	249.021.260	249.021.460	249.021.660	249.021.860
8500	646	620	632	-	249.021.270	249.021.470	249.021.670	249.021.870
9000	669	643	655	-	249.021.280	249.021.480	249.021.680	249.021.880
9500	692	666	678	-	249.021.290	249.021.490	249.021.690	249.021.890
10000	715	689	701	-	-	249.021.500	249.021.700	249.021.900
10500	738	712	724	-	-	249.021.510	249.021.710	249.021.910
11000	761	735	747	-	-	249.021.520	249.021.720	249.021.920
11500	784	758	770	-	-	-	249.021.730	249.021.930
12000	807	781	793	-	-	-	249.021.740	249.021.940
12500	830	804	816	-	-	-	-	249.021.950
13000	853	827	839	-	-	-	-	249.021.960

Fundamentet skal monteres med "sterk" akse mot spor som vist på skissen.

Spormidte

Merknader:
Stålkvalitet : NS-EN 10025
Stålet skal inneholde 0,15-0,25 % Si
Toleranser : NS-ISO 2768-1-GROV. NS-EN ISO 13920, nøyaktighetsgrad C skal benyttes på mastens lengdemål.
Sveising : NS 470 KLASSE B, NS-EN 288 og NS-EN 287
Hjørner og kanter avrundes/slipes.
Alt stål skal varmforsinkes : Fe/Zn NS-EN ISO 1461, gjennomsnittstykkelse 115 µm
Merking : Produktet skal merkes med produsentens firmanavn og produksjonsdato
Skjøt av mast tillates kun for mastehøyde 12,5 og 13,0 meter. Skjøtepunktet er i og ved mastehøyde 12,0 meter.
Alle mål er oppgitt i millimeter dersom ikke annet er angitt

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F nr. / Anmerkning
m	6	Flatstål	NS 1902	S355J2	Se tabell 1
1	5	Stålplate	NS-EN 10051	S355J2	Se tabell 3 og 4
4	4	Flatstål 150x10x65	NS 1902	S355J2	
1	3	Stålplate 10x250xL	NS-EN 10029	S355J2	Se tabell 5
2	2	Stålplate	NS-EN 10051	S355J2	Se tabell 2
2	1	Kanalstål. L=mastelengde	NS 1911	S355J2	Se tabell 4

Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
000	Ny tegn. av B-mast tilp. ny fundamenttype med boltavstand 374 x 191	11.03.2008	HMH	Blal	[illegible]

Kontaktlednigsanlegg
Stålmast type B2-B6 for montasje
på fundament tegning EK.800091-000,
EK.800150-000 og EK.800151-000

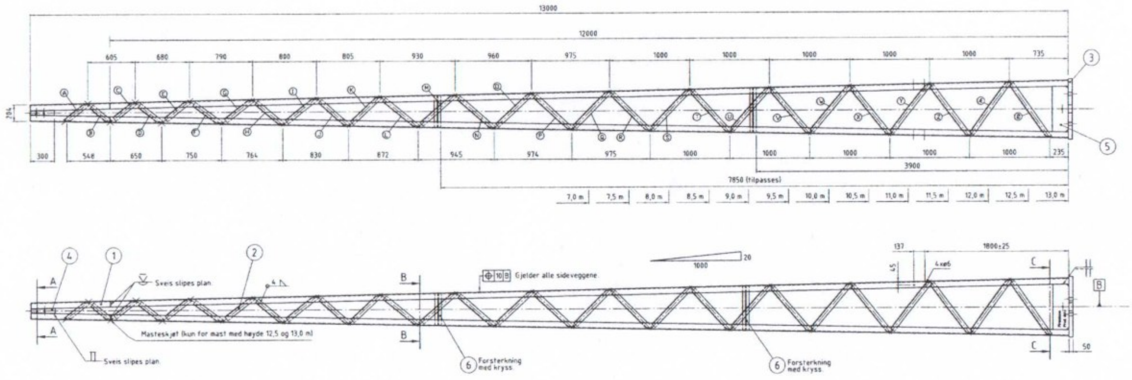
Målestokk: 1:20
Fritekst 1
Fritekst 2
Fritekst 3
Produsent
Prod.tegn.nr.
Erstatning for
Erstattet av

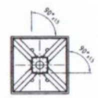
Jernbaneverket

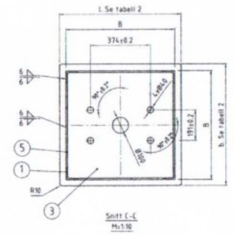
Tegningsnummer: EK.800092-000 Rev.: 000

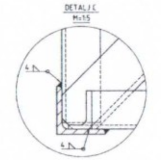
1.32° ∠ → Sin → 0.0228

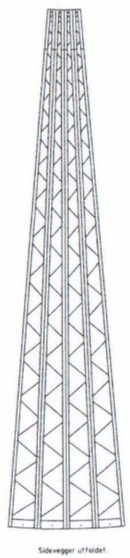
1.000 43











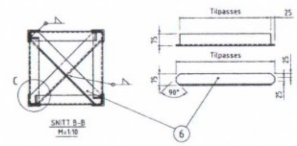
Fundamentet skal monteres med "sterk" akse mot spor som vist på skissen.

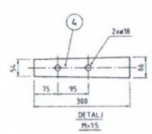
Tabell 1				
Mastelengde (mm)	Avstand (B) mellom yttersidene av pos. 1 i bunnen av masten (mm)	Lengder for pos. 5		F.nr.
		L1 = B-158	L2 = B-150	
7000	484	326	334	249.019.650
7500	504	345	354	249.019.660
8000	524	366	374	249.019.670
8500	544	386	394	249.019.680
9000	564	406	414	249.019.690
9500	584	426	434	249.019.700
10000	604	446	454	249.019.710
10500	624	466	474	249.019.720
11000	644	486	494	249.019.730
11500	664	506	514	249.019.740
12000	684	526	534	249.019.750
12500	704	546	554	249.019.760
13000	724	566	574	249.019.770

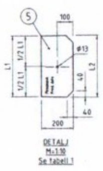
Tabell 2	
Dimensjon fotplate pos. 3	
Mastelengder (m)	txl x b (mm)
7,0-9,5	50x620x620
10,0-13,0	50x760x760

Tabell 3	
Angivelse av lengder av vinkelstål pos. 2	
Pos.	L
A	354
B	355
C	383
D	390
E	420
F	425
G	458
H	467
I	499
J	508
K	544
L	555
M	618
N	635
O	674
P	692
Q	709
R*	427
S*	745
T*	763
U*	782
V*	800
W*	820
X*	839
Y*	858
Z*	878
Æ*	897
Ø*	917

*Pos. 2 må tilpasses mål 235 mm fra fotplate.







Merknader:
Stålkvalitet : NS-EN 10025
Stålet skal inneholde 0,15-0,25 % Si
Toleranser : NS-ISO 2768-1-GROV, NS-EN ISO 13920, nøyaktighetsgrad C skal benyttes på mastens lengdemål.
Sveising : NS 470 klasse B, NS EN 287 og NS EN 288.
Hjørner og kanter avrundes/slipes. Utvendig sveis slipes fra 4,5 m og oppover.
Firmanavn og produksjonsdato/nr. preges i mastefoten.
Alt stål skal varmforsinkes : NS EN ISO 1461, beleggtykkelse 115 µm.
Skjøt av mast tillates kun for mastelengde 12,5 og 13,0 m. Skjøtepunktet er i og ved mastehøyde 12,0 m.
Alle mål er oppgitt i mm dersom ikke annet er angitt.

Antall	Pos.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F.nr. / Anmerkning
4	6	Vinkelstål 75x75x10 i=tilpasses	NS-EN 10056-2	S355J2	
4	5	Stålplate 10x200xL	NS-EN 10029	S355J2	Se tabell 1
4	4	Stålplate 8x66x300	NS-EN 10051	S355J2	
1	3	Stålplate	NS-EN 10029	S355J2	Se tabell 2
m	2	Vinkelstål 60x60x6	NS-EN 10056-2	S355J2	Se tabell 3
4	1	Vinkelstål 75x75x10 l=mastehøyde	NS-EN 10056-2	S355J2	

Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
000	Ny tegn. av H-mast tilp. ny fundamenttype med boltavstand 374 x 191	04.04.2008	HMH		

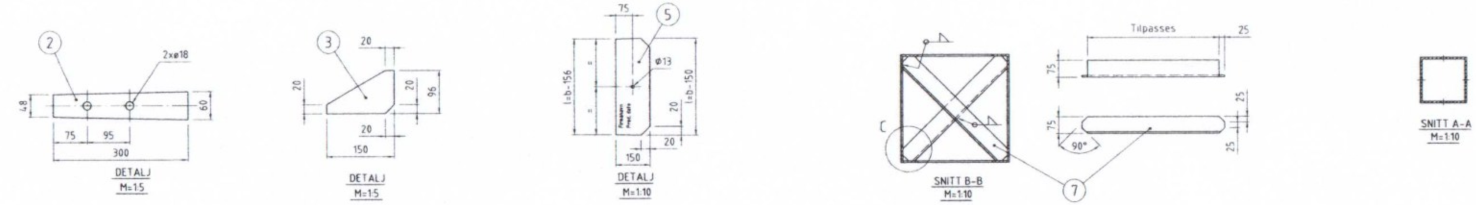
Kontaktledningsanlegg
Stålmast type H6 for montasje
på fundament tegning EK.800091-000,
EK.800150-000 og EK.800151-000

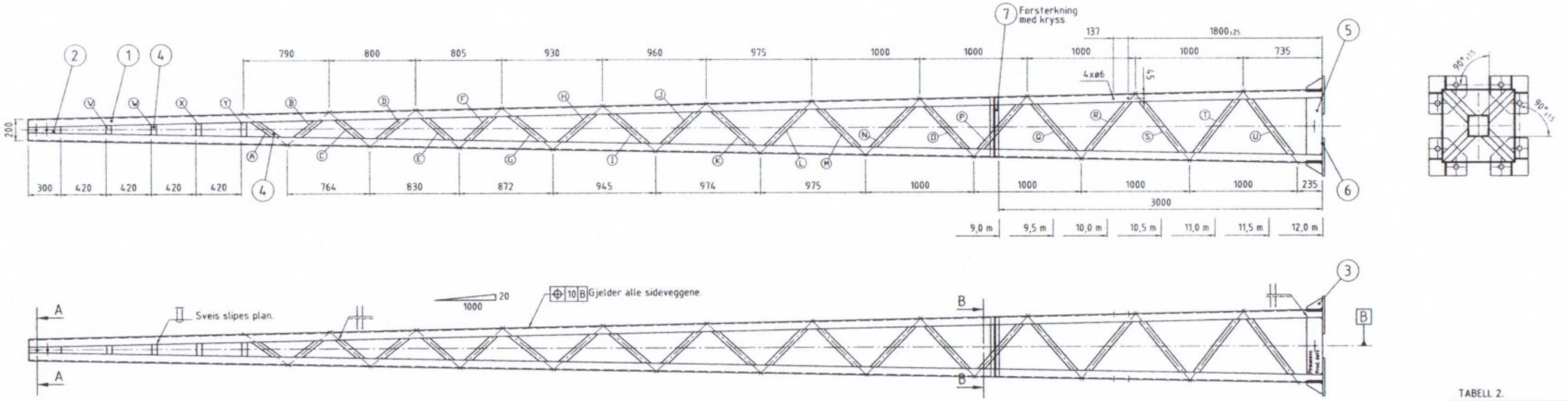
Målestokk: 1:20

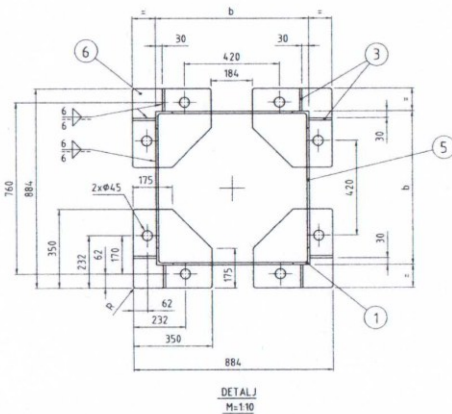
Jernbaneverket

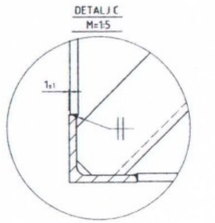
EK.800094-000 | Rev. 000

1.146 ° ∠ & sin( ) = 0.019996
1.000 .50









TABELL 1.
(Bredde x Tykkelse)
FLATSTÅL 50x10

POS	ANT	LENGDE (l)
A	4	236
B	4	251
C	4	261
D	4	300
E	4	308
F	4	322
G	4	372
H	4	385
I	4	416
J	4	430
K	4	460
L	4	466
M	4	495
N	4	514
O	4	532
P	4	550
Q	4	568
R	4	586
S	4	604
T	4	622
U	4	640
V	4	77
W	4	94
X	4	111
Y	4	128

TABELL 2.

MASTE-HØYDE mm	BREDDE (b) mm	F nr.
9000	560	249.015.54
9500	580	249.015.55
10000	600	249.015.56
10500	620	249.015.57
11000	640	249.015.58
11500	660	249.015.59
12000	680	249.015.60

Stålkvalitet : NS-EN 10025
Stålet skal inneholde 0,15-0,25 % Si
Toleranser : NS-ISO 2768-1-GROV
Sveising : NS 470 KLASSE B
Hjørner og kanter avrundes/slipes. Utvendig sveis slipes fra 4,5 m og oppover.
Firmanavn og produksjonsdato/nr. preges i mastefoten.
Alt stål skal varmforsinkes : Fe/Zn KLASSE B NS 1978

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F nr. / Anmerkning
2	7	Vinkeljern 75x75x10	NS-EN 10056-2	S235JRG2	
4	6	Stålplate 20x350x350	NS-EN 10029	S235J2G3	
4	5	Flatstål 150x10xl	NS 1902	S235JRG2	
m	4	Flatstål 50x10xl	NS 1902	S235JRG2	Se tabell 1.
8	3	Flatstål 150x10x96	NS 1902	S235JRG2	
4	2	Stålplate 6x60x300	NS-EN 10051	S235JRG2	
4	1	Vinkeljern 75x75x10 L=mastehøyde	NS-EN 10056-2	S235JRG2	

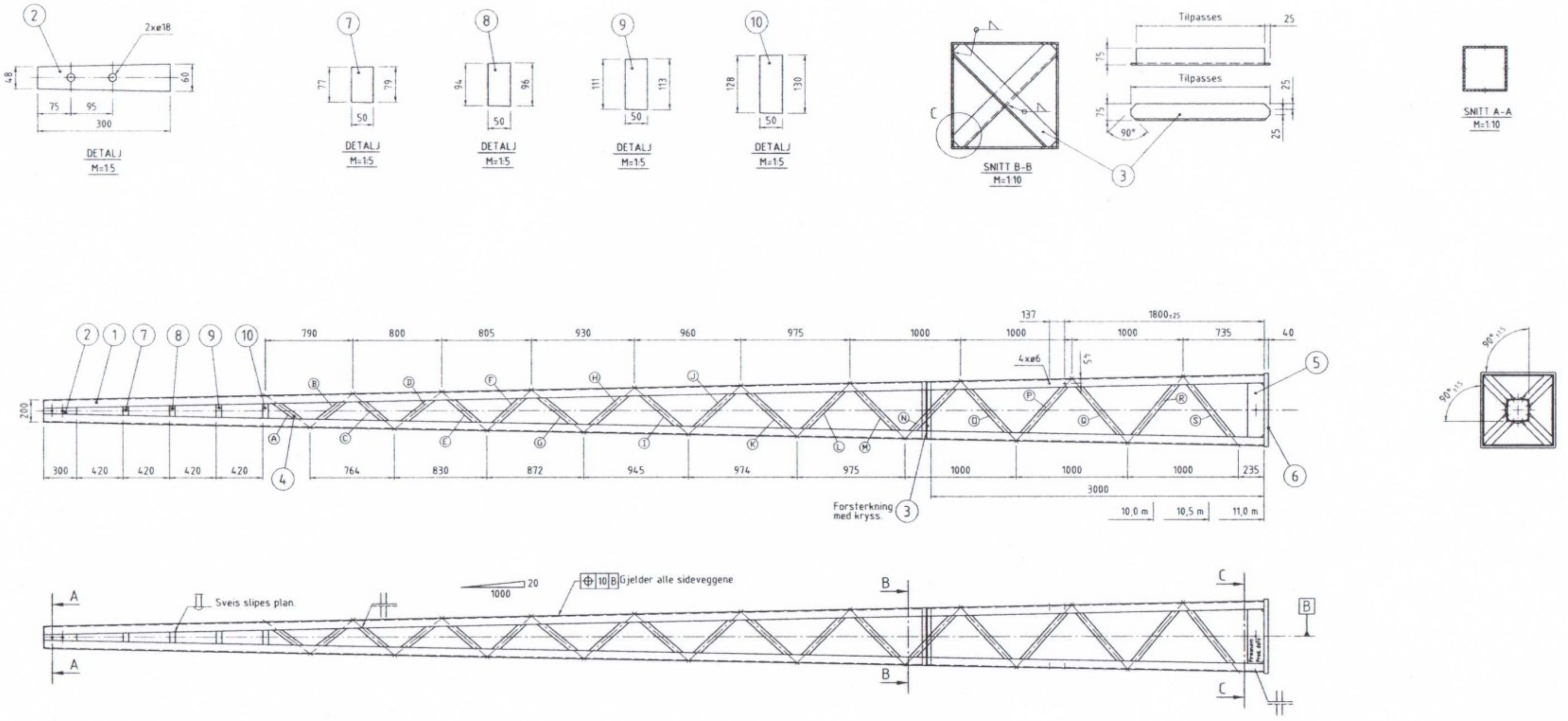
Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
002	Tegningen utfases og erstattes av mastetegning med hullmønster 374x191.	13.02.2009	HMH		
001	Dimensjoner Pos. 3, 4, 5 - Stykkliste	13.11.01	PHS		
000	Utgitt	02.02.2000	VE	ALR	TEI

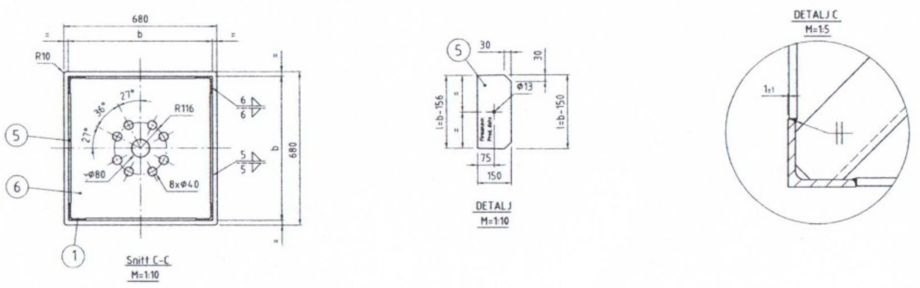
Kontaktledningsanlegg
Stålmast, type H5 for
plasstøpte fundamenter.
L=9,0m – 12,0m.

Målestokk: 1:20
Fritekst 1
Fritekst 2
Fritekst 3
Produsent
Prod.tegn.nr.
Erstatning for: E-4308
Erstattet av: EK.800093-000

Jernbaneverket

Tegningsnummer: EK.707491-002
Rev.: 002





TABELL 1.
(Bredde x Tykkelse)
FLATSTÅL 50x10

POS	ANT	LENGDE (l)
A	4	236
B	4	251
C	4	261
D	4	300
E	4	308
F	4	322
G	4	372
H	4	385
I	4	416
J	4	430
K	4	460
L	4	466
M	4	495
N	4	514
O	4	532
P	4	550
Q	4	568
R	4	586
S	4	604

TABELL 2.

MASTE-HØYDE mm	BREDDE (b) mm	F.nr.
10000	600	249.017.180
10500	620	249.017.190
11000	640	249.017.200

Stålkvalitet : NS-EN 10025
Stålet skal inneholde 0,15-0,25 % Si
Toleranser : NS-ISO 2768-1-GROV
Sveising : NS 470 klasse B
Hjørner og kanter avrundes/slipes. Utvendig sveis slipes fra 4,5 m og oppover.
Firmanavn og produksjonsdato/nr. preges i mastefoten.

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F.nr. / Anmerkning
4	10	Flatstål 50x10x130	NS 1902	S235JRG2	
4	9	Flatstål 50x10x113	NS 1902	S235JRG2	
4	8	Flatstål 50x10x96	NS 1902	S235JRG2	
4	7	Flatstål 50x10x79	NS 1902	S235JRG2	
1	6	Stålplate 40x680x680	NS-EN 10029	S355J2G3	
4	5	Flatstål 150x10xL	NS 1902	S235JRG2	
m	4	Flatstål 50x10xL	NS 1902	S235JRG2	Se tabell 1.
2	3	Vinkeljern 75x75x8	NS-EN 10056-2	S235JRG2	
4	2	Stålplate 6x60x300	NS-EN 10051	S235JRG2	
4	1	Vinkeljern 75x75x8 L=mastehøyde	NS-EN 10056-2	S235JRG2	

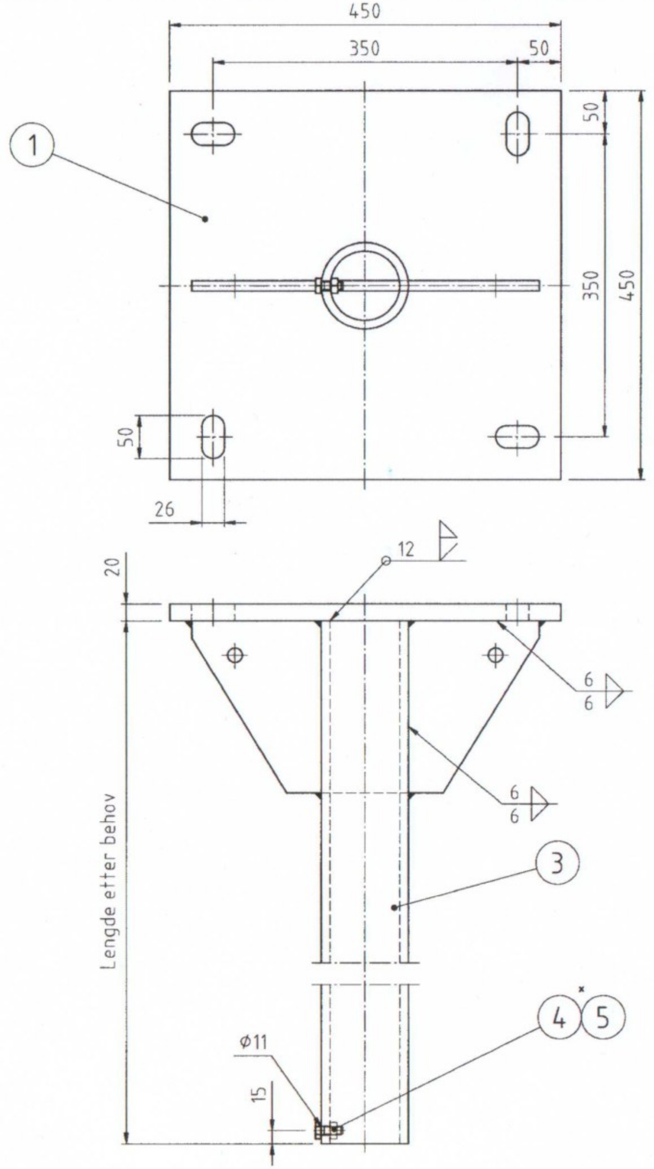
Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
002	Tegningen utfases og erstattes av mastetegning med hullmønster 374x191.	11.02.2009	HMH		
001	Tillegg Pos. 7, 8, 9, 10, Dimensjoner Pos. 5, 6, Stykkliste	01.11.01	PHS	ALR	TET
000	Utgitt	27.11.2000	VE	ALR	TET

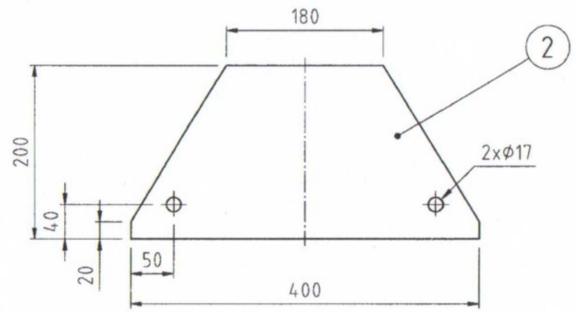
Kontaktledningsanlegg
Stålmast, type H3 for
borede fundamenter.
L=10,0m – 11,0m.

Målestokk: 1:20
Frifelt 1
Frifelt 2
Frifelt 3
Produsent
Prod.tegn.nr.
Erstatning for
Erstattet av EK.800093-000

Jernbaneverket

Tegningsnummer: EK.707493-004
Rev.: 002





Sveising: NS-ISO-10042 klasse C.
Tilsetningsmateriale: DIN 1732-S-AlSi5.

x) Settes inn med kontaktpasta.

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F nr. / Anmerkning
1	5	Mutter M10	NS-EN-ISO 3506-2	A2-80	
1	4	Sekskantskrue M10x25	NS-EN-ISO 3506-1	A2-80	
1	3	Rør 100x10 L=tilpasset	E-7291	EN AW-6082 T6	251.405.25
1	2	Plate 12x400x200		EN AW-6082 T6	
1	1	Plate 20x450x450		EN AW-6082 T6	

Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
2	Ny stykkliste, NS-EN standarder	21.03.00	ViE	FLR 10/11.00	TET
1	Slisse endret	09.08.94	HMH		TET

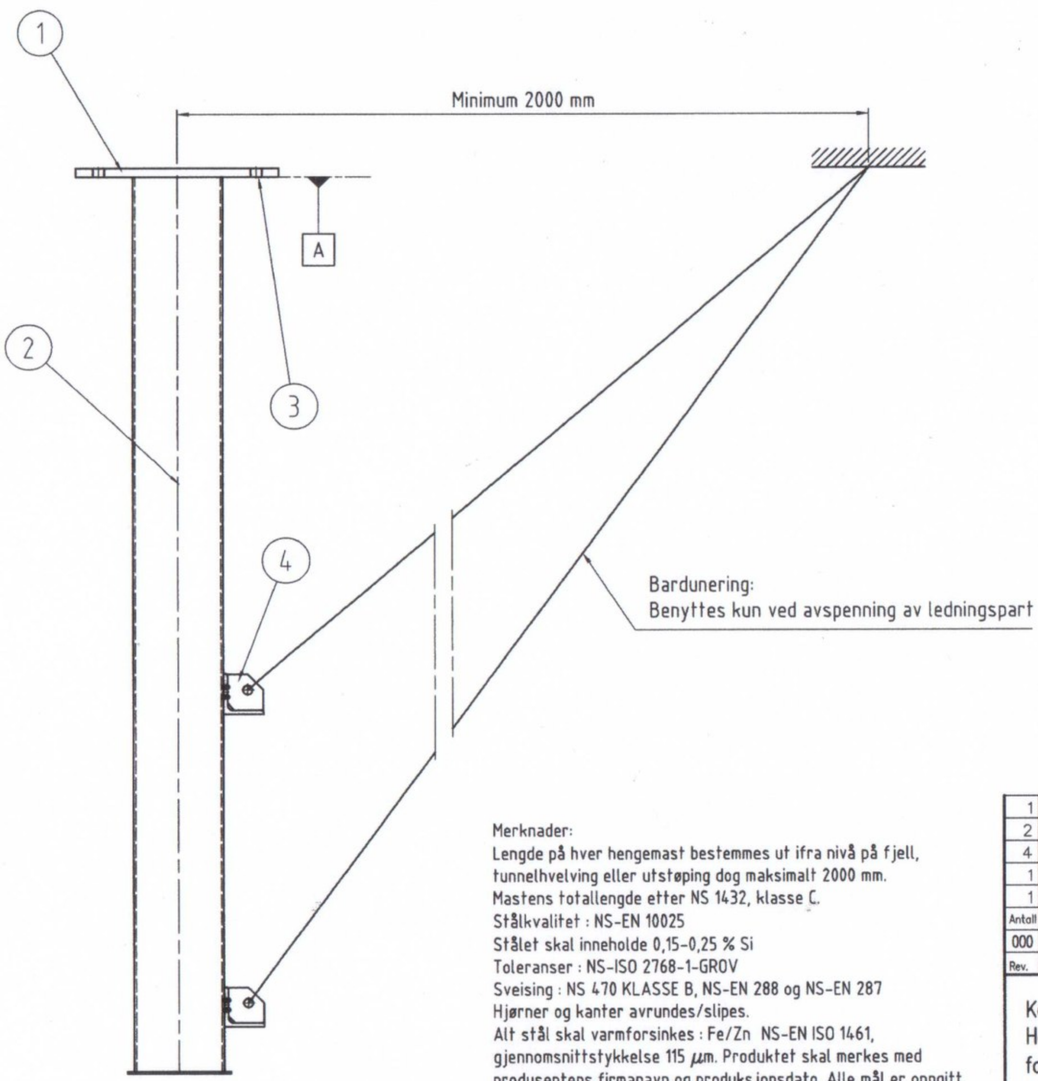
Kontaktledningsanlegg
Hengemast i tunell (L<3,6m)

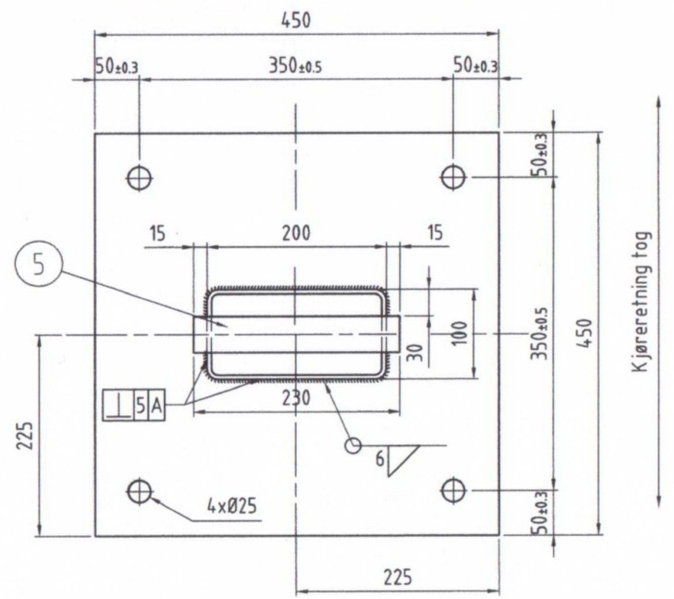
System 20 og 25

Målestokk	1:5
Dato	12.10.92
Tegnet av	HMH
Kontrollert av	
Godkjent av	TET
Arkiv bet.	3-04.61.76
Erstatn. for	
Erstattet av	
Tegning nr	E-7311
Rev	2

Jernbaneverket

E-7311.dwg





PLAN
TOPPLATE FOR HENGEMAST
1:5

Merknader:
Lengde på hver hengemast bestemmes ut ifra nivå på fjell, tunnelhvelving eller utstøping dog maksimalt 2000 mm.
Mastens totallengde etter NS 1432, klasse C.
Stålkvalitet : NS-EN 10025
Stålet skal inneholde 0,15-0,25 % Si
Toleranser : NS-ISO 2768-1-GROV
Sveising : NS 470 KLASSE B, NS-EN 288 og NS-EN 287
Hjørner og kanter avrundes/slipes.
Alt stål skal varmforsinkes : Fe/Zn NS-EN ISO 1461, gjennomsnittstykkelse 115 µm. Produktet skal merkes med produsentens firmanavn og produksjonsdato. Alle mål er oppgitt i millimeter dersom ikke annet er angitt

Anvendelsesområde: 1 utligger eller avspenning av ledningspart S35, S20 og S25 og begge i kombinasjon.

Antall	Pos. nr.	Navn, type, dimensjon	Tegn. nr. / Standard	Materiale	F nr. / Anmerkning
1	5	Flatstål 40x5	NS-EN 10025	S235J2G3	Varmforsinket
2	4	Festejern for avspenning	EK.707306-001		Varmforsinket
4	3	Gjengestang M20 8.8	DIN 975		Varmforsinket
1	2	HUP 200x100x5	NS EN 10210-2	S355NH	Varmforsinket
1	1	Stålplate 450x450x20	NS-EN 10029	S355J2G3	Varmforsinket

Rev.	Revisjonen gjelder	Dato	Tegnet av	Kontrollert av	Godkjent av
000	Ny hengemast	03.03.08	HMH	Bsøl	

Kontaktledningsanlegg
Hengemast HUP 200x100x5
for bru og tunnel.
Maksimal lengde 2000 mm.

Målestokk: 1:10
Fritekst 1
Fritekst 2
Fritekst 3
Produsent
Prod.tegn.nr.
Erstatning for
Erstattet av

Jernbaneverket

Tegningsnummer: EK.800187-000
Rev.: 000

Appendix D: Inputs of Foreground Data in SimaPro

Below tables of inputs being used in SimaPro are mentioned.

Table of information about catenary, structure support and power feed components for systems 20A, 20B and 25; and catenary components for systems 35 and 35MS.

Material	Process	Comment	Calculation guide	Amount	Unit
CuAg0.1 (100mm^2)	Contact Wire-S20 A - open section	Contact wire type is CuAg0.1 that means 99.9% of it is copper and 0.1% it is silver. Amount is for one km.	Zigzag = 300 mm Span length = 65 m Length of contact wire for 65 m = 65.003 Cross-section 100 mm^2	65,003*1000/65	m
Bz II 10	Dropper-S20 A - open section	Dropper Type is Bz II which is CuMg0.5 This means it is made of 99.5% copper and 0.5% magnesium. Amount is for one km.	In each 65 meters of span length there is approx. 5.373 meters of dropper.	5,373*1000/65	m
Bz II 50	Messenger Wire-S20 A - open section		Span length: 65 m Length of messenger wire for 65 meter = 65.065 m and in 1 km the total length is 1001 meter	65,065*1000/65	m
Bz II 25	Stitch Wire-S20 A - open section		In each 65 meters of span lenght there is approx. 10.6 meters of dropper.	10,6*1000/65	m
CuAg0.1 (100mm^2)	Contact Wire-S20 B	Contact wire type is CuAg0.1 that means 99.9% of	Zigzag = 300 mm Span length = 65 meter Length of contact wire	65,003*1000/65	m

		it is copper and 0.1% it is silver. Amount is for one km.	for 65 meter = 65.003 Cross-section 100 mm2		
Bz II 10	Dropper-S20 B	Dropper Type is Bz II which is CuMg0.5 This means it is made of 99.5% copper and 0.5% magnesium. Amount is for one km.	In each 65 meters of span length, there is approx. 9.362 meters of dropper.	9,362*1000/65	m
Bz II 50	Messenger Wire-S20 B	Messenger wire (CuMg0.5). Amount is for one km.	Span length: 65 m Length of messenger wire for 65 meter = 65.065 m and in 1 km the total length is 1001 meter	65,065*1000/65	m
CuAg0.1 (120mm2)	Contact Wire-S25	Contact wire type is CuAg0.1 that means 99.9% of it is copper and 0.1% it is silver Amount is for one km.	Zigzag = 200 mm Span length = 65 meter Length of contact wire for 65 meter = 65.001 Cross-section 120 mm2	65,001*1000/65	m
Bz II 10	Dropper-S25	Dropper Type is Bz II which is CuMg0.5 This means it is made of 99.5% copper and 0.5% magnesium. Amount is for	In each 65 meters of span lenght there is approx. 6.22 meters of dropper.	6,22*1000/65	m

		one km.			
Bz II 70	Messenger Wire-S25	Messenger wire (CuMg0.5) Amount is for one km	Span length: 65 m Length of messenger wire for 65 meter = 65.065 m and in 1 km the total length is 1001 meter	65,065*1000/65	m
Bz II 35	Stitch Wire-S25	Stitch wire (CuMg0.5). Amount is for one km	In each 65 meters of span length, there is approx. 18.12 meters of dropper.	18,12*1000/65	m
Cu ($100m^2$)	Contact Wire-S35	Contact wire type is Cu100. Amount is for one km.	Zigzag = 300 mm (it doesn't effect on the total length) Span length = 60 meter Cross-section 100 mm2	60*1000/60	m
Bz II 10	Dropper-S35	Dropper Type is Bz II which is CuMg0.5 This means it is made of 99.5% copper and 0.5% magnesium. Amount is for one km.	In each 60 meters of span length, there is 7.001 meters of dropper.	7,001*1000/60	m
Bz II 50	Messenger Wire-S35	Messenger wire (CuMg0.5) Amount is for one km	Span length: 60 m Length of messenger wire for 65 meter = 60.06 m	60,06*1000/60	m
Bz II 35	Stitch Wire-S35	Stitch wire (CuMg0.5) Amount is for one km	In each 60 meters of span length, there is approx. 11 meters of dropper.	11*1000/60	m
Cu ($100m^2$)	Contact Wire-	Contact wire type	Zigzag = 300 mm (it	60*1000/60	m

	S35 MS	is Cu100. Amount is for one km.	doesn't effect on the total length) Span length = 60 meter Cross-section 100 mm2		
Bz II 10	Dropper-S35 MS	Dropper Type is Bz II which is CuMg0.5 This means it is made of 99.5% copper and 0.5% magnesium. Amount is for one km.	In each 60 meters of span length, there is 8.547 meters of dropper.	8,547*1000/60	m
Bz II 35	Messenger Wire-S35 MS	Messenger wire (CuMg0.5). Amount is for one km.	Span length: 60 m Length of messenger wire for 65 meter = 60.06 m	60,06*1000/60	m
Insulators (feeders)	Insulator - power supply	In 1000 meters It only considers insulators on top of masts Interval: 65 meters	Number of insulators in one kilometer	1*1000/65	p
Tranformator oil	Auto Transformer	In one kilometer (the interval for an AT is 10km)		3196/10	kg
Steel (low quality)	Auto Transformer			9964/10	kg
Copper (Contact Wire) & (winding)	Auto Transformer			5640/10	kg
Transport, lorry >16t, Components	Auto Transformer		Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km	(320+996+564)*0,1	tkm

			assumed		
Electricity, Production (NORDIC)	Auto Transformer		Based on "Compressed air, optimized generation, >30kW, 8 bar gauge, at compressor/RER U", average electricity consumption for manufacturing[24]	0,137	kWh
Aluminium Feeder Cables (240mm^2)	Negative current (cable)	Area of cable is 240mm^2[25]	1000 meter on track AT in each 10 km of interval	1000	m
Aluminium Feeder Cables (240mm^2)	Positive current (cable)	Area of cable is 240mm^2	1000 meter on track AT in each 10 km of interval	1000	m
Ø55 Al tube	Cantilever S20 A - open section	In 1000 meters Interval: 65 meters	Strekkstag: 3.33m Trykkstag: 3m	(3,33+3)*1000/65	m
Ø42 Al tube	Cantilever S20 A - open section		Horisontalstag: 3.2m	3,2*1000/65	m
Ø26 Al tube	Cantilever S20 A - open section	In 1000 meters Interval: 65 meters	Direksjonsstag: 1m	1*1000/65	m
Ø6 Steel wire	Cantilever S20 A - open section		Steel wire: 1.3	1,3*1000/65	m
Insulators (cantilever)	Cantilever S20 A - open section		Number of insulators in one kilometer	1*1000/65	p
Ø55 Al tube	Cantilever S20	In 1000 meters	Strekkstag: 3.33m	(3,33+1,31)*1000/65	m

[24] This assumption is not correct, there was no other relevant numbers that I could assume for manufacturing an atuotransformer
[25] The area of both negative and positive current cables are coming from COWI's Follobanen project (++++++)

	A – tunnel	Height reduction from 1.6 to 0.7m. the reduction only applied to "Trykkstag" & "Steel wire"	Trykkstag: 1.31m		
Ø42 Al tube	Cantilever S20 A – tunnel		Horisontalstag: 3.2m	3,2*1000/65	m
Ø26 Al tube	Cantilever S20 A – tunnel		Direksjonsstag: 1m	1*1000/65	m
Ø6 Steel wire	Cantilever S20 A – tunnel		Steel wire: 0.57m	0,57*1000/65	m
Insulators (cantilever)	Cantilever S20 A - tunnel		Number of insulators in one kilometer	1*1000/65	p
Ø70 Al tube	Cantilever S20 B - open section	In 1000 meters	Trykkstag: 2.35m	2,35*1000/65	m
Ø55 Al tube	Cantilever S20 B - open section	In 1000 meters	Strekkstag: 2.56m	2,56*1000/65	m
Ø26 Al tube	Cantilever S20 B - open section	In 1000 meters	Direksjonsstag: 1m	1*1000/65	m
Ø6 Steel wire	Cantilever S20 B - open section	In 1000 meters	Steel wire: 0.98m	0,98*1000/65	m
Ø42 Al tube	Cantilever S20 B - open section	In 1000 meters	Horisontalstag: 2.6m	2,6*1000/65	m
Insulators (cantilever)	Cantilever S20 B - open section	In 1000 meters	Number of insulators in one kilometer	1*1000/65	p
Ø70 Al tube	Cantilever S20 B – tunnel	System 20 B Height reduction from 1.6 to 0.7m. the reduction only applied on "Trykkstag" and "Steel wire"	Trykkstag: 1.03m	1,03*1000/65	m
Ø55 Al tube	Cantilever S20 B – tunnel		Strekkstag: 2.56m	2,56*1000/65	m
Ø26 Al tube	Cantilever S20 B – tunnel		Direksjonsstag: 1m	1*1000/65	m
Ø6 Steel wire	Cantilever S20		Steel wire: 0.43m	0,43*1000/65	m

	B – tunnel				
Ø42 Al tube	Cantilever S20 B – tunnel		Horisontalstag: 2.6m	2,6*1000/65	m
Insulators (cantilever)	Cantilever S20 B - tunnel		Number of insulators in one kilometer	1*1000/65	p
Ø70 Al tube	Cantilever S25 - open section	In 1000 meters Height: 1.8m	Trykkstag: 2.6m (Assumption)	2,6*1000/65	m
Ø55 Al tube	Cantilever S25 - open section		Strekkstag: 2.7m (Assumption)	2,7*1000/65	m
Ø42 Al tube	Cantilever S25 - open section		Direksjonsstag: 1.595m (Assumption) Horisontalstag: 0.72m (Assumption)	(1,595+0,72)*1000/65	m
Ø6 Steel wire	Cantilever S25 - open section		Steel wire: 0.87 (Assumption)	0,87*1000/65	m
Insulators (cantilever)	Cantilever S25 - open section		Number of insulators in one kilometer	1*1000/65	p
Ø70 Al tube	Cantilever S25 – tunnel	In 1000 meters Height reduction from 1.8 to 1.1m. the reduction only applied on "Trykkstag" & "Steel wire"	Trykkstag: 1.59 (Assumption)	1,59*1000/65	m
Ø55 Al tube	Cantilever S25 – tunnel		Strekkstag: 2.7m (Assumption)	2,7*1000/65	m
Ø42 Al tube	Cantilever S25 – tunnel		Direksjonsstag: 1.595m (Assumption) Horisontalstag: 0.72m (Assumption)	(1,595+0,72)*1000/65	m
Ø6 Steel wire	Cantilever S25 – tunnel		Steel wire: 0.53m (Assumption)	0,53*1000/65	m
Insulators (cantilever)	Cantilever S25 – tunnel		Number of insulators in one kilometer	1*1000/65	p
Steel (Cantilever/tube)	Cantilever S35 & S35 MS - open section	In 1000 meters	Due to zigzag effect the length of horizontal bar changes between 2089 mm and 2989 mm Strekkstag: 2310 mm	(((8,1471+11,6571)/2)+9,01+9,36)*1000/60	kg

			Trykkstag: 2400 mm Density: 3.9 kg/m		
Aluminium (Cantilever/Tube)	Cantilever S35 & S35 MS - open section	In 1000 meters	Metal: EN AW-6060 Density: 2.7 g/m3	0,235*1000/60	kg
Insulators (cantilever)	Cantilever S35 & S35 MS - open section	In 1000 meters	Number of insulators in one kilometer	1*1000/60	p
Steel (Cantilever/tube)	Cantilever S35 & S35 MS – tunnel	In 1000 meters	Due to zigzag effect the length of horizontal bar changes between 2089 mm and 2989 mm Strekkstag: 2310 mm Trykkstag: 1080 mm Density: 3.9 kg/m	(((8,1471+11,6571)/2)+9,01+4,212)*1000/60	kg
Aluminium (Cantilever/Tube)	Cantilever S35 & S35 MS – tunnel	In 1000 meters	Metal: EN AW-6060 Density: 2.7 g/m3	0,235*1000/60	kg
Insulators (cantilever)	Cantilever S35 & S35 MS - tunnel	In 1000 meters	Number of insulators in one kilometer	1*1000/60	p
Fundament (Mast)	Fundament for Masts - S20 & S25 - open section	In 1000 meters	Number of fundaments in one kilometer	1000/65	p
Steel (Mast, seksjonsskonsoll)	Mast-S20 A, S20 B & S25 - open section	The function is number of mast and seksjonsskonsoll in 1000 meters	Weight of model HEB200 (kg/m) = 61.3 Hight: 9.5 m Span length: 65m	9,5*61,3*1000/65	kg
Steel (Mast, seksjonsskonsoll)	Mast-S20 A, S20 B & S25 - open section		Weight of model Kanalstål =10.6 Length: 1.44 m	10,6*1,44*1000/65	kg
Welding, arc, steel/RER U	Mast-S20 A, S20 B & S25 -		Welding with length of 0.5m	0.5*1000/65	m

	open section				
Aluminium (Cantilever/Tube)	Mast-S20 A, S20 B & S25 - tunnel	System 20 and 25 height of 2 meters is assumed	Rør 100*10 In this case the process of "Aluminium (Cantilever/Tube)" is assumed due to similarity in process of manufacturing. Weight: 7.92 kg/m	15,84*1000/45	kg
Aluminium (plate)	Mast-S20 A, S20 B & S25 - tunnel		Plate weight 20*450*450: 0.00405kg Plate weight 12*400*200:0.000696kg Density:2700 kg/m3	(0,00405+0,000696)*1000/45	kg
Welding, arc, aluminium/RER U	Mast-S20 A, S20 B & S25 - tunnel		Welding with length of 0.3m	0.3*1000/45	m

Table of information for signaling components for one kilometer of a tunnel or an open section.

Material	Process	Comment	Calculation guide	Amount	Unit
Lysleder *Light guide*	Signaling - open section	Numbers are from Follobanen report. Numbers are divided by 4.4 to get the results for one kilometer of an open section.		(6.6/4.4)	km
Kobber (signal) *Copper (signaling)*	Signaling - open section			(6.6/4.4)	km
Kabelkasse *Cable box*	Signaling - open section			(4.4/4.4)	km
Mast *Mast*	Signaling - open section			(8/4.4)	p
Signal *Signal*	Signaling - open section			(24/4.4)	p
Signallys	Signaling -			(400/4.4)	p

Signal light	open section				
Fundament *Fundament*	Signaling - open section			(8/4.4)	p
Drivmaskin *Driving machine*	Signaling - open section	Numbers are from Follobanen report. Numbers are divided by 4.4 to get the results for one kilometer of an open section.		(24/4.4)	p
ATC-utstyr *ATC equipment*	Signaling - open section			(20/4.4)	p
Akselteller *Axle Counter*	Signaling - open section			(16/4.4)	p
Beskyttelseskasse *Protection box*	Signaling - open section			(1/4.4)	p
Lysleder *Light guide*	Signaling – tunnel	Numbers are from Follobanen report. Numbers are divided by 40.5 to get the results for one kilometer of a tunnel.		50/40.5	km
Kobber (signal) *Copper (signaling)*	Signaling – tunnel			50/40.5	km
Mast (tunnel) *Mast*	Signaling – tunnel			10/40.5	p
Signal (tunnel) *Signal*	Signaling – tunnel			10/40.5	p
Signallys *Signal light*	Signaling – tunnel			100/40.5	p
ATC-utstyr *ATC equipment*	Signaling – tunnel			25/40.5	p
Akselteller *Axle Counter*	Signaling – tunnel			6/40.5	p
Beskyttelseskasse *Protection box*	Signaling - tunnel			10/40.5	p

Table of information for telecommunication components for one kilometer of a tunnel or an open section.

Material	Process	Comment	Calculation guide	Amount	Unit

Lysleder *Light guide*	Telecommunication - open section	Numbers are from Follobanen report. Numbers are divided by 4 to get the results for one kilometer of an open section.		28000/4	m
Basisstasjon *Protection box*	Telecommunication - open section			4/4	p
Lysleder *Light guide*	Telecommunication - tunnel	Numbers are from Follobanen report. Numbers are divided by 40.5 to get the results for one kilometer of a tunnel.		50/41	km
Lysleder *Light guide*	Telecommunication – tunnel			46/41	km
Lysleder *Light guide*	Telecommunication – tunnel			46/41	km
Kobber (signal) *Copper (signaling)*	Telecommunication – tunnel			50/41	km
Kobber (tele) *Copper (tele)*	Telecommunication – tunnel			40/41	km
Repeater *Repeater*	Telecommunication – tunnel			152/41	p
El-tavle *El switchboard*	Telecommunication - tunnel			40/41	p

Appendix E: Inputs of Background to Foreground Data in SimaPro

Tables of background to foreground data that indicates materials and energy are used in this project.

Material	Process	Comment	Calculation guide	Amount	Unit
Aluminium (Cable)	Aluminium Feeder Cables (240mm2)	Possitive or negative feeder diameter of conductor: 18.8 mm thickness of sheath (PVC): 2.5 mm thickness of insulation (PEX): 8 mm Weight of cable: 2820 (kg/ km)	Density of aluminium 2700 (kg/m3) Area: 240 mm2 (COWI Follobanen)	2700*0,00024	kg
PVC			Density of PVC 1.39 (kg/m3) Area of PVC: =0.0006 m2	0,0006*1,39	kg
PEX			Area: 0.0012 m2 The same density as PVC assumed	0,0012*1,39	kg
Transport, lorry >16t, fleet average/RER U			Based on "Aluminium alloy, AlMg3, at plant/RER U" transportation of 100 km assumed	2,82*0,1	tkm
Copper (Contact Wire) & (winding)	Bz II 10	Droppers (CuMg0.5)	Density 0.090 (kg/m) (Puschmann) 99.5% copper	0,09*0,995	kg
Magnesium			Density 0.090 (kg/m) (Puschmann) 0.5% Magnesium	0,09*0,005	kg
Electricity, Production (European Mix)			Assumption based on average "Aluminium alloy, AlMg3, at plant/RER U" & "Magnesium-alloy, AZ91, at plant/RER U"	0,09*1,5	kWh
Transport, lorry >16t, fleet average/RER U			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	0,09*0,1	tkm

Copper (Contact Wire) & (winding)	Bz II 25	Droppers (CuMg0.5)	Density 0.218 (kg/m) (Puschmann) 99.5% copper	0,218*0,995	kg
Magnesium			Density 0.218 (kg/m) (Puschmann) 0.5% magnesium	0,218*0,005	kg
Electricity, Production (European Mix)			Assumption based on average "Aluminium alloy, AlMg3, at plant/RER U" & "Magnesium-alloy, AZ91, at plant/RER U"	1,5*0,218	kWh
Transport, lorry >16t, fleet average/RER U			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	0,218*0,1	tkm
Copper (Contact Wire) & (winding)	Bz II 35	Droppers (CuMg0.5)	Density 0.310 (kg/m) (Puschmann) 99.5% copper	0,995*0,31	kg
Magnesium			Density 0.310 (kg/m) (Puschmann) 0.5% magnesium	0,005*0,31	kg
Electricity, Production (European Mix)			Assumption based on average "Aluminium alloy, AlMg3, at plant/RER U" & "Magnesium-alloy, AZ91, at plant/RER U"	1,5*0,31	kWh
Transport, lorry >16t, fleet average/RER U			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	0,31*0,1	tkm
Copper (Contact Wire) & (winding)	Bz II 50	Droppers (CuMg0.5)	Density 0.446 (kg/m) (Puschmann) 99.5% copper	0,446*0,995	kg
Magnesium			Density 0.446 (kg/m) (Puschmann) 0.5% Magnesium	0,446*0,005	kg
Electricity, Production (European Mix)			Assumption based on average "Aluminium alloy, AlMg3, at plant/RER U" & "Magnesium-alloy, AZ91, at plant/RER U"	1,5*0,446	kWh
Transport, lorry >16t, fleet average/RER U			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	0,446*0,1	tkm
Copper (Contact	Bz II 70	Droppers	Density 0.596 (kg/m) (Puschmann)	0,596*0,995	kg

Wire) & (winding)		(CuMg0.5)	99.5% copper		
Magnesium			Density 0.596 (kg/m) (Puschmann) 0.5% copper	0,596*0,005	kg
Electricity, Production (European Mix)			Assumption based on average "Aluminium alloy, AlMg3, at plant/RER U" & "Magnesium-alloy, AZ91, at plant/RER U"	1,5*0,596	kWh
Transport, lorry >16t, fleet average/RER U			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	0,596*0,1	tkm
Copper (Contact Wire) & (winding)	Cu (100m2)	Contact wire for system 35 and 35MS	Density 0.89 (kg/m) (Puschmann)	0,89	kg
Transport, lorry >16t, fleet average/RER U			Based on "Aluminium alloy, AlMg3, at plant/RER U" transportation of 100 km assumed	0,89*0,1	tkm
Copper (Contact Wire) & (winding)	CuAg0.1 (100mm2)	Contact wire System 20	Density 0.89 (kg/m) (Puschmann) 99.9% Copper	0,999*0,89	kg
Silver			Density 0.89 (kg/m) (Puschmann) 0.1% Silver	0,001*0,89	kg
Electricity, Production (European Mix)			Assumption based on average "Aluminium alloy, AlMg3, at plant/RER U" & "Magnesium-alloy, AZ91, at plant/RER U"	1,5*0,89	kWh
Transport, lorry >16t, fleet average/RER U			Based on "Aluminium alloy, AlMg3, at plant/RER U" transportation of 100 km assumed	0,89*0,1	tkm
Copper (Contact Wire) & (winding)	CuAg0.1 (120mm2)	Contact wire System 25	Density 1.07 (kg/m) (Puschmann) 99.9% Copper	0,999*1,07	kg
Silver			Density 1.07 (kg/m) (Puschmann) 0.1% Silver	0,001*1,07	kg
Electricity, Production			Assumption based on average "Aluminium alloy, AlMg3, at plant/RER U" & "Magnesium-alloy, AZ91,	1,5*1,07	kWh

(European Mix)			at plant/RER U"		
Transport, lorry >16t, fleet average/RER U			Based on "Aluminium alloy, AlMg3, at plant/RER U" transportation of 100 km assumed	1,07*0,1	tkm
Glass (Insulator)	Insulators (cantilever)	Two insulators for one cantilever weight of each insulator is 3.9 kg lead : 11340 kg/m3 Glass: 2400-2800 kg/m3	Assumed 50% of weight is based on glass	0,5*3,9*2	kg
lead-antimony (insulator)			Assumed 50% of weight is based on lead-antimony	0,5*3,9*2	kg
Transport, lorry >16t, Components			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	3,9*0,1	tkm
Electricity, Production (NORDIC)			Assumption based on average "Aluminium alloy, AlMg3, at plant/RER U" & "Magnesium-alloy, AZ91, at plant/RER U"	1,5*3,9	kWh
Porcelain (insulator)	Insulators (feeders)	The same insulator as it is considered for cantilever is taken into account, but instead of glass, porcelain is used. Two insulators for one cantilever weight of each	Assumed 50% of weight is based on Porcelain	0,5*3,9*2	kg
lead-antimony (insulator)			Assumed 50% of weight is based on lead-antimony	0,5*3,9*2	kg
Transport, lorry >16t, Components			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	3,9*0,1	tkm
Electricity, Production (NORDIC)			Assumption based on average "Aluminium alloy, AlMg3, at plant/RER U" & "Magnesium-alloy, AZ91, at plant/RER U"	1,5*3,9	kWh

		insulator is 3.9 kg lead : 11340 kg/m3			
Lubricating oil, at plant/RER U	Tranformator oil	use in a transformer	Relatively large uncertainty (from Follobanen info.)	1	kg
Aluminium (Cantilever/Tube)	Ø26 Al tube	Used in cantilever S20 and S25	Density: 0.668 (kg/m)	0,668	kg
Transport, rail, components			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	0,668*0,1	tkm
Aluminium (Cantilever/Tube)	Ø42 Al tube	Used in cantilever S20 and S25	Density: 1.289 (kg/m)	1,289	kg
Transport, lorry >16t, Components			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	1,289*0,1	tkm
Aluminium (Cantilever/Tube)	Ø55 Al tube	Used in cantilevers S20 and S25	Density: 2.494 (kg/m)	2,494	kg
Transport, lorry >16t, Components			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	2,494*0,1	tkm
Steel (Cantilever/Wire)	Ø6 Steel wire	Used in cantilever S20 and S25	Density: 0.134 (kg/m)	0,134	kg
Transport, lorry >16t, Components			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	0,134*0,1	tkm
Aluminium (Cantilever/Tube)	Ø70 Al tube	Used in cantilever S20 and S25	Density: 3.257 (kg/m)	3,257	kg
Transport, lorry >16t, Components			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	3,257*0,1	tkm

Some dummy processes used in this process that are considering manufacturing of materials like manufacturing of tubes, cables etc. in SimaPro that are shown in table below.

Material	Process	Comment	Calculation guide	Amount	Unit
Aluminium, production mix, at plant/RER U	Aluminium (Cable)	Modeled from Follobanen project		1	kg
Sheet rolling, aluminium/RER U	Aluminium (Cable)	Modeled from Follobanen project		1	kg
Section bar extrusion, aluminium/RER U	Aluminium (Cantilever/Tube)	Cantilever for system 20 and 25	Modeling tubes for cantilever	1	kg
Aluminium, production mix, at plant/RER U	Aluminium (Cantilever/Tube)			1	kg
Aluminium, production mix, at plant/RER U	Aluminium (plate)	For masts in tunnels		1	kg
Sheet rolling, aluminium/RER U				1	kg
Wire drawing, copper/RER U	Copper (Contact Wire) & (winding)	It is a generic model of contact wires		1	kg
Copper, at regional storage/RER U				1	kg
Flat glass, uncoated, at plant/RER U	Glass (Insulator)			1	kg

Tempering, flat glass/RER U			Increase the strength of glass (Puschmann)	1	kg
Electricity, production mix RER/RER U	Electricity, Production (European Mix)	Used in production of components such as cables, insulators etc.		1	kWh
Electricity, production mix NORDEL/NORDEL U	Electricity, Production (NORDIC)	Nodic country mix	Manufacturing of components	1	kWh
Concrete, normal, at plant/CH U	Fundament (Mast)	Fundaments for masts	Cylindrical fundament Ø 555 mm - up to 4,5 m depth. In this project a depth of 4 meters is considered (Puschmann) Area: ((0.555/2)^2)*3.14 = 0.242 m2	0,242*4	m3
Antimony, at refinery/CN U	lead-antimony (insulator)	Use in insulator	Puschmann	0,02	kg
Lead, at regional storage/RER U			Puschmann book [26]	0,98	kg
Manganese, at regional storage/RER U	Magnesium	Used in catenary	Use in Bz II cables	1	kg
Polyethylene, HDPE, granulate, at plant/RER U	PEX	Using in feeder cables	COWI, Follobanen	1	kg
Sanitary ceramics, at regional storage/CH U	Porcelain (insulator)		Sanitary ceramics were the closest assumption for insulator with porcelain structure!	1	kg
Polyvinylchloride	PVC	Feeder		1	kg

[26] "http://www.battcon.com/PapersFinal2009/ClarkPaper2009FINAL_12.pdf"

, at regional storage/RER U		cables insulation			
Silver, at regional storage/RER U	Silver	Used in catenary	A substance for Copper alloy (CuAg0.1)	1	kg
Steel, electric, chromium steel 18/8, at plant/RER U	Steel (Cantilever/tube)	Cantilever for system 35 and 35 MS		1	kg
Hot rolling, steel/RER U			Modeling tubes for cantilever	1	Kg
Drawing of pipes, steel/RER U			Modeling tubes for cantilever	1	Kg
Zinc coating, pieces/RER U			Diameter 0.25 inch (=6.35 mm) Surface of tube:	0,00013	m2
Wire drawing, steel/RER U	Steel (Cantilever/Wire)			1	kg
Steel, converter, chromium steel 18/8, at plant/RER U				1	kg
Reinforcing steel, at plant/RER U	Steel (low quality)	To use in transformers (from Follobanen)		1	kg
Hot rolling, steel/RER U				1	kg
Steel, electric, chromium steel 18/8, at plant/RER U	Steel (Mast HEB200, seksjonsskonsoll)	Mast Model: HEB200 seksjonsskonsoll: UPN 100		1	kg
Hot rolling, steel/RER U				1	kg
Zinc coating, pieces/RER U			Coefficient of surface to weight Weight of model HEB200 (kg/m) = 61.3 Surface area (m2/m) = 1.15	1,15/61,3	m2

Transport, lorry >16t, Components			Based on "Aluminium alloy, AlMg3, at plant/RER U", transportation of 100 km assumed	1*0,1	tkm
Steel, electric, chromium steel 18/8, at plant/RER U	Steel (plate)	For masts in tunnels		1	kg
Sheet rolling, steel/RER U				1	kg
Transport, lorry >16t, fleet average/RER U	Transport, lorry >16t, Components	lorry >16t	Transportation of goods	1	tkm
Transport, freight, rail/RER U	Transport, rail, components	freight transportation	Based on COWI report	1	tkm

Appendix F:

Tables below provide quantitative comparison results for the LCIA.

Below a table of quantitative impact assessments that juxtapose the tree DSs with each other in open section.

		S20 A - Open Section		S20 B - Open Section		S25 - Open Section	
Impact category	Unit	Constructution	Maintenance	Constructution	Maintenance	Constructution	Maintenance
Climate change	kg CO2 eq	8.27E+04	5.67E+04	8.22E+04	5.65E+04	8.35E+04	5.78E+04
Ozone depletion	kg CFC-11 eq	5.71E-03	4.52E-03	5.68E-03	4.51E-03	5.77E-03	4.60E-03
Terrestrial acidification	kg SO2 eq	7.55E+02	8.17E+02	7.50E+02	8.13E+02	8.04E+02	8.67E+02
Freshwater eutrophication	kg P eq	2.13E+02	2.87E+02	2.11E+02	2.86E+02	2.34E+02	3.09E+02

Below there are relative results from the table above that are made in respect of S25 in open section.

		S25 - S20 A - Open Section		S25 - S20 B - Open Section	
Impact category	Unit	Constructution	Maintenance	Constructution	Maintenance
Climate change	kg CO2 eq	1.02%	1.96%	1.58%	2.25%
Ozone depletion	kg CFC-11 eq	1.08%	1.76%	1.62%	2.02%
Terrestrial acidification	kg SO2 eq	6.11%	5.80%	6.79%	6.29%
Freshwater eutrophication	kg P eq	9.06%	6.91%	9.84%	7.46%

Below a table of quantitative impact assessments that juxtapose the tree DSs with each other in tunnel section.

		S20 A - Tunnel		S20 B - Tunnel		S25 - Tunnel	
Impact category	Unit	Constructution	Maintenance	Constructution	Maintenance	Constructution	Maintenance
Climate change	kg CO2 eq	4.11E+04	4.27E+04	4.05E+04	4.26E+04	4.20E+04	4.38E+04
Ozone depletion	kg CFC-11 eq	3.28E-03	3.79E-03	3.24E-03	3.78E-03	3.34E-03	3.86E-03
Terrestrial acidification	kg SO2 eq	7.15E+02	1.23E+03	7.11E+02	1.23E+03	7.63E+02	1.28E+03
Freshwater eutrophication	kg P eq	2.67E+02	4.97E+02	2.66E+02	4.96E+02	2.87E+02	5.18E+02

Below there are relative results from the table above that are made in respect of S25 in tunnel section.

		S25 - S20 A - Tunnel Section		S25 - S20 B - Tunnel Section	
Impact category	Unit	Constructution	Maintenance	Constructution	Maintenance
Climate change	kg CO2 eq	2.03%	2.52%	3.46%	2.87%
Ozone depletion	kg CFC-11 eq	1.86%	2.04%	3.06%	2.31%
Terrestrial acidification	kg SO2 eq	6.25%	3.81%	6.77%	3.98%
Freshwater eutrophication	kg P eq	7.13%	3.98%	7.48%	4.13%

In the next page, there is a quantitative table is provided to see how big of a difference is between the three DS systems in open section and tunnel section.

		S20 A - Open Section								S20 A - Tunnel									
		Constructution				Maintenance				Constructution					Maintenance				
Impact category	Unit	Total	OCS S20 A	Signaling	Tele	Total	OCS S20 A	Signaling	Tele	Total	OCS S20 A	Signaling	Tele	Lighting	Total	OCS S20 A	Signaling	Tele	Lighting
Climate change	kg CO2 eq	8.27E+04	6.63E+04	1.22E+04	4.24E+03	5.67E+04	1.97E+04	2.43E+04	1.27E+04	4.11E+04	2.70E+04	2.52E+03	7.16E+03	4.45E+03	4.27E+04	1.18E+04	5.03E+03	2.15E+04	4.45E+03
Ozone depletion	kg CFC-11 eq	5.71E-03	4.32E-03	1.11E-03	2.85E-04	4.52E-03	1.45E-03	2.22E-03	8.56E-04	3.28E-03	2.01E-03	1.84E-04	6.75E-04	4.06E-04	3.79E-03	9.85E-04	3.69E-04	2.03E-03	4.06E-04
Terrestrial acidification	kg SO2 eq	7.55E+02	5.35E+02	1.63E+02	5.69E+01	8.17E+02	3.20E+02	3.26E+02	1.71E+02	7.15E+02	3.42E+02	1.05E+02	2.37E+02	3.14E+01	1.23E+03	2.79E+02	2.10E+02	7.10E+02	3.14E+01
Freshwater eutrophication	kg P eq	2.13E+02	1.36E+02	5.71E+01	1.93E+01	2.87E+02	1.15E+02	1.14E+02	5.79E+01	2.67E+02	1.18E+02	4.40E+01	9.69E+01	8.11E+00	4.97E+02	1.10E+02	8.79E+01	2.91E+02	8.11E+00

		S20 B - Open Section								S20 B - Tunnel									
		Constructution				Maintenance				Constructution					Maintenance				
Impact category	Unit	Total	OCS S20 B	Signaling	Tele	Total	OCS S20 B	Signaling	Tele	Total	OCS S20 B	Signaling	Tele	Lighting	Total	OCS S20 B	Signaling	Tele	Lighting
Climate change	kg CO2 eq	8.22E+04	6.58E+04	1.22E+04	4.24E+03	5.65E+04	1.95E+04	2.43E+04	1.27E+04	4.05E+04	2.64E+04	2.52E+03	7.16E+03	4.45E+03	4.26E+04	1.16E+04	5.03E+03	2.15E+04	4.45E+03
Ozone depletion	kg CFC-11 eq	5.68E-03	4.29E-03	1.11E-03	2.85E-04	4.51E-03	1.44E-03	2.22E-03	8.56E-04	3.24E-03	1.97E-03	1.84E-04	6.75E-04	4.06E-04	3.78E-03	9.75E-04	3.69E-04	2.03E-03	4.06E-04
Terrestrial acidification	kg SO2 eq	7.50E+02	5.30E+02	1.63E+02	5.69E+01	8.13E+02	3.16E+02	3.26E+02	1.71E+02	7.11E+02	3.38E+02	1.05E+02	2.37E+02	3.14E+01	1.23E+03	2.77E+02	2.10E+02	7.10E+02	3.14E+01
Freshwater eutrophication	kg P eq	2.11E+02	1.35E+02	5.71E+01	1.93E+01	2.86E+02	1.14E+02	1.14E+02	5.79E+01	2.66E+02	1.17E+02	4.40E+01	9.69E+01	8.11E+00	4.96E+02	1.10E+02	8.79E+01	2.91E+02	8.11E+00

		S25 - Open Section								S25 - Tunnel									
		Constructution				Maintenance				Constructution					Maintenance				
Impact category	Unit	Total	OCS S25	Signaling	Tele	Total	OCS S25	Signaling	Tele	Total	OCS S25	Signaling	Tele	Lighting	Total	OCS S25	Signaling	Tele	Lighting
Climate change	kg CO2 eq	8.35E+04	6.71E+04	1.22E+04	4.24E+03	5.78E+04	2.08E+04	2.43E+04	1.27E+04	4.20E+04	2.79E+04	2.52E+03	7.16E+03	4.45E+03	4.38E+04	1.29E+04	5.03E+03	2.15E+04	4.45E+03
Ozone depletion	kg CFC-11 eq	5.77E-03	4.38E-03	1.11E-03	2.85E-04	4.60E-03	1.53E-03	2.22E-03	8.56E-04	3.34E-03	2.08E-03	1.84E-04	6.75E-04	4.06E-04	3.86E-03	1.06E-03	3.69E-04	2.03E-03	4.06E-04
Terrestrial acidification	kg SO2 eq	8.04E+02	5.84E+02	1.63E+02	5.69E+01	8.67E+02	3.70E+02	3.26E+02	1.71E+02	7.63E+02	3.90E+02	1.05E+02	2.37E+02	3.14E+01	1.28E+03	3.27E+02	2.10E+02	7.10E+02	3.14E+01
Freshwater eutrophication	kg P eq	2.34E+02	1.58E+02	5.71E+01	1.93E+01	3.09E+02	1.37E+02	1.14E+02	5.79E+01	2.87E+02	1.38E+02	4.40E+01	9.69E+01	8.11E+00	5.18E+02	1.31E+02	8.79E+01	2.91E+02	8.11E+00

Appendix G: Material Impact Assessments

Below there are tables that demonstrate how material contribute to the four impact categories. By looking at the results, having smaller or bigger numbers doesn't mean lower or higher impacts. The reason is due to different unit factors for different impact categories. In practice, the way that is done in this study is to compare the same impact categories with themselves for example, comparing the results from CC with CC not OD.

Table below shows the total environmental impacts in open section

		S 20 B - Open Section				S20 A - Open Section				S20 - Open Section			
		Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication	Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication	Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication
		kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq
Total	Copper	1.56E+04	1.22E-03	8.50E+02	3.63E+02	1.58E+04	1.23E-03	8.58E+02	3.66E+02	1.76E+04	1.37E-03	9.56E+02	4.08E+02
	Silver	1.79E+02	1.40E-05	3.69E+00	1.62E+00	1.79E+02	1.40E-05	3.69E+00	1.62E+00	2.15E+02	1.68E-05	4.44E+00	1.94E+00
	Electricity, Production (European Mix)	1.97E+03	9.35E-05	7.83E+00	1.67E+00	2.02E+03	9.56E-05	8.00E+00	1.71E+00	2.58E+03	1.22E-04	1.02E+01	2.18E+00
	Transport, lorry >16t	4.28E+02	6.91E-05	2.45E+00	4.12E-02	4.29E+02	5.35E-05	1.90E+00	3.19E-02	4.39E+02	7.57E-05	2.51E+00	4.22E-02
	Magnesium	1.19E+01	6.59E-07	8.05E-02	1.00E-02	1.27E+01	7.02E-07	8.58E-02	1.07E-02	1.79E+01	9.92E-07	1.21E-01	1.51E-02
	Aluminium	2.24E+04	1.50E-03	9.09E+01	1.04E+01	2.29E+04	1.53E-03	9.27E+01	1.06E+01	2.25E+04	1.51E-03	9.10E+01	1.04E+01
	PVC	4.02E+00	6.88E-09	1.02E-02	1.31E-04	4.02E+00	6.88E-09	1.02E-02	1.31E-04	6.69E+00	1.15E-08	1.70E-02	2.19E-04
	PEX	7.72E+00	2.83E-09	2.36E-02	1.08E-04	7.72E+00	2.83E-09	2.36E-02	1.08E-04	1.29E+01	4.72E-09	3.94E-02	1.80E-04
	Porcelain (insulator)	2.81E+02	3.35E-05	5.02E-01	7.22E-02	2.81E+02	3.35E-05	5.02E-01	7.22E-02	2.81E+02	3.35E-05	5.02E-01	7.22E-02
	lead-antimony (insulator)	2.47E+02	1.33E-05	5.09E+00	1.17E+00	2.47E+02	1.33E-05	5.09E+00	1.17E+00	3.09E+02	1.66E-05	6.36E+00	1.46E+00
	Electricity, Production (NORDIC)	4.72E+01	3.53E-06	1.20E-01	8.47E-03	4.72E+01	3.53E-06	1.20E-01	8.47E-03	5.90E+01	4.41E-06	1.49E-01	1.06E-02
	Tranformator oil	6.70E+02	4.14E-04	5.27E+00	2.46E-01	6.70E+02	4.14E-04	5.27E+00	2.46E-01	6.70E+02	4.14E-04	5.27E+00	2.46E-01
	Steel (low quality)	3.43E+03	1.68E-04	1.09E+01	2.01E+00	3.43E+03	1.68E-04	1.09E+01	2.01E+00	3.43E+03	1.68E-04	1.09E+01	2.01E+00
	Glass (Insulator)	8.74E+01	8.28E-06	6.47E-01	1.23E-02	8.74E+01	8.28E-06	6.47E-01	1.23E-02	8.74E+01	8.28E-06	6.47E-01	1.23E-02
	Welding, arc, Steel	1.12E+00	5.22E-08	4.21E-03	7.78E-04	1.12E+00	5.22E-08	4.21E-03	7.78E-04	1.12E+00	5.22E-08	4.21E-03	7.78E-04
	Steel (high quality)	6.08E+04	3.48E-03	2.99E+02	2.87E+01	6.08E+04	3.48E-03	2.99E+02	2.87E+01	6.08E+04	3.48E-03	2.99E+02	2.87E+01
	Zinc coating	1.28E+03	1.62E-04	1.08E+01	1.47E+00	1.28E+03	1.62E-04	1.08E+01	1.47E+00	1.28E+03	1.62E-04	1.08E+01	1.47E+00
	Concrete	7.60E+03	2.57E-04	1.29E+01	3.98E-01	7.60E+03	2.57E-04	1.29E+01	3.98E-01	7.60E+03	2.57E-04	1.29E+01	3.98E-01
	Cable	1.58E+04	7.91E-04	2.39E+02	8.29E+01	1.58E+04	7.91E-04	2.39E+02	8.29E+01	1.58E+04	7.91E-04	2.39E+02	8.29E+01
	Polycarbonate	4.35E+03	1.64E-03	1.29E+01	4.91E-01	4.35E+03	1.64E-03	1.29E+01	4.91E-01	4.35E+03	1.64E-03	1.29E+01	4.91E-01
	Metal working machine	3.78E+03	3.59E-04	1.22E+01	2.26E+00	3.78E+03	3.59E-04	1.22E+01	2.26E+00	3.78E+03	3.59E-04	1.22E+01	2.26E+00
	Light emitting diode, LED	2.19E+01	1.47E-06	9.81E-02	1.96E-02	2.19E+01	1.47E-06	9.81E-02	1.96E-02	2.19E+01	1.47E-06	9.81E-02	1.96E-02

Table below shows the total environmental impacts in tunnel section

		S 20 B - Tunnel				S 20 A - Tunnel				S 25 - Tunnel			
		Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication	Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication	Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication
		kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq
Total	Copper	2.98E+04	2.33E-03	1.62E+03	6.93E+02	2.99E+04	2.33E-03	1.63E+03	6.95E+02	3.16E+04	2.47E-03	1.72E+03	7.35E+02
	Silver	1.79E+02	1.40E-05	3.69E+00	1.62E+00	1.79E+02	1.40E-05	3.69E+00	1.62E+00	2.15E+02	1.68E-05	4.44E+00	1.94E+00
	Electricity, Production (European Mix)	1.96E+03	9.30E-05	7.79E+00	1.66E+00	1.98E+03	9.39E-05	7.86E+00	1.68E+00	2.52E+03	1.20E-04	1.00E+01	2.14E+00
	Transport, lorry >16t	1.84E+02	2.96E-05	1.05E+00	1.77E-02	1.85E+02	2.98E-05	1.06E+00	1.78E-02	1.94E+02	3.14E-05	1.11E+00	1.87E-02
	Magnesium	1.17E+01	6.48E-07	7.93E-02	9.87E-03	1.21E+01	6.67E-07	8.16E-02	1.02E-02	1.70E+01	9.39E-07	1.15E-01	1.43E-02
	Aluminium	2.36E+04	1.58E-03	9.56E+01	1.10E+01	2.43E+04	1.63E-03	9.83E+01	1.13E+01	2.39E+04	1.20E-03	7.27E+01	8.40E+00
	PVC	4.02E+00	6.88E-09	1.02E-02	1.31E-04	4.02E+00	6.88E-09	1.02E-02	1.31E-04	4.02E+00	6.88E-09	1.02E-02	1.31E-04
	PEX	2.95E+03	7.33E-04	1.01E+01	7.29E-01	2.95E+03	7.33E-04	1.01E+01	7.29E-01	2.95E+03	7.33E-04	1.01E+01	7.29E-01
	Porcelain (insulator)	2.81E+02	3.35E-05	5.02E-01	7.22E-02	2.81E+02	3.35E-05	5.02E-01	7.22E-02	2.81E+02	3.35E-05	5.02E-01	7.22E-02
	lead-antimony (insulator)	2.89E+02	1.55E-05	5.94E+00	1.37E+00	2.89E+02	1.55E-05	5.94E+00	1.37E+00	2.89E+02	1.55E-05	5.94E+00	1.37E+00
	Electricity, Production (NORDIC)	5.51E+01	4.11E-06	1.39E-01	9.88E-03	5.51E+01	4.11E-06	1.39E-01	9.88E-03	5.51E+01	4.11E-06	1.39E-01	9.88E-03
	Tranformator oil	6.70E+02	4.14E-04	5.27E+00	2.46E-01	6.70E+02	4.14E-04	5.27E+00	2.46E-01	6.70E+02	4.14E-04	5.27E+00	2.46E-01
	Steel (low quality)	3.43E+03	1.68E-04	1.09E+01	2.01E+00	3.43E+03	1.68E-04	1.09E+01	2.01E+00	3.43E+03	1.68E-04	1.09E+01	2.01E+00
	Glass (Insulator)	1.26E+02	1.20E-05	9.35E-01	1.77E-02	1.26E+02	1.20E-05	9.35E-01	1.77E-02	1.26E+02	1.20E-05	9.35E-01	1.77E-02
	Welding, arc, Aluminium	1.59E+00	9.99E-08	6.56E-03	8.97E-04	1.59E+00	9.99E-08	6.56E-03	8.97E-04	1.59E+00	9.99E-08	6.56E-03	8.97E-04
	Cable	8.55E+03	4.27E-04	1.29E+02	4.48E+01	8.55E+03	4.27E-04	1.29E+02	4.48E+01	8.55E+03	4.27E-04	1.29E+02	4.48E+01
	Polycarbonate	1.48E+03	5.59E-04	4.39E+00	1.67E-01	1.48E+03	5.59E-04	4.39E+00	1.67E-01	1.48E+03	5.59E-04	4.39E+00	1.67E-01
	Metal working machine	2.57E+03	2.44E-04	8.30E+00	1.54E+00	2.57E+03	2.44E-04	8.30E+00	1.54E+00	2.57E+03	2.44E-04	8.30E+00	1.54E+00
	Light emitting diode, LED	8.32E+02	5.60E-05	3.73E+00	7.45E-01	8.32E+02	5.60E-05	3.73E+00	7.45E-01	8.32E+02	5.60E-05	3.73E+00	7.45E-01
	Steel (high quality)	6.10E+03	3.01E-04	2.84E+01	2.97E+00	6.10E+03	3.01E-04	2.84E+01	2.97E+00	6.10E+03	3.01E-04	2.84E+01	2.97E+00

Table below shows the environmental impacts of construction in open section

		Construction											
		S 20 B - Open Section				S20 A - Open Section				S20 - Open Section			
		Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication	Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication	Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication
		kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq
Overhead Contact System	Copper	4.52E+03	3.53E-04	2.46E+02	1.05E+02	4.59E+03	3.58E-04	2.50E+02	1.07E+02	5.49E+03	4.28E-04	2.99E+02	1.28E+02
	Silver	8.94E+01	7.00E-06	1.85E+00	8.08E-01	8.94E+01	7.00E-06	1.85E+00	8.08E-01	1.08E+02	8.41E-06	2.22E+00	9.71E-01
	Electricity, Production (European Mix)	9.86E+02	4.68E-05	3.91E+00	8.36E-01	1.01E+03	4.78E-05	4.00E+00	8.55E-01	1.29E+03	6.11E-05	5.11E+00	1.09E+00
	Transport, lorry >16t	2.46E+02	3.97E-05	1.41E+00	2.36E-02	2.47E+02	3.98E-05	1.41E+00	2.37E-02	2.51E+02	4.06E-05	1.44E+00	2.42E-02
	Magnesium	5.95E+00	3.29E-07	4.03E-02	5.01E-03	6.34E+00	3.51E-07	4.29E-02	5.34E-03	8.96E+00	4.96E-07	6.06E-02	7.55E-03
	Aluminium	1.45E+04	9.74E-04	5.88E+01	6.74E+00	1.49E+04	9.99E-04	6.03E+01	6.91E+00	1.45E+04	9.75E-04	5.89E+01	6.74E+00
	PVC	3.35E+00	5.74E-09	8.49E-03	1.09E-04	3.35E+00	5.74E-09	8.49E-03	1.09E-04	3.35E+00	5.74E-09	8.49E-03	1.09E-04
	PEX	6.43E+00	2.36E-09	1.97E-02	8.98E-05	6.43E+00	2.36E-09	1.97E-02	8.98E-05	6.43E+00	2.36E-09	1.97E-02	8.98E-05
	Porcelain (insulator)	1.40E+02	1.68E-05	2.51E-01	3.61E-02	1.40E+02	1.68E-05	2.51E-01	3.61E-02	1.40E+02	1.68E-05	2.51E-01	3.61E-02
	lead-antimony (insulator)	1.55E+02	8.32E-06	3.18E+00	7.32E-01	1.55E+02	8.32E-06	3.18E+00	7.32E-01	1.55E+02	8.32E-06	3.18E+00	7.32E-01
	Electricity, Production (NORDIC)	2.95E+01	2.20E-06	7.47E-02	5.29E-03	2.95E+01	2.20E-06	7.47E-02	5.29E-03	2.95E+01	2.20E-06	7.47E-02	5.29E-03
	Tranformator oil	3.35E+02	2.07E-04	2.64E+00	1.23E-01	3.35E+02	2.07E-04	2.64E+00	1.23E-01	3.35E+02	2.07E-04	2.64E+00	1.23E-01
	Steel (low quality)	1.72E+03	8.41E-05	5.45E+00	1.00E+00	1.72E+03	8.41E-05	5.45E+00	1.00E+00	1.72E+03	8.41E-05	5.45E+00	1.00E+00
	Glass (Insulator)	7.28E+01	6.90E-06	5.39E-01	1.02E-02	7.28E+01	6.90E-06	5.39E-01	1.02E-02	7.28E+01	6.90E-06	5.39E-01	1.02E-02
	Welding, arc, Steel	9.35E-01	4.35E-08	3.51E-03	6.49E-04	9.35E-01	4.35E-08	3.51E-03	6.49E-04	9.35E-01	4.35E-08	3.51E-03	6.49E-04
	Steel (high quality)	3.80E+04	2.27E-03	1.90E+02	1.78E+01	3.80E+04	2.27E-03	1.90E+02	1.78E+01	3.80E+04	2.27E-03	1.90E+02	1.78E+01
	Zinc coating	1.07E+03	1.35E-04	9.03E+00	1.23E+00	1.07E+03	1.35E-04	9.03E+00	1.23E+00	1.07E+03	1.35E-04	9.03E+00	1.23E+00
	Concrete	3.89E+03	1.32E-04	6.61E+00	2.04E-01	3.89E+03	1.32E-04	6.61E+00	2.04E-01	3.89E+03	1.32E-04	6.61E+00	2.04E-01
Signaling	Cable	7.31E+02	3.65E-05	1.10E+01	3.83E+00	7.31E+02	3.65E-05	1.10E+01	3.83E+00	7.31E+02	3.65E-05	1.10E+01	3.83E+00
	Copper	2.13E+03	1.66E-04	1.16E+02	4.95E+01	2.13E+03	1.66E-04	1.16E+02	4.95E+01	2.13E+03	1.66E-04	1.16E+02	4.95E+01
	Steel (high quality)	4.94E+03	2.44E-04	2.31E+01	2.41E+00	4.94E+03	2.44E-04	2.31E+01	2.41E+00	4.94E+03	2.44E-04	2.31E+01	2.41E+00
	Polycarbonate	1.21E+03	4.55E-04	3.57E+00	1.36E-01	1.21E+03	4.55E-04	3.57E+00	1.36E-01	1.21E+03	4.55E-04	3.57E+00	1.36E-01
	Aluminium	1.18E+03	7.91E-05	4.78E+00	5.43E-01	1.18E+03	7.91E-05	4.78E+00	5.43E-01	1.18E+03	7.91E-05	4.78E+00	5.43E-01
	Metal working machine	1.07E+03	1.02E-04	3.46E+00	6.41E-01	1.07E+03	1.02E-04	3.46E+00	6.41E-01	1.07E+03	1.02E-04	3.46E+00	6.41E-01
	Concrete	9.78E+02	3.31E-05	1.66E+00	5.12E-02	9.78E+02	3.31E-05	1.66E+00	5.12E-02	9.78E+02	3.31E-05	1.66E+00	5.12E-02
	Light emitting diode, LED	7.30E+00	4.91E-07	3.27E-02	6.53E-03	7.30E+00	4.91E-07	3.27E-02	6.53E-03	7.30E+00	4.91E-07	3.27E-02	6.53E-03
Telecommunicatio	Cable	3.41E+03	1.70E-04	5.14E+01	1.79E+01	3.41E+03	1.70E-04	5.14E+01	1.79E+01	3.41E+03	1.70E-04	5.14E+01	1.79E+01
	Aluminium	3.66E+02	2.46E-05	1.48E+00	1.69E-01	3.66E+02	2.46E-05	1.48E+00	1.69E-01	3.66E+02	2.46E-05	1.48E+00	1.69E-01
	Copper	4.73E+01	3.69E-06	2.58E+00	1.10E+00	4.73E+01	3.69E-06	2.58E+00	1.10E+00	4.73E+01	3.69E-06	2.58E+00	1.10E+00
	Steel (high quality)	9.43E+01	4.65E-06	4.40E-01	4.60E-02	9.43E+01	4.65E-06	4.40E-01	4.60E-02	9.43E+01	4.65E-06	4.40E-01	4.60E-02
	Polycarbonate	1.82E+02	6.88E-05	5.40E-01	2.06E-02	1.82E+02	6.88E-05	5.40E-01	2.06E-02	1.82E+02	6.88E-05	5.40E-01	2.06E-02
	Metal working machine	1.40E+02	1.33E-05	4.53E-01	8.40E-02	1.40E+02	1.33E-05	4.53E-01	8.40E-02	1.40E+02	1.33E-05	4.53E-01	8.40E-02

Table below shows the environmental impacts of maintenance in open section

		Maintenance											
		S 20 B - Open Section				S20 A - Open Section				S20 - Open Section			
		Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication	Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication	Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophication
		kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq
Overhead Contact System	Copper	4.52E+03	3.53E-04	2.46E+02	1.05E+02	4.59E+03	3.58E-04	2.50E+02	1.07E+02	5.49E+03	4.28E-04	2.99E+02	1.28E+02
	Silver	8.94E+01	7.00E-06	1.85E+00	8.08E-01	8.94E+01	7.00E-06	1.85E+00	8.08E-01	1.08E+02	8.41E-06	2.22E+00	9.71E-01
	Electricity, Production (European Mix)	9.86E+02	4.68E-05	3.91E+00	8.36E-01	1.01E+03	4.78E-05	4.00E+00	8.55E-01	1.29E+03	6.11E-05	5.11E+00	1.09E+00
	Transport, lorry >16t	1.82E+02	2.94E-05	1.04E+00	1.75E-02	1.83E+02	1.37E-05	4.85E-01	8.15E-03	1.88E+02	3.51E-05	1.07E+00	1.80E-02
	Magnesium	5.95E+00	3.29E-07	4.03E-02	5.01E-03	6.34E+00	3.51E-07	4.29E-02	5.34E-03	8.96E+00	4.96E-07	6.06E-02	7.55E-03
	Aluminium	2.91E+03	1.95E-04	1.18E+01	1.35E+00	2.98E+03	2.00E-04	1.21E+01	1.38E+00	2.91E+03	1.95E-04	1.18E+01	1.35E+00
	PVC	6.69E-01	1.15E-09	1.70E-03	2.19E-05	6.69E-01	1.15E-09	1.70E-03	2.19E-05	3.35E+00	5.74E-09	8.49E-03	1.09E-04
	PEX	1.29E+00	4.72E-10	3.94E-03	1.80E-05	1.29E+00	4.72E-10	3.94E-03	1.80E-05	6.43E+00	2.36E-09	1.97E-02	8.98E-05
	Porcelain (insulator)	1.40E+02	1.68E-05	2.51E-01	3.61E-02	1.40E+02	1.68E-05	2.51E-01	3.61E-02	1.40E+02	1.68E-05	2.51E-01	3.61E-02
	lead-antimony (insulator)	9.28E+01	4.99E-06	1.91E+00	4.39E-01	9.28E+01	4.99E-06	1.91E+00	4.39E-01	1.55E+02	8.32E-06	3.18E+00	7.32E-01
	Electricity, Production (NORDIC)	1.77E+01	1.32E-06	4.48E-02	3.18E-03	1.77E+01	1.32E-06	4.48E-02	3.18E-03	2.95E+01	2.20E-06	7.47E-02	5.29E-03
	Tranformator oil	3.35E+02	2.07E-04	2.64E+00	1.23E-01	3.35E+02	2.07E-04	2.64E+00	1.23E-01	3.35E+02	2.07E-04	2.64E+00	1.23E-01
	Steel (low quality)	1.72E+03	8.41E-05	5.45E+00	1.00E+00	1.72E+03	8.41E-05	5.45E+00	1.00E+00	1.72E+03	8.41E-05	5.45E+00	1.00E+00
	Glass (Insulator)	1.46E+01	1.38E-06	1.08E-01	2.04E-03	1.46E+01	1.38E-06	1.08E-01	2.04E-03	1.46E+01	1.38E-06	1.08E-01	2.04E-03
	Welding, arc, Steel	1.87E-01	8.70E-09	7.01E-04	1.30E-04	1.87E-01	8.70E-09	7.01E-04	1.30E-04	1.87E-01	8.70E-09	7.01E-04	1.30E-04
	Steel (high quality)	7.60E+03	4.55E-04	3.80E+01	3.55E+00	7.60E+03	4.55E-04	3.80E+01	3.55E+00	7.60E+03	4.55E-04	3.80E+01	3.55E+00
	Zinc coating	2.14E+02	2.70E-05	1.81E+00	2.45E-01	2.14E+02	2.70E-05	1.81E+00	2.45E-01	2.14E+02	2.70E-05	1.81E+00	2.45E-01
	Concrete	7.78E+02	2.63E-05	1.32E+00	4.07E-02	7.78E+02	2.63E-05	1.32E+00	4.07E-02	7.78E+02	2.63E-05	1.32E+00	4.07E-02
Signaling	Cable	1.46E+03	7.30E-05	2.20E+01	7.66E+00	1.46E+03	7.30E-05	2.20E+01	7.66E+00	1.46E+03	7.30E-05	2.20E+01	7.66E+00
	Copper	4.26E+03	3.32E-04	2.32E+02	9.90E+01	4.26E+03	3.32E-04	2.32E+02	9.90E+01	4.26E+03	3.32E-04	2.32E+02	9.90E+01
	Steel (high quality)	9.89E+03	4.88E-04	4.61E+01	4.83E+00	9.89E+03	4.88E-04	4.61E+01	4.83E+00	9.89E+03	4.88E-04	4.61E+01	4.83E+00
	Polycarbonate	2.41E+03	9.10E-04	7.14E+00	2.73E-01	2.41E+03	9.10E-04	7.14E+00	2.73E-01	2.41E+03	9.10E-04	7.14E+00	2.73E-01
	Aluminium	2.36E+03	1.58E-04	9.55E+00	1.09E+00	2.36E+03	1.58E-04	9.55E+00	1.09E+00	2.36E+03	1.58E-04	9.55E+00	1.09E+00
	Metal working machine	2.15E+03	2.04E-04	6.92E+00	1.28E+00	2.15E+03	2.04E-04	6.92E+00	1.28E+00	2.15E+03	2.04E-04	6.92E+00	1.28E+00
	Concrete	1.96E+03	6.61E-05	3.33E+00	1.02E-01	1.96E+03	6.61E-05	3.33E+00	1.02E-01	1.96E+03	6.61E-05	3.33E+00	1.02E-01
	Light emitting diode, LED	1.46E+01	9.81E-07	6.54E-02	1.31E-02	1.46E+01	9.81E-07	6.54E-02	1.31E-02	1.46E+01	9.81E-07	6.54E-02	1.31E-02
Telecommunication	Cable	1.02E+04	5.11E-04	1.54E+02	5.36E+01	1.02E+04	5.11E-04	1.54E+02	5.36E+01	1.02E+04	5.11E-04	1.54E+02	5.36E+01
	Aluminium	1.10E+03	7.38E-05	4.45E+00	5.07E-01	1.10E+03	7.38E-05	4.45E+00	5.07E-01	1.10E+03	7.38E-05	4.45E+00	5.07E-01
	Copper	1.42E+02	1.11E-05	7.73E+00	3.30E+00	1.42E+02	1.11E-05	7.73E+00	3.30E+00	1.42E+02	1.11E-05	7.73E+00	3.30E+00
	Steel (high quality)	2.83E+02	1.40E-05	1.32E+00	1.38E-01	2.83E+02	1.40E-05	1.32E+00	1.38E-01	2.83E+02	1.40E-05	1.32E+00	1.38E-01
	Polycarbonate	5.47E+02	2.06E-04	1.62E+00	6.18E-02	5.47E+02	2.06E-04	1.62E+00	6.18E-02	5.47E+02	2.06E-04	1.62E+00	6.18E-02
	Metal working machine	4.21E+02	4.00E-05	1.36E+00	2.52E-01	4.21E+02	4.00E-05	1.36E+00	2.52E-01	4.21E+02	4.00E-05	1.36E+00	2.52E-01

Table below shows the environmental impacts of construction in tunnel section

		Construction											
		S 20 B - Tunnel				S 20 A - Tunnel				S 25 - Tunnel			
		Climate change	**Ozone depletion**	**Terrestrial acidification**	**Freshwater eutrophication**	**Climate change**	**Ozone depletion**	**Terrestrial acidification**	**Freshwater eutrophication**	**Climate change**	**Ozone depletion**	**Terrestrial acidification**	**Freshwater eutrophication**
		kg CO2 eq	**kg CFC-11 eq**	**kg SO2 eq**	**kg P eq**	**kg CO2 eq**	**kg CFC-11 eq**	**kg SO2 eq**	**kg P eq**	**kg CO2 eq**	**kg CFC-11 eq**	**kg SO2 eq**	**kg P eq**
Overhead Contact System	Copper	4.50E+03	3.51E-04	2.45E+02	1.05E+02	4.53E+03	3.54E-04	2.47E+02	1.05E+02	5.40E+03	4.22E-04	2.94E+02	1.26E+02
	Silver	8.94E+01	7.00E-06	1.85E+00	8.08E-01	8.94E+01	7.00E-06	1.85E+00	8.08E-01	1.08E+02	8.41E-06	2.22E+00	9.71E-01
	Electricity, Production (European Mix)	9.81E+02	4.65E-05	3.89E+00	8.32E-01	9.91E+02	4.70E-05	3.93E+00	8.40E-01	1.26E+03	5.98E-05	5.00E+00	1.07E+00
	Transport, lorry >16t	1.24E+02	2.00E-05	7.09E-01	1.19E-02	1.25E+02	2.01E-05	7.15E-01	1.20E-02	1.29E+02	2.09E-05	7.41E-01	1.24E-02
	Magnesium	5.86E+00	3.24E-07	3.96E-02	4.94E-03	6.03E+00	3.34E-07	4.08E-02	5.08E-03	8.48E+00	4.69E-07	5.74E-02	7.15E-03
	Aluminium	1.82E+04	1.22E-03	7.35E+01	8.47E+00	1.87E+04	1.25E-03	7.58E+01	8.73E+00	1.84E+04	8.35E-04	5.05E+01	5.85E+00
	PVC	3.35E+00	5.74E-09	8.49E-03	1.09E-04	3.35E+00	5.74E-09	8.49E-03	1.09E-04	3.35E+00	5.74E-09	8.49E-03	1.09E-04
	PEX	6.43E+00	2.36E-09	1.97E-02	8.98E-05	6.43E+00	2.36E-09	1.97E-02	8.98E-05	6.43E+00	2.36E-09	1.97E-02	8.98E-05
	Porcelain (insulator)	1.40E+02	1.68E-05	2.51E-01	3.61E-02	1.40E+02	1.68E-05	2.51E-01	3.61E-02	1.40E+02	1.68E-05	2.51E-01	3.61E-02
	lead-antimony (insulator)	1.89E+02	1.02E-05	3.89E+00	8.94E-01	1.89E+02	1.02E-05	3.89E+00	8.94E-01	1.89E+02	1.02E-05	3.89E+00	8.94E-01
	Electricity, Production (NORDIC)	3.61E+01	2.69E-06	9.13E-02	6.47E-03	3.61E+01	2.69E-06	9.13E-02	6.47E-03	3.61E+01	2.69E-06	9.13E-02	6.47E-03
	Tranformator oil	3.35E+02	2.07E-04	2.64E+00	1.23E-01	3.35E+02	2.07E-04	2.64E+00	1.23E-01	3.35E+02	2.07E-04	2.64E+00	1.23E-01
	Steel (low quality)	1.72E+03	8.41E-05	5.45E+00	1.00E+00	1.72E+03	8.41E-05	5.45E+00	1.00E+00	1.72E+03	8.41E-05	5.45E+00	1.00E+00
	Glass (Insulator)	1.05E+02	9.97E-06	7.79E-01	1.48E-02	1.05E+02	9.97E-06	7.79E-01	1.48E-02	1.05E+02	9.97E-06	7.79E-01	1.48E-02
	Welding, arc, Aluminium	1.32E+00	8.33E-08	5.46E-03	7.48E-04	1.32E+00	8.33E-08	5.46E-03	7.48E-04	1.32E+00	8.33E-08	5.46E-03	7.48E-04
Signaling	Cable	6.01E+02	3.00E-05	9.07E+00	3.15E+00	6.01E+02	3.00E-05	9.07E+00	3.15E+00	6.01E+02	3.00E-05	9.07E+00	3.15E+00
	Copper	1.75E+03	1.37E-04	9.55E+01	4.08E+01	1.75E+03	1.37E-04	9.55E+01	4.08E+01	1.75E+03	1.37E-04	9.55E+01	4.08E+01
	Steel (high quality)	7.80E+01	3.85E-06	3.64E-01	3.81E-02	7.80E+01	3.85E-06	3.64E-01	3.81E-02	7.80E+01	3.85E-06	3.64E-01	3.81E-02
	Aluminium	4.49E+01	3.01E-06	1.82E-01	2.07E-02	4.49E+01	3.01E-06	1.82E-01	2.07E-02	4.49E+01	3.01E-06	1.82E-01	2.07E-02
	Polycarbonate	2.34E+01	8.81E-06	6.91E-02	2.64E-03	2.34E+01	8.81E-06	6.91E-02	2.64E-03	2.34E+01	8.81E-06	6.91E-02	2.64E-03
	Metal working machine	1.69E+01	1.61E-06	5.47E-02	1.01E-02	1.69E+01	1.61E-06	5.47E-02	1.01E-02	1.69E+01	1.61E-06	5.47E-02	1.01E-02
Telecommunication	Cable, data cable in infrastructure, at pl	1.69E+03	8.42E-05	2.54E+01	8.84E+00	1.69E+03	8.42E-05	2.54E+01	8.84E+00	1.69E+03	8.42E-05	2.54E+01	8.84E+00
	Copper	3.76E+03	2.93E-04	2.05E+02	8.75E+01	3.76E+03	2.93E-04	2.05E+02	8.75E+01	3.76E+03	2.93E-04	2.05E+02	8.75E+01
	Polyethylene, LDPE	7.36E+02	1.83E-04	2.51E+00	1.82E-01	7.36E+02	1.83E-04	2.51E+00	1.82E-01	7.36E+02	1.83E-04	2.51E+00	1.82E-01
	Aluminium	4.18E+02	2.81E-05	1.69E+00	1.93E-01	4.18E+02	2.81E-05	1.69E+00	1.93E-01	4.18E+02	2.81E-05	1.69E+00	1.93E-01
	Steel (high quality)	2.42E+02	1.19E-05	1.13E+00	1.18E-01	2.42E+02	1.19E-05	1.13E+00	1.18E-01	2.42E+02	1.19E-05	1.13E+00	1.18E-01
	Polycarbonate	1.56E+02	5.89E-05	4.62E-01	1.76E-02	1.56E+02	5.89E-05	4.62E-01	1.76E-02	1.56E+02	5.89E-05	4.62E-01	1.76E-02
	Metal working machine	1.60E+02	1.52E-05	5.17E-01	9.59E-02	1.60E+02	1.52E-05	5.17E-01	9.59E-02	1.60E+02	1.52E-05	5.17E-01	9.59E-02
Lighting	Copper	2.55E+02	1.99E-05	1.39E+01	5.94E+00	2.55E+02	1.99E-05	1.39E+01	5.94E+00	2.55E+02	1.99E-05	1.39E+01	5.94E+00
	Steel (high quality)	2.45E+03	1.21E-04	1.14E+01	1.19E+00	2.45E+03	1.21E-04	1.14E+01	1.19E+00	2.45E+03	1.21E-04	1.14E+01	1.19E+00
	Polycarbonate	3.94E+02	1.49E-04	1.17E+00	4.45E-02	3.94E+02	1.49E-04	1.17E+00	4.45E-02	3.94E+02	1.49E-04	1.17E+00	4.45E-02
	Light emitting diode, LED	4.16E+02	2.80E-05	1.87E+00	3.73E-01	4.16E+02	2.80E-05	1.87E+00	3.73E-01	4.16E+02	2.80E-05	1.87E+00	3.73E-01
	Metal working machine	9.41E+02	8.93E-05	3.03E+00	5.62E-01	9.41E+02	8.93E-05	3.03E+00	5.62E-01	9.41E+02	8.93E-05	3.03E+00	5.62E-01

Table below shows the environmental impacts of maintenance in tunnel section

		Maintenance											
		S 20 B - Tunnel				S 20 A - Tunnel				S 25 - Tunnel			
		Climate change	**Ozone depletion**	**Terrestrial acidification**	**Freshwater eutrophication**	**Climate change**	**Ozone depletion**	**Terrestrial acidification**	**Freshwater eutrophication**	**Climate change**	**Ozone depletion**	**Terrestrial acidification**	**Freshwater eutrophication**
		kg CO2 eq	**kg CFC-11 eq**	**kg SO2 eq**	**kg P eq**	**kg CO2 eq**	**kg CFC-11 eq**	**kg SO2 eq**	**kg P eq**	**kg CO2 eq**	**kg CFC-11 eq**	**kg SO2 eq**	**kg P eq**
Overhead Contact System	Copper	4.50E+03	3.51E-04	2.45E+02	1.05E+02	4.53E+03	3.54E-04	2.47E+02	1.05E+02	5.40E+03	4.22E-04	2.94E+02	1.26E+02
	Silver	8.94E+01	7.00E-06	1.85E+00	8.08E-01	8.94E+01	7.00E-06	1.85E+00	8.08E-01	1.08E+02	8.41E-06	2.22E+00	9.71E-01
	Electricity, Production (European Mix)	9.81E+02	4.65E-05	3.89E+00	8.32E-01	9.91E+02	4.70E-05	3.93E+00	8.40E-01	1.26E+03	5.98E-05	5.00E+00	1.07E+00
	Transport, lorry >16t	5.97E+01	9.64E-06	3.42E-01	5.75E-03	6.01E+01	9.69E-06	3.44E-01	5.78E-03	6.49E+01	1.05E-05	3.72E-01	6.24E-03
	Magnesium	5.86E+00	3.24E-07	3.96E-02	4.94E-03	6.03E+00	3.34E-07	4.08E-02	5.08E-03	8.48E+00	4.69E-07	5.74E-02	7.15E-03
	Aluminium	3.64E+03	2.43E-04	1.47E+01	1.69E+00	3.74E+03	2.51E-04	1.52E+01	1.75E+00	3.68E+03	2.47E-04	1.49E+01	1.72E+00
	PVC	6.69E-01	1.15E-09	1.70E-03	2.19E-05	6.69E-01	1.15E-09	1.70E-03	2.19E-05	6.69E-01	1.15E-09	1.70E-03	2.19E-05
	PEX	1.29E+00	4.72E-10	3.94E-03	1.80E-05	1.29E+00	4.72E-10	3.94E-03	1.80E-05	1.29E+00	4.72E-10	3.94E-03	1.80E-05
	Porcelain (insulator)	1.40E+02	1.68E-05	2.51E-01	3.61E-02	1.40E+02	1.68E-05	2.51E-01	3.61E-02	1.40E+02	1.68E-05	2.51E-01	3.61E-02
	lead-antimony (insulator)	9.97E+01	5.36E-06	2.05E+00	4.72E-01	9.97E+01	5.36E-06	2.05E+00	4.72E-01	9.97E+01	5.36E-06	2.05E+00	4.72E-01
	Electricity, Production (NORDIC)	1.90E+01	1.42E-06	4.82E-02	3.41E-03	1.90E+01	1.42E-06	4.82E-02	3.41E-03	1.90E+01	1.42E-06	4.82E-02	3.41E-03
	Tranformator oil	3.35E+02	2.07E-04	2.64E+00	1.23E-01	3.35E+02	2.07E-04	2.64E+00	1.23E-01	3.35E+02	2.07E-04	2.64E+00	1.23E-01
	Steel (low quality)	1.72E+03	8.41E-05	5.45E+00	1.00E+00	1.72E+03	8.41E-05	5.45E+00	1.00E+00	1.72E+03	8.41E-05	5.45E+00	1.00E+00
	Glass (Insulator)	2.10E+01	1.99E-06	1.56E-01	2.95E-03	2.10E+01	1.99E-06	1.56E-01	2.95E-03	2.10E+01	1.99E-06	1.56E-01	2.95E-03
	Welding, arc, Aluminium	2.64E-01	1.67E-08	1.09E-03	1.50E-04	2.64E-01	1.67E-08	1.09E-03	1.50E-04	2.64E-01	1.67E-08	1.09E-03	1.50E-04
Signaling	Cable	1.20E+03	6.01E-05	1.81E+01	6.30E+00	1.20E+03	6.01E-05	1.81E+01	6.30E+00	1.20E+03	6.01E-05	1.81E+01	6.30E+00
	Copper	3.50E+03	2.74E-04	1.91E+02	8.15E+01	3.50E+03	2.74E-04	1.91E+02	8.15E+01	3.50E+03	2.74E-04	1.91E+02	8.15E+01
	Steel (high quality)	1.56E+02	7.69E-06	7.28E-01	7.61E-02	1.56E+02	7.69E-06	7.28E-01	7.61E-02	1.56E+02	7.69E-06	7.28E-01	7.61E-02
	Aluminium	8.97E+01	6.02E-06	3.64E-01	4.14E-02	8.97E+01	6.02E-06	3.64E-01	4.14E-02	8.97E+01	6.02E-06	3.64E-01	4.14E-02
	Polycarbonate	4.67E+01	1.76E-05	1.38E-01	5.28E-03	4.67E+01	1.76E-05	1.38E-01	5.28E-03	4.67E+01	1.76E-05	1.38E-01	5.28E-03
	Metal working machine	3.39E+01	3.22E-06	1.09E-01	2.03E-02	3.39E+01	3.22E-06	1.09E-01	2.03E-02	3.39E+01	3.22E-06	1.09E-01	2.03E-02
Telecommunication	Cable	5.06E+03	2.53E-04	7.63E+01	2.65E+01	5.06E+03	2.53E-04	7.63E+01	2.65E+01	5.06E+03	2.53E-04	7.63E+01	2.65E+01
	Copper	1.13E+04	8.80E-04	6.14E+02	2.62E+02	1.13E+04	8.80E-04	6.14E+02	2.62E+02	1.13E+04	8.80E-04	6.14E+02	2.62E+02
	Polyethylene, LDPE	2.21E+03	5.50E-04	7.52E+00	5.47E-01	2.21E+03	5.50E-04	7.52E+00	5.47E-01	2.21E+03	5.50E-04	7.52E+00	5.47E-01
	Aluminium	1.25E+03	8.42E-05	5.08E+00	5.78E-01	1.25E+03	8.42E-05	5.08E+00	5.78E-01	1.25E+03	8.42E-05	5.08E+00	5.78E-01
	Steel (high quality)	7.27E+02	3.58E-05	3.39E+00	3.55E-01	7.27E+02	3.58E-05	3.39E+00	3.55E-01	7.27E+02	3.58E-05	3.39E+00	3.55E-01
	Polycarbonate	4.69E+02	1.77E-04	1.39E+00	5.29E-02	4.69E+02	1.77E-04	1.39E+00	5.29E-02	4.69E+02	1.77E-04	1.39E+00	5.29E-02
	Metal working machine	4.81E+02	4.56E-05	1.55E+00	2.88E-01	4.81E+02	4.56E-05	1.55E+00	2.88E-01	4.81E+02	4.56E-05	1.55E+00	2.88E-01
Lighting	Copper	2.55E+02	1.99E-05	1.39E+01	5.94E+00	2.55E+02	1.99E-05	1.39E+01	5.94E+00	2.55E+02	1.99E-05	1.39E+01	5.94E+00
	Steel (high quality)	2.45E+03	1.21E-04	1.14E+01	1.19E+00	2.45E+03	1.21E-04	1.14E+01	1.19E+00	2.45E+03	1.21E-04	1.14E+01	1.19E+00
	Polycarbonate	3.94E+02	1.49E-04	1.17E+00	4.45E-02	3.94E+02	1.49E-04	1.17E+00	4.45E-02	3.94E+02	1.49E-04	1.17E+00	4.45E-02
	Light emitting diode, LED	4.16E+02	2.80E-05	1.87E+00	3.73E-01	4.16E+02	2.80E-05	1.87E+00	3.73E-01	4.16E+02	2.80E-05	1.87E+00	3.73E-01
	Metal working machine	9.41E+02	8.93E-05	3.03E+00	5.62E-01	9.41E+02	8.93E-05	3.03E+00	5.62E-01	9.41E+02	8.93E-05	3.03E+00	5.62E-01

Appendix H: System 35 and 35 MS

Below are tables that compare environmental impact assessments from all systems 20 and 25 with systems 35.

Table below is the result from open section.

Calculation:	Compare					
Results:	Impact assessment					
Product 1:	1 p OCS S20 A - Mast HEB200 - open section (of project Electrification of Railways)					
Product 2:	1 p OCS S20 B - Mast HEB200 - open section (of project Electrification of Railways)					
Product 3:	1 p OCS S25 - Mast HEB200 - open section (of project Electrification of Railways)					
Product 4:	1 p OCS S35 - open section (of project Electrification of Railways)					
Product 5:	1 p OCS S35 MS - open section (of project Electrification of Railways)					
Method:	Electrification of railways_ReCiPe Midpoint (H) V1.04 / World ReCiPe H					
Indicator:	Characterization					
Unit:	%					
Skip categories:	Never					
Exclude infrastructure processes:	No					
Exclude long-term emissions:	No					
Sorted on item:	Impact category					
Sort order:	Ascending					
Impact category	Unit	OCS S20 A - Mast HEB200 - open section	OCS S20 B - Mast HEB200 - open section	OCS S25 - Mast HEB200 - open section	OCS S35 - open section	OCS S35 MS - open section
Climate change	kg CO2 eq	6.43E+04	6.37E+04	6.63E+04	7.12E+04	7.00E+04
Ozone depletion	kg CFC-11	3.96E-03	3.91E-03	4.10E-03	4.36E-03	4.27E-03
Photochemical oxidant formation	kg NMVOC	2.90E+02	2.87E+02	3.19E+02	3.18E+02	3.04E+02
Terrestrial acidification	kg SO2 eq	6.31E+02	6.22E+02	7.31E+02	6.71E+02	6.21E+02
Freshwater eutrophication	kg P eq	1.80E+02	1.76E+02	2.22E+02	1.84E+02	1.63E+02

Table below is the result from tunnel section.

Calculation:	Compare					
Results:	Impact assessment					
Product 1:	1 p OCS S20 A - tunnel (of project Electrification of Railways)					
Product 2:	1 p OCS S20 B - tunnel (of project Electrification of Railways)					
Product 3:	1 p OCS S25 - tunnel (of project Electrification of Railways)					
Product 4:	1 p OCS S35 - tunnel (of project Electrification of Railways)					
Product 5:	1 p OCS S35 MS - tunnel (of project Electrification of Railways)					
Method:	Electrification of railways_ReCiPe Midpoint (H) V1.04 / World ReCiPe H					
Indicator:	Characterization					
Unit:	%					
Skip categories:	Never					
Exclude infrastructure processes:	No					
Exclude long-term emissions:	No					
Sorted on item:	Impact category					
Sort order:	Ascending					
Impact category	Unit	OCS S20 A - tunnel	OCS S20 B - tunnel	OCS S25 - tunnel	OCS S35 - t	OCS S35 MS - tunnel
Climate change	kg CO2 eq	1.71E+04	1.64E+04	1.91E+04	1.89E+04	1.77E+04
Ozone depletion	kg CFC-11	1.19E-03	1.13E-03	1.33E-03	1.26E-03	1.17E-03
Photochemical oxidant formation	kg NMVOC	1.27E+02	1.25E+02	1.55E+02	1.43E+02	1.28E+02
Terrestrial acidification	kg SO2 eq	3.97E+02	3.91E+02	4.94E+02	4.20E+02	3.70E+02
Freshwater eutrophication	kg P eq	1.57E+02	1.55E+02	1.98E+02	1.60E+02	1.39E+02

Appendix I: Sensitivity Analyses of Masts

Below is a table that is a sensitivity analysis for S20 A

Calculatioı	Compare					
Results:	Process contribution					
Product 1:	1 p System 20 A - Mast B3 - open section (of project Electrification of Railways - B3)					
Product 2:	1 p System 20 A - Mast B6 - open section (of project Electrification of Railways - B6)					
Product 3:	1 p System 20 A - Mast H6 - open section (of project Electrification of Railways - H6)					
Product 4:	1 p System 20 A - Mast HEB200 - open section (of project Electrification of Railways)					
Method:	Electrification of railways_ReCiPe Midpoint (H) V1.04 / World ReCiPe H					
Indicator:	Inventory					
Unit:	?					
Default un	Yes					
Exclude inf	No					
Exclude lo	No					
Sorted on	Project					
Sort order	Descending					
			System 20 A			
No	Process	Unit	Mast B3	Mast B6	Mast H6	Mast HEB200
1	Ø6 Steel wire	m	24	24	24	24
2	Ø55 Al tube	m	116.8615	116.8615	116.8615	116.86154
3	Ø42 Al tube	m	59.07692	59.07692	59.07692	59.076923
4	Ø26 Al tube	m	18.46154	18.46154	18.46154	18.461538
5	Transport, rail, components	tkm	1.233231	1.233231	1.233231	1.2332308
6	Transport, lorry >16t, Components	ktkm	1.264488	1.771104	2.081886	1.5426794
7	Tranformator oil	kg	639.2	639.2	639.2	639.2
8	Telecommunications facilities_Innføring til Ski	p	4	4	4	4
9	Telecommunication - open section	p	1	1	1	1
10	System 20 A - Mast H6 - open section	p	1	1	1	1
11	Support structure S20 A - Mast H6 - open section	p	1	1	1	1
12	Stål (høykvalitet)	ton	3.209535	3.209535	3.209535	3.2095345
13	Stitch Wire-S20 A - open section	p	2	2	2	2
14	Steel (Mast, seksjonsskonsoll)	ton	8.25096	13.31712	16.42494	11.032874
15	Steel (low quality)	ton	1.9928	1.9928	1.9928	1.9928
16	Steel (Cantilever/Wire)	kg	3.216	3.216	3.216	3.216
17	Silver	kg	1.780082	1.780082	1.780082	1.7800822
18	Signallys	p	272.7273	272.7273	272.7273	272.72727
19	signaling_Innføring til Ski	p	3	3	3	3
20	Signaling - open section	p	1	1	1	1
21	Signal (dagstrekning)	p	16.36364	16.36364	16.36364	16.363636
22	PVC	kg	2.0016	2.0016	2.0016	2.0016
23	Power feed	p	1	1	1	1
24	Positive current (cable)	p	1.2	1.2	1.2	1.2
25	Porcelain (insulator)	kg	120	120	120	120
26	Plast (polykarbonat)	kg	474.3636	474.3636	474.3636	474.36364
27	PEX	kg	4.0032	4.0032	4.0032	4.0032
28	OCS S20 A - Mast H6 - open section	p	1	1	1	1
29	Negative current (cable)	p	1.2	1.2	1.2	1.2
30	Montering/Demontering, metallpodukter	ton	2.660227	2.660227	2.660227	2.6602273
31	Messanger Wire-S20 A - open section	p	2	2	2	2
32	Mast H6-S20 A, S20 B & S25 - open section	p	1.2	1.2	1.2	1.2
33	Mast (dagstrekning)	p	5.454546	5.454546	5.454546	5.4545455
34	Magnesium	kg	4.894363	4.894363	4.894363	4.8943631
35	Lysleder	km	32.5	32.5	32.5	32.5
36	Lysdioder (LED)	p	272.7273	272.7273	272.7273	272.72727
37	lead-antimony (insulator)	kg	192	192	192	192
38	Kobber, ledninger	kg	80	80	80	80
39	Kobber (signal)	km	4.5	4.5	4.5	4.5
40	Kabelkasse	km	3	3	3	3
41	Insulators (feeders)	p	30.76923	30.76923	30.76923	30.769231
42	Insulators (cantilever)	p	18.46154	18.46154	18.46154	18.461538
43	Insulator - power supply	p	2	2	2	2
44	Glass (Insulator)	kg	72	72	72	72
45	Fundament for Masts - S20 & S25 - open section	p	1.2	1.2	1.2	1.2
46	Fundament (Mast)	p	18.46154	18.46154	18.46154	18.461538
47	Fundament	p	5.454546	5.454546	5.454546	5.4545455
48	Electricity, Production (NORDIC)	GJ	1.0368	1.0368	1.0368	1.0368
49	Electricity, Production (European Mix)	GJ	14.89836	14.89836	14.89836	14.898356
50	Dropper-S20 A - open section	p	2	2	2	2
51	Drivmaskin	p	16.36364	16.36364	16.36364	16.363636
52	CuAg0.1 (100mm2)	km	2.000092	2.000092	2.000092	2.0000923
53	Copper (Contact Wire) & (winding)	ton	3.88028	3.88028	3.88028	3.8802803
54	Contact Wire-S20 A - open section	p	2	2	2	2
55	Catenary S20 A - open section	p	1	1	1	1
56	Cantilever S20 A - open section	p	1.2	1.2	1.2	1.2
57	Bz II 50	km	2.002	2.002	2.002	2.002
58	Bz II 25	m	326.1539	326.1539	326.1539	326.15385
59	Bz II 10	m	165.3231	165.3231	165.3231	165.32308
60	Beskyttelseskasse (datamaskin)	p	0.681818	0.681818	0.681818	0.68181818
61	Basisstasjon	p	4	4	4	4
62	ATC-utstyr	p	13.63636	13.63636	13.63636	13.636364
63	AT	p	2	2	2	2
64	Aluminium Feeder Cables (240mm2)	km	2.4	2.4	2.4	2.4
65	Aluminium (Cantilever/Tube)	kg	379.9351	379.9351	379.9351	379.93514
66	Aluminium (Cable)	ton	1.5552	1.5552	1.5552	1.5552
67	Aluminium	kg	532.8891	532.8891	532.8891	532.88909
68	Akselteller	p	10.90909	10.90909	10.90909	10.909091

Below is a table that is a sensitivity analysis for S20 B

Calculation	Compare					
Results:	Process contribution					
Product 1:	1 p System 20 B - Mast B3 - open section (of project Electrification of Railways - B3)					
Product 2:	1 p System 20 B - Mast B6 - open section (of project Electrification of Railways - B6)					
Product 3:	1 p System 20 B - Mast H6 - open section (of project Electrification of Railways - H6)					
Product 4:	1 p System 20 B - Mast HEB200 - open section (of project Electrification of Railways)					
Method:	Electrification of railways_ReCiPe Midpoint (H) V1.04 / World ReCiPe H					
Indicator:	Inventory					
Unit:	?					
Default un	Yes					
Exclude inf	No					
Exclude lo	No					
Sorted on	Project					
Sort order	Descending					
			System 20 B			
No	Process	Unit	Mast B3	Mast B6	Mast H6	Mast HEB200
1	Ø70 Al tube	m	43.38462	43.38462	43.38462	43.384615
2	Ø6 Steel wire	m	18.09231	18.09231	18.09231	18.092308
3	Ø55 Al tube	m	47.26154	47.26154	47.26154	47.261538
4	Ø42 Al tube	m	48	48	48	48
5	Ø26 Al tube	m	18.46154	18.46154	18.46154	18.461538
6	Transport, rail, components	tkm	1.233231	1.233231	1.233231	1.2332308
7	Transport, lorry >16t, Components	ktkm	1.252643	1.759259	2.070041	1.5308344
8	Tranformator oil	kg	639.2	639.2	639.2	639.2
9	Telecommunications facilities_Innføring til Ski	p	4	4	4	4
10	Telecommunication - open section	p	1	1	1	1
11	System 20 B - Mast H6 - open section	p	1	1	1	1
12	Support structure S20 B - Mast H6 - open section	p	1	1	1	1
13	Stål (høykvalitet)	ton	3.209535	3.209535	3.209535	3.2095345
14	Steel (Mast, seksjonsskonsoll)	ton	8.25096	13.31712	16.42494	11.032874
15	Steel (low quality)	ton	1.9928	1.9928	1.9928	1.9928
16	Steel (Cantilever/Wire)	kg	2.424369	2.424369	2.424369	2.4243692
17	Silver	kg	1.780082	1.780082	1.780082	1.7800822
18	Signallys	p	272.7273	272.7273	272.7273	272.72727
19	signaling_Innføring til Ski	p	3	3	3	3
20	Signaling - open section	p	1	1	1	1
21	Signal (dagstrekning)	p	16.36364	16.36364	16.36364	16.363636
22	PVC	kg	2.0016	2.0016	2.0016	2.0016
23	Power feed	p	1	1	1	1
24	Positive current (cable)	p	1.2	1.2	1.2	1.2
25	Porcelain (insulator)	kg	120	120	120	120
26	Plast (polykarbonat)	kg	474.3636	474.3636	474.3636	474.36364
27	PEX	kg	4.0032	4.0032	4.0032	4.0032
28	OCS S20 B - Mast H6 - open section	p	1	1	1	1
29	Negative current (cable)	p	1.2	1.2	1.2	1.2
30	Montering/Demontering, metallpodukter	ton	2.660227	2.660227	2.660227	2.6602273
31	Messenger Wire-S20 B	p	2	2	2	2
32	Mast H6-S20 A, S20 B & S25 - open section	p	1.2	1.2	1.2	1.2
33	Mast (dagstrekning)	p	5.454546	5.454546	5.454546	5.4545455
34	Magnesium	kg	4.594088	4.594088	4.594088	4.5940877
35	Lysleder	km	32.5	32.5	32.5	32.5
36	Lysdioder (LED)	p	272.7273	272.7273	272.7273	272.72727
37	lead-antimony (insulator)	kg	192	192	192	192
38	Kobber, ledninger	kg	80	80	80	80
39	Kobber (signal)	km	4.5	4.5	4.5	4.5
40	Kabelkasse	km	3	3	3	3
41	Insulators (feeders)	p	30.76923	30.76923	30.76923	30.769231
42	Insulators (cantilever)	p	18.46154	18.46154	18.46154	18.461538
43	Insulator - power supply	p	2	2	2	2
44	Glass (Insulator)	kg	72	72	72	72
45	Fundament for Masts - S20 & S25 - open section	p	1.2	1.2	1.2	1.2
46	Fundament (Mast)	p	18.46154	18.46154	18.46154	18.461538
47	Fundament	p	5.454546	5.454546	5.454546	5.4545455
48	Electricity, Production (NORDIC)	GJ	1.0368	1.0368	1.0368	1.0368
49	Electricity, Production (European Mix)	GJ	14.57406	14.57406	14.57406	14.574058
50	Dropper-S20 B	p	2	2	2	2
51	Drivmaskin	p	16.36364	16.36364	16.36364	16.363636
52	CuAg0.1 (100mm2)	km	2.000092	2.000092	2.000092	2.0000923
53	Copper (Contact Wire) & (winding)	ton	3.820526	3.820526	3.820526	3.8205255
54	Contact Wire-S20 B	p	2	2	2	2
55	Catenary S20 B - open section	p	1	1	1	1
56	Cantilever S20 B - open section	p	1.2	1.2	1.2	1.2
57	Bz II 50	km	2.002	2.002	2.002	2.002
58	Bz II 10	m	288.0615	288.0615	288.0615	288.06154
59	Beskyttelseskasse (datamaskin)	p	0.681818	0.681818	0.681818	0.68181818
60	Basisstasjon	p	4	4	4	4
61	ATC-utstyr	p	13.63636	13.63636	13.63636	13.636364
62	AT	p	2	2	2	2
63	Aluminium Feeder Cables (240mm2)	km	2.4	2.4	2.4	2.4
64	Aluminium (Cantilever/Tube)	kg	333.3783	333.3783	333.3783	333.37828
65	Aluminium (Cable)	ton	1.5552	1.5552	1.5552	1.5552
66	Aluminium	kg	532.8891	532.8891	532.8891	532.88909
67	Akselteller	p	10.90909	10.90909	10.90909	10.909091

Below is a table that is a sensitivity analysis for S25

Calculatioı	Compare					
Results:	Process contribution					
Product 1:	1 p System 25 - Mast B3 - open section (of project Electrification of Railways - B3)					
Product 2:	1 p System 25 - Mast B6 - open section (of project Electrification of Railways - B6)					
Product 3:	1 p System 25 - Mast H6 - open section (of project Electrification of Railways - H6)					
Product 4:	1 p System 25 - Mast HEB200 - open section (of project Electrification of Railways)					
Method:	Electrification of railways_ReCiPe Midpoint (H) V1.04 / World ReCiPe H					
Indicator:	Inventory					
Unit:	?					
Default un	Yes					
Exclude inf	No					
Exclude lo	No					
Sorted on	Project					
Sort order:	Descending					
				System 25		
No	Process	Unit	Mast B3	Mast B6	Mast H6	Mast HEB200
1	Ø70 Al tube	m	48	48	48	48
2	Ø6 Steel wire	m	16.06154	16.06154	16.06154	16.061538
3	Ø55 Al tube	m	49.84615	49.84615	49.84615	49.846154
4	Ø42 Al tube	m	42.73846	42.73846	42.73846	42.738462
5	Transport, lorry >16t, Components	ktkm	1.604692	2.111308	2.422089	1.882883
6	Tranformator oil	kg	639.2	639.2	639.2	639.2
7	Telecommunications facilities_Innføring til Ski	p	4	4	4	4
8	Telecommunication - open section	p	1	1	1	1
9	System 25 - Mast H6 - open section	p	1	1	1	1
10	Support structure S25 - Mast H6 - open section	p	1	1	1	1
11	Stål (høykvalitet)	ton	3.209535	3.209535	3.209535	3.2095345
12	Stitch Wire-S25	p	2	2	2	2
13	Steel (Mast, seksjonsskonsoll)	ton	8.25096	13.31712	16.42494	11.032874
14	Steel (low quality)	ton	1.9928	1.9928	1.9928	1.9928
15	Steel (Cantilever/Wire)	kg	2.152246	2.152246	2.152246	2.1522462
16	Silver	kg	2.140033	2.140033	2.140033	2.1400329
17	Signallys	p	272.7273	272.7273	272.7273	272.72727
18	signaling_Innføring til Ski	p	3	3	3	3
19	Signaling - open section	p	1	1	1	1
20	Signal (dagstrekning)	p	16.36364	16.36364	16.36364	16.363636
21	PVC	kg	2.0016	2.0016	2.0016	2.0016
22	Power feed	p	1	1	1	1
23	Positive current (cable)	p	1.2	1.2	1.2	1.2
24	Porcelain (insulator)	kg	120	120	120	120
25	Plast (polykarbonat)	kg	474.3636	474.3636	474.3636	474.36364
26	PEX	kg	4.0032	4.0032	4.0032	4.0032
27	OCS S25 - Mast H6 - open section	p	1	1	1	1
28	Negative current (cable)	p	1.2	1.2	1.2	1.2
29	Montering/Demontering, metallpodukter	ton	2.660227	2.660227	2.660227	2.6602273
30	Messanger Wire-S25	p	2	2	2	2
31	Mast H6-S20 A, S20 B & S25 - open section	p	1.2	1.2	1.2	1.2
32	Mast (dagstrekning)	p	5.454546	5.454546	5.454546	5.4545455
33	Magnesium	kg	6.916268	6.916268	6.916268	6.9162677
34	Lysleder	km	32.5	32.5	32.5	32.5
35	Lysdioder (LED)	p	272.7273	272.7273	272.7273	272.72727
36	lead-antimony (insulator)	kg	192	192	192	192
37	Kobber, ledninger	kg	80	80	80	80
38	Kobber (signal)	km	4.5	4.5	4.5	4.5
39	Kabelkasse	km	3	3	3	3
40	Insulators (feeders)	p	30.76923	30.76923	30.76923	30.769231
41	Insulators (cantilever)	p	18.46154	18.46154	18.46154	18.461538
42	Insulator - power supply	p	2	2	2	2
43	Glass (Insulator)	kg	72	72	72	72
44	Fundament for Masts - S20 & S25 - open section	p	1.2	1.2	1.2	1.2
45	Fundament (Mast)	p	18.46154	18.46154	18.46154	18.461538
46	Fundament	p	5.454546	5.454546	5.454546	5.4545455
47	Electricity, Production (NORDIC)	GJ	1.0368	1.0368	1.0368	1.0368
48	Electricity, Production (European Mix)	GJ	19.02575	19.02575	19.02575	19.025747
49	Dropper-S25	p	2	2	2	2
50	Drivmaskin	p	16.36364	16.36364	16.36364	16.363636
51	CuAg0.1 (120mm2)	km	2.000031	2.000031	2.000031	2.0000308
52	Copper (Contact Wire) & (winding)	ton	4.64223	4.64223	4.64223	4.6422302
53	Contact Wire-S25	p	2	2	2	2
54	Catenary S25 - open section	p	1	1	1	1
55	Cantilever S25 - open section	p	1.2	1.2	1.2	1.2
56	Bz II 70	km	2.002	2.002	2.002	2.002
57	Bz II 35	m	557.5385	557.5385	557.5385	557.53846
58	Bz II 10	m	191.3846	191.3846	191.3846	191.38462
59	Beskyttelseskasse (datamaskin)	p	0.681818	0.681818	0.681818	0.68181818
60	Basisstasjon	p	4	4	4	4
61	ATC-utstyr	p	13.63636	13.63636	13.63636	13.636364
62	AT	p	2	2	2	2
63	Aluminium Feeder Cables (240mm2)	km	2.4	2.4	2.4	2.4
64	Aluminium (Cantilever/Tube)	kg	335.7422	335.7422	335.7422	335.74218
65	Aluminium (Cable)	ton	1.5552	1.5552	1.5552	1.5552
66	Aluminium	kg	532.8891	532.8891	532.8891	532.88909
67	Akselteller	p	10.90909	10.90909	10.90909	10.909091