Royal Institute of technology

LIFE CYCLE ASSESSMENT

of

Solar Powered Radio Station

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AG2800 Life Cycle Assessment

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Group 2

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ABSTRACT

The report deals with the life cycle assessment of the 'Solar Powered Radio Station' located at Sudan, Africa. The study will include the analysis of the various sub- systems in the solar powered radio base. In the first phase we will go into length in collecting data of all the materials and processes used in the manufacturing, use and disposal phase of these systems as well the different energy utilized during these processes. In the second phase using SimaPro we shall assess the impact of these sub systems on the environment in terms of the CO2 emissions produced by the entire station in one year over its lifetime. Once the study is over it can be made useful to the potential target audience who can benefit from this study directly or indirectly.

Contents

1. GOAL and SCOPE

1.1Goal of the study

This study is carried out with the goal of evaluating the environmental impact over the whole lifecycle of a solar-based base station that is for rural areas where there is no connection of electricity grid. The basic questions that are to be answered are 'Which life cycle stage does the major impact?' and 'Which part of the solution has the highest CO2 output?'

The life cycle approach inclines to evaluate the impact throughout the resources (inputs: energy, raw materials, water etc.) and environmental emissions (outputs: to air, water or soil). Moreover LCA method guides this study in order to help analyzing the parameters that are to be monitored and to control the system as a whole in terms of system performance (Baumann and Tillman, 2004).

1.1.1. Target Audience and Intended Application

The results of this LCA study will guide in decision making process in the related companies, will help for the further researches and also underline the system performance of each sub-system as a part of the whole to make improvements in terms of environmental performance of the solution. It will also used as a marketing source for the potential market. Therefore the target audience will be the Information and Communication industries especially the marketing and environmental related departments of these companies and also fellow researchers. The intended application of this study is to draw the environmental profile of the solution throughout its entire lifetime since to be applicable for further studies and in company wise to assist for product development.

1.1.2 Type of LCA

This study is used to analyze a single product and focus on its environmental characteristic which is CO2 emissions released for each phase and for each sub-system. So it is a stand-alone LCA along with accounting LCA used in this study.

1.2. Scope

1.2.1. System definition/description

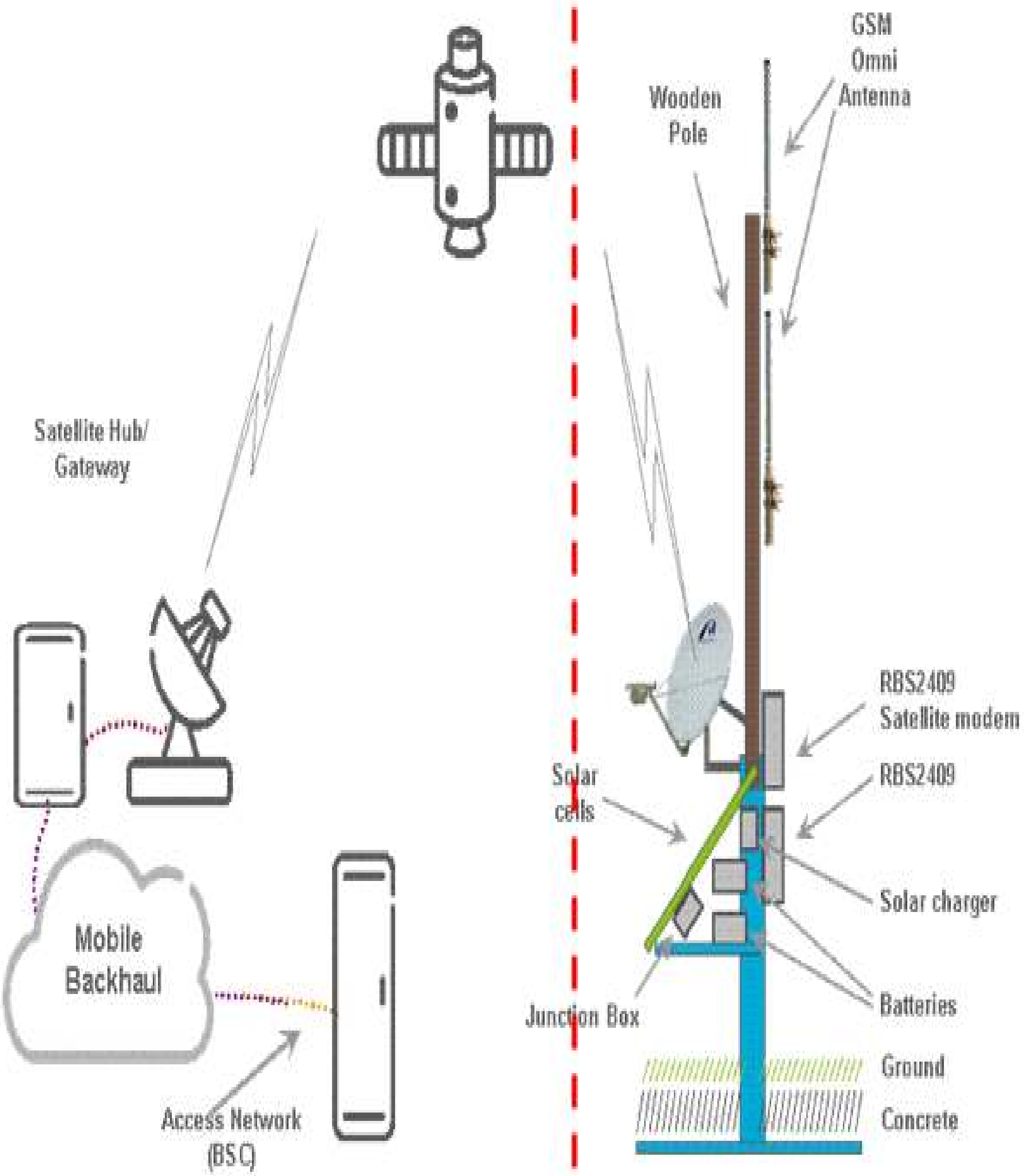


Figure 1: Model of the Solar Base Station

The system shown in the figure above is the model of the Solar Powered Radio Station. This system is being designed and installed by Ericsson Company in remote location is Sudan, Africa. As a test run initially a pilot model is being tested at Kista, Stockholm at their Swedish Head Office in order to check the performance of the system. For the purpose of this study we have limited the usage of data in accordance with the privacy policies of the company and hence certain assumptions were to be made.

The solution is designed for rural areas where there is no grid connection. The main function is to provide communication for people living in rural areas. The study will be stand-alone and evaluate environmental impacts upon this one Solar Powered Radio Station site that consists of; a radio base station, photovoltaic module, solar battery, antenna and the construction part which are antenna pole, tower and a foundation. The system is directly connected to the satellite and receives/sends data upon the antenna. The coverage area will be 5 m^2.

For the manufacturing phase, the data will be provided from the decided supplier for each sub-system through the product catalogs of the companies and also during assembling/disassembling test of the pilot site. Transportation for PV module, solar battery, antenna and the construction part will be included. The operation time will be one year so the use phase also will be included with some assumptions. End-of life phase will also be added to the study.

SUB-SYSTEM	DETAILS/PIECE	NO OF PIECES/SITE
PV	*72 cells monocristalline 180Wp, 24V*	4
BATTERY	*Sealed grid plate lead acid solar battery 12V, 230AhC100*	2
ANTENNA	*Single antenna, Omni 11dBi, 1710-1880MHz, upright mount*	2
ANTENNA POLE	*4 meter over tower*	1
TOWER	*2 meter*	6
FOUNDATION	*volume 2,3*2,3*0,3 = 0,432 m3*	1

Table 1.Sub-System Details

1.2.2. Functional Unit

The function of the solution in general is to make people communicate via voice and data transfer in anywhere and anytime within the covered area. Although the lifetime of the station is for twenty years we have chosen the functional unit as **'Access to one Solar Powered Radio Station during one year'**.

1.2.3. System Boundary

The system boundary consists of the unit processes that should be the part of the whole system according to ISO14040 standards which is each part of the design that will be studied within this LCA study. As in connection with the goal of the study to evaluate the environmental performance of the solution from a life cycle point of view, LCA of this design will be in cradle to grave approach for the defined solution.

The life cycle phases will be studied in the following path; manufacturing phases that will consist of raw material extraction as well, which can also be defined as cradle to gate phase, transportation, operation and end-of-life treatment. The system boundary of natural and technical system depends on the materials entering and leaving the system naturally which is how they are extracted from the nature.

1.2.3.1. The geographical boundary:

The geographical boundary of the system is the rural areas where people have problems in communication which is for this study Africa, Sudan. Thus the transportation data will be specified according to this specific area which is 100 km away from Port Sudan. The construction parts of the system will be constructed in Sweden as well. The electricity mixture of the whole system will be chosen in accordance to the chosen area and the product suppliers' region/country. For example radio base station will be Swedish and in its life cycle phases, Swedish electricity mixture data is used within the Ecoinvent database in SimaPro software.

1.2.3.2. Time horizon:

In this study we have made use of the data that is available up to date. But the time frame is set to about 10 years (2001-2011). There are some exceptions for some sub-systems which will be explained in detail in the next parts. Supplier or site specific data are used. Because of the time limitation average data is not used.

Each sub-system of the site has different life-times are listed below.

- Antenna: 20 years
- PV module: 20 years
- Tower: 20 years
- Antenna pole: 20 years
- Battery: 5 years
- Foundation: 20 years

It is important to note that the above mentioned lifetime years is used to calculate the impact the Solar Powered Radio Station has on the environment for one year by dividing the various inputs in SimaPro by the lifetime years.

1.2.3.3. Cut-off criteria:

From the figure 1 we clearly see the various parts that go into the making of the Solar Powered Base Station and for the purpose of our LCA study, owing to the fact that it is difficult to procure the data sets for certain parts of the system, we have excluded the entire satellite communication system parts and also a critical electronic part called RBS.

Although the satellite plays a critical role in the system, we have excluded it as we were more interested in checking the environmental impact of the actual installation that takes place on site per site. We know for fact that the satellite station in space will be shared with various other applications. Hence it would not be feasible to assess the system clearly without having further knowledge about how this system works which is very time consuming and will take away a substantiate part of the time allotted for the project under this task.

1.2.4. Assumptions and Limitations

At the various stages of the project we had to make a few assumptions in order to be able to assess the system better. The first consideration was to remove two parts which are not mentioned that is the satellite and RBS (critical electronic component) from our scope of study as it was difficult to find apt data for these products as well as privacy policy was limiting our understanding of the various components that go into the making of these systems.

The assumptions at the various stages such as Manufacturing/Transportation/Disposal are:

The manufacturing of the sub –systems is assumed to be in Sweden, the raw materials and the energy mix used are that of Sweden. The various materials that go into the making of the subsystems have been sought from various sources, which will be listed in detail in later sections; these materials are approximated to the ones available in the SimaPro database.

Once the products are ready at the manufacturing stations they will be transported to Kista, Stockholm, Sweden making use of the road transportation. An average of 1000 Km is taken in total for all the subsystem towards its transportation from the various production units located in different parts of Sweden to Kista.

Once all the sub- systems are assembled at Kista , the entire system will be gathered/assembled into one package and transported to the Port of Marseille in France again by road for a distance of 2615 Km. From the port making use of seaways and using a freight ship , the system will be transported to the Port of Said in Egypt for a distance of 2710 Km. From the Port of Sudan using seaways - freight ship the system will be transported for a distance of 1380 Km to the Port of Sudan . On reaching the Port of Sudan by road the system will be taken to the site for a distance of 100 Km. The kilometers indicated in this section is based on distance approximation obtained from Google maps.

After the life time of the system, the various components are to be disposed. But owing to fact that the station is located in Sudan, which does not have any specific recycling or disposal units the components have a rather simple disposal scenario. Due consideration was given whether or not it would be practically viable to transport the system back to Sweden for recycling, but since the nature of the project is to experiment the use of Solar Powered Radio Station in remote location, the disposal was not given much weightage. Hence we had to limit our waste disposal to 'Incineration and Landfill' options the only ones available in Sudan. But what we have best tried to do is to sensibly allocate the ratio towards incineration and landfill appropriately for each of the sub-systems.

1.2.5. Life Cycle Impact Categories and Impact Assessment Method

In this study as written in the report instructions for the course ReCiPe Midpoint (Hierarchist) Method has been chosen in order to model and get the results. This approach consists of 18 midpoint indicators and 3 endpoint indicators within its database. Each contains some baseline factors with respect to three cultural perspectives which in this study Hierarchist consensus model, as often encountered in scientific model was chosen (PRE Product Ecology Consultants, 2008).

Climate change indicator is based on global warming potential (GWP) concept has been chosen as a midpoint impact category to be the main result basis but also some results for the other impact categories have been evaluated like; human toxicity, ionizing radiation, freshwater eutrophication, freshwater and marine ecotoxicity and metal depletion.

The time horizon for Hierarchist is 100 years. So the concept considers contributors that effect to potential global warming for 100 years (PRE Product Ecology Consultants, 2008). The unit of GWP100 is kg CO2-equivalent, and the greenhouse gases that are the basis for this concept are; CO_2, NO_x, SO_x, CH_4 and CFCs. In this concept GWP is defined as the cumulative radiative forcing between the present and pre-decided later time horizon caused by a unit mass of gas emitted now, which is defined according to a specific gas which is in this study CO_2. CO_2 refers to direct emissions where CO_2e (CO_2 equivalent) refers to other gases written above. Since during decomposition these other gases turns into CO_2 that's why CO_2e is used as a unit in this concept (Malmodin, 2009)

1.2.6. Normalization

In this study we use normalization which is defined in ReCiPe Midpoint (Hierarchist) Method.

1.2.7. LCA software

The software used in our study is the SimaPro 7.3.0 .

2. LIFE CYCLE INVENTORY ANALYSIS

In the goal and scope definition the requirements for this study has been underlined and this stage of the study have been done in accordance with these needs. First the flowchart of the system that shows the activities that have been included has been drawn. The processes are assembly, transportation, operation and end-of-life treatment. All these stages are connected within each other and energy requirement for each phase has been included as well. In the second part data collections for all processes that are mentioned above have to be included. All input and output data should be the collected. In the last part of inventory analysis resource use and emissions to air, soil and water amounts should be calculated and evaluated in accordance with the chosen functional unit.

2.1 Process Flowchart

This flow chart shows the various sub-systems that are considered and part of our LCA study.

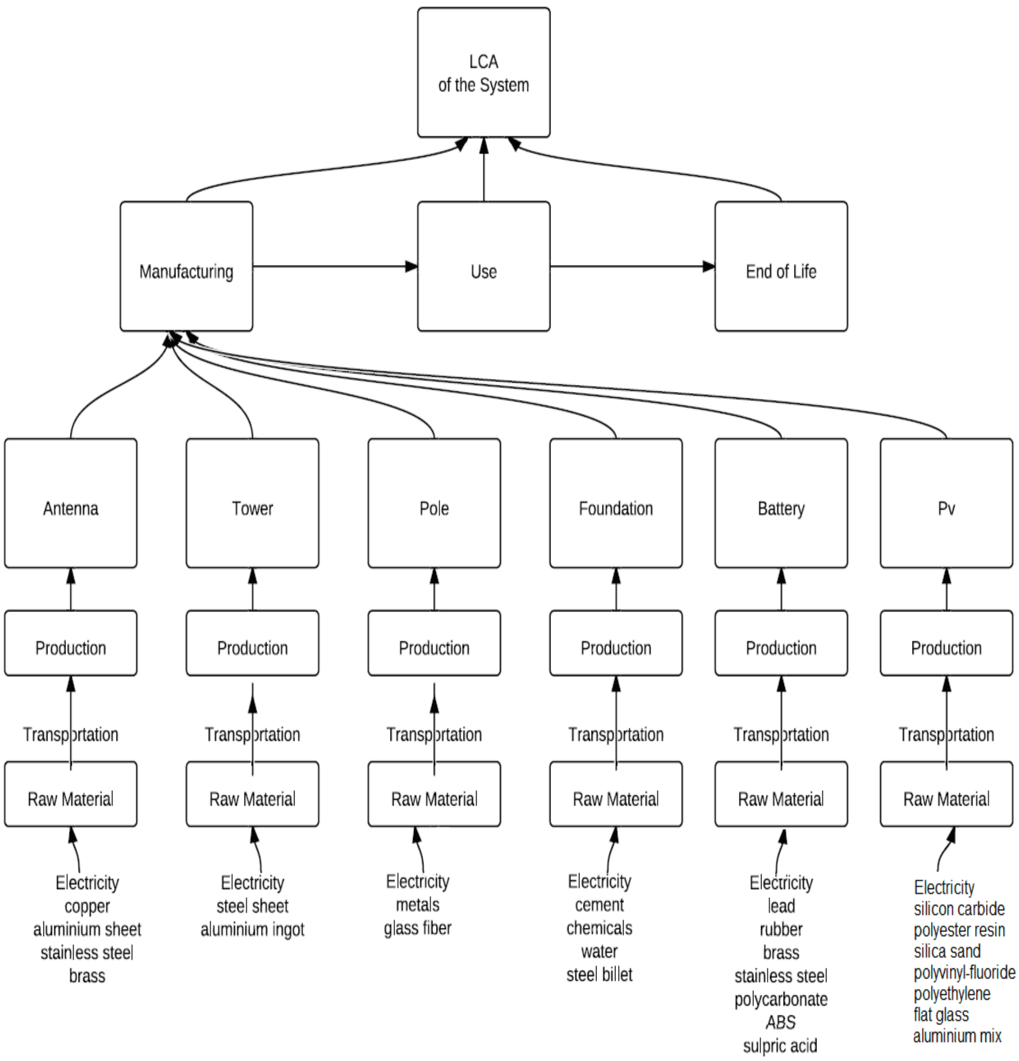


Figure 2.LCA Flowchart of the entire Solar Powered Base Station setup

2.2 Data

2.2.1 Data requirements, data quality and data gaps

Data collection stage is mainly depending on the information of the supplier contacts for this study. For some of the sub-systems previous LCA studies and published reports have been used. The pilot site had been visited and for the construction parts of the system, site specific data is used with the information from Ericsson employees on site. Throughout the data collection phase, the most important thing was to find as accurate and up-to-date data as possible. But of course because of the limited time frame some assumptions and limitations have been done within this stage which will be explained within the report.

During inventory analysis if some data gaps are involved or if data has not reached the standards, sensitivity analysis has been used in order to control the uncertainties and their effects to the system. Being aware of this method trial and error approach has been used to have the best results for the study. In sensitivity analysis, the procedure is to vary the studied input parameter and revise the results for the new value where all the other parameters are constant.

In general for the whole analysis, it can be said that to determine the region of the processes plays a large role in LCI. Also it is really difficult to find the certain region for each process and also energy requirement should be chosen depending on this region and its electricity mixture. Moreover when inserting raw materials, in some cases similar data have been used rather than the exact one since database did not consist of the raw material that should be used for that process (Malmodin, 2009).

All these have been created some data gaps and less qualified data have been used rather than the real data. While interpreting the results of this study for instance in manufacturing scenario if it is moved from one region to another or raw material choice would give completely different results.

Raw materials and energy requirements for each sub-system's assembly phase can be seen in the below tables and figure. The source and used database also included in the tables.

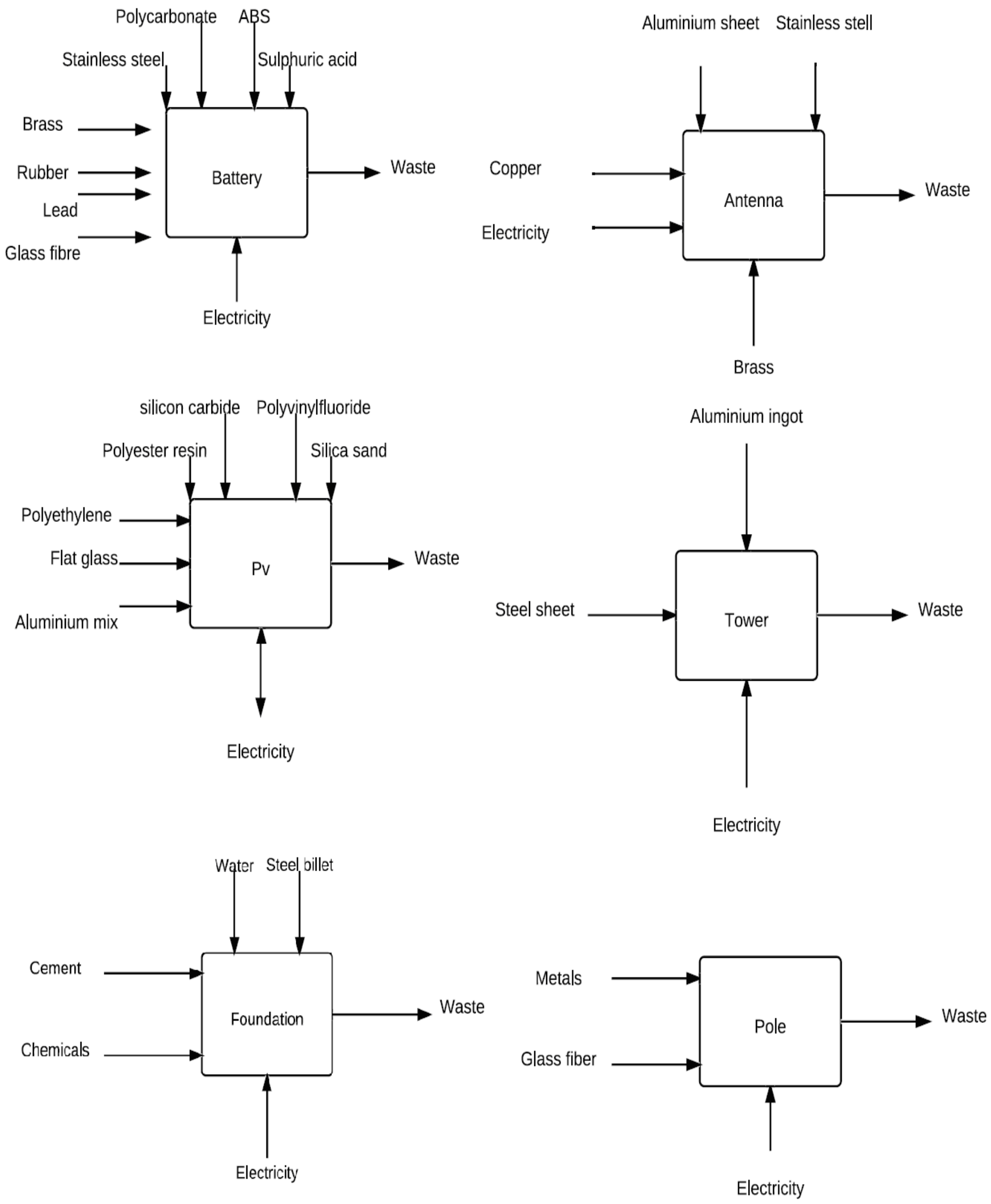


Figure 3.General overview of the raw materials for each sub-system

2.2.1. Antenna

The data for the antenna was found with the supplier contact from the KATHREIN-Werke KG Company which is a German company. But for this study a Swedish product have been used. So this is an LCI model (German) that has been used to describe another similar product from a Swedish supplier. We approximated the German case to Swedish one as they are similar.

The specifications of the antenna: Single antenna, Omni 11dBi, 1710-1880MHz

MATERIALS	Amount	SOURCE	DATABASE IN SIMAPRO
Silicon, production mix, photovoltaics, at plant/GLO U	0.0044 kg	(KATHREIN-Werke KG, 2011)	Ecoinvent unit process
Hydrogen fluoride, at plant/GLO U	0.01 kg	(KATHREIN-Werke KG, 2011)	Ecoinvent unit process
Stainless steel hot rolled coil, annealed & pickled, elec. arc fur	1.18 kg	(KATHREIN-Werke KG, 2011)	ELCD
Polypropylene granulate (PP), production mix, at plant RER	0.708 kg	(KATHREIN-Werke KG, 2011)	ELCD
Polystyrene (general purpose) granulate (GPPS), production mix	0.118 kg	(KATHREIN-Werke KG, 2011)	ELCD
Synthetic rubber, at plant/RER U	0.34 kg	(KATHREIN-Werke KG, 2011)	Ecoinvent unit process

Aluminium casting, plant/RER/I U	0	(KATHREIN-Werke KG, 2011)	Ecoinvent unit process
Aluminium sheet, primary prod., prod. mix, aluminium semi-fin	3.9 kg	(KATHREIN-Werke KG, 2011)	ELCD
Aluminum, cast, semi-permenant mold (SPM), at plant/kg/US	0.144 kg	(KATHREIN-Werke KG, 2011)	USLCI
Copper, at regional storage/RER U	2.27 kg	(KATHREIN-Werke KG, 2011)	Ecoinvent unit process
Brass, at plant/CH U	1.39 kg	(KATHREIN-Werke KG, 2011)	Ecoinvent unit process
PVC injection moulding E	0.0054 kg	(KATHREIN-Werke KG, 2011)	Industry data 2.0
PROCESSES			
Electricity, production mix SE/SE U	900 MJ	Based on our assumption that it is manufactured in Sweden.	Ecoinvent unit process

Table 2.Raw materials and sources for antenna

2.2.2. Antenna Pole

The data is site specific data which is found during the site visit of the pilot site in Kista, Stockholm. Ericsson employees have weighted the sub-systems during the disassembly and CUE DEE AB employee gave the material flow of the product.

The specifications of the Antenna Pole: This is a 4 meters of construction material.

MATERIALS	Amount	SOURCE	DATABASE IN SIMAPRO
Steel, billets, at plant/US	19 kg	(CUE DEE AB ,2011)	USLCI
Glass fibre, at plant/RER U	19kg	(CUE DEE AB ,2011)	Ecoinvent unit process
PROCESSES			
Electricity, production mix SE/SE U	1528.26 MJ	Based on our assumption that it is manufactured in Sweden.	Ecoinvent unit process

Table 3.Raw materials and sources for antenna pole

2.2.3. Battery

The data for the battery is from a previous study within Ericsson.

The specifications of the battery: sealed grid plate solar battery 12V, 230AhC100.

MATERIALS	Amount	SOURCE	DATABASE IN SIMAPRO
Glass fibre, at plant/RER U	1kg	(Ericsson LCA, 2011)	Ecoinvent unit process
Lead, at regional storage/RER U	51.5 kg	(Ericsson LCA, 2011)	Ecoinvent unit process

Synthetic rubber, at plant/RER U	0.4 kg	(Ericsson LCA, 2011)	Ecoinvent unit process
Brass, at plant/CH U	0.4 kg	(Ericsson LCA, 2011)	Ecoinvent unit process
Stainless steel hot rolled coil, annealed & pickled, elec. arc fur	0.5 kg	(Ericsson LCA, 2011)	ELCD
Polycarbonate, at plant/RER U	2.35 kg	(Ericsson LCA, 2011)	Ecoinvent unit process
Acrylonitrile-butadiene-styrene granulate (ABS), production mix	2.35 kg	(Ericsson LCA, 2011)	ELCD
Sulphuric acid, liquid, at plant/RER U	11.5 kg	(Ericsson LCA, 2011)	Ecoinvent unit process
PROCESSES			
Electricity, production mix SE/SE U	15.2 MJ	Based on our assumption that it is manufactured in Sweden.	Ecoinvent unit process

Table 4.Raw materials and sources for battery

2.2.4. Foundation

The data is site specific data which is found during the site visit of the pilot site in Kista, Stockholm. Ericsson employees have weighted the construction parts during the assembling/disassembling test.

MATERIALS	Amount	SOURCE	DATABASE IN SIMAPRO
Portland cement (CEM I), CEMBUREAU technology mix CEMB	114 kg	(Ericsson employee,2011)	ELCD
Sand, at mine/CH U	270 kg	(Ericsson employee,2011)	Ecoinvent unit process
Gypsum stone (CaSO4-dihydrate) DE S	425 kg	(Ericsson employee,2011)	ELCD
Water, deionised, at plant/CH U	166 kg	(Ericsson employee,2011)	Ecoinvent unit process
PROCESSES			
Electricity, production mix SE/SE U	2600 MJ	Based on our assumption that it is manufactured in Sweden.	Ecoinvent unit process

Table 5.Raw materials and sources for foundation

2.2.5. Photovoltaic (PV)

The specifications of the PV: mono-crystalline 180Wp, 24V.

The data specified is based on the LCA study conducted in the University of Michgan for a mono-crystalline PV panel. This paper was the closet to giving the detailed listing of the materials used in manufacturing of the panel.

MATERIALS	Amount	SOURCE	DATABASE IN SIMAPRO
Argon, liquid, at plant/RER U	0.58 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Ammonia E	0.01 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Industry data 2.0

Hydrogen fluoride at plant/GLO U	0.1 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Sulphuric acid, liquid, at plant/RER U	0.39 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Polyethylene, HDPE, granulate, at plant/RER U	1.04 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Flat glass, coated, at plant/RER U	7.49 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Aluminium, production mix, at plant/RER U	2.39 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Tin, at regional storage/RER U	0.2 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Copper, from combined metal production, at beneficiation/SE	0.2 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Polyester resin, unsaturated, at plant/RER U	1.06 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Silica sand, at plant/DE U	4.45 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process

Silicon carbide, at plant/RER U	1.15 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
Polyvinylfluoride, at plant/US U	5.02 kg	(Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian, 2011)	Ecoinvent unit process
PROCESSES			
Electricity, production mix SE/SE U	3080.1 MJ	Based on our assumption that it is manufactured in Sweden.	Ecoinvent unit process

Table 6.Raw materials and sources for PV

2.2.5. Tower

The data for the tower was found with the supplier contact from the CUE DEE AB company. Ericsson employees have weighted the construction parts during the assembling/disassembling test.

MATERIALS	Amount	SOURCE	DATABASE IN SIMAPRO
Galvanized steel sheet, at plant/RNA	550 kg	(CUE DEE AB ,2011)	USLCI
Aluminum ingot, production mix, at plant/US	11.1 kg	(CUE DEE AB ,2011)	USLCI
PROCESSES			
Electricity, production mix SE/SE U	22694.9 MJ	Based on our assumption that it is manufactured in Sweden.	Ecoinvent unit process

Table 7.Raw materials and sources for tower

2.2.6. Data Quality of Use Phase

For the use phase, calculations have been done according to the lifetimes of each sub-system. Since the functional unit is one operation year of the site, each sub-system has been divided into its own lifetime and contribution to the use phase is calculated within the SimaPro with respect to these calculations.

2.2.7. Data Quality of Transportation Phase

In this phase some assumptions and limitations have been made; all the products within the site assumed to be manufactured in Sweden and 300 km of road transport with trucks have been chosen in order to collect all the parts in Kista, Stockholm first. And also for the whole transportation phase directions are chosen from google.maps. The route has been chosen according to which option has the most sea transport mode since to have less environmental impact.

2.2.8. Data Quality of End-of Life Treatment

Since the site is planned to be assembled in Sudan, end-of-life treatment phase will mostly take part in Sudan after disassembly. In this phase some assumptions have been made and also some data gaps are involved since the waste treatment is mostly dependent on land filling. This phase should done with more detailed data and deeper researches from the previous examples in Sudan but since the limited time frame a general quantification has been done including mostly land filling.

3. LIFE CYCLE INTERPRETATION

3.1 Results

3.1.1 Comparison of the system components

The solar powered radio station consists of several components that contribute to the total environmental impact of the system. The contribution of the components of the system is studied according to their impacts on environment. The results may be used to mitigate the solar station's total environmental impact.

Components of the system, antenna, antenna pole, PV, battery, foundation and tower, are compared on each. The comparison of the each sub-system is categorized in environmental impacts. Some of the environmental impacts are not considered in the project due to their low score in normalization of the system. The impacts studied are climate change, human toxicity, ionizing radiation, freshwater eutrophication, freshwater ecotoxicity, marine ecotoxicity, and metal depletion. Each sub-system's normalized environmental impacts are shown in Figure 4.

Nonetheless, CO2 emissions of the solar powered radio station and its components are introduced using SimaPro 7.3.0. The flow charts of CO2 emissions and used raw materials of each sub-system can be found in Appendix. The ReCiPe Midpoint (Hierarchist) method is imposed for the LCIA of the project.

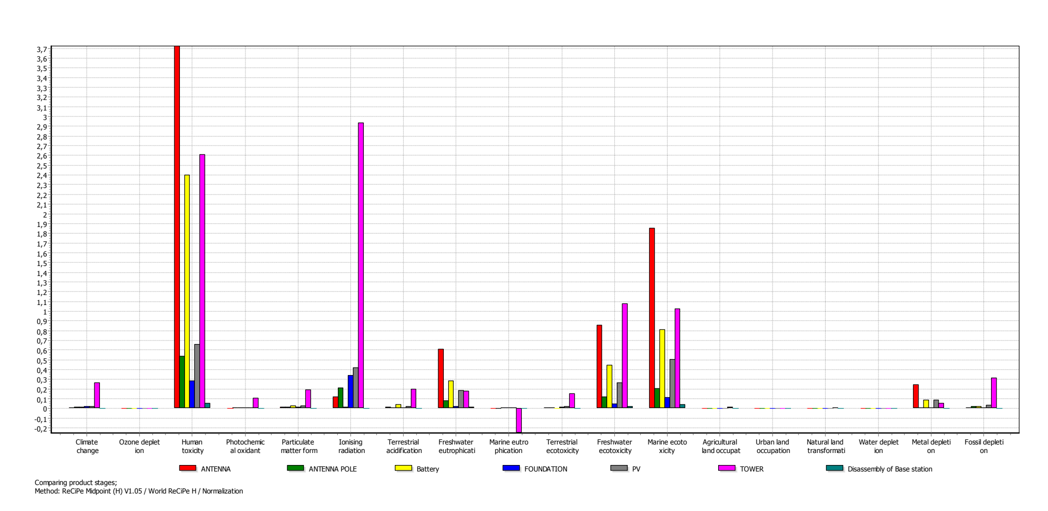


Figure 4: Environmental impacts of the solar powered radio station in normalization.

3.1.1.1. Climate change

The sub-system with the biggest climate change impact is the tower. The tower is made of galvanized steel. The fundamental reason is the weight of the tower. However, Contribution to climate change is not only based on weight but on the production process that includes energy intensive heat treatment and coating. In Figure 5, emissions rate of the solar powered radio station in climate change characterization are shown below. The major emission is CO_2 and followed by methane.

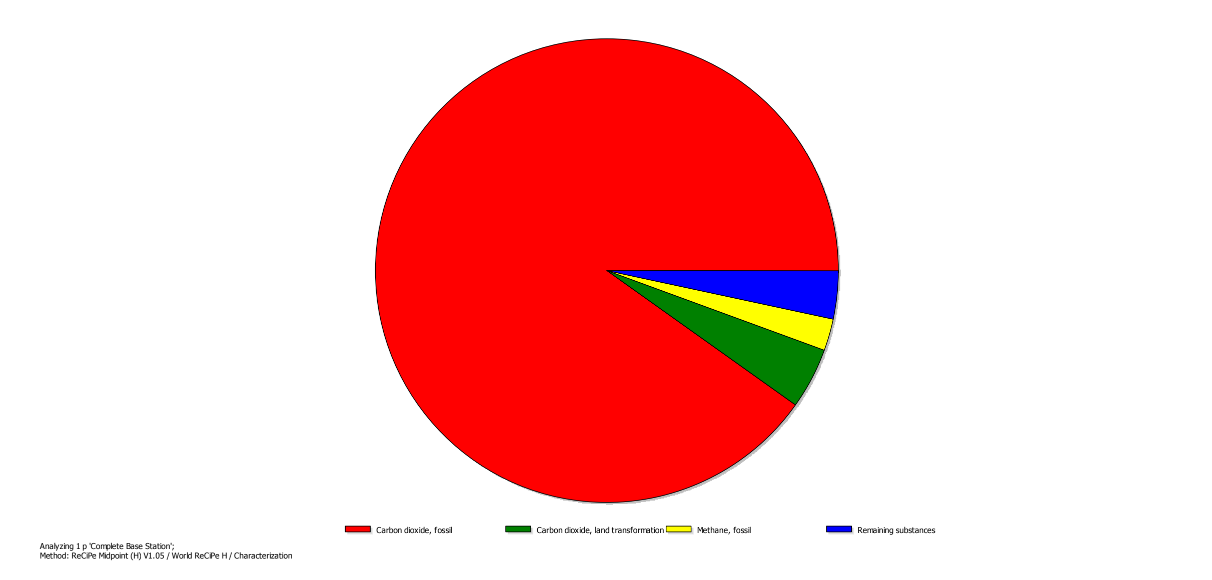


Figure 5: Emissions rate of the solar powered radio station in climate change characterization, cut off: 1%

3.1.1.2. Human toxicity

The biggest impact related to human toxicity is antenna followed by tower and battery. The harmful elements to human health, manganese and arsenic, are included by antenna. Tower is made of galvanized steel and battery has lead in its body, which are also harmful to human body. The rates of these harmful substances are indicated in Figure 6.

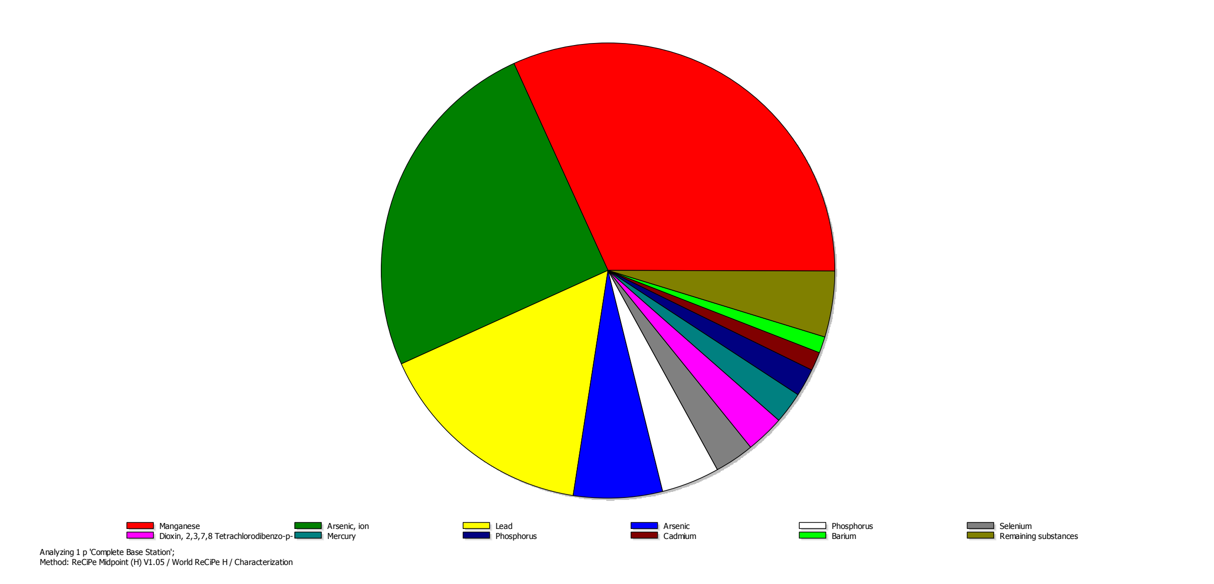


Figure 6: Emissions rate of the solar powered radio station in human toxicity characterization, cut off: 1%

3.1.1.3. Ionizing radiation

The biggest impact related to ionizing radiation is the tower, followed by foundation. As already mentioned, the tower is the heaviest part of the system. Ionizing radiation is related to the emission of radioactive pollutants not directly from the components but indirectly from the use of nuclear power in the manufacturing phase. It is likely that one of the used raw materials contains radioactive materials. In the tower and foundation sub-systems, 99% of the ionizing radiation gasses are emitted, which are radon-222 and carbon-14, can be seen in Figure 7.

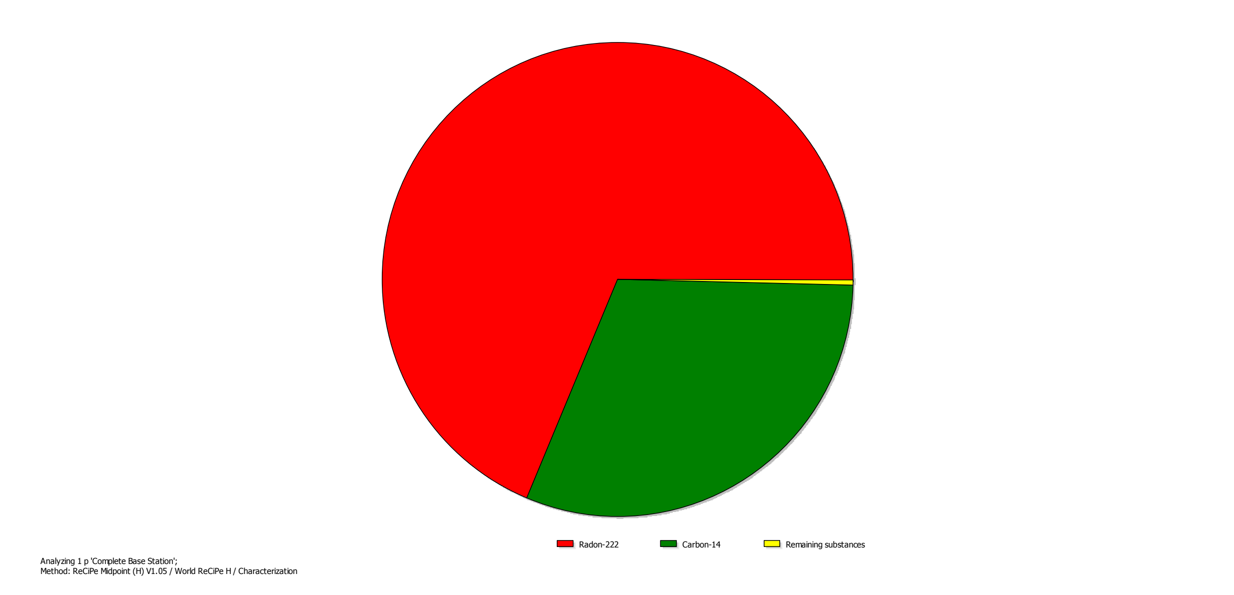


Figure7: Emissions rate of the solar powered radio station in ionizing radiation characterization, cut off: 1%

3.1.1.4. Freshwater eutrophication

The biggest impact is caused by antenna, which contains aluminum, copper and brass. Battery has also big impact that contains lead. Mining can cause erosion issues where phosphorus may be transferred to freshwater. Eutrophication is caused due to excess amounts of phosphorus and nitrogen. The rate of the phosphorus can be seen in the Figure 8.

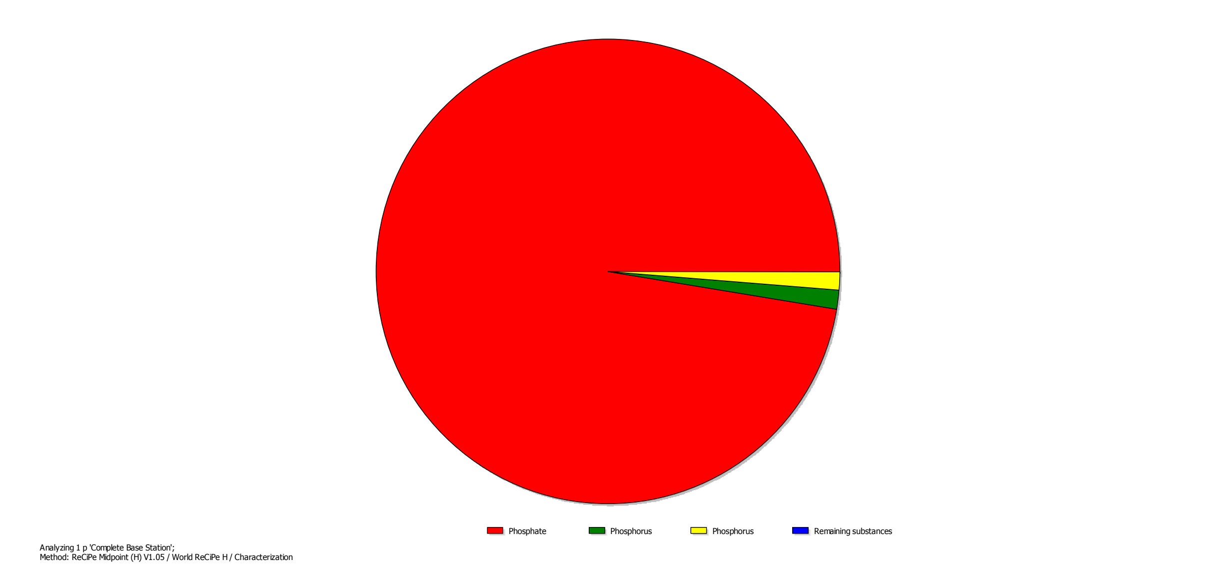


Figure 8: Emissions rate of the solar powered radio station in freshwater eutrophication characterization, cut off: 1%

3.1.1.5. Freshwater and Marine ecotoxicity

Due to their emission of toxics during mining, heavy metal components cause ecotoxicity. Production and extraction of galnanized steel in the tower and aluminum, copper and brass in the antenna are not only to cause heavy metals emission but also lead in the battery. Extraction of the necessary raw materials for the production of antenna and tower mining should be intensive leading to eutrophication problems both to the freshwater and marine. Nikel, manganese, zinc and cyanide are highly emitted by the system;

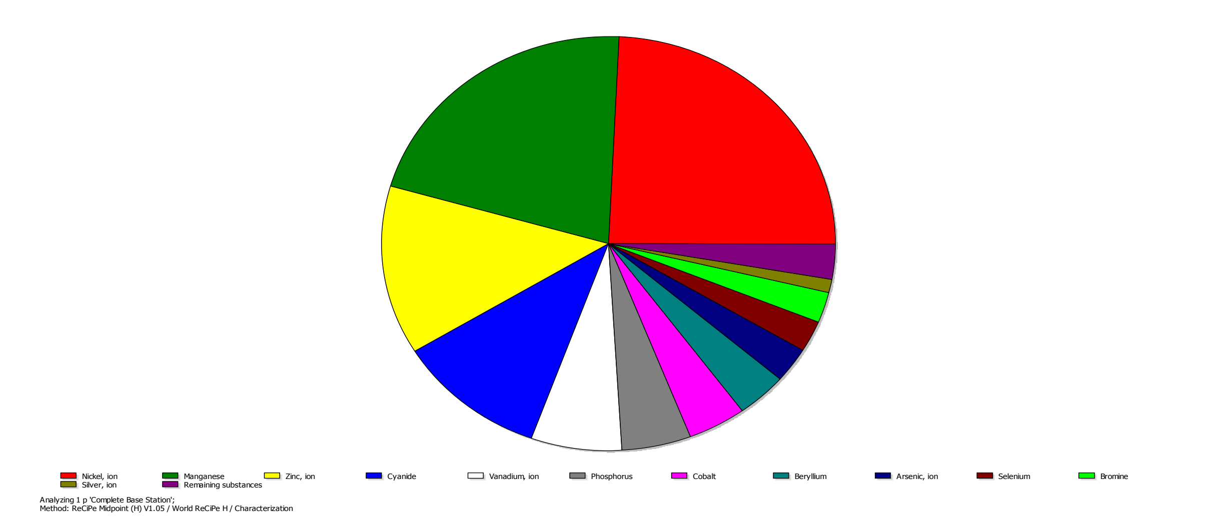


Figure 9: Emissions rate of the solar powered radio station in freshwater ecotoxicity characterization, cut off: 1%

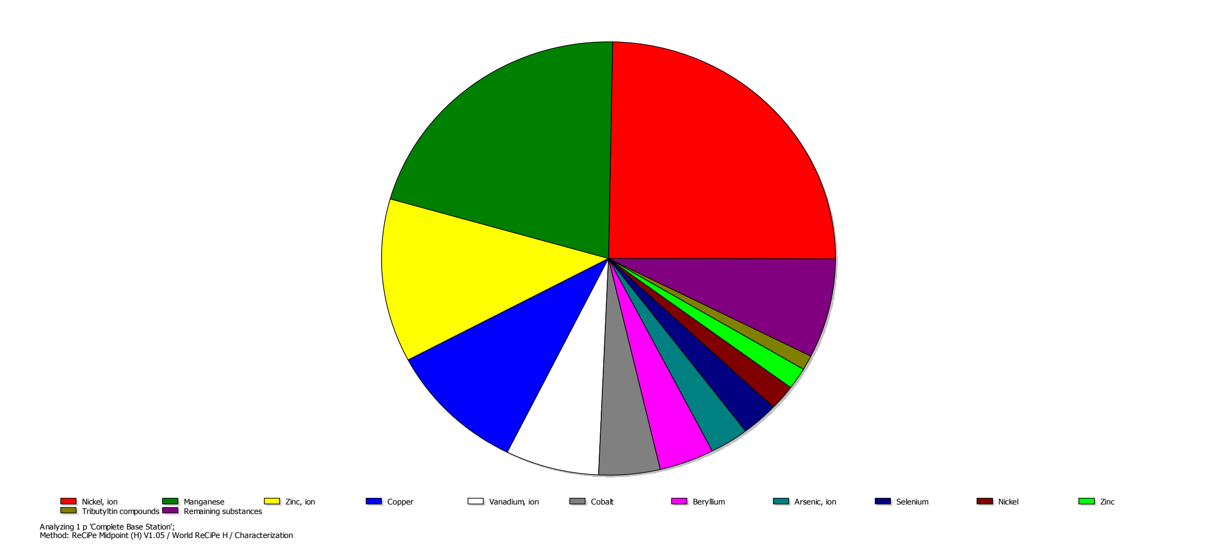


Figure 10: Emissions rate of the solar powered radio station in marine ecotoxicity characterization, cut off: 1%

3.1.1.6. Metal depletion

Tower contains the largest amount of metals is therefore suppose to be the largest contributor. However, antenna has the most impact due to its various kinds of metals. Another sub-system that contributes the metal depletion is battery. The rates of metals are shown in the Figure 11.

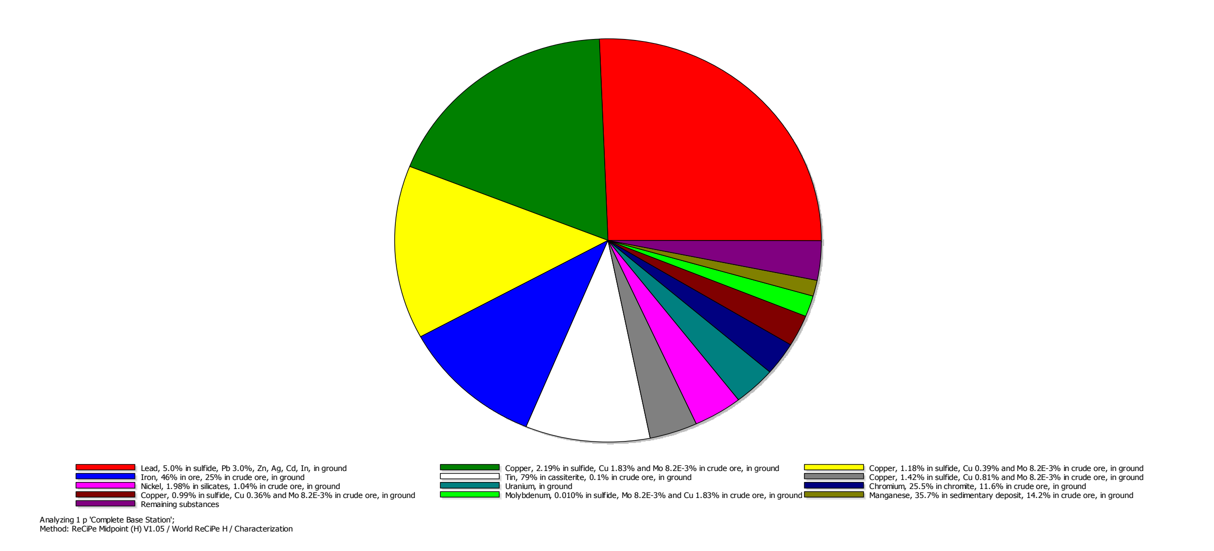


Figure 11: Emissions rate of the solar powered radio station in metal depletion characterization, cut off: 1%

3.1.2. Waste treatment

The contribution of the waste treatment in indicated in Figure 12. Due to low capacity of recycling in Sudan, the waste is incinerated and land filled, can been seen in Appendix. Thus the contribution of the disposal of the system exists in positive site.

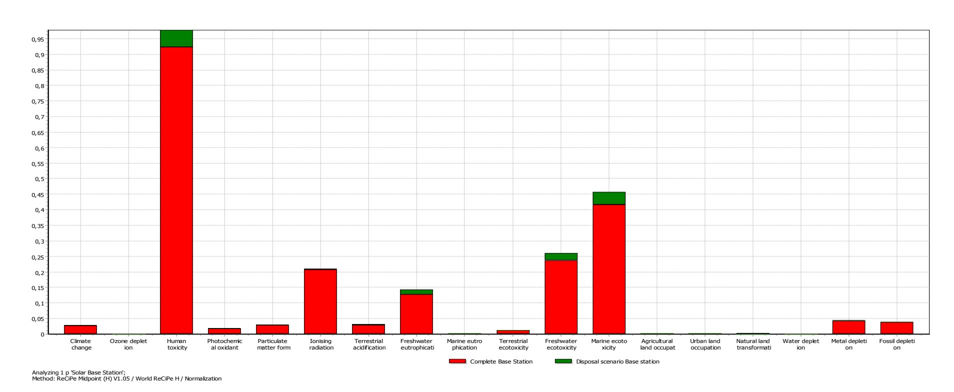


Figure 12: Comparison of the complete solar system and disposal of the system in normalization.

3.1.3. Carbon dioxide emission of the solar powered radio station

One of the main aims of the project shows that how much carbon dioxide is released in the production from one solar powered radio station. Companies mainly focus on carbon dioxide emission of their products due to most well-known environmental impact is carbon dioxide. Network of the carbon dioxide emission of the solar powered radio station is shown in Figure 13. The total CO_2 emission of the radio station is 173kg. The biggest impact related to CO_2 emission is the tower, followed by transportation of the radio station from Sweden to Sudan. Tower contains the largest amount of metals is therefore the largest contributor with 550kg galvanized steel per station, can be seen in Appendix. Other sub-systems' CO_2 contributions are also shown in Appendix.

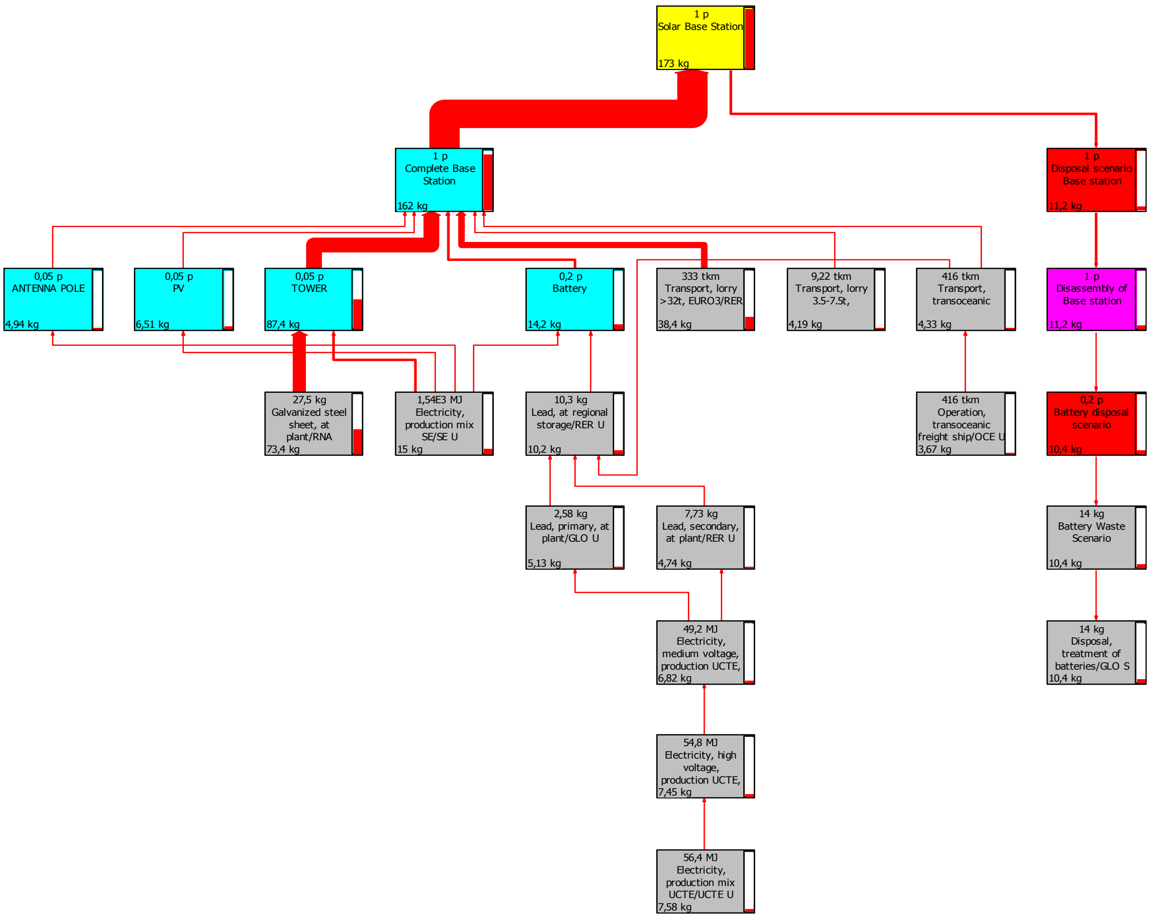


Figure 13: Network of the carbon dioxide emission of the solar powered radio station (kg), cut off 2%

3.2. Conclusions and recommendations

Based on the goals of this project, which aimed to determinate the different environmental impacts of the various sub systems of the solar powered radio station; it is possible to conclude that the most impact categories according to normalization of The ReCiPe Midpoint (Hierarchist) method are climate change, human toxicity, ionizing radiation, freshwater eutrophication, freshwater ecotoxicity, marine ecotoxicity, and metal depletion.

According to the discussed results in this study, CO_2 emission is in considerable amount. Therefore, GHG emission, as the most important factor of the climate change, is higher in the tower. The components that contribute in GHG emission are CO_2, CH_4, O_3, and N_2O so it is obvious that the amount of GHG emission is high in the tower due to weight of the galvanized steel.

Due to the components, manganese and arsenic; antenna has higher human toxicity impact during production. Antenna also has the highest impact in freshwater eutrophication. The major impacts in freshwater and marine ecotoxicity are caused by the antenna and the tower. The tower also has the biggest impact on ionizing radiation. The antenna has the major impact on metal depletion due to its various types of metal components.

Due to the various assumptions made in the study in order to assess the system, we might have excluded one of the major part such as the satellite which may have changed the order of the

This project has been developed to serve as the basis for decision-makers in the process of build ing a solar powered radio station. As a result of the study, the antenna and the tower have the biggest environmental impacts. A company, as a decision-maker, may consider the results of the project and choose other materials in the antenna and the tower in order to build more eco-friendly solar powered radio station.

4. REFERENCES

Baumann, H., Tillman, A-M., 2004. *The Hich Hiker´s Guide to LCA – An orientation in life cycle assessment methodology and application.* 1st ed.

Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian. 2006. *Life Cycle Assessment of the 33 kW Photovoltaic System on the Dana Building at the University of Michigan:Thin Film Laminates, Multi-crystalline Modules, and Balance of System Component.* Ann Arbor : Center for Sustainable Systems, University of Michigan, 2006. CSS05-09.

PRE Product Ecology Consultants 2008. Recipe Report. [Online Report] PRE. *ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level.* 1st ed. Available at: http://www.pre-sustainability.com/content/reports [Accessed 2011-12-01].

Ericsson internal; by Pernilla Bergmark, Anders Andrae, 2001. Lead-acid battery, manufacturing process. 2001-01-15. FCP 103 2560 Uen Rev A (2001).

Ericsson internal; by Jens Malmodin, 2009. Life cycle assessment of Ericsson mobile communication systems. 2009-04-15. Uen PB5 (2009).

External product declarations

KATHREIN-Werke KG, 2011. Product Overview: Data Sheet Outdoor antennas DCS 400, [Online]. Available at: http://www.kathrein.de/en/mcs/index.htm [Accessed 2011-10-25].

CUE DEE AB, 2009. Product and Services Data Sheet antenna pole - tower, [Online].

Available at: http://www.cuedee.se/# [Accessed 2011-10-16].

Personal communication

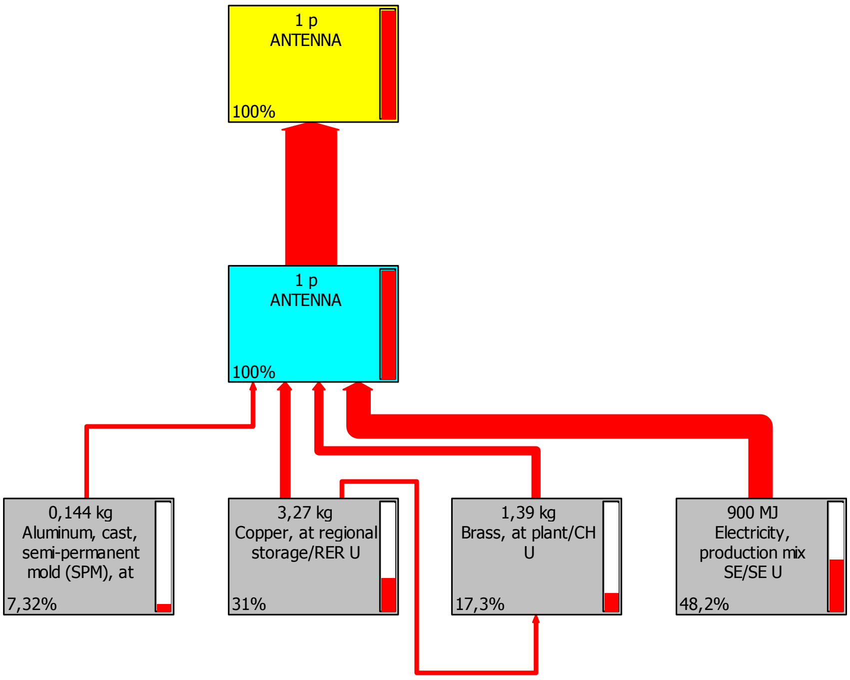
KATHREIN-Werke KG employee; Re: Data to Ericsson research [E-mail] Message to B.Kultur (begum.kultur@ericsson.com). Sent 2011-10-14, 11:36. [Accessed 2011-10-14].

CUE DEE AB employee; Re: Product specification [E-mail] Message to B.Kultur (begum.kultur@ericsson.com). Sent 2011-09-16, 13:47. [Accessed 2011-09-16].

Ericsson employee; Re: Disassembly measurements [E-mail] Message to B.Kultur (begum.kultur@ericsson.com). Sent 2011-08-30, 14:02. [Accessed 2011-08-30].

APPENDIX

A- Antenna, CO_2 emission (kg), cut off 5%



Name: ANTENNA

Image

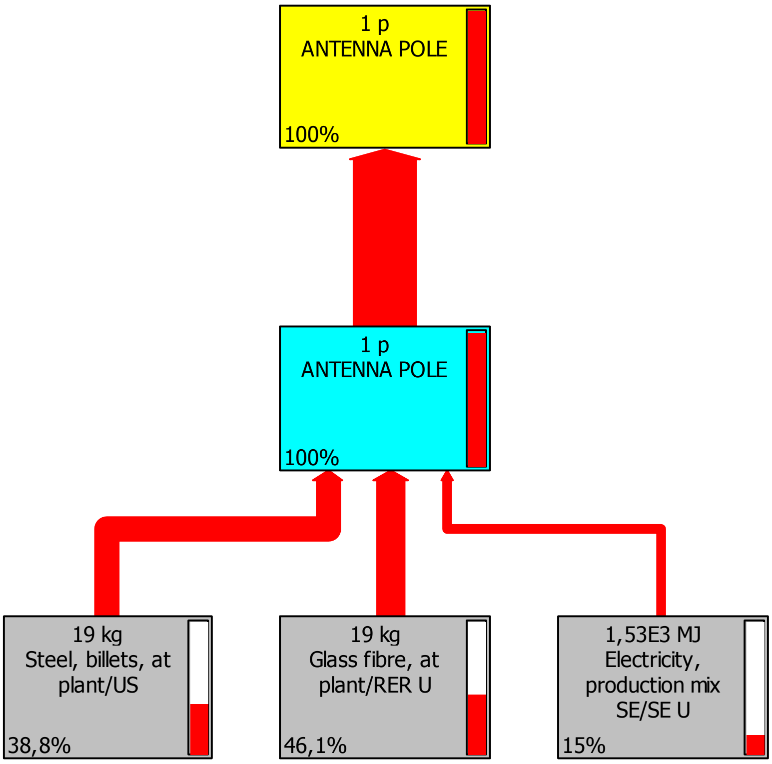
Comment: IMPACT FOR ONE YEAR SHOULD BE FOUND=20 YEARS LIFE TIME (DATA IS FOR 2 ANTENNAS PER SITE)

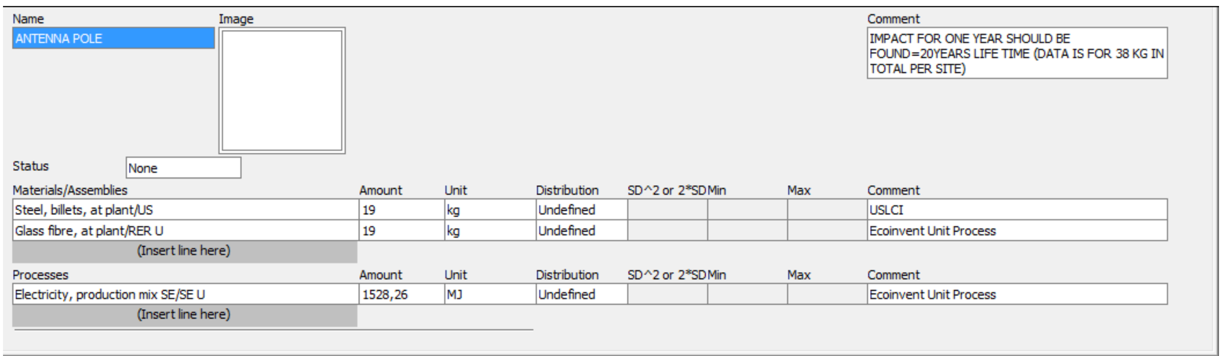
Status: None

Materials/Assemblies	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Silicon, production mix, photovoltaics, at plant/GLO U	0,0044	kg	Undefined				ecoinvent unit process
Hydrogen fluoride, at plant/GLO U	0	kg	Undefined				ecoinvent unit process
Stainless steel hot rolled coil, annealed & pickled, elec. arc fur	1,18	kg	Undefined				ELCD
Polypropylene granulate (PP), production mix, at plant RER	0,708	kg	Undefined				ELCD
Polystyrene (general purpose) granulate (GPPS), prod. mix, F	0,118	kg	Undefined				ELCD
Synthetic rubber, at plant/RER U	0,34	kg	Undefined				ecoinvent unit process
Aluminium casting, plant/RER/I U	0	p	Undefined				ecoinvent unit process
Aluminium sheet, primary prod., prod. mix, aluminium semi-fin	3,9	kg	Undefined				ELCD
Aluminum, cast, semi-permanent mold (SPM), at plant/kg/US	0,144	kg	Undefined				USLCI
Copper, at regional storage/RER U	2,27	kg	Undefined				ecoinvent unit process
Brass, at plant/CH U	1,39	kg	Undefined				ecoinvent unit process
PVC injection moulding E	0,0054	kg	Undefined				INDUSTRY DATA 2.0
(Insert line here)							

Processes	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Electricity, production mix SE/SE U	900	MJ	Undefined				
(Insert line here)							

B- Antenna pole, CO_2 emission (kg), cut off 5%





Name: ANTENNA POLE

Image

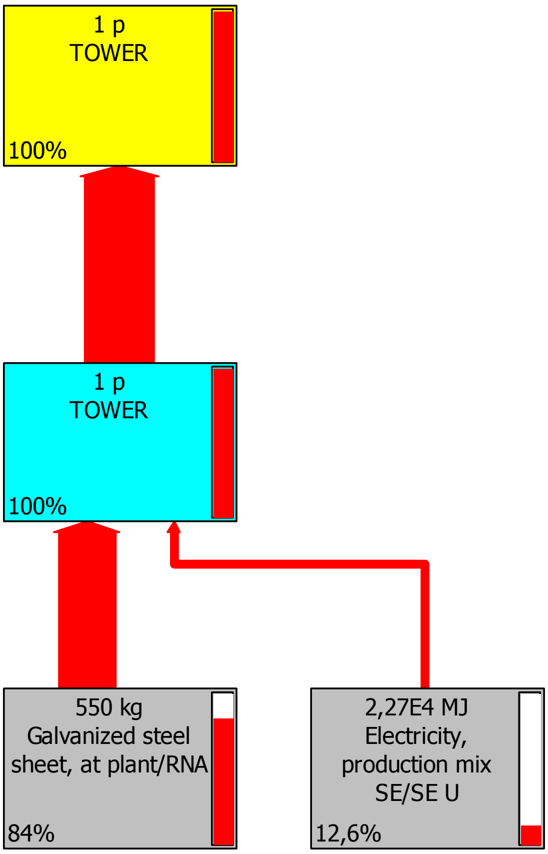
Comment: IMPACT FOR ONE YEAR SHOULD BE FOUND=20YEARS LIFE TIME (DATA IS FOR 38 KG IN TOTAL PER SITE)

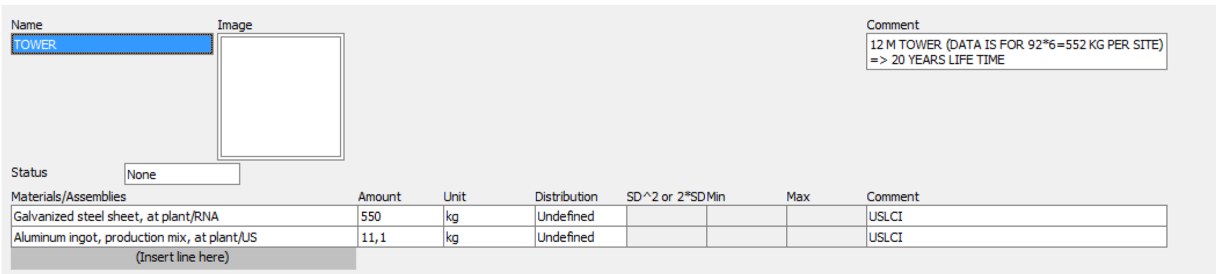
Status: None

Materials/Assemblies	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Steel, billets, at plant/US	19	kg	Undefined				USLCI
Glass fibre, at plant/RER U	19	kg	Undefined				Ecoinvent Unit Process
(Insert line here)							

Processes	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Electricity, production mix SE/SE U	1528,26	MJ	Undefined				Ecoinvent Unit Process
(Insert line here)							

C- Tower, CO_2 emission (kg), cut off 5%




Name: TOWER

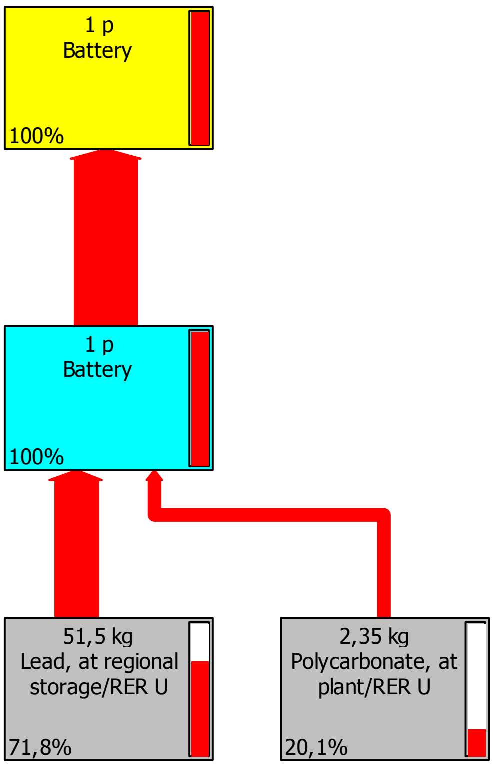
Image

Comment: 12 M TOWER (DATA IS FOR 92*6=552 KG PER SITE) => 20 YEARS LIFE TIME

Status: None

Materials/Assemblies	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Galvanized steel sheet, at plant/RNA	550	kg	Undefined				USLCI
Aluminum ingot, production mix, at plant/US	11,1	kg	Undefined				USLCI
(Insert line here)							

D- Battery, CO_2 emission (kg), cut off 5%



Name: Battery

Image

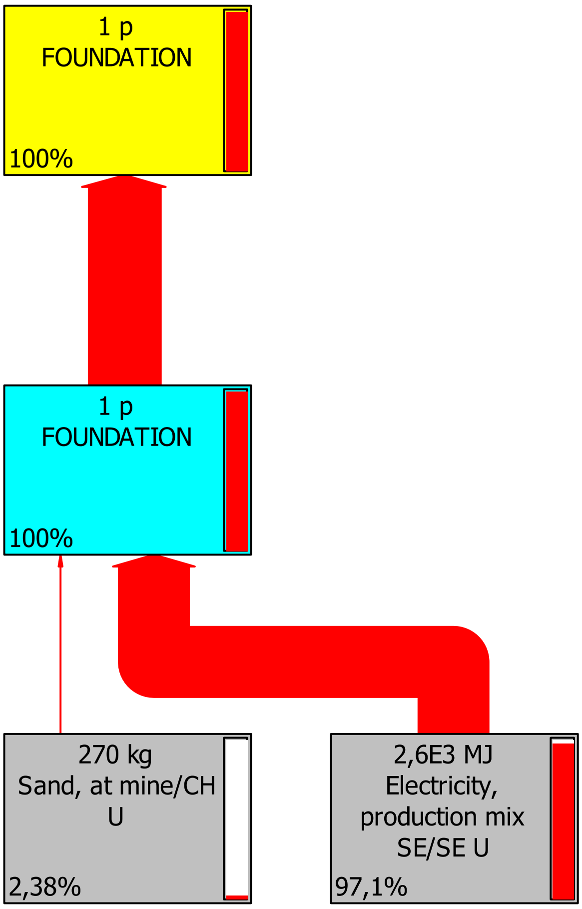
Comment: One Lead Acid Battery
Life Time= 5 years

Status: None

Materials/Assemblies	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Glass fibre, at plant/RER U	1	kg	Undefined				ECOINVENT
Lead, at regional storage/RER U	51,5	kg	Undefined				ECOINVENT
Synthetic rubber, at plant/RER U	0,4	kg	Undefined				ECOINVENT
Brass, at plant/CH U	0,4	kg	Undefined				ECOINVENT
Stainless steel hot rolled coil, annealed & pickled, elec. arc fur	0,5	kg	Undefined				ELCD
Polycarbonate, at plant/RER U	2,35	kg	Undefined				ECOINVENT
Acrylonitrile-butadiene-styrene granulate (ABS), production n	2,35	kg	Undefined				ELCD
Sulphuric acid, liquid, at plant/RER U	11,5	kg	Undefined				ECOINVENT
(Insert line here)							

Processes	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Electricity, production mix SE/SE U	15,2	MJ	Undefined				
(Insert line here)							

E- Foundation, CO_2 emission (kg), cut off 2%



Name: FOUNDATION

Image

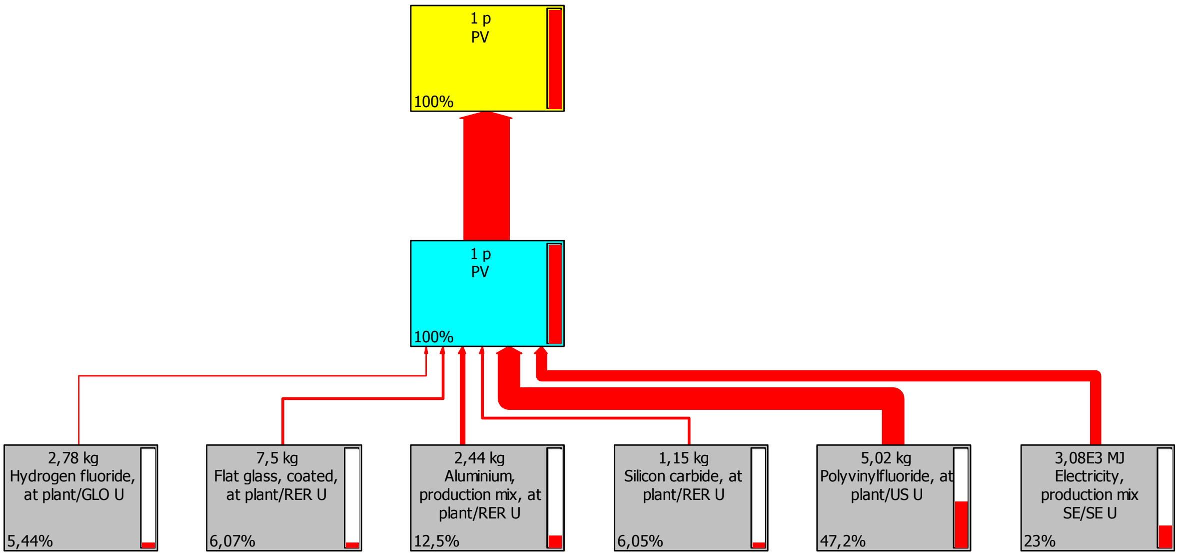
Comment: Life time= 20 years

Status: None

Materials/Assemblies	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Portland cement (CEM I), CEMBUREAU technology mix, CEMB	114	kg	Undefined				ELCD
Sand, at mine/CH U	270	kg	Undefined				ECOINVENT
Gypsum stone (CaSO4-dihydrate) DE S	425	kg	Undefined				ELCD
Water, deionised, at plant/CH U	166	kg	Undefined				ECOINVENT
(Insert line here)							

Processes	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Electricity, production mix SE/SE U	2600	MJ	Undefined				ECOINVENT
(Insert line here)							

F- PV, CO_2 emission (kg), cut off 5%



Name: PV

Image

Comment: One PV Module, 11.9 kg
Life Time= 20 years

Status: None

Materials/Assemblies	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Argon, liquid, at plant/RER U	0,58	kg	Undefined				ECOINVENT
Ammonia E	0,01	kg	Undefined				INDUSTRY DATA 2.0
Hydrogen fluoride, at plant/GLO U	0,10	kg	Undefined				ECOINVENT
Sulphuric acid, liquid, at plant/RER U	0,39	kg	Undefined				ECOINVENT
Polyethylene, HDPE, granulate, at plant/RER U	1,04	kg	Undefined				ECOINVENT
Flat glass, coated, at plant/RER U	7,49	kg	Undefined				ECOINVENT
Aluminium, production mix, at plant/RER U	2,39	kg	Undefined				ECOINVENT
Tin, at regional storage/RER U	0,02	kg	Undefined				ECOINVENT
Copper, from combined metal production, at beneficiation/SE	0,02	kg	Undefined				ECOINVENT
Polyester resin, unsaturated, at plant/RER U	1,06	kg	Undefined				ECOINVENT
Silica sand, at plant/DE U	4,45	kg	Undefined				ECOINVENT
Silicon carbide, at plant/RER U	1,15	kg	Undefined				ECOINVENT
Polyvinylfluoride, at plant/US U	5,02	kg	Undefined				ECOINVENT
(Insert line here)							

Processes	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Electricity, production mix SE/SE U	3080,1	MJ	Undefined				ECOINVENT
(Insert line here)							

G- Waste, CO_2 emission (kg), cut off 5%