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A comparative Life Cycle Analysis of new and old designs of crane truck frames - Case study at Vemservice

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Abstract

The main objective of this Bachelor's thesis is to investigate and deliver the results of environmental impacts of two different designs of crane truck frames. The aim is to investigate if additional new design of crane truck frames, with less energy and transportation during manufacturing of the crane truck, can improve energy efficiency of crane trucks throughout their lifecycle. Case study object for this report is Vemservice in Vemdalen, Sweden. As basis for the report the The Life Cycle Analysis ISO 14040 and ISO 14044 are used in this report in order to evaluate and compare the environmental impacts related to the lifecycle of new and old designs of 92 tonmeter crane truck frames from cradle to grave. The data was mainly collected and calculated by using the SimaPro software 8.0.5 which is based on the Ecoinvent 3 database. This study mainly analyzes environmental impacts such as GWP (Global Warming Potential), CED (Cumulative Energy Demand) and ReCiPe environmental impacts. The results showed that although new design frame has less transportation and energy demand during the manufacturing phase of the crane truck, the overall life cycle of the new design crane truck frame has higher environmental impacts than the existing old design of the crane truck frame. This is due to that the new design frame is 213kg heavier than the old design frame, which the crane truck is carrying during its using period. This study also investigated whether the new design frame, with stronger steel (Ecoupgraded steel) and a reduction of 15% of the total weight of frame, has a lower environmental impact in the life cycle of the EcoUpgraded steel frame compared to the current new design and old design frames life cycle.

Key words: LCA, Life cycle analysis, Crane truck, GWP, global worming potential, CED, cumulative energy demand.

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Mahmudur Khan Aryan Rahman, 2018

KEY TO ABBREVIATIONS

CED	**Cumulative Energy Demand**
GWP	**Global Warming Potential**
GHG	**Greenhouse Gas**
ISO	**International Organization for Standardization**
LCA	**Life Cycle Assessment**
LCI	**Life Cycle Inventory**
LCIA	**Life Cycle Impact Assessment**
GWP 100	**Global warming potential calculated on a time interval of 100 years**
Kg CO2-eq	**Carbon dioxide equivalents in kilogram**
MJ	**Megajoule**
GJ	**Gigajoule**
TJ	**Terajoule**
Pt	**Point**
SSAB	**Svenskt Stål Aktiebolag (Swedish Steel Corporation)**
HYBRIT	**Hydrogen Breakthrough Ironmaking Technology**
92 tm Crane truck	**92 Tonmeter crane mounted on a truck**
Tkm	**Ton kilometre**
Cradle-to-gate	**Raw material extract to product manufacture**
Cradle-to-grave	**Raw material extract to product end life**

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1. Introduction

A crane truck is a truck that has a crane mounted on the truck. The truck can carry-out lifting work and transporting of goods at the same time. A crane truck is the most widely used crane installed on ordinary trucks or tailor-made chassis with strong operability (Sang et al., 2016). Beddows and Harrison's (2008) study showed that the emission factors depends on the vehicle type, the vehicle gross weight, the engine size, fuel and emission legislation and the road condition such as rural, urban or a highway road. Dhingra and Das' (2014) LCA study expressed that reducing the weight of the vehicles is one way of achieving better fuel economy during the use stage of the automobile's life cycle. This can be done by replacing the cast iron and steel in the engine with other lighter weight metals (Dhingra & Das, 2014). In the study of Kelly et al. (2015), it was showed that material substitution can reduce vehicle weight, and it often increases vehicle-cycle (all the process related to manufacturing cycle) GHGs. This is due to replacing steel with other metal such as aluminium might be a better option, which will increase vehicle-cycle (until manufacturing cycle) GHGs. However, lifetime fuel economy benefits often overcome the vehicle manufacturing cycle, resulting in a net total life-cycle GHG benefit (Kelly et al., 2015). The vehicles' life cycle use stage impact directly depends on the quantity of fuel consumed (Nemry et al., 2008). Koffler and Rodhe-Branburger (2010) study expressed that vehicles' total weight has significant affect of fuel consumption and about one third of total fuel consumption directly depends on vehicles mass. The total weight reduction of a crane truck may have less environmental impacts in the life time. On the other hand, all the process related to the manufacturing cycle of a crane truck, such as reducing energy and transportation during manufacture period but increasing the total weight of a crane truck, is likely to increase the total environmental impacts of the crane truck's lifecycle.

1.1. Background

This study is part of a project of crane truck manufacturing company called Vemservice that is situated in Vemdalen, Sweden. This project is partly funded by the Swedish Vehicle Strategic Research and Innovation (FFI, 2015) and Swedish Energy Authority (in Swedish Energimyndigheten). The name of the project is 'Additional decision-research and development on increased energy efficiency of crane trucks' (Energimyndigheten, 2014).

The project aims to investigate if additional new design of crane truck frames, with less energy and transportation during manufacturing of the crane truck, can improve energy efficiency of crane trucks throughout their lifecycle.

Vemservice is taking into account the entire life cycle of their crane trucks which is important according to FFI's (Fordons Strategisk forskning och innovation) strategic roadmap (FFI, 2015). Therefore, it is important to take into account the energy consumption during production, which is an important factor during the project new design application.

1.1.1. Crane truck

The main functions of a crane truck is that it can carry out lifting work, carry goods all over the truck and it can be driven on both motorways and individual roads. The crane truck can transport what is to be lifted and possible to drive in near to the place where the goods are to be lifted to or from. The crane truck also has the possibility of angling the lifting arm so that, for example, it can lift an object from a room high up or grab an object further away from the truck's support legs (Alkerud & Larsson, personal communication, April 18, 2018).

Figure 1.1: Activities of crane truck manufactured by Vemservice (Vemservice, 2018).

1.1.2. Crane truck for this study (Vemservice)

Vemservice manufactures and delivers different crane sizes of crane trucks, depending on the crane lifting capacity which is decided by the customers. At present they manufacture crane trucks mostly mounted with 92 tonmeter crane, 78 tonmeter crane or less than 78 tonmeter cranes. For this study, the crane truck mounted with 92 tonmeter crane has been chosen that has total weight of 26 tonnes without load. The crane truck can transport a capacity of maximum 6 tonnes. So the total weight of this type of crane truck including load is 32 tonnes. The total weight of the frame of crane truck with 92 tonmeter crane is 2117 kg (Alkerud & Larsson, personal communication, April 18, 2018). The figure 1.2 shows the current old design frame with one pair of beam for the crane truck with 92 tonmeter crane. The truck used for crane truck at Vemservice is usually Volvo and Scania with Euro 6 engine (Vemservice, 2018). The total of weight of crane truck should not exceed more than 32 tonnes according to Swedish Transport Agency (Transportstyrelsen, 2010).

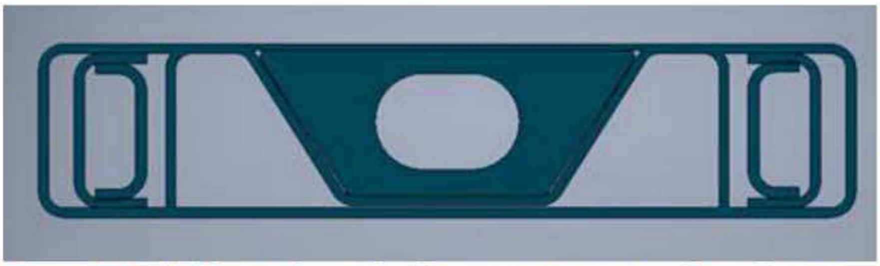

Figure 1.2: Old design frame for 92 tonmeter crane trucks with one pair of beam in cross section view. (SSAB, n.d.)

1.1.3. New design crane truck for this study

New design frame 92 tonmeter crane truck was chosen for this study to make a reasonable life cycle analysis comparison with the old design frame 92 tonmeter crane truck. This is due to both crane trucks having the same kind of crane that is mounted in the truck. The weight of the new design 92 tonmeter crane truck frame is 2330 kg which is 213 kg more than old design crane truck frame. That means new design crane truck will carry this additional 213 kg weight in its whole life cycle period. This additional 213 kg is due to extensive new design which is increases crane truck strength during lifting operation and transportation goods. Figure 1.3 shows new design frame with two pair of beams for 135 tonmeter crane truck. New design frame for 92 tonmeter crane truck will have one pair of beam instead of two pair of beams.

Figure 1.3: New design of crane truck central frame with double beam in cross section view. (SSAB, n.d)

The table 1.1 shows the different types of crane truck frames, their weights and the types of crane that fits according to the frame. The LCA comparison was chosen in this study between old design frame with one pair of beam and new design frame with one pair of beam and both frame having the same crane 92 tonmeter that mounted on trucks (Blue text in table 1.1).

Frame Type	Weight of frame	Crane size for trucks
Old design frame without pair of beams	1782 kg	78 tonmeter or less
Old design frame with 1 pair of beams	2117 kg	92 tonmeter
New design frame without pair of beams	1862 kg	78 tonmeter or less
New design frame with 1 pair of beams	2330 kg	92 tonmeter
New design frame with 2 pair of beams	2695 kg	135 tonmeter

Table 1.1: Frame types, frame weights and crane sizes. (SSAB, 2017)

The weight difference between new and old design 92 tonmeter crane truck frame = (2330kg – 2117kg)
= 213kg

1.1.3. Why new design crane truck frame?

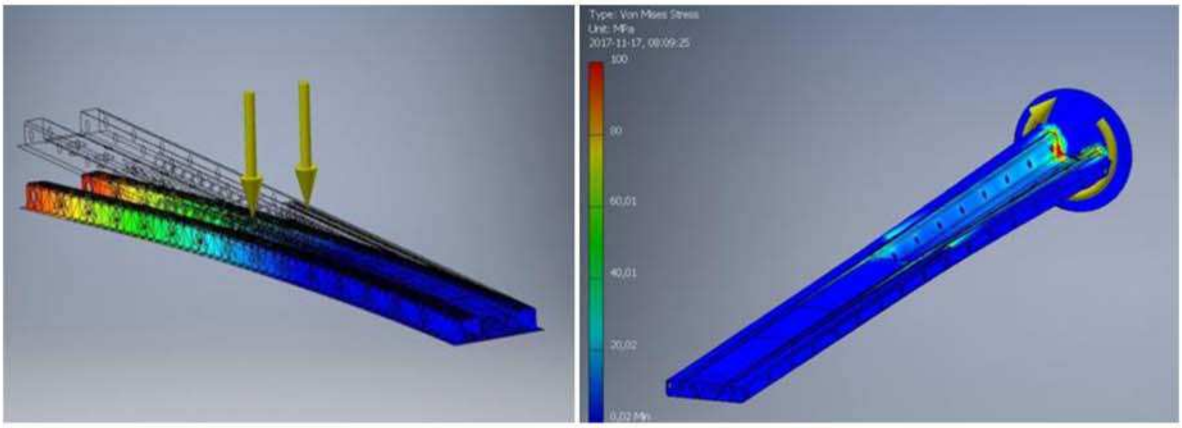

Figure 1.4: Bending resistance and torsional stiffness of new design of crane truck central frame.(SSAB, n.d.)

The SSAB's FEM mechanical study report shows (figure 1.4) that additional new design of the crane truck's central frame increased three times bending resistance and 1.5 times torsional stiffness from the old design crane truck frame (SSAB, 2017; SSAB, n.d.). Bending resistance means new design frame will be more stable instead of bending during transportation goods on crane truck (figure 1.4 left).

According to Larsson and Alkerud (personal communication, April 18, 2018) by implementing a new design, the lifting capacity of crane trucks can make it possible to increase mounting from 92 tonmeter crane to 135 tonmeter crane. This is due to torsional stiffness of new design frame, which means that when a crane will lift goods the truck will be standing stable instead of tilted one side. Vemservice's aim is to replace mobile cranes with truck cranes to a greater extent through increased lifting capacity for truck cranes. The new design crane truck body frame construction will be bolted instead of welded. This can make the new design crane truck frame easier to transport during the crane truck manufacture at Vemservice. The new design will allow transporting the production of materials five times more because it will come as flat packets from SSAB to Vemservice. Moreover, the new design body frame will be allowing a single construction to be used for all chassis brackets like Volvo 850 and Scania's 770 mm. The new design crane truck with double beam (figure 1.3) frame can increase lifting capacity by mounting 135 tonmeter cranes in the truck. In that case, the crane's own weight increases by two tonnes and the frame weight with double beam is 2695 kg. The total weight of the truck with 135 tonmeter crane will be around 28.5 tonnes and still it will be allowed to carry goods of maximum 3.5 tonnes. For additional goods transportation a trailer can be added (Alkerud & Larsson, personal communication, April 18, 2018).

1.2. Problem definition

The project's relevant objectives express that old design crane truck frames' may have higher energy consumption in the crane truck manufacturing stage due to welding, only one crane truck frame can be transported to Vemservice at a time and after that be transported additionally two times for painting during manufacturing of the crane truck at Vemservice.

The current old design crane truck frames' bending resistance and torsional stiffness may need to be improved in order to increase transportation of goods and crane lifting capacity. The new design crane truck is capable to replace mobile cranes in some case by mounting high lifting capable 135 tonmeter crane in the truck.

2. Goal and scope definition

2.1. Goal

The main goal of this study is to make a comparative LCA cradle-to-grave (raw material extraction to end life) between the existing old design frame of crane trucks and the new design frame of crane trucks.

Comparison between old and new crane truck frames of cradle-to-gate (from raw material extraction to crane truck manufacture) will be conducted in this LCA study since cradle-to-gate is a part of cradle-to-grave of a product. It is important to show also cradle-to-gate in this study in order to evaluate old and new design crane truck manufacture at Vemservice. Hence, Vemservice takes into account the energy consumption during production, which is an important factor during the project new design application.

The investigation is a case study of the crane trucks manufactured at Vemservice in Vemdalen, Sweden. This LCA study aims to identify which design (old design or new design) of the crane truck that have the highest environmental impact in global warming potentials, energy demand, and other environmental impacts and why they have such values.

2.2. Methodology

The Life-cycle assessment (LCA), also referred to as Life-cycle analysis, is a cradle-to-grave analysis methodology used in this study in order to quantify and compare the environmental impacts between the old design crane truck body frame with the new design crane truck body frame. Cradle-to-gate analysis is also used in this study in order to show the environmental impacts from raw material extraction for crane truck frame to crane tuck manufacture at Vemservice. Life-cycle assessment is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. This study is followed according to the ISO 14040 (ISO 14040:2006, 2016) and ISO 14044 (ISO 14044:2006, 2016) regulations that describe following four basic steps of the assessment procedure:

(1) Goal and scope definition,

(2) Life cycle inventory (LCI),

(3) Life cycle impact assessment (LCIA)

(4) Life cycle interpretation.

2.2.1. System boundary

The system boundary chosen to this LCA study was ‘cradle to grave’ of the crane truck frame. This type of system boundary includes a product’s extraction of raw materials, manufacturing, transportation, use and end life.

The system boundary in this study (figure 2.1) included the frame of crane truck that is produced of low-alloyed steel production at SSAB, processed steel used for manufacturing the crane trucks at Vemservice, transportation during manufacturing of crane trucks, and transportation and maintenance during the use phase of crane trucks to end-life. This study will especially investigate the energy consumption and environmental impacts of two different designs of the crane truck frames in their life cycle.

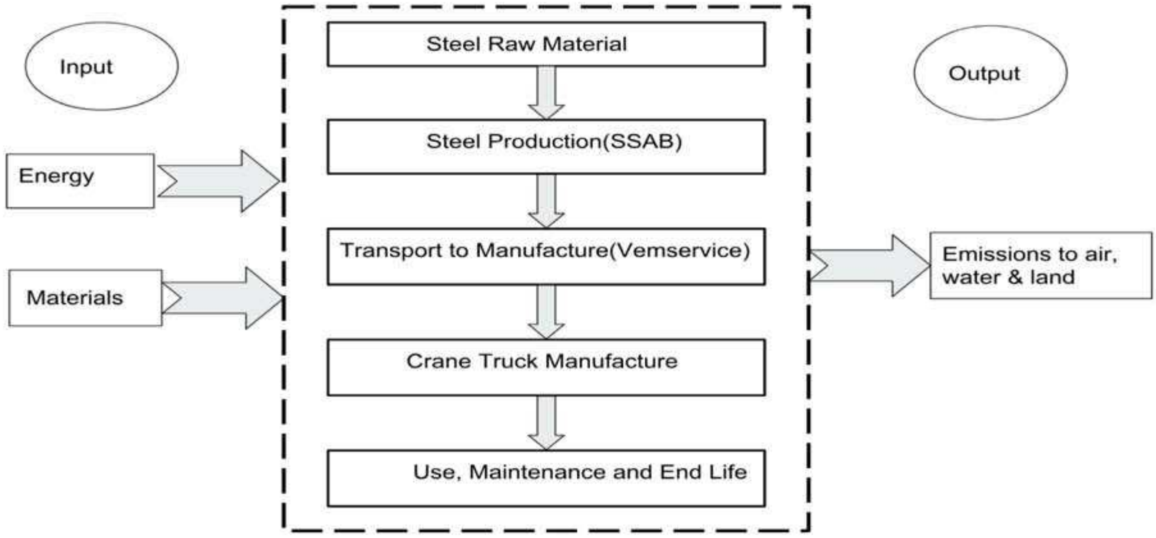

Figure 2.1: System Boundary of the study.

The included and excluded factors of this study are shown in Table 2.1. Since this is a comparative LCA from cradle-to-grave, the study has been limited to include the part that has highest to minimum lowest impact on the crane trucks frame life cycle.

Included factors		**Excluded factors**
Steel raw material extraction for crane truck frame		Energy for steel bending, laser cutting, welding outside at Vemservice.
Primary steel production and process at SSAB		Truck manufacture
Electricity and energy for steel manufacture		Crane manufacture
Steel frame transport to crane truck manufacture at Vemservice		Energy for painting
Transportation of crane truck for painting		Human labour energy
Total electricity use at Vemservice yearly		Crane lifting energy and emission
Crane truck use phase, operation, maintenance and end of life of vehicle and road infrastructures		Transportation of stakeholders (for instance workers and costumers)
Transportation of goods		Industrial buildings and equipment of the manufacturing industry

Table 2.1: Included and excluded factors of the study

2.3. Data collection methods

2.3.1. Primary data

The primary data was collected from the description of the project (FFI Energi och Miljö, 2017) and SSAB's mechanical study (SSAB, 2017). The additional data has been collected by interviews with project developers Benny Larsson and Christer Alkerud from the crane truck manufacturing company Vemservice. Additional data related to steel production was collected by interviewing Erik Hansson who is responsible as a technical support for SSAB's Eco –upgraded steel production.

2.3.2. Background data, data quality and assumption

The background data is based on average datasets that was mainly collected and calculated by using the SimaPro software 8.0.5 (SimaPro, 2016) which is based on the Ecoinvent 3 database. The Ecoinvent version 3 database contains LCI data from various sectors such as materials of different metal, energy production, transportation, production of chemicals etc. The entire database consists of over 10,000 interlinked datasets, each of which describes a life cycle inventory on a process level (Ecoinvent, 2017). This database is used in this study in order to acquire inventory data from the manufacturers and use phase to assess environmental impacts. Ecoinvent 3 database is recognised being the internationally most consistent, transparent and updated database for life cycle inventory. The activities of life cycle inventory analysis in the SimaPro database chosen for this study were European condition (used as {RER} in SimaPro database) at first and then as much as close to Swedish conditions as possible chosen in the SimaPro database (Frischknecht et al., 2007). Moreover, some of the estimation data based on assumptions which were used in this study were based on interviews, a literature study and previous studies.

2.4. Functional unit

One (1) 92 tonmeter crane truck frame is assumed to have a life cycle of 500,000 km on a crane truck.

2.5. Life cycle impact assessment method categories

Life cycle impact assessment (LCIA) helps to evaluate the magnitude and significance of the potential environmental impacts of a product or a service throughout its entire life cycle based on LCI (LC-Impact, 2016). The LCIA was expressed by using the LCA software package SimaPro v.8.0.5 (SimaPro, 2016). The results of the LCIA methods were calculated and the main sources of environmental impacts identified. Three life cycle impact methods were chosen in order to communicate and compare the results of this study, which were 1) IPCC (2013) GWP 100a, 1) Cumulative energy demand (CED) and 3) European ReCiPe (H). The impact assessment steps were Characterization, Damage Assessment, Normalization, Weighting and Single Score (Hischier et al, 2010).

2.5.1. The IPCC GWP 100a

The IPCC GWP 100a 2013 is the successor of the IPCC 2007 method, which was developed by the Intergovernmental Panel on Climate Change. According to IPCC 2007, assessments of climate change impacts, adaptation and vulnerability are undertaken to inform decision-making in an environment of uncertainty. GWP is the most commonly used environmental impact method that is used in LCIA. The IPCC GWP 100a method provides a quantitative assessment of the impact of the greenhouse gas effect as a function of the carbon dioxide equivalent (CO2 eq.) released during the assumed time horizon of 100 years (IPCC, 2013). Global warming potential (GWP 100a) was chosen in this study in order to compare the potential climate change associated with emissions of different greenhouse gases over a 100 years period. The characterisation values for greenhouse gas emissions are based on global warming potentials published by the IPCC (IPCC, 2013).

2.5.2 Cumulative energy demand (CED)

Energy consumption is one of the most important aspects of crane truck frame production from steel and the crane truck use phase. Methods to calculate Cumulative Energy Demand (CED), based on the method published by ecoinvent version 2.0 and expanded by PRé Consultants for raw materials, are available in the SimaPro 8.0.5 database (Frischknecht et al, 2007).

The CED method is chosen in this study in order to investigate and compare new and old design crane truck frame's energy demand through the lifecycle of a crane truck. The CED methods includes the direct and indirect energy or grey energy used throughout the life cycle of the product and that is included in the energy consumed during the raw materials extraction, manufacturing, and disposal of raw materials. This method consists of five resource categories: two non-renewable (fossil and nuclear) and three renewable (biomass, water and "wind, solar, geothermal"), which are given for the energy resources as characterization factors (Hishier et. Al., 2010).

2.5.3 European ReCiPe (H) endpoint, hierarchist version.

European ReCiPe endpoint (H) characterization method is chosen in the study in order to present and compares the old and new design crane trucks' effects on human health, ecosystem and resource consumption. European ReCiPe (European H/A) refers to the normalisation values of Europe with the average weighting set (Simapro, 2018).

In ReCiPe methods, the indicators are established at two levels that are midpoint level and endpoint level. The midpoint level has 18 indicators that show single environmental impacts such as ozone depletion, human toxicity and freshwater eutrophication etc. The endpoint indicators show the environmental impact on three higher accumulation levels which have effect on 1) human health, 2) ecosystem and 3) resource scarcity. Converting midpoints to endpoints simplifies the interpretation of the LCIA results. The ReCiPe unit point (Pt) expressed the total environmental impact as a single score which is combined with characterization, damage assessment, normalization and weighting (Goedkoop et al., 2009).

3. Life Cycle Inventory (LCI)

3.1 Primary steel production

For this inventory, steel, low-alloyed steel production, converter and allocation default system with EU technology mix was selected in the SimaPro database. This process produces primary steel which is included in cradle-to-gate of steel production, which means that this process includes raw material extraction to processed steel for crane truck frames. Transports of hot metal and other input materials to converter, steelmaking process and casting are included in the process. Electricity high voltage Swedish mix was selected in SimaPro database for steel production at SSAB due to larger industry usually uses high voltage electricity in their production. According to the SSAB Environmental product declaration ISO 14025 report, for 1kg cold-rolled steel plates, sheets and coils production energy needed is 29.8MJ/kg or 8.27 kWh/kg and GWP is 2.66 kg CO2eq/kg of steel production (SSAB, 2014). Since the crane truck steel frame is produced by SSAB, therefore an additional 1.7 kWh electricity was added for 1 kg steel production in the SimaPro database, in order to make balance with energy and GWP.

3.2 Transportation during crane truck manufacturing at Vemservice

According to the project developers Benny Larsson and Christer Alkerud (personal communication, April 18, 2018), the old design of one single crane truck frame is transported around 1000 km before arriving at Vemservice. And then it needs to be transported 400 km twice for being painted. Hence, the total transportation for one crane truck of the old design was calculated to be 1800 km.

For new design crane trucks, five frames as flat packets at a time including one painting will be able to be transported to Vemservice and the distance will be around 1000 km. This means 200 km distance for one new design crane truck frame. It needs to be transported 400 km for one more time painting. So the total transportation was calculated 600 km during one new design crane truck manufactured at Vemservice.

Transport, freight lorry >32 metric ton, Euro 3 {RER} was selected in the SimaPro database during the transportation of crane truck frame from SSAB until Vemservice. Transport, freight lorry 16-32 metric ton, Euro 6 {RER} was selected during the painting phase due to crane truck assembled Euro 6 engine (Ecoinvent 3, 2015).

3.3 Electricity for crane truck frame manufacturing at Vemservice

For this inventory, electricity medium voltage Swedish mix was selected in the SimaPro database. This dataset describes the electricity available on the medium voltage level in the country. This is done by showing the transmission of 1 kWh electricity at medium voltage.

At present, Vemservice manufactures 20 crane trucks per year and electricity consumption per year is 180,000 kWh. This means that for manufacturing one old design crane truck the consumption of electricity is around 9,000 kWh. With the new design Benny Larsson estimates that Vemservice is able to manufacture 30 crane trucks per year. This is due to onetime less painting during crane truck manufacturing at Vemservice and less welding than old design.

For the new design the electricity consumption is estimated to be 200,000 kWh per year according to Benny Larsson. For manufacturing one new design crane truck electricity consumption will be around 6700 kWh (personal communication, April 18, 2018).

3.4 Transportation use phase

Transport, freight lorry 16-32 metric ton, Euro 6 {RER} (Trucks with Euro 6 engine mostly used at Vemservice) was selected in the SimaPro database for this inventory. The transport datasets refer to the entire transport life cycle i.e. to the operation, maintenance and end of life of vehicle and road. Fuel consumption and emissions are for average European journeys. The average load factors are taken from the Tremove model v2.7b (Transport and Mobility Leuven, 2009) and EcoTransIT (Eco Transit World, 2011) report.

Transportation for one crane truck in life cycle is assumed to be around 500,000 km according to Benny Larsson (personal communication, April 18, 2018; Truck NL, 2018).

3.5 Calculation for transportation

Total weight of the frame kg * Distance Km / 1000 = TKm (tonkilometer)
Transportation during manufacturing old design frame: 2117kg x 1800km /1000 = 3810 TKm
Transportation during use phase old design frame: 2117kg x 500 000km /1000 = 1058 500 TKm

Transportation during manufacturing new design frame: 2330kg x 600km /1000 = 1398 TKm
Transportation during use phase old design frame: 2330kg x 500 000km /1000 = 1165 000 TKm

4. Life Cycle Impact Analysis (LCIA)

The main objective of the study is to investigate and deliver the results of environmental impacts of two different designs of crane trucks frame. The results of the environmental impact assessment of each phase of new design and old design crane truck frame life cycle are presented in table 4.1 and table 4.2. The numbers from the both tables shown that transportation during use of crane truck has the highest GWP, energy demand and ReCiPe environmental impacts. Electricity and transportation during manufacturing of crane truck has lowest impacts compare to steel production for frame and transportation during use of crane truck for both old and new design frame. The life cycle impact assessment of the inventory in more detail is presented in the Appendix A.

Phase	IPCC 2013 Climate change GWP 100a V 1.00 (kg CO2-Eq)	Cumulative energy demand. (Only fossil and nuclear, without renewable energy) (MJ-Eq)	European ReCiPe (H) Human Health (Daily) (Pt)	European ReCiPe (H) Ecosystem (Species.yr) (Pt)	European ReCiPe (H) Resources($) (Pt)
Steel Production	5909	57 500	387	116	657
Steel process	6200	91 500	398	131	663
Electricity for Steel process SSAB	204	34 100	10.5	14,6	6,04
Electricity Crane Truck manufacturer (Vemservice)	346	57 700	17,7	24,7	10,2
Transport during manufacture	119	2030	5,58	2,92	4,95
Transport during use crane truck	195 000	3 130 000	7990	4280	7790
Total	201 000	3 310 000	8410	4440	8470

Table 4.1: Life cycle impact analysis of new design crane truck

Phase	IPCC 2013 Climate change GWP 100a V 1.00 (kg CO2-Eq)	Cumulative energy demand. (Only fossil and nuclear, without renewable energy) (MJ-Eq)	European ReCiPe (H) Human Health (Daily) (Pt)	European ReCiPe (H) Ecosystem (Species.yr) (Pt)	European ReCiPe (H) Resources($) (Pt)
Steel Production	5440	52 200	352	105	597
Steel process	5630	83 200	361	119	603
Electricity for Steel process (SSAB)	186	31 000	9,52	13,3	5,49
Electricity Crane Truck manufacturer (Vemservice)	560	78 900	28,8	36,2	18,5
Transport during manufacture	324	5520	15,2	7,96	13,5
Transport during use phase of crane truck	177 000	2 870 000	7260	3,89E3	7080
Total	183 000	3 040 000	7660	4060	7720

Table 4.2: Life cycle impact analysis of old design crane truck

4.1 Crane truck manufacture (Cradle-to-gate)

Figure 4.1 shows the energy consumption from raw material extraction for frame to manufacture of crane truck (cradle to gate) and new crane truck needs 17GJ or around 11% less energy than the old design crane truck. Although, new design frame has 213kg more steel. This is due to less transportation and less electricity during the manufacturing phase of new design crane truck. New design crane truck needs 8400 MJ less energy or 2330kWh less electricity than old design crane truck manufacture phase at Vemservice. Processed steel for frame and electricity use for manufacture crane truck at Vemservice are the biggest contributor in this cradle to gate process. Figure 4.2 shows the opposite result that new design crane truck manufacture (6810kg CO_2 eq) has 160 kg higher GWP than old design (6650kg CO_2 eq). This is clearly seen from figure 4.2 that is due to high amount of CO_2 emission from steel production at SSAB for the crane truck frame.

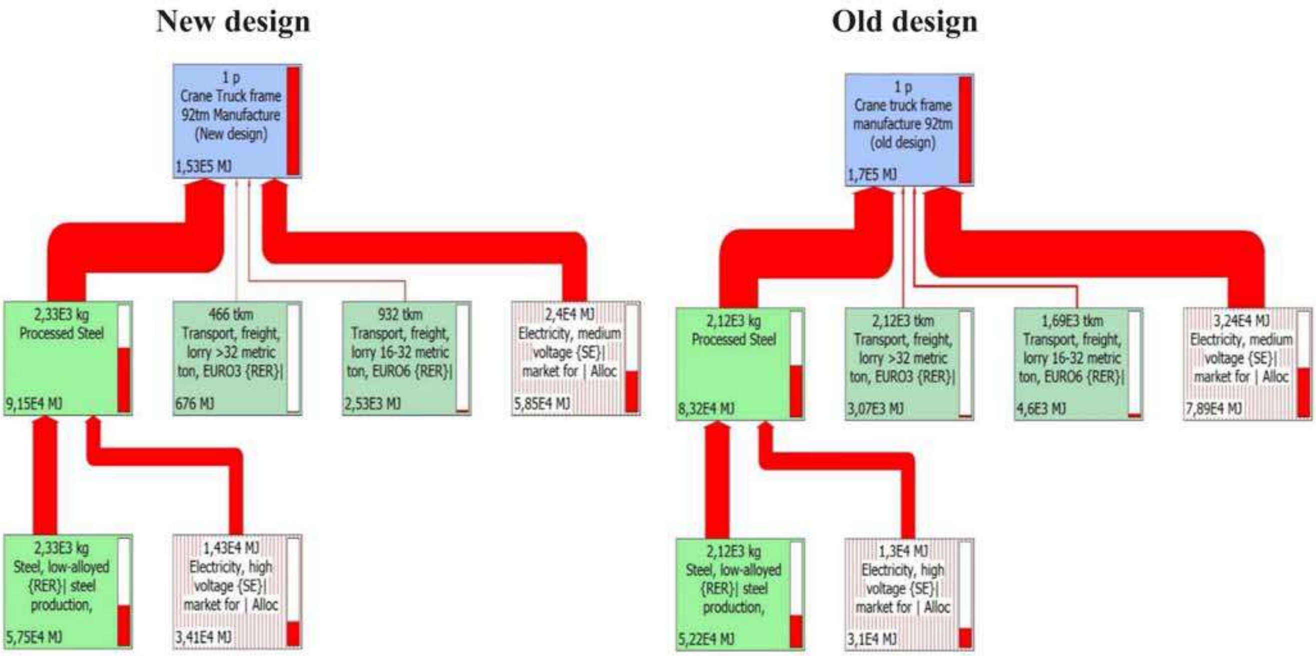

Figure 4.1: Contribution of energy input in crane truck manufacture new and old design

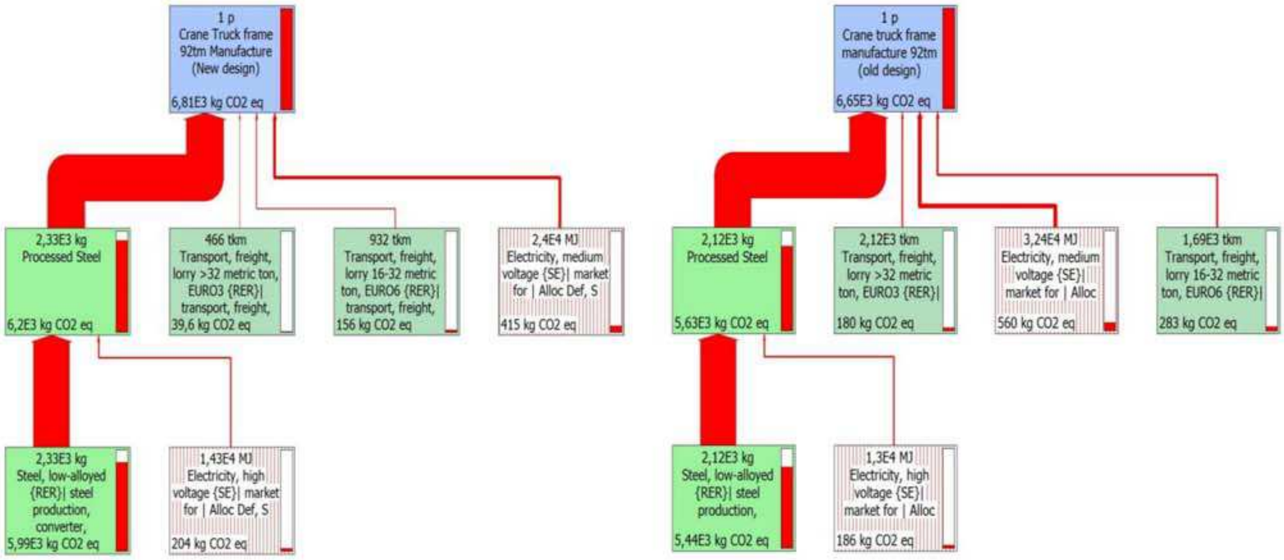

Figure 4.2: Contribution of GWP kg CO2 eq input in crane truck manufacture new and old design

4.2 Crane truck frames life cycle (Cradle-to-grave)

The figure 4.3 and figure 4.4 show the GWP (kg CO2 eq.) and energy consumption from raw material extraction to end life (cradle-to-grave) of crane truck frame. The figures (4.3 and 4.4) show that transportation during the use phase (biggest red part) is the largest contributor of GWP (kg CO2 eq.) and energy demand in both new and old crane truck frame life cycle. This is due to use of fossil fuel during use phase of crane truck frame. The figures (4.3 and 4.4) also show that GWP and CED contribution of other phases such as steel production, electricity and transportation during manufacturing phases are very low compare to use phase of crane truck frame life cycle. The overall results show that new design crane truck frame life cycle has 18 tonnes or around 9% more GWP (kg CO2 eq.) than old design crane truck frame. The energy demand (figure 4.4) of new design of crane truck frame lifecycle is 270 GJ higher that old design crane truck frame lifecycle. This is due to 213 kg additional weight of new design crane truck frame.

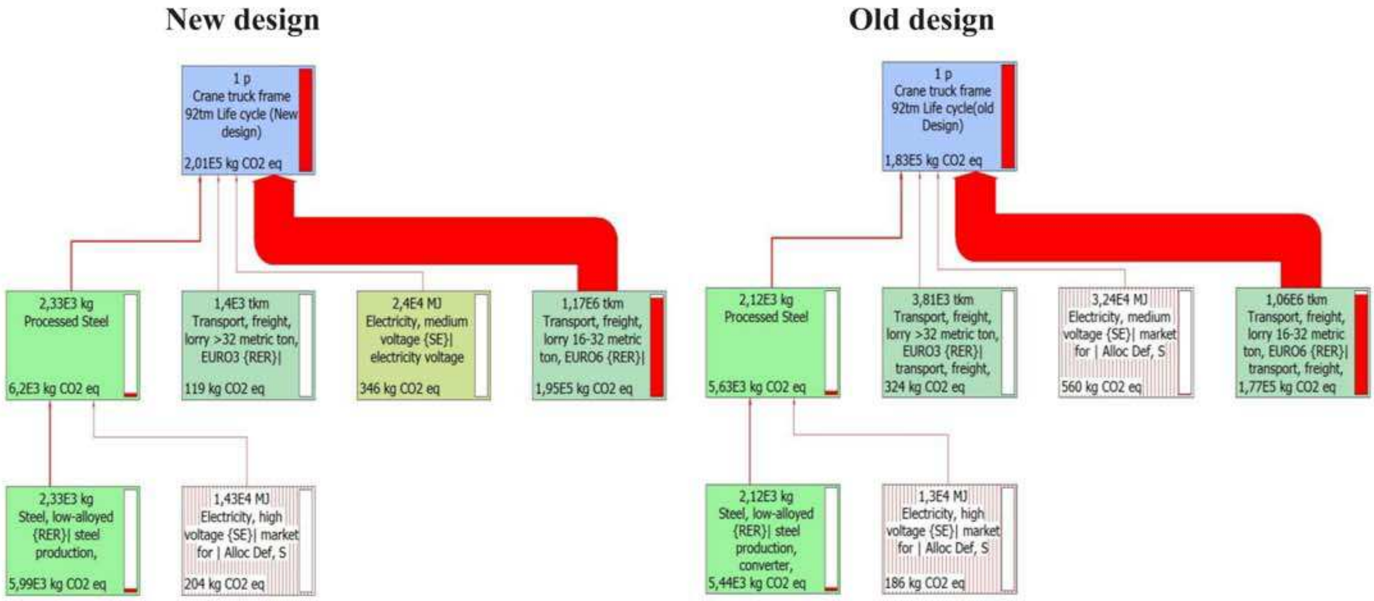

Figure 4.3: GWP (kg CO2 eq.) contribution of new and old design crane truck life cycle

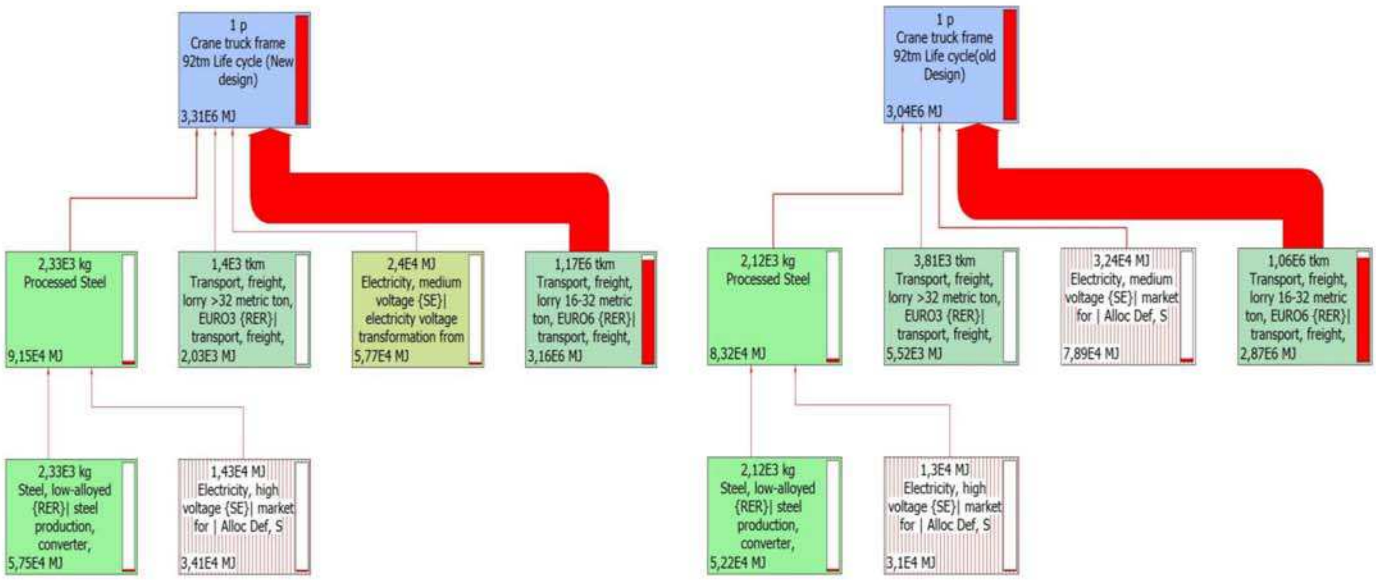

Figure 4.4: Energy contribution of new and old design crane truck life cycle

5. Life Cycle Interpretation and discussion

The comparison results of new design and old design of the crane truck frame's life cycle is presented in table 5.1. The differences value of the table showed that new design crane truck frame has 18 tonnes more GWP climate impact and 270GJ more energy demand than old design crane truck frame in the lifecycle. New design has 750 Pt more negative impact on human health and resources scare, and 380 Pt negative impacts on ecosystem.

Crane truck frame	IPCC 2013 Climate change GWP 100a V 1.00 (kg CO2-Eq)	Cumulative energy demand. (Only fossil and nuclear, without renewable energy) (MJ)	European ReCiPe (H) Human Health (Daily) (Pt)	European ReCiPe (H) Ecosystem (Species.yr) (Pt)	European ReCiPe (H) Resources($) (Pt)
New design crane truck frame 92 tm life cycle	201 000	331 0000	8410	4440	8470
Old design crane truck frame 92 tm life cycle	183 000	304 0000	7660	4060	7720
Differences	18 000	270 000	750	380	750

Table 5.1: Comparison impact between new and old design crane truck life cycle

The figure 5.1 shows (cradle-to-gate) that old design crane truck manufacturing consume 69 GJ more energy than new design crane truck manufacture. Non-renewable fossil fuel, nuclear energy and hydro (water renewable) energy are the biggest energy sources.

On the other hand, figure 5.2 diagram shows (cradle-to-grave) that the energy consumption of new design crane truck frame lifecycle is 270 GJ more than old design crane truck frame lifecycle. The non-renewable fossil fuel is the biggest part of the energy consumption due to fossil fuel for example diesel consumption at the use phase for 500 000 km transportation of crane truck. This is due to new design crane truck frame has 213kg additional weight, that new design crane truck will carry during its entire 500 000 km use phase cycle.

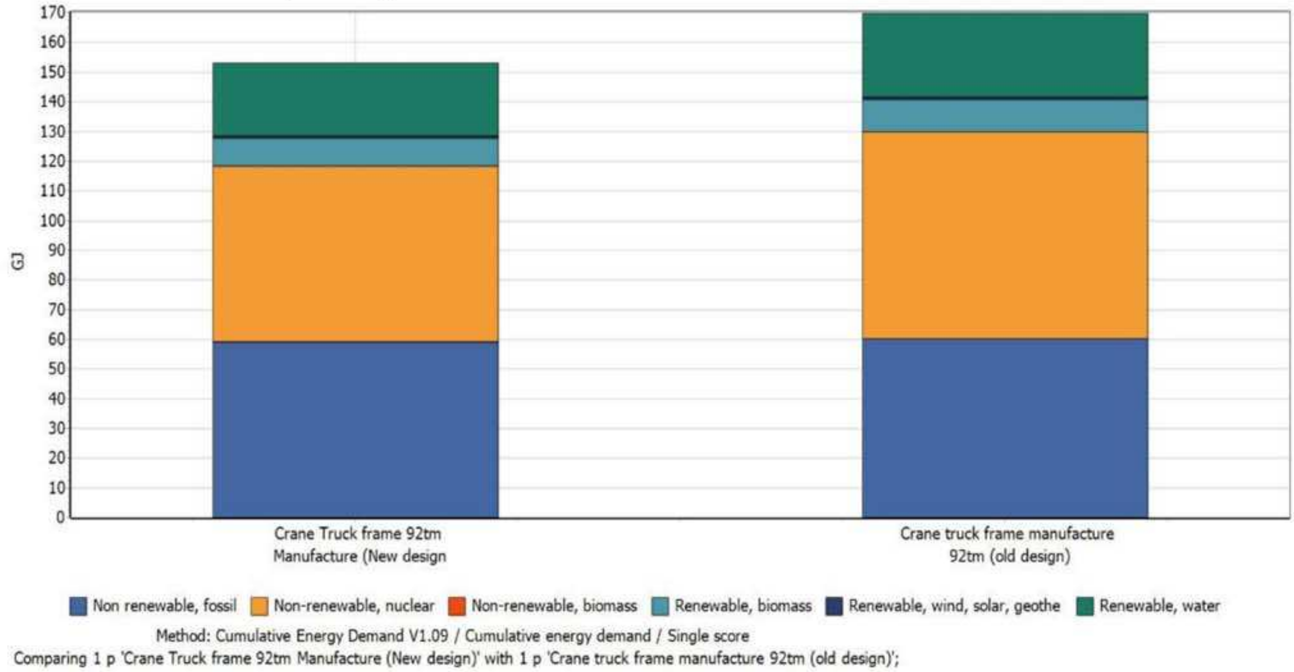

Figure 5.1: Comparison energy (CED) between new and old design crane truck manufacturing at Vemservice

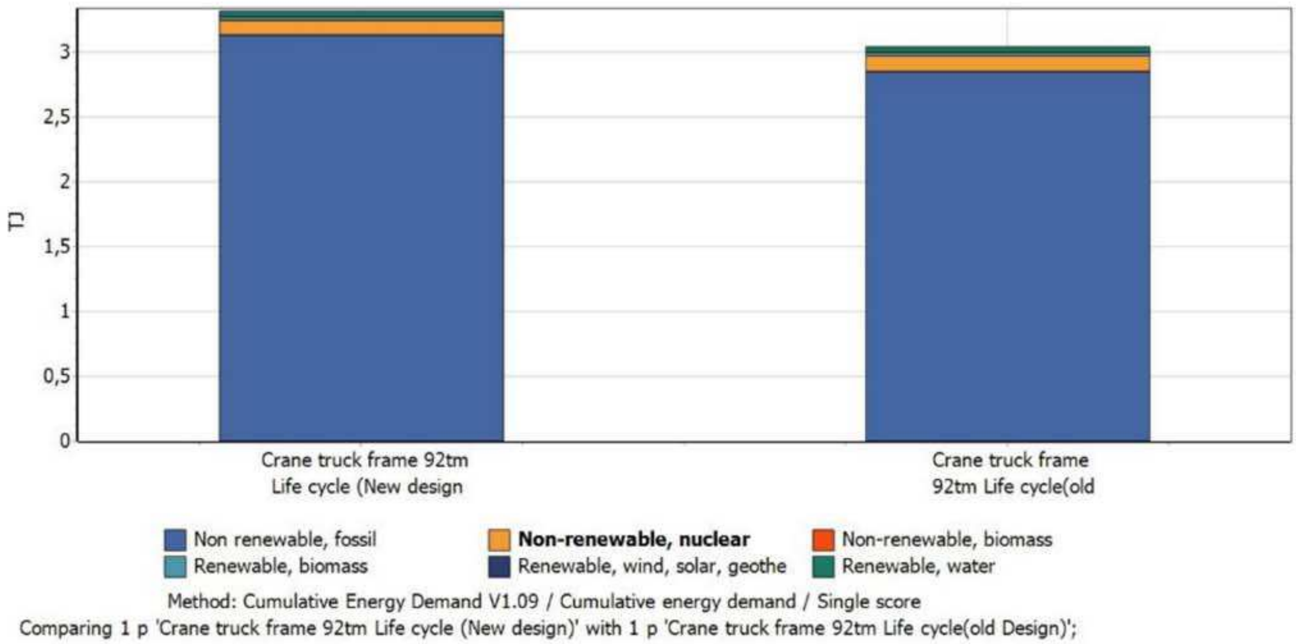

Figure 5.2: Comparison energy (CED) consumption between new and old design crane truck life cycle

The diagram in figure 5.3 shows the ReCiPe environmental impacts on single score level from the new and old design crane truck frame life cycle. It presents that two indicators, agricultural land occupation and ionising radiation, are almost in the same level. Figure 5.4 shows the endpoint indicators of the environmental impact of old and new design crane trucks' life cycles on three higher accumulation levels which are 1) human health, 2) ecosystem and 3) resource scarcity. It presents that new design crane truck has higher impact in all three indicators.

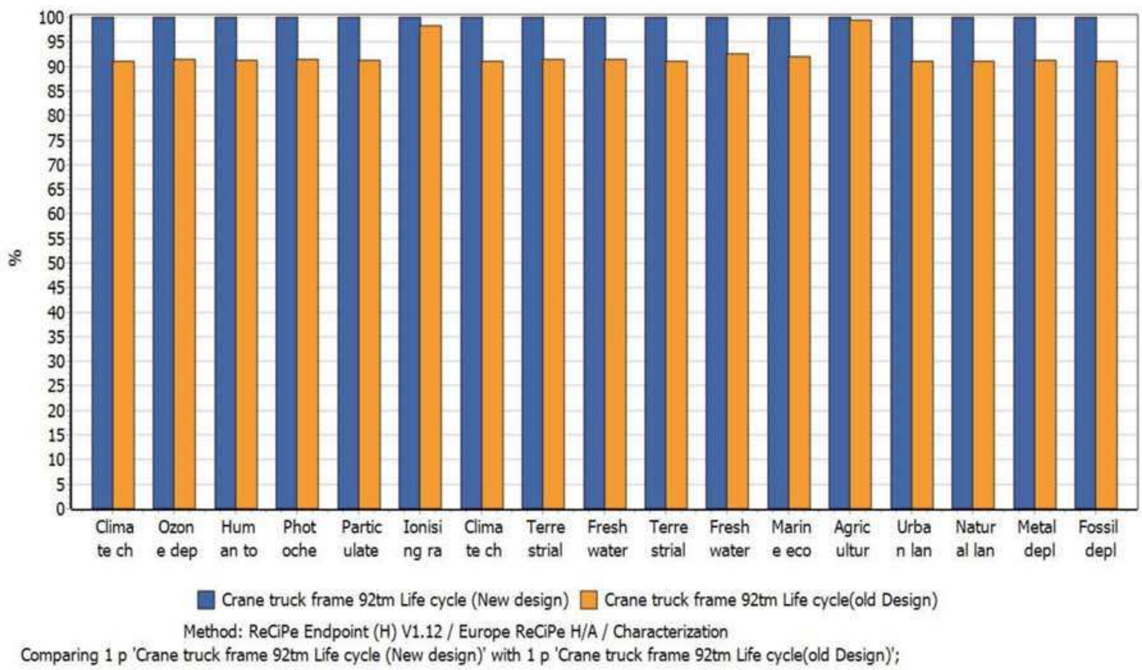

Figure 5.3: Comparison of the environmental impact assessment between new and old design crane truck life cycle based on the Recipe endpoint (H).

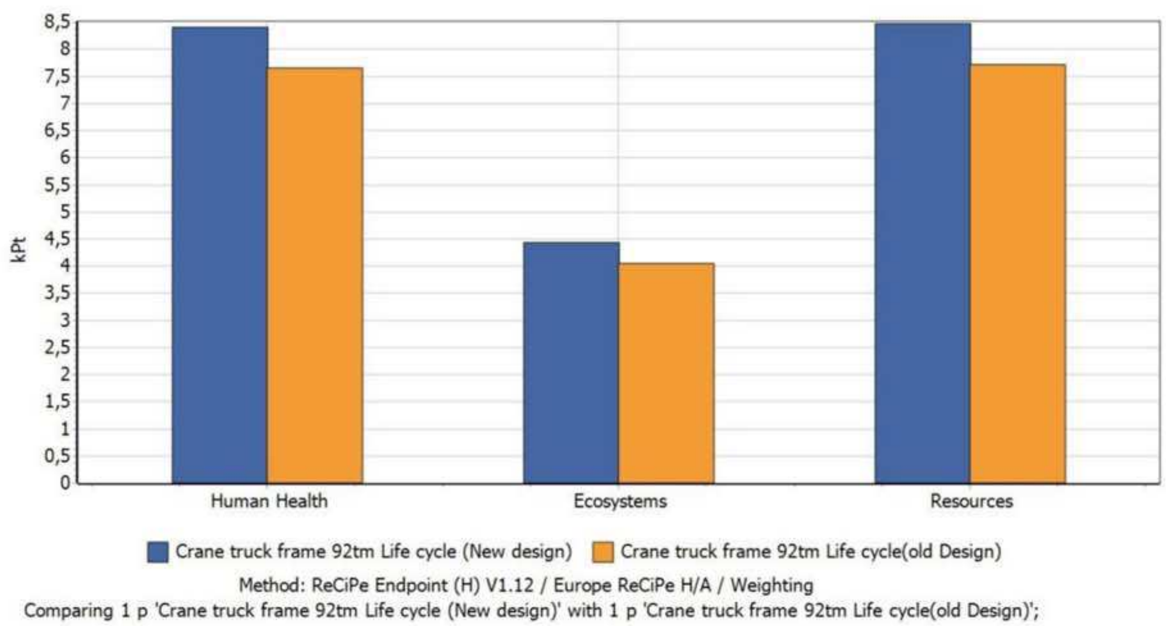

Figure 5.4: Comparison between life cycle of new and design crane trucks' negative effects on human health, ecosystem and resource scarcity

The diagram in figure 5.5 shows the ReCiPe environmental impacts on single score level from the new and old design crane truck manufacture (cradle-to-gate) which is different than the lifecycle (cradle-to-gate) of crane truck frames. It presents that old design crane truck manufacturing has highest environmental impact in most cases, except metal depletion, freshwater eutrophication, human toxicity, and particulate matter formation. Metal depletion is higher due to new design crane truck frame need 213kg more steel than old design.

Figure 5.6 shows the endpoint indicators of the environmental impact where new design crane truck manufacture has higher impact on human health and resource scarcity. On the other hand, impact on ecosystem shows opposite results.

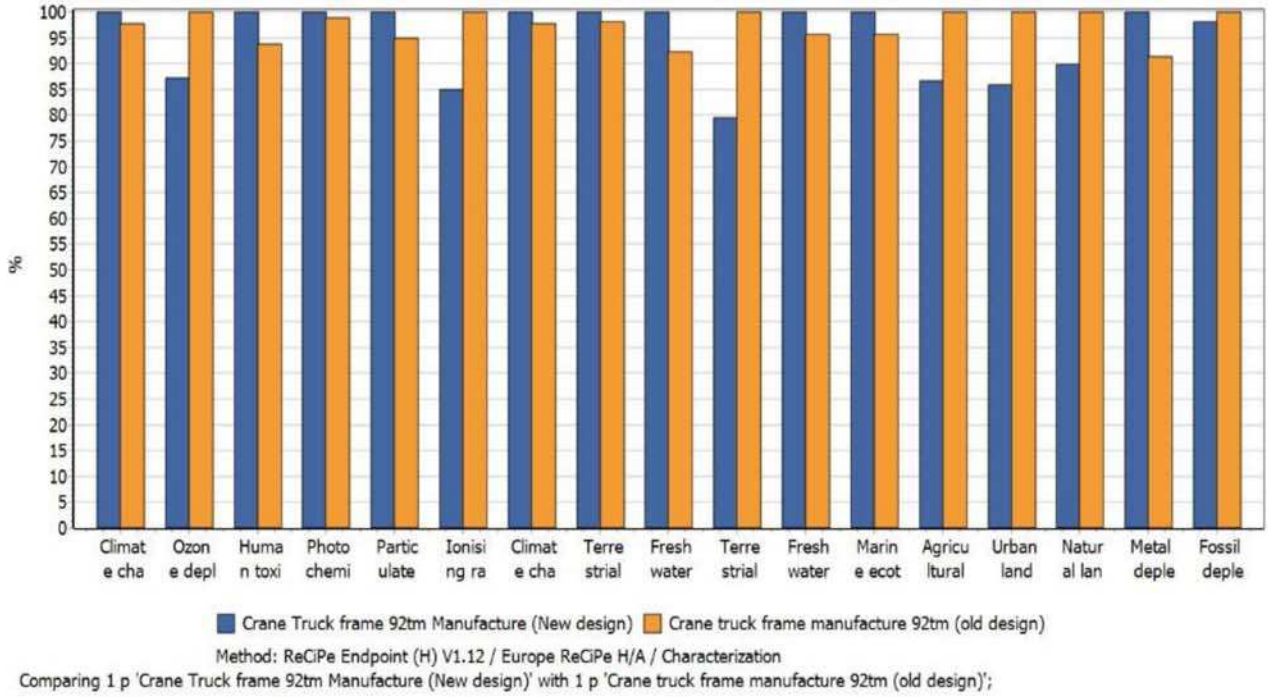

Figure 5.5: Comparison the environmental impact assessment between new and old design crane truck manufacturer based on the Recipe endpoint (H).

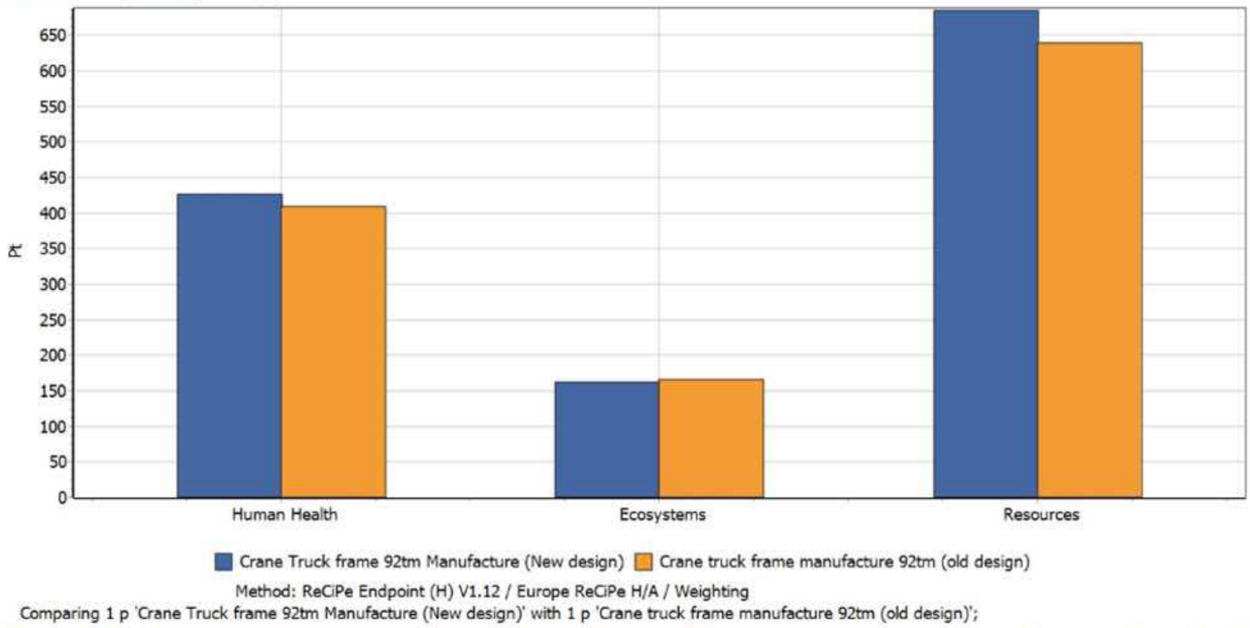

Figure 5.6: Comparison between manufacture phase of new and design crane trucks negative effects on human health, ecosystem and resource scarcity

5.1 Mobile crane replaced by crane truck 135 tm crane

According to an earlier study by Nora Lundblad (2017), a crane truck with 92 tonmeter crane (total weight crane truck 26 tonnes) that runs 100 km to the workplace with 40L fuel consumption and only carries out the lift work (fuel consumption 3l/h for lift work) has 230kg GWP compared to mobile crane when a mobile crane runs 100km to the workplace with 70L fuel consumption and carries out the lift work has 345kg GWP. It showed that crane truck has 42% less GWP climate impact and energy consumption compared mobile crane (Lundblad, 2017). By using data from Lundblad's report it was calculated from the same scenario perspective (which was Scenario 3 in her report) that when new design crane truck with 135 tonmeter crane (28.5 tonnes total weight of crane truck) runs to the workplace 100km and only carries out the lift work (assumed fuel consumption 4,5l/h for lift work) has 274kg GWP. Crane truck with 135 tonmeter crane has 22,5% less GWP climate impact and energy consumption than mobile crane when a mobile crane has driven 100km to workplace and carries out the lift work. In addition, 135 tm crane trucks still can transport 3.5 tonnes goods during the operation. It means new design frame with 135 tonmeter crane has less environmental impact when it replaced to mobile crane.

5.2 Use of stronger EcoUpgraded steel

If new design 92 tm crane truck frames steel called Strenx 700 MC is replaced by stronger SSAB's EcoUpgraded Strenx 1100 MC steel, then it might have different environmental impact in crane truck life cycle (SSAB, 2018). According to Erik Hansson (personal communication, May 11, 2018) from SSAB, the energy and emission of Strenx 700 MC and Strenx 1100 MC is more or less same but they have different raw material compositions in the production and rolling processes. However, the Strenx 1100 MC steel is more expensive due to expensive raw material input. Weight reduction depends on the application of the product. If the steel yield strength is double then weight reduction will be half in general. But it depends on the application of the product (Erik Hansson, personal communication, May 11, 2018). A similar project at SSAB's loader crane showed that if the steel yield strength of crane truck beam could be increased from 800 MPa to Strenx 1100 by reducing around 15% of the upgraded parts. As a result, it increases the load capacity of the truck, reducing fuel consumption per ton transported (SSAB, 2018).

By using SimaPro database calculation, it showed that if the new design crane truck frames steel Strenx 700 MC were replaced by Strenx 1100 MC with 15% weight reduction of crane truck frame then around 30 tonnes CO2 eq. and 650 GJ energy or equivalent 180 555 kWh electricity can be possible to save during the whole life cycle of the crane truck frame (table 5.2).

New design Crane truck frame Steel	Weight of frame (Kg)	IPCC 2013 Climate change GWP 100a V 1.00 (kg CO2-Eq)	Cumulative energy demand. (Only fossil and nuclear, without renewable energy) (MJ)
Life cycle of new design 92 tm crane truck frame steel Strenx 700 MC	2330	201 000	3 310 000
Lifecycle of new design 92 tm crane truck frame steel Eco-Upgraded Strenx 1100 MC	1980	171 000	2 660 000
Savings	350	30 000	650 000

Table 5.2: Comparison GWP and energy saving between new design crane truck life cycle frame with Strenx 700 MC steel and EcoUpgraded Strenx 1100 MC steel

Table 5.3 shows the results of the environmental impacts of three different designs or different steel frames of crane trucks. The life cycle analysis showed that new design 92 tm crane truck had the highest environmental impact in all kind of impact categories and new design with the Eco-Upgraded steel frame had lowest environmental impact.

LCIA method	Damage/impact category	Unit	Old design 92 tm lifecycle	New design 92 tm lifecycle	New design EcoUpgraded 92 tm Lifecycle
IPCC	Carbon footprint	kg CO2 eq	183241.8	201170.5	171137,6
CED	Total energy demand	MJ	3040000	3310000	2830000
	Nonrenewable, fossil	MJ	2850132	3129925	2662135
	Non Renewable, nuclear	MJ	117000	111000	99900
	Non renewable, biomass	MJ	81.4	87.5	16.2
	Renewable, biomass	MJ	27300	27300	24200
	Renewable, wind, solar, geothermal	MJ	3750	3920	3400
	Renewable, water	MJ	43100	41300	36900
Recipe midpoint(H)	Climate change	Kg CO2 eq	183241.8	201170.5	171137,6
	Ozone Depletion	kg CFC-11 eq	0.0333	0.0364	0.031
	Terrestrial acidification	kg SO2 eq	442	484	412
	Freshwater eutrophication	kg P eq	17.4	19	16.2
	Marine eutrophication	kg N eq	69.2	73.4	63,2
	Human toxicity	kg 1.4-DB eq	76700	84100	71600
	Photochemical oxidant formation	kg NMVOC	456	498	424
	Particulate matter formation	kg PM10 eq	295	323	275
	Terrestrial ecotoxicity	kg 1.4-DB eq	131	144	122
	Freshwater ecotoxicity	kg 1.4-DB eq	1600	1730	1490
	Marine ecotoxicity	kg 1.4-DB eq	2320	2520	2160
	Ionizing radiation	kg U235 eq	22000	22400	19600
	Agricultural land occupation	m2a	3820	3830	3390
	Urban land occupation	m2a	9580	10500	8940
	Natural land transformation	m2	65.7	72.1	61.3
	Water depletion	m3	647	692	594
	Metal depletion	kg Fe eq	17400	19100	16300
	Fossil depletion	kg oil eq	64500	70800	60200

Table 5.3: Comparative analysis results of the environmental indicators of three different design crane truck lifecycle.

The figure 5.7 and figure 5.8 shows life cycle comparison of GWP climate impacts and cumulative energy demand (CED) between old design, new design and Ecoupgraded Strenx 1100 MC steel frame of crane truck. From the both diagram it is clearly seen that crane truck with Ecoupgraded Strenx 1100 MC steel frame has lowest GWP climate impact and energy demand that old and new design crane. This is due lower weight of Ecoupgraded crane truck frame (1980 kg) than old design frame (2117 kg) and new design frame (2330 kg). According to SSAB stronger Ecoupgraded steel increases the load capacity of the truck; reduce fuel consumption per ton transportation (SSAB).

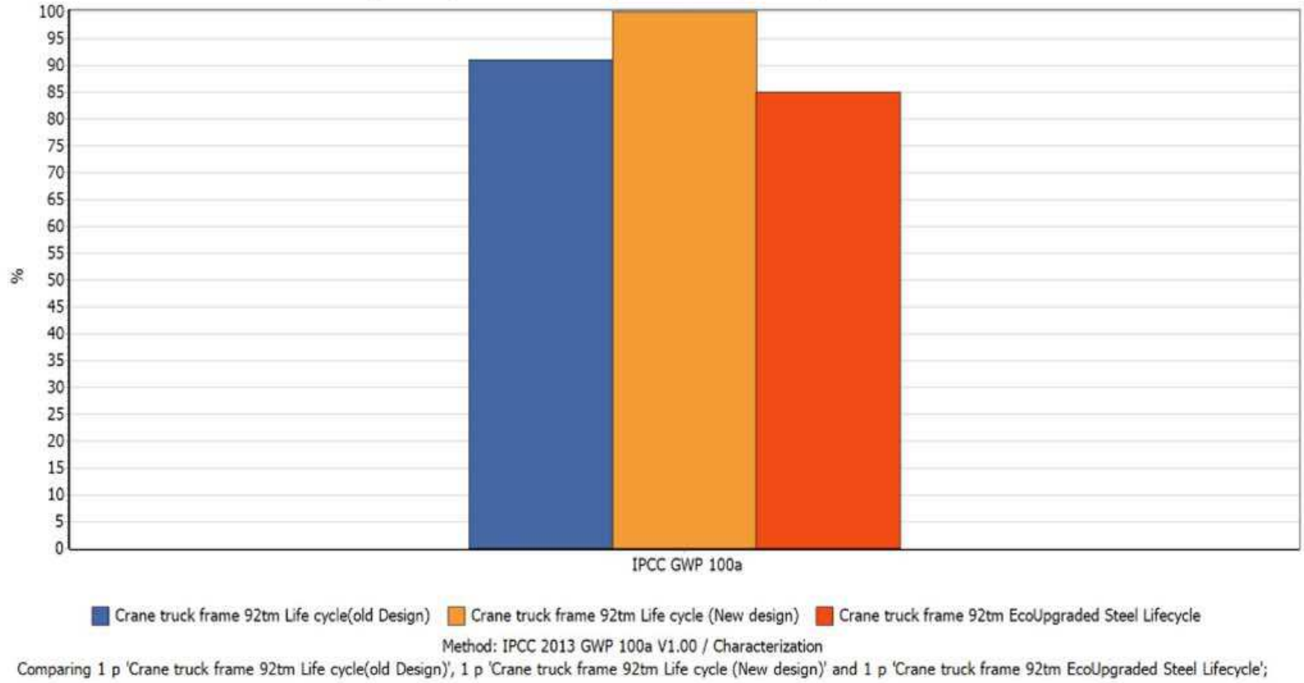

Figure 5.7: Comparison GWP between Old design vs new design vs Eco Upgraded steel frame life cycle.

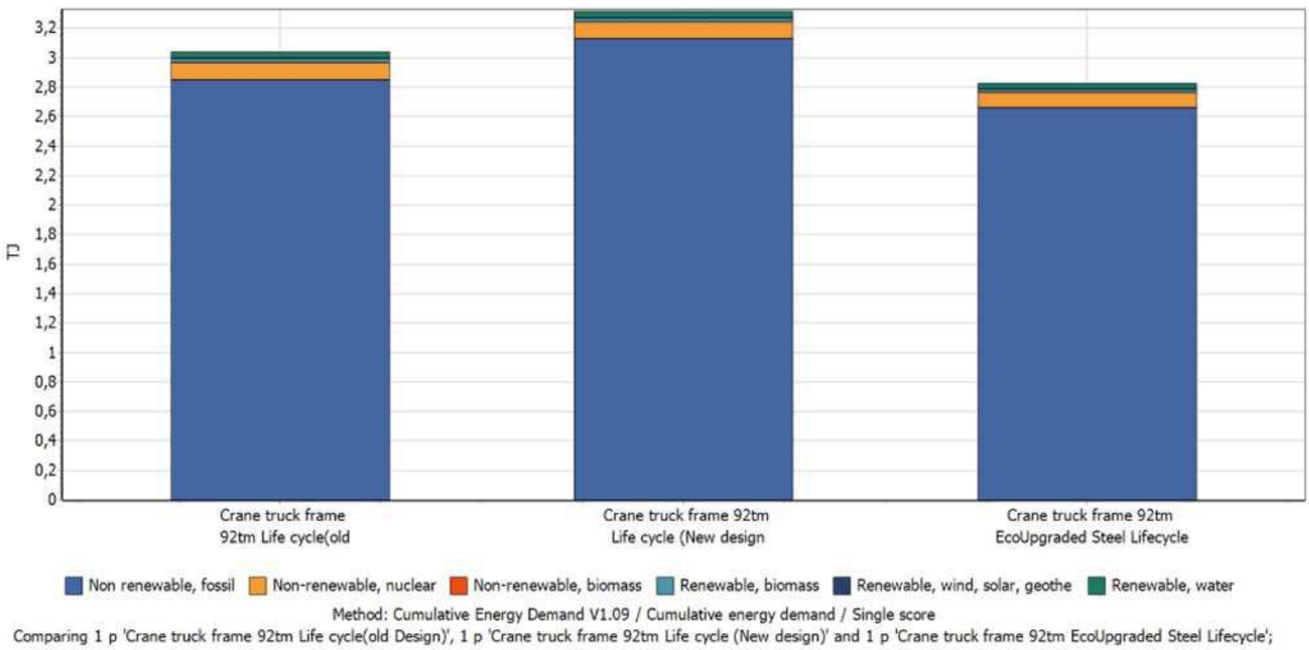

Figure 5.8: Comparison CED between old design vs new design vs EcoUpgraded steel frame crane truck lifecycle

Figure 5.9 shows the ReCiPe endpoint indicators of environmental impact on three higher accumulation levels; human health (blue), ecosystem (yellow) and resource scarcity (red). New design crane truck frame has highest impacts, old design frame has second highest impacts and new design with Ecoupgraded steel frame has lowest impacts on human health, ecosystem and resource scarcity.

Figure 5.10 shows the ReCiPe midpoint level on single environmental problem where new design crane truck frame (yellow) is dominating in all environment problems. New design (yellow) and old design (blue) frame has almost same impacts on agricultural land occupation and ionizing radiation. Ecoupgraded steel frame has lowest impact in all single environmental impact.

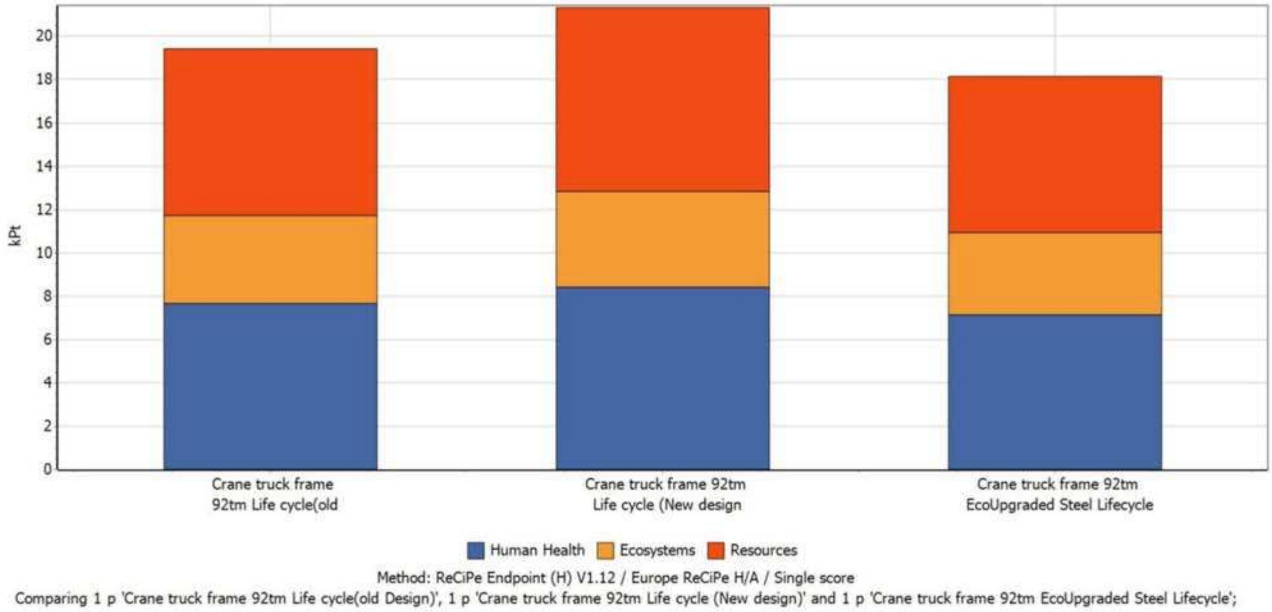

Figure 5.9: Comparison ReCiPe environmental impact endpoint level between crane truck with Ecoupgraded steel frame, new design frame and old design lifecycle.

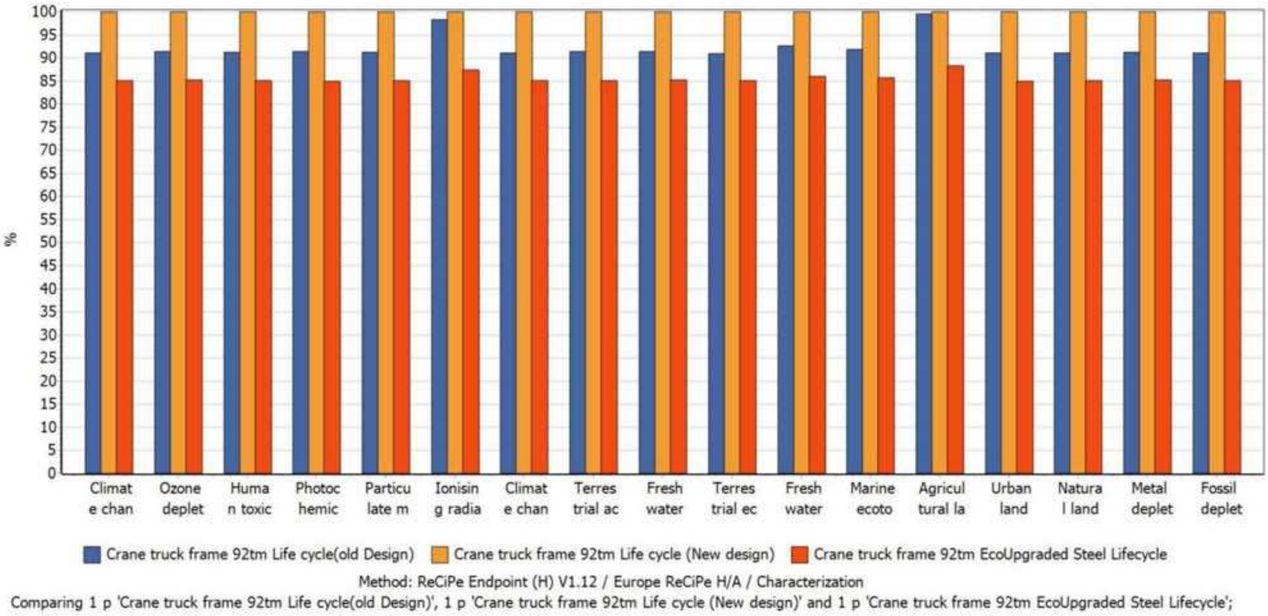

Figure 5.10: Comparison ReCiPe (characterization) environmental impact between crane truck with Ecoupgraded steel frame, new design frame and old design lifecycle.

6. Conclusion

The Life Cycle Analysis ISO 14040 (ISO 14040:2006, 2016) and ISO 14044 (ISO 14044:2006, 2016) is used in this report in order to evaluate and compare the energy consumption and environmental impacts related to the lifecycle of new and old designs of frames of 92 tonmeter crane trucks from cradle to grave. In summary, following conclusions can be drawn:

a) The results of LCA from the cradle to gate excluding using phase (steel production for crane truck frame from raw materials extraction to manufacture of crane truck at Vemservice) evaluation of the two crane truck systems showed that the new design crane truck with 92 tonmeter crane manufacturing has less energy demand and less impact on ecosystem services. This is due to new design frame needs less transportation and less energy consumption during manufacture at Vemservice. New design crane truck manufacturing has higher GWP climate impact, higher impact on human health and resources scarcity than old design 92 tonmeter crane truck. This is due to new design crane needs more steel for frame production than old design.

b) The results of LCA from the cradle to grave including using phase (steel production for crane truck frame from raw materials extraction to end life of a crane truck) evaluation of the two crane truck systems showed that the new design crane truck frame lifecycle has higher GWP climate impact, energy demand and ReCiPe environmental impacts than the existing old design crane truck frame lifecycle. This is due to additional 213 kg frame weight that new design 92 tonmeter crane truck carry throughout all its life cycle. The new design crane truck frame lifecycle only has less environmental impacts and is more energy efficient when new design 135 tonmeter crane trucks replaces the mobile crane.

c) The primary estimation of the LCA results showed that if the new design 92 tonmeter crane truck frame would be replaced by the stronger EcoUpgraded steel frame then it will have less GWP climate impact, energy demand and other environmental impacts, compared to both the new and old design of the the 92 tonmeter crane truck frame lifecycle.

d) Recommendation for future studies is therefore to make a further study based on the findings presented in point C as well as investigate possible economic benefits from using the EcoUpgraded Strenx 1100 MC steel.

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8. Appendices

Appendix A: Life Cycle Impact Analysis Inventory of Crane trucks

Crane truck new design 92tm crane lifecycle GWP								
Calculation:	Analyze							
Results:	Inventory							
Product:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)							
Method:	IPCC 2013 GWP 100a V1.00							
Indicator:	Characterization							
Compartment:	All compartments							
Per sub-compartment:	No							
Skip unused:	No							
Category:	IPCC GWP 100a							
Cut-off:	0,10 %							
Exclude infrastructure processes:	No							
Exclude long-term emissions:	No							
Sorted on item:	Substance							
Sort order:	Ascending							
No	Substance	Compartment	Unit	Total	Processed Steel	Transport manufacture phase	Electricity manufacture phase	Transport Use phase
	Total		kg CO2 eq	201170,52	6195,5894	118,74483	346,20991	194509,98
	Remaining substances		kg CO2 eq	302,20064	17,557886	0,19017636	9,3184367	275,13414
1	Carbon dioxide, fossil	Air	kg CO2 eq	193142,54	5676,4181	114,96787	301,8888	187049,27
2	Dinitrogen monoxide	Air	kg CO2 eq	2307,9418	38,745093	0,40701126	16,105763	2252,684
3	Methane, fossil	Air	kg CO2 eq	5417,8348	462,8684	3,1797743	18,896908	4932,8897

Crane truck new design 92tm life cycle CED								
Calculation:	Analyze							
Results:	Inventory							
Product:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)							
Method:	Cumulative Energy Demand V1.09 / Cumulative energy demand							
Indicator:	Single score							
Compartment:	All compartments							
Per sub-compartment:	No							
Skip unused:	No							
Cut-off:	0,10 %							
Default units:	No							
Exclude infrastructure processes:	No							
Exclude long-term emissions:	No							
Sorted on item:	Substance							
Sort order:	Ascending							
No	Substance	Compartment	Unit	Total	Processed Steel	Transport manufactue phase	Electricity manufacture phase	Transport use phase
	Total		TJ	3,3140235	0,09153666	2,03E-03	0,057706792	3,162753
	Remaining substances		TJ	0,004923448	0,000699153	2,46E-06	0,000864286	0,003357545
1	Coal, brown	Raw	TJ	0,014574509	0,000903246	9,52E-06	0,000203063	0,013458685
2	Coal, hard	Raw	TJ	0,1856818	0,032594666	1,01E-04	0,001251538	0,15173415
3	Energy, gross calorific value, in biomass	Raw	TJ	0,02731148	0,0041778	1,42E-05	5,00E-03	0,018118403
4	Energy, potential (in hydropower reservoir), converted	Raw	TJ	0,041295264	0,011726564	1,20E-05	0,012975988	0,01658071
5	Gas, mine, off-gas, process, coal mining/m3	Raw	TJ	0,003539502	0,000620382	1,93E-06	2,53E-05	0,002891933
6	Gas, natural/m3	Raw	TJ	0,20566435	0,006788615	1,30E-04	0,000988393	0,19775717
7	Oil, crude	Raw	TJ	2,7195535	0,010273167	0,001718152	0,000808408	2,7067538
8	Uranium	Raw	TJ	0,11147962	0,023753068	3,72E-05	0,035588765	0,052100605

Crane truck old design 92tm crane lifecycle GWP								
Calculation:	Analyze							
Results:	Inventory							
Product:	1 p Crane truck frame 92tm Life cycle(old Design) (of project Steel)							
Method:	IPCC 2013 GWP 100a V1.00							
Indicator:	Characterization							
Compartment:	All compartments							
Per sub-compartment:	No							
Skip unused:	No							
Category:	IPCC GWP 100a							
Cut-off:	0,10 %							
Exclude infrastructure processes:	No							
Exclude long-term emissions:	No							
Sorted on item:	Substance							
Sort order:	Ascending							
No	Substance	Compartment	Unit	Total	Processed Steel	Transport, manufacture	Electricity, manufacture	Transport, use phae
	Total		kg CO2 eq	183241,75	5629,2115	323,61788	560,32868	176728,59
	Remaining substances		kg CO2 eq	305,74951	15,952809	0,51829179	39,29602	249,98239
1	Carbon dioxide, fossil	Air	kg CO2 eq	175889,47	5157,5009	313,32444	468,72607	169949,91
2	Dinitrogen monoxide	Air	kg CO2 eq	2105,7184	35,20316	1,1092367	22,654109	2046,7519
3	Methane, fossil	Air	kg CO2 eq	4940,8162	420,55468	8,6659085	29,652482	4481,9431

Crane truck old design 92tm life cycle CED								
Calculation:	Analyze							
Results:	Inventory							
Product:	1 p Crane truck frame 92tm Life cycle(old Design) (of project Steel)							
Method:	Cumulative Energy Demand V1.09 / Cumulative energy demand							
Indicator:	Single score							
Compartment:	All compartments							
Per sub-compartment:	No							
Skip unused:	No							
Cut-off:	0,10 %							
Default units:	No							
Exclude infrastructure processes:	No							
Exclude long-term emissions:	No							
Sorted on item:	Substance							
Sort order:	Ascending							

No	Substance	Compartment	Unit	Total	Processed Steel	Transport, Manufacture	Electricity, manufacture	Transport, freight, use phase
	Total		TJ	3,0412605	0,083168717	0,005524358	0,078941682	2,8736258
	Remaining substances		TJ	0,004850875	0,000635239	6,72E-06	0,001158309	0,003050611
1	Coal, brown	Raw	TJ	0,013366691	0,000820674	2,59E-05	0,00029174	0,012228341
2	Coal, hard	Raw	TJ	0,1695553	0,029614982	0,000276481	0,001800659	0,13786317
3	Energy, gross calorific value, in biomass	Raw	TJ	0,027333857	0,003795881	3,87E-05	0,00703723	0,016462086
4	Energy, potential (in hydropower reservoir), converted	Raw	TJ	0,04309215	0,010654565	3,27E-05	0,017339913	0,015064963
5	Gas, mine, off-gas, process, coal mining/m3	Raw	TJ	0,003232635	0,000563669	5,25E-06	3,62E-05	0,002627563
6	Gas, natural/m3	Raw	TJ	0,18781768	0,006168024	0,000354761	0,001615962	0,17967894
7	Oil, crude	Raw	TJ	2,4751394	0,009334032	0,004682518	0,001810561	2,4593123
8	Uranium	Raw	TJ	0,11687189	0,02158165	0,000101324	0,047851156	0,04733776

Crane truck old design 92tm life cycle ReCiPe	
Calculation:	Analyze
Results:	Inventory
Product:	1 p Crane truck frame 92tm Life cycle(old Design) (of project Steel)
Method:	ReCiPe Endpoint (H) V1.12 / Europe ReCiPe H/A
Indicator:	Single score
Compartment:	All compartments
Per sub-compartment:	No
Skip unused:	No
Cut-off:	0,10 %
Default units:	No
Exclude infrastructure processes:	No
Exclude long-term emissions:	No
Sorted on item:	Substance
Sort order:	Ascending

No	Substance	Compartment	Unit	Total	Processed Steel	Transport, manufacture	Electricity, manufacture	Transport, use phase
	Total		kPt	19,434178	1,0826192	0,036651958	0,083570083	18,231336
	Remaining substances		kPt	0,3205536	0,064962669	0,000499871	8,49E-03	0,24660318
1	Antimony	Air	kPt	0,5502292	0,000307024	7,19E-04	1,95E-05	0,54918322
2	Arsenic	Water	kPt	0,047072889	1,59E-02	4,76E-05	1,19E-03	0,029952527
3	Barium	Air	kPt	0,021974376	2,14E-05	2,88E-05	4,71E-06	0,021919543
4	Carbon dioxide, fossil	Air	kPt	7,9609613	0,23343447	1,42E-02	0,021215086	7,6921303
5	Chromium	Raw	kPt	0,094179029	0,074785192	3,75E-05	0,000353157	0,019003152
6	Coal, brown	Raw	kPt	0,032546677	0,001998267	6,31E-05	0,000710361	0,029774899
7	Coal, hard	Raw	kPt	0,4124508	7,20E-02	6,73E-04	4,38E-03	0,3353583
8	Copper	Air	kPt	0,034008968	4,81E-05	4,45E-05	6,04E-06	0,033910262
9	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore	Raw	kPt	0,027322775	0,000932339	3,47E-05	0,000717515	0,025638181
10	Dinitrogen monoxide	Air	kPt	0,10708905	0,001790303	5,64E-05	0,001152104	0,10409023
11	Gas, natural/m3	Raw	kPt	0,43216702	0,014192576	0,000816301	0,003718315	0,41343982
12	Iron	Raw	kPt	0,24969041	0,10775761	0,000230799	0,001723612	0,13997839
13	Lead	Air	kPt	0,097909139	0,003700678	1,25E-04	0,000342575	0,093740549
14	Manganese	Raw	kPt	0,20023176	0,16462604	7,21E-05	0,00018663	0,035347011
15	Manganese	Water	kPt	0,1922681	0,05934938	2,51E-04	2,10E-03	0,13056666
16	Mercury	Air	kPt	0,021616307	0,00130525	3,25E-05	9,13E-05	0,020187289
17	Methane, fossil	Air	kPt	0,19957082	0,016987162	3,50E-04	0,001197731	0,1810359
18	Nickel, 1.98% in silicates, 1.04% in crude ore	Raw	kPt	0,12889432	0,097264485	6,15E-05	0,000400071	0,031168304
19	Nitrogen oxides	Air	kPt	0,30532406	0,014114137	0,002492028	0,001723849	0,28699405
20	Occupation, forest, intensive	Raw	kPt	0,095958798	0,013087584	0,000142962	0,023874822	0,058853429
21	Occupation, traffic area, rail/road embankment	Raw	kPt	0,072755658	0,000361988	0,000264701	4,04E-04	0,071724645
22	Occupation, traffic area, road network	Raw	kPt	0,34290651	0,00064975	0,001256602	3,23E-05	0,3409679
23	Oil, crude	Raw	kPt	6,0233437	0,022714714	0,011395082	0,004406068	5,9848278
24	Particulates, < 2.5 um	Air	kPt	0,43982458	0,036282209	0,000834481	0,001529244	0,40117865
25	Particulates, > 2.5 um, and < 10um	Air	kPt	0,47634663	0,046515962	0,000920217	0,001444991	0,42746546
26	Sulfur dioxide	Air	kPt	0,2983758	0,015433358	0,0005436	0,001548834	0,28085001
27	Transformation, from forest	Raw	kPt	0,23464772	0,001116926	0,000444571	0,000207817	0,23287841
28	Transformation, from forest, intensive	Raw	kPt	0,19103213	0,025670526	0,000284817	0,047587774	0,11748902
29	Transformation, from unknown	Raw	kPt	0,040722946	0,001609484	1,26E-04	4,38E-04	0,038548857
30	Transformation, to forest	Raw	kPt	-0,02648476	-0,000627014	-9,39E-05	-3,67E-05	-0,025727223
31	Transformation, to forest, intensive	Raw	kPt	-0,19131263	-0,025691954	-0,000285265	-0,047593078	-0,11774233

Crane truck new design 92tm life cycle ReCiPe

Calculation:	Analyze
Results:	Inventory
Product:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)
Method:	ReCiPe Endpoint (H) V1.12 / Europe ReCiPe H/A
Indicator:	Single score
Compartment:	All compartments
Per sub-compartment:	No
Skip unused:	No
Cut-off:	0,10 %
Default units:	No
Exclude infrastructure processes:	No
Exclude long-term emissions:	No
Sorted on item:	Substance
Sort order:	Ascending

No	Substance	Compartment	Unit	Total	Processed Steel	Transport, manufacture	Electricity, manufacture	Transport, Use phase
	Total		kPt	21,323379	1,1915459	0,013448671	0,052718747	20,065665
	Remaining substances		kPt	0,34720263	0,071498828	0,000183417	4,11E-03	0,27141494
1	Antimony	Air	kPt	0,6050531	0,000337915	2,64E-04	1,24E-05	0,60443878
2	Arsenic	Water	kPt	0,051200604	1,75E-02	1,75E-05	7,40E-04	0,032966172
3	Barium	Air	kPt	0,02416241	2,35E-05	1,06E-05	3,39E-06	0,024124957
4	Carbon dioxide, fossil	Air	kPt	8,7418556	0,25692127	5,20E-03	0,013663837	8,4660669
5	Chromium	Raw	kPt	0,10346011	0,082309635	1,38E-05	0,000221573	0,020915137
6	Coal, brown	Raw	kPt	0,035487605	0,002199321	2,32E-05	0,000494439	0,032770674
7	Coal, hard	Raw	kPt	0,45167925	7,93E-02	2,47E-04	3,04E-03	0,36910007
8	Copper	Air	kPt	0,037394774	5,30E-05	1,63E-05	3,35E-06	0,037322111
9	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore	Raw	kPt	0,029328076	0,001026145	1,27E-05	7,14E-05	0,028217743
10	Dinitrogen monoxide	Air	kPt	0,11737339	0,001970432	2,07E-05	0,00081908	0,11456318
11	Gas, natural/m3	Raw	kPt	0,47323205	0,015620549	3,00E-04	0,002274285	0,45503769
12	Iron	Raw	kPt	0,27396881	0,11859954	8,47E-05	0,001222393	0,15406219
13	Lead	Air	kPt	0,10746595	0,004073018	4,60E-05	0,000174769	0,10317217
14	Manganese	Raw	kPt	0,22024851	0,18118973	2,65E-05	0,000128913	0,038903417
15	Manganese	Water	kPt	0,21014989	0,065320763	9,21E-05	1,03E-03	0,14370351
16	Mercury	Air	kPt	0,023727804	0,001436576	1,19E-05	6,09E-05	0,022218414
17	Methane, fossil	Air	kPt	0,21883869	0,018696309	1,28E-04	0,000763289	0,19925065
18	Nickel, 1.98% in silicates, 1.04% in crude ore	Raw	kPt	0,14164364	0,10705066	2,26E-05	0,000266152	0,034304275
19	Nitrogen oxides	Air	kPt	0,33342105	0,015534218	9,14E-04	0,001102747	0,31586969
20	Occupation, forest, intensive	Raw	kPt	0,096236363	0,014404379	5,25E-05	0,017004613	0,064774913
21	Occupation, traffic area, rail/road embankment	Raw	kPt	0,079728955	0,000398409	9,71E-05	2,92E-04	0,078941154
22	Occupation, traffic area, road network	Raw	kPt	0,37647156	0,000715124	0,000461084	2,13E-05	0,37527407
23	Oil, crude	Raw	kPt	6,6181344	0,025000134	0,004181188	0,001967291	6,5869858
24	Particulates, < 2.5 um	Air	kPt	0,48280466	0,03993271	0,000306195	0,001022886	0,44154286
25	Particulates, > 2.5 um, and < 10um	Air	kPt	0,52300383	0,051196123	0,000337654	0,000995553	0,4704745
26	Sulfur dioxide	Air	kPt	0,32711406	0,016986171	0,000199463	0,00082096	0,30910747
27	Transformation, from forest	Raw	kPt	0,25780248	0,001229304	0,000163126	0,000100802	0,25630925
28	Transformation, from forest, intensive	Raw	kPt	0,19145769	0,028253342	1,05E-04	0,033789773	0,12931006
29	Transformation, from unknown	Raw	kPt	0,044557372	0,001771421	4,64E-05	3,12E-04	0,042427415
30	Transformation, to forest	Raw	kPt	-0,02906491	-0,0006901	-3,44E-05	-2,46E-05	-0,028315744
31	Transformation, to forest, intensive	Raw	kPt	-0,19176148	-0,028276926	-0,000104672	-0,033791012	-0,12958887

Comparison old and design 92tm crane truck lifecycle GWP					
Calculation:	Compare				
Results:	Inventory				
Product 1:	1 p Crane truck frame 92tm Life cycle(old Design) (of project Steel)				
Product 2:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)				
Method:	IPCC 2013 GWP 100a V1.00				
Indicator:	Characterization				
Compartment:	All compartments				
Per sub-compartment:	No				
Skip unused:	No				
Category:	IPCC GWP 100a				
Cut-off:	0,10 %				
Exclude infrastructure processes:	No				
Exclude long-term emissions:	No				
Sorted on item:	Substance				
Sort order:	Ascending				
No	Substance	Compartment	Unit	Crane truck frame 92tm Life cycle(old Design)	Crane truck frame 92tm Life cycle (New design)
	Total		kg CO2 eq	183241,75	201170,52
	Remaining substances		kg CO2 eq	305,74951	302,20064
1	Carbon dioxide, fossil	Air	kg CO2 eq	175889,47	193142,54
2	Dinitrogen monoxide	Air	kg CO2 eq	2105,7184	2307,9418
3	Methane, fossil	Air	kg CO2 eq	4940,8162	5417,8348

Comparison old and design 92tm crane truck lifecycle CED					
Calculation:	Compare				
Results:	Inventory				
Product 1:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)				
Product 2:	1 p Crane truck frame 92tm Life cycle(old Design) (of project Steel)				
Method:	Cumulative Energy Demand V1.09 / Cumulative energy demand				
Indicator:	Single score				
Compartment:	All compartments				
Per sub-compartment:	No				
Skip unused:	No				
Cut-off:	0,10 %				
Default units:	No				
Exclude infrastructure processes:	No				
Exclude long-term emissions:	No				
Sorted on item:	Substance				
Sort order:	Ascending				
No	Substance	Compartment	Unit	Crane truck frame 92tm Life cycle (New design)	Crane truck frame 92tm Life cycle(old Design)
	Total		TJ	3,3140235	3,0412605
	Remaining substances		TJ	0,004923448	0,004850875
1	Coal, brown	Raw	TJ	0,014574509	0,013366691
2	Coal, hard	Raw	TJ	0,1856818	0,1695553
3	Energy, gross calorific value, in biomass	Raw	TJ	0,02731148	0,027333857
4	Energy, potential (in hydropower reservoir), converted	Raw	TJ	0,041295264	0,04309215
5	Gas, mine, off-gas, process, coal mining/m3	Raw	TJ	0,003539502	0,003232635
6	Gas, natural/m3	Raw	TJ	0,20566435	0,18781768
7	Oil, crude	Raw	TJ	2,7195535	2,4751394
8	Uranium	Raw	TJ	0,11147962	0,11687189

Comparison old and design 92tm crane truck lifecycle ReCiPe					
Calculation:	Compare				
Results:	Inventory				
Product 1:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)				
Product 2:	1 p Crane truck frame 92tm Life cycle(old Design) (of project Steel)				
Method:	ReCiPe Endpoint (H) V1.12 / Europe ReCiPe H/A				
Indicator:	Single score				
Compartment:	All compartments				
Per sub-compartment:	No				
Skip unused:	No				
Cut-off:	0,10 %				
Default units:	No				
Exclude infrastructure processes:	No				
Exclude long-term emissions:	No				
Sorted on item:	Substance				
Sort order:	Ascending				
No	Substance	Compartment	Unit	Crane truck frame 92tm Life cycle (New design)	Crane truck frame 92tm Life cycle(old Design)
	Total		kPt	21,392973	19,49741
	Remaining substances		kPt	0,35262223	0,32547776
1	Antimony	Air	kPt	0,60506947	0,55024407
2	Arsenic	Water	kPt	0,0521781	0,047961026
3	Barium	Air	kPt	0,024166889	0,021978445
4	Carbon dioxide, fossil	Air	kPt	8,7598932	7,97735
5	Chromium	Raw	kPt	0,10375261	0,094444788
6	Coal, brown	Raw	kPt	0,036140314	0,033139718
7	Coal, hard	Raw	kPt	0,45569819	0,41610235
8	Copper	Air	kPt	0,037399201	0,03401299
9	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore	Raw	kPt	0,029422386	0,027408463
10	Dinitrogen monoxide	Air	kPt	0,11845465	0,10807147
11	Gas, natural/m3	Raw	kPt	0,47623433	0,43489484
12	Iron	Raw	kPt	0,27558249	0,25115658
13	Lead	Air	kPt	0,10769666	0,098118761
14	Manganese	Raw	kPt	0,22041869	0,20038639
15	Manganese	Water	kPt	0,21151425	0,19350773
16	Mercury	Air	kPt	0,023808199	0,021689354
17	Methane, fossil	Air	kPt	0,21984631	0,20048633
18	Nickel, 1.98% in silicates, 1.04% in crude ore	Raw	kPt	0,14199499	0,12921355
19	Nitrogen oxides	Air	kPt	0,33487679	0,30664672
20	Occupation, forest, intensive	Raw	kPt	0,11868417	0,11635451
21	Occupation, traffic area, rail/road embankment	Raw	kPt	0,080114774	0,073106207

GWP of Crane truck new design 92tm manufacture

Calculation:	Analyze							
Results:	Inventory							
Product:	1 p Crane Truck frame 92tm Manufacture (New design) (of project Steel)							
Method:	IPCC 2013 GWP 100a V1.00							
Indicator:	Characterization							
Compartment:	All compartments							
Per sub-compartment:	No							
Skip unused:	No							
Category:	IPCC GWP 100a							
Cut-off:	0,10 %							
Exclude infrastructure processes:	No							
Exclude long-term emissions:	No							
Sorted on item:	Substance							
Sort order:	Ascending							

No	Substance	Compartment	Unit	Total	Processed Steel	Transport, frame to Vemservice	Transport to painting	Electricity, manufacture
	Total		kg CO2 eq	6805,7958	6195,5894	39,581609	155,60798	415,01677
	Remaining substances		kg CO2 eq	13,611817	8,5302324	0,025373763	0,10183708	4,9543739
1	Carbon dioxide, fossil	Air	kg CO2 eq	6211,5499	5676,4181	38,322622	149,63941	347,16977
2	Dinitrogen monoxide	Air	kg CO2 eq	57,462054	38,745093	0,13567042	1,8021472	16,779143
3	Methane, biogenic	Air	kg CO2 eq	11,872873	6,0075237	0,017893868	0,053894425	5,7935609
4	Methane, fossil	Air	kg CO2 eq	489,83724	462,8684	1,0599248	3,9463118	21,962605
5	Sulfur hexafluoride	Air	kg CO2 eq	21,461948	3,0201301	0,020124488	0,064375808	18,357317

CED of Crane truck new design 92tm manufacture								
Calculation:	Analyze							
Results:	Inventory							
Product:	1 p Crane Truck frame 92tm Manufacture (New design) (of project Steel)							
Method:	Cumulative Energy Demand V1.09 / Cumulative energy demand							
Indicator:	Single score							
Compartment:	All compartments							
Per sub-compartment:	No							
Skip unused:	No							
Cut-off:	0,10 %							
Default units:	No							
Exclude infrastructure processes:	No							
Exclude long-term emissions:	No							
Sorted on item:	Substance							
Sort order:	Ascending							
No	Substance	Compartment	Unit	Total	Processed Steel	Transport, frame to Vemservice	Transport, to painting	Electricity, manufacture
	Total		GJ	153,21202	91,53666	6,76E-01	2,53E+00	58,469472
	Remaining substances		GJ	0,11449833	0,10326466	0,000456234	0,001453725	0,009323711
1	Coal, brown	Raw	GJ	1,1332671	0,90324565	0,003172091	0,010766948	0,21608237
2	Coal, hard	Raw	GJ	34,083559	32,594666	0,033816331	0,12138732	1,3336884
3	Energy, gross calorific value, in biomass	Raw	GJ	9,4092653	4,1778002	0,004728468	0,014494723	5,2122419
4	Energy, kinetic (in wind), converted	Raw	GJ	0,72553072	0,31998271	0,000322565	0,001083685	0,40414176
5	Energy, potential (in hydropower reservoir), converted	Raw	GJ	24,586925	11,726564	0,004000727	0,013264568	12,843095
6	Gas, mine, off-gas, process, coal mining/m3	Raw	GJ	0,65011366	0,62038153	0,000642336	0,002313546	0,026776248
7	Gas, natural/m3	Raw	GJ	8,1870999	6,7886145	0,043390672	0,15820573	1,196889
8	Oil, crude	Raw	GJ	14,35231	10,273167	0,57271746	2,165403	1,3410222
9	Peat	Raw	GJ	0,72055177	0,2759054	4,27E-05	0,000148626	0,444455
10	Uranium	Raw	GJ	59,248897	23,753068	0,012392949	0,041680484	35,441756

GWP of Crane truck old design 92tm manufacture								
Calculation:	Analyze							
Results:	Inventory							
Product:	1 p Crane truck frame manufacture 92tm (old design) (of project Steel)							
Method:	IPCC 2013 GWP 100a V1.00							
Indicator:	Characterization							
Compartment:	All compartments							
Per sub-compartment:	No							
Skip unused:	No							
Category:	IPCC GWP 100a							
Cut-off:	0,10 %							
Exclude infrastructure processes:	No							
Exclude long-term emissions:	No							
Sorted on item:	Substance							
Sort order:	Ascending							
No	Substance	Compartment	Unit	Total	Processed Steel	Transport, frame to Vemservice	Electricity, manufacture	Transport to painting
	Total		kg CO2 eq	6652,122	5629,2115	179,81602	560,32868	282,76575
	Remaining substances		kg CO2 eq	14,73983	7,75043	0,11527094	6,6890736	0,18505502
1	Carbon dioxide, fossil	Air	kg CO2 eq	6072,2434	5157,5009	174,09655	468,72607	271,91986
2	Dinitrogen monoxide	Air	kg CO2 eq	61,748411	35,20316	0,61633966	22,654109	3,2748031
3	Methane, biogenic	Air	kg CO2 eq	13,459653	5,458338	0,081290385	7,8220895	0,097935192
4	Methane, fossil	Air	kg CO2 eq	462,19342	420,55468	4,8151518	29,652482	7,171109
5	Sulfur hexafluoride	Air	kg CO2 eq	27,737304	2,744041	0,091423908	24,784857	0,11698162

CED of Crane truck old design 92tm manufacture

Calculation:	Analyze
Results:	Inventory
Product:	1 p Crane truck frame manufacture 92tm (old design) (of project Steel)
Method:	Cumulative Energy Demand V1.09 / Cumulative energy demand
Indicator:	Single score
Compartment:	All compartments
Per sub-compartment:	No
Skip unused:	No
Cut-off:	0,10 %
Default units:	No
Exclude infrastructure processes:	No
Exclude long-term emissions:	No
Sorted on item:	Substance
Sort order:	Ascending

No	Substance	Compartment	Unit	Total	Processed Steel	Transport, frame to Vemservice	Electricity, manufacture	Transport to painting
	Total		GJ	169,77777	83,168717	3,0695708	78,941682	4,5978012
	Remaining substances		GJ	0,11112715	0,09382459	0,002072634	0,012588268	0,002641662
1	Coal, brown	Raw	GJ	1,1463905	0,82067427	0,014410549	0,29174037	0,019565346
2	Coal, hard	Raw	GJ	31,789848	29,614982	0,15362483	1,8006594	0,22058108
3	Energy, gross calorific value, in biomass	Raw	GJ	10,880932	3,7958811	0,021481043	7,0372303	0,026339337
4	Energy, kinetic (in wind), converted	Raw	GJ	0,83981163	0,29073107	0,001465386	0,54564594	0,001969236
5	Energy, potential (in hydropower reservoir), converted	Raw	GJ	28,036757	10,654565	0,018174974	17,339913	0,02410394
6	Gas, mine, off-gas, process, coal mining/m3	Raw	GJ	0,60694227	0,56366854	0,00291808	0,03615155	0,004204101
7	Gas, natural/m3	Raw	GJ	8,2685927	6,1680244	0,19712028	1,6159617	0,2874863
8	Oil, crude	Raw	GJ	17,681302	9,3340323	2,6018087	1,8105611	3,9348997
9	Peat	Raw	GJ	0,85122165	0,25068315	0,000194173	0,60007426	0,000270079
10	Uranium	Raw	GJ	69,564847	21,58165	0,056300157	47,851156	0,075740415

Comparison GWP New and old desigm manufacture					
Calculation:	Compare				
Results:	Inventory				
Product 1:	1 p Crane Truck frame 92tm Manufacture (New design) (of project Steel)				
Product 2:	1 p Crane truck frame manufacture 92tm (old design) (of project Steel)				
Method:	IPCC 2013 GWP 100a V1.00				
Indicator:	Characterization				
Compartment:	All compartments				
Per sub-compartment:	No				
Skip unused:	No				
Category:	IPCC GWP 100a				
Cut-off:	0,10 %				
Exclude infrastructure processes:	No				
Exclude long-term emissions:	No				
Sorted on item:	Substance				
Sort order:	Ascending				
No	Substance	Compartment	Unit	Crane Truck frame 92tm Manufacture (New design)	Crane truck frame manufacture 92tm (old design)
	Total		kg CO2 eq	6805,7958	6652,122
	Remaining substances		kg CO2 eq	13,611817	14,73983
1	Carbon dioxide, fossil	Air	kg CO2 eq	6211,5499	6072,2434
2	Dinitrogen monoxide	Air	kg CO2 eq	57,462054	61,748411
3	Methane, biogenic	Air	kg CO2 eq	11,872873	13,459653
4	Methane, fossil	Air	kg CO2 eq	489,83724	462,19342
5	Sulfur hexafluoride	Air	kg CO2 eq	21,461948	27,737304

Comparison CED New and old desigm manufacture					
Calculation:	Compare				
Results:	Inventory				
Product 1:	1 p Crane Truck frame 92tm Manufacture (New design) (of project Steel)				
Product 2:	1 p Crane truck frame manufacture 92tm (old design) (of project Steel)				
Method:	Cumulative Energy Demand V1.09 / Cumulative energy demand				
Indicator:	Single score				
Compartment:	All compartments				
Per sub-compartment:	No				
Skip unused:	No				
Cut-off:	0,10 %				
Default units:	No				
Exclude infrastructure processes:	No				
Exclude long-term emissions:	No				
Sorted on item:	Substance				
Sort order:	Ascending				
No	Substance	Compartment	Unit	Crane Truck frame 92tm Manufacture (New design)	Crane truck frame manufacture 92tm (old design)
	Total		GJ	153,21202	169,77777
	Remaining substances		GJ	0,11449833	0,11112715
1	Coal, brown	Raw	GJ	1,1332671	1,1463905
2	Coal, hard	Raw	GJ	34,083559	31,789848
3	Energy, gross calorific value, in biomass	Raw	GJ	9,4092653	10,880932
4	Energy, kinetic (in wind), converted	Raw	GJ	0,72553072	0,83981163
5	Energy, potential (in hydropower reservoir), converted	Raw	GJ	24,586925	28,036757
6	Gas, mine, off-gas, process, coal mining/m3	Raw	GJ	0,65011366	0,60694227
7	Gas, natural/m3	Raw	GJ	8,1870999	8,2685927
8	Oil, crude	Raw	GJ	14,35231	17,681302
9	Peat	Raw	GJ	0,72055177	0,85122165
10	Uranium	Raw	GJ	59,248897	69,564847

Comparison ReCiPe Ecoupgraded and new 92tm crane truck lifecycle					
Calculation:	Compare				
Results:	Inventory				
Product 1:	1 p Crane truck frame EcoUpgraded Steel Life cycle (of project Steel)				
Product 2:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)				
Method:	ReCiPe Endpoint (H) V1.12 / Europe ReCiPe H/A				
Indicator:	Single score				
Compartment:	All compartments				
Per sub-compartment:	No				
Skip unused:	No				
Cut-off:	0,10 %				
Default units:	No				
Exclude infrastructure processes:	No				
Exclude long-term emissions:	No				
Sorted on item:	Substance				
Sort order:	Ascending				
No	Substance	Compartment	Unit	Crane truck frame EcoUpgraded Steel Life cycle	Crane truck frame 92tm Life cycle (New design)
	Total		kPt	18,143416	21,323379
	Remaining substances		kPt	0,29792627	0,34720263
1	Antimony	Air	kPt	0,51443052	0,6050531
2	Arsenic	Water	kPt	0,043777094	0,051200604
3	Barium	Air	kPt	0,020543888	0,02416241
4	Carbon dioxide, fossil	Air	kPt	7,4356108	8,7418556
5	Chromium	Raw	kPt	0,087998596	0,10346011
6	Coal, brown	Raw	kPt	0,030271974	0,035487605
7	Coal, hard	Raw	kPt	0,3845987	0,45167925
8	Copper	Air	kPt	0,031795267	0,037394774
9	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore	Raw	kPt	0,025405263	0,029328076
10	Dinitrogen monoxide	Air	kPt	0,099965631	0,11737339
11	Gas, natural/m3	Raw	kPt	0,40310673	0,47323205
12	Iron	Raw	kPt	0,23310931	0,27396881
13	Lead	Air	kPt	0,091472295	0,10746595
14	Manganese	Raw	kPt	0,18720412	0,22024851
15	Manganese	Water	kPt	0,17930575	0,21014989
16	Mercury	Air	kPt	0,020187772	0,023727804
17	Methane, fossil	Air	kPt	0,18626711	0,21883869
18	Nickel, 1.98% in silicates, 1.04% in crude ore	Raw	kPt	0,12044739	0,14164364
19	Nitrogen oxides	Air	kPt	0,28337275	0,33342105

Comparison GWP Ecoupgraded and new 92tm crane truck lifecycle					
Calculation:	Compare				
Results:	Inventory				
Product 1:	1 p Crane truck frame EcoUpgraded Steel Life cycle (of project Steel)				
Product 2:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)				
Method:	IPCC 2013 GWP 100a V1.00				
Indicator:	Characterization				
Compartment:	All compartments				
Per sub-compartment:	No				
Skip unused:	No				
Category:	IPCC GWP 100a				
Cut-off:	0,10 %				
Exclude infrastructure processes:	No				
Exclude long-term emissions:	No				
Sorted on item:	Substance				
Sort order:	Ascending				
No	Substance	Compartment	Unit	Crane truck frame EcoUpgraded Steel Life cycle	Crane truck frame 92tm Life cycle (New design)
	Total		kg CO2 eq	171137,55	201170,52
	Remaining substances		kg CO2 eq	278,07158	302,20064
1	Carbon dioxide, fossil	Air	kg CO2 eq	164282,37	193142,54
2	Dinitrogen monoxide	Air	kg CO2 eq	1965,6488	2307,9418
3	Methane, fossil	Air	kg CO2 eq	4611,4533	5417,8348

Comparison CED Ecoupgraded and new 92tm crane truck lifecycle					
Calculation:	Compare				
Results:	Inventory				
Product 1:	1 p Crane truck frame 92tm EcoUpgraded Steel Lifecycle (of project Steel)				
Product 2:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)				
Method:	Cumulative Energy Demand V1.09 / Cumulative energy demand				
Indicator:	Single score				
Compartment:	All compartments				
Per sub-compartment:	No				
Skip unused:	No				
Cut-off:	0,10 %				
Default units:	No				
Exclude infrastructure processes:	No				
Exclude long-term emissions:	No				
Sorted on item:	Substance				
Sort order:	Ascending				
No	Substance	Compartment	Unit	Crane truck frame 92tm EcoUpgraded Steel Lifecycle	Crane truck frame 92tm Life cycle (New design)
	Total		TJ	2,8266416	3,3140235
	Remaining substances		TJ	0,004308224	0,004923448
1	Coal, brown	Raw	TJ	0,012432486	0,014574509
2	Coal, hard	Raw	TJ	0,15810552	0,1856818
3	Energy, gross calorific value, in biomass	Raw	TJ	0,024175566	0,02731148
4	Energy, potential (in hydropower reservoir), converted	Raw	TJ	0,036912876	0,041295264
5	Gas, mine, off-gas, process, coal mining/m3	Raw	TJ	0,003014002	0,003539502
6	Gas, natural/m3	Raw	TJ	0,17518822	0,20566435
7	Oil, crude	Raw	TJ	2,3125577	2,7195535
8	Uranium	Raw	TJ	0,099947051	0,11147962

GWP of Ecoupgraded new design 92tm life cycle									
Results:	Inventory								
Product:	1 p Crane truck frame EcoUpgraded Steel Life cycle (of project Steel)								
Method:	IPCC 2013 GWP 100a V1.00								
Indicator:	Characterization								
Compartment:	All compartments								
Per sub-compartment:	No								
Skip unused:	No								
Category:	IPCC GWP 100a								
Cut-off:	0,10 %								
Exclude infrastructure processes:	No								
Exclude long-term emissions:	No								
Sorted on item:	Substance								
Sort order:	Ascending								
No	Substance	Compartment	Unit	Total	Processed Steel	Transport, frame to vemservice	Transport to painting	Electricity manufacture	Transport Use phase
	Total		kg CO2 eq	171137,55	5264,9215	33,635874	132,23339	415,01677	165291,74
	Remaining substances		kg CO2 eq	278,07158	14,920435	0,053869698	0,18704398	29,105252	233,80498
1	Carbon dioxide, fossil	Air	kg CO2 eq	164282,37	4823,7372	32,566005	127,16139	347,16977	158951,74
2	Dinitrogen monoxide	Air	kg CO2 eq	1965,6488	32,925015	0,11529074	1,5314384	16,779143	1914,298
3	Methane, fossil	Air	kg CO2 eq	4611,4533	393,33881	0,9007086	3,3535181	21,962605	4191,8977

CED of Ecoupgraded new design 92tm life cycle									
Calculation:	Analyze								
Results:	Inventory								
Product:	1 p Crane truck frame 92tm EcoUpgraded Steel Lifecycle (of project Steel)								
Method:	Cumulative Energy Demand V1.09 / Cumulative energy demand								
Indicator:	Single score								
Compartment:	All compartments								
Per sub-compartment:	No								
Skip unused:	No								
Cut-off:	0,10 %								
Default units:	No								
Exclude infrastructure processes:	No								
Exclude long-term emissions:	No								
Sorted on item:	Substance								
Sort order:	Ascending								
No	Substance	Compartment	Unit	Total	Processed Steel	Transport, frame to Vemservice	Transport to painting	Electricity, manufacture	Transport, use phase
	Total		TJ	2,8266416	0,077786518	0,000574185	0,002150129	0,058469472	2,6876613
	Remaining substances		TJ	0,004308224	0,00059413	6,98E-07	2,28E-06	0,00085792	0,002853193
1	Coal, brown	Raw	TJ	0,012432486	0,000767565	2,70E-06	9,15E-06	0,000216082	0,011436994
2	Coal, hard	Raw	TJ	0,15810552	0,027698472	2,87E-05	0,000103153	0,001333688	0,12894147
3	Energy, gross calorific value, in biomass	Raw	TJ	0,024175566	0,003550234	4,02E-06	1,23E-05	0,005212242	0,015396755
4	Energy, potential (in hydropower reservoir), converted	Raw	TJ	0,036912876	0,009965063	3,40E-06	1,13E-05	0,012843095	0,014090045
5	Gas, mine, off-gas, process, coal mining/m3	Raw	TJ	0,003014002	0,000527191	5,46E-07	1,97E-06	2,68E-05	0,002457522
6	Gas, natural/m3	Raw	TJ	0,17518822	0,005768866	3,69E-05	0,000134441	0,001196889	0,16805115
7	Oil, crude	Raw	TJ	2,3125577	0,008729988	0,000486687	0,001840128	0,001341022	2,3001599
8	Uranium	Raw	TJ	0,099947051	0,02018501	1,05E-05	3,54E-05	0,035441756	0,044274333

ReCiPe of Ecoupgraded new design 92tm life cycle

Calculation:	Analyze
Results:	Inventory
Product:	1 p Crane truck frame EcoUpgraded Steel Life cycle (of project Steel)
Method:	ReCiPe Endpoint (H) V1.12 / Europe ReCiPe H/A
Indicator:	Single score
Compartment:	All compartments
Per sub-compartment:	No
Skip unused:	No
Cut-off:	0,10 %
Default units:	No
Exclude infrastructure processes:	No
Exclude long-term emissions:	No
Sorted on item:	Substance
Sort order:	Ascending

No	Substance	Compartment	Unit	Total	Processed Steel	Transport, frame to Vemservice	Transport, freight to painting	Electricity, manufacture	Transport use phae
	Total		kPt	18,143416	1,0125584	0,003809495	0,013641208	0,061897575	17,05151
	Remaining substances		kPt	0,29792627	0,060758661	5,20E-05	0,000184516	0,006286686	0,23064445
1	Antimony	Air	kPt	0,51443052	0,000287155	7,48E-05	0,000410915	1,44E-05	0,51364326
2	Arsenic	Water	kPt	0,043777094	0,014851273	4,95E-06	2,24E-05	0,000884291	0,028014172
3	Barium	Air	kPt	0,020543888	2,00E-05	2,99E-06	1,64E-05	3,49E-06	0,020501036
4	Carbon dioxide, fossil	Air	kPt	7,4356108	0,21832794	0,001473975	0,005755472	0,015713307	7,1943401
5	Chromium	Raw	kPt	0,087998596	0,069945527	3,90E-06	1,42E-05	0,000261572	0,017773378
6	Coal, brown	Raw	kPt	0,030271974	0,001868951	6,56E-06	2,23E-05	0,000526141	0,02784804
7	Coal, hard	Raw	kPt	0,3845987	0,067377766	6,99E-05	0,000250925	0,003244257	0,31365585
8	Copper	Air	kPt	0,031795267	4,50E-05	4,63E-06	2,54E-05	4,47E-06	0,031715786
9	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore	Raw	kPt	0,025405263	0,000872003	3,61E-06	1,92E-05	0,000531439	0,023979026
10	Dinitrogen monoxide	Air	kPt	0,099965631	0,001674445	5,86E-06	7,79E-05	0,000853325	0,097354115
11	Gas, natural/m3	Raw	kPt	0,40310673	0,013274114	8,48E-05	0,000309348	0,002754032	0,38668439
12	Iron	Raw	kPt	0,23310931	0,10078416	2,40E-05	0,000104736	0,001276622	0,1309198
13	Lead	Air	kPt	0,091472295	0,003461191	1,30E-05	7,01E-05	0,000253734	0,087674203
14	Manganese	Raw	kPt	0,18720412	0,15397239	7,49E-06	2,64E-05	0,00013823	0,033059556
15	Manganese	Water	kPt	0,17930575	0,055508631	2,61E-05	9,77E-05	0,001556198	0,12211714
16	Mercury	Air	kPt	0,020187772	0,001220782	3,37E-06	1,51E-05	6,76E-05	0,018880884
17	Methane, fossil	Air	kPt	0,18626711	0,015887851	3,64E-05	0,000135456	0,00088712	0,1693203
18	Nickel, 1.98% in silicates, 1.04% in crude ore	Raw	kPt	0,12044739	0,09097009	6,39E-06	2,33E-05	0,000296319	0,029151272
19	Nitrogen oxides	Air	kPt	0,28337275	0,013200752	0,000259014	0,000214737	0,001276797	0,26842145
20	Occupation, forest, intensive	Raw	kPt	0,085027587	0,012240631	1,49E-05	4,40E-05	0,017683285	0,055044776
21	Occupation, traffic area, rail/road embankment	Raw	kPt	0,067802251	0,000338562	2,75E-05	5,37E-05	0,000299469	0,067083041
22	Occupation, traffic area, road network	Raw	kPt	0,31991975	0,000607702	0,000130607	0,000255122	2,39E-05	0,31890243
23	Oil, crude	Raw	kPt	5,6276949	0,021244749	0,001184371	0,00447802	0,003263427	5,5975244
24	Particulates, < 2.5 um	Air	kPt	0,41067048	0,033934234	8,67E-05	0,000300173	0,00113266	0,37521668
25	Particulates, > 2.5 um, and < 10um	Air	kPt	0,44479383	0,043505718	9,56E-05	0,000319842	0,001070256	0,39980236
26	Sulfur dioxide	Air	kPt	0,27852343	0,014434601	5,65E-05	0,00021014	0,00114717	0,26267502
27	Transformation, from forest	Raw	kPt	0,21922688	0,001044645	4,62E-05	0,000174246	0,000153923	0,21780786
28	Transformation, from forest, intensive	Raw	kPt	0,16925927	0,024009278	2,96E-05	8,79E-05	0,035246678	0,10988581
29	Transformation, from unknown	Raw	kPt	0,037926013	0,001505328	1,31E-05	2,88E-05	0,000324497	0,036054198
30	Transformation, to forest	Raw	kPt	-0,0247049	-0,000586437	-9,76E-06	-1,92E-05	-2,71E-05	-0,024062306
31	Transformation, to forest, intensive	Raw	kPt	-0,1695204	-0,024029319	-2,96E-05	-8,81E-05	-0,035250606	-0,11012273

Comparison GWP EcoUpgraded vs new vs old 92tm crane truck lifecycle						
Calculation:	**Compare**					
Results:	**Inventory**					
Product 1:	**1 p Crane truck frame 92tm EcoUpgraded Steel Lifecycle (of project Steel)**					
Product 2:	**1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)**					
Product 3:	**1 p Crane truck frame 92tm Life cycle(old Design) (of project Steel)**					
Method:	**IPCC 2013 GWP 100a V1.00**					
Indicator:	**Characterization**					
Compartment:	**All compartments**					
Per sub-compartment:	**No**					
Skip unused:	**No**					
Category:	**IPCC GWP 100a**					
Cut-off:	**0,10 %**					
Exclude infrastructure processes:	**No**					
Exclude long-term emissions:	**No**					
Sorted on item:	**Substance**					
Sort order:	**Ascending**					
No	**Substance**	**Compartment**	**Unit**	**Crane truck frame 92tm EcoUpgraded Steel Lifecycle**	**Crane truck frame 92tm Life cycle (New design)**	**Crane truck frame 92tm Life cycle(old Design)**
	Total		**kg CO2 eq**	**171137,55**	**201170,52**	**183241,75**
	Remaining substances		**kg CO2 eq**	**278,07158**	**302,20064**	**305,74951**
1	**Carbon dioxide, fossil**	**Air**	**kg CO2 eq**	**164282,37**	**193142,54**	**175889,47**
2	**Dinitrogen monoxide**	**Air**	**kg CO2 eq**	**1965,6488**	**2307,9418**	**2105,7184**
3	**Methane, fossil**	**Air**	**kg CO2 eq**	**4611,4533**	**5417,8348**	**4940,8162**

Comparison CED EcoUpgraded vs new vs old 92tm crane truck lifecycle						
Calculation:	Compare					
Results:	Inventory					
Product 1:	1 p Crane truck frame 92tm EcoUpgraded Steel Lifecycle (of project Steel)					
Product 2:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)					
Product 3:	1 p Crane truck frame 92tm Life cycle(old Design) (of project Steel)					
Method:	Cumulative Energy Demand V1.09 / Cumulative energy demand					
Indicator:	Single score					
Compartment:	All compartments					
Per sub-compartment:	No					
Skip unused:	No					
Cut-off:	0,10 %					
Default units:	No					
Exclude infrastructure processes:	No					
Exclude long-term emissions:	No					
Sorted on item:	Substance					
Sort order:	Ascending					
No	Substance	Compartment	Unit	Crane truck frame 92tm EcoUpgraded Steel Lifecycle	Crane truck frame 92tm Life cycle (New design)	Crane truck frame 92tm Life cycle(old Design)
	Total		TJ	2,8266416	3,3140235	3,0412605
	Remaining substances		TJ	0,004308224	0,004923448	0,004850875
1	Coal, brown	Raw	TJ	0,012432486	0,014574509	0,013366691
2	Coal, hard	Raw	TJ	0,15810552	0,1856818	0,1695553
3	Energy, gross calorific value, in biomass	Raw	TJ	0,024175566	0,02731148	0,027333857
4	Energy, potential (in hydropower reservoir), converted	Raw	TJ	0,036912876	0,041295264	0,04309215
5	Gas, mine, off-gas, process, coal mining/m3	Raw	TJ	0,003014002	0,003539502	0,003232635
6	Gas, natural/m3	Raw	TJ	0,17518822	0,20566435	0,18781768
7	Oil, crude	Raw	TJ	2,3125577	2,7195535	2,4751394
8	Uranium	Raw	TJ	0,099947051	0,11147962	0,11687189

Comparison ReciPe EcoUpgraded vs new vs old 92tm crane truck lifecycle						
Calculation:	Compare					
Results:	Inventory					
Product 1:	1 p Crane truck frame 92tm EcoUpgraded Steel Lifecycle (of project Steel)					
Product 2:	1 p Crane truck frame 92tm Life cycle (New design) (of project Steel)					
Product 3:	1 p Crane truck frame 92tm Life cycle(old Design) (of project Steel)					
Method:	ReCiPe Endpoint (H) V1.12 / Europe ReCiPe H/A					
Indicator:	Single score					
Compartment:	All compartments					
Per sub-compartment:	No					
Skip unused:	No					
Cut-off:	0,10 %					
Default units:	No					
Exclude infrastructure processes:	No					
Exclude long-term emissions:	No					
Sorted on item:	Substance					
Sort order:	Ascending					
No	Substance	Compartment	Unit	Crane truck frame 92tm EcoUpgraded Steel Lifecycle	Crane truck frame 92tm Life cycle (New design)	Crane truck frame 92tm Life cycle(old Design)
	Total		kPt	18,143416	21,323379	19,434178
	Remaining substances		kPt	0,29792627	0,34720263	0,3205536
1	Antimony	Air	kPt	0,51443052	0,6050531	0,5502292
2	Arsenic	Water	kPt	0,043777094	0,051200604	0,047072889
3	Barium	Air	kPt	0,020543888	0,02416241	0,021974376
4	Carbon dioxide, fossil	Air	kPt	7,4356108	8,7418556	7,9609613
5	Chromium	Raw	kPt	0,087998596	0,10346011	0,094179029
6	Coal, brown	Raw	kPt	0,030271974	0,035487605	0,032546677
7	Coal, hard	Raw	kPt	0,3845987	0,45167925	0,4124508
8	Copper	Air	kPt	0,031795267	0,037394774	0,034008968
9	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore	Raw	kPt	0,025405263	0,029328076	0,027322775
10	Dinitrogen monoxide	Air	kPt	0,099965631	0,11737339	0,10708905
11	Gas, natural/m3	Raw	kPt	0,40310673	0,47323205	0,43216702
12	Iron	Raw	kPt	0,23310931	0,27396881	0,24969041
13	Lead	Air	kPt	0,091472295	0,10746595	0,097909139
14	Manganese	Raw	kPt	0,18720412	0,22024851	0,20023176
15	Manganese	Water	kPt	0,17930575	0,21014989	0,1922681
16	Mercury	Air	kPt	0,020187772	0,023727804	0,021616307
17	Methane, fossil	Air	kPt	0,18626711	0,21883869	0,19957082
18	Nickel, 1.98% in silicates, 1.04% in crude ore	Raw	kPt	0,12044739	0,14164364	0,12889432
19	Nitrogen oxides	Air	kPt	0,28337275	0,33342105	0,30532406
20	Occupation, forest, intensive	Raw	kPt	0,085027587	0,096236363	0,095958798
21	Occupation, traffic area, rail/road embankment	Raw	kPt	0,067802251	0,079728955	0,072755658
22	Occupation, traffic area, road network	Raw	kPt	0,31991975	0,37647156	0,34290651
23	Oil, crude	Raw	kPt	5,6276949	6,6181344	6,0233437
24	Particulates, < 2.5 um	Air	kPt	0,41067048	0,48280466	0,43982458
25	Particulates, > 2.5 um, and < 10um	Air	kPt	0,44479383	0,52300383	0,47634663

Appendix B: Additional images from SimaPro database

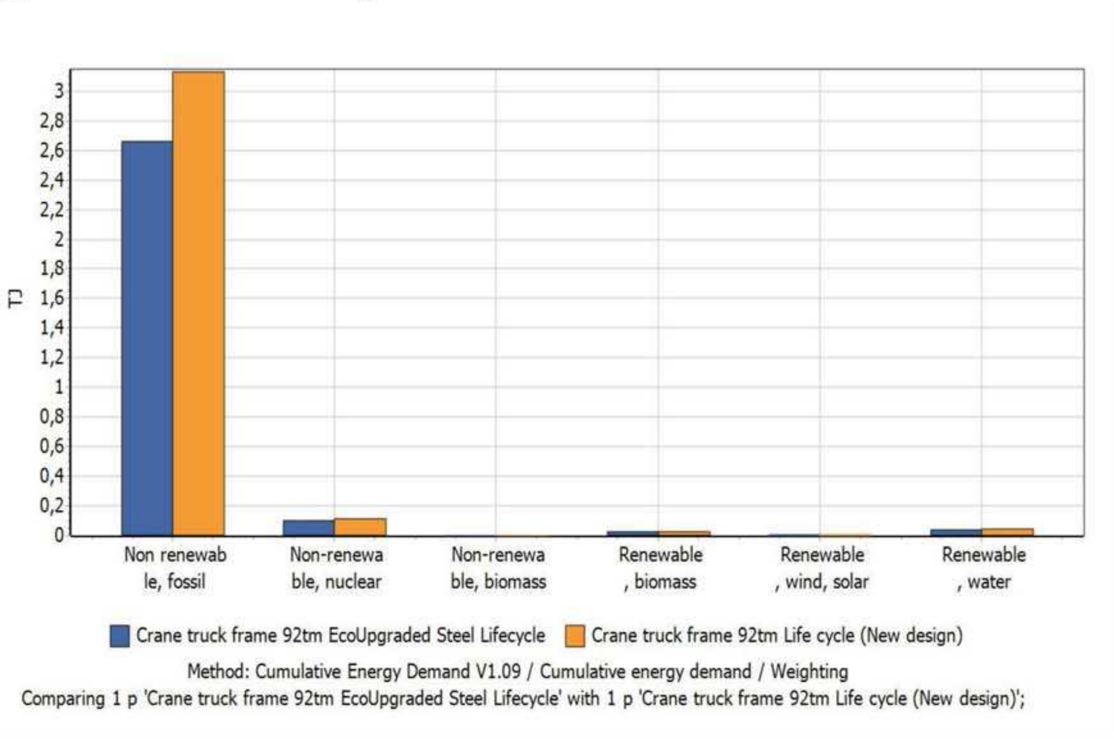

Figure 1: Comparison CED (weighting) energy demand between crane truck with Ecoupgraded steel frame and new design frame lifecycle.

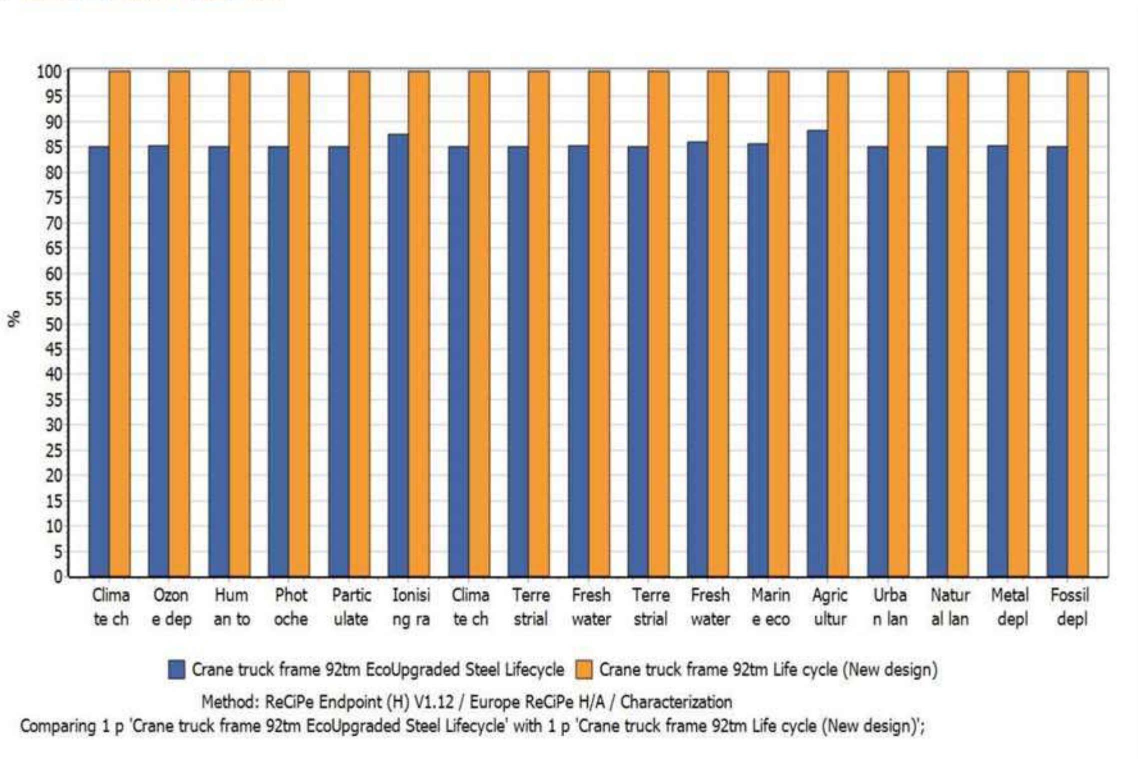

Figure 2: Comparison ReCiPe environmental impact between crane truck with Ecoupgraded steel frame and new design frame lifecycle.

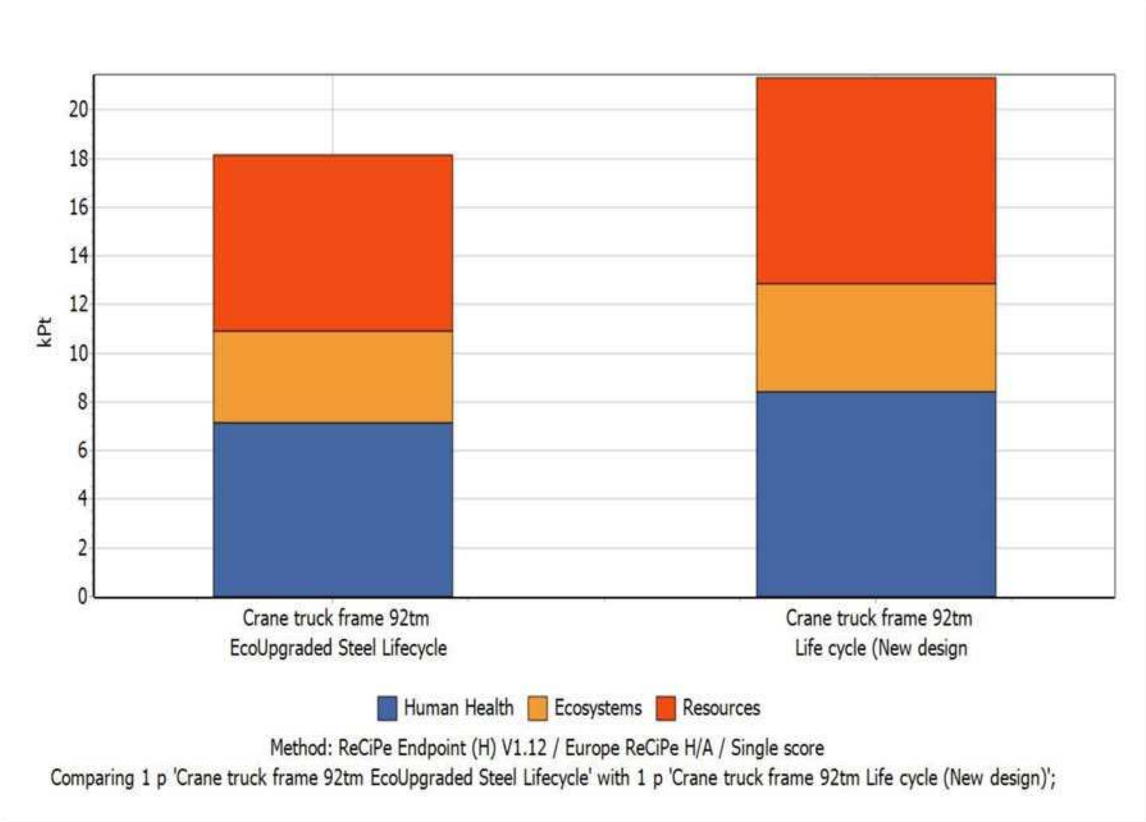

Figure 3: Comparison ReCiPe single score environmental between crane truck with Ecoupgraded steel frame and new design frame lifecycle.

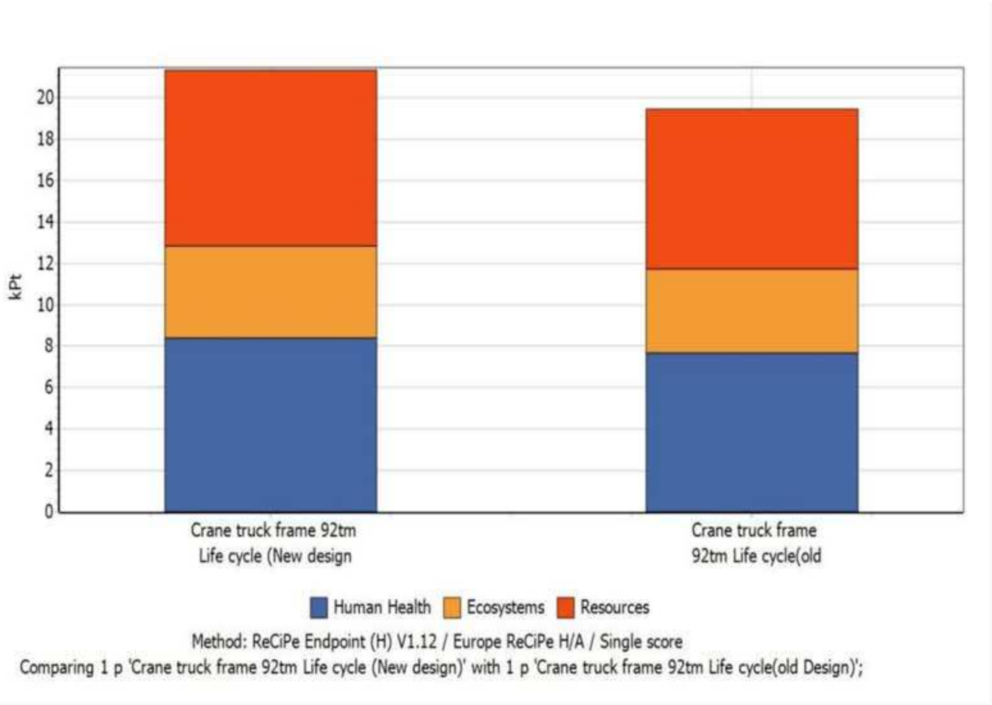

Figure 4:Comparison ReCiPe single score environmental between crane truck with new old design crane truck lifecycle.

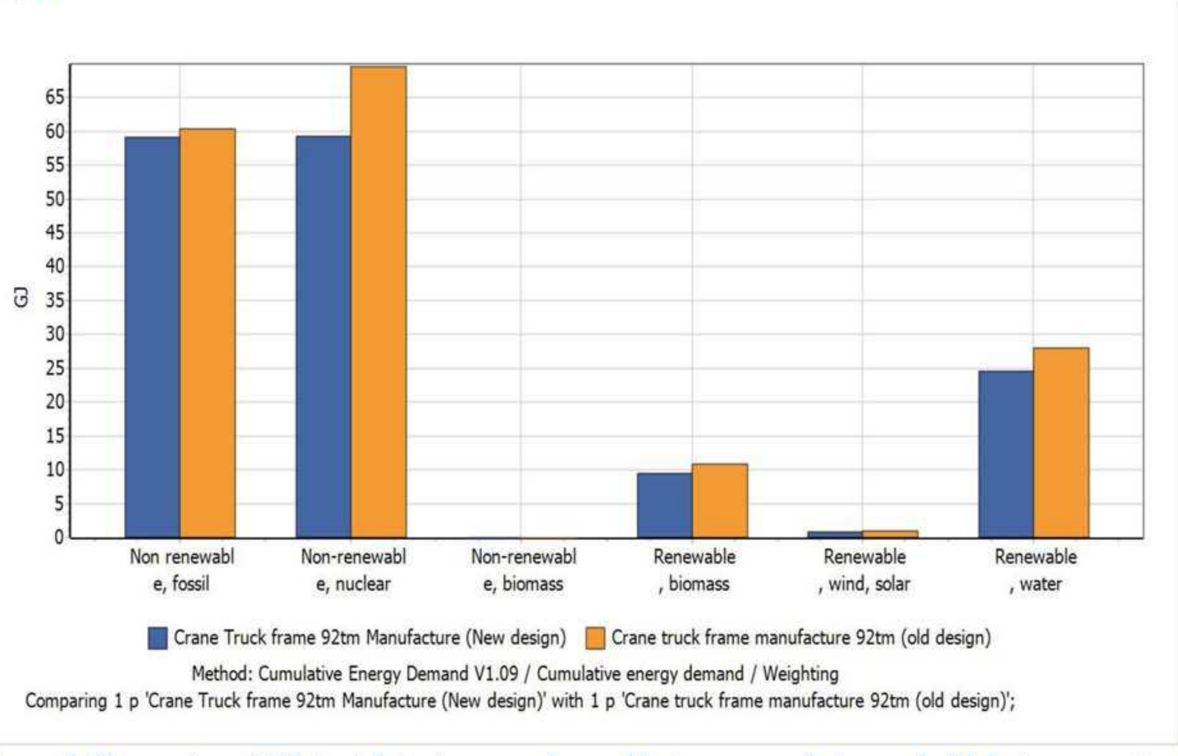

Figure 5: Comparison CED (weighting) energy demand between new design and old design crane truck manufacture.

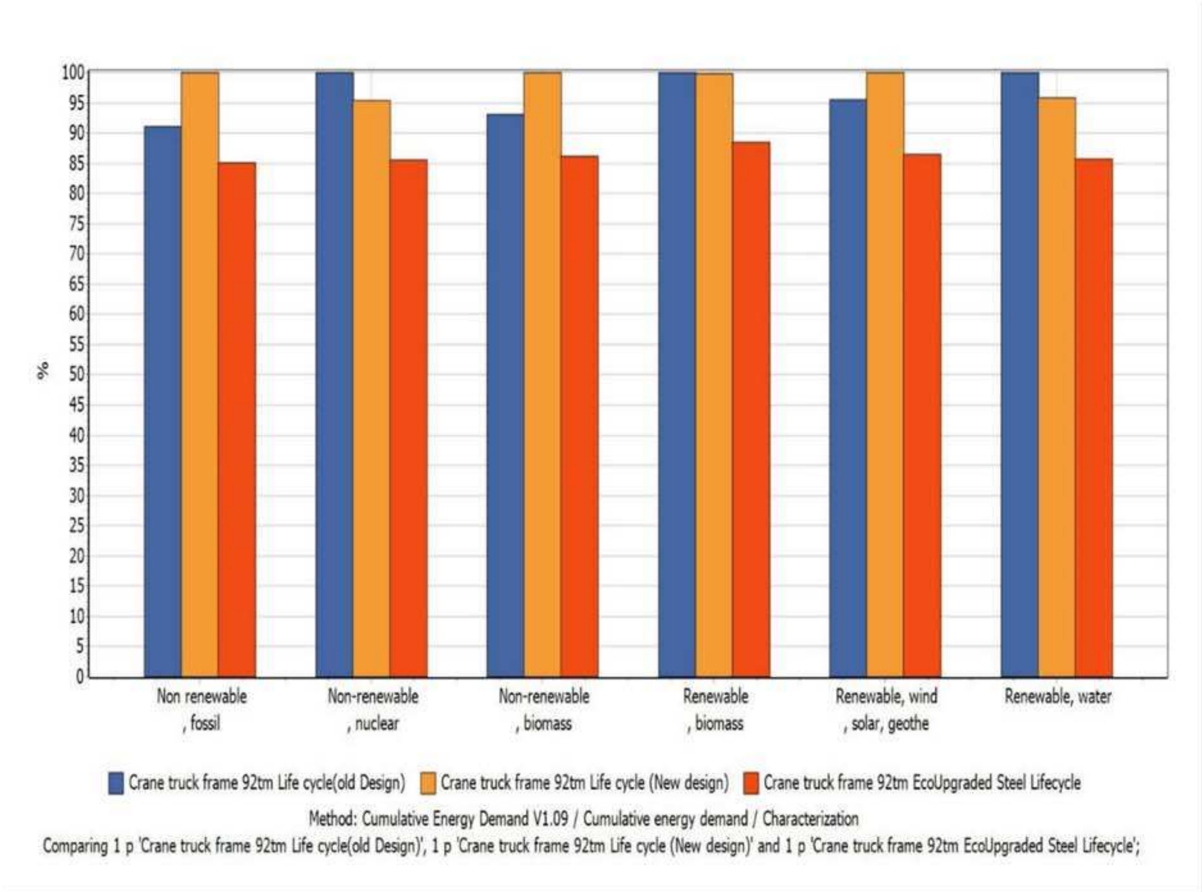

Figure 6: Comparison CED (characterization) energy demand between crane truck with Ecoupgraded steel frame, new design frame and old design lifecycle.

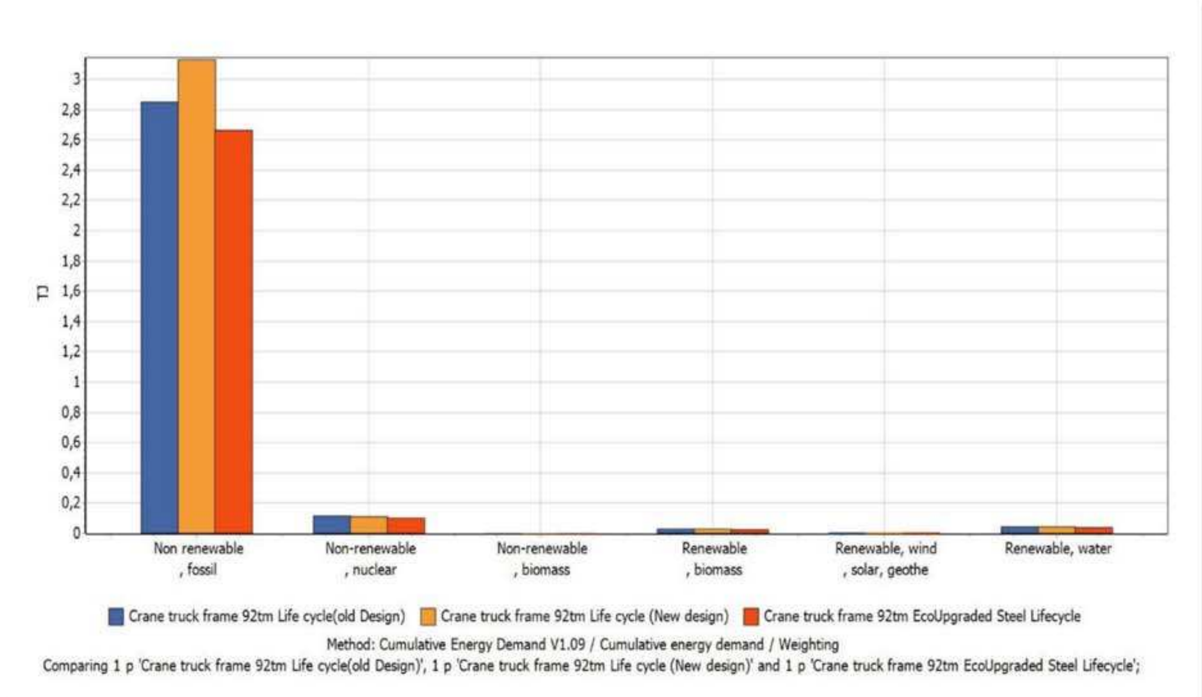

Figure 7: Comparison CED (Weighting) energy demand between crane truck with Ecoupgraded steel frame, new design frame and old design lifecycle.