Comparative Life Cycle Analysis

Doro camera system and home visits

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Foreword

This report was written for Doro AB, in the course *Engineering Training Course IYT000* at Faculty of Technology, Lund by 5th year student Björn Fridqvist Nimvik, Master of Science in Electrical Engineering - energy and environment specialisation. See `https://kurser.lth.se/kursplaner/20_21%20eng/IYT000.html` for more info.

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Abbreviations

GWP	Global Warming Potential
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
IC	Integrated Circuit
ICT	Information and Communication Technology
LCA	Life Cycle Assessment

1 Introduction

1.1 Background

If anyone is in need of assistance to be able to live at home because of age or disability,it is possible in all Swedish municipals to get it. This report will focus on people living at home who has the need of nightly visual checks for various reasons. This is carried out by the municipalities, and often several times a night for every person, by driving to the person and physically check on them. In some cases the only purpose of the visit is the visual check, and when the care givers arrive they disturb both the sleep and the integrity of the person. This can be avoided with a camera safety system that is only active during the visual checks. This study sets out to find whether or not it is beneficial to the climate to replace home visits, where the only purpose is to visually check on a person, with a remote camera safety system.

In order to gain perspective into the matter it is a good idea to do a life cycle assessment, from here on referred to as *LCA*, on both subjects and compare them. Then it is possible to objectively compare them in certain chosen categories.

1.2 What is an LCA

One definition of an LCA can derived from *(ISO 14044:2006) - Environmental management - Life cycle assessment - Requirements and guidelines* [3].

"LCA addresses the environmental aspects and potential environmental impacts) (e.g. use of resources and environmental consequences of releases) throughout a devices' life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave)."

2 Goal and scope definition

2.1 Goal

The overall goal of the report is to do a comparative LCA between a Doro camera system and home visits carried out by municipalities, in accordance with *ISO14044*. It is not the intention of this study to get the exact number on emissions related to each device's life cycle, but rather to get the larger picture.

The purpose is to find out whether or not it is beneficial to the environment to replace home visits with a Doro Care safety service, specifically the Doro camera system.
Another purpose with the study is to find and identify environmental "red flags", that is in which process step of the life cycle has the highest Global Warming Potential (GWP).

2.2 Functional Unit

The function of both systems is to visually check on users throughout the night, and determine whether they need intervention or not. In order to compare the climate impact, this study will only analyse the related GWP, measured in CO_2eq. Therefore we will define the functional unit as the emitted CO_2eq-emissions in one year and one system. $[\frac{CO_2eq}{system*year}]$.

Since the Doro camera system has different emissions for different part of its lifetime, the total cradle-to-grave emissions will be calculated and divided by years of use.

2.3 System boundary

2.3.1 Doro camera system

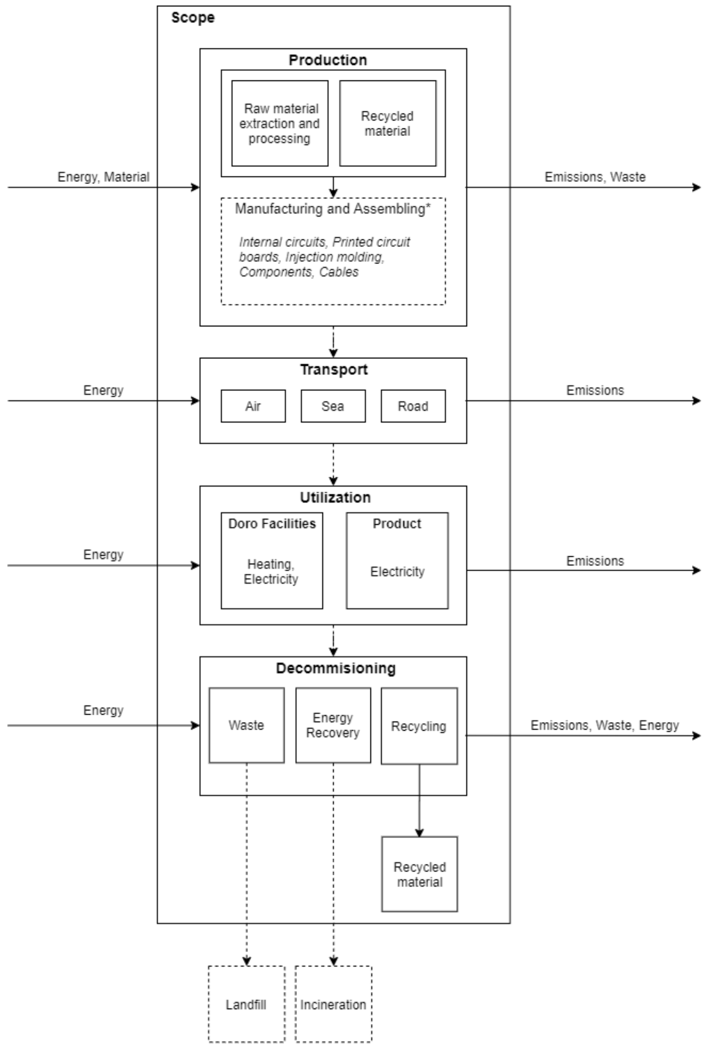


Figure 1: Scope for Doro camera system

The camera system is set as a realistic minimum requirement for any user in need of a camera safety system. A user that has the need for the camera would most likely also be in need of the alarm trigger, the central communication hub and a reliable router. The camera system includes; **Doro Eliza**, **Doro Enzo** and **Doro Visit** and **Doro Visit Router**. The lifetime is estimated to be 5 years for Enzo and 7 years for Eliza, Visit and Visit Router. The lifetime of each device are not limited to one user, since all devices can transfer to new care recipients when they are no longer needed by the former one. The reason for Enzo having lower lifetime is due to it being submitted to heavy wear since it is always worn by a user.

2.3.1.1 Production

Manufacturing and Assembling are in dotted line since some components are not considered as significant and can be disregarded. This is further explained in section 4.1.1

2.3.1.2 Transport

The only transport included is the transport of the final products to its customers.

2.3.1.3 Utilization

Utilization from Doro call centers is limited to one third of total heating and electricity consumption of the offices analysed. Electricity use will be limited to Sweden.

2.3.1.4 Decommissioning

Decommissioning of a device will become waste, energy or recycled material. This study will be limited to recycled material in Sweden.

2.3.2 Home visits

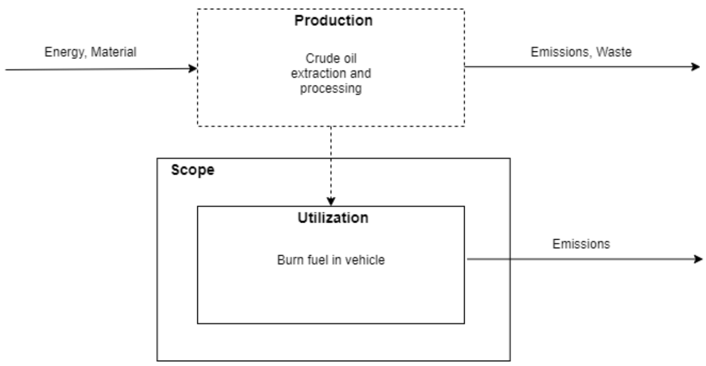


Figure 2: Scope for home visits

The scope for home visits only includes the utilization of the cars used in home visits and is limited to Sweden. The "Well-to-Tank" stage e.g. the production and distribution stage is excluded since there is not enough data available.

2.4 Allocation

Any emission data resulting in less than 0.01 $kgCO_2eq/year$ are omitted from this study. Such could be production of small electronic components (resistors, capacitors, inductors, diodes, small cables etc.), production of screws and nuts.

The following items are within the scope of the study, but were chosen not to be investigated further due to lack of data.

- Mobile communication card, in Visit Router

- Mobile communication card, in Eliza
- Camera **lens**, in Visit (the sensor is still included)

2.5 Methodology

First the initial goal and scope was defined for this study. Then data was collected by disassembling each device, observing, measuring and weighing all components that were accessible, using a kitchen scale and a ruler. Information about what materials used in each device was gathered, for Enzo and Eliza by questioning the technical department of Doro AB, and for Visit and Visit router making qualified assumptions.
To make an estimation of the produced emission for each component, many public carbon intensity studies were collected and used, and those results went into this study's emissions calculation. Throughout the information gathering process the scope was adjusted to fit what was deemed significant or not. The environmental impact assessment was done according to predetermined criteria to make the comparison fair between the two systems.

2.5.1 Data quality

All sources collected in this report are from the public domain or in some instances thorough academic platforms, such as LUBsearch, (Lund University Libraries). No life cycle inventory databases or programs were used in this study.
To make the results from this report as credible as possible it is important that the data used were geographically relevant and no more than ten years old for data regarding Information and Communication Technology (ICT) devices.

Raw material of complex components such as IC, PCB and batteries are not presented, but emission data from production is included in report. This is because sources used for emissions calculations includes the raw material extraction and processing step.

2.5.1.1 Data base

This study utilizes no pre-existing data base for eco analysis, but instead build its own. see appendix B.

3 Systems description

3.1 Doro camera system

The Doro camera system is set up around the need of visual nightly checks of a person. The system allows for remote checks during the night, that is less intrusive on the sleep and privacy of the user, than home visits are. It also allows the user to trigger an alarm and communicate with a Doro call center anywhere in their home.

3.1.1 Doro Enzo

Figure 3: Doro Enzo

3.1.1.1 General Description

Doro Enzo is a long-range alarm trigger that is compatible with all Doro Care phones and base units. It uses a two-way transceiver that monitors the connection to the base unit so that the user can confirm that any alarm send has been received. It can be used in shower or bath and comes with both neck cord and wrist strap. The battery is replaceable.

3.1.1.2 Specific description

The alarm trigger Enzo is manufactured and assembled in China. It is first transported by truck within China then flown to Doro warehouse in Czech Republic where final products are put in kits and sent to costumers. Enzo is put in together with Eliza and transported by truck to Sweden. It is paired to an Eliza communication hub. If the initial user does no longer have a need for Enzo, it will be sent to get cleaned, wristband replaced and sent to another user. When it is time to decommission Enzo, it can be left at any waste station in Sweden where it will be disassembled and the parts will be recycled, incinerated or stored in a depot.

3.1.2 Doro Eliza

Figure 4: Doro Eliza

3.1.2.1 General Description

Doro Eliza is a versatile base unit designed to deliver high security and reliability to the user by implementing both 4G and IP-network communication. Eliza allows for two way communication between Doro Care service center and its user, utilizing the built in microphone and speaker. It is compatible with many Doro Care wireless devices, such as smoke detectors and radio triggers, and adaptable for future needs. Eliza is planned to replace the Doro Visit Router in the near future.

3.1.2.2 Specific Description

The communication hub Eliza is manufactured and assembled in China. It is first transported by truck within China where it is then shipped to Netherlands and driven to warehouse in Czech Republic. It is put together with Enzo and shipped by truck to Sweden. During utilization phase Eliza is expected to be in network standby mode the absolute majority of time, and have a power consumption of 1.8W. Eliza has an estimated lifetime of 7 years and can be transferred between users if necessary.

3.1.3 Doro Visit

Figure 5: Doro Visit

3.1.3.1 General Description

Doro Visit is a remote supervision service system, allowing for virtual checks as an alternative to home visits. It provides a way for municipalities to carry out night time checks without intruding on its users integrity or sleep. The camera will always point towards the roof when not in use.

3.1.3.2 Specific Description

Visit is manufactured and assembled in China. It is transported to Netherlands by sea, and to a warehouse in Czech Republic by road before it is taken to Sweden by road. During utilization Visit is expected to be in networked standby mode the absolute majority of time, and have a power consumption of 1.8W.

3.1.4 Doro Visit Router

Figure 6: Doro Visit Router

3.1.4.1 General Description

In order to reassure the redundancy of all Doro Care devices it is not possible to rely on the users own routers for communication. The Doro Visit Router uses both 4G and IP-network communication and is compatible with many Doro Care wireless devices.

3.1.4.2 Specific Description

The router is manufactured in China. It is first transported within China by road, and then to Germany by sea. From there it goes to a warehouse in Czech Republic by road before it is taken to Sweden by road. During utilization phase the router is expected to be in networked standby mode the absolute majority of time, and have a power consumption of 2W.

3.2 Home visits

3.2.0.1 General Description

If anyone is in need of assistance to be able to live at home because of age or disability, it is possible in all Swedish municipals to get it. The municipalities care givers drives to their users in need of assistance several times throughout the day and night. In some cases at night the only purpose of the visit it to visually check that the user is still in their bed. It is only those cases that will be included in this report.

3.2.0.2 Specific Description

All emissions data regarding driving is based on average emissions from new cars in Sweden, supplied Transportstyrelsen [31]. Distances driven and time saved is collected from a report published by Swedish government agency Socialstyrelsen [6] and analyses five Swedish municipals: Falun, Kramfors, Norrtälje, Järfälla and Karlstad.

4 Life cycle inventory analysis

In this section the inventory analysis for the Doro camera system and home visits are described. Inventory analysis for this study consists of four categories for the camera system; **production**, **transport** of final product, **utilization**, and **decommissioning**. For the home visit system only **utilization** is included. It specifies where and how the data have been gathered.

4.1 Doro camera system

4.1.1 Production

The production phase consists of two parts, *raw materials and extraction*, and *manufacturing and assembling*. In a few cases the manufacturing phase is omitted to due to the scope of this report, and only their materials accounted for.
They are simply omitted because it was considered that their contribution to final results was not big enough to justify the time needed to analyse each individual component.
An overview of the production phase is shown in figure 7

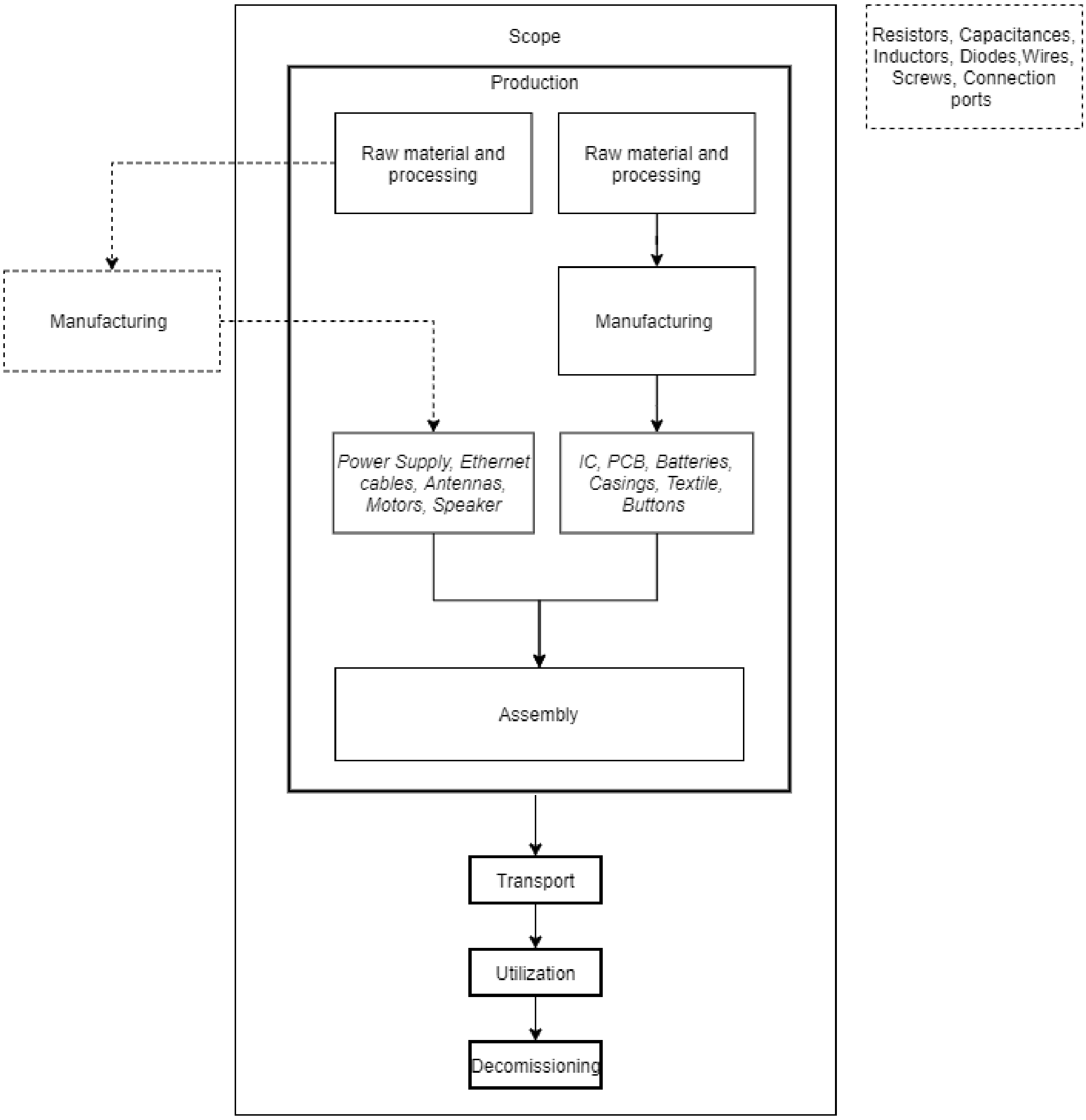


Figure 7: Flowshart, production

For parts such as the small electrical components on the PCB (IC, resistors, capacitors, inductors etc.) were not accessible without breaking the product and thus not possible to weigh. Instead area of PCB and IC was measured and emissions calculated based on area, rather than weight, was used. It is these inventory tables that will be the ground for all emissions calculations, i.e., emissions calculations can not be derived from any other data than those presented in this section.
For a detailed list of contents and materials, see appendix A

4.1.1.1 Enzo

Table 1: Production inventory, Enzo

Paper			
	Paper	0.05	kg
Plastics			
	ABS	0.04	kg
	TPE	0.01	kg
	PE	0.003	kg
	PC	0.04	kg
Electronics			
	IC	0.32	cm2
	PCBA	5.9	cm2
Other			
	Battery	0.00071	kWh
Manufacturing processes			
	Polymer injection moulding	0.09	kg
	Polyester textile production	0.11	kg
	Assembling	0	kWh

4.1.1.2 Eliza

Table 2: Production inventory, Eliza

Paper			
	Paper	0.014	kg
	Corrugated board	0.224	kg
Plastics			
	PC	0.43	kg
	PE	0.01	kg
	PMMA	0.03	kg
Metals			
	Aluminium	0.01	kg
	Copper	0.04	kg
	Neodynium	0.01	kg
Electronics			
	IC	9	cm2
	PCBA	290	cm2
Other			
	Battery	0.0074	kWh
Manufacturing processes			
	Polymer injection moulding	0.47	kg
	Assembling	0	kWh

4.1.1.3 Visit

Table 3: Production inventory, Visit

Paper			
	Paper	0.011	kg
	Corrugated board	0.085	kg
Plastics			
	PC	0.25	kg
	PE	0.047	kg
Metals			
	Aluminium	0.03	kg
	Copper	0.05	kg
	Neodynium	0.01	kg
	Iron	0.017	kg
Electronics			
	IC	3.45	cm2
	PCBA	100.47	cm2
	LED	13	pcs
Manufacturing processes			
	Polymer injection moulding	0.286	kg
	Assembling	0	kWh

4.1.1.4 Visit Router

Table 4: Production inventory, Visit Router

Paper			
	Paper	0.02	kg
	Corrugated board	0.18	kg
Plastics			
	PC	0.09	kg
	PE	0.08	kg
Metals			
	Aluminium	0.62	kg
	Copper	0.11	kg
Electronics			
	IC	4.67	cm2
	PCBA	314.00	cm2
Manufacturing processes			
	Polymer injection moulding	0.12	kg
	Assembling	0	kWh

4.1.2 Transport

The only transport that is included within the scope of this study is transportation of final product to the customer, all other form of transport e.g. raw material to processing factory is omitted. Shipping and flight distances were always assumed to be shortest path possible if no other information was given. Malmö will be the final destination for all products, even though they would be distributed all over Sweden. Two scenarios, sea and air, were set up for every product to be able to compare emissions depending on method of transport.

All emissions from transport phase were based on data received from Doros forwarding agent *DSV*. The GWP per tonne and km is presented in table 5

Table 5: GWP

Air	0.71 $kgCO_2e/(tonne * km)$
Road	0.083 $kgCO_2e/(tonne * km)$
Sea	0.0074 $kgCO_2e/(tonne * km)$

4.1.2.1 Enzo

Weight		0.034 kg	
From	**To**	**Distance [km]**	**Activity**
Air Route			
China	China	-	Road
China	Czech Republic	8665	Air
Sea Route			
China	China	-	Road
China	Germany	21,142	Sea
Germany	Czech Republic	860	Road

4.1.2.2 Eliza

Weight		0.992 kg	
From	**To**	**Distance [km]**	**Activity**
Air Route			
China	China	-	Road
China	Czech Republic	8665	Air
Czech Republic	Sweden	1040	Road
Sea Route			
China	China	-	Road
China	Germany	21,142	Sea
Germany	Czech Republic	860	Road
Czech Republic	Sweden	1040	Road

4.1.2.3 Visit

DSV emissions data is applied on *DHL* freighting, and is assumed to be very similar.

Weight		0.547 kg	
From	**To**	**Distance [km]**	**Activity**
Air Route			
China	China	-	Road
China	Czech Republic	8665	Sea
Czech Republic	Sweden	1040	Road
Sea Route			
China	China	-	Road
China	Netherlands	20,664	Sea
Netherlands	Netherlands	244	Road
Netherlands	Czech Republic	992	Road
Czech Republic	Sweden	1040	Road

4.1.2.4 Visit Router

DSV emissions data is applied on *DHL* freighting, and is assumed to be very similar.

Weight		1.335 kg	
From	**To**	**Distance [km]**	**Activity**
Air Route			
China	China	-	Road
China	Czech Republic	8665	Air
Czech Republic	Sweden	1040	Road
Sea Route			
China	China	-	Road
China	Germany	21,142	Sea
Germany	Germany	392	Road
Germany	Slovakia	581	Road
Slovakia	Czech Republic	130	Road
Czech Republic	Sweden	1040	Road

4.1.3 Utilization

Utilization was mainly measured by the author of this study by setting up the Doro camera system and connecting each device to a power meter. Standby mode and active alarm mode was measured. Utilization phase is in this study limited to Sweden, and as such, Swedish electricity mix is used in all emission calculation. Active alarm mode will not be included in the report as it is considered not to have any relevant impact on end result since its time frame relative to standby mode is insignificant. Doro call center facilities are within the scope of the study because the camera system would be useless unless someone was able to respond to a triggered alarm.

4.1.3.1 Call centers

There are two call centers in Sweden, Malmö and Kalix, and a backup center in Malmö. The call centers are a part of the Doro office buildings and account for about a third of the total space, therefore we will account a third of the emissions from the offices to the call centers. The emissions from buildings mainly comes from energy usage and heating, emissions from transport of employees is considered to many steps away from the camera system and is omitted. All heating comes from district heating in both call centers. In Malmö it is delivered by *Eon* and in Kalix by *Vasa Värme*.

Table 6: Call centers emission

Sites (call centers)	**Kalix**	**Malmö**	**BC Malmö**	**All**
Area [m^2]	615	669	58	
Energy use, heating,1 year [MWh]	67.7	48	5.24	
Energy use, electricity, 1 year [MWh]	46.7	45.7	4.27	
Alarm connections				87,000

4.1.3.2 Devices

The only emissions that occurs during utilization of a device comes from energy production, that the device then consumes. Table 7 displays power ratings in standby mode for each device. Enzo uses a battery, and as such no emissions will occur in utilization.

Table 7: Power rating

Standby	**Power [W]**	**Energy, 1 year [kWh]**
Enzo	n/a	n/a
Eliza	1.8	15.8
Visit	1.8	15.8
Visit Router	2	17.5

4.1.4 Decomissioning

Decomissioning phase refers to the end-of-life treatment and disposal of the devices. Doro is part of non-profit organisation *El-kretsen*, that makes sure that all decommissioning of electronics is taken care of in accordance to Swedish laws. The parts becomes either recycled, incinerated for energy or put in depots.

When electronic waste arrives at a recycling facility it is put on a conveyor belt where hazardous waste such as batteries gets separated by hand, as well as PCBAs that contains small parts of valuable metals e.g. gold, silver and copper etc. The rest continues to a fragmentation process, where it gets crushed to smaller bits so that they can be sorted into four categories; metals, glass, plastic and other. It is further separated through magnets, optics, density or by hand. In the end almost all of the metal and glass put into the process will be recycled, and about 50% of the plastic. The rest will be incinerated, or in a few cases put into depots.
Metals and glass can be recycled indefinitely, while paper and plastic can be recycled up to about ten

times [13]. The energy needed for the recycling process is just a fraction of the extraction and processing of new materials, and not accounted for. The net emissions from the decommissioning phase will be negative since this study assumes that the recycled materials will replace virgin materials in new products, and thus reduce new emissions.

4.1.4.1 Material recycling

Material	Method	Share	Enzo[kg]	Eliza[kg]	Visit[kg]	Router[kg]
Metals						
Aluminium	Recycling	*1*	*0.00*	*0.01*	*0.03*	*0.62*
Neodynium	Recycling	*1*	*0.00*	*0.01*	*0.01*	*0.00*
Copper	Recycling	*1*	*0.00*	*0.04*	*0.04*	*0.08*
Iron	Recycling	*1*	*0.00*	*0.00*	*0.02*	*0.00*
Paper and cardboard	Recycling	*1*	*0.05*	*0.24*	*0.10*	*0.19*
Glass	Recycling	*1*	*0.00*	*0.00*	*0.00*	*0.00*
PCBA (PCB + IC + Other small components)						
	Recycling	*~0*	*n/a*	*n/a*	n/a	n/a
	Incineration	*0.55*	*omitted*	*omitted*	*omitted*	*omitted*
	Landfill	*0.45*	*omitted*	*omitted*	*omitted*	*omitted*
Plastics			*0.20*	*0.47*	*0.31*	*0.55*
	Recycling	0.50	*0.10*	*0.235*	*0.155*	*0.275*
	Incineration	0.50	*0.10*	*0.235*	*0.155*	*0.275*

4.2 Municipality home Visits

To calculate GWP data is collected from *Socialstyrelsen* report on welfare technology [6]. There are five municipalities that have reported on camera use instead of home visits. The average value is then used for all calculations. Fuel mix is based on average new car in Sweden 2019, and is estimated to be 119.75 $gCO2ekv/km$.
Data presented is based on one night and one year as reported by Socialstyrelsen [6].

Municipality (24h)	**Falun**	**Kramfors**	**Norrtälje**	**Järfälla**	**Karlstad**	**Avarage**
Population	59,406	18,282	62,622	79,990	93,898	**62,839**
Nr of people that has need of home visits	89	64	111	90	270	**125**
Nr of home visits, total	328	91	155	148	393	**223**
Home visits with no other intended purpose than visual check	118	10	61	95	*no data*	**71**
Nr of people that has camera	19	14	32	17	20	**20**
Nr of camera checks	26	21	68	32	32	**36**

Municipality (1 year)	**Falun**	**Kramfors**	**Norrtälje**	**Järfälla**	**Karlstad**	**Avarage**
Estimated time in car that camera replaces [hours]	2516	2118	4270	*no data*	*no data*	**2968**
Estimated distance not driven because of camera [km]	34,060	63,080	*no data*	*no data*	*35,660*	**44,260**
Estimated saved km per camera user [km]	1790	4500	*no data*	*no data*	1780	**2690**

5 Results

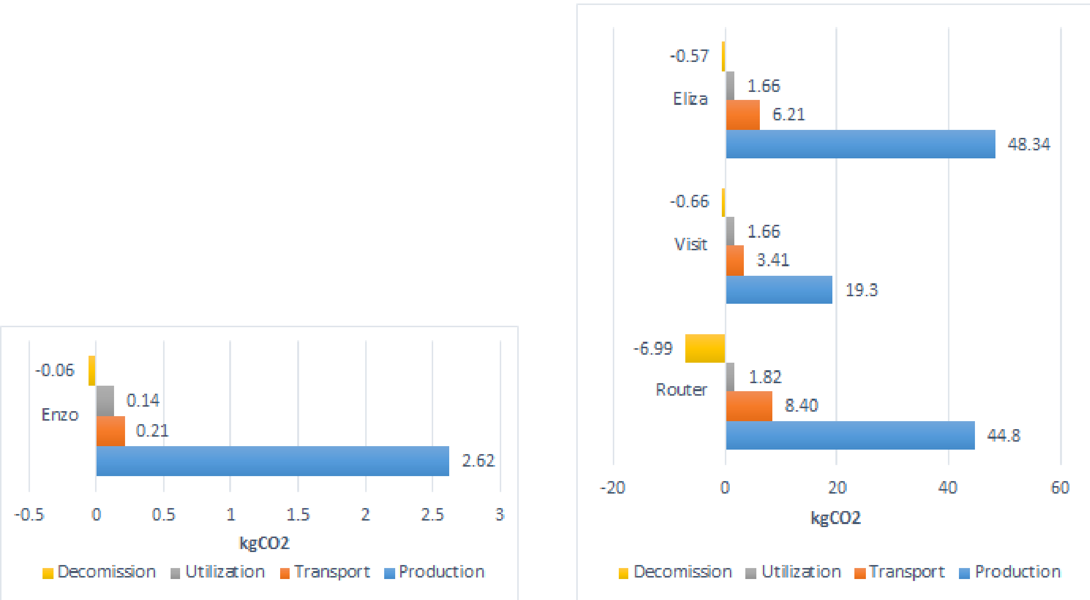
5.1 Doro Camera system

In table 8, the results from all phases for all devices are presented. For transport the air route is used.

Table 8: Results for camera system

[kgCO2e]	*Enzo*	*Eliza*	*Visit*	*Router*
Expected lifetime	*5*	*7*	*7*	*7*
Production	2.6	48.3	16.3	44.8
Transport	0.2	6.2	3.4	8.4
Utilization	0.14	1.66	1.66	1.88
Decommission	-0.06	-0.57	-0.66	-6.99

Emissions total	2.9	55.6	23.7	48.0
Emissions yearly	**0.6**	**7.9**	**3.4**	**6.9**
Camera system yearly emissions	**18.8**			

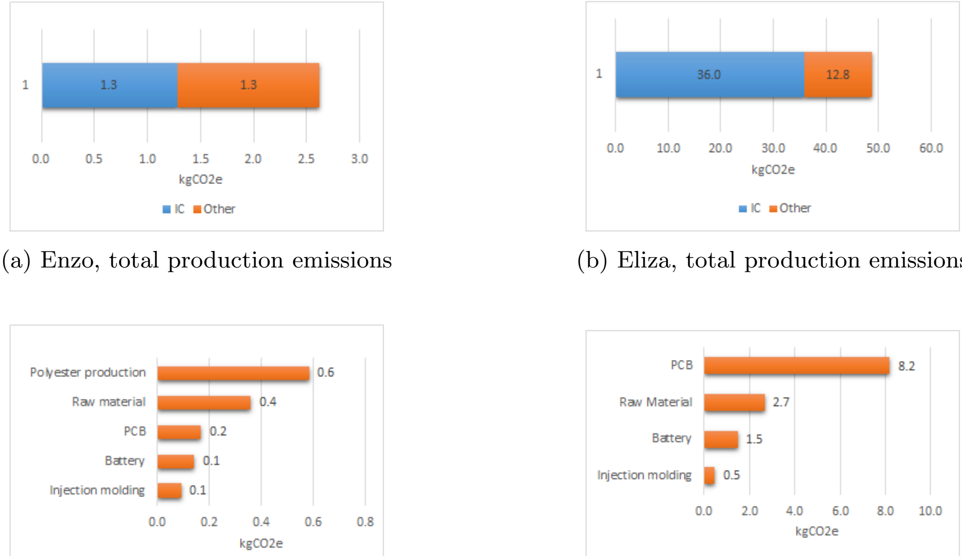


(a) Enzo total emissions

(b) Eliza, Visit Router total emissions

Figure 8: Doro Camera system total emissions

5.1.0.1 Production



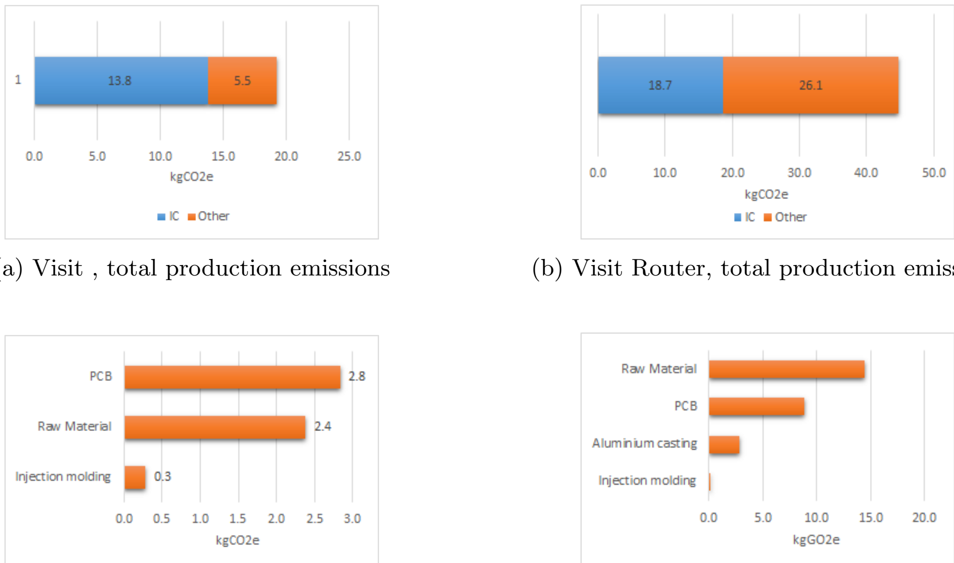
(a) Enzo, total production emissions

(b) Eliza, total production emissions

(c) Enzo, other

(d) Eliza, Other

Figure 9: Enzo & Eliza,total production emissions



(a) Visit , total production emissions

(b) Visit Router, total production emissions

(c) Visit, other

(d) Visit Route, Other

Figure 10: Visit & Visit Router, total production emission

5.1.0.2 Transport

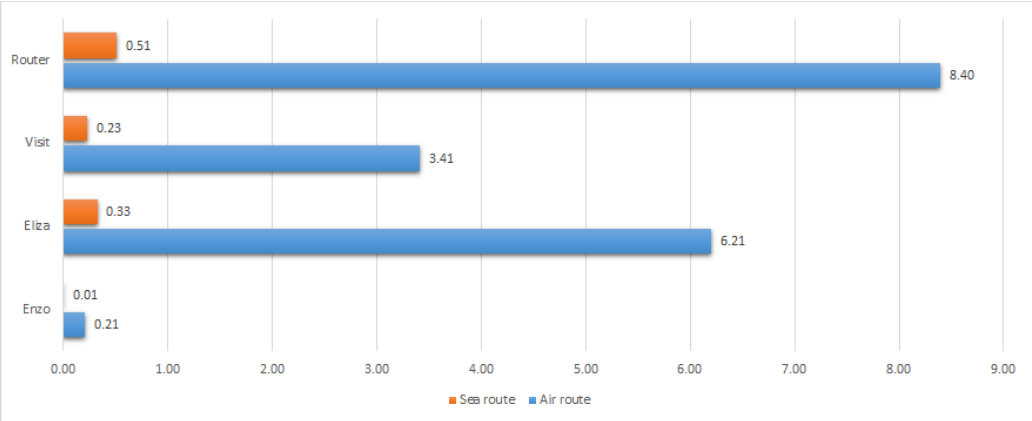
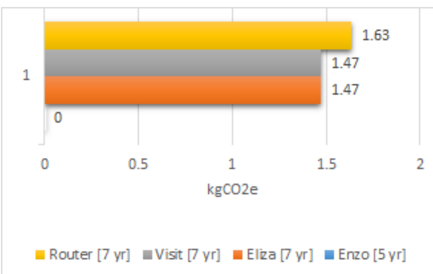


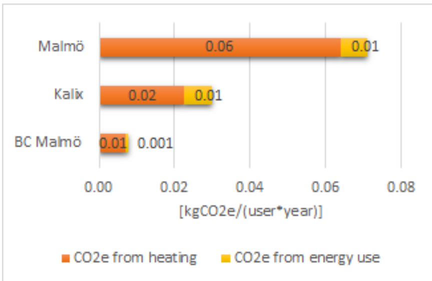
Figure 11: Transport emissions

5.1.0.3 Utilization

Since our functional unit is $\frac{kgCO_2e}{year}$ per system, total yearly emissions from call center facilities was divided by amount of connections (87,000). This gives a fair estimation of how much emission one connection is responsible for.



(a) Utilization emmissions, total



(b) Call centers emissions, yearly for one system

Figure 12: Utilization emissions

5.1.0.4 Decommission

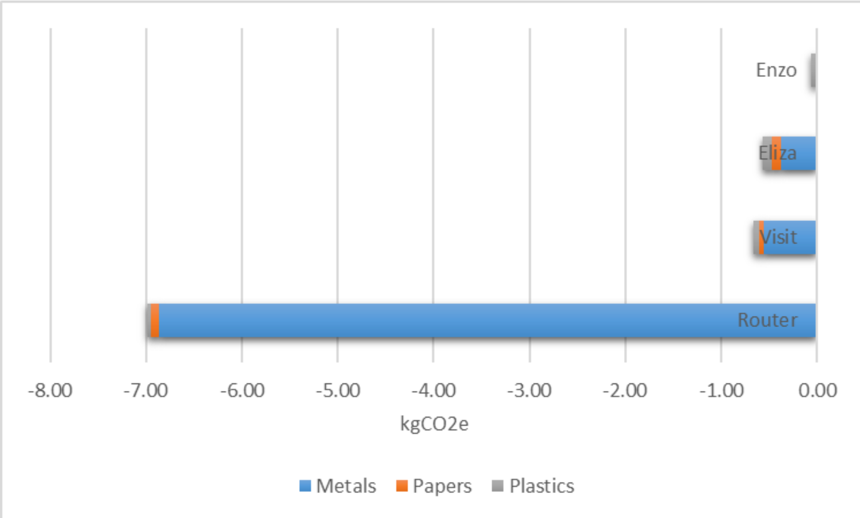


Figure 13: Decommission emissions from material recycling

5.2 Home visits

Figure 14 shows the yearly emissions from driving to home visits in three municipalities. A mean value, and 95% confidence interval between 149 $kgCO_2e$ and 496 $kgCO_2e$ is also shown. (although considering the small sample size, the confidence interval is uncertain)

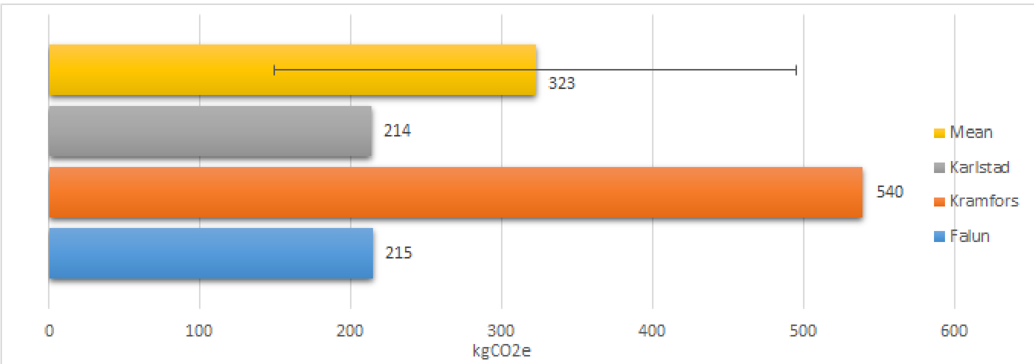


Figure 14: Home visits yearly emissions per user

5.3 Comparison of the two system

In figure 15 the final comparison of the two systems is presented. It includes all phases for each system and the net difference for replacing home visits with a camera system is shown. The home visits system has considerably higher GWP.

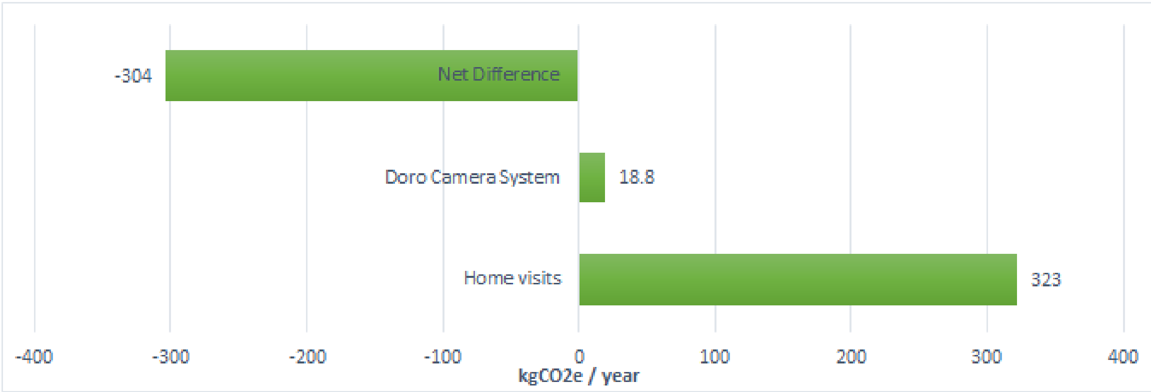


Figure 15: Comparison of the two systems

6 Interpretation

6.1 Discussion of results

6.1.1 Camera system

As for most information and communication technology (ICT), production phase has the largest GWP in the lifecycle. The IC production was the single biggest contributor of emissions for all components, followed by PCB. This is because IC- and PCB construction requires a lot of energy when manufactured, and it's mainly produced in China where a large part of the electricity mix comes from fossil fuel. This will further be discussed in section 6.2.1.

There is a large difference in transport emissions when choosing between the sea- or air route, about a factor 20. Air transport GWP are in fact about 100 larger than sea transport per tonne-km, according to data from DSV, but the air route is always shorter. It is however not enough to compensate for the larger emissions.

Swedish carbon intensity of electricity is used for all calculations and it does not add up to a significant amount. However this might not be the case outside of Sweden as Sweden has one of the lowest GWP per produced Wh in the world.

Doro call centers are based on emissions from energy use and heating. What is interesting to note here is that even though Malmö has a lower energy consummation for heating it has higher emissions for it, see section 4.1.3. This is explained by the fact that Eon, who delivers district heating to Malmö, uses a higher mix of fossil fuel in their fuel mix than Vasa Värme, who delivers to Kalix. 21.0% [14] and 2.7% [15] respectively. The final result is very little because it is devided by all connections (users).

The decommissioning phase shows negative values for all devices. This is because we assume that the recycled materials will be used to replace virgin materials in other devices in the future. Metals have the highest impact because extracting and processing of minerals into metals is a very energy consuming process, as opposed to plastic production where production of virgin and recycled material is very similar. This, however, does not mean that it's unnecessary to recycle plastics. More on this in section 6.6.0.3

6.1.2 Home visits

The emissions show in figure 14 displays the emissions from driving to users in three municipalities, and the mean value. The emissions in Kramfors is more than twice as big as Karlstand or Fauln, because it is less densely populated and the care givers have to drive longer to visually check on a user. The conficence interval goes from 149 $kgCO_2e$ to 496 $kgCO_2e$ which is quite i large spread, and we would have liked to have data from more municipalities to narrow this down. At least 30 samples is necessary when we don't know the *true mean* of all municipalities in Sweden. The mean value will be used in the final comparison between the two systems.

6.1.3 Comparison of the two system

The avarage net difference when replacing a home visit system with a Doro Camera system is -304 $kgCO_2e$, which means that 304 $kgCO_2e$ could be saved yearly for every new user. To add perspective, this is almost equivalent to a one way flight from Copenhagen to New Delhi, according to SAS [2].

6.2 Identification of significant issues

6.2.1 Integrated Circuit

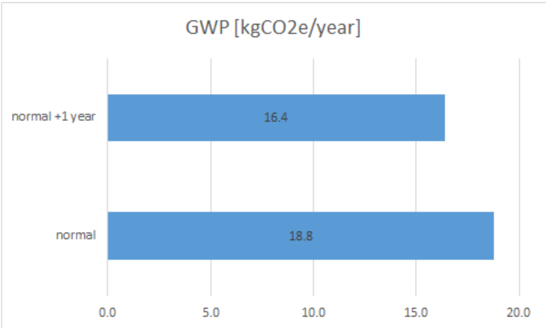
As shown in previous section, IC- production is a major contributor of emissions in all devices. In short, an IC is a small electronic circuit made out of the semiconducting material silicon, gold, aluminium, boron, phosphorus etc., that has the ability to make an incredible amount of calculations in a fraction of a second. This is possible thanks to hundreds of thousand to millions nano-sized transistors that are fitted onto the silicon die, through many advanced and energy demanding steps. The integrated circuit is the core of all ICT devices today, and there is no alternative technology yet that could replace it, and even though an IC is very small they have a huge global warming potential. According to a study from University on Pittsburgh [21], the production effort (energy) per cm^2 is 80MJ or 22.2kWh.
It is also practically impossible to reuse any IC, partly because of its specified task in any given device but mainly because there is no economic incentive, it is just so much cheaper to buy new. The recycle phase is also not very attractive since any IC is mostly silicon, the second most abundant element on earth. There is of course some gold and silver to be found, but it makes up less than 0.2% of the total weight [24].
As demand for higher computing speed and larger memory grows, IC construction is expected to be an even larger part of any device's global warming potential in the future.

6.2.2 Transportation - air and sea

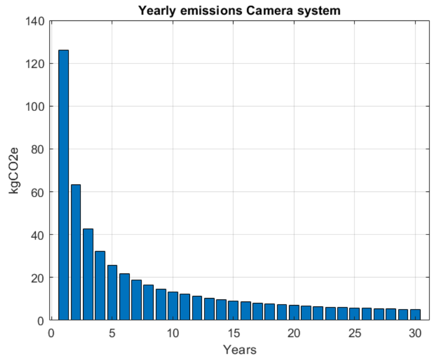
As shown in the results, the transmission from long haul air freight was about 20 times higher than deep sea freight. It is, from a climate point of view, important to make sure that everything that can be transported by sea is transported by sea. Air transport should only be used when necessary.

6.3 Sensitivity analysis

6.3.0.1 Prolong the lifetime of the system



(a) One more year of service



(b) Emissions per years of service

Figure 16: Prolonged lifetime lowers yearly emissions

Since production emissions are so much larger than utilization emissions, eight years of service instead of seven will reduce the yearly emissions for the system by 12.7%. Figure 16b shows us that the longer expected lifetime of the system, the lower the yearly emissions become. By year 30 the GWP is about $5kgCO^2e/year$.

6.3.0.2 Best case scenario

								
	Doro Enzo		Doro Eliza		Doro Visit		Router	
	Best case	Worst case	Best case	Worst case	Best case	Worst case	Best case	Worst case
Produktion [kgCO2eq]	2.17	2.62	36.08	48.34	14.10	19.30	28.40	44.80
Transport [kgCO2eq]	0.01	0.21	0.33	6.21	0.23	3.41	0.51	8.40
Utilization [kgCO2eq]	0.14	0.14	1.66	1.66	1.66	1.66	1.82	1.82
Decomission [kgCO2eq]	-0.06	-0.06	-0.57	-0.57	-0.66	-0.66	-6.99	-6.99
Emissions tot. [kgCO2eq]	2.3	2.9	37.5	55.6	15.3	23.7	23.7	48.0
expected liftime [yr]	5	5	7	7	7	7	7	7
Emissions yearly [(kgCO2e/yr)]	0.5	0.6	5.4	7.9	2.2	3.4	3.4	6.9

Figure 17

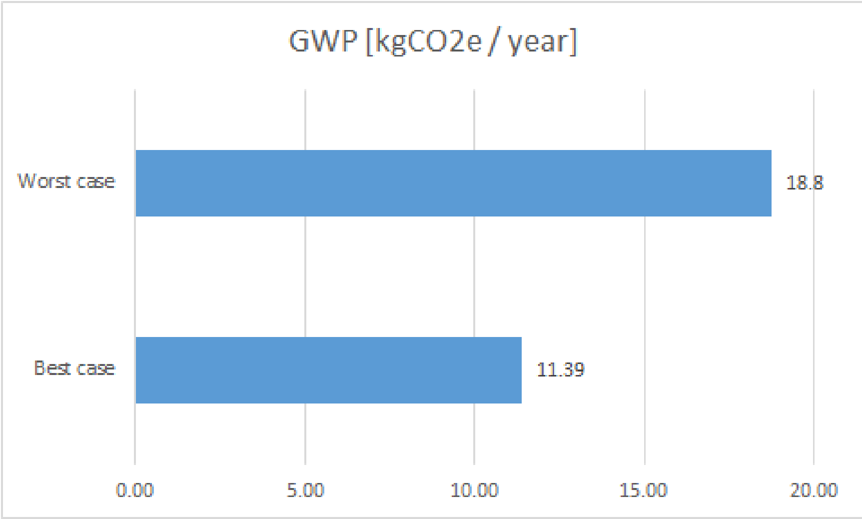


Figure 18: Lower Estimate production

This model displays the lower estimation range of emissions. In this model all materials comes from recycled sources and IC and PCB production uses very optimistic emissions estimation. Sea route is also used. The emissions are reduced by 40%

6.3.0.3 Sea route or Air route

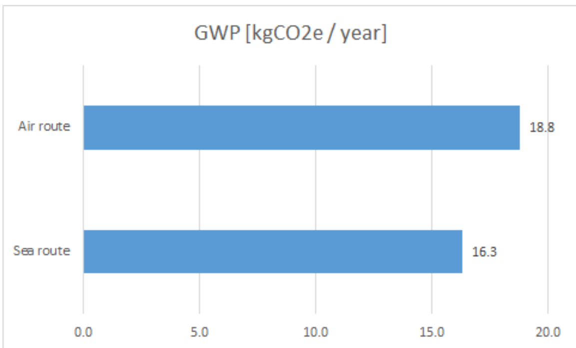


Figure 19: Yearly emissions form the camera system

By transporting all products via sea route it is possible to reduce yearly emissions for the system by 13.3%

6.3.1 Comparison to other ICT products

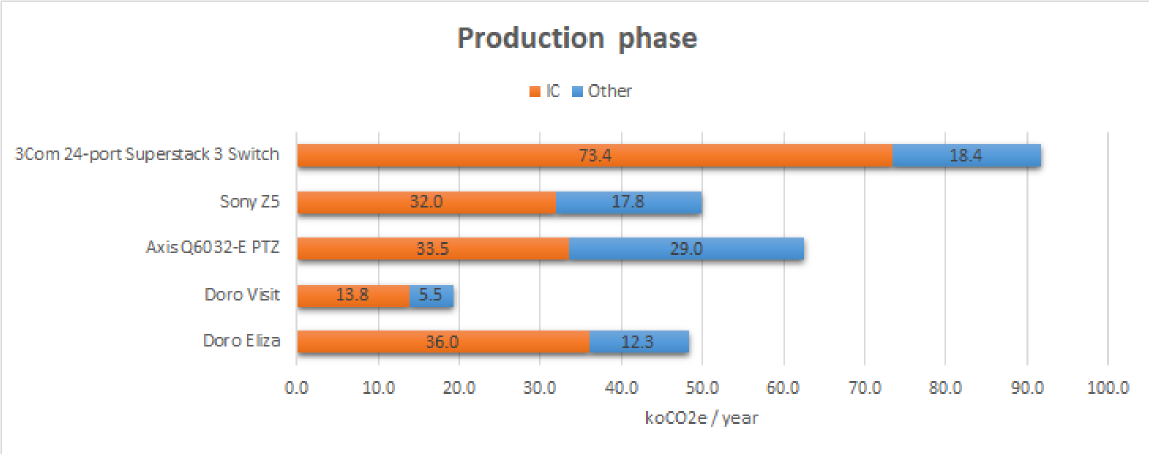


Figure 20: Comparison of diferent ICT devices

Figure 20 shows comparison of the production phase for five ICT devices, *3Com Switch* [30] *Sony Z5*[25], *Axis Q6032-E* [19] *Doro Visit* and *Doro Eliza*. For all devices the IC-construction is still the largest contributor of green house gases. We see that this study's results seems to follow the same trends as for other devices.

6.4 Conclusions

As shown in figure 15 the net difference of replacing home visits with a Doro care system is negative and it is clear that there is a huge benefit in the climate aspect in doing so.

- This study concludes that the Doro camera system has far lesser impact on the climate than home visits.
- When transporting the devices, sea freight should always be used if possible.
- Integrated circuits production is the biggest single contributor of greenhouse gasses through a device's lifetime
- In order to reduce carbon emissions from ICT-devices, the expected lifetime should be as long as possible.

6.5 Limitation

This study was made without any special software or databases and as such had to rely solely on public accessed sources and the model made by the author.
Furthermore any bill of materials was not available for this study, so it had to be reversed engineered by disassembling each device and analysing its contents, making the results less accurate.

6.6 Recommendations

6.6.0.1 Extend Lifetime

The easiest way to reduce emissions from an electronic device is by prolonging its lifetime. This can be done by building with better quality materials, or making the device more reusable and repairable.

6.6.0.2 Demand reusable energy in IC- and PCB- construction

When producing ICT, it's impossible to avoid IC and PCBs, because they supply the core function of most devices. What becomes the problem then is the high use of energy during production. By demanding that a supplier utilizes renewable energy sources it is possible that the GWP of IC and PCB construction could be lowered.

6.6.0.3 Recyclable plastics

Plastic by itself is not a bad material. It has great expected lifetime, is durable and a very low climate impact in manufacturing. The problem is sustainability. Plastic is oil, and oil is finite. Out of all plastic in electronic waste that gets left for recycling, only 50% can be made into recycled materials. This is because use of non standard plastics or plastic laminates that are very hard to separate, so it ends up in incineration. By sticking to standardized plastics, the recycling process becomes much more efficient. [13].

6.6.1 Continue this study

If one were to continue this study, I suggest working with the program *SimaPro*. It includes some of the biggest Eco Inventory databases there is, such as *EcoInvent*. It would also be necessary to have access to a detailed bill of materials in order to get accurate results.

A Camera system: Emissions Calculations

A.1 Production

A.1.1 Enzo

Enzo	Material	Amount		min. kgCO2eq	max. kgCO2eq
		Raw Materials			
Manual	Paper	0.05	kg	0.0	0.0
Packaging	PE	0.003	kg	0.0	0.0
Casing	ABS	0.04	kg	0.1	0.1
Button	TPE	0.01	kg	0.1	0.1
Wristband	PES	0.07	kg	*included in manufacturing*	*included in manufacturing*
Neckband clip	Assumed PC	0.04	kg	0.1	0.1
Neckband	PES	0.04	kg	*included in manufacturing*	*included in manufacturing*
Printed Circuit Board Assembly *				*included in manufacturing*	*included in manufacturing*
Internal Circuits *				*included in manufacturing*	*included in manufacturing*
		Manufacturing			
PCB tot	5,9cm2	5.9	cm2	0.1	0.2
IC	0.4 x 0.4, 2pcs				
IC tot		0.32	cm2	1.0	1.3
Battery	CR2032, 235mAh,3g , 0.000710kWh	0.0007	kWh	0.1	0.1
Small elenctronic components	23 resistors, 1 LED, capacitanses etc.			*omitted*	*omitted*
Injection moudling process	Polymer processing	0.09	kg	0.0	0.1
PES textile production		0.11	kg	0.6	0.6
Assembly	Manual labour	0	kWh	0.0	0.0
Total [kgCO2eq]				2.2	2.6

Figure 21: Complete list of contents and calculation of emission, Enzo

A.1.2 Eliza

Eliza	Material	Amount		min. kgCO2eq	max. kgCO2eq
		Raw Materials			
Packaging	corrogated board	0.224	kg	0.2	0.2
Manual	paper	0.014	kg	0.0	0.0
Plastic bag	"8" PE	0.01	kg	0.0	0.0
Casing (bottom), gray plastic	PC	0.09	kg	0.3	0.3
Casing (top), gray plastic	PC	0.01	kg	0.0	0.0
Casing (side) , white	PC	0.25	kg	0.9	0.9
Button mount (inside)	PC	0.015	kg	0.1	0.1
Button	Assumed PC	0.004	kg	0.0	0.0
Opaque button mount (inside)	Assumed PC	0.006	kg	0.0	0.0
Control panel (top), transparent/black,	PMMA	0.03	kg	0.1	0.1
Power supply		0.105	kg		
	Assumed PC [50%]	0.05	kg	0.2	0.2
	Copper [25%[	0.03	kg	0.0	0.2
	PCBA			*included in manufacturing*	*included in manufacturing*
Speaker		0.05	kg		
	Assumed Neodynium [25%]	0.01	kg	0.2	0.3
	Copper [25%]	0.01	kg	0.0	0.1
	Aluminium [25%]	0.01	kg	0.0	0.1
	Other [25%]	*0.01*	*kg*	*omited*	*omited*
Printed Circuit Board Assembly *				*included in manufacturing*	*included in manufacturing*
Internal Circuits *				*included in manufacturing*	*included in manufacturing*

Figure 22: Complete list of contents and calculation of emissions, Eliza (1/2)

	Manufacturing				
IC bottom PCB, big	2.2cm x 2.6cm, 1pc				
IC bottom PCB, medium	1x1 (2pcs), 0.5x0.5 (3pcs)				
IC bottom PCB small	0.2x0.2 (7pcs)				
IC top PCB	0.5x0.5 cm, 1 pc				
IC tot		9	cm2	27	36
PCB side, green	10cm x 5cm, 0.01 kg				
PCB top, blue	13cm x7cm, 0.03 kg				
PCB bottom, blue	16cm x 8 cm, 0.08kg				
PCB tot		269	cm2	5.4	7.6
Battery	Li-ion, 0.04kg	0.0074	kWh	1.1	1.5
Power supply		0.1	kg		
	PCBA [25%]	21	cm2	0.4	0.6
Microphone		0.005	kg	*omitted*	*omitted*
Other electrical components, top PCBA	resistors, diodes,			*omitted*	*omitted*
Other electrical components, bottom PCBA	resistors 100-150st, inductances, capacitors etc.			*omitted*	*omitted*
Ports	USB x 2, Ethernet, audio 3.5mm, etc.			*omitted*	*omitted*
Mobile communication card				*not enough information*	*not enough information*
Assembly	Manual labour			0	0
Injection modling process	Polymer processing	0.47	kg	0.2	0.5
Total [kgCO2eq]				36.1	48.3

Figure 23: Complete list of contents and calculation of emission, Eliza (2/2)

A.1.3 Visit

Visit	**Material**	**Amount**		**min. kgCO2eq**	**max. kgCO2eq**
	Raw Materials				
Packaging	Corrogated board	0.085	kg	0.1	0.1
Manual	paper	0.011	kg	0.0	0.0
Packaging inside, soft plastic	PE	0.001	kg	0.0	0.0
Packaging inside, hard plastic	Assumed PE	0.032	kg	0.1	0.1
case (bottom)	Assumed PC	0.015	kg	0.1	0.1
case (middle)	Assumed PC	0.014	kg	0.1	0.1
upper body (outer shell)	Assumed PC	0.027	kg	0.1	0.1
upper body (inner mount)	Assumed PC	0.02	kg	0.1	0.1
upper body (moving pieces)	Assumed PC	0.022	kg	0.1	0.1
upper body (camera shell)	Assumed PC	0.06	kg	0.2	0.2
Cameramount	Assumed PC	0.04	kg	0.1	0.1
2 Motors, 20BYJ46 5V DC		0.064	kg		
	Copper [11%]	0.007	kg	0.0	0.0
	Aluminium [46.3%]	0.030	kg	0.0	0.3
	Neodymium [16.7%]	0.011	kg	0.1	0.3
	Iron [26%]	0.017	kg	0.03	0.05
Power supply		0.1	kg		
	Assumed PC [50%]	0.05	kg	0.2	0.2
	Copper [25%]	0.03	kg	0.0	0.1
	PCBA [25%]				
Ethernetsladd (1m)		0.027	kg		
	Copper [25%]	0.00675	kg	0.0	0.0
	Assumed PE [75%]	0.02025	kg	0.0	0.1
Antenna		0.008			
	Copper [25%]	0.002	kg	0.00	0.01
	Assumed PC [75%]	0.006	kg	0.02	0.02
Printed Circuit Board Assembly *				*included in manufacturing*	*included in manufacturing*
Internal Circuits *				*included in manufacturing*	*included in manufacturing*

Figure 24: Complete list of contents and calculation of emission, Visit (1/2)

		Manufacturing			
IC on bottom PCB, big	1x1cm 2pcs	2	cm2		
IC on bottom PCB, medium	0.5x0.5, 1pc	0.25	cm2		
IC on bottom PCB, small	0.2x0.1cm , 5pcs	0.1	cm2		
IC on top PCB	0.2x0.1cm, 5pcs	0.1	cm2		
Image Sensor	1x1cm	1			
IC tot		3.45	cm2	10.4	13.8
PCB bottom	0.02 kg, circle d=7cm	38.47	cm2		
PCB top, big	5x5cm	25	cm2		
PCB top, small	4x4cm	16	cm2		
PCB tot		79.47	cm2	1.6	2.2
Power supply		0.1	kg		
	PCBA	21	cm2	0.4	0.6
other electrical components, bottom PBC	~50 resistors,			*omitted*	*omitted*
other electrical components, upper PCB	50 resistors, camera lens, 13 led			*omitted*	*omitted*
ports				*omitted*	*omitted*
Assembly	Manual labour			0	0
Injection moulding polymer processing		0.286	kg	0.1	0.3
Total [kgCO2eq]				14.1	19.3

Figure 25: Complete list of contents and calculation of emission, Visit 2/2

A.1.4 Visit Router

Visit Router	Material	Amount		min. kgCO2eq	max. kgCO2eq
		Raw Materials			
Packaging	Corrogated board	0.18	kg	0.12	0.19
SIM-card papers & manual	paper	0.02	kg	0.01	0.01
Packaging	plastic foam, assumed PE	0.03	kg	0.05	0.09
Plastic wapping	PE	0.01	kg	0.02	0.03
Top casing	metal, assumed Al	0.29	kg	0.4	2.6
Bottom casing	metal, assumed Al	0.31	kg	0.4	2.7
Square metal part	assumed aluminuim	0.026	kg	0.03	0.23
Ethernet calbe		0.03	kg		
	Copper [75%]	0.02	kg	0.03	0.14
	Assumed PE [25%]	0.01	kg	0.01	0.02
Ethernet-VGA cable		0.05	kg		0.24
	Copper [25%]	0.01	kg	0.02	0.08
	Assumed PE [75%]	0.38	kg	0.60	1.15
Power supply		0.1	kg		
	Assumed PC [50%]	0.05	kg	0.0	0.0
	Copper [25%]	0.03	kg	0.0	0.1
	PCBA [25%]			*included in manufacturing*	*included in manufacturing*
Ant-M		0.03	kg		
	Assumed PC [75%]	0.02	kg	0.09	0.09
	Copper [25%]	0.01	kg	0.01	0.05
WIFI antenn		0.02	kg		
	Assumed PC [75%]	0.01			
	Copper [25%]	0.00			
ANT-A		0.04	kg		
	Assumed PC [75%]	0.02925	kg	0.11	0.11
	Copper [25%]	0.00975	kg	0.01	0.01
Printed Circuit Board Assembly *				*included in manufacturing*	*included in manufacturing*
Internal Circuits *				*included in manufacturing*	*included in manufacturing*

Figure 26: Complete list of contents and calculation of emission, Visit Router

Manufacturing					
PCB main	20x13cm	260	cm2		
PCB 4g card	6x6cm	36	cm2		
PCB tot		293	cm2	5.9	8.3
IC, big	1x0.8cm				
	1x1 cm				
	1.4x0.8cm				
IC, medium	0.5x0.5				
	0.5x0.3 ,3pcs				
	1x0.3				
IC, small	0.3x0.3, 1pc. 0.2x0.3, 11pcs				
IC tot		4.67	cm2	14.0	18.7
Power supply		0.1	kg		
	PCBA	21	cm2	0.4	0.6
Ports				*omitted*	*omitted*
other electrical electronics	150+ resistors, capacitors,3x 220µF, LED ,cr1220			*omitted*	*omitted*
Mobile communication card		0.006	kg	*not enough information*	*not enough information*
Assembly	manual labour			0	0
Aliminium casting		0.60		1.00893	2.75
Injection moulding polymer processing		0.12		0.06	0.12
Total [kgCO2eq]				28.4	44.8

Figure 27: Complete list of contents and calculation of emission, Visit Router 2/2

A.2 Transport

Data collected from data sheet "*Emission report Doro_FY 2019_EN16258*" supplied by DSV. Their total emissions (Well-to-wheel), distances and transported weight were used to calculate the emission units $\frac{kgCO^2eq}{tonne*km}$ for each way of transport.

Air Freight Transports

Origin	Destination	Cargo quantity (kg)	Great circle distance (km)	Transported volume (tonne-km)	Tank-to-wheel-CO2e (kg)	Well-to-wheel-CO2e (kg)	Tank-to-wheel-Energy consumption (MJ)	Well-to-wheel-Energy consumption (MJ)
China	Czech Republic	168,626	8,348	1,407,690	830,537	999,460	11,683,826	13,724,97
Hong Kong, Hong Kong	Czech Republic	315,279	8,559	2,698,473	1,592,099	1,915,916	22,397,326	26,310,11
Hong Kong, Hong Kong	USA	150,479	6,496	977,512	576,732	694,033	8,113,346	9,530,73
Hong Kong, Hong Kong	UK	667	9,640	6,430	3,794	4,565	53,368	62,69
Hong Kong, Hong Kong	Germnay	9,852	9,154	90,185	53,209	64,031	748,537	879,30
AIR - Grand Total / Ratios		**644,903**	**42,197**	**5,180,289**	**3,056,371**	**3,678,006**	**42,996,403**	**50,507,822**
	kgCO2/(tonne-km)	0.71						

Figure 28: Calculation of $kgCO^2/(tonne*km)$, Air

Average fuel consumption	l/100 km	l/km	km/l	l/tonne-km
Average - Transport operator fleet values	28.4032	0.2840	3.5226	0.0262

Emission of CO_2e and SO_2	g/km	g/tonne-km
Tank-to-wheel CO_2e	721.4403	66.6319
Well-to-wheel CO_2e	900.3802	83.1587
SO_2	0.0046	0.0004

Energy consumption	MJ/km	MJ/tonne-km
Tank-to-wheel	10.1399	0.9365
Well-to-wheel	12.4974	1.1543

Emission of NO_x, HC, CO og Particles

Export/Import incl. distribution	DSV Road			
Weight of goods	NO_x (g/km)	HC (g/km)	CO (g/km)	Particles (g/km)
> 20 ton	2.89	0.12	0.34	0.01
14-20 ton	2.64	0.12	0.34	0.01
8-13 ton	**2.41**	**0.12**	**0.33**	**0.01**
1-7 ton	2.20	0.12	0.30	0.01
< 1 ton	2.01	0.11	0.28	0.01

kgCO2/tonne-km
0.0831587

Emission figures for CO_2e and SO_2

Fuel (Diesel/Bio-diesel blend 5 %), physical data:			
Density	0.8349	kg/litre	Source: EN16258:2012, Table A.4
Energy factor - Tank-to-wheel	42.8000	megajoule/kg	Source: EN16258:2012, Table A.4
Energy factor - Tank-to-wheel	35.7000	megajoule/litre	Source: EN16258:2012, Table A.4
CO_2e emission - Tank to-wheel	2.5400	kg/litre	Source: EN16258:2012, Table A.4
Energy factor - Well-to-wheel	44.0000	megajoule/litre	Source: EN16258:2012, Table A.4
CO_2e emission - Well-to-wheel	3.1700	kg/litre	Source: EN16258:2012, Table A.4
SO_2 emission factor - Tank-to-wheel	0.0005	g/megajoule	Source: http://www.oliebranchen.dk/Viden/Temaer/Benzin/Artikler/Emissioner.aspx
SO_2 emission - Tank-to-wheel	0.0161	g/litre	

Figure 29: Calculation of $kgCO^2/(tonne * km)$, Road

Sea - Container Ship Transports (FCL + LCL)

Origin	Destination	Cargo quantity (kg)	Number of TEU	Average distance (km)	Transported volume (tonne-km)	Transported volume (TEU-km)	Tank-to-wheel-CO2e (kg)	Well-to-wheel-CO2e (kg)	Tank-to-wheel-Energy consumption (MJ)	Well-to-wheel-Energy consumption (MJ)
FCL - Full Container Transports					obs egen räknad colonn		0.03	0.03	0.40	0.43
China	Czech Republic	84,350	18.00	19,818	1,671,648	356,724	10,984	11,879	141,232	153,78
2*10^-5	Czech Republic	150,604	47.00	18,686	2,814,186	878,242	27,041	29,245	347,708	378,61
Hong Kong, Hong Kong	USA	26,688	10.00	10,644	284,067	106,440	5,428	7,451	82,534	88,34
FCL - Subtotal / Ratios		**261,642**	**75.00**		**4,769,902**	**1,341,406**	**43,453**	**48,575**	**571,473**	**620,746**
LCL - Part Container Transports										
China	Czech Republic	39,630	4.95	19,818	785,387	98,099	3,020	3,267	38,839	42,29
Hong Kong, Hong Kong	Czech Republic	176,121	22.01	18,686	3,290,997	411,279	12,663	13,696	162,831	177,30
Hong Kong, Hong Kong	Tunisia	563	0.07	14,223	8,008	996	30.65	33.15	394	42
LCL - Subtotal / Ratios		**216,314**	**27.03**		**4,084,392**	**510,374**	**15,714**	**16,995**	**202,064**	**220,025**
OCEAN - Grand Total / Ratios		**477,956**	**102**	**101,875**	**8,854,294**	**1,851,780**	**59,167**	**65,571**	**773,537**	**840,771**
	kgCO2/(tonne-km)	0.007405515								

Figure 30: Calculation of $kgCO^2/(tonne * km)$, Sea

A.2.1 Enzo

Enzo			
total weight [kg]	0.034		
volume [width x depth x height]	0.16 x 0.09 x 0.02		
volume [m3]	0.000288		
Route	China - China (Road)	China -> Czech Republic (Air)	
travel distance [km]	120	8665	
max. kgCO2e	0.0003	0.21	
tot. kgCO2e	0.21	*(kgCO2/ton*km)*(ton)*(km)*	
Sea route	China - China (Road)	China -> Germany (Sea)	Germany -> Czech Republic (Road)
travel distance [km]	120	21142	860
kgCO2e	0.0003	0.01	0.002
tot. kgCO2e	0.01		

Figure 31: Emissions from transportation, Enzo

A.2.2 Eliza

Eliza				
total weight [kg]	0.992			
volume [width x depth x height]	0.22 x 0.18 x 0.11			
volume [m3]	0.004356			
Sea route	China - China (Road)	China -> Germany (Sea)	Germany -> Czech Republic (Road)	Czech Republic -> Sweden (Road)
travel distance [km]	200	21142	860	1040
kgCO2e	0.02	0.16	0.07	0.09
tot. kgCO2e	0.33			
Air route	China - China (Road)	China-> Czech Republic (Air)	Czech Republic -> Sweden (Road)	
travel distance [km]	200	8665	1040	
kgCO2e	0.02	6.10	0.09	
tot. kgCO2e	6.21			

Figure 32: Calculation of $kgCO^2$, transportation Eliza

A.2.3 Visit

Visit					
total weight [kg]	0.547				
volume [width x depth x height]	0.15 x 0.11 x 0.14				
volume [m3]	0.00231				
Sea route	China - China (road)	China - Netherlands (sea)	Netherlands - Netherlands (road)	Netherlands - Czech Republic	Czech Republic -> Sweden (road)
travel distance [km]	950	20664	244	992	1040
kgCO2e	0.04	0.08	0.011	0.05	0.05
tot. kgCO2e	0.23				
Air route	China - China (road)	China -> Czech Republic (air)	Czech Republic -> Sweden (road)		
travel distance [km]	28	8665	1040		
kgCO2e	0.001	3.37	0.05		
tot. kgCO2e	3.41				

Figure 33: Calculation of $kgCO^2$, transportation Visit

A.2.4 Visit Router

Visit Router						
total weight [kg]	1.335					
volume [width x depth x height]	0.3 x 0.25 x 0.07					
volume [m3]	0.00525					
Route	China - China (road)	China - Germany (sea)	Germany - Germany (road)	Germany - Slovakia (road)	Slovakia - Czech Republic (road	Czech Republic - Sweden (road)
travel distance [km]	612	21142	392	581	130	1040
kgCO2e	0.07	0.21	0.04	0.06	0.01	0.12
tot. kgCO2e	**0.51**					
Air route	China - China (road)	China-> Czech Republic (air)	Czech Republic -> Sweden (road)			
travel distance [km]	612	8665	1040			
kgCO2e	0.068	8.21	0.12			
tot. kgCO2e	**8.40**					

Figure 34: Calculation of $kgCO^2$, transportation Visit Router

A.3 Utilization

A.3.1 Call centers

Sites	**All**	**BC Malmö**	**Kalix**	**Malmö**
Alarm connections	87000			
Area [m2]		175	1845	2007
Energy use, Heating[MWh]		15.73	203	140
Energy use [MWh]		12.80	144	137
CO2e from heating [kgCO2e]		1872	5887	16660
CO2e from energy use [kgCO2e]		170	1915	1822
Part used as call center		0.33	0.33	0.33
Call center CO2e tot [kg]	**9442.19**	**680.75**	**2600.73**	**6160.70**
[kgCO2e/(connection*year)]	**0.11**	**0.01**	**0.03**	**0.07**

Figure 35: Call center emission calculaton

A.3.2 Devices

Devices	Enzo	Eliza	Visit	Router
Current (standyby) [A]	0.000002			
Voltage [V]	3.1			
Power [kW] (Standby)	6.2E-09	0.0018	0.0018	0.002
Effekt [W] (Active)		*5*	*5.5*	*2.8*
1 yr [kWh]	5.41632E-05	15.8	15.8	17.5
kgCO2e/year		**0.2**	**0.2**	**0.2**

Figure 36: Devices Emission

A.4 Decommissioning

Material	Measure	Difference: Secondary - Primary [kgCO2eq/kg]	Share	Mass [kg]	Enzo [kgCO2]	Mass [kg]	Eliza [kgCO2]	Mass [kg]	Visit [kgCO2]	Mass [kg]	Router [kgCO2]
Metals											
Aluminium	Recycling	-10.6	1	*0.00*	0.00	*0.01*	-0.13	*0.03*	-0.31	*0.62*	-6.60
Neodynium	Recycling	-15.1	1	*0.00*	0.00	*0.01*	-0.19	*0.01*	-0.16	*0.00*	0.00
Copper	Recycling	-4.6	1	*0.00*	0.00	*0.04*	-0.06	*0.04*	-0.07	*0.08*	-0.27
Iron	Recycling	-0.8		*0.00*	0.00	*0.00*	0.00	*0.02*	-0.01	*0.00*	0.00
Paper and cardboard	Recycling	-0.4	1	*0.05*	-0.02	*0.24*	-0.10	*0.10*	-0.04	*0.19*	-0.08
Glass	Recycling	-0.4	1	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00
PCBA (PCB + IC + Other small components) [kg]											
	Recycling		~0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Incineration		0.55	*omitted*	*omitted*	*omitted*	*omitted*	*omitted*	*omitted*	*omitted*	*omitted*
	Landfill		0.45	*omitted*	*omitted*	*omitted*	*omitted*	*omitted*	*omitted*	*omitted*	*omitted*
Plastics [kg]				*0.20*		*0.47*		*0.31*		*0.55*	
	Recycling	-0.8	0.25	*0.05*	-0.04	*0.12*	-0.09	*0.08*	-0.06	*0.14*	-0.11
	Incineration		0.75	*0.15*	*omitted*	*0.35*	*omitted*	*0.23*	*omitted*	*0.41*	*omitted*
Tot [kgCO2]					**-0.06**		**-0.57**		**-0.66**		**-7.06**

Figure 37: Calculation of kgCO2e, decommissioning all devices

B Database

Raw Materials - extraction and processing	Min. est.	Max. est.	Unit	Source
Plastic				
ABS, Acrylonitrile butadiene styrene	3.1	3.1	kgCO2eq/kg	[28]
PE, Polyethylene	1.58	3	kgCO2eq/kg	[10]
TPE, Thermodurcible Polyurethane	5	5	kgCO2eq/kg	[1]
PMMA, Polymethyl methacrylate	3.75	3.75	kgCO2eq/kg	[4]
PC, Polycarbonates	3.6	3.6	kgCO2eq/kg	[29]
Metal				
Aluminium	10.4	21	kgCO2eq/kg	[27]
Copper	1.3	5.9	kgCO2eq/kg	[12]
Crude steel (iron)	2.1	2.9	kgCO2eq/kg	[18]
Neodymium	12.5	27.6	kgCO2eq/kg	[20]
Papper				
Corrogated board	0.7	1.1	kgCO2eq/kg	[23]
Copying paper	0.6	0.6	kgCO2eq/kg	[5]
Production - Manufacturing and assembly				
Processes				
IC (Integrated circuit)	3	4	kgCO2eq/cm2	[16], [22]
PCB (PrintedCircuitBoard)	0.020	0.028	kgCO2eq/cm2	[9],[22]
Battery Li-Ion	150	200	kgCO2eq/kWh	[17]
Injection Moulding polymer processing	0.5	1	kgCO2eq/kg	[11]
Aluminium shape casting	1.69	2.75	kgCO2eq/kg	[8]
PES, Polyester - Textile fibre	5.3	5.3	kgCO2eq/kg	[26]
Transportation				
Air (long haul)		0.71	kgCO2eq/(tonne-km)	DSV
Road (avarage)		0.0831	kgCO2eq/(tonne-km)	DSV
Sea (deep sea)		0.0074	kgCO2eq/(tonne-km)	DSV
Utilization				
Swedish electricity mix		0.0133	kgCO2/kWh	[7]
District heating, E.ON, Malmö		0.119	kgCO2/kWh	[15]
District heating, Vasa Värme, Kalix		0.029	kgCO2/kWh	[14]

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