

# Life Cycle Assessment of an Elevator

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## 1. INTRODUCTION

Environmental impacts of buildings and construction products have been the subject of growing interest among researchers and the construction industry. Research has prompted the development of design tools, simulation models, and design guidelines for the industry to adopt environmental practices. However, little if any research is being done on the environmental impacts of elevators, specifically using Life Cycle Assessment (LCA) methodology according to the ISO 14040 standards.

An LCA study was performed to evaluate the environmental impacts of an elevator and to provide information for LCA studies of entire multi-storey buildings. The elevator studied is an energy-efficient, machine room less elevator for residential buildings. The study includes all stages from raw material acquisition to final disposal. The function of an elevator is to give people access to multi-storey buildings. Additionally, the LCA study includes sensitivity analyses and the calculation of material distribution.

## 2. GOAL AND SCOPE OF THE LCA

The objective of this study was to identify the environmental characteristics of an elevator and to provide basic information for environmental product declaration (EPD) and LCAs on entire building.

The function of an elevator is to give people access to multi-storey buildings. The functional unit for the study is a distance of 1km travelled by elevator. The results for a complete service lifetime are also calculated (25 years, frequency of starts 150 000 per year, average travelling height 9m).

Below are some specifics of the elevator:

Elevator:	KONE MonoSpace®
Building type:	5 floor residential building
Hoisting capacity:	8 persons (630kg) and 1.0 m/s



Figure 1 KONE MonoSpace®.

### 3. LIFE CYCLE INVENTORY ANALYSIS

Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. These inputs and outputs may include the use of resources and releases into air, water and land associated with the system.

The life cycle of an elevator is divided into 8 stages: material production, component manufacturing, delivery, installation, use, maintenance, modernisation and end-of-life treatment.

Materials weighing less than 1kg were omitted from the LCA study, except for electrification components. Some materials, such as linoleum and glass, were left out because their inventories were not available. The total mass of the elevator for the life cycle inventory without packing was 2847,6kg and the omitted mass 40,2kg. Roughly 95% of the elevator materials were metals. The share of wrought steels was about 55% and cast iron 40%. The share of electronics and electromechanical components was about 5%. The elevator also included small amounts of plastics, rubber and glass. Material summary is presented in table 1.

Table 1 Material summary.

	<b>Weight [kg]</b>	<b>Weight-%</b>
<b>Metals</b>	<b>2657,8</b>	<b>93,3</b>
Aluminium	18,2	0,6
Cast iron	1070,0	37,6
Copper	26,4	0,9
Stainless Steel	1,0	0,0
Steel (uncoated)	979,4	34,4
Steel (zinc coated)	562,9	19,8
<b>Plastics</b>	<b>21,8</b>	<b>0,8</b>
<b>Rubber</b>	<b>0,6</b>	<b>0,0</b>
<b>Glass</b>	<b>28,0</b>	<b>1,0</b>
<b>Others</b>	<b>3,2</b>	<b>0,1</b>
<b>Electronics and electromechanical components</b>	<b>136,2</b>	<b>4,8</b>
<b>TOTAL</b>	<b>2847,6</b>	<b>100,0</b>

Components for elevators are manufactured in many different factories. The hoisting machine, for example, was manufactured in Hämeenlinna, Finland, the landing doors and the car in Pero, Italy, and the car sling, over speed governor and door operator in Scheibbs, Austria. The inventories of electrifications were calculated from EIME program results obtained from Tampere University of Technology. LCA was done for 5 floors elevator, but dividing components for floor and basic modules allows easy changing of number of floors for the elevator.

The inventory of the delivery stage takes into account all component transportation to the logistics centre in Pero, Italy, and onward to the building site in Brussels, Belgium.

The elevator in this study was installed in Brussels. During the period of use the electricity data was taken as the average OECD value. The following assumptions were made for the period of use: lifetime of the elevator 25 years, frequency of starts 150 000 per year, energy consumption 2 000kWh per year, and average travelling height 9m. This brought the complete travelling distance of the elevator to 33 750km.

The maintenance inventory included emission from a service car with average mileage (data from Finland) and a change of ropes at the typical change interval of 10 years.

Installation and modernisation were assumed to be zero in this LCA study. The impact of installation was assessed to be low. Modernisation was left out to keep the assessment simple.

End-of-life treatment is the recycling process for multimetal scrap. Some materials have no need for a multimetal separation process, as they can be smelted at a foundry without pre-processing. The assumed amount of material requiring multimetal separation was 45% of the material weight.

### **3.1 Data quality, collection and calculation procedures**

Table 2 Data sources.

Life cycle stage	Data sources
Material production	SimaPro 5.0 databases 1. Buwal250 2. Idemat 3. Data Archive Idemat 98 European Aluminium Association, EAA Rautaruukki Oyj Finnish Environment Institute VTT Building and Transport Neorem Magnets Oy
Component manufacturing	Data managed by KONE
Delivery	Inventories of transports from VTT Building and Transport database LIPASTO Starting and arrival places from KONE Delivery distances (km) from <a href="http://www.mapblast.com/myblast/index.mb">http://www.mapblast.com/myblast/index.mb</a> and <a href="http://www.indo.com/cgi-bin/dist/">http://www.indo.com/cgi-bin/dist/</a>
Installation	Data managed by KONE
Use	Data managed by KONE
Maintenance	Data managed by KONE
Modernization	Data managed by KONE
EOL Treatment	Finnish Environment Institute
Electricity	SimaPro 5.0 database: Buwal250 Eidgenössische Technische Hochschule

LCA calculation was performed at VTT Industrial Systems with KCL-Eco 3.0 software.

### 3.2 Life Cycle Inventory results

The biggest releases (CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>) into the atmosphere are listed in Table 3.

Table 3 Releases of CO<sub>2</sub>, NO<sub>x</sub> and SO<sub>x</sub> emissions into the atmosphere during the life cycle of an elevator.

		Material production	Component manufacturing	Delivery	Use	Maintenance	EOL	TOTAL
CO <sub>2</sub>	kg	5 129,6	1 125,3	176,1	28 075	406,4	32,0	34 944,4
CO <sub>2</sub>	kg/ 1km	0,16	0,03	0,005	0,83	0,01	0,0009	1,04
NO <sub>x</sub>	kg	11,5	11,9	2,2	64,5	1,0	0,3	91,4
NO <sub>x</sub>	kg/ 1km	0,0003	0,0004	6,38E-05	0,002	3,07E-05	7,89E-06	0,003
SO <sub>x</sub>	kg	14,3	11,3	0,019	121,3	0,5	0,03	147,5
SO <sub>x</sub>	kg/ 1km	0,0004	0,0003	5,67E-07	0,0036	1,34E-05	9,87E-07	0,004

#### 4. LIFE CYCLE IMPACT ASSESSMENT

The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impacts using the results of life cycle inventory analysis. The methodological and scientific framework for impact assessment is still being developed. Models for impact categories are in different stages of development. The inventory data above was converted into environmental impact using Eco-Indicator 95 and Swedish EPD methods.

Eco-Indicator is a commonly used application for life cycle impact assessment. Eco-Indicator 95 uses three kinds of factors: characterisation, normalisation and weighting factors. These scores are based on an LCA method developed by PRé in collaboration with Philips, NedCar, Océ, Schuurink and several universities (Amsterdam, Leiden and Delft) and consultancies.

The EPD method uses only characterisation factors [The Swedish Environmental Management Council 1999]. The Swedish Environmental Management Council has developed the EPD system which classifies environmental impacts in 5 categories: Global warming GWP, Acidification potential AP, Eutrophication, Ozone depletion potential ODP and Photochemical oxidants POCP.

The result of impact assessment using Eco-Indicator 95 is 65,7 ecopoints. About 81% of these ecopoints were generated during the period of use. Roughly 11% of the ecopoints are generated at the stage of material production and about 7% during component manufacturing. Emissions which cause the most ecopoints are SO<sub>x</sub> (147,5kg) 20,9 ecopoints, Pb to water (0,09kg) 8,4 ecopoints, NO<sub>x</sub> (91,4kg) 7,2 ecopoints and CO<sub>2</sub> (34 944,4kg) 6,7 ecopoints. These four emissions account for about 66% of the total ecopoints.

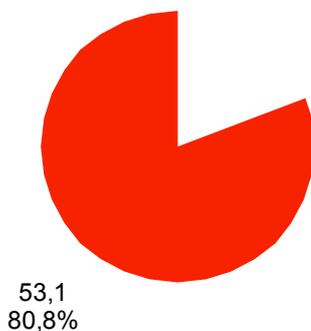


Figure 2 Life Cycle Impact Assessment using Eco-Indicator 95.

#### 5. SENSITIVITY ANALYSES

Sensitivity analysis is a systematic procedure for investigating how reported results vary along with changes in the key assumptions on which the results are based. The objective of the sensitivity analyses was to investigate the effects on the relative importance of life cycle stages when assumptions of the lifetime of the elevator, the degree of use, the number of floors and the national electricity generation profiles were changed. The LCA study includes four sensitivity analyses.

The first sensitivity analysis was made for a lifetime of 15 years. The second sensitivity analysis concerned the frequency of starts. The LCA study (basic case) was done with 150 000 starts per year, and in this sensitivity analysis the frequency of starts were 100 000 and 200 000 per year. The third sensitivity analysis concerned the number of floors and the frequency of starts. The LCA study was done for a 5-floor elevator with 150 000 starts per year, the sensitivity analysis being for an 8-floor elevator and frequency of starts 150 000 and 200 000 per year. The fourth sensitivity analysis concerned the use of national emission profiles for the electricity generation in the country of the elevator. In the LCA study the elevator was used in Brussels but for this sensitivity analysis the elevator was in Finland, Sweden or the Netherlands.

Roughly 80% of the ecopoints were found to be induced during the period of use, except in two sensitivity analyses: when the elevator lifetime was 15 years and when the profile of Swedish electricity was used. The reasons for the smaller share of the use stage are the following: In the case of a reduced lifetime of 15 years (from 25 years), the electricity consumption was reduced by 40% and thus other stages of the life cycle have a proportionally larger impact. In the case of the Swedish electricity production mix, the use stage emissions are smaller than for the OECD average due to the large share of hydro and nuclear power (about 54% hydropower, 40% nuclear power and other about 6%).

## **6. CONCLUSION**

The life cycle interpretation shows that most of the environmental impacts of an elevator occur during its period of use. The environmental impacts of the period of use are from the electricity production. The amount of carbon dioxide emission during the lifetime of an elevator is almost 35 tons. Roughly 80% of CO<sub>2</sub> emissions are generated during the use stage, as are about 71% of nitrogen oxide emissions and around 82% of sulphur oxide emissions. By comparison, during material production CO<sub>2</sub> emissions are 15% and during component manufacturing 3% of the total.

The LCA values of end-of-life treatment are from the recycling process for multimetal scrap. Some components have no need for a multimetal separation process, as they can be smelted at a foundry without pre-processing. The assumed amount of material requiring multimetal separation is 45% of the material weight of the elevator. When metals are recycled there is a clear reduction in environmental life cycle impacts, primarily because recycling of metals lowers the demand for primary metals as raw materials. On average, 70% scrap metal is used when producing cast iron and 20% when producing sheet steel.

## **7. REFERENCES**

The Swedish Environmental Management Council. 1999. Environmental product declarations, EPD. An application of ISO TR 14025 Type III EPD. MSR 1991:1. Draft version 1.

SFS-EN ISO 14040. Environmental management. Life cycle assessment. Principles and framework (ISO 14040:1997). fi/en 1997-09-22, 23 p.

SFS-EN ISO 14041. Environmental management. Life cycle assessment. Goal and scope definition and inventory analysis (ISO 14041:1998). fi/en 1998-11-30, 40 p.

SFS-EN ISO 14042. Environmental management. Life cycle assessment. Life cycle impact assessment (ISO 14042:2000). fi/en 2000-08-21, 30 p.

SFS-EN ISO 14043. Environmental management. Life cycle assessment. Life cycle interpretation (ISO 14043:2000). fi/en 2000-08-21, 36 p.