The Jungheinrich Environmental Commendation

An examination to determine the life cycle assessment

of the Jungheinrich industrial truck fleet

based on ISO 14040

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I. List of Abbreviations

AG	Public limited company (German abbreviation)
CAFE	Corporate Average Fuel Economy
CO_2	Carbon dioxide
h	Hour
HF	High-frequency
ICE truck	Internal combustion engine counterbalanced truck
ISO	International Organization for Standardization
IT	Industrial truck
kg	Kilogram
kWh	Kilowatt hour
LCA	Life cycle assessment
LPG	Liquefied petroleum/propane gas
m	Metre
OI	Order intake
Ser.	Series
t	Tonne
Trafo	Transformer
TÜV	German Association for Technical Inspection
USA	United States of America
VDI	Association of German Engineers
WG	Working group
WGEB	Working Group on Energy Balances, inc. assc.

0. Life Cycle Assessment of the Jungheinrich Industrial Truck Fleet

More than ten million industrial trucks are used worldwide every day in single- or multiple-shift operation in intralogistics. Measures for reducing energy consumption make sense and should be pursued not only because of costs, but also for environmental reasons.

In this context, the automotive industry uses the Corporate Average Fuel Economy method, usually abbreviated as CAFE. This method describes how to calculate vehicle energy consumption. It is a legal requirement in the USA with the goal of protecting resources. There is no such standardised method at this time in the area of industrial trucks.

The purpose of the Environmental Commendation is to point the way towards a transparent, documentable and reproducible process for monitoring the environmental performance of the Jungheinrich industrial truck fleet on a sustainable basis, tracking it systematically and making improvements to it.

The Environmental Commendation is a tested life cycle assessment based on the ISO 14040 and 14044 standards and conducted by independent examiners from TÜV Nord. The life cycle assessment consisted of an examination of the industrial truck fleet, from tiller-operated electric pallet trucks to counterbalanced trucks with internal combustion engines, based on VDI Guideline 2198.

The term "life cycle assessment", often abbreviated as LCA, is understood to mean a systematic analysis of the environmental effects of our products during the phases of manufacturing, usage and refurbishing. For Jungheinrich AG, CO_2 emissions currently represent the only sustainable, comparable and controllable variable.

Since innovations and new technology often produce not only enhanced direct customer benefits, but also better environmental properties than the technology used in the predecessor model, we would like to emphasize the benefits of continuous, environmental product optimisation.

Sustainable improvements to the energy efficiency of our industrial truck fleet can be attributed in part to the optimisation of existing technologies and in part to the introduction of new technologies.

1. Vehicles Examined in the Jungheinrich Fleet

The examination of the Jungheinrich life cycle assessment included different product segments with different usage properties and drive types such as electric, diesel and LPG systems.

The development of factors included the life cycle assessment was analysed over the period from 2000 to 2010.

1.1 Purpose and Target Group of the Examination

To ensure that the products examined could be compared, the Jungheinrich product portfolio in Table 1 was divided into clusters based on VDI 2198 with comparable technical properties and application cases. This categorisation applies to all phases of the examination.

	Product cluster	Drive	Main function
1	Electric counterbalance trucks with driver’s seat/operator platform >1.6t	Electric	Goods handling with capacity over 1.6t
2	ICE truck	Internal combustion engine	Goods handling outdoors
3	Electric forklift trucks <1.6t	Electric	Goods handling with capacity under 1.6t
4	Reach truck with driver’s seat/ operator platform	Electric	Stacking and retrieving at high lift heights, transport
5	High-lift fork trucks and other stacker trucks	Electric	Transport, stacking and retrieving
6	Pallet trucks and other lift trucks	Electric	Transport, order picking
7	Trucks, tow tractors	Electric	Horizontal transport of materials over long distances

Table 1: Categorisation of the product portfolio per VDI 2198

In accordance with VDI 2198, a specific measurement cycle can be assigned to each of the product clusters described above to determine vehicle energy consumption in the usage phase. This VDI guideline describes the number of operations per hour, distance travelled (in metres) and lift height (in metres) for different types of vehicles (see Table 1 and Table 2).

	1, 2	3	4	5	6	7
Product cluster	Electric counter-balanced truck with driver’s seat/ operator’s stand >1.6t and all ICE trucks	Electric forklift truck <= 1.6t	Reach truck with driver’s seat/	Gabel-hoch-hub-wagen und sonstige Hochhub-wagen	Gabelhub-wagen und sonstige Hubwagen	Wagen, Schlepper
Number of operations/ h	60	45	35	20	20	40
Distance L in m	30	30	30	30	30	50
Lift for A and B in m	2	2	4	2	0.1	-

Table 2: Measurement cycles as per VDI 2198

The given consumption values are based on the measurement cycles as per VDI 2198 described in Table 2.

The calculation took into account only those industrial trucks manufactured at Jungheinrich production sites in Europe.

Since “system devices” product group, which consists of narrow aisle trucks, currently has no defined VDI measurement cycle, these vehicles were not included in the calculation and therefore do not appear in the defined product clusters either.

Special vehicles that are produced in very small quantities for individual customer requests are also excluded from the calculation.

The two excluded vehicle groups currently make up about 10% of vehicles produced annually by Jungheinrich.

The goal of the examination is to represent development since 2000 and make a summary statement about the environmental performance of each product cluster.

1.2 Function and Functional Unit of the Trucks Examined

Typical application areas of Jungheinrich trucks include transport, stacking, order picking and handling of goods for intralogistics (see also Table 1).

Within the seven product clusters listed here, Jungheinrich AG has a large number of product groups of different performance classes. Since each product group in turn consists of a number of products that are very similar in design and style, a reference vehicle was defined for each product group. This reference vehicle is the most frequently sold unit. It has already been used in the past to determine consumption values and will also serve in future as the reference object of a series.

The reference vehicles of the various product groups are listed in the following tables (Table 3 to Table 9).

Product cluster 1: Electric counterbalanced trucks with driver’s seat/operator platform >1.6t

Range	Reference vehicle
EFG 213–220	EFG 216
EFG 316–320	EFG 316
EFG 425–430	EFG 425
EFG 535–550	EFG 550

Table 3: Product cluster 1 (electric counterbalanced truck >1.6t)

Product cluster 2: ICE truck

Range	Reference vehicle
DFG 316–320	DFG 316
DFG 316–320s	DFG 316s
DFG 425–435	DFG 425
DFG 425–435s	DFG 425s
DFG 540–550	DFG 540
DFG 540–550s	DFG 540s
DFG 660–690	DFG 660
TFG 316–320	TFG 316
TFG 316–320s	TFG 316s
TFG 425–435	TFG 425
TFG 425–435s	TFG 425s
TFG 540–550	TFG 540
TFG 540–550s	TFG 540s
TFG 660–690	TFG 660

Table 4: Product cluster 2 (ICE truck)

Product cluster 3: Electric forklift trucks <1.6t

Range	Reference vehicle
EFG 110–115	EFG 115

Table 5: Product cluster 3 (electric counterbalanced truck <1.6t)

Product cluster 4: Reach truck with driver's seat/operator platform

Range	Reference vehicle
ETV 110–116	ETV 112
ETM/V 214–216	ETV 214
ETM/V 320–325	ETV 325
ETV Q20/Q25	ETV Q20
ETV C16/C20	ETV C16

Table 6: Product cluster 4 (reach truck with driver's seat/operator platform)

Product cluster 5: High-lift fork trucks and other stacker trucks

Range	Reference vehicle
EJD 220	EJD 220
EJC 110–112	EJC 12/110
EJC 214–216	EJC 14/214
EJC Z 14–16	EJC 214z
EJC BR B	EJC B14
ERD 220	ERD 220
ERC 212–216	ERC 214
ERC Z 12–16	ERC Z14
ESC 214–216z	ESC 214z
EMC 110/B	EMC 110

Table 7: Product cluster 5 (high-lift fork trucks and other stacker trucks)

Product cluster 6: Pallet trucks and other lift trucks

Range	Reference vehicle
EJE 116–120	ELE 16/EJE 116
EJE C20	ELS 18/EJE C20
EJE 220–225	EJE 20/220
ERE 120	ERE 120
ERE 225	ERE 20/224/225
ESE 120	ESE 120
ESE 220–320	ESE 220
ECE BR2	ECE 20/220

Table 8: Product cluster 6 (pallet trucks and other lift trucks)

Product cluster 7: Trucks, tow tractors

Range	Reference vehicle
EZS 130	EZS 130
EZS 350	EZS 350
EZS 570	EZS 570

Table 9: Product cluster 7 (trucks, tow tractors)

Note:
The product cluster for tow tractors has only been part of the Jungheinrich AG product range since 2006. Because of this, the trend for this cluster cannot be determined as a percentage based on the year 2000. It is based instead on the first sales year (2006).

1.3 Framework of the Examination

The framework of the examination for determining CO_2 emissions includes the manufacturing, usage and refurbishing phases of industrial trucks.

Manufacturing phase: generation of raw materials, production of trucks and transport of trucks to customers or distribution centres.

Usage phase: energy consumption during the truck's life cycle in addition to the energy required to make fuel or alternative energy available (including the upstream chain). Energy consumption is thus considered from energy generation through to end usage.

Refurbishing phase: transport of trucks to the refurbishing factory, generation of raw materials, refurbishment of trucks and transport of trucks from the refurbishing factory back to customers.

Factors have been used for all calculations in the phases listed above (including the upstream chain).

Fig. 1 is a visual representation of the examination framework of the life cycle assessment.

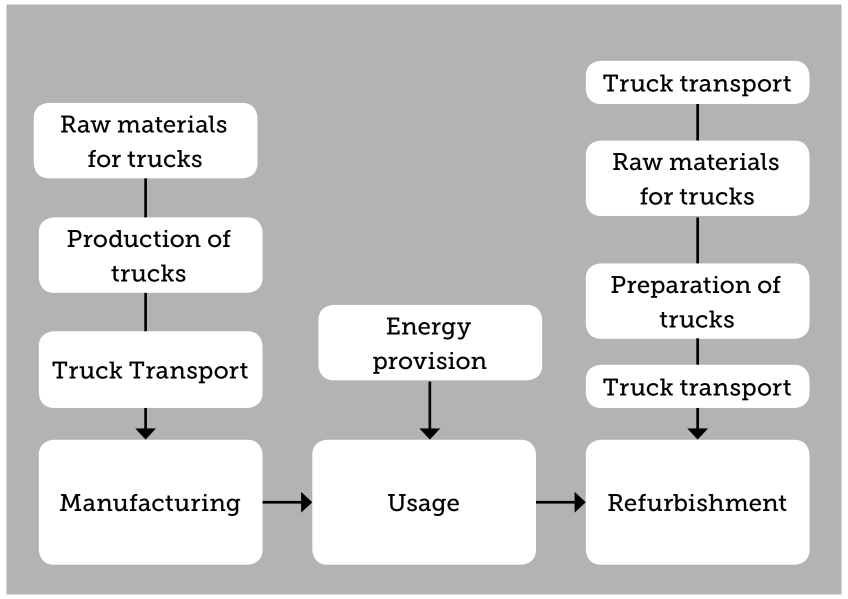

Fig. 1: Examination framework of the life cycle assessment
The service life of a truck is set at an average of 10,000 service hours. This is equivalent to the average duration for customers in intralogistics.

1.4 Data Basis and Data Quality

The means of calculation for determining the data required in the phases of manufacturing, usage and refurbishing are explained below.

1.4.1 Manufacturing Phase

When considering the CO_2 emissions produced during manufacturing, we examined the generation of raw materials, the production phase and transport to customers or distribution centres.

The raw materials required to manufacture industrial trucks are derived from an average mix of materials (based on the percentage of a material in the trucks) for each product cluster. Material values are determined for the individual raw materials used in manufacturing and the respective CO_2 output is derived from these values. The determined values include the upstream chain and thus take into consideration the extraction of raw materials. Depending on the mix of materials, different CO_2 emission values per kg of truck are derived for each product cluster. For battery-operated trucks, the battery is included in the mix of materials. Therefore the weight of the truck used in calculations includes the battery weight.

To calculate the average machine weight for each product cluster per year, sales figures of each unit are multiplied by the weight of the corresponding reference vehicle and added together. The total is divided by the overall unit total of trucks in the product cluster. The average weight multiplied by the CO_2 emissions per kg of truck then yields the CO_2 output per year and truck in the corresponding product cluster.

To determine emissions in the production phase of industrial trucks, the direct and indirect energy sources consumed annually at the Jungheinrich production facilities in Norderstedt, Lüneburg, Moosburg and Landsberg were determined and converted into CO_2 levels. Direct energy sources include natural gas, while energy sources such as electricity and district heating are considered indirect.

Table 10 shows a list of all production facilities where trucks are manufactured for Jungheinrich for the product clusters being examined. Changes in the location of production lines are also indicated.

	Landsberg	Leighton Buzzard	Lüneburg	Moosburg	Norderstedt
Electric counterbalanced truck >1.6t				X	
ICE truck		up to 2003		from 2004	
Electric counterbalanced truck <1.6t				X	
Reach truck with driver's seat/operator platform					X
High-lift fork trucks and other high-lift trucks	X				
Pallet trucks and other lift trucks	from 2009				up to 2008
Trucks, tow tractors			X		

Table 10: Production facilities of the product clusters examined

The annual figures for direct and indirect energy sources between 2000 and 2010 are determined at the factories. The CO_2 output of the production facilities is calculated using the corresponding conversion factors for energy sources and these levels are added together. The values used include the upstream chain.

If trucks with internal combustion engines are used as operating trucks in factories, the number of these machines is multiplied by the average usage period of 220 days per year at 6 hours per day. The result is then multiplied by the average value from the VFG fleet consumption calculation. This yields the CO_2 output per year and factory for trucks used for operational purposes.

The total amount of CO_2 from direct and indirect energy sources in addition to the operating fleet yields the total CO_2 output per factory per year. The total CO_2 output is allocated to trucks per factory per year according to order intake statistics and calculated for each machine per product cluster. Consumption figures per machine are reported directly by Dantruck.

For the transport of trucks from factories to customers or distribution centres, machines delivered in Europe were evaluated in terms of surface transport. An average transport distance per product cluster was derived from the sales figures for 2010 to serve as the basis for the last ten years. The locations of distribution centres and the breakdown of transport distances to the distribution centres have not changed significantly since 2000.

The total number of truck units in each product cluster was multiplied by the appropriate distance to obtain the total distance in kilometres per product cluster. The total distances were divided by the total number of machines per product cluster to yield the average transport distance per truck.

To calculate the annual CO_2 output per truck per product cluster, all unit totals for series (order intake statistics) in the relevant product cluster were first multiplied by the weight of the corresponding reference vehicle. The resulting total weight was divided by the total number of machines in the product cluster to give the average truck weight per product cluster and year. This value is used for transport in both the manufacturing phase and the refurbishing phase.
Multiplying the average transport distance by the average weight yields the average annual tonne kilometres per machine and product cluster. Lorries are used exclusively for transport. A contractual agreement with transport partners stipulates that optimum loading must be ensured by the transport companies.

The average annual tonne kilometres per product cluster multiplied by the CO_2 factor yields the average CO_2 output per machine per product cluster in the relevant year. The calculation for machines designated for refurbishing is similar.

1.4.2 Usage Phase

To determine the average CO_2 output of a Jungheinrich truck by product cluster in the usage phase, a series of calculations must be made based on a number of assumptions. This procedure is explained in the following paragraphs.

The first step was to determine energy consumption for a product group within a product cluster. A specific vehicle within the group was defined as a reference for this purpose. The reference vehicle is the vehicle with the highest number of units sold within the product group (see section 1.2).

The energy consumption of all selected reference vehicles was determined using the current VDI 2198 measurement cycles (as of 2011). Each test performed was repeated five times. An average was derived from the measured values to compensate for possible measurement errors.

To determine CO_2 emissions, the consumption of electricity, diesel fuel or liquefied gas was converted into CO_2 levels. The EU current mix of the corresponding years 2000 and 2010 was used to convert electrical current into CO_2. There is a constant conversion factor for diesel fuel and liquefied gas (see Table 11).

All CO_2 conversion factors include provision of the energy sources (upstream chain).

CO_2 conversion factors:

Energy source	Conversion
Current (EU)	1 kWh = 629 g CO_2 (2000) and 563 g CO_2 (2010)
Diesel	1 l = 4.432 g CO_2
Liquefied gas (LPG/"auto gas")	1 kg = 3.496 g CO_2

Table 11: Conversion factors for determining CO_2 emissions

The composition of the liquefied gas meets the requirements of DIN 51622, meaning that it consists primarily of propane (at least 95%).

The CO_2 emissions determined for the reference vehicles with electrical drive were then multiplied by the "charge factor".

The reason for this that less energy can be taken from the battery than expended for charging due to electrical and electrochemical loss during charging and discharging. Losses also occur in the charger because not all energy is transferred from the socket to the battery: a proportion is converted to heat.

The charge factor in our calculation is the mains energy (in kWh) required to generate 1 kWh of output.
To determine the mains energy required ("charge factor"), the following factors must be known:

1. Specific charge factor for the battery and charge type
2. Charge efficiency of the battery (depends on the charging and discharging process)
3. Device efficiency of the charger

The charge factor determined by the battery and charging type differs according to different types of batteries that can be used with different charge characteristics (Wa, pulse and IU characteristic, see the ZVEI information sheet) and different charging technologies (transformer and high-frequency).
The charge factor lies in the range between about 1.2 for (older) wet batteries with a Wa characteristic curve and about 1.05 for closed batteries with defined electrolytes (gel batteries) with an IU characteristic curve (see VDI information sheet B2 "Approximate Cost Determination of a Battery Charge"). A value of 1.05 means that 1.05 kWh of mains energy must be expended to generate 1 kWh of output.

The charge efficiency of the battery is defined as the ratio between the charge and discharge quantity. Depending on the battery technology, this ranges from 0.83 to 0.95 (see VDI information sheet B2).

The device efficiency is the energy efficiency of the charger during the entire charging process. It differs depending on the charger technology (see VDI information sheet B2). Typically it ranges from 0.75 for chargers with unregulated technology to about 0.9 for devices with primary pulsed technology (HF devices).

To determine an overall charge factor, the specific charge factor for the relevant battery and charge type is divided by the charge efficiency of the battery and the device efficiency.

Sample calculation:

1 kWh of output will be made available. How much mains energy [kWh] is required?

Specific charge factor for the battery and charge type: 1.2
Charge efficiency of the battery: 0.85 (85%)
Device efficiency of the charger: 0.88 (88%)

Formula:
Output * (specific charge factor for battery and charge type/charge efficiency of the battery/ device efficiency of the charger) = mains energy

1 kWh * (1.2/0.85/0.88) = 1.60

The charge factor was taken into consideration in the overall calculation for the usage phase, in which it was multiplied by annual CO_2 consumption. Because different charging technologies are used (transformer/high-frequency), different average charge factors were applied for high-lift fork trucks and other high-lift trucks (product cluster 5) and for pallet trucks and other lift trucks (product cluster 6) than for other electric trucks.

In the next step, a calculation is made of the CO_2 output per life cycle of a truck. A basic value of 10,000 services hours was used for each truck with either electrical or internal combustion engine drive. This corresponds to the duration of an average first truck service life.

To be able to determine the overall average CO_2 emissions per life cycle, the annual consumption of individual trucks is weighted based on the number of units sold in the relevant years (order intake statistics). The result is the CO_2 output of an average truck per life cycle. The average truck is not a vehicle that actually exists but a statistical creation.

1.4.3 Refurbishing Phase

Consideration of the refurbishing phase begins in 2006 with the opening of the central refurbishing factory for used forklift trucks in Klipphausen (near Dresden). Used vehicles received at this factory are refurbished and prepared for a second service life before being returned to the customer.

The raw materials required for refurbishing are derived from an average mix of materials per product cluster. The relevant data for manufacturing these raw materials (similar to the process for the manufacturing phase) is applied to determine CO_2 output.
The calculation uses the annual average weight per machine per product cluster from the manufacturing phase. The average weight multiplied by the CO_2 emissions per kg of truck yields the CO_2 output per year and refurbished truck in the corresponding product cluster.

For the refurbishment of trucks, the annual consumption of direct and indirect energy sources in Dresden is determined and converted into CO_2 levels. The conversion factors are used the same way as in the manufacturing phase.

The total amount of CO_2 from direct and indirect energy sources in addition to the operating fleet yields the total annual CO_2 output of the refurbishing plant in Dresden. The total CO_2 output is allocated to refurbished trucks in Dresden on an annual basis.

The general calculation of CO_2 output for transport in the refurbishing phase is described in the paragraph "Manufacturing Phase". The calculation was performed in a similar manner when evaluating the refurbishment of designated machines in Dresden. Refurbished trucks are picked up directly from the customer and returned again after refurbishing. The values for distance are therefore multiplied by a factor of 2.

1.5 Error Approximation and Sensitivity Analysis

To support the credibility and accuracy of the examination, possible error sources will be tracked at this point and approaches to corresponding solutions will be described. An estimate will also determine how much determined values could vary up or down and what effect possible fluctuations could have on the overall result.

1.5.1 Error Approximation for the Manufacturing Phase

Raw materials
The CO_2 factors were selected so that the highest value would always be used for a mix of materials.

For metal composites and metal-plastic composites, the proportion of steel to plastic ranges between 80:20 and 50:50. The error approximation was made in the product cluster where the percentage of material is highest (metal composite reach trucks, metal-plastic composite ICE trucks). The results are shown in Table 12.

Production
Calculation of CO_2 output at factories is based on actual energy consumption figures.

The conversion factors are derived from recognised sources. No systematic source error could be detected here.

Transport
We used the Diesel MIX DE 2010 lorry transport records from GEMIS database version 4.7, Goods Transport 2010 as the factor for transport. This value includes the entire life cycle (transport tasks plus preparation).
Distances are determined from the actual sales figures for shipment to various countries.

No systematic source error could be detected here.

1.5.2 Error Approximation in the Usage Phase

Determining energy consumption
The energy consumption of reference vehicles was determined based on guideline VDI 2198.
The VDI cycle was repeated at least five times and an average was obtained from the measured values. All measured values are given in the measurement report.
A tolerance of about 0.5% is permissible for the determined values of power consumption and time for the VDI load cycle (see the measurement report).
To exclude the possibility of errors while measuring currents, two ammeters were always used at the same time. If there were no deviations between the two measurements, it can be assumed that no measurement errors occurred.

Charge factor
Because the charge factor consists of three different factors (charge factor for the specific battery and charge type, battery efficiency and device efficiency of the charger), the same minor fluctuation of up to 5% can occur for all these factors.

The same system was used for all calculations.

1.5.3 Error Approximation for the Recycling Phase

Raw materials
The CO_2 factors were selected so that the highest value would always be used for a mix of materials.

For metal composites and metal-plastic composites, the proportion of steel to plastic ranges between 80:20 and 50:50. The error approximation was made in the product cluster where the percentage of material is highest (metal composite reach trucks, metal-plastic composite ICE trucks). The results are shown in Table 12.

Refurbishing
Calculation of CO_2 output at the Dresden refurbishing factory is based on actual consumption figures.

The conversion factors are derived from recognised sources. No systematic source error could be detected here.

Transport
We used the Diesel MIX DE 2010 lorry transport records from GEMIS database version 4.7, Goods Transport 2010 as the factor for transport. This value includes the entire life cycle (transport tasks plus preparation).
Distances are determined from the actual sales figures for shipment to various countries.

No systematic source error could be detected here.

1.5.4 Sensitivity Analysis

The effects of the possible error sources determined in sections 1.5.1 to 1.5.3 on the overall result are illustrated below. It should be mentioned in advance that the usage phase has the greatest effect on the overall result (manufacturing and usage), accounting for at least 80%.

Manufacturing phase		
Value considered	**Assumption**	**Effect on the manufacturing phase**
Metal composites Steel/plastic 80%/20% for reach trucks	Use worse value, plastic at 100% (1.6 kg CO_2 instead of 1.37 kg CO_2)	Deterioration of 1.01%
Metal-plastic composites Steel/plastic 50%/50% for ICE trucks	Use worse value, plastic at 100% (1.6 kg CO_2 instead of 1.37 kg CO_2)	Deterioration of 0.14%
Usage phase		
Value considered	**Assumption**	**Effect on the usage phase**
Energy consumption as per VDI 2198	The measured values (power consumption and time) have the greatest possible deviation from the VDI cycle (0.5%)	Deviation of 0.5%
Charge factor	All charge factors are 5%	Improvement in percentage trend of 0.1%
Refurbishing phase		
Value considered	**Assumption**	**Effect on the refurbishing phase**
Metal composites Steel/plastic 80%/20% for reach trucks	Use worse value, plastic at 100% (1.6 kg CO_2 instead of 1.37 kg CO_2)	Deterioration of 1.29%
Metal-plastic composites Steel/plastic 50%/50% for ICE trucks	Use worse value, plastic at 100% (1.6 kg CO_2 instead of 1.37 kg CO_2)	Deterioration of 0.85%

Table 12: Sensitivity calculations

Conclusion: The effects described here could affect the absolute CO_2 results, but not the percentage trends between 2000 and 2010.

2. Model Assumptions and Definitions of the Life Cycle Assessment

The basic assumptions made for the examination are summarised below.

Goals of the life cycle assessment

- Track the trend of CO_2 output within the defined product cluster for trucks placed in operation between 2000 and 2010
- Establish a starting point for goals to further reduce CO_2 output.

Examination framework

- Function: Use of trucks in intralogistics over an average operating time of 10,000 service hours (first truck service life).
- Comparability: comparable travel and lift output within the individual product clusters (defined work cycle).
- System limits: The system limits include the manufacturing phase, the usage phase (including the provision of energy) and the refurbishing phase.
- Cut-off criteria: maintenance, upkeep, disposal and recycling are not included in the examination.
- Allocation: The input/output streams are described for the various phases by the means of calculation. Example for the production phase: input includes direct and indirect energy sources; output is the resulting CO_2 output, which represents a partial result of the entire system.

Data basis

- Measurement results according to the VDI 2198 measurement cycle
- Technical specification sheets
- Sales/order intake statistics
- Annual CO_2 conversion factor (current mix)
- Conversion factor for diesel and liquefied gas (constant)
- Charge factor (includes charge factor for specific battery and charge type, battery charge efficiency, device efficiency of the charger and the distribution of unit totals over different charger types)
- Average life cycle (service hours)
- Mix of materials for product clusters as the basis for the manufacturing and refurbishing phases
- CO_2 conversion factors
- Factory energy consumption values
- Conversion factors for natural gas, district heating, etc.
- Conversion factor for transport
- Evaluation of transport for 2010
- Order intake statistics for Dresden 2011 (refurbishing rate)

Results of assessment

- The material assessment results record CO_2 emissions in the various phases.
- No estimate of effects was performed.

3. Results of the Life Cycle Assessment

3.1 Assessment Results for Manufacturing and Usage

The results of the examination for the manufacturing and usage phases are summarised below. The figures in Table 13 refer to the entire truck fleet:

Tonnes of CO_2 per life cycle per average truck

	Manufacturing			Usage			Total		
	2000	2010	%	2000	2010	%	2000	2010	%
Electric counterba-lanced truck >1.6t	7.6	7.9	+4.4	59.1	43.9	-25.7	66.6	52.8	-20.8
ICE truck	12.5	12.1	-3.1	160.1	117.8	-26.4	172.6	129.9	-24.7
Electric counterba-lanced truck <1.6t	6.6	6.5	-0.6	48.1	33.3	-30.7	54.6	39.8	-27.1
Reach truck with driver's seat/	5,1	5,0	-2,8-	48,1	33,5	-30,4	53,3	38,5	-27,7
operator platform	5.1	5.0	-2.8	48.1	33.5	-30.4	53.3	38.5	-27.7
High-lift fork trucks and other high-lift trucks	1.2	1.5	+20.3	10.3	8.2	-20.4	11.6	9.7	-16.1
Pallet trucks and other lift trucks	1.1	1.1	+0.8	5.6	4.3	-22.5	6.6	5.4	-18.8
Trucks, tow tractors	2.0*	2.0	-2.0*	14.5*	15.1	+3.5*	16.6	17.1	+2.8

Table 13: Examination results manufacturing and usage
* Figures from the first sales year (2006)/ trend for 2006

It is clear that Jungheinrich AG has achieved considerable reductions in CO_2 in all product clusters in the last ten years (2000-2010). In some product clusters there was an increase in CO_2 output during the manufacturing phase.

There were reductions of 3.1% in CO_2 output in the manufacturing phase over the years from 2000 to 2010 for trucks with internal combustion engines. CO_2 output also fell for electric forklift trucks <1.6t, reach trucks and trucks/tow tractors (the period of calculation for trucks and tow tractors was 2006 to 2010).
An increase in CO_2 output was recorded for high forklift trucks (20.3%) and for electric forklift trucks >1.6t (4.4%). One reason for the increase for high-lift fork trucks was the increasing number of heavy machines, which resulted in higher CO_2 output, especially in the consumption of raw materials and for transport. Relocation production of two pallet truck series (low-lift) from Norderstedt to Landsberg in 2009 and three more in 2010 had an effect on production in Norderstedt.
For electric forklift trucks >1.6t, the increase in CO_2 output of 4.4% (compare high-lift fork trucks) can be explained by the addition of heavier machines to the product cluster in 2004.

The financial crisis from 2007 to 2009 had an effect on CO_2 output in production. With lower utilisation of plant capacity, energy consumption was allocated to fewer machines, increasing CO_2 output per machine. This effect is especially noticeable in 2009.

In the usage phase it can be noted that considerable increases in efficiency (between 20% and 31%) were achieved for all product clusters already included in the Jungheinrich AG portfolio in 2000. This trend can be attributed in part to the introduction of newer technologies, but also to improvements to existing technology, for example by truck optimisation. The charge factor and EU current mix are also factors that play a significant role. Significant improvement has also been achieved in these areas over the last ten years.

The product cluster of trucks and tow tractors experienced a negative trend between 2006 and 2010. Although each individual reference vehicle in this product cluster shows an improvement in the period under consideration, the overall trend of the average vehicle deteriorated. The reason for this is that especially the more powerful/larger series with correspondingly higher CO_2 emissions have been sold most recently and these have (initially) lowered the result for the average vehicle because of the number of units taken into consideration.

3.2 Assessment Results for Refurbishing

Reductions in CO_2 output between 1.3% and 7.4% were recorded in the refurbishing phase across all product clusters. The number of machines delivered in Germany and Austria, for example, has risen significantly since 2006. Therefore the average number of transport kilometres per machine is reduced, contributing to a reduction in CO_2 output.

The results for the refurbishing phase can be seen in the following overview. Currently about 7% of trucks are refurbished:

Tonnes of CO_2 per life cycle per average truck

	Electric counter-balanced truck >1.6t	ICE truck	Electric counter-balanced truck < 1.6t	Reach truck with driver's seat/ operator's stand	High-lift fork truck and other high-lift trucks	Pallet trucks and other lift trucks	Trucks, tow tractors
2006	1.6	2.1	1.6	1.4	0.5	0.4	–
2010	1.5	2.0	1.5	1.3	0.5	0.4	–
%	-5.6	-7.4	-5.6	-7.2	-1.3	-4.1	–

Table 14: Examination results for refurbishing

3.3 CO_2 Output for Machines Placed in Circulation (Manufacturing and Refurbishing)

Machines considered as placed in circulation are those that are manufactured in a given year as well as refurbished machines. Due to the significantly lower CO_2 output for refurbished machines, CO_2 output is reduced for the overall number of machines placed in circulation. The proportion of refurbished machines is likely to increase in the future, so greater reductions in CO_2 output may be expected.

The product cluster of trucks and tow tractors is not taken into consideration for this evaluation because these vehicles were not added to the Jungheinrich product portfolio until 2006. Because of this, none of these trucks are being refurbished yet.

With a current refurbishing rate of 7%, the reductions in CO_2 output shown in Table 15 will be achieved for the trucks placed in circulation.

Tonnes of CO_2 per life cycle per average truck

	Manufacturing			Machines placed in circulation (manufacturing and refurbishing)			Change in CO_2 output due to refurbishing in 2010	
	2000	2010	%	2000	2010	%	Absolute	%
Electric counter-balanced truck >1.6t	7.6	7.9	+4.4	7.6	7.3	-3.7	0.6	-7.7
ICE truck	12.5	12.1	-3.1	12.5	11.0	-12.1	1.1	-9.3
Electric counter-balanced truck <1.6t	6.6	6.5	-0.6	6.6	5.8	-12.2	0.8	-11.7
Reach truck with driver's seat/ operator platform	5.1	5.0	-2.8	5.1	4.7	-8.6	0.3	-5.9
High-lift fork trucks and other high-lift trucks	1.2	1.5	+20.3	1.2	1.4	+16.3	0.05	-3.4
Pallet trucks and other lift trucks	1.1	1.1	+0.8	1.1	1.0	-2.6	0.04	-3.3

Table 15: Change in CO_2 output due to refurbishing (2010)

Consistent refurbishing of trucks can significantly reduce energy requirements: CO_2 emissions per truck are up to 84% less in the second life cycle.

Table 16 shows an overview of potential reductions.

Tonnes of CO_2 for manufacturing/refurbishing per individual truck in 2010

	Electric counter-balanced truck >1.6t	ICE truck	Electric counter-balanced truck <1.6t	Reach truck with driver's seat/operator platform	High-lift fork truck and other high-lift trucks	Pallet trucks and other lift trucks
Manufactu-ring (new machine)	7.6	12.1	6.5	5.0	1.5	1.1
Refurbishing (used machine)	1.5	2.0	1.5	1.3	0.5	0.4
Δ as %	- 81	- 84	- 77	- 74	- 69	- 64

Table 16: Potential savings in CO_2 output per machine through refurbishing

3.4 Balance Sheet Total

In drawing up a balance sheet total for the examination framework, it becomes clear that CO_2 emissions have been reduced by up to 28.5% over the last ten years.

If refurbished trucks are included in the overall result, reductions in CO_2 output are even greater (see Table 17, figures without refurbishing in parentheses). By consistently increasing the refurbishing rate of trucks, savings on the manufacturer side can be increased still further.

If trucks and tow tractors are also refurbished in future, significant reductions in output can be expected in this product cluster as well.

Tonnes of CO_2 per life cycle per average truck

	Machines placed in circulation (manufacturing + refurbishing)			Usage			Total		
	2000	2010	%	2000	2010	%	2000	2010	%
Elektro-Gegengewichts-stapler > 1,6 t	7.6	7.3	-3.7	59.1	43.9	-25.7	66.6	52.2 (52.8)	-21.7 (-20.8)
V-Stapler	12.5	11.0	-12.1	160.1	117.8	-26.4	172.6	128.8 (129.9)	-25.4 (-24.7)
Elektro-Gabelstapler <1,6t	6.6	5.8	-12.2	48.1	33.3	-30.7	54.6	39.1 (39.8)	-28.5 (-27.1)
Schubstapler mit Fahrersitz/ -stand	5.1	4.7	-8.6	48.1	33.5	-30.4	53.3	38.2 (38.5)	-28.3 (-27.7)
Gabelhochhub-wagen und sonstige Hochhub-wagen	1.2	1.4	+16.3	10.3	8.2	-20.4	11.6	9.7 (9.7)	-16.5 (-16.1)
Gabelhubwagen und sonstige Hubwagen	1.1	1.0	-2.6	5.6	4.3	-22.5	6.6	5.3 (5.4)	-19.3 (-18.8)
Wagen, Schlepper	2.0*	2.0	-2.0*	14.5*	15.1	+3.5*	16.6	17.1	+2.8

Table 17: Balance sheet total

* Figures from the first sales year (2006)/ trend for 2006

Jungheinrich creates a second life cycle for trucks through high-quality refurbishing. This means that fewer new trucks need to be produced: a used truck is sufficient for the customer in many applications.

As the preceding examination illustrates, refurbishing is associated with significantly lower energy consumption when compared to new production. When refurbishing is taken into consideration, there is a difference of up to 0.6 tonnes of CO_2 per truck for the EFG <1.6t. This difference can be credited to the product cluster in the CO_2 balance sheet.

4. Declaration of Validity

The statements made in the Environmental Commendation of Jungheinrich are supported by the TÜV Nord certificate of validity. The certificate of validity confirms that the Life Cycle Assessment is based on reliable data and that the method used complies with the requirements of DIN EN ISO 14040.

5. List of Literature and Sources

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6. Appendix

Ökobilanz_Herstellungsphase_Aufarbeitungsphase_Stand_2011final (Excel file with calculations and sources for the manufacturing and refurbishing phases)

Ökobilanz_Nutzungsphase_Stand_2011final (Excel file with all calculations and sources for the usage phase)

Anhang_Ökobilanz_Ladefaktor_Stand_2011final (Excel file with all calculations for determining charge factors)

GÜLTIGKEITSERKLÄRUNG TÜV NORD

DIN EN ISO 14040 : 2009
(Produkt-Ökobilanz)

Der Nachweis der regelwerkskonformen Anwendung wurde erbracht und wird gemäß TÜV NORD CERT-Verfahren bescheinigt für

Jungheinrich AG
Am Stadtrand 35
22047 Hamburg
Deutschland

Geltungsbereich

Das Jungheinrich-Umweltprädikat

Die Forderungen werden erfüllt, nachgewiesen durch eine kritische Prüfung hinsichtlich

- **ordnungsgemäßer Methodologien**
- **repräsentativer Bilanzierungs- und Wirkungskategorien**
- **durchgängiger Transparenz und Konsistenz**

Auditbericht-Nr. 3508 3799

Zertifizierungsstelle der TÜV NORD CERT GmbH

Essen, 2011-10-15

Dr. Winfried Hirtz
Umweltgutachter

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TÜV NORD CERT Umweltgutachter GmbH

TÜV NORD Certification

Hanover, 15.10.2011
TNC Umweltgutachter-H

Report

Critical Review of Life Cycle Assessment

The Environmental Commendation of Jungheinrich

Report No.:	8000 396 269
Client:	Jungheinrich AG Am Stadtrand 35 22047 Hamburg Germany
Author of Life Cycle : Assessment	Jungheinrich AG Abteilungen: Qualität und Umwelt Zentrales Portfoliomanagement
External reviewer :	Dr. Winfried Hirtz
Length of report:	8 pages

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1 General

1.1 Object and Terms of Reference

Jungheinrich AG, Department Quality and Environment and Department Central Portfolio Management, have drawn up a comparative Life Cycle Assessment "The Environmental Commendation of Jungheinrich".

The Jungheinrich AG, commissioned TÜV NORD CERT Umweltgutachter GmbH to carry out a critical review of the Life Cycle Assessment as an independent body in accordance with DIN ISO 14040 and DIN ISO14044.

The review was carried out for TÜV NORD Cert GmbH by Dr.-Ing. Winfried Hirtz, Environmental Assessors licensed under the Environmental Audit Act.

Under the terms of reference, the objective of the critical review was to verify the reliability, transparency, relevance and representative nature of the methods used for Life Cycle Assessment with respect to

- Objective and scope of assessment
- Life Cycle Inventory
- Life Cycle Impact Assessment and
- Evaluation of assessment

1.2 Procedure

Taking into account the general quality criteria (chiefly transparency, reproducibility, quality of the computer programs and data used, and information on the sources of data), the procedure used for the critical review was as follows:

- Review of the objective and scope of the assessment, especially the function and functional equivalence of system boundaries and cut-off criteria (space, time, technology), allocation procedures together with the allocation and distribution rules adopted, and the selection of significant parameters and materials.

- Review of the Life Cycle Inventory drawn up, especially with regard to the input/output analyses (major process chains), the input and output data used and

- Überprüfung der ausgeführten Sachbilanz insbesondere im Hinblick auf die Input/ Output-Analysen (Hauptketten), die verwendeten Input/Output-Daten (I/O-Daten) incl. deren Zuverlässigkeit, die Systematik, Vollständigkeit und Plausibilität der I/O-Analyse, die Sensitivitätsanalyse und Fehlerabschätzung, die Plausibilität und Seriosität der EDV-Programme und die Berücksichtigung von vorgelagerten Prozessketten, Koppelprodukten und sekundären Nachnutzungseffekten

- Überprüfung der Wirkungsabschätzung mit den Schwerpunkten der Auswahl der Wirkungskategorien (sach- und problemorientiert) und der Aggregation der Daten hinsichtlich der Wirkungskategorien

- Überprüfung der Bewertung und der vergleichenden Aussagen infolge der Wirkungsabschätzung.

Dies erfolgte stichprobenartig durch Einsichtnahme und vergleichende Verfolgung bei relevanten Systemabbildungen, Dateien und weiteren repräsentativen Unterlagen sowie bei Datenerhebungs- und Berechnungsvorgängen mit z.T. gezielter Variation am Rechner.

Eingesehen wurden z.B. Daten hinsichtlich des Materialeinsatzes und Materialmix, des Verbrauchs in der Nutzungsphase, insbesondere das Herleiten und Berechnen des Ladefaktors sowie beispielsweise Berechnungen zur Aufarbeitung. Zur aktuellen Technologie wurde die Bilanz auf der Basis von Modellrechnungen vorgenommen.

In dieser Ökobilanzstudie wurde nicht nur auf ein einzelnes Gerät Bezug genommen, sondern auf die Jungheinrich-Flotte. Hierzu wurde in einer intensiven Untersuchung die Möglichkeit der Zusammenfassung von einzelnen Geräten in Clustern untersucht. Aus der Vielzahl der Geräte konnten 7 Produktcluster gebildet werden. Es wurde im Vergleich 2010 zu 2000 ein Vergleichsgerät aus dem gleichen Cluster herangezogen. Konsistenz-Checks der Daten wurden durch den Umweltgutachter systematisch vorgenommen. Protokolle zu den Modellrechnungen wurden eingesehen und geprüft. Insgesamt wurde bei der kritischen Prüfung auf Doppelarbeit verzichtet. Das einschlägige Fachschrifttum der Produkt-Ökobilanztechnik ist berücksichtigt worden.

2 Result of Critical Review

2.1 Objective of Assessment

The objectives of the Life Cycle Assessment are defined clearly and unambiguously; external and internal target groups for the assessment are also stated. The presentation adopted for the Environmental Commendation provides sufficient appropriate information to make the intended environmentally holistic approach clear and comprehensible.

2.2 Scope of Assessment

The Life Cycle Assessment considers the manufacture, use and treatment at the end of the life of industrial trucks concluding accumulated in an overall view of the fleet.

The balance is made as a study to real values without an assessment of effects. All equipment in one cluster has the same functional equivalence. This has been checked intensive as a precondition for this study. The scope and system boundaries of the assessment are clearly and unambiguously defined in relation to the entire system with respect to space, time and technology. The boundaries are compatible with the selected function unit and are defined over the life cycle.
Environmental impact are presented in the category greenhouse gas emissions (expressed in tons of CO_2) and calculated for the total life cycle.

Within the scope of the assessment, all relevant materials, components and processes were logged, analysed and finally grouped together for the subsequent Life Cycle Inventory into three main modules appropriate for the object of the assessment:

- Manufacture phase/raw material production, production and transports
- Utilisation phase / energy consumption
- Treatment phase at the end of the life

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The consumption is referred to VDI 2198 and an industrial truck referenced to a model range. These trucks are weighted according to the produced units in the cluster. Characteristics and exclusions are mentioned in the report.

The graphs and tables in the assessment confirm the systematic nature and completeness of the procedure selected.

In summary it can be stated that all relevant factors have been identified and taken into consideration within the area investigated in accordance with the state of the art of Life Cycle Assessments.

2.3 Life Cycle Inventory

The input/output analyses for the main modules mentioned above were carried out and the Life cycle Inventory for the Life Cycle Assessment was documented using a computer system. The calculations themselves were performed with an EDP system.

2.3.1 Data sources

The main processes in the individual areas have been modelled realistically. The data sources are based on generally accepted files, they are comprehensible and representative as regards this Life Cycle Assessment. The data basis is comprehensive. Values are from ProBas (Federal Environment Agency, FEA) and from Ökoinstitut. Additionally to generally accepted data it has been used official measurements according to VDI, reading values or accounts of energy consumptions. The data can be understood and traced completely.

2.3.2 Plausibility and completeness review

The computer system reflects the systems boundaries systematically and are consistent with the assessment area defined. Boundaries are drawn at points where no (significant) impact on the results of the individual areas or the overall assessment is exerwarten ist (vgl. auch die systematisch durchgeführten Sensitivitätsanalysen für alle relevanten Bereiche). Es ist eine hohe Datenqualität und trotz des Vergleiches über 10 Jahre eine sehr gute Datensymmetrie zu attestieren.

Stichprobenprüfungen wurden für alle Sachbilanzbereiche durchgeführt. Dabei wurden die Richtigkeit der Bilanzierungen und die Plausibilität der Berechnungen und Ergebnisse an ausgewählten Parametern geprüft. Ausgehend von der Prozessplanung, der Einbeziehung von Teilbilanzen und der Datengrundlage wurde so auch die Verknüpfung der einzelnen Module und Hierarchie der Daten bei der Bilanzrechnung dargestellt.

Um die Rückverfolgbarkeit von Daten auf Ursprungsdaten zu gewährleisten, wurden sowohl die Berechnungen als auch die Dokumentation dahingehend untersucht, insgesamt ist diese sehr übersichtlich und klar sind.

Alle signifikanten Parameter sind vorhanden, repräsentativ, systematisch angelegt und vollständig bilanziert. Die Bilanzen und die hinterlegten Datenerhebungs- und Berechnungsverfahren sind transparent und nachvollziehbar.

2.3.3 Allokationen

Allokationen treten bei der Fahrzeug-Herstellung auf. Sie sind in einer Datenbank vorhanden und konnten entsprechend dargestellt werden. Sie sind vollständig übersichtlich und plausibel in der EDV dargestellt.

Soweit Allokationen aus Datenbanken in den Prozessplan importiert werden, ist die Datengrundlage ausreichend. Allokationen aus den Datenbanken wurden bereits dort berücksichtigt.

2.3.4 Fehlerabschätzungen

Separate Fehlerabschätzungen wurden für alle Sachbilanzphasen durchgeführt. In Anbetracht der numerischen Stabilität und der nachgewiesenen Datenqualität sind nur vernachlässigbare Einzelfehler möglich und es wird auf die Einbeziehung von separa-

ten Fehlerabschätzungen verzichtet. Zusätzlich wurden allerdings umfangreiche Sensitivitätsanalysen durchgeführt (s.a. 2.3.5).

2.3.5 Sensitivitätsanalyse

Sensitivitätsberechnungen wurden überall dort durchgeführt, wo relevante Änderungen in den Bilanzen nicht ausgeschlossen werden konnten. Schwerpunkte waren dabei Materialmix bei der Herstellung und Aufbereitung sowie Stromaufnahme und Ladefaktoren für den Gerätewirkungsgrad beim Ladevorgang. Ebenso wurden Transporte intensiv geprüft. Für die Berechnungen der Bilanzen wurden jeweils die konservativen Werte herangezogen.

Um diese Aussage zu prüfen, wurden vor Ort Berechnungen zu Sensitivitäten und die dazu benötigte Parametrisierung geprüft. Es wurden keine Hinweise darauf gefunden, dass zusätzliche Sensitivitätsberechnungen durchzuführen sind.

2.4. Wirkungsabschätzung

Auf eine Wirkungsabschätzung wurde verzichtet.

2.5 Auswertung

Die vorgelegte Auswertung der Ergebnisse der Sachbilanz orientiert sich konsequent und sachgerecht an den definierten Zielen der Ökobilanz-Studie.
Weitere Aussagen und ableitbare Empfehlungen sind strikt von der Ökobilanz getrennt.

3 Summary of the critical review

The critical review of the Life Cycle Assessment "The Environmental Commendation of Jungheinrich" conducted by the undersigned in accordance with the requirements of international standards DIN EN ISO 14040:2009 and DIN EN ISO 14044:2006 may be summarised as follows:

- The methods used for drawing up the Life Cycle Assessment are in accordance with the requirements of DIN EN ISO 14040:2009 / DIN EN ISO 14044:2006. The methods are scientifically well-founded and are in accordance with the state of the art of Life Cycle Assessments.
- The data used are adequate, appropriate and well-founded with reference to the objective of the assessment.
- The evaluations take into consideration the objective of the assessment and the limitations which were identified.
- The Life Cycle Assessment is consistent and transparent.

A certificate of validity has been issued concerning the critical review which was conducted (cf. Appendix). The report of the critical review will become part of the detailed version of the Life Cycle Assessment.

Dr. Winfried Hirtz
Environmental Verifier
DE-V-0151

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