Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

EuroCombis in Germany – “ecocombis” or “climate killers”?

Stefan Eckert[a]*, Michael Faltenbacher[a], Theresa Gutberlet[b], Alexander Labinsky[b], Hans-Paul Kienzler[b]

[a]*thinkstep AG, Hauptstraße 111-113, 70771 Leinfelden-Echterdingen, Germany*
[b]*Prognos AG, Goethestr. 85, 10623 Berlin, Germany*

Abstract

Since January 1, 2017, 25.25 m EuroCombis (ECs) with a maximum gross vehicle weight rating (GVWR) of 40 t are allowed in German national freight transport on a specified part of the road network. This decision was based on a field test of the potential risks of the EC operation that was carried out under the surveillance by the Federal Highway Research Institute (BASt). However, the assessment mainly focused on safety concerns rather than on environmental impacts. To gain additional insights on the climate effects related to the EC use, a dedicated study was initiated by the state government of Baden-Württemberg and Daimler AG. In this paper, we present the impact of ECs on the modal split of national road and rail freight transport and the corresponding impact on greenhouse gas (GHG) emissions. Analysis was carried out for a 2010 scenario mirroring the conditions of the field test and for a 2030 scenario with a non-restricted highway network.

Keywords: Sustainability / Life Cycle Analysis (Modelling and Prediction), Environmental Impact of Transport, Transport Modeling & Simulation

* Corresponding author. Tel.: +49-(711)-341817-473; fax: +49-(711)-341817-25.
E-mail address: Stefan.Eckert@thinkstep.com

1. Introduction

As in most European countries, in Germany the length of conventional trucks (CTs) is limited to 16.50 m for tractor-trailer combinations and 18.75 m for drawbar combinations, respectively. For the transport of high-volume goods, the available storage space does not suffice to fully utilize the allowed gross vehicle weight rating (GVWR) of 40 t. Forwarders therefore demanded the use of longer trucks with more loading space. This intention raised a lot of public controversies about safety concerns and climate effects due to a suspected modal shift from rail to road transport.

To examine the risks of longer trucks' operation, a national field test was carried out from 2012 to 2016, in which more than 50 companies participated with different types of EuroCombis (ECs). The used ECs had a length of up to 25.25 m while their GVWR was restricted to 40 t as for CTs. The field test resulted in the allowance of ECs in German national freight transport, yet limiting their operation to a dedicated part of the road network that is specified by the Federal States for their respective territory.

However, the assessments carried out in the field test mainly focused on automotive and traffic engineering rather than on environmental impacts. Therefore, to gain additional insights on the climate effects related to EC use, a dedicated study was initiated by the state government of Baden-Württemberg and Daimler AG. The study consisted of a thorough assessment of the modal shift induced by the deployment of ECs and the related impact on the greenhouse gas (GHG) emissions of German freight transport.

1.1. Approach

First, expert interviews with shippers and carriers were conducted to evaluate the possible range of application and logistical constraints for ECs in transport business. Based on these interviews, the goods suitable for EC transport were identified according to the NST-2007 goods classification. The gross potential for EC use in Germany was then obtained by analyzing the demand matrices of the 2030 Federal Transport Infrastructure Plan and developing regional demand coefficients at district (NUTS 3) level. Employing a cross price elasticity approach, we obtained the expected intramodal (from CTs) and intermodal (from freight trains) shift to ECs. The calculation was based on the specific transport costs, considering specific road and rail transport distances as well as reloading for combined transport. Analysis was carried out for a 2010 scenario mirroring the dedicated EC road network of the field test, and for a 2030 scenario with a non-restricted highway network.

The modal shift results served as input for the determination of the GHG impact. To account for their different fuel consumption, new dedicated fuel consumption functions for CTs and ECs were derived, based on current operational data and truck consumption simulations. The necessary traction power in the case of rail transport was estimated modeling a standard train for wagonload and for combined transport. Fuel and rail traction power related GHG emissions were calculated Well-to-Wheel by means of Life Cycle Analysis (LCA), considering today's and future diesel and electricity generation. Based on the results of the transport analysis, the GHG balance of the EC operation in the two scenarios and the impact on the GHG emissions of German freight transport were obtained.

2. Methodology

2.1. Modal shift

The most commonly used ECs in the field test were the EC type 2 and type 3, both with a length of 25.25 m. They provide up to 53 locations for europallets, while a conventional tractor-trailer combination (CT type 98) may only contain up to 34 and a conventional drawbar combination (CT type 41) up to 38 europallets (see Table 1). The number of trips for a certain transport volume may thus substantially be reduced with the use of ECs, offering significant cost reductions. However, cost savings can only be maximized when the entire loading space is utilized. Given the GVWR restriction of 40 t, not all goods are suitable for EC transport. Goods like printing paper or metal products are so heavy that the GVWR is reached before the loading space even of a CT is filled. Due to their additional equipment, ECs have a higher curb weight than CTs, and therefore can take up even less of such heavy goods. Accordingly, only sufficiently light goods are suitable for ECs in order to utilize their whole volume capacity. Table 1 depicts the payload, the number of pallet locations, and the pallet weight up to which all available pallet locations can be used for the different truck types.

Table 1. Payload, number of pallet locations, and maximum pallet weight for the different truck types.

Truck type	Payload	Number of pallet locations	Average maximum pallet weight
EC Type 2	19.100 kg	53	360 kg
EC Type 3	17.400 kg	53	328 kg
CT Type 98	25.000 kg	34	735 kg
CT Type 42	22.100 kg	38	582 kg

In addition to weight restrictions, goods transported in tanks or by special superstructures as well as hazardous goods were generally excluded as improper for EC transport. Taking this into account together with the logistical constraints as expressed in the expert interviews, the remaining goods were examined with respect to their EC suitability, following the NST-2007 goods classification. While e.g. agricultural products would be light enough, their irregular and seasonal amount together with frequent cooling requirements led to their exclusion. The goods in ten of the 20 goods divisions were at least partially suitable for EC transport, as presented in Table 2. The partially suitable NST-2007 divisions were further analyzed by matching industrial production statistics with information about company locations on a rural district level, developing regional EC potential coefficients.

Table 2. Suitable goods for EC transport and their respective road freight volume in 2010 and 2030 according to Schubert et al. (2014).

NST-2007 goods divisions	Suitability	Total road freight volume (million tonnes)	
		2010	2030
04 Food products	Partially	276	329
05 Textiles	Fully	11	14
06 Wood and paper	Partially	108	126
08 Chemical products and plastics	Partially	110	121
11 Machinery	Partially	47	58
13 Furniture	Fully	12	14
15 Parcels	Fully	30	36
16 Material for goods transport	Partially	66	82
18 Consolidated cargo	Fully	83	103
19 Unidentifiable goods	Partially	20	26

Food products, accounting for about one tenth of all goods transports in Germany, turned out to be the goods division with the highest potential for EC transport, followed by chemical products and wood and paper. In total, the EC suitable goods make up 29.1% and 29.5% of national road freight volume in 2010 and 2030, respectively. However, most of the road freight volume (in terms of tonnes) will never become suitable for EC transport and was therefore disregarded in the further analysis.

For a possible modal shift to ECs, the dedicated EC road network of the field test had to be considered, as shown in Fig. 1 (a). Hence, only transports where the starting as well as the end point were located within a district connected to the EC road network were considered. For the 2030 scenario, a non-restricted highway network was assumed (Fig. 1 (b)). To obtain the specific CT and EC transport distance for a connection, the road network was mapped with shapefiles and underlaid with road class-specific velocities. Then, the route with the minimal driving time was determined employing ArcGIS Network Analyst. Rail distances were derived from Schubert et al. (2014).

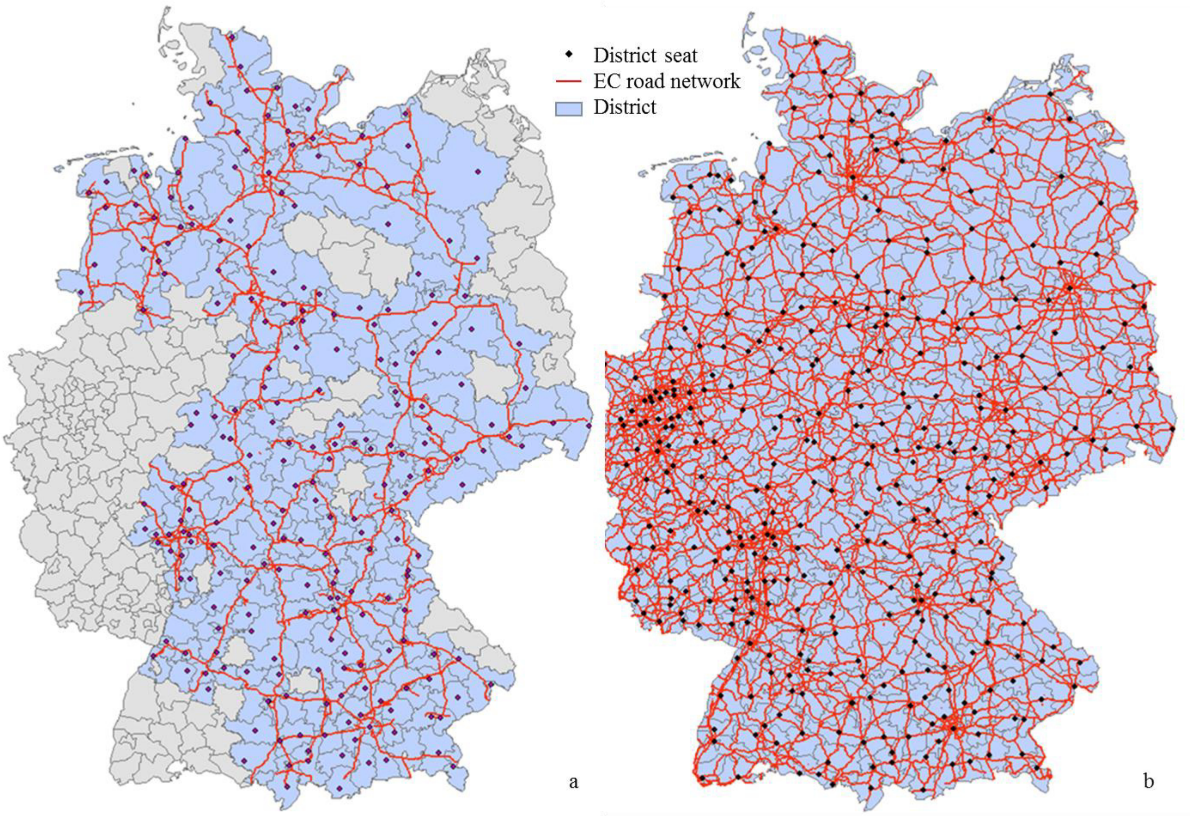

Fig. 1 (a) dedicated EC road network of the field test; (b) non-restricted highway network

For the determination of the modal shift, transport costs of CTs and rail transport, respectively, were compared to those of EC transport on a single-relation/single-type of goods basis, taking into account the respective transport distance and type of good. Table 3 depicts the specific costs per vehicle kilometer for road transport, which are higher for ECs compared to CTs due to the higher purchase costs for the additional equipment, higher driver salaries, and higher fuel consumption. Transport costs were calculated by multiplying the specific costs with the transport distance and the number of vehicles required for the considered freight volume. The calculation thus reflects possible detours for ECs due to road network limitations.

Table 3. Specific Transport costs for CTs and ECs for 2010 and 2030

Truck type	Year	Specific Transport costs (EUR/vehicle km)
CT	2010	1.11
CT	2030	1.27
EC	2010	1.22
EC	2030	1.38

For those relations and goods for which EC transport costs are lower than with CTs or train, the share of the freight volume that is shifted to ECs was calculated using a cross-price elasticity approach. This accounts for the fact that even if another transport mode offers lower costs, not all forwarders will shift their transports, e.g. due to logistic constraints. Generally, the cross-price elasticity is an indicator for the responsiveness of demand for one good related to a change in the price of another good. As EC transport is a new service where a price variation cannot be determined yet, the change in demand had to be related to the relative cost difference between EC and CT transport.

$$e_{EC,CT} = \frac{\frac{X_{EC}}{X_{CT}}}{\frac{C_{EC} - C_{CT}}{C_{CT}}}$$

where:

$e_{EC,CT}$	Cross-price elasticity of EC transport in relation to CT transport
X_{EC}	New freight volume transported by ECs
X_{CT}	Original freight volume transported by CTs
C_{EC}	Costs for transporting the original freight volume with ECs
C_{CT}	Costs for transporting the original freight volume with CTs

The freight volume transported by ECs can then be expressed as:

$$X_{EC} = e_{EC,CT} X_{CT} \frac{C_{EC} - C_{CT}}{C_{CT}}$$

For the intermodal shift the formula is analogous. Empirical studies of European road and rail transport reveal a range of cross-price elasticities between -0.1 and -0.9 (de Jong et al. (2010)). Therefore, a cross-price elasticity of -0.4 was applied for the intermodal shift from rail to ECs. For the intramodal shift from CTs to ECs, a cross-price elasticity of -0.6 was assumed, as this requires fewer organizational adjustments than an intermodal shift.

However, the high purchase costs for ECs require a certain freight volume to enable the forwarder to operate the EC profitably. Hence, an annual minimum freight volume of 50 EC trips per relation and type of good was assumed, below which no modal shift would occur.

2.2. GHG balance

For the calculation of GHG emissions of road and rail transport, only the fuel and electricity consumption, respectively, were considered. The production of the haulage means and the necessary infrastructure was not taken into account as their effect on the GHG balance is low in the case of long-haul transport. Based on Volvo (2001), a truck's GHG impact is clearly dominated by its diesel consumption over its mileage of 1 Mio. km. The production related share of GHG emissions stays below 2 %. Due to its significantly longer lifetime, the GHG contribution of freight train production is considered even smaller. With the small usage share of the considered transports in relation to the overall traffic volume, the GHG impact of the traffic infrastructure can be neglected.

The fuel consumption for a given traffic situation, e.g. driving on a highway, is generally approximated by a linear function of the vehicle weight, with the gradient depending on the topography. The commonly applied fuel consumption functions (FCFs) for trucks as given in the Handbook Emission Factors for Road Transport (HBEFA, see Rexeis et al. (2014)) proved to be considerably too high compared to actual real-world consumption values as provided by the forwarders. In addition, the HBEFA database up to now does not consider ECs. Therefore, new FCFs were derived, based on the information by the forwarders, on consumption data determined in the European Truck Challenge 2014 and 2014 (Bennühr and Wildhage (2016), Schwarz (2014), Schwarz (2016)), various truck tests, and consumption simulations provided by Daimler. Fig. 2 shows the FCFs that were established for both CTs and ECs and for three different topographies (flat, medium and hilly).

However, it proved to be impossible to account for the topography for every single relation. Therefore, the medium FCFs for CTs and ECs were consistently employed to determine the transport related GHG emissions. The following two assumptions further affected the fuel consumption:

- The share of empty trips was set at 10 % for CTs. For ECs, a lower share of 5 % of empty trips was assumed, reflecting their higher operating costs and thus higher necessity to avoid empty trips. In the 2030 scenario, this will increase to 7.5 %. The fuel consumption of the empty trips was allocated to the laden trips according to the respective payload. This resulted in a fuel consumption of 27.6 l/100 km for CTs and 33.5 l/100 km for ECs for the mean payload of 8.96 t and 12.24 t, respectively.
- For the 2030 scenario, a reduction in consumption of 16.1 % for CTs and 19.4 % for ECs was assumed due to expected efficiency improvements, which were considered higher for ECs.

The GHG emissions of fuel consumption were calculated from Well-to-Wheel by means of Life Cycle Analysis (LCA), taking into account biodiesel shares of 5.6 vol. % for 2010 and 10.8 vol. % for 2030. The resulting GHG emission factors were 2.95 kg CO_2e/l diesel for 2010 and 2.82 kg CO_2e/l diesel for 2030, respectively.

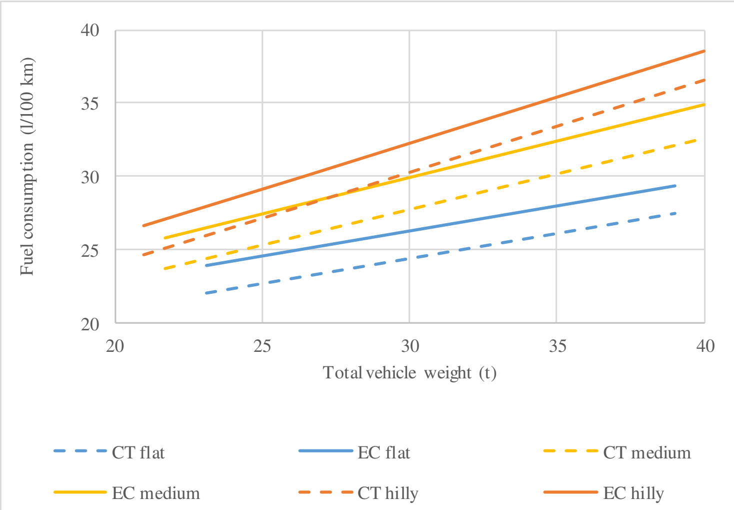

Fig. 2 Established FCF for CTs and ECs for three different topographies (flat, medium and hilly)

The necessary traction power in the case of rail transport was estimated modeling a standard train with 23 wagons for combined transport (33 pallet locations per wagon) and for wagonload transport (45 pallet locations per wagon), respectively. Due to their cost advantage, shift effects for block trains were considered unlikely. Thus, rail relations with a freight volume of more than 30,000 t/a were supposed to be conducted with block trains and excluded from the calculations. As no information on the load distribution of the remaining relations was available, the share of wagons laden with EC suitable goods had to be set arbitrarily. It was assumed that five wagons of a train contain the EC suitable good, while the remaining 18 wagons were laden with an average weight.

The electricity consumption for the train traction was then calculated as a function of its total weight according to EWI (2016). Similar further assumptions as for road transport were made:

- For rail transport, a share of empty wagons replaced the share of empty trips, as completely empty trains were considered unlikely. To each train, 20 % of empty wagons were added. In analogy to trucks, the electricity consumption for their traction was allocated to the laden wagons.
- Because of efficiency improvements, the electricity consumption would decline by 13.1 % from 2010 to 2030.

Depending on the pallet weight of the considered good, the calculated specific electricity consumption per tonne payload varies between 0.0595-0.0538 kWh/tkm for combined transport and 0.0434-0.0394 kWh/tkm for wagonload transport.

The GHG emissions of electricity consumption depend on the energy mix by which the electricity is generated. Based on DB Mobility Logistics (2014), Deutsche Bahn (2016) and Nitsch (2015), the share of renewables in the railway energy mix was assumed to increase from today 33 % to 55 % in 2030. According to the assumed composition of the energy mix, the LCA revealed Well-to-Wheel GHG emission factors for rail electricity consumption of 471 g CO_2e/kWh in 2010 and 399 g CO_2e/kWh in 2030.

3. Results

Table 4 summarizes the results of the modal shift calculation for the 2010 and 2030 scenario, both for the intra- and the intermodal shift. In 2010, the restrictions of the dedicated EC road network led to an EC suitable freight volume of only 100 million tonnes in road transport and close to five million tonnes in rail transport (total for combined and wagonload transport). The opening towards an unrestricted highway network in 2030 increased this potential significantly by about the factor four in road transport and 3.4 in rail transport, respectively.

The intramodal shift amounted to 9 % and 10 %, respectively, in the two scenarios. Thus, the share of EC suitable freight volume that was shifted from CTs to ECs stayed nearly constant. In contrast, the share of intermodal shift from rail freight to ECs even declined between 2010 and 2030. The efficiency improvements for rail transport and the increased transport costs for ECs outweighed the better logistical conditions of the unrestricted road network.

Generally, the intermodal shift resulted in a lower total mileage due to the higher transport capacity of the ECs and consequently fewer necessary trips. This is also clearly indicated by the lower share of mileage of ECs compared to their share of transported freight volume.

Table 4. Summarized results of the modal shift calculation for the 2010 and 2030 scenario

	EC suitable freight volume (m. t)	Shifted to ECs (m. t)	Total mileage (bn. vehicle-km)	Mileage by ECs (bn. vehicle-km)
2010 intramodal shift				
without ECs	100.00	0	2.19	0
with ECs	100.00	8.91 (9 %)	2.14	0.11 (5 %)
2010 intermodal shift				
Without ECs	4.93	0	rail: 4.30 bn. tkm / road: 0.02	0
With ECs	4.93	0.05 (1 %)	rail: 4.27 bn. tkm / road: 0.02	0.0005 (<1 %)
2030 intramodal shift				
without ECs	415.00	0	10.00	0
with ECs	415.00	41.6 (10 %)	9.73	0.58 (6 %)
2030 intermodal shift				
without ECs	16.60	0	rail: 7.95 bn. tkm / road: 0.06	0
with ECs	16.60	0.07 (<1 %)	rail: 7.93 bn. tkm / road: 0.07	0.0008 (<1 %)

When considering the national total freight volumes as given in BVU et al. 2014, it became evident that ECs will only be employed in specific applications. Even under the favourable conditions of the 2030 scenario, the EC suitable freight volume only accounted for about 11 % of the German road freight volume and about 4 % of the German rail freight volume, respectively. Related to the total freight volumes, less than 1 % of road freight and less than 0.2 % of rail freight were shifted to ECs.

In Table 5, the effects of these shifts in transport mode on the GHG emissions are summarized. While in 2010 the intramodal shift led to a GHG emission reduction of less than 22 t CO_2e/a, the reduction in 2030 amounted to over 113 t CO_2e/a, correlating with the higher shift of freight volume. In contrast, the intermodal shift from rail to ECs implied an increase in GHG emissions. However, due to the minor importance of the intermodal shift, this increase stayed below 0.5 t CO_2e/a and thus comparatively low. By this, the GHG savings resulting from the intramodal shift were reduced by 1.6 and 0.4 %, respectively, in 2010 and 2030. The GHG balance in both scenarios was therefore clearly dominated by the intramodal shift and the related impact on GHG emissions.

According to Umweltbundesamt (2010), the combined GHG emissions of heavy road and rail freight transport are predicted to rise from 42.33 m. t CO_2e/a in 2010 to 50.9 m. t CO_2e/a in 2030. In relation to these numbers, the changes in GHG emissions due to the shift effects induced by ECs corresponded to a reduction of 0.05 % in 2010 and 0.22 % in 2030.

Table 5. Changes in GHG emissions.

	Change in GHG emissions (t CO_2e/a)
2010	
Intramodal shift	-21,656
Intermodal shift	+337
Ratio inter-/intramodal shift	1.6 %
Total inter- and intramodal	-21,319
2030	
Intramodal shift	-113,428
Intermodal shift	+419
Ratio inter-/intramodal shift	0.4 %
Total inter- and intramodal	-113,009

4. Conclusions

According to our results, the overall impact of ECs will be small as its use is limited to specific application areas. The intramodal shift to ECs resulted in GHG emission savings for individual transports of up to 20 %. However, in the case of intermodal shift, the GHG emissions for individual transports would be more than threefold. The intramodal shift between different truck types was far more important than the intermodal shift between rail and road. Accordingly, it clearly dominated the impact on GHG emissions. Compared to total freight volumes, the effect of the expected shift on the GHG emissions of road and rail freight transport stayed far below 1 %.

To avoid negative impacts on GHG emissions, policy regulations regarding ECs should focus on individual trips and emission-efficient operation. The opening of the highway network can prevent detours and unnecessary long trips lowering the potential GHG emission reduction of the intramodal shifts. However, the usage of ECs may also lead to intermodal shifts, implying a significant increase of GHG emissions for the affected relations. The intermodal shift should therefore be avoided as far as possible.

The study at hand provides an insight into GHG emission changes related to EC usage under the current legal and operational framework conditions. However, possible changes of the framework may alter the results of this investigation substantially. The impacts of ECs in cross-border transports, or the widespread use of EC types other than the types 2 and 3 that were considered in this study, are questions that would require further investigation.

Acknowledgements

We are grateful for the support and feedback of the members of the project advisory council, the fuel consumption and payload data provided by the forwarders, and the fuel consumption simulations performed by Daimler. Without this input and information, the study could not have been conducted likewise.

References

Bennühr, S., Wildhage, H.-J., 2016. European Truck Challenge. DVZ Themenheft.

DB Mobility Logistics, 2014. Ökologisch handeln aus Verantwortung und Überzeugung, Umweltbroschüre 2014. Berlin.

de Jong, G., Schroten, A., van Essen, H., Otten, M., Bucci, P., 2010. Price sensitivity of European road freight transport – towards a better understanding of existing results. A report for Transport & Environment.

Deutsche Bahn, 2016. Die Deutsche Bahn auf dem Weg zum Umweltvorreiter. Presentation DB Umwelt, April 2016.

EWI EcoTransIT World Initiative (ed.), 2014. Ecological Transport Information Tool for Worldwide Transports - Methodology and Data Update.

Nitsch, J., 2015. SZEN-15, Aktuelle Szenarien der deutschen Energieversorgung unter Berücksichtigung der Eckdaten des Jahres 2014. Kurzexpertise für den Bundesverband Erneuerbare Energien e.V.. Stuttgart.

Rexeis, M., Hausberger, S., Kühlwein, J., Luz, R., 2014. Handbuch Emissionsfaktoren – Version 3.2. Basel.

Schubert, M., Kluth, T., Nebauer, G., Ratzenberger, R., Kotzagiorgis, S., Butz, B., Schneider, W., Leible, M., 2014. Verkehrsverflechtungsprognose 2030 – Schlussbericht. BMVI, Berlin.

Schwarz, A., 2014. European Truck Challenge ETC 2014. KFZ anzeiger, special issue.

Schwarz, A., 2016. European Truck Challenge. Der große Vergleichstest 2016: Resultate, Eindrücke, Messdaten. KFZ anzeiger, special issue.

Umweltbundesamt (ed.), 2010. CO2-Emissionsminderung im Verkehr in Deutschland: Mögliche Maßnahmen und ihre Minderungspotenziale – Ein Sachstandsbericht des Umweltbundesamtes. UBA Texte 05/2010, Berlin.

Volvo (ed.), 2001. Environmental product declaration Volvo FH12 and Volvo FM12, Euro 3. Göteborg.