GHG Mitigation Potential of European Rolling Resistance Labelling and Phase-out Scheme for Heavy-Duty Truck Tyres

Technical Report

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the
Environment, Nature Conservation,
Building and Nuclear Safety

of the Federal Republic of Germany

TRANSfer

Disclaimer

Acknowledgements

We would like to thank also Axel Friedrich and Martin Schmied for their valuable comments in the preparation of this report.

GHG Mitigation Potential of European Rolling Resistance Labelling and Phase-out Scheme for Heavy-Duty Truck Tyres

Technical Report

Frank Dünnebeil and Heiko Keller
ifeu – Institute for Energy and Environmental Research Heidelberg

INSTITUT FÜR ENERGIE-
UND UMWELTFORSCHUNG
HEIDELBERG

The TRANSfer project

The TRANSfer project is implemented by GIZ and funded through the International Climate Initiative of the German Ministry for the Environment, Nature Conversation, Building and Nuclear Safety (BMUB). Its objective is to support developing countries to develop and implement climate change mitigation strategies in the transport sector as „Nationally Appropriate Mitigation Actions“ (NAMAs).

The project provides technical assistance in the partner countries Indonesia, Columbia, Peru and South Africa. In addition, TRANSfer supports mutual international learning. Therefore, the project closely cooperates with other projects under the International Climate Initiative of BMUB. This includes transport projects in China, which can provide plenty of experiences on MRV and implementation of mitigation actions in urban transport, transport technology and logistics. Mitigation actions in China are currently not registered as single NAMAs, but serve to achieve the national target to decrease carbon intensity by 40-45 percent until 2020 (compared to 2005). Interacting within the existing partner network of GIZ, TRANSfer in China will explore the synergies with ongoing projects and extract lessons learned for GHG accounting and implementation of local actions.

One task of the TRANSfer project in China is to describe mitigation actions that could be developed into NAMAs – in China or in other countries. This includes the development of MRV approaches for the identified mitigation actions and an estimation of potential GHG emission savings for an exemplary case in China. Two areas have been identified for the proposals:

1. Certification and introduction scheme of low rolling resistance tires for heavy-duty vehicles in China;
2. National sustainable urban transport policy.

For more information see:
www.transport-namas.org

Table of Contents

1. Background and Scope **1**

2. European tyre labelling and phase-out scheme **3**

3. Impacts **5**

- 3.1. Fuel consumption and GHG emissions 5
- 3.2. Linkages to other measures 6
- 3.3. Non-GHG effects 6

4. Methodology of the GHG impact assessment **8**

- 4.1. GHG assessment boundaries 8
- 4.2. Methodology and data sources 9
  - 4.2.1. Fuel consumption and GHG emissions from rolling resistance 9
  - 4.2.2. Overall fuel consumption and GHG emissions of heavy-duty trucks and savings potential in Europe 15

5. Scenario results **17**

- 5.1. Results for share of fuel consumption and GHG emissions from rolling resistance 17
- 5.2. Overall fuel and GHG savings potential for heavy-duty truck transport in Europe 18

References **24**

1. Background and Scope

In 2010 the transport sector was responsible for 33 % of final energy consumption and 26 % of greenhouse gas (GHG) emissions in Europe. Road transportation accounts for the largest share with 72 % of total GHG emissions from transport [EU 2013] Heavy-duty trucks, with a gross vehicle weight (GVW) more than 3.5t, account for about a quarter of energy consumption and GHG emissions in road transport at present [Papadimitriou, / Ntziachristos, 2013]. Projections expect substantial increases of road freight transport (2010 to 2050: +55 %) [Capros, et al., 2013]. In consequence, to comply with climate change mitigation goals and to minimise final energy consumption, a substantial reduction of fuel consumption and GHG emissions associated with road freight transport is needed. One of the major strategies to reduce fuel consumption of heavy-duty vehicles (HDV) is to improve rolling resistance through better tyres (see info box ‘role of rolling resistance’ below). As a co-benefit, transportation costs for the vehicle owners can decrease considerably.

In 2009, the European Union (EU) introduced regulations for technical specifications of new tyres for all on-road vehicle types, including rolling resistance, wet grip and noise generation. These laws included a mandatory labelling for tyres (in classes) and phase-out regulations for tyres with high rolling resistance coefficients (RRC), aiming to speed-up the market penetration of low rolling resistance tyres[1]. This study assesses the fuel saving and GHG emission reduction potentials of the tyre labelling and phase-out regulations for European road freight transport. It is based on scenarios of future transport activities and specific fuel consumption and on most recent available data on actual rolling resistance of heavy-duty trucks in Europe.

Background of the analysis is the interest of the Chinese Government to gain a better understanding of the effectiveness of European regulations. It is a contribution to the China Green Freight Initiative (CGFI), initiated by the China Road Transport Association (CRTA), with the aim to analyse potential fuel and GHG savings of a similar scheme in China. The study was commissioned by GIZ in the context of the project ‘Transfer of Climate Friendly Technologies and Measures’ (TRANSfer) funded by the International Climate Initiative of the German Ministry of Environment.

Providing information on possible GHG impacts of the tyre labelling and phase-out regulations in Europe could also serve as a basis for the dissemination of this measure to other regions in the world, e.g. in the context of Nationally Appropriate Mitigation Actions (NAMAs)[2].

---

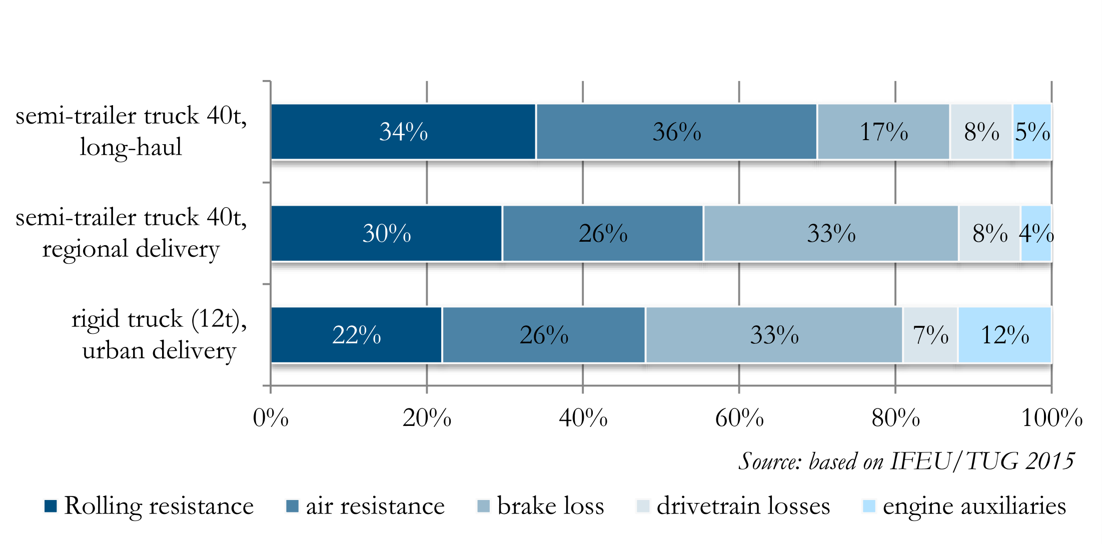
[1] European regulations for on-road vehicle tyres have been assessed in 2008 [COM, 2008; EPEC, 2008a].

[2] “Nationally Appropriate Mitigation Actions (NAMAs) refer to any action that reduces […] under the umbrella of a national governmental initiative. They can be policies directed at transformational change within an economic sector, or actions across sectors for a broader national focus. NAMAs are supported and enabled by technology, financing, and capacity-building and are aimed at achieving a reduction in emissions relative to 'business as usual' emissions in 2020” [United Nations Framework Convention on Climate Change, n.d.] .

Role of rolling resistance for fuel consumption and GHG emissions

Specific energy consumption of heavy-duty trucks depends primarily on the total driving resistance of the vehicle, the resulting mechanical energy demand and on the powertrain efficiency (conversion efficiency of the engine and power losses in the gearbox and axles). Furthermore, specific energy demand of auxiliary consumers (e.g. air conditioning and steering pump) contributes to energy consumption. Total driving resistance of a truck consists of rolling resistance, aerodynamic drag, acceleration and braking losses. Contributions of particular driving resistances vary highly depending on the technical characteristics of the vehicle as well as on the driving profile (velocity, acceleration and topography).

Figure 1 shows contributions of different driving resistances for European EURO VI heavy-duty trucks of different sizes and with different profiles of fuel consumption. Contribution of rolling resistance is in the range of about 20 % for urban delivery trucks up to 35 % for large semi-trailer trucks in long-haul transport. This is therefore a main contributor to fuel consumption and GHG emissions in all truck segments.



Source: based on IFEU/TUG 2015

Figure 1:Contributions to fuel consumption of EURO VI heavy-duty trucks

Rolling resistance is directly correlated with the rolling resistance coefficients (RRC) of tyres, the vehicle mass and the driving speed. As with higher speed the distance covered also increases, the contribution of rolling resistance to fuel consumption per distance travelled is widely speed-independent. Technical requirements on truck tyres includes RRC, but also road grip and braking performance, durability, noise generation, riding comfort etc. Requirements can be interdependent. For instance, [EPEC, 2008a] sees possible trade-offs between reducing rolling resistance and at the same time improving wet grip. Furthermore, tyre noise is influenced by wet grip requirements. Importance of different requirements varies, depending on the typical vehicle operation field. This leads to different RRCs for each truck segments, operation fields and even for different axles of the same vehicle. Additionally, operation conditions (e.g. tyre pressure, road gradient and surface) can influence the actual RRC of a tyre during use.

2. European tyre labelling and phase-out scheme

In 2009 and 2011, the EU introduced and amended regulations for technical specifications of new tyres for most on-road vehicle types, i.e. for cars (C1), vans (C2) and trucks (C3) [EC, 2009a; b, 2011]. The main objectives of these regulations are improvements on rolling resistance of vehicle tyres in order to reduce specific fuel consumption of the vehicles, at the same time with improvements for traffic safety and noise emission reduction. Accordingly, the regulations include the following tyre parameters:

- RRC (in kg/t)[3] as key factor for the fuel efficiency of a tyre,
- Wet grip index as indicator for braking performance of a tyre under wet conditions, defined by comparison with a predefined reference tyre,
- External rolling noise classes for the drive-by noise emission generated by a tyre (in dB).

These parameters are interdependent as described in [EPEC, 2008a; b], i.e. changing one parameter affects other ones. Depending on the method to reduce the RRC, (e.g. tread compounds or tread pattern) there can be a trade-off with improving wet grip. Furthermore, tyre noise is influenced by wet grip requirements.

In the first step of regulation [EC, 2009a], limit values of the defined parameters have been specified in order to induce a phase-out of particularly inefficient tyre models. For truck tyres, only limit values for rolling resistance and external rolling noise have been defined. These are shown in Table 1.

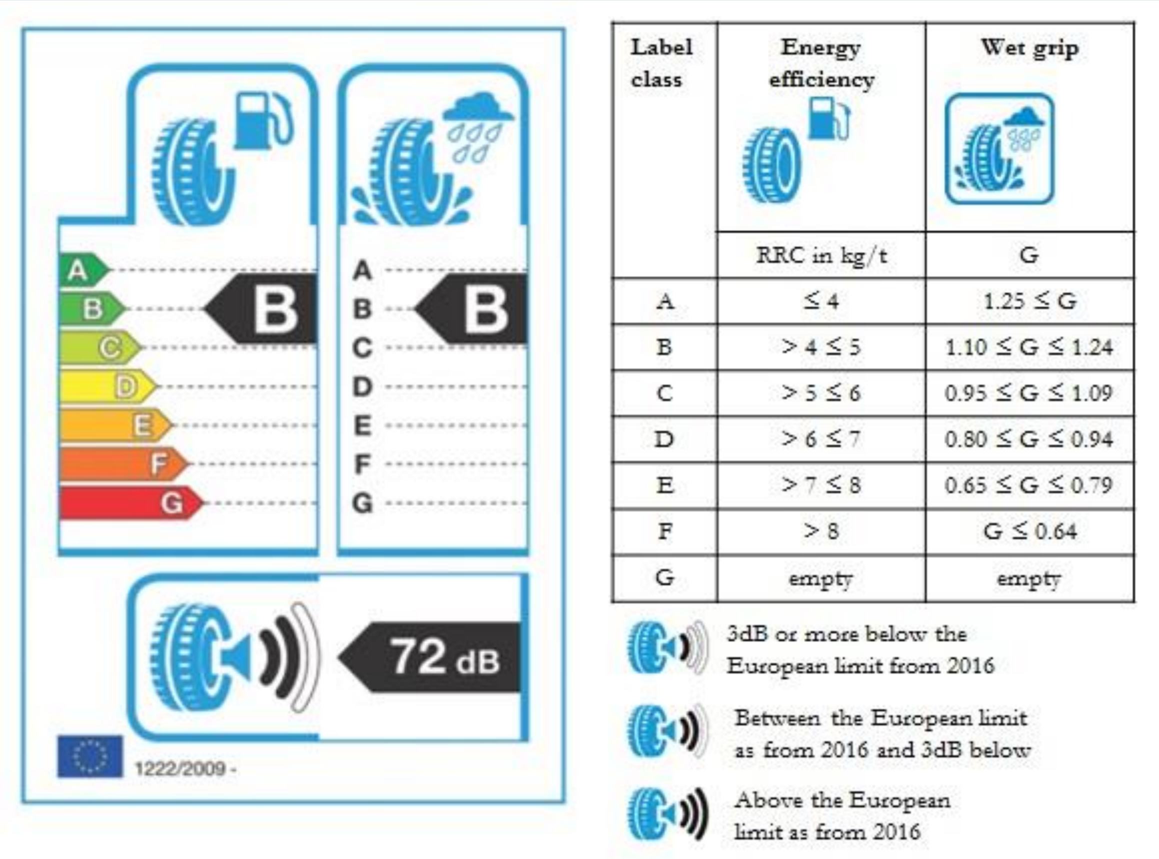
Table 1: European limit values for RRCs and external rolling noise of C3 tyres (Source: EC, 2009a)

Rolling Resistance coefficient (RRC)	
8.0 kg/t	Valid from 01.11.2016 for original equipment of new vehicles and replacement tyres (sale and entry into service)
6.5 kg/t	Valid from 01.11.2016 for new types of tyres (type approval) and from 01.11.2020 for original equipment of new vehicles and replacement tyres (sale and entry into service)
External rolling noise (as from 01.11.2016)	
73 dB(A)	Normal tyres
75 dB(A)	Traction tyres

The second step of regulation was the introduction of a standardised tyre label including the three defined tyre parameters, effective as from the year 2012 as presented in Figure 2 [EC, 2009b, 2011]. This label is mandatory for all tyres except for retreaded tyres, motorcycles and for special applications. The tyre label must be made available for all tyre types from the manufacturers and be provided from the tyre dealers to the end users prior to the sale. In this way, vehicle owners get supporting information for their buying decision regarding the three aspects: fuel efficiency, road safety and external rolling noise. Figure 2 shows the tyre label and the defined label classes of each parameter for C3 tyres type for heavy-duty trucks which are the focus of the present study.

---

[3] RRCs are actually dimensionless coefficients. However, in most literature sources such as in present EC regulations, they are expressed in kg/t or in N/kN, which results in 1000-fold higher values.



Label class	Energy efficiency	Wet grip
	RRC in kg/t	G
A	≤ 4	1.25 ≤ G
B	> 4 ≤ 5	1.10 ≤ G ≤ 1.24
C	> 5 ≤ 6	0.95 ≤ G ≤ 1.09
D	> 6 ≤ 7	0.80 ≤ G ≤ 0.94
E	> 7 ≤ 8	0.65 ≤ G ≤ 0.79
F	> 8	G ≤ 0.64
G	empty	empty

3dB or more below the European limit from 2016

Between the European limit as from 2016 and 3dB below

Above the European limit as from 2016

Figure 2: An exemplary EU tyre label with explanation of segments (Source: EC, 2009b, 2011)

3. Impacts

This section describes the cause-impact relation of GHG reduction and non-GHG effects of the European tyre labelling and phase-out regulations. This includes GHG reduction effects, linkages to other measures and non-GHG effects.

3.1. Fuel consumption and GHG emissions

The total amount of GHG emissions caused by motorised transport depends on kilometres driven (travel activity), as well as on the specific energy consumption of the used means of transportation and on the specific GHG emission intensity of the final energy carriers. In addition to noise reduction, the intended main effect of EU tyre regulation is to reduce the specific energy consumption and subsequently GHG emissions. There are no direct impacts of tyre labelling on the total kilometres driven, shift to other modes or carbon content of fuels. However, fuel-saving tyres also reduce the costs of vehicle operation and subsequently this could lead to a slight increase of transport activities (rebound effect).

Rolling resistance of a heavy-duty truck is directly correlated with the RRC of tyres, the vehicle weight and the driving speed. However, the rolling resistance related energy demand per kilometre travelled is rather speed-independent, as the travelled distance increases by higher speeds. The vehicle weight depends on the empty vehicle's weight and on the actual load weight. The RRCs depend primarily on the technical characteristics of the tyre.

Due to the interdependencies between RRC of tyres, the vehicle weight and the driving speed (see info box "role of rolling resistance" in section 1) and different needs of vehicle owners, RRCs vary considerably for different truck segments, operation fields and even for different axles. Tyres for drive axles have generally higher RRCs than steer and trailer tyres. For that reason and also due to weight distribution in the vehicles, tyres on different axles can contribute divergent shares to the overall rolling resistance of a truck (see example for a semi-trailer truck in Figure 3). Actual RRC of a vehicle during use is additionally influenced by the individual operation conditions (e.g. tyre pressure, road gradient and surface condition).

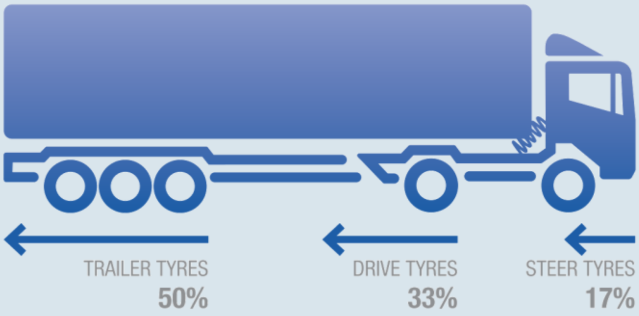


Figure 3: Contribution of tyres on different axles to total vehicle rolling resistance on a typical 40 t semi-trailer truck [Source: Goodyear, 2012]

Besides the rolling resistance, the powertrain efficiency of the vehicle (i.e. the conversion efficiency of the engine and the power losses in gearbox and axles in order to provide the mechanical energy) is also relevant for the contribution of rolling resistance to fuel consumption of the vehicle.

Accordingly, the part of fuel consumption per vehicle kilometre travelled (VKT) resulting from rolling resistance can be estimated with the following simple formula:

$$FC_{RR} = RRC \times C_{RRC} \times m \times g / \eta_{pt}$$

Where:

FC_{RR}	Fuel consumption per VKT resulting from rolling resistance
RRC	Rolling resistance coefficient
C_{RRC}	RRC correction factor
m	vehicle weight (=empty weight + vehicle load)
g	gravity acceleration (9,81 m/s^2)
η_{pt}	average powertrain efficiency of the vehicle

This formula can also be used to calculate the fuel and GHG savings from low rolling resistance tyres by comparing calculations with baseline RRCs with calculations with improved RRCs.

3.2. Linkages to other measures

GHG savings potential in road freight transport from the European tyre labelling and phase-out regulations are directly correlated to other measures that effect vehicle efficiency. The European Commission has been discussing probable strategies for the reduction of CO_2 emissions from heavy-duty vehicles in collaboration with its member states and summarised first results in a so called *Key Issues Paper* in 2014 [EC, 2014]. Especially policies regarding specific fuel consumption and GHG emissions from heavy-duty vehicles could accelerate the introduction and dissemination of fuel saving tyres. In addition to tyres, there are three important aspects:

- Increase efficiency of powertrain technologies,
- Reduce vehicle weight,
- Improve aerodynamics.

There can be trade-offs between some measures, especially with respect to light weight as this also reduces rolling resistance. As a consequence, the results of the scenarios on low-rolling resistance tyres depend on assumptions of other technologies used. This is also the case with respect to measures that reduce carbon content in fuels (e.g. biofuels and synthetic fuels) as well as measures that reduce total mileage of road freight (e.g. increase load factor of trucks, shift to rail, etc.).

3.3. Non-GHG effects

GHG mitigation measures can also have other environmental as well as economic and social effects. Therefore, the impact assessment of the EU tyre regulations considered non-GHG impacts.

Environmental impacts

Typical non-GHG environmental impacts can directly affect the transport activities regarding air quality and noise. Reducing the mechanical energy demand with low rolling resistance tyres reduces the engine load and can lead to a reduction of engine-out emissions of NOx and particles. However, exhaust emissions depend primarily on the efficiency of the downstream exhaust treatment system. As current particle filters reduce particle emissions by 99 %, low rolling resistance tyres have no considerable impact on soot particle emissions. NOx exhaust emissions can decrease slightly as less fuel is burned, but is regarded as a minor effect compared to options for downstream treatment.

Emissions from tyre abrasion (particulate matter PM10, PM2.5 and embedded heavy metals) depend on the abrasion characteristics of the tyres and on their material composition. Changes in the tyre materials can therefore affect the emissions from tyre abrasion. However, data situation on PM and heavy metal emissions is generally uncertain with large bandwidths of emission factors[4] . As tyre abrasion contributes only a small fraction to overall PM concentrations, impacts on air quality due to low rolling resistance tyres are not considered. No reliable data is available about the contribution of heavy metal emissions from tyre abrasion to pollution of soil and water [IFEU, 2013].

As described in [EPEC, 2008a], no direct correlation was found between rolling resistance and noise. However, tyre noise is influenced by wet grip requirements, which in turn can have a trade-off with rolling resistance[5]. The European tyre labelling and phase-out regulations also include requirements for wet grip and external noise, hence noise levels might be influenced by the parallel optimization of rolling resistance and wet grip. Actual noise impacts of the European regulations could be analysed using the noise label, which has to be published for all tyres when corresponding statistical or market information is available.

Different materials and production processes between conventional and low rolling resistance tyres can lead to different environmental impacts in production and recycling processes. However, environmental impacts from other life cycle stages of a tyre are relatively low compared to the impacts during its use [Continental, 1999] and therefore are neglected in the impact assessment.

Road safety

The EU tyre labelling regulation also includes a label scheme for wet grip, which is an important indicator for road safety of tyres. As analysed in [EPEC, 2008a], *"the key trade-offs that are likely to arise from a focus on reducing rolling resistance are a reduced level of wet grip and possibly aquaplaning"* [EPEC, 2008a p. 10]. Road safety could be considerably lower, if tyre development would only focus on the improvement of rolling resistance. However, the EU tyre labelling system includes rolling resistance and wet grip, so it is expected that this dual labelling will not lead to a deterioration of wet grip *"because customers are likely to rank safety as a more important attribute than fuel efficiency when purchasing a tyre"* [EPEC, 2008a p. 66]. *"This increased challenge for tyre producers to optimise not just rolling resistance and wet grip but also to ensure tyre noise does not exceed the standards set is reflected in the higher tyre production costs estimated for dual labelling"* [EPEC, 2008a p. 63].

Vehicle operation costs

Purchasing low rolling resistance tyres requires higher investment costs for vehicle owners. Improving rolling resistance of all tyres of a vehicle by one RRC label class (e.g. from label C to label B) means additional investment costs of about 200 € for a semi-trailer truck and less than 50 € for a rigid truck. On the other hand, this improvement of rolling resistance reduces fuel consumption by about 1-4 % and consequently fuel costs. In this way, a semi-trailer truck in long-haul transport can save about 2000 € fuel costs per year. Even a rigid truck in urban delivery saves about 300 € per year [IFEU, / TU Graz, 2015]. Hence, investment in current low rolling resistance tyres has a payback within few months and leads to a considerable reduction of vehicle operation costs. Even higher fuel cost savings are possible by changing tyres to best available RRC label class. For semi-trailer trucks first "label A" tyres for all vehicle axles are on the market since end of 2014 [M.Kern, 2014].

---

[4] See [European Environment Agency, 2009] part B 1.A.3.b.vi-vii.

[5] [EPEC, 2008a], p. 63: "There is an identified trade-off between increased performance on wet grip and tyre noise … such that dual labelling might give rise to increased tyre noise levels (although not above adopted standards)."

4. Methodology

The European tyre labelling regulation has been assessed in advance for its potential impacts on all concerned vehicle types [EPEC, 2008a; b]. The impact of phase out regulation was not included in the mitigation scenarios but in the reference development (business as usual). Furthermore, the data base of the existing assessment is rather outdated and information on heavy-duty trucks is generally limited. For this reason, this study has been conducted with an individual approach.

The boundaries for the GHG impact assessment were defined to cover all road freight transport activities that are affected by the European tyre labelling and phase-out regulations.

Three scenarios were defined within the assessment boundaries:

- **Baseline scenario**: In this scenario, no European tyre labelling and phase-out regulation exists. Accordingly, future developments of RRCs are only driven by market and consumer demands.
- **Phase-out scenario:** In this scenario the implementation of the first step of the European regulations, the mandatory phase-out of tyres with very high RRCs, was analysed.
- **Phase-out and Tyre-label scenario:** This scenario assesses the whole impact of the European regulations including the mandatory phase-out of tyres with very high RRCs and the additional mandatory energy efficiency labelling of new tyres.

For each scenario fuel consumption and GHG emissions were calculated. These results were compared to assess the fuel and GHG emission savings potential of the European tyre labelling and phase-out regulations for road freight transport in Europe.

4.1. GHG assessment boundaries

The impact assessment analyses fuel and GHG emission savings potential in the road freight transport sector in the EU caused by an increasing share of low rolling resistance tyres. Emissions are calculated in five-5 year intervals from 2010 to 2030 (temporal boundaries).

The European tyre labelling and phase-out regulations cover road transport activities in all 28 member states of the EU (EU 28). Assuming that only vehicles registered in EU are equipped with tyres sold in EU (original equipment of new vehicles and regular tyre replacement), the measure affects all road transport activities on the EU territory. EU cross-border road freight transport can be assumed to be relatively small due to the large territory of the EU and the high share of seacoast borders. Therefore, geographical boundaries were defined as road transport activities within the EU territory.

Regarding sectoral boundaries (emission sources), the impact assessment focuses only on GHG savings potential in the heavy-duty road freight sector, even if the European tyre labelling and phase-out regulations cover tyres of other on-road vehicle types, including passenger cars, light-duty vehicles and buses. Accordingly, the analyses were limited to heavy-duty trucks with a gross vehicle weight (GVW) from 3.5 to 60 tons. Such lorries account for only 8 % of VKT and at the same time for about a quarter of energy consumption and GHG emissions in European road transportation [Papadimitriou, / Ntziachristos, 2013].

Different future developments of transport demand and overall energy efficiency are expected from different vehicle sizes and operation fields (e.g. long-haul and urban delivery) in Europe [Hill, et al., 2011]. Furthermore, rolling resistance and its contribution to total energy demand also differ significantly for different vehicle segments (see info box “Rolling resistance” in section 1). In order to consider this in the impact assessment, heavy-duty trucks have been differentiated into three vehicle segments with different typical operation fields:

1. **Small:** Rigid trucks with 3.5 to 12 t GVW, typical for urban delivery.
2. **Medium:** Rigid trucks with 12 to 40 t GVW and articulated trucks or tractor-trailer combinations with up to 28 t GVW; mainly used for urban and regional delivery.
3. **Large:** Articulated trucks or tractor / trailer combinations with 28 to 60 t GVW, which are primarily used for long-haul freight transport, but also for regional delivery.

In this impact assessment, considered GHG emissions cover well-to-wheel CO_2 equivalent emissions of CO_2, CH_4 and N_2O including both fuel consumption in the vehicles and in upstream processes. Life cycle stages as tyre production and end of life are not included.

4.2. Methodology and data sources

Fuel consumption and GHG emissions were calculated for (1) the baseline scenario without any tyre regulations and for the two reduction scenarios with (2) implementation of the phase-out regulations and (3) implementation of both phase-out and tyre-labelling regulations. Fuel and GHG emission savings potential of the European tyre labelling and phase-out regulations for road freight transport in Europe were assessed by comparing the results of the reduction scenarios to the baseline scenario.

Fuel and GHG savings potential of the measure were calculated in two steps:

1. Calculation of the part of fuel consumption and GHG emissions resulting from rolling resistance and estimation of total fuel and GHG savings potential:
   - Development of assumptions for the baseline scenario (business-as-usual developments of RRCs of truck tyres without tyre regulations).
   - Estimating effects of the European tyre regulations on the development of RRCs.
   - Calculating fuel consumption and GHG emissions resulting from rolling resistance in the baseline scenario and in the two reduction scenarios (development including tyre regulations and improved rolling resistance of heavy-duty trucks).
   - Calculation of total fuel and GHG savings in the reduction scenarios.
2. Calculation of overall fuel consumption and GHG emissions of heavy-duty trucks in Europe and savings potential for the heavy-duty road freight transport in Europe.

4.2.1. Fuel consumption and GHG emissions from rolling resistance

In the first calculation step the part of fuel consumption and GHG emissions resulting directly from rolling resistance were calculated for the three scenarios according to the formula introduced in section 3.1. The following parameters must be identified for three vehicle segments (small, medium and large):

- Medium RRCs for each vehicle segment from 2010 to 2030 in different scenarios,
- Vehicle weight, including empty vehicle weight and average vehicle load,
- RRC correction factors,
- Medium powertrain energy efficiency of each vehicle segment and the development until 2030.

In addition, the following parameters are needed for calculating the part of fuel consumption and GHG emissions resulting from rolling resistance for total heavy-duty truck transport in Europe:

- Total VKT of heavy-duty trucks per vehicle segment in Europe per year
- GHG conversion factor for diesel fuel in Europe

Figure 4 gives an overview of the model approach and parameters. Regarding fuel efficiency, the European tyre regulations only influence the development of RRC. Therefore, RRCs are the only parameters which differ between the baseline and the reduction scenarios. Other calculation parameters and their development are constant between all scenarios.

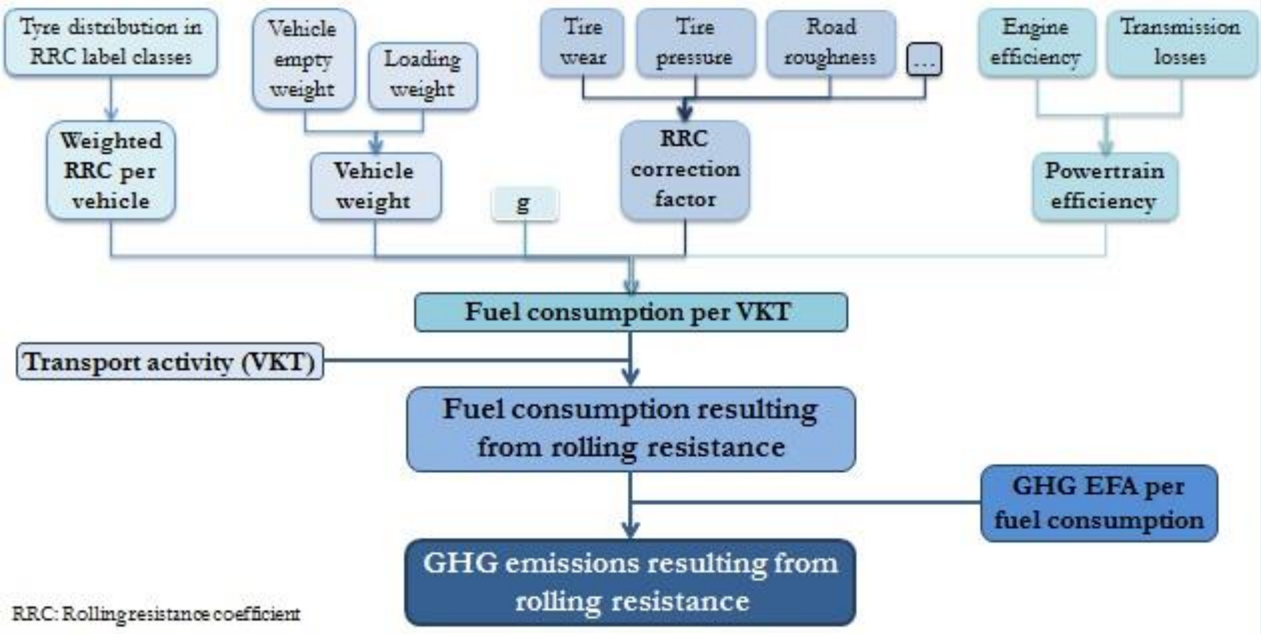


Figure 4: Model approach for fuel consumption and GHG emissions related to rolling resistance

The following sections give an overview on the data and parameters used in the scenarios, as well as sources and the complementary assumptions.

4.2.1.1. Development of RRCs in the scenarios

The most important input parameter for this impact assessment is the weighted average RRC for each vehicle segment and calculation year in the defined scenarios. Typical RRCs of tyres vary strongly for certain vehicle segments and application fields and even for different axles of a vehicle. In this study, weighted average RRC values per vehicle were estimated for each vehicle segment and applied in calculations of different scenarios.

Rolling resistance coefficients in the base year 2010

As an identical basis for all scenarios, plausible RRC values of the base year 2010 and of the present situation were estimated based on a literature research and additional analysis of market offers for RRC distributions of truck tyres and on average RRC values in different vehicle segments:

- The EU impact assessment [EPEC, 2008a; b] provides a RRC distribution of all truck tyres for the year 2004 based on data from the European tyre and rubber manufacturers' association

ETRMA. For this study, ETRMA provided additional data from aggregated EU sales statistics for 2004 and 2007. Data were differentiated by steer and drive axle, though not by vehicle size [ETRMA, 2014].

- A recent study on tyre pressure monitoring systems [TNO, / TU Graz, 2013] provides average RRC values for articulated trucks of 40t and rigid trucks of 11t.
- The online shop *Reifenleader* filtered data of truck tyres offered by size and axle (steer, drive and trailer) and shows the number of products in each RRC label class [Reifenleader, 2015]. Hence, the RRC distribution for offered truck tyres in different vehicle segments can be estimated. Although the RRC distribution of the tyre offer probably is not congruent with sales number, the data analysis gives at least an approximate overview of the present RRC distribution of truck tyres.

RRC distributions are shown in Figure 5. Weighted average RRC values are compared in Table 2.

Data from [EPEC, 2008a; b] and [ETRMA, 2014] show only slight differences between RRC distribution in 2004 and 2007 with reduced shares of RRC class E+F tyres, but at the same time of class A-C tyres. There was no improvement of average RRCs of truck tyres in this period of time. Data indicate better RRCs for steer axles than for drive axles.

Market offer at the beginning of year 2015 also confirms that truck tyres for steer (and trailer) axles have better RRCs than tyres for drive axles. Besides, these data show that truck tyres with larger diameter (22.5” for large rigid and articulated trucks) achieve better RRC classes than tyres with smaller diameters (17.5-19.5”) [Reifenleader, 2015]. In comparison to the RRC distribution of market sales in 2004 and 2007, RRC distribution in the analysed market offer of the year 2015 shows considerably lower shares of RRC classes E+F and higher shares of class D. However, it must be considered that data from 2015 represent the RRC distribution of tyre offer, not of actual tyre sales.

The first impacts of the EU regulation could already be reflected in the weighted average RRC values, which have been estimated on the basis of the data on tyre offer as well as on average RRC values in [TNO, / TU Graz, 2013]. Linking average RRCs per vehicle segment to the VKT distribution in Europe (see Table 3), an average RRC for whole heavy-duty truck transport of about 6.7 kg/t can be estimated for today. Hence, EU tyre labelling and phase-out regulations might have caused reduced shares of truck tyres in high RRC classes E+F. However, there is no evidence that regulations might have already induced significant improvements of average RRCs.

Based on the analysis of recent developments of RRC values, average RRCs per vehicle segment were estimated for the base year 2010 in this study. An average RRC of 7.1 kg/t was assumed for the large vehicle segment (rigid trucks and for tractor/trailer combinations or articulated trucks up to 28 t GVW). An average RRC of 6.3 kg/t was assumed for the small and medium vehicle segment (tractor/trailer combinations or articulated trucks with more than 28 t GVW).

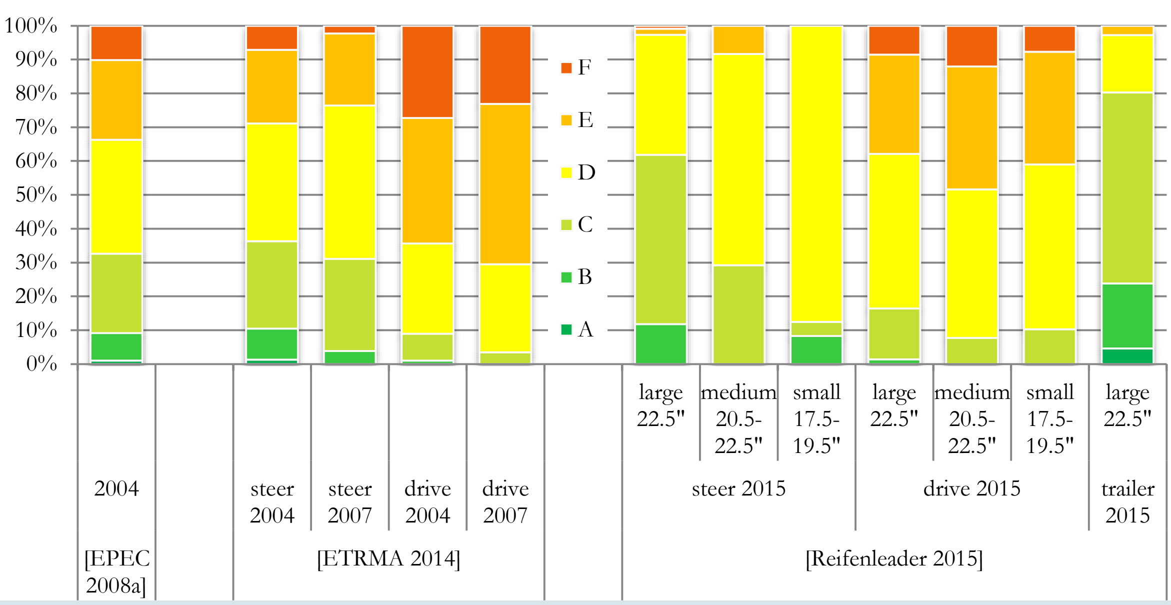


Figure 5: Distributions of truck tyres in EU tyre label RRC classes from different data sources

Table 2: Estimated average RRC values (kg/t) of truck tyres from different data sources

Data source	Year	Vehicle size	Average	Steer axle	Drive axle	Trailer axle
[EPEC, 2008a], [ETRMA, 2014]	2004	all	6.6	6.4	7.4	-
	2007	all	-	6.4	7.4	-
[TNO, / TU Graz, 2013]	2010/ 2012	11 t rigid truck	7.1	-	-	-
		40 t articulated truck	6.3	-	-	-
[Reifenleader, 2015]	2015	small	6.9	6.6	7.2	-
		medium	6.9	6.6	7.3	-
		large	6.2	6.1	7.1	5.7

Future development of RRCs

For the future development of RRCs up to the year 2030, specific assumptions were made for each of the defined scenarios based on the situation in the year 2010.

In the baseline scenario no improvement of RRCs was assumed from 2010 to 2030 for all vehicle segments due to the following reasons: In many operation fields (except long-haul transport) fuel costs have only low relevance for the total costs of vehicle operation [IFEU, / TU Graz, 2015]. Therefore, other criteria have higher importance for buying decisions (e.g. purchase price and durability, see [COM, 2008a]). In consequence, there are no market drivers for the development of tyres with reduced rolling resistance. In long-haul transport, vehicle owners are generally more interested in technologies to reduce specific fuel consumption of their trucks, though they remain rather sceptical about manufacturers' promises on efficiency gains [NACFE, 2013]. Without official tyre labels they have no reliable information about actual rolling resistance. As a result, vehicle owners are likely to consider other, more understandable criteria when deciding on tyre purchase.

In the phase-out scenario, only the impact of mandatory phase-out regulations is analysed. In this initial tyre regulation step, RRC limit values have been specified in order to induce a phase-out of particularly inefficient tyre models. As from November 2016, all new truck tyres must meet an RRC of 8.0 kg/t. This limit value is reduced to 6.5 kg/t as from November 2020. In the scenario, impacts of these limit values on RRC distribution and on average RRCs per vehicle segment are estimated based on the RRC distribution in the baseline scenario: Percentage shares of tyres exceeding the RRC limit value of the respective scenario year are considered to be replaced. The trucks that used those tyres are then allocated among the other RRC classes according to their share in the market. This scenario draws the most conservative picture of RRC improvements and related GHG emission savings resulting from minimum requirements of the European tyre regulations.

In the phase-out and tyre label scenario, maximum improvement potentials of RRCs resulting from the European tyre regulations are estimated and form an optimistic scenario. The official tyre label helps vehicle owners to include rolling resistance when purchasing tyres. It can be assumed that most vehicle owners will buy those tyres with lowest rolling resistance on the market (as far as this means no deterioration of other important criteria as safety and durability). Accordingly, the availability of first RRC class A tyre models can induce a strong market shift to this RRC class.

- **Large vehicle segment:** For 40 t semi-trailer trucks "label A" tyres for all vehicle axles are on the market since the end of 2014 [M.Kern, 2014]. It is therefore assumed that by the year 2020, 50 % of trucks and by 2025 all trucks in this vehicle segment have RRC class A tyres on all axles, meeting an average RRC of 4.0 kg/t. Up to the year 2030, 50 % of the truck fleet in this segment will have made even further improvements to RRCs below 3.5 kg/t (e.g. new class A+).
- **Medium and small vehicle segment:** Truck tyres of smaller vehicle segments still have considerably higher RRC values. They are about one label class above tyres of large semi-trailer trucks (see Figure 5). As fuel savings are of minor criteria for vehicle owners in these vehicle segments, it is assumed that, despite official tyre labels, future RRC improvements in this segment are delayed. The scenario assumes that by the year 2020 vehicle tyres are on average in label class C. Up to 2030, improvements to class B and first tyre models with class A are assumed.

Figure 6 summarizes the resulting average RRC values per vehicle segment in the baseline scenarios and in the reduction scenarios.

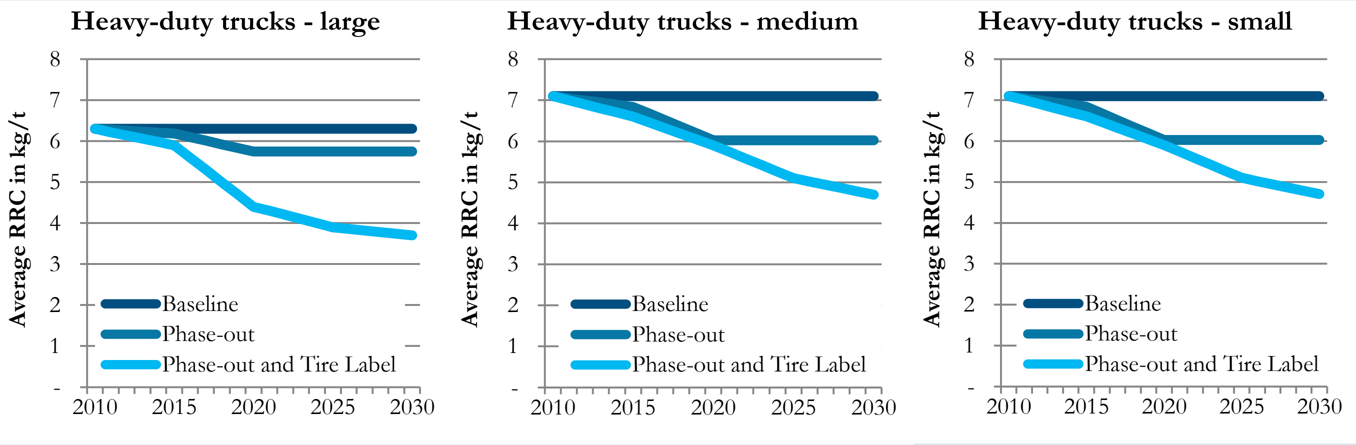


Figure 6: Development of fleet average RRCs for heavy-duty trucks in Europe in scenarios

4.2.1.2. Further parameters used in scenarios

Vehicle weight

The total vehicle weight of a heavy-duty truck is the sum of vehicle empty weight and the weight of the loading. Empty weights of vehicles in different segments can be found in the European emission factor database HBEFA 3.1 [Infras, 2010]. Average loading weights were calculated for the base year 2010 as a quotient of ton.km and veh.km values per vehicle segment provided in TRACCS [Papadimitriou, / Ntziachristos, 2013][6]. No change of vehicle load factors and average loading weights per vehicle segment was assumed for the future development. This is also consistent with other European databases, e.g. with TREMOVE [TML, 2010].

RRC correction factor

The RRC does not only depend on the construction properties of the tyres. It is also influenced by other factors such as abrasive wear, tyre pressure, track alignment, deformation through load, ambient temperature, road roughness and water on the road [Bode, / Bode, 2013]. For example, the RRC of a tyre with a half worn profile on a flat road is almost 30 % lower compared to the RRC of the new tyre. Other factors increase the RRC, but vary considerably depending on the actual conditions during the drive. Therefore, no general correction factor exists. In this study, it was assumed that RRC increasing factors in sum offset the average RRC reduction from abrasive wear. An RRC correction factor of 1.0 was used in all scenarios.

Powertrain energy efficiency

Powertrain energy efficiency includes conversion efficiency of the engine and power losses in gearbox and axles. It depends on vehicle characteristics and varies depending on the driving situation (engine map characteristics). Medium powertrain energy efficiency values for recent 12 t and 40 t heavy-duty trucks EURO V and EURO VI are available from [IFEU, / TU Graz, 2015]. Large trucks have a higher efficiency than smaller trucks, while recent EURO VI models have a higher efficiency than older EURO V models. This information was also used to estimate powertrain efficiency for older vehicles (Euro 0-IV) as well as for future developments of powertrain efficiency of new vehicles. Based on the powertrain efficiency estimated per vehicle segment and age, medium powertrain efficiency of the vehicle fleet was calculated considering average age distributions per vehicle segment and year as in the European model TREMOVE [TML, 2010] in each scenario year.

Transport activities (VKT) of heavy-duty truck transport in Europe

There are several models and scenarios in Europe featuring future developments of transport activities in the road freight sector which are also used in strategic processes in the European Union[7]. For this analysis, VKT data for the base year 2010 and future developments were adopted from projects providing up-to-date and differentiated data for heavy-duty trucks. These data had been prepared for the European Commission and were also used in official EU processes:

- Detailed basic data for total VKT of heavy-duty trucks in Europe differentiated by vehicle segments in the base year 2010 were adopted from TRACCS [Papadimitriou, / Ntziachristos,

---

[6] In this European research project, an extensive set of historical transport data (vehicle stock, VKT, ton.km, fuel consumption factors etc.) has been collected for all European Member States, based on European as well as national statistics, other databases and models (e.g. Copert, HBEFA/TREMOD, TREMOVE). The TRACCS data base provides therefore a detailed up-to-date and comprehensive data base for the transport sector (up to 2010) and is also used in several European processes.

[7] e.g. Trends to 2050, reference scenario 2013 [EC, 2013]; Baseline Projections of Greenhouse Gases and Air Pollutants in the European Union up to 2030 [IIASA, 2013]; TREMOVE economic transport and emissions model (v3.3.2) [TML, 2010];

2013]. In this project, an extensive set of historical transport data (vehicle stock, VKT, ton.km, fuel consumption factors etc.) had been collected for all European Member States, based on European as well as national statistics, other databases and models (e.g. Copert, HBEFA/TREMOD, TREMOVE). The TRACCS data base is therefore a detailed, up-to-date and comprehensive data base for the transport sector in Europe. It was used in several EU processes.

- Future developments of transport activities for each vehicle segment without further measures were adopted from the LOT 1 study [Hill, et al., 2011]. This project was commissioned by the European Commission as an initial step in the strategic process for reducing CO_2 emissions from heavy-duty vehicles in Europe (see [EC, 2014]). It includes analyses of the heavy duty vehicle market and fleet, the current and future fuel use, plus an analysis of CO_2 emissions from heavy duty vehicles as well as technological options and possible policies and other measures to control and reduce CO_2 emissions from heavy-duty vehicles.

Basic data and data sources for the VKT of heavy-duty trucks in the scenario calculations in this study are summarised in Table 3.

Well-to-wheel GHG conversion factors

Well-to-wheel GHG conversion factors for diesel fuel were adopted from the European standard EN 16258 “Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)” (see Table 3). The conversion factors applied in this study not only consider fossil diesel, but also the development of biodiesel shares in total diesel fuel in each scenario year according to the reference scenario of the year 2013 by the European Commission [EC, 2013].

Table 3: Basic data and data sources for transport activities (VKT) and GHG conversion factors

	VKT		GHG conversion factor		
	2010	**2010-2030**	**2010**	**2020**	**2030**
	billion vkm	*%*	*g $CO_{2}e$/MJ well-to-wheel*		
Rigid truck <12t	97	+36 %	88.8	87.2	86.6
Rigid truck >12t and trailer-truck <28t	108	+32 %			
trailer-truck >28t	109	+29 %			
Sources	[Papadimitriou, / Ntziachristos, 2013]	[Hill, et al., 2011]	*EN 16258*		

4.2.2. Overall fuel consumption and GHG emissions of heavy-duty trucks and savings potential in Europe

Complementary to the specific calculations for the partial fuel consumption and GHG emissions from rolling resistance, additional scenarios for the overall development of fuel consumption and GHG emissions in the years 2010-2030 were calculated. With these additional calculations, results of the specific calculations were transferred to potentials for reducing overall fuel consumption and GHG emissions of the whole heavy-duty road freight transport in Europe.

Baseline scenario

Fuel consumption and GHG emissions of transport activities are calculated by multiplying VKT by specific fuel consumption and GHG conversion factors. Therefore, the following parameters were needed or the baseline scenario of overall fuel consumption and GHG emissions:

- Total VKT of heavy-duty trucks per vehicle segment in Europe per year,
- Specific fuel consumption of heavy-duty trucks per vehicle segment in Europe per year and
- GHG conversion factor for diesel fuel in Europe.

Total VKT and GHG conversion factors were already determined for the specific scenarios (see previous section). Additional information was only required for the specific fuel consumption in the base year 2010 and for its development during 2010-2030 in the baseline scenario without European tyre regulations. This information was adopted from the same data sources as VKT development:

- Specific fuel consumption of heavy-duty trucks in Europe in the base year 2010 differentiated by vehicle segments was adopted from TRACCS [Papadimitriou, / Ntziachristos, 2013].
- Future developments of transport activities for each vehicle segment without further measures were adopted from the LOT 1 study [Hill, et al., 2011]. This study includes analyses of heavy duty vehicle market and fleet, the current and future fuel consumption of heavy duty vehicles without fuel-saving measures and estimates fuel savings potential resulting from additional technological options. As low rolling resistance tyres are identified as a relevant fuel saving option, it can be assumed that related fuel saving effects are not included in the trend projections.

Basic data and data sources of the baseline scenario are summarised in Table 4.

Table 4: Basic data and data sources for specific fuel consumption in the baseline scenario

	Specific fuel consumption	
	2010	**2010-2030**
	MJ/vkm	%
Rigid truck <12t	5.3	-6.6 %
Rigid truck >12t and trailer-truck <28t	9.2	-8.4 %
trailer-truck >28t	11.6	-10.1 %
Sources	[Papadimitriou, / Ntziachristos, 2013]	[Hill, et al., 2011]

Reduction scenarios and savings potential

Overall fuel consumption and GHG emissions of heavy-duty truck transport in Europe in the two reduction scenarios were modelled by subtracting the absolute fuel and GHG savings potential (section 4.2.1) from overall fuel consumption and GHG emissions in the baseline scenario.

The savings potential given in percentage of overall fuel consumption and GHG emissions of heavy-duty road freight transport in Europe was derived by comparing the scenario results.

5. Scenario results

This section presents the results of the analysis of fuel consumption and GHG emission savings potential resulting from the European tyre labelling and phase-out regulations. The first part shows specific results for the part of fuel consumption and GHG emissions from rolling resistance. In the second part, these specific results are transferred to potentials for reducing overall fuel consumption and GHG emissions of the whole heavy-duty road freight transport in Europe.

The development of VKT in the baseline and in the reduction scenarios are the same. Furthermore, no other developments (e.g. regarding powertrain efficiency and biofuels) were assumed between the scenarios. In consequence, differences between scenario results and identified fuel and GHG savings potential result exclusively from the estimated impacts of the European tyre regulations on the development of RRCs in heavy-duty truck transport.

5.1. Results for part of fuel consumption and GHG emissions from rolling resistance

Figure 7 compares the development of partial fuel consumption and GHG emissions from rolling resistance in the baseline scenario and in the two scenarios for each heavy-duty truck vehicle segment. Developments of fuel consumption and GHG emissions are very similar. The only differences result from the slight reduction of GHG conversion factors from 2010 to 2030 due to increasing share of biofuels in Europe (see section 4.2.1.2). Therefore, following explanations mainly refer to fuel consumption.

- **Large heavy-duty trailer trucks >28-60 t GVW:** In the baseline scenario, partial fuel consumption from rolling resistance increases by 20 % from 2010 to 2030. This increase is slightly lower than the increase of VKT (+29%). It is due to expected improvements of powertrain efficiency which also reduce partial fuel consumption from rolling resistance (see explanations in section 3.1). In the conservative phase-out scenario, partial fuel consumption increases only by 9 %. This means a reduction of 45 Peta-Joule, corresponding to 1.3 billion litres diesel fuel per year. In the most optimistic phase-out and tyre label scenario, partial fuel consumption from rolling resistance decreases by 30 % from 2010-2030. In the year 2030, the consumption will be about 213 Peta-Joule or 6.0 billion litres diesel lower than in the baseline scenario.
- **Medium heavy-duty trucks (trailer trucks ≤ 28 t GVW and rigid trucks > 12 t GVW) and Small heavy-duty trucks (rigid trucks >3.5-12 t GVW):** In the baseline scenario, partial fuel consumption from rolling resistance increases from 2010 to 2030 by 22 %, respectively 26 %. In the phase-out scenario, partial fuel consumption from rolling resistance from 2010 to 2030 increases by 3 % (medium) and 7 % (small). However, in the phase-out and tyre label scenario, partial fuel consumption is reduced by 17-19 % against the year 2010 in the same vehicle segments. Fuel consumption in the year 2030 is in the phase-out scenario about 81 Peta-Joule (2.3 billion litres diesel) and in the phase-out and tyre label scenario about 180 Peta-Joule (5.0 billion litres diesel) lower than in the baseline scenario.

In total, summing up all vehicle segments, 3.5-11 billion litres diesel can be saved by the European tyre regulations by 2030. This refers to savings from 12 to 37 % compared to the baseline scenario. Regarding GHG emissions the following results occur among all vehicle segments from 2010 to 2030:

- **Baseline scenario:** increase by 18 %
- **Conservative 'phase-out scenario':** increase by 4 %.
- **More ambitious 'phase-out and tyre label scenario':** decrease by 29 %.

In the year 2030, GHG emissions in the two mitigation scenarios are about 11-36 million tons CO_2 equivalents lower than in the baseline scenario.

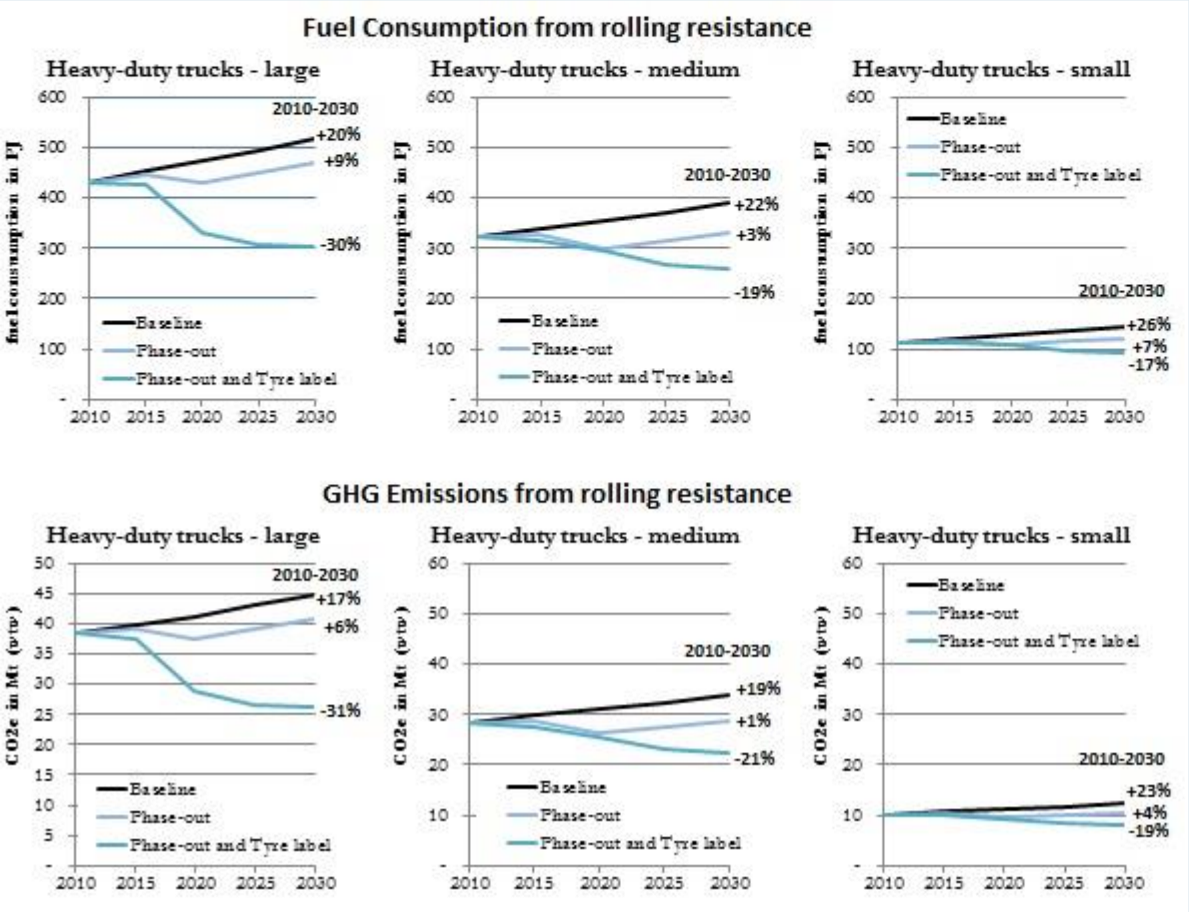


Figure 7: Development of part of fuel consumption and GHG emissions from rolling resistance

5.2. Overall fuel and GHG savings potential for heavy-duty truck transport in Europe

Key developments in heavy-duty truck transport between the base year 2010 and in 2030 are a general increase of transport activities combined with an improving energy efficiency of the heavy-duty vehicle fleet (see section 4.2.1). Future improvements of fuel efficiency cannot compensate the increase in transport activities (more trips and longer distances). Therefore, total annual fuel consumption will increase in the baseline scenario by 20 % from 2010 to 2030 (see Figure 8, left).

GHG emissions will only increase by 17 % because the share of biofuels with low CO_2 conversion factors will increase in future.

GHG emissions from large heavy-duty trucks (articulated trucks and trailer-trucks up to 60 tons GVW) increase by 16 %, less than GHG emission increase from medium and small heavy-duty trucks (trailer trucks < 28 t GVW, rigid trucks). Reasons are slightly lower VKT increase and at same time increasing efficiency of large heavy-duty trucks. Nevertheless, large heavy-duty trucks contribute 44 % to total fuel consumption and GHG emissions of heavy-duty truck transport in Europe in the year 2030.

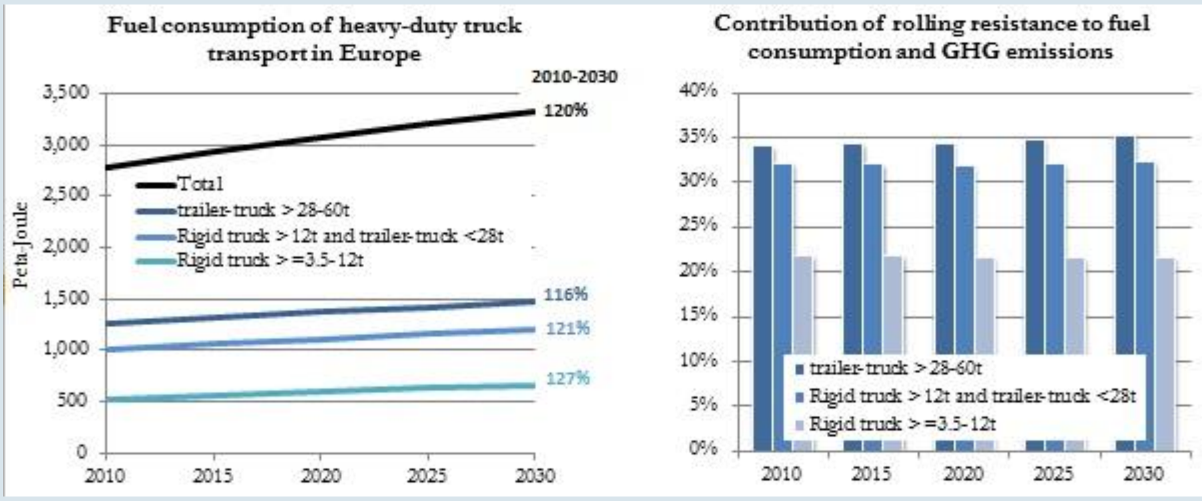


Figure 8: Annual fuel consumption of heavy-duty truck transport in Europe 2010 to 2030 in the baseline scenario (left) and calculated contribution of rolling resistance to total fuel consumption per vehicle segment (right)

Contribution of rolling resistance to fuel consumption in the baseline scenario

The considered part of fuel consumption resulting from rolling resistance can be compared to total fuel consumption of heavy-duty truck transport in Europe (Figure 8, right). In the year 2010, rolling resistance is accountable for about 34 % of fuel consumption from trailer-trucks >28 t and 32 % of fuel consumption from heavy-duty trucks > 12t GVW. However, for heavy-duty trucks of >3.5-7.5 t only about 22 % of fuel consumption results from GVW. These results match well with contribution of rolling resistance according to scientific literature (see info box “Role of rolling resistance” in section 1).

From 2010 to 2030, the contribution of rolling resistance to total fuel consumption in the baseline scenario does not change significantly. There is only a slight increase in the large segment of semi-trailer trucks >28-60 t GVW. This is plausible, as rolling resistance of vehicles does not change in the baseline scenarios and the assumed powertrain improvements not only reduce fuel demand for rolling resistance, but also all driving resistances.

Overall fuel and GHG savings potential from European tyre labelling and phase-out regulations

Total fuel consumption and GHG savings potential from the European tyre labelling and phase-out regulations were calculated by comparing the sum of GHG emissions of whole heavy-duty truck transportation in the reduction scenarios with the baseline scenario (Figure 9).

- **In the conservative phase-out scenario**, it is estimated, that with minimum impacts of the European tyre regulations on RRCs, annual fuel consumption and GHG emissions of heavy-duty truck transport in Europe can be reduced by about 4 % compared to the baseline scenario. This is a fuel saving of 115 Peta-Joule (3.2 billion litres diesel) in 2020 and 126 Peta-Joule (3.5 billion litres diesel) in 2030. Compared to the baseline, GHG emissions are reduced by 10-11 million tons CO_2e per year. Total GHG emissions of heavy-duty truck transport in Europe from 2010 to 2030 increase only by 12 % compared to +17 % in the baseline scenario.
- **In the more ambitious phase-out and tyre label scenario**, representing an optimistic estimate of potential RRC improvements, the estimated reductions are by about 7 % in 2020 and even 12 % in 2030 compared to the baseline scenario. This is a fuel saving of 224 Peta-Joule (6.3 billion litres diesel) in 2020 and 393 Peta-Joule (11 billion litres diesel) in 2030. GHG emissions can be reduced by 20-34 million tons CO_2e per year. Total GHG emissions of heavy-duty truck transport in Europe from 2010 to 2030 increase only by 4 % in this scenario.

The scenario results illustrate clearly that future GHG emissions increase from heavy-duty truck transport in Europe can be considerably reduced through the labelling and phase-out regulations. At the same time, the measure will lead to substantial fuel savings of 3 to 11 billion litres diesel per year. More than half of the GHG emissions savings are related to large trailer trucks due to both high annual mileage and above-average improvements in tyre fuel efficiency in this vehicle segment.

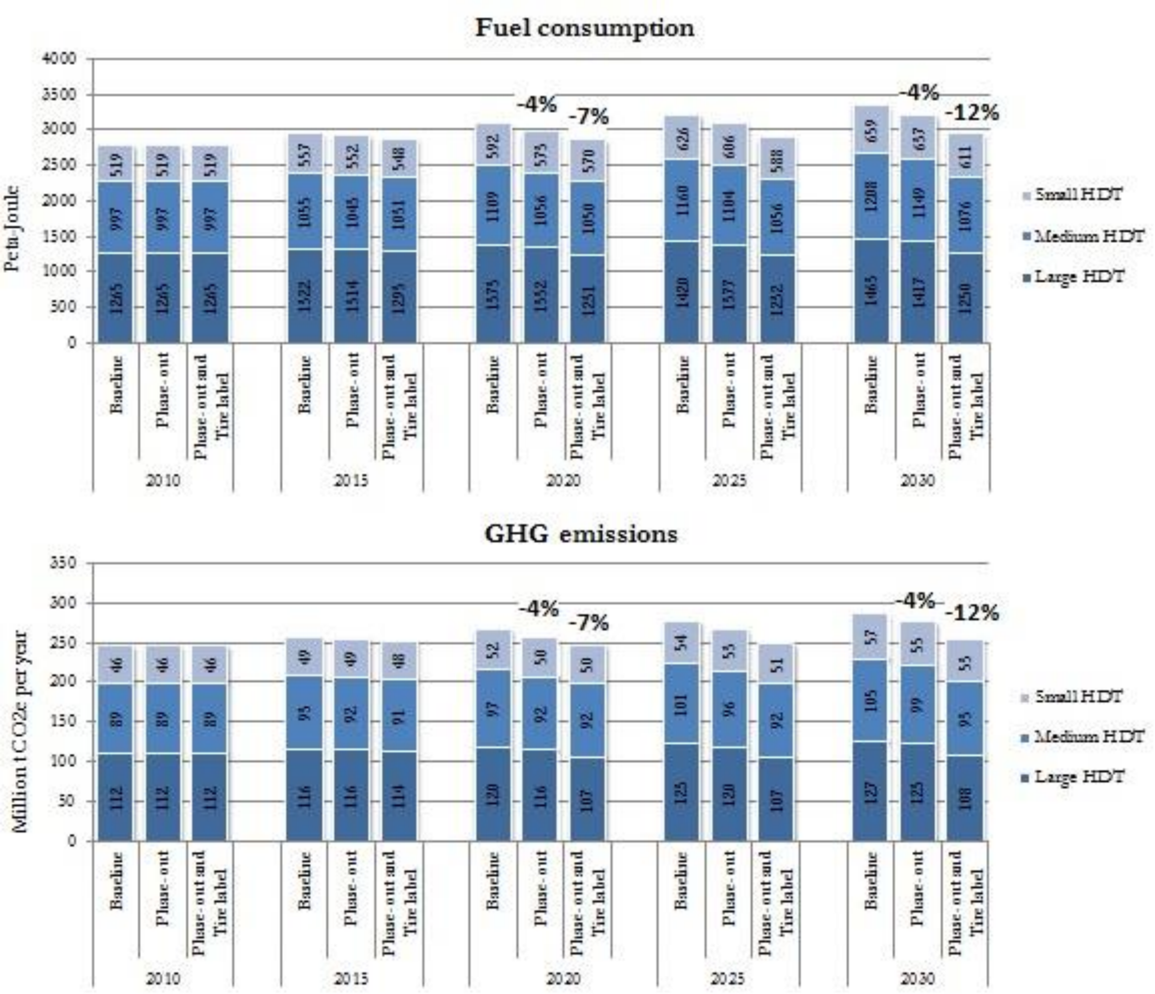


Figure 9: Total annual fuel consumption and GHG emissions from HDV transport in Europe in baseline and reduction scenarios (percentage against baseline).

Plausibility of the results

The results of this impact assessment were additionally checked for their plausibility with other scientific research on GHG savings potential from fuel-efficient tyres. Table 5 shows the bandwidth of indicated fuel savings potential in scientific literature.

- Most data in other reports refer to 40 t trucks, half or full loaded in different mission profiles. Rolling resistance improvements of approx. 1-2 kg/t yield 3-11 % fuel savings. Fuel savings increase with RRC improvements and load factor, long-haul transports having the highest potentials. In the present study, RRCs of trailer-trucks >28-60 t GVW with average load factors and a mix of all mission profiles are improved by 0.6-1.9 kg/t in the year 2020 in the reduction scenarios compared to the baseline, resulting in fuel and GHG savings of 3-10 %. Specific results for large truck trailer in this study are therefore in good accordance to other reports. For the year 2030, this study estimates higher fuel and GHG savings potential of up to 15 %. The estimated average RRC improvement of 2.6 kg/t is beyond ranges of the other reports.
- Only [IFEU, / TU Graz, 2015] analyses fuel savings potential for rigid trucks 12 t GVW. RRC improvements of about 0.5-2.7 kg/t yield 1-6 % fuel savings. In this study, RRCs of heavy-duty trucks 3.5-12 t are improved by 1.1-1.2 kg/t (2020) and 1.2-2.4 kg/t (2030) in the reduction scenarios

compared to the baseline scenario. Resulting fuel and GHG savings in this segment are 3-4 % (2020) and 3-7 % (2030). These results are slightly higher than in the other report, though still being in the same range.

To sum up, plausibility checks show that the calculated fuel and GHG savings potential match with other publications on this topic.

Table 5: Fuel savings potential with energy-efficient tyres in various studies

Source	**Vehicle segment, load factor**	**mission profile**	**RRC change**	**Fuel/GHG saving**
[EPEC, 2008b] (referring to [Barrand, / Bokar, 2009]	40 t, half loaded	sub urban	1 kg/t (5.5 to 4.5 kg/t)	3.3%
		regional		3.9%
		long-haul		5.4%
	40 t, full loaded	sub urban		3.4%
		regional		3.7%
		long-haul		6.0%
[Volvo Group, 2010]	40 t, full loaded	Not specified	Not specified	11%
[Brünglinghaus, 2013], [Lanxess, 2014]	40 t, half loaded	98% motorway,	Ca. 2 kg/t (class DDD to class BCB)	8.5%
[IFEU, / TU Graz, 2015]	40 t, 19.3 t load	long-haul	0.8 kg/t (5.37 to 4.55)	3.7%
			1.3 kg/t (5.37 to 4.09)	5.6%
	40 t, 19.3 t load	regional	0.8 kg/t (5.37 to 4.55)	2.9%
			1.3 kg/t (5.37 to 4.09)	4.7%
	12 t, 2.8 t load	urban	0.5 kg/t (6.75 to 6.24)	0.9%
			2.7 kg/t (6.75 to 4.08)	5.7%

List of tables

Table 1: European limit values for RRCs and external rolling noise of C3 tyres (Source: EC, 2009a) . 3

Table 2: Estimated average RRC values (kg/t) of truck tyres from different data sources 12

Table 3: Basic data and data sources for transport activities (VKT) and GHG conversion factors.... 15

Table 4: Basic data and data sources for specific fuel consumption in the baseline scenario 16

Table 5: Fuel savings potential with energy-efficient tyres in various studies 22

List of Figures

Figure 1: Contributions to fuel consumption of EURO VI heavy-duty trucks 2

Figure 2: An exemplary EU tyre label with explanation of segments (Source: EC, 2009b, 2011) 4

Figure 3: Contribution of tyres on different axles to total vehicle rolling resistance on a typical 40 t semi-trailer truck [Source: Goodyear, 2012] 5

Figure 4: Model approach for fuel consumption and GHG emissions related to rolling resistance .. 10

Figure 5: Distributions of truck tyres in EU tyre label RRC classes from different data sources 12

Figure 6: Development of fleet average RRCs for heavy-duty trucks in Europe in scenarios 13

Figure 7: Development of part of fuel consumption and GHG emissions from rolling resistance 18

Figure 8: Annual fuel consumption of heavy-duty truck transport in Europe 2010 to 2030 in the baseline scenario (left) and calculated contribution of rolling resistance to total fuel consumption per vehicle segment (right) 19

Figure 9: Total annual fuel consumption and GHG emissions from HDV transport in Europe in baseline and reduction scenarios (percentage against baseline). 21

References

Barrand, J.; Bokar, J. (2009): Reducing Tire Rolling Resistance to Save Fuel and Lower Emissions. In: *SAE Int. J. Passeng. Cars - Mech. Syst.* Vol. 1, No.1, pp. 9–17.

Bode, O. D.-I. .; Bode, M. D.-I. (2013): Untersuchung des Rollwiderstands von Nutzfahrzeugreifen auf echten Fahrbahnen. In: *FAT-255*. FAT, Berlin.

Brünglinghaus, C. (2013): Mit rollwiderstandsoptimierten Lkw-Reifen Kraftstoff sparen. <http://www.springerprofessional.de/mit-rollwiderstandsoptimierten-lkw-reifen-kraftstoff-sparen/4795280.html>.

Capros, P.; De Vita, A.; Tasios, N.; Papadopoulos, D.; Siskos, P.; Apostolaki, E.; Zampara, M.; Paroussos, L.; Fragiadakis, K.; Kouvaritakis, N. (2013): EU Energy, Transport and GHG Emissions - Trends to 2050. European Commission; DG ENER, DG CLIMA and DG MOVE.

COM (2008): Impact Assessment - Tyre labelling.

Continental (1999): Life Cycle Assessment of a Tire. S. Krömer, E. Kreipe, D. Reichenbach,R. Stark, Hannover.

EC (2009a): Regulation (EC) No 661/2009 of the European Parliament and of the Council of 13 July 2009 concerning type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor.

EC (2009b): Regulation (EC) No 1222/2009 of the European Parliament and of the Council of 25 November 2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters. European Parliament and Council.

EC (2011): Commission Regulation (EU) No 1235/2011 of 29 November 2011 amending Regulation (EC) No 1222/2009 of the European Parliament and of the Council with regard to the wet grip grading of tyres, the measurement of rolling resistance and the verification proced. pp. 17–23.

EC (2013): Trends to 2050 - Reference Scenario 2013. Europäische Kommission.

EC (2014): Strategy for reducing Heavy-Duty Vehicles' fuel consumption and CO2 emissions. European Commission, Brüssel.

EPEC (2008a): Impact Assessment Study on Possible Energy Labelling of Tyres. European Policy Evaluation Consortium, Brussels.

EPEC (2008b): Impact Assessment Study on Possible Energy Labelling of Tyres. Annexes. European Policy Evaluation Consortium, Brussels.

ETRMA (2014): Market data for C3 tires. European Tyre & Rubber Manufacturers' Association, Brussels, Personal communication,11 Nov 2014.

European Commission (2001): EU Transport in figures 2013. In: *European Commission*.

European Environment Agency (2009): EMEP/EEA air pollutant emission inventory guidebook - Technical guidance to prepare national emission inventories - Part B: Sectoral guidance chapters. In: *EEA Technical report*. European Environmental Agency. *http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009*.

Goodyear (2012): Factors affecting truck fuel economy. <http://www.goodyear.eu/home_en/images/Brochure Fuel Economy Trucks HR.pdf> (Oct. 26, 2015).

Hill, N.; Finnegan, S.; Norris, J.; Brannigan, C.; Wynn, D.; Baker, H.; Skinner, I. (2011): Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy. In: *AEA/Ricardo*. Nikolas Hill, Stephen Finnegan, John Norris, Charlotte Brannigan, David Wynn, Hannah Baker, Ian Skinner (AEA, Ricardo). No.4.

IFEU (2013): Erfassung von Emissionen des Verkehrs in Deutschland im PRTR. Erarbeitung methodischer Grundlagen Quellen für den Bereich Verkehr im nationalen Schadstofffreisetzungs- und -verbringungsregister PRTR.

IFEU; TU Graz (2015): Zukünftige Maßnahmen zur Kraftstoffeinsparung und Treibhausgasminderung bei schweren Nutzfahrzeugen. Frank Dünnebeil, Carsten Reinhard, Udo Lambrecht (Institut für Energie- und Umweltforschung Heidelberg), Antonius Kies, Stefan Hausberger, Martin Rexeis (Technische Universität Graz), Heidelberg.

IIASA (2013): Baseline Projections of Greenhouse Gases and Air Pollutants in the European Union up to 2030.

Infras (2010): Handbuch Emissionsfaktoren des Straßenverkehrs, Version 3.1. Dokumentation in Vorbereitung, Bern. pp. 1–34.

Lanxess (2014): Grüne Reifen - Fakten und Zahlen. Lanxess.

M.Kern (2014): Dreigestrichenes A. In: *Lastauto Omnibus*. Vol. 12, pp. 26–27.

NACFE (2013): Barriers to the Increased Adoption of Fuel Efficiency Technologies in the North American On-Road Freight Sector. Mike Roeth, Dave Kircher, Joel Smith, Rob Swim. *http://www.theicct.org/hdv-technology-market-barriers-north-america*.

Papadimitriou, G.; Ntziachristos, L. (2013): TRACCS : Transport data collection supporting the quantitative analysis of measures relating to transport and climate change " From collected data to final dataset ." Papadimitriou, G Ntziachristos, L Notter, B Keller, M Fridell, E Winnes, H Styhre, L Commission. *http://traccs.emisia.com*.

Reifenleader (2015): Reifenleader Online shop. <http://www.reifenleader.de/>.

TML (2010): TREMOVE v3.3.2 (2010). Leuven.

TNO; TU Graz (2013): Study on Tyre Pressure Monitoring Systems (TPMS) as a means to reduce Light- Commercial and Heavy-Duty Vehicles fuel consumption and CO2 emissions. Stephan van Zyl, Sam van Goethem, Stratis Kanarachos, Martin Rexeis, Stefan Hausberger, Richard Smokers (TNO, TU Graz), Commissioned by the European Commission DG Clima, Delft, Netherlands.

United Nations Framework Convention on Climate Change (n.d.): FOCUS: Mitigation - NAMAs, Nationally Appropriate Mitigation Actions. <http://unfccc.int/focus/mitigation/items/7172.php> (Oct. 26, 2015).

Volvo Group (2010): Major test reveals that simple measures can cut fuel consumption by almost 15 per cent. <http://www.volvogroup.com/group/global/en-gb/newsmedia/corpnews/2010/_layouts/CWP.Internet.VolvoCom/NewsItem.aspx?News.ItemId=87944&News.Language=en-gb>.

Publishedby
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Sunflower Tower Room 860
37 Maizidian Street, Chaoyang District
100125 Beijing, P.R. China

T +86 (0)10 8527 5589
F +86 (0)10 8527 5591

E jingzhu.li@giz.de
I http://sustainabletransport.org

Address Partners
ifeu - Institute for Energy- and Environmental Research Heidelberg GmbH
Wilckensstraße 3
69120 Heidelberg, Germany

Author(s):
Frank Dünnebeil, Heiko Keller (ifeu – Institute for Energy and Environmental Research Heidelberg)

Picture credits / Sources
Scania U.S.A. Inc

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Sitz der Gesellschaft
Bonn und Eschborn

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn/Deutschland
T +49 61 96 79-0
F +49 61 96 79-11 15
E info@giz.de
I www.giz.de