GHG Mitigation Potential of a Green Tyre Programme for Road Freight in China

Technical Report

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

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TRANSfer

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Technical Report

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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

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1. Background and Scope

In 2013, China had 14.19 million commercial road freight vehicles that carried a total volume of 30.7 billion tonnes of freight with a turnover volume of 55.7 trillion ton kilometres. All of these figures grew with annual rates of over 10% in the last years [STATS, 2013]. In the coming years, further substantial increases of road freight transport are to be expected. In consequence, measures to reduce fuel consumption of road freight vehicles can offer considerable savings potential for fuel and greenhouse gas (GHG) emissions.

One of the major contributors to fuel consumption in road freight transport is rolling resistance (see info box on the next page). Therefore, measures improving rolling resistance of vehicles can substantially reduce fuel consumption and GHG emissions in road freight transport. As a co-benefit, transportation costs for the vehicle owners would decrease considerably.

The voluntary standard "Technical Specifications for Green Tyres" issued by the China Rubber Industry Association (CRIA) in March 2014 is China's first technical standard for low rolling resistance tyres and has laid a foundation for China to implement a voluntary tyre grading and labelling system [CRIA, 2014]. In the green tyre standard, green tyres are characterized by low rolling resistance, low fuel consumption, excellent operating stability and shorter braking distance. The China Green Freight Initiative (CGFI) is managed by the China Road Transport Association (CRTA) with support from scientific research institutions, development institutions and non-governmental organizations. Its aim is improving efficiency of freight vehicles. Further standards and regulations for tyre classification and labelling will be discussed in the coming years. In the present report, this series of standards and regulations which are partially already implemented, partially planned and continuously extended is referred to as "China's Green Tyre Programme".

This study provides an ex-ante assessment of fuel and GHG emission savings potential of low rolling resistance tyres in China's commercial road freight sector resulting from China's Green Tyre programme. It is based on most recent available data of future transport activities and specific fuel consumption of commercial trucks and developments of rolling resistance of truck tyres analysed in preparation of this report in [Yang, 2015].

Role of rolling resistance for fuel consumption and GHG emissions

Specific energy consumption of road vehicles 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) to provide the required mechanical energy. Furthermore, specific energy demand of auxiliary consumers (e.g. air conditioning and steering pump) contributes to energy consumption. Total driving resistance of a vehicle 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 to European EURO VI heavy-duty trucks of different sizes and with different mission profiles to fuel consumption. Contribution of rolling resistance is in the range of about 20 % for urban delivery trucks and up to 35 % for large semi-trailer trucks in long-haul transport. Rolling resistance is therefore an important factor for fuel consumption and GHG emissions in all truck segments.

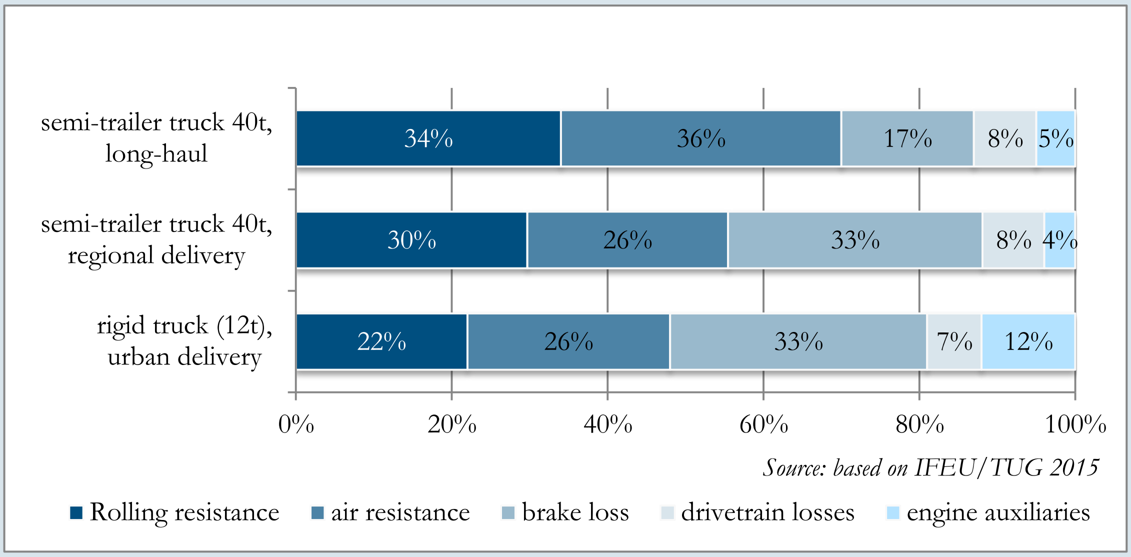

Figure 1: Analysis of causes for fuel consumption of EURO VI heavy-duty trucks

Rolling resistance is directly correlated with the rolling resistance coefficients (RRC) of the tyres, the vehicle mass and the driving speed. As with higher speed the covered distance also increases, the contribution of rolling resistance to fuel consumption per distance travelled is rather speed-independent. Technical requirements on truck tyres include RRCs, road grip and braking performance, durability, noise generation, riding comfort etc. Different requirements can be interdependent. For instance, [Bozeat, 2008] sees possible trade-offs between reducing rolling resistance and at the same time improving wet grip. Importance of different requirements varies depending on the typical vehicle operation field. This leads to different RRCs for each truck segment, 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. China's green tyre programme

This section summarizes the present and upcoming regulation of tyres in China with a focus on energy efficiency of truck tyres. The research on energy-efficient tyres in China dates back to 2011and was inspired by the discussion about tyre labelling regulations in the European Union (EU). During 2011 to 2013 CRIA has conducted a research project 'Research on the Development of Green Tyre Industry' sponsored by the Ministry of Industry and Information Technology (MIIT) that lead to the voluntary industry standard 'Technical Specification for Green Tyre' [CRIA, 2014]. At the same time, China's Tyre and Rim Standardization Technical Committee has conducted a research project 'Limit value of rolling resistance coefficients for tyres' sponsored by the MIIT that resulted in the publication of the standard 'Limit value of rolling resistance coefficients' [China's Tyre and Rim Standardization Technical Committee, 2012]. In 2014 to 2016, CRIA and China's Tyre and Rim Standardisation Technical Committee have planned a series of standards supporting the classification and labelling of tyres. After their planned implementation in 2017, mandatory certification of green tyre will be possible.

The voluntary industry standard puts forward four requirements on green tyres and specifies green tyres in terms of its life cycle:

- Green raw materials: raw materials which meet EU REACH[1] standards,
- Green production process: the whole production process is controlled to realize low energy consumption, low noise, low dust and low emissions,
- Green tyre products: low rolling resistance, fuel saving, safety (i.e. wet grip) and ability for retreading,
- Improve and increase the recycling rate of used tyres.

The green tyre standard also specifies three indexes similar to the European labelling methods for green tyre products, namely rolling resistance, wet grip and rolling noise performance. The limits for rolling resistance and wet grip are equivalent to EU label class E (see Table 1 – Table 3).

Currently the Tyre and Rim Standardisation Technical Committee is considering releasing the following legislation for classification and labelling of energy-efficient tyres in China:

- Wet grip performance test methods of tyres (2015);
- Noise test methods of tyres (2015);
- Classification of Green Tyres (2016);
- Mandatory certification and labelling of green tyres (2017).

The labelling legislation of China could include similar phase-out regulations as in the EU but with different schedule for implementation. The first stage may be implemented in 2017 with the class E limit, and the second stage may be implemented in 2020 with the class D limit. In 2030, China may have the same standard as Europe.

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[1] "REACH is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry. It also promotes alternative methods for the hazard assessment of substances in order to reduce the number of tests on animals." More details at http://echa.europa.eu/regulations/reach

Table 1: Voluntary standard: Limits for rolling resistance coefficients (RRCs) of green tyres. Limits for snow tyre may be increased by 1 N/kN.. (Source: CRIA, 2014)

Type of tyre			**RRC (in N/kN)**
Passenger car tyre			11.5
Mini / light-duty truck tyre	Load index of single tyre ≤ 121 (load capacity ≤ 1450 kg)	Speed symbol ≥ N	10.0
		Speed symbol ≤ M	7.5
	Load index of single tyre > 121 (load capacity > 1450 kg)		7.5
Truck tyre			7.5

Table 2: Voluntary standard: Limits for wet grip of green truck tyres (Source: CRIA, 2014)

Type of tyre		**No-slipping Index on wet surface (G)**	
		Other types	Contraction type
Common tyre		≥ 0.65	≥ 0.65
Snow tyre		≥ 0.65	≥ 0.65
	Snow tyre used under heavy snow	≥ 0.65	≥ 0.65
Special tyre		≥ 0.65	≥ 0.65

Table 3: Voluntary green tyre standard: Limits for noise emissions of green tyres. For special use tyres, limits are increased by 2dB (A). (Source: CRIA, 2014)

Type of tyre	**Type of use**	**Limit dB (A)**
Mini / light-duty truck tyre (increased limits for snow tyres)	Common tyre	72 (+1)
	Traction tyre	73 (+2)
Truck tyre	Common tyre	73
	Traction tyre	75

3. Impacts of promoting green tyres in China

This section describes the cause-impact relation of GHG reduction and non-GHG effects of the tyre labelling and phase-out regulations in China. 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. The intended main effect of 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).

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**Error! Reference source not found.**) and different needs of vehicle owners, RRCs vary considerably for different truck segments, operation fields and even for different axles. In Europe, 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 European semi-trailer truck in Figure 2). Actual RRC of a vehicle during use is additionally influenced by the individual operation conditions (e.g. tyre pressure, road gradient and surface).

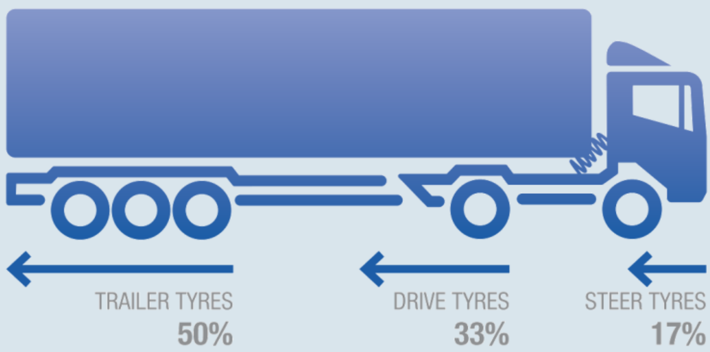

Figure 2: Contribution of tyres on different axles to total vehicle rolling resistance on a typical 40 t semi-trailer truck [Source: Goodyear, 2012]

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 share 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 green tyres by comparing calculations with baseline RRCs with calculations with improved RRCs.

3.2. Linkages to China's fuel economy policies

GHG savings potential from improving rolling resistance of the vehicles are directly correlated to other measures that effect vehicle efficiency. This is especially relevant for fuel efficiency standards that may contribute to disseminate fuel saving tyres. Other means to increase efficiency are:

- 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.).

In the assessment of fuel and GHG savings potential of the Green Tyre Programme linkages to the existing vehicle efficiency standards for trucks in China have to be regarded. Basically there are two relevant standards:

- In 2008, Ministry of Transport (MOT) published the 'fuel consumption limit and measuring methods for commercial freight vehicles' standard JT 719-2008 [MOT, 2008]. Since then, all the commercial vehicles should fulfil the limit. Those who do not meet the standards will be excluded from commercial usage. The standards set two stage limits, stage one was applied in 2009; the second stage was applied in 2011. Currently, those two standards are going to be upgraded and modified to be promoted as 'national level standards', and the third and fourth stage of energy efficiency limits will be applied starting from 2016.
- Furthermore, MIIT has also setup an energy efficiency management system for newly-produced commercial vehicles[2] in 2011. The fuel consumption limits for heavy-duty commercial vehicles (GC/T 924-2011) have been upgraded in 2014 into a second phase, (GB 30510-2014,

[2] For details regarding this standard see information provided by the International Council for Clean Transportation (ICCT) at http://www.transportpolicy.net/index.php?title=China:_Heavy-duty:_Fuel_Consumption

- Table 4, [MIIT, 2014].

Table 4: The weight-based fuel consumption limits for GC/T 924-2011 (Phase I) and GB 30510-2014 (Phase II)

Maximum design weight (tons)	Phase I (l/100km)	Phase II (l/100km)	Phase II (dump trucks only)
3.5-4.5	15.5	13	15
4.5-5.5	16.5	14	16
5.5-7	18.5	16	17.5
7-8.5	22	19	20.5
8.5-10.5	24	21.5	23
10.5-12.5	28	25	25.5
12.5-16	31	28	28
16-20	35	31.5	34
20-25	41	37.5	43.5
25-31	47.5	43	47
>31	50	45.5	49

In China, fuel efficiency limits have played an important role in the decreasing of vehicle fuel consumptions. As observed in the past few years, the fuel efficiency of commercial vehicles showed an annual improvement rate of 2-3%. As planned by MOT and MIIT, the fuel efficiency of newly registered vehicles in 2020 should reach the level of developed countries.

3.3. Non-GHG impacts

GHG mitigation measures can also have other environmental as well as economic and social impacts. Therefore, the impact assessment considers also non-GHG impacts.

Environmental impacts

Typical non-GHG environmental impacts can directly affect the transport activities regarding air quality and noise. Indirect impacts as from provision of energy carriers, production and recycling of vehicles and infrastructure can also be included.

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 existence of downstream exhaust treatment system, e.g. particle filters for PM. In comparison to such systems, low rolling resistance tyres have no considerable impact on air pollutant emissions. They may be reduced slightly but this 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 from tyre abrasion is generally uncertain with large bandwidths of emission factors[3] . As tyre abrasion contributes only a small fraction to PM air quality problem impacts on air quality due to low rolling resistance tyres are not considered.

As explained 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[4]. If China's Green Tyre Programme will also include requirements for wet grip and external noise, co-benefits in this area are likely to occur.

Environmental impacts from other life cycle stages of a tyre are generally very low compared to the impacts during its use [Continental, 1999]. However, relevant improvements of environmental impacts might also come from improving other life cycle stages as industry processes in China are still less environmentally friendly than in Europe. China's Green Tyre programme may have positive impacts as it potentially includes cleaner production and recycling of waste tyres (see section 2).

Road safety

China's green tyre standard also includes requirements for wet grip, which is an important indicator for road safety of tyres. As analysed in [Bozeat, 2008], "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". These parameters are important for road safety. Therefore, by only focusing on the improvement of rolling resistance of future tyres, road safety could be considerably affected. However, China's green tyre standard includes rolling resistance as well as wet grip. Customers are likely to rank safety as a more important attribute than fuel efficiency when purchasing a tyre. In consequence, parallel improvements of both fuel efficiency and road safety are to be expected.

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) in Europe 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 may also in China payback within few months and leads to a considerable reduction of vehicle operation costs.

[3] See [European Environment Agency, 2009] part B 1.A.3.b.vi-vii.
[4] [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 of the GHG impact assessment

This section presents the methodology of the impact assessment of China's Green Tyre programme on fuel consumption and GHG emissions from road freight transport. The boundaries for the GHG impact assessment were defined to cover all road freight transport activities that are affected by China's Green Tyre programme.

Three scenarios were defined within the assessment boundaries:

- **Baseline scenario**: In this scenario, the absence of a Green Tyre Programme was assumed. Future developments of RRCs result only from the requirements from vehicle fuel efficiency standards in China.
- **Voluntary industry standard scenario**: In this scenario, improvements of RRCs of truck tyres resulting from the voluntary industry standard were analysed. It is estimated that 50% of all commercial truck tyres will meet class E and 100% meet class G in 2020, all tyres on the market will meet class E in 2030.
- **Mandatory classification and labelling scenario**: This scenario assesses the impacts of the planned legislation for classification and labelling and mandatory certification of green tyres in China (see section 2). It is estimated that 30% of commercial truck tyres will meet at least RRC class D in 2020 (thereof 10% in RRC class C), all tyres meet RRC class D, thereof 40 % meet RRC class C and 10 % meet RRC class B in 2030.

Fuel consumption and GHG emissions were calculated for each of the scenarios. These results were compared to assess the fuel and GHG emission savings potential of China's Green Tyre programme.

4.1. Boundaries of the impact assessment

The impact assessment analyses fuel and GHG emission savings potential in the road freight transport sector in China caused by an increasing share of low rolling resistance tyres following the introduction of a Green Tyre programme. Emissions are calculated in 10-year intervals from 2010 to 2030 (temporal boundaries) for the People's Republic of China (territorial boundaries).

Regarding sectoral boundaries (emission sources), the impact assessment focuses only on GHG savings potential in the heavy-duty road freight sector. While the Chinese Green Tyre programme affects transport activities of the whole road transport sector in China, including passenger cars, buses and trucks, this impact assessment addresses only road freight transport activities covered in China's official statistics. Also data about freight transport of agriculture and industry are not available and not included in the statistic. According to official China's statistics, this sector showed a traffic volume of 1763 billion VKT in 2010 [Yang, 2015].

Different future developments of transport demand and overall energy efficiency are expected for different vehicle sizes in China [Yang, 2015]. 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**Error! Reference source not found.**). In order to consider this in the impact assessment, commercial trucks have been differentiated into three vehicle segments:

1. **Small:** Trucks with a verified loading capacity (VLC) of up to 2 t, which corresponds to a gross vehicle weight (GVW) of up to 5 t, additionally differentiated by fuel type (diesel, gasoline).
2. **Medium:** Trucks with 2 to 4 t VLC corresponding to a GVW of about 5.5 to 8-9 t.

3. **Large:** Trucks with a VLC of more than 4 t, which leads to a GVW of more than 8-9 t.

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 the baseline scenario without green tyre programme and for the two reduction scenarios with (1) voluntary standard and (2) mandatory classification and labelling. Fuel and GHG emission saving potential of China's Green Tyre programme for road freight transport in China were assessed by comparing the results of the reduction scenarios to the baseline scenario.

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

1. Calculation of total fuel consumption and GHG emissions of commercial trucks in China in the baseline scenario without China's Green Tyre programme is based on expectations of future developments of transport demand and total energy efficiency of commercial trucks in China. The methods of estimating the part of rolling resistance contributing to total fuel consumption (and future improvements) without tyre specific measures are explained in detail in section 4.2.1.
2. Calculation of fuel and GHG savings potential resulting from China's Green Tyre programme is based on specific improvements of rolling resistance and related fuel consumption in the reduction scenarios and explained in section 4.2.2.

4.2.1. Baseline scenario

Total fuel consumption and GHG emissions of commercial trucks in China

In the first calculation step, a baseline scenario of total fuel consumption and GHG emissions from commercial trucks in China for the years 2010 - 2030 was calculated. Fuel consumption and GHG emissions are calculated by multiplying transport demand (in VKT), specific fuel consumption and GHG conversion factors. Therefore, the following parameters were needed for the baseline scenario:

- Total VKT of commercial trucks per vehicle segment per year,
- Specific fuel efficiency of commercial trucks per vehicle segment per year,
- Fuel-specific GHG conversion factors.

Total VKT of commercial trucks in the year 2010 was about 1763 billion vehicle km according to official China's statistics. This total VKT was divided by vehicle size and type of motor into four vehicle segments: small diesel and gasoline trucks, medium and large trucks. Annual VKT of each vehicle segment was determined based on vehicle stocks and daily VKT estimates per vehicle segment in [Yang, 2015]. As the sum of estimated VKT from the four groups - based on daily VKT - only reached 70 % of total VKT from statistics, differentiated results were levelled out to meet with total VKT from statistics. Future developments of total transport activities from 2010 to 2030 were calculated from developments of vehicle stock and daily VKT per vehicle in each vehicle segment. These developments were estimated in Yang [2015] with an economic elasticity method that relates VKT to per-capita GDP as it is expected that VKT of trucks increases as the economy grows.

Average specific fuel efficiency per vehicle segment in the year 2010 was adopted from the fuel consumption announcement database for road transport commercial vehicle of MOT ([Yang, 2015], p. 15). For small gasoline trucks a 15 % higher specific fuel consumption compared to small diesel trucks was assumed in the calculations according to research results in [Yang, 2015]. From 2010 to 2030, specific fuel consumption of commercial trucks is assumed to decrease by about 30-35 %, taking requirements from China's fuel efficiency standards into account (see section 3.2, [MIIT, 2014; MOT, 2008; Yang, 2015]).

Well-to-wheel GHG conversion factors for fossil gasoline and 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)" [CEN, 2012] because well-to-wheel emissions of fossil diesel fuel are widely identical worldwide.

Basic data for transport activities and fuel efficiency are summarised in Table 5. GHG conversion factors are provided in Source: Yang, 2015

Table 6.

Table 5: Basic data for transport activities and fuel efficiency of commercial trucks in China

<table>
<tr><th></th><th colspan="3">Vehicle stock (thousand)</th><th colspan="3">VKT per day</th><th colspan="3">Fuel efficiency (L/100km)</th></tr>
<tr><th>Vehicle segment</th><th>2010</th><th>2020</th><th>2030</th><th>2010</th><th>2020</th><th>2030</th><th>2010</th><th>2010-2020</th><th>2010-2030</th></tr>
<tr><td>Large</td><td>3570</td><td>8636</td><td>13093</td><td>460</td><td>483</td><td>500</td><td>30.0</td><td colspan="2" rowspan="4">-25 %
(-20-30 %)
-32.5 %
(-30-35 %)</td></tr>
<tr><td>Medium</td><td>986</td><td>3459</td><td>6038</td><td>460</td><td>483</td><td>500</td><td>17.5</td></tr>
<tr><td>Small Diesel</td><td>4688</td><td>8528</td><td>11796</td><td rowspan="2">210</td><td rowspan="2">235</td><td rowspan="2">250</td><td>11.7</td></tr>
<tr><td>Small Gasoline</td><td>1258</td><td>2288</td><td>3165</td><td>13.5</td></tr>
</table>

Source: Yang, 2015

Table 6: Well-to-wheel GHG conversion factors for fossil gasoline and diesel fuel

	Gasoline	Diesel
GHG conversion factor (kg CO2e/litre fuel well-to-wheel)	2.88	3.24

Source: European Standard EN 16258 [CEN, 2012]

Part of rolling resistance contributing to total fuel consumption in the baseline scenario

Rolling resistance accounts for about 20-30 % of total fuel costs of freight enterprises in China [Smart Freight Centre, 2014] and is, accordingly, in a similar range as in Europe (see info box "Rolling resistance" in section 1). As shown for Europe, the part of rolling resistance contributing to fuel consumption and costs (given in percentages) is higher for large commercial trucks in long-haul operation than for smaller trucks in regional and urban delivery. Therefore, in this impact assessment it was assumed, that in 2010 rolling resistance contributed by 20 % to fuel consumption of small commercial trucks and 30 % for large commercial trucks (see Table 7).

From 2010 to 2030, total specific fuel consumption of commercial trucks is assumed to decrease by about 30-35 % due to China's vehicle efficiency standards (see Table 5), which will require improvements of powertrain efficiency and all driving resistances. Improvements of rolling resistance contribute by 3-5 % to these total fuel efficiency improvements according to estimates in [Yang, 2015], meaning an improvement of rolling resistance coefficients of about 15 % in the baseline scenario. As these rolling resistance improvements are below the average of total efficiency improvements the part of rolling resistance contributing t total fuel consumption (given in percentages) increase in the baseline scenario, mainly in the years up to 2020 when the main part of overall efficiency improvements is achieved (Table 7).

Table 7: Part of rolling resistance contributing to total fuel consumption in the base year 2010

	2010	2020	2030
Small trucks (gasoline, diesel)	20 %	23 %	25 %
Medium trucks	25 %	31 %	32 %
Large trucks	30 %	40 %	40 %

4.2.2. GHG reduction scenarios

Two scenarios for the introduction of a Green Tyre programme in China were analysed: one with modest improvements of rolling resistance resulting from the voluntary industry standard, one with more ambitious improvements resulting from the additional planned legislation for classification of low rolling resistance tyres in China. Calculation steps were:

1. Estimating average RRCs for the base year 2010 and improvements in the scenarios. Percentage values on RRC improvements in the reduction scenarios compared to the baseline scenario are identical to resulting percentage values on savings of rolling resistance related fuel consumption and GHG emissions
2. Calculating absolute fuel and GHG savings potential in the reduction scenarios and comparison to total fuel consumption and GHG emissions in the baseline scenario.

Recent average distribution of RRCs in China into different RRC classes was available from China Rubber Industry Association CRIA (see Table 8). An average RRC for recent truck tyres of 8.5 N/kN was estimated based on this RRC distribution.

Table 8: Rolling resistance coefficient distribution of China's truck and bus tyres in 2010 (base year)

	A	B	C	D	E	F	G	Below G
RRC range (N/kN)	≤ 4	> 4 ≤ 5	> 5 ≤ 6	> 6 ≤ 7	> 7 ≤ 8	> 8 ≤ 9	> 9 ≤ 10*	>10
Shares	-	-	-	15%	30%	25%	15%	15%

* Additional assumptions for RRC range as this RRC class is empty for truck tyres in Europe.

Sources: China Rubber Industry Association CRIA

For future RRC developments the following assumptions were made in the scenarios:

- **Baseline scenario**: Average RRC improves from 2010 to 2030 by 15 % according to its assumed contribution to total fuel efficiency improvements of commercial trucks (see section 4.2.1).

- **Voluntary industry standard scenario**: It is estimated that as from 2020 all tyres meet at least RRC class G. In 2020, 50% of commercial vehicles will use green tyres according to the voluntary industry standard of 7.5 N/kN. In 2030, the share of green tyres will reach 100% [Yang, 2015]. The share of tyres exceeding in the base year the voluntary industry standard are allocated proportionally among the better RRC classes. This scenario draws the most conservative picture of additional RRC improvements resulting from China's Green Tyre programme.
- **Mandatory classification and labelling scenario**: RRC improvements in this ambitious scenario are based on tightened requirements on tyres from planned and discussed legislative classification and labelling for being classified as green tyres (see section 2).
  - For the year 2020, it is estimated that 30 % of all commercial truck tyres meet an RRC of 6.5 N/kN (according to second implementation stage), including first tyres (10 %) of RRC class C $\leqslant$ 6.0 N/kN (e.g. from large domestic tyre companies and international manufacturers).
  - In the year 2030, China's classification of green tyres is envisaged to meet according European standards. As there is still no European standard defined for 2030, we assume that a European standard in 2030 will at least require RRC class C $\leqslant$ 6.0 N/kN for small and medium truck tyres and RRC class B $\leqslant$ 5.0 N/kN for large truck tyres. Tyre models meeting these RRC values are already available on the European market today (see [IFEU, 2015]). For the situation in China it is assumed that in 2030 all tyres meet at least an RRC of 6.5 N/kN (RRC class D), thereof 40 % meet RRC class C $\leqslant$ 6.0 N/kN and 10 % meet RRC class B $\leqslant$ 5.0 N/kN.

Resulting RRCs average in the scenarios are presented in Figure 3.

	2010	2020	2030
Baseline scenario	8.5	7.9	7.3
Voluntary industry standard scenario	8.5	7.8	6.9
Mandatory classification and labelling scenario	8.5	7.4	5.9

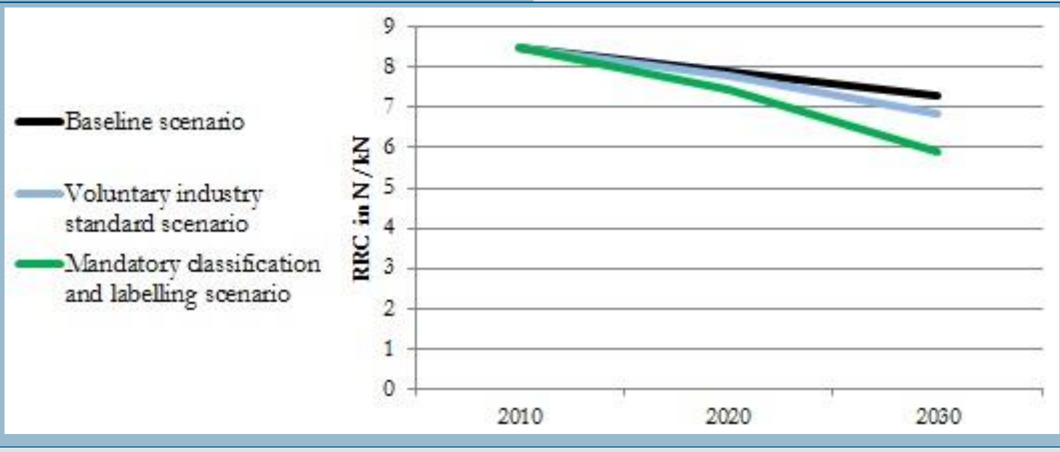

Figure 3: Average RRCs for truck tyres in China in the scenarios

Fuel and GHG emission reduction potential were calculated by using the percentage value regarding RCC reduction in the mitigation scenarios compared to the baseline scenario as proxy for rolling resistance related fuel consumption and GHG emissions reduction. Accordingly, an 18% reduction of average RRCs in the mandatory classification and labelling scenario 2010- 2030 (see Figure 3) is assumed to equal an 18% reduction of rolling resistance related fuel consumption. With a 40% contribution of rolling resistance to total fuel consumption and GHG emissions of large commercial trucks in the baseline scenario in 2030 (see Table 7), this would result in an overall GHG emission reduction of 18% x 40% = 7.2%.

5. Scenario results

Key developments in future commercial truck transport in China are a strong increase of transport activities combined with an improving energy efficiency of the vehicle fleet (see section 4.2.1). From 2010 to 2030, total annual VKT of commercial trucks in China is likely to increase fourfold. Future improvements of fuel efficiency resulting from China's fuel efficiency standards for road vehicles cannot compensate this strong VKT increase. Therefore, total annual fuel consumption and GHG emissions will increase from 2010 to 2030 in the baseline scenario by 175 % and are almost three times higher in the year 2030 than in 2010 (see Figure 4).

Developments are clearly different for the individual vehicle segments. Large commercial trucks contribute by 50 % to total VKT and by 70 % to fuel consumption and GHG emissions due to their higher specific fuel consumption. Accordingly, VKT and fuel efficiency developments in this segment are main drivers for overall developments in the commercial truck sector. Small and medium commercial trucks show a heterogeneous picture with a threefold increase of small trucks' VKT, but a six fold increase in the medium truck segment. In consequence, fuel consumption and GHG emissions of small commercial trucks only double from 2010 to 2030, whereas those of medium commercial trucks more than quadruple.

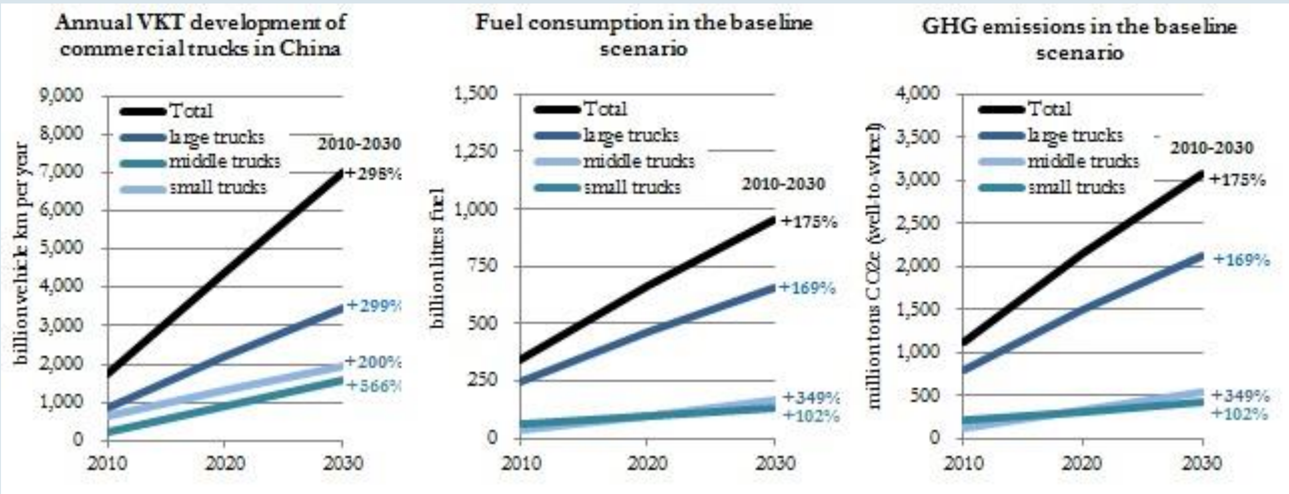

Figure 4: Total fuel consumption and GHG emissions from China's commercial trucks in the baseline scenario

Total fuel consumption and GHG savings potential for the commercial truck sector from China's Green Tyre programme in the defined reduction scenarios were calculated by subtracting absolute fuel and GHG saving potential of the individual vehicle segments from the baseline scenario. The results are presented in Figure 5.

- In the conservative voluntary industry standard scenario, where minimum impacts of China's Green Tyre programme on RRCs were estimated, fuel consumption and GHG emissions of commercial trucks in China can be reduced by 1-2 % (against baseline). This results in savings of 4 billion litres fuel in 2020 and 21 billion litres fuel in 2030. GHG emissions can be reduced by 12-68 million tons CO_2e per year. Accordingly, total GHG emissions of commercial trucks in China 2010-2030 increase in this reduction scenario by 169 % (compared to +175 % in the baseline scenario).

- In the ambitious mandatory classification and labelling scenario, annual fuel consumption and GHG emissions of commercial trucks in China can be reduced by about 2 % in 2020 and by 7 % in 2030 (against baseline). This equals fuel savings of 15 billion litres fuel in 2020 and 68 billion litres diesel in 2030. GHG emissions can be reduced by 47-219 million tons CO_2e per year. Total GHG emissions of commercial trucks in China 2010-2030 increase in this ambitious reduction scenario only by 156 %.

The scenario results clearly illustrate that the increase of GHG emissions from commercial trucks in the future could be considerably limited as a result of China's Green Tyre programme. At the same time the programme would lead to substantial fuel savings of minimum 4 billion litres diesel and maximum 68 billion litres diesel per year. Almost 3/4 of the fuel and GHG emissions saving potential account for large commercial trucks, due to both their high annual mileage and above-average relevance of rolling resistance on fuel consumption in this vehicle segment.

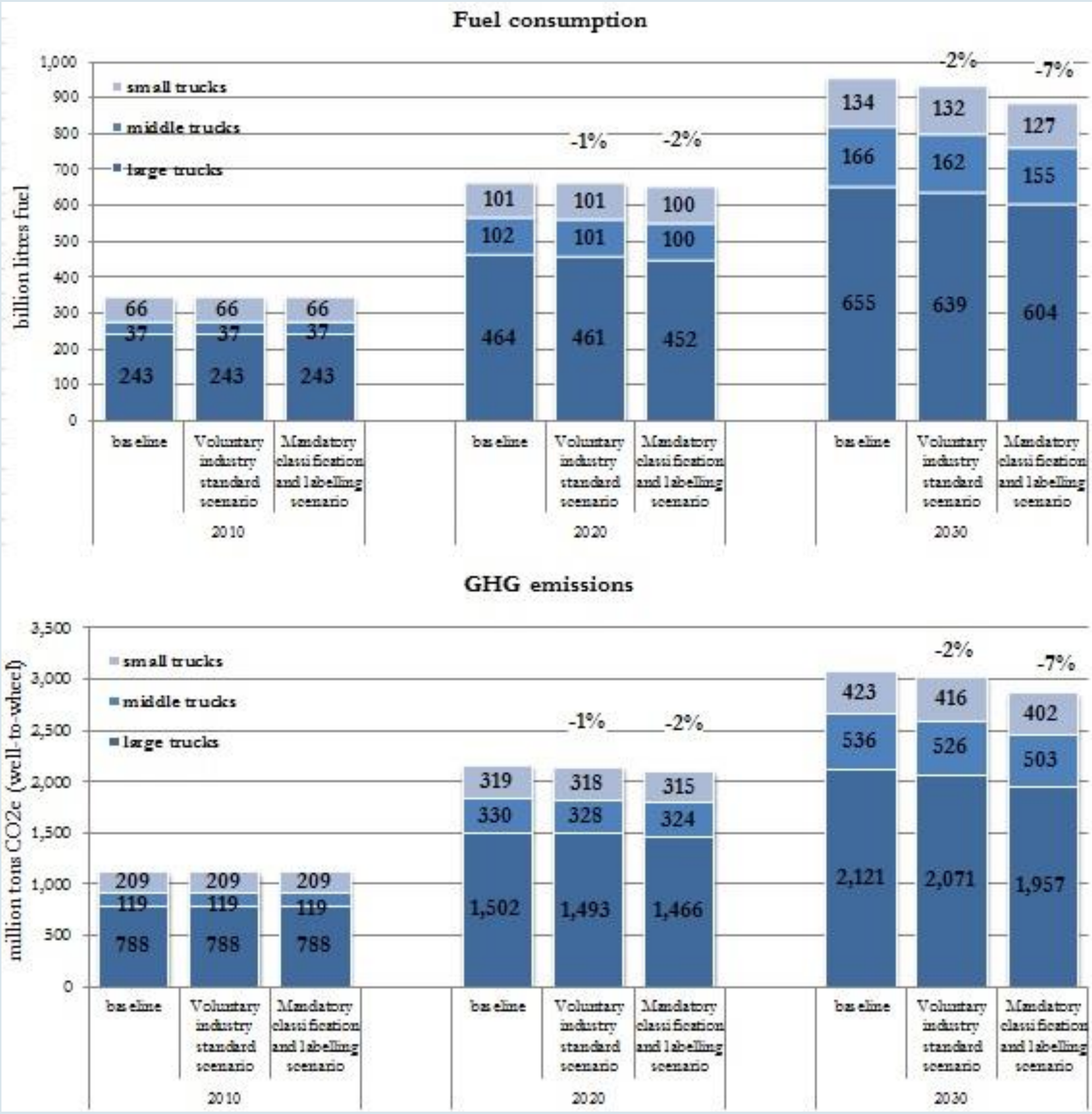

Figure 5: Total annual fuel consumption and GHG emissions from commercial trucks in China in baseline and mitigation scenarios (percentages indicate annual savings against the baseline)

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