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2014

Low Carbon Frameworks: Transport

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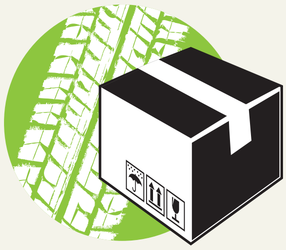

UNPACKING FREIGHT EMISSIONS AND MITIGATION OPPORTUNITIES IN THE SOUTH AFRICAN CONTEXT

WWF's low carbon frameworks transport project explores the implications of carbon emission reduction strategies in the freight transport sector, as well as where the mitigation options lie.

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Introduction

One of the objectives of the WWF low carbon frameworks transport project is to explore the implications of strategies for carbon emission reductions in the freight transport sector. This requires an understanding of where the majority of emissions in the freight sector in South Africa arise as well as where the mitigation opportunities lie. While the contribution of freight emissions as a whole and even by mode to total emissions may be understood, as are the mitigation options applicable to the freight sector, this analysis attempts to delve a bit deeper to unpack contributions and mitigation opportunities applicable to different modes, transport typologies and commodity groups. This added resolution aims to identify the emission "hot spots" in the freight sector and is the first step to understanding what level of mitigation is possible. Bringing about this level of mitigation and the knock-on implications of low carbon freight transport in South Africa is the wider objective of the WWF low carbon frameworks transport project.

Freight activity data

Publicly available data and statistics relating to overland freight movement (road and rail) within South Africa are limited. The best source for estimates of national freight movement is based on the outputs of:

- The National Freight Flow Model (NFFM); and
- The Freight Demand Model (FDM).

These models were developed by the Centre for Supply Chain Management in the Department of Logistics at Stellenbosch University in response to the lack of freight activity data in South Africa (Havenga, 2007). The models draw on economic input-output tables, traffic count data from SANRAL and rail freight data from Transnet. They estimate freight flows across all modes (rail, road, domestic maritime and air transport) through gravity modelling for 74 commodity groupings in 356 magisterial districts (van Eeden and Havenga, 2010).

The FDM separates road and rail freight into the following categories or transport typologies:

- **Primary**: the bulk transport of primary commodities by rail for export;
- **Corridor**: rail and road traffic along the main transport links between cities (e.g. Cape Town-Johannesburg link on the N1);
- **Rural**: traffic within the rural areas of provinces (excluding Gauteng) that feeds into the corridor and metropolitan networks; and
- **Metropolitan**: traffic within cities.

The characteristics of these typologies are described below.

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Characteristics of transport typologies

Characteristic	Primary	Corridor	Rural	Metropolitan
Type of freight	Bulk low-value commodities (e.g. export coal and iron ore)	Mostly manufacturing and some agriculture	Mostly agriculture	Mostly final delivery
Distance	Long	Long and short	Medium and short	Short
Origin-Destination (OD) pairs*	Few and one-directional	Few long-distance ODs, many ODs at end points	Many	Many

Data source: Havenga and Pienaar (2012)
Note: * An Origin-Destination pair is a specified point of pick up and point of delivery for freight.

The outputs of the NFFM and FDM underpin the figures published in the annual State of Logistics Surveys (CSIR, 2013). These surveys present the aggregated modelled road and rail freight flows for the country. Transnet and the Department of Transport have access to the model results, as well as to 30-year forecasts.

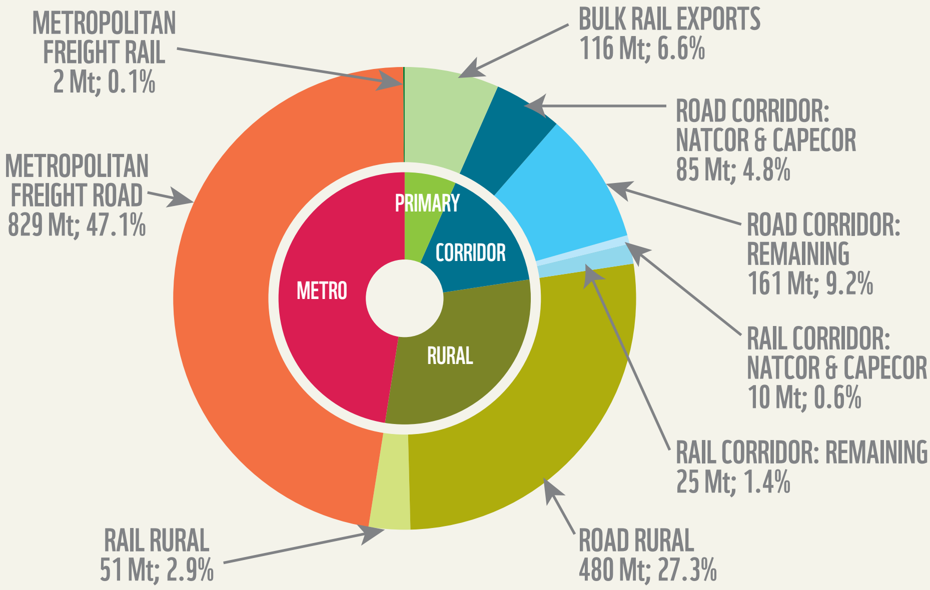
40%

CORRIDOR FREIGHT TRANSPORT ACCOUNTED FOR ALMOST 40% OF THE TOTAL FREIGHT FLOW IN 2012

We summarise the total freight flow reported for 2012 in the ninth State of Logistics Report in megatonne (Mt) and tonne-kilometres (t-km) respectively within each of the typologies in Figures 1 and 3. Note the following:

- While a large tonnage of freight is transported on metropolitan networks (47%), the contribution to freight activity in terms of t-km is low, at just 15%, because of the short distances involved.
- Corridor freight accounts for only 16% of total tonnages transported, but because of the long distances associated with corridor transport, it accounts for almost 40% of all freight t-km.
- The long distances associated with the transport of bulk rail exports to markets mean that similar trends are observed for this category.
- Rural freight is transported over short to medium distances and makes up approximately 30% of freight tonnages and 27% of freight t-km.

Figure 1 **Breakdown of freight volumes by typology and mode in 2012**



Data source: CSIR (2013)

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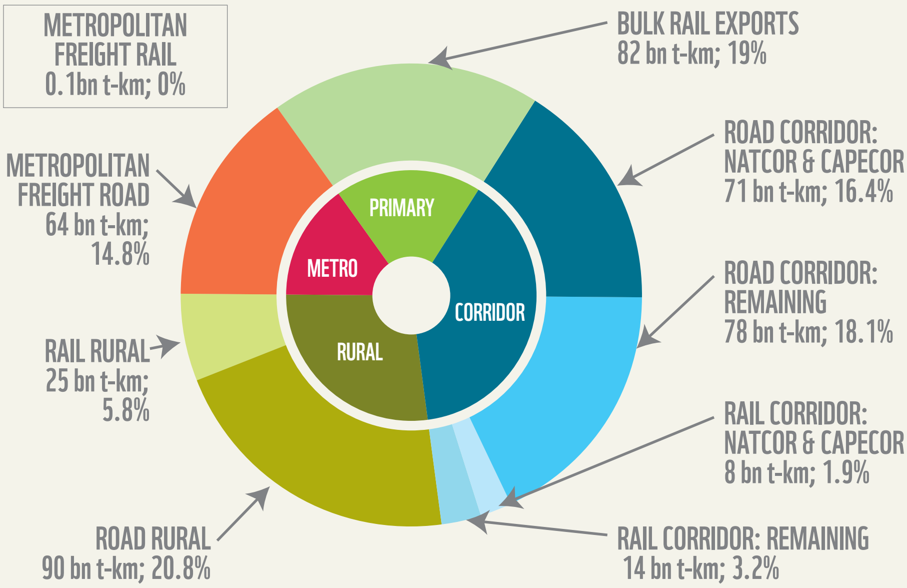
Figure 2 **Breakdown of freight t-km by typology and mode in 2012**



Data source: CSIR (2013)

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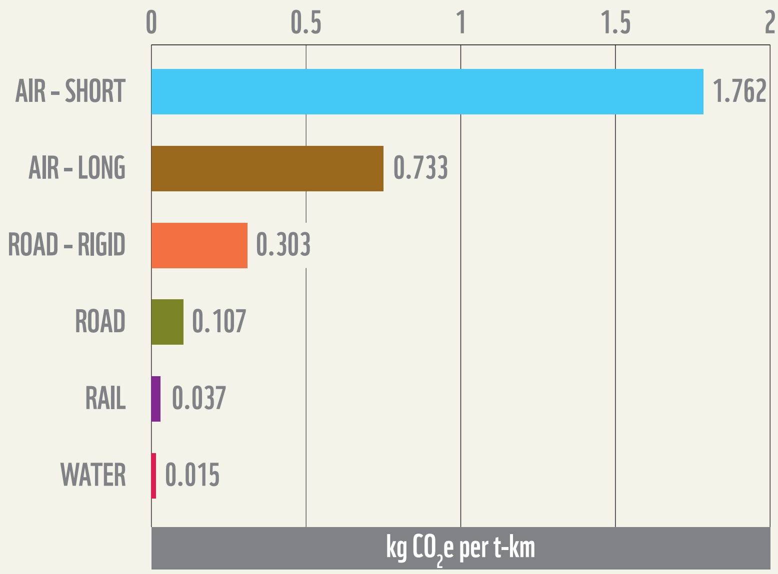
Freight emissions intensity

The emissions intensity of freight transport differs significantly between transport modes, with air freight being the most emissions intensive, followed by road and then rail. The lowest freight emissions are associated with shipping.

Figure 3 **Typical freight emission intensities per mode**



Data source: Shrink That Footprint (2013)

39.4 MT CO_2E

SOUTH AFRICA'S GHG INVENTORY FROM ENERGY USED IN TRANSPORT IN 2000

Freight energy and emissions data

As with freight activity data, disaggregated freight energy and emissions data are not readily available. The available aggregated freight emissions data are presented below, along with the estimated disaggregated emissions from the FDM.

National GHG inventory – 2000 data

South Africa's latest official Greenhouse Gas (GHG) inventory,[1] published in 2009 but reflecting data from 2000, indicates total emissions of 39.4 Mt CO_2e from energy used in transport in that year. The inventory provides some disaggregation of these emissions into different modes of transport (as shown in the table that follows). However, it does not distinguish between freight and passenger transport. Furthermore, these figures only include emissions from diesel and petrol consumption for road transport, diesel for rail transport, and an estimate of emissions from domestic aviation. Use of electricity (primarily for rail) is not included. The updated national GHG inventory is anticipated to disaggregate passenger and freight emissions.

Contribution of different modes of transport to emissions in 2000

Mode and energy carrier	GHG emissions (kt CO_2e)	Percentage contribution to overall transport emissions
Domestic aviation (kerosene and aviation gas)	2,033	5.2
Road (petrol)	25,026	63.5
Road (diesel)	11,666	29.6
Road (liquefied petroleum gas – LPG)	3	0
Rail (diesel only)	688	1.7
TOTAL	39,416	100

Data source: DEAT (2009)

Emissions per typology from FDM results

The FDM's freight movements per typology (Figure 2) can be converted to GHG emissions using the following average emission factors for rail and road respectively: 0.022 kg/t-km and 0.11 kg/t-km (Transnet, 2012). The resulting breakdown of freight GHG emissions is shown in Figure 4.

It should be noted that by using average emission factors, these results are indicative only. Nevertheless, the following is noted:

- Contrasting the pie chart that follows with Figure 1, it is clear that road freight is far more emissions intensive than rail – with rail only accounting for 8% of freight emissions despite accounting for 30% of freight activity.
- Emissions from road freight dominate as expected, with road freight along corridors contributing 46% of freight emissions.

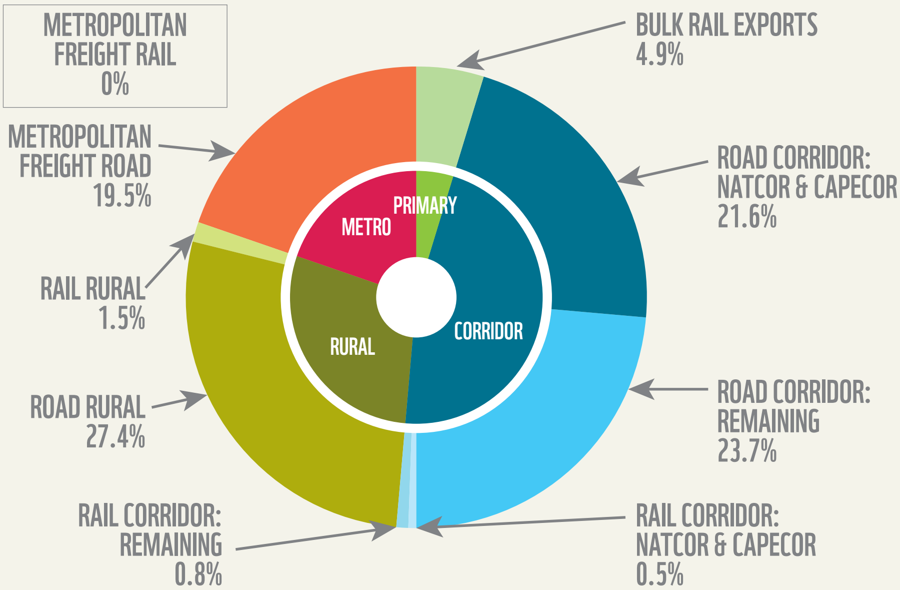
1 The Department of Environment is currently busy with an update of the inventory using 2007 data, but this has not yet been officially released.

RAIL FREIGHT

IS A MUCH SMALLER SOURCE OF GHG EMISSIONS THAN ROAD FREIGHT

- This is followed by rural road freight, which accounts for close to 30% of freight emissions, and metropolitan road freight, which accounts for almost 20% of freight emissions.

Figure 4 **Breakdown of freight GHG emissions by typology and mode in 2012**



Data source: Own calculation based on CSIR (2013)

PHOTO: ELSABE GELDERBLOM

Emissions per commodity from FDM results

Based on the disaggregated data from the FDM and aggregated emission factors for road freight transport, it is possible to estimate road freight emissions associated with each of the commodity groupings. The complete output of the FDM was not available at the time of writing. Therefore, a limited data set of earlier model data for 2008 provided in van Eeden and Havenga (2010) was used for demonstration. It is not anticipated that the results will be significantly different to more recent years. The data and analysis provided in van Eeden and Havenga (2010) identified the top 12 commodity groups on the Durban-Gauteng corridor, the Cape Town-Gauteng corridor and the remaining corridors in terms of t-km together with the current rail market share. To obtain the road emissions, the t-km were adjusted for rail market share and converted to indicative GHG emissions using the emission factors described above. This provides the following estimate of the breakdown of emissions per commodity type on the Durban-Gauteng, Cape Town-Gauteng and remaining South African road corridors in 2008.

Road corridor freight GHG emissions contribution by commodity type

Durban-Gauteng corridor Top 12 commodity groups in terms of t-km	% contribution of commodity to Durban-Gauteng road corridor GHG emissions	Cape Town-Gauteng corridor Top 12 commodity groups in terms of t-km	% contribution of commodity to Cape Town-Gauteng road corridor GHG emissions	Remaining corridors Top 12 commodity groups in terms of t-km	% contribution of commodity to remaining road corridor GHG emissions
Processed foods	20	Processed foods	23	Processed foods	20
Fuel and petroleum products	20	Beverages	9	Other mining	11
Beverages	7	Other mining	9	Beverages	7
Other chemicals	6	Coal	9	Limestone	6
Paper and paper products	4	Other chemicals	6	Fuel and petroleum products	6
Iron and steel	4	Non-metallic mineral products	4	Other chemicals	6
Wood and wood products	4	Fertiliser	4	Wood and wood products	4
Industrial chemicals	3	Wood and wood products	4	Non-metallic mineral products	3
Non-metallic mineral products	3	Fuel and petroleum products	4	Cement	3
Machinery and equipment	2	Iron and steel	2	Other non-ferrous metal mining	3
Wheat	1	Other agriculture	2	Industrial chemicals	2
Coal	0	Paper and paper products	2	Coal	1
Other commodities	27	Other commodities	21	Other commodities	28
	100		**100**		**100**

Data source: van Eeden and Havenga (2010)
Note: Entries may not sum to total due to rounding.

PROCESSED FOODS
IS THE COMMODITY GROUP WITH THE HIGHEST FREIGHT CARBON FOOTPRINT ON ALL THE ROAD CORRIDORS

This analysis suggests that the commodity group with the highest freight carbon footprint on all of the road corridors considered is processed foods, followed by other mining, beverages, other chemicals, and wood and wood products. This is consistent with the findings of van Eeden and Havenga (2010), who prioritised processed foods, beverages, chemicals (other), paper and paper products, and wood and wood products as being the most attractive markets for intermodal solutions, based on an assessment of quantities transported by road corridor (in t-km) and also a consideration of the ease with which these commodities can be palletised and/or containerised.


PHOTO: SHUTTERSTOCK

Mitigation in the freight transport sector

Transport mitigation opportunities are often grouped according to the widely adopted avoid-shift-improve framework. Within this framework, illustrated in Figure 5, a distinction is made between the following:

- Mitigation **measures** that are implemented to reduce GHG emissions;
- Mitigation **opportunities**, which are achieved by implementing the measures; and
- The **instruments** that are used to support the implementation of measures.

Figure 5 provides examples of opportunities and measures, with Figure 6 giving examples of the instruments that can be used. It is important to highlight that the same instruments may be used to support Avoiding, Shifting and Improvement, and that a single instrument may facilitate multiple opportunities.

Figure 5 **The avoid-shift-improve framework describing the opportunities, measures and instruments applicable to freight transport**

	AVOID	SHIFT	IMPROVE
OPPORTUNITY	Reduction in freight activity	Shift to lower carbon modes of freight transport	Improve the energy efficiency of transport modes or vehicle technologies
MEASURES	Smart logistics Sustainable consumption	Intermodal solutions Increased capacity	Improved vehicle technologies Improved operational efficiency Alternative fuels
INSTRUMENTS*	PREI	PREIT	REIT

Data source: based on Dalkmann and Brannigan (2007)
Note: * P = planning; R = regulatory; E = economic; I = information; T = technological

Figure 6 **Examples of instruments for mitigation of emissions from freight transport**

Planning instruments	Regulatory instruments	Economic instruments	Information instruments	Technological instruments
Infrastructure planning, planning of low carbon electricity sources	Physical standards (emission limits, vehicle and fuel standards), export restrictions, special limits	Carbon tax, fuel subsidies/taxes, congestion charging, toll roads, incentives for cleaner fuels	Increase awareness of real costs and alternatives, eco-driving schemes, awareness campaigns, labelling	R&D for fuel improvements, cleaner technologies, improved vehicles

Data source: based on Dalkmann and Brannigan (2007) and Dalkmann and Sakamoto (2011)

PHOTO: ELSABE GELDERBLOM

Overview of mitigation measures applicable to freight transport

The adjoining table describes the mitigation measures available in the freight sector.

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Summary of mitigation measures applicable to freight transport

Opportunity	Measure	Description
Avoid or reduce freight activity	Sustainable consumption of goods	Sustainable consumption essentially addresses the demand for goods and thus (in this context) the associated transport. Reduced demand for transport can also be achieved through changes in the structure of the economy. Policies that serve to restrict exports in favour of local beneficiation are examples of such a structural change. By reducing exports, the associated transport of exports to ports is reduced.
	Increasing the proportion of goods sourced locally and seasonally	Current consumer demand requires fresh fruit and vegetables to be supplied throughout the year, regardless of whether their local growing cycles are seasonal or not. Provision of such goods requires imports from distant growing areas. By promoting the purchase of local, seasonal produce rather than produce that is transported long distances, the demand for transport of fresh produce can be reduced. Similarly, promoting the purchase of non-perishable goods that are manufactured locally avoids the need for long-distance transport of goods manufactured elsewhere. In this context, a life-cycle perspective is necessary as local consumption of goods may decrease imports in favour of increased local production. In terms of emissions, this may result in increased land-based freight transport of goods (and associated increase in national emissions), but reduced long-distance transport associated with imported products.
	Reducing and improving packaging	By reducing the volume of packaging and improving the efficiency of packing of goods in trucks and containers, vehicles are able to transport a larger volume of goods and therefore require fewer trips to deliver the same volume. Furthermore, as fuel consumption and hence GHG emissions are linked to mass of goods transported, reducing the weight of packaging of the goods can contribute to reducing emissions.
	Optimising logistics	Examples of this measure include optimising the location of distribution centres to reduce the number of trips carried out by delivery vehicles, and optimising vehicle usage using reverse logistics (back hauling) and freight consolidation.
Shift to lower carbon modes of freight transport	Improving rail infrastructure, availability of rolling stock, reliability of service and cost competitiveness	The majority of South Africa's freight is currently transported on roads. Although the cost of physically transporting goods may be cheaper on rail than on road, rail is less cost competitive on a full cost accounting basis. Furthermore, rail is perceived to be inefficient and unreliable due to poor infrastructure and management. Additionally, it is reported that more investment into ensuring the necessary rolling stock for transport of products is required (Marsay, 2012). Addressing these issues will facilitate the shift of some goods to rail. In recent years, Transnet has been investing in infrastructure and rolling stock in an effort to increase the rail share of freight in the country, which has resulted in some increases in the freight modal share. This trend is expected to continue.
	Improving infrastructure and operation for intermodal links	Intermodal freight transport refers to using at least two different modes of transport to deliver goods to the consumer. Typically, trucks are used for the first and last legs, with the majority of the transport distance on rail and/or waterways. Intermodal transport is considered more cost-effective and sustainable than single-truck load transportation (Ranaiefar and Regan, 2011). One of the key requirements to support usage of intermodal links is ensuring the availability and efficient operation of the infrastructure to transfer goods between the different modes as quickly and seamlessly as possible. Intermodal transport is also facilitated by containerisation, which enables easy handling between the different transport modes.
Improved efficiency of freight transport: operational measures	Intelligent routing and scheduling	Computerised routing, scheduling and vehicle tracking have been used to significantly improve the operational efficiency of logistics systems (Zanni and Bristow, 2010). Savings here are achieved through real-time selection of routes with the least traffic, best road conditions, etc., as well as through allowing maximum utilisation of trucks by servicing multiple drop-off and collection points. This measure also facilitates back hauling of freight.

Opportunity	Measure	Description
	Delivery point measures	Various delivery point measures have been used to improve efficiency and reduce fuel consumption and emissions, particularly in metropolitan areas. Off-peak or night-time deliveries help to reduce congestion on roads during peak periods. Shorter turnaround times at delivery points help to reduce fuel use and emissions (FTA, 2011), as do measures such as those which require drivers to switch off engines rather than idle during deliveries. Scheduling deliveries to certain zones in a city on certain days avoids trucks having to cover large distances within the city every day.
	Ongoing vehicle maintenance	Regular vehicle inspection and maintenance helps to increase operational efficiency that directly results in improved fuel efficiency (FTA, 2011). In addition to maintaining and optimising engine performance, maintaining tyre pressures is an important part of maintaining efficiency, with automated tyre pressure adjustment systems being available.
	Driver training	Driver training is aimed at effecting a behaviour change by improving drivers' understanding of fuel-efficient driving practices. For truck drivers, fuel-efficient driving involves driving within the truck's most efficient RPM range, reducing idling time, reducing speeds, changing routes, cutting rapid acceleration and reducing stops and starts by predicting traffic flows. Train driver education around energy-efficient driving can also result in savings for this mode of transport.
Improved efficiency of freight transport: technology measures	Reducing driving resistance: aerodynamic drag and rolling resistance	The higher the driving resistance of a vehicle, the greater the power required to accelerate or stop it. Driving resistance is a combination of aerodynamic drag, rolling resistance and mechanical losses through friction (Ranaiefar and Regan, 2011). Aerodynamic drag may be reduced by changing trailer shape design (tapering) and installing aerodynamic fairings, mud flaps or spoilers, which are add-on devices that help reduce drag and thus improve fuel consumption (Baker et al., 2009). The benefit of reducing aerodynamic drag is greatest for freight vehicles travelling on constant high-speed routes. The simplest method of reducing rolling resistance is to optimise the air pressure in tyres by means of automatic tyre pressure adjustment (Baker et al., 2009). This has the added benefit of reduced wear and tear on tyres, which results in a reduction in maintenance and replacement costs. Low rolling resistance tyres or replacing the standard two thinner wheels with a single wide-base tyre are also technology options here (Baker et al., 2009).
	Changes to vehicle design	Reducing the weight of vehicles can contribute to lower fuel consumption and hence reduced emissions for the same volume of freight transported. Vehicle weight can be reduced by lightweight construction methods that result in increased payload and more efficient transport. Increased use of aluminium and composite materials in vehicle and trailer construction may offer weight-saving opportunities (Litschke and Knitschky, 2012). Double-decker trailers, high-cube trailers and longer vehicles all result in a higher volume of material that can be transported per load.
	Increasing engine efficiency	Truck engine efficiency improvements can be achieved by technology measures that improve combustion system efficiency, reduce engine friction and improve gas exchange handling (Baker et al., 2009).
	Waste heat recovery	Various technologies are available to recover exhaust gas energy, including mechanical or electrical turbo-compounding, heat exchangers and thermoelectric generators. These methods, however, are costly to implement for fairly limited fuel and GHG emissions savings (Baker et al., 2009).
	Changing transmission systems	Replacing manual transmissions with automated transmission systems that have a similar mechanical efficiency can optimise engine speed and result in lower fuel consumption (Baker et al., 2009).
	Hybrid and electric vehicles	Hybrid and electric vehicles can deliver greater efficiency in terms of energy consumption and CO_2 emissions than petrol/diesel vehicles. Hybrid vehicles operate on a combination of petrol/diesel and electricity (delivered through batteries), or petrol/diesel and gas. Various configurations of hybrid vehicles are available. A mild hybrid consists of a small motor that supplements engine power and is usually used together with a downsized engine. Although there is increased performance and generating power, it is expensive and space is required for electronic and battery cooling. A full hybrid has one or two high-power electric motors, and can be driven by either the internal combustion engine or the electric motor. This technology has the best balance in terms of fuel consumption but is very expensive. A plug-in hybrid is an electric vehicle with a small internal combustion engine that acts as a range extender. Finally, full electric vehicles do not have internal combustion engines, and run purely on batteries (Baker et al., 2009).

Opportunity	Measure	Description
Improved efficiency of freight transport: technology measures (continued)	Hybrid and electric vehicles (continued)	Electric vehicles have zero emissions at the tailpipe end but have expensive battery requirements and require vehicle-charging infrastructure. Although there are no tailpipe emissions, overall CO_2 emissions are dependent on the electricity source. Since plug-in hybrids and full electric vehicles need charging, suitable networks of charging stations are required (Baker et al., 2009). Hybrid and electric vehicles are typically considered to be best suited for urban delivery vehicles in high-traffic areas, due to shorter ranges and stop-start technology that shuts off the engine when the vehicle is stationary and restarts the vehicle on pull-away (Baker et al., 2009).
	Improving driving efficiency	In addition to driver training, there are technology measures available that assist in improving driving efficiency. These include predictive cruise control, which involves using knowledge of the road ahead to control vehicle speed for lowest fuel consumption, and vehicle platooning, which allows vehicles to follow safely at a close distance "train" in order to reduce fuel consumption and improve traffic flows (Baker et al., 2009). Technologies for remote monitoring of driver behaviour (speeds, braking behaviour and other factors) are already employed by many logistics companies to monitor driving efficiency.
	Conversion of diesel rail to electric rail	Electric rail has a lower emissions profile than diesel rail, although the difference between the two depends on the electricity supply mix, and the route may determine the potential for implementation of electric rail. Conversion from diesel to electric rail also requires significant investment in both rail infrastructure and locomotives.
	Regenerative braking on trains	In regenerative braking systems, during braking kinetic energy is converted into another form of energy which is either stored or used immediately, often using an electric motor. This is as opposed to the energy being lost as heat, as occurs in kinetic braking systems.
Improve GHG emissions efficiency of freight transport: alternative fuels	Biofuels	Liquid biofuels are distinguished by type and feedstock used in manufacture, with the CO_2 benefit of using biofuel depending on the feedstock and production process. The two key types of liquid biofuels are biodiesel and bioethanol. Biodiesel can be used in diesel engines, while ethanol can either be used as a fuel in its own right, or blended with petrol. For ethanol, a certain limit of blending is possible, above which engine modifications are required. In terms of distinction by feedstock, so-called "first generation" bioethanol is made from readily fermentable crops with high sugar contents, such as sugar cane, maize, wheat and sugar beet. First generation biodiesel is typically produced from Fatty Acid Methyl Ester, which in turn is made from vegetable oils or animal fats and alcohols. Concerns regarding first generation biofuels relate to competition for resources, land and energy between food production and crops for biofuel production (Litschke and Knitschky, 2012). "Second generation" biofuels seek to overcome some of these limitations by producing fuels from lignocellulosic biomass or woody crops and agricultural residues. Second generation biofuels are harder to produce, and many production processes are still under development. Biogas, which is also readily produced from biological residues, can be used in any vehicle designed to run on CNG (see the following section).
	Compressed natural gas (CNG) and liquefied petroleum gas (LPG)	CNG is a fossil fuel that is recovered from deposits and compressed prior to use, while LPG is a product of crude oil refining processes. Both can be used in modified internal combustion engines. Gas has the benefit of being cleaner burning than petrol and diesel, with lower CO_2 emissions. Gas engines also emit less noise than diesel engines (Litschke and Knitschky, 2012).
	Hydrogen	Hydrogen is a secondary source of energy and is produced from other primary sources of energy so its overall CO_2 emissions are dependent on the method of production of the hydrogen. Hydrogen can be used for vehicle propulsion in either internal combustion engines or in fuel cells in electrically powered vehicles (Litschke and Knitschky, 2012). Fuel cells have a number of potential efficiency benefits. The only reaction product formed is water, so there are no local emissions. Most modern fuel cells have an efficiency of up to 58%, although fuel cell technology requires further development to be economically competitive in comparison to combustion engines (Litschke and Knitschky, 2012). A further application of fuel cell technology would be as auxiliary power units to supply energy to long-haul, heavy-duty trucks while stationary, instead of the trucks idling to provide auxiliary power. This technology is still under development.
	Reducing the carbon intensity of the electricity grid mix	The emissions associated with electric vehicles charged via the grid, as well as electric trains, depend on the emissions intensity of the electricity grid. While not strictly a transport sector measure, therefore, the reduction of the grid emissions intensity, through introduction of more renewables for example, can contribute to reducing the emissions intensity of these transport modes.

PHOTO: SHUTTERSTOCK

In the South African context, the implementation and uptake of these mitigation measures will depend largely on the planning, economic and regulatory instruments introduced by the government. Information instruments may also have a role to play, with the availability and development of the required vehicle technologies and alternative fuels also critical to achieving significant mitigation in the sector. The key planning, regulatory and economic instruments are discussed below.

Planning instruments

Urban planning, transport infrastructure planning, and electricity supply planning are all planning instruments that are available to national, provincial and local policy and decision-makers to reduce the need to travel or to reduce the emissions associated with travel. Planning instruments are usually long-term strategies aimed at promoting sustainable transport practices. They include:

- **Urban/land use planning**: Placing shops, public services, residential areas and places of employment within close proximity to each other; with effective travel links, congestion on the roads can be substantially reduced. Shorter travel distances and reduced congestion have a direct impact on emissions associated with metropolitan freight transport (Dalkmann and Brannigan, 2007).
- **Transport infrastructure planning**: This is needed to support measures required to realise the shift from road to rail. Here the requirements of improving rail infrastructure and intermodal links were identified as being necessary to effect those shifts. Integrated infrastructure planning is the instrument needed to ensure this is effectively achieved.
- **Planning for low carbon electricity sources**: In order for measures such as converting the rail lines from diesel to electric, shifting freight goods from road to rail, and market penetration of electric vehicles to be viable strategies, cleaner/low carbon electricity sources are required.

Regulatory instruments

Regulatory measures may be used to restrict the use of certain vehicle types, as well as to ensure that vehicles conform to certain standards. Examples include:

- **Limits on emissions**: Introducing a limit on the amount of CO_2 emitted from vehicles gives vehicle manufacturers the opportunity to develop eco-innovative features to meet CO_2 emission targets and can encourage businesses to purchase low-emission vehicles. Indicating the fuel efficiency/CO_2 labelling of vehicles and component parts will enhance market transparency and enable businesses to make informed vehicle purchases.
- **Efficiency standards on new vehicles**: Similar to the limits on vehicle emissions, legislation can be implemented to set performance and efficiency standards for vehicles and vehicle components. Minimum efficiency standards for air-conditioning, tyre pressure monitoring systems and tyre rolling resistance limits are among the vehicle components that can be targeted (Smokers et al., 2010).
- **Speed limits**: Vehicles travelling at higher speeds have greater fuel consumption and higher vehicle emissions. Enforcing lower speed limits will therefore contribute to reducing vehicle emissions through enforcement of driver behaviour (Dalkmann and Brannigan, 2007).

PHOTO: ELSABE GELDERBLOM

- **Restriction of vehicles entering particular areas or at particular times of day**: To reduce vehicle emissions, access of certain vehicles to particular areas can be physically restricted. By reducing the volume of traffic and consequently congestion, GHG emissions can be reduced. Vehicle restrictions are typically implemented only during peak periods of the day. Knock-on benefits of vehicle-free zones include enabling the public to reclaim the streets, so promoting a better quality of life in cities (Dalkmann and Brannigan, 2007).
- **Low emission zones**: These are areas where access is permitted only to vehicles complying with a prescribed standard of vehicle emissions, thus improving local air quality and, as a knock-on effect, congestion, fuel consumption and GHG emissions. However, this instrument requires a high

SOUTH AFRICA'S NATIONAL BIOFUELS INDUSTRIAL STRATEGY

In South Africa, the National Biofuels Industrial Strategy was developed in 2007 with the short-term focus of achieving 2% penetration of bioethanol and biodiesel into the national fuel supply. Since total national fuel consumption is around 20 billion litres per annum, this would mean a blending target of 400 million litres per annum. The total production capacity of the biofuels plants that had been granted licences to operate in South Africa by October 2013 is over 1,200 million litres per annum of bioethanol and biodiesel. If all of these projects had to be established, the proposed penetration level of biofuels would be exceeded by 4%. Around 70% of this is biodiesel, while the remainder is bioethanol.

The proposed feedstocks for bioethanol production in South Africa include sugar cane and grain sorghum, with sunflower seeds and soya beans being targeted for biodiesel production. In addition to the carbon emission reduction benefits, biofuel production and use have several macroeconomic advantages and social benefits. These include job creation, emerging farmer support, rural development, energy security and a reduction in GHG emissions. Historically disadvantaged areas have been selected for biofuel feedstock production, creating employment and economic activity.

There are proposed incentives and subsidies for biofuel producers, with all renewable energy projects, including biofuels, currently qualifying for an accelerated depreciation allowance of 50:30:20 over three years. The funding for the proposed subsidies would come from the adjusted fuel pricing structure, meaning that motorists will pay for the subsidies at a cost of around 3.5 to 4 cents per litre of fuel. The only pricing incentive for biodiesel is a 50% rebate on the general fuel levy. Since bioethanol falls outside the fuel tax net, it would not incur a general fuel levy.

In September 2013, it was gazetted that the mandatory blending of biofuels will commence on 1 October 2015. However, important decisions such as blending levels and the incentives and subsidies provided for biofuel producers have not yet been stipulated. The Department of Energy established a Biofuels Implementation Committee to ensure that this mandate is successfully implemented. This committee has been tasked with developing the biofuels pricing framework, subsidy criteria, logistics, sustainability of feedstock supply, tax and customs excise issues and coordination of the activities between the various government departments involved (GreenCape, 2013).

level of administration and technology to set up and enforce restrictions (Dalkmann and Brannigan, 2007).

- **Fuel blending regulations**: Regulations can be put into place that require the blending of a certain volume of alternative fuels such as biofuels with fossil fuels, which will result in a reduction of emissions associated with driving. This instrument has been put into place in South Africa, as discussed in the box.

Economic instruments

Economic instruments are used to provide financial incentives to encourage the use of alternative modes of transport, improve efficiency or reduce the volumes of goods that are transported (Dalkmann and Brannigan, 2007). In the past, economic instruments were often used to finance infrastructure development costs. Currently, economic instruments are used to encourage more efficient transport use. Economic instruments quantify external costs such as the effect of GHG emissions. Although fiscal measures are often met with strong opposition, they can be an efficient and effective way to improve the efficiency of existing freight transport and drive a shift to alternative modes. Examples of economic instruments include:

- **Fuel taxes**, where every litre of diesel or petrol carries additional levies, can result in implementation of many of the measures discussed above, such as a shift to alternatives with lower fuel consumption, logistics optimisation, behavioural interventions and technological measures (Dalkmann and Brannigan, 2007).
- **Emissions taxes (including the carbon tax)**: This instrument imposes a tax on vehicle emissions, with the intention of promoting the purchase of fuel-efficient vehicles or shifting to lower carbon alternatives. In South Africa, a once-off emissions tax on new vehicles was implemented in 2010 with a more broad-based carbon tax commencing in 2015 (DNT, 2013).
- **Road pricing (toll roads)**: The motivations behind road pricing include raising revenue to pay for infrastructure, and reducing congestion and vehicle emissions. Implementing road pricing may significantly increase the cost of freight transport (Dalkmann and Brannigan, 2007), and could result in a shift to more cost-effective vehicles – such as heavier vehicles which are more cost-effective on toll roads due to a greater loading capacity (Christidis and Leduc, 2009) or smaller vehicles that pay lower toll fees – or improved productivity through intelligent routing, reducing empty travel or increasing load factors (Ranaiefar and Regan, 2011). The implementation of toll roads may, however, result in a shift of freight vehicles to secondary roads which cannot support their frequency/load, causing damage to these roads.
- **Vehicle taxes**: Implementing a tax for vehicle ownership may significantly increase their purchase price, therefore discouraging new vehicle purchases or encouraging shifts to alternative transport options. Two types of vehicle taxes could be imposed: either a sales tax when the vehicle is purchased or an annual vehicle tax/registration applicable to all vehicles, which would be a continuous financial burden. Vehicle taxes could be calculated according to different fuel consumption levels (Dalkmann and Brannigan, 2007).
- **Congestion charges** are used as a demand management strategy to discourage driving in certain high-traffic areas. Congestion charges are usually time variable with higher pricing during peak periods and lower or no pricing during off-peak periods. Lower congestion results in reduced fuel consumption.

Information instruments

Information instruments are used to educate transport users for the purposes of effecting behavioural changes. Information instruments complement or act as an alternative to more resource-intensive instruments. Options here include:

- Driver training towards more fuel-efficient/eco driving;
- Awareness campaigns;
- Product labelling to encourage buying local products.

Technological improvements and instruments

Technological improvements and instruments relate to the development and availability of more efficient options for transport. They link very closely with the technological measures detailed previously. The difference between the measure and the instrument is subtle, but the former can be thought of as the actual technologies, whereas the instrument can be thought of as the development trajectory of the technology and its availability in South Africa. These trajectories include:

- Vehicles with increased fuel efficiencies;
- Vehicles that operate on alternative fuels;
- Alternative fuels sector; and
- ICT in the transport sector.

Mapping mitigation opportunities and measures onto the freight industry

A key observation that has come out of this preliminary work into understanding the freight sector and its emissions is that not all freight is the same in terms of its inherent characteristics, as well as the most appropriate way for it to be transported. By extension it follows that not all mitigation opportunities are applicable to all types of freight.

The sections that follow explore which mitigation opportunities and measures are most applicable to different sectors of the freight industry.

Mapping of mitigation opportunities onto the freight industry by commodity

Transnet's freight demand planning forecasts and associated data (Transnet, 2012), which are based on the outputs of the FDM, are used to map mitigation opportunities onto different commodity types. The Transnet data contain projections from 2012 to 2042 of national freight demand per commodity in megatonnes per annum in terms of that "suitable for rail", "competing", "suitable for road" and "planned rail". For analysis purposes, this data set was summarised to average per cent suitable for rail, average per cent competing, average per cent suitable for road, current rail market

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share and projected rail market share in 2042. Commodities were then grouped into a number of categories:

- Commodities that are most suited to road transport. Currently transported by road and remaining on road;
- Commodities that could have a portion transported on rail (25–50%). Currently transported by road and likely to remain on road;
- Commodities that are suitable for rail (25–100%). A portion currently on rail, but targeted for a road to rail shift (i.e. rail market share increasing);
- Commodities that are most suited to rail transport. Currently transported by rail and remaining on rail; and
- Other (e.g. rail market share decreasing, commodities transported by conveyer, rail to road shift).

The table on the next page summarises the groupings and maps the applicable mitigation opportunities onto each group.

Mapping of mitigation measures onto commodity groupings

Type	Examples	Mitigation opportunities
Most suitable for road; on road; staying on road	Perishables: dairy, livestock, deciduous fruit Fast-moving consumer goods (FMCG): pharmaceuticals, textiles, furniture Bricks, stone, machinery	Reduction in freight activity Improved efficiency – operational and technology measures (ROAD) Alternative fuels
Some could go on rail; on road; staying on road	Agriculture: sugar cane Perishables: vegetables, poultry, subtropical fruit Liquid fuels Some mining products	Reduction in freight activity Improved efficiency – operational and technology measures (ROAD) Alternative fuels
Suitable for rail; on road and rail; increasing rail	Agriculture: maize, wheat, wood FMCG: processed food, beverages, paper Bulk liquid: fuel, fertiliser Mining: limestone, granite Cement, chemicals Intermodal: containers, automotive	Reduction in freight activity Shift to lower emission transport modes Improved efficiency – operational and technology measures (ROAD and RAIL) Alternative fuels (mainly ROAD)
Mostly suitable for rail; on rail; staying on rail	Export coal Export iron ore Export manganese Domestic coal	Reduction in freight activity Improved efficiency – operational and technology measures (RAIL)

The above analysis is not unexpected, but highlights the fact that not all freight can be considered in the same way. It further serves to identify target sectors for mitigation instruments and measures.

Mapping of mitigation measures onto transport typologies

Not all the measures presented earlier apply to all transport typologies. The table below begins to separate these out with the purpose of ultimately informing the model development.

Mapping of mitigation measures onto transport typologies

Typology	Examples of relevant mitigation measures
Primary Rail Freight Corridor Rail Freight Rural Rail Freight	Reduction in activity Improving efficiency – rail technology Reducing emissions intensity of the grid
Corridor Road Freight	Improving rail infrastructure, availability of rolling stock and reliability of service Improving intermodal links Improving freight loading Improving efficiency: heavy goods vehicles (HGV) Alternative fuels – biofuels blending
Metropolitan Road Freight	Optimising logistics Intelligent routing and scheduling Delivery point measures Driver training Hybrid and electric vehicles Alternative fuels – biofuels blending, LPG/CNG vehicles Technologies for improving driving efficiency Improving efficiency: light commercial vehicles (LCV)
Rural Road Freight	Road improvements Both corridor and metro mitigation measures apply to varying degrees Optimising logistics Intelligent routing and scheduling

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The way forward: system dynamics modelling of mitigation in the freight transport sector

This work builds on previous work for WWF on low carbon planning (WWF, 2011) in which a quantitative modelling framework to support national low carbon planning was proposed. This framework had at its core a system dynamics (SD) model developed through a stakeholder engagement process known as "mediated modelling". Mediated modelling aims to achieve a high degree of consensus and understanding among stakeholders by involving them collaboratively in the model building. Mediated modelling is used together with a computer-based modelling paradigm. Here, a simulation modelling paradigm known as SD is often used. SD allows for the exploration of the evolution of a complex system over time, through consideration of the feedback loops and dynamic behaviour of the system. The first step in constructing an SD model is the development of causal loop diagrams, which demonstrate relationships between the different variables in the system. Models

MEDIATED MODELLING INCREASES STAKEHOLDERS' UNDERSTANDING OF THE SYSTEM BY INVOLVING THEM COLLABORATIVELY IN THE MODEL BUILDING

are then constructed on the basis of the causal loop diagrams and populated with equations that describe the interrelationships between variables, and how these evolve with time. This approach is useful in that it overcomes some of the problems inherent in linear thinking and compartmentalised, non-participatory decision-making. Unlike in expert modelling, the aim of mediated modelling is not necessarily to predict a precise outcome, but rather to increase the understanding of the system by the people involved in building the model.

In this work, the SD modelling platform is also used. WWF has an established network of role players and stakeholders within the transport sector who are engaged and willing and able to effect change. While a fully mediated modelling approach has not been possible due to the time investment required of the stakeholders, stakeholder input has nonetheless been used as input to the models and to ensure buy-in in their construction. A series of workshops has been scheduled with each of business, labour and government stakeholder sets and these are already under way. The reason for keeping sets of stakeholders separate is that it was felt that different stakeholder groups may hold and develop significantly different understandings of the system, which will allow for more creative discussions on low carbon opportunities for the sector.

Informing model development

The purpose of the work presented in this document – both the understanding of freight activity and emissions as well as the review of mitigation opportunities, measures and instruments – is to inform the SD modelling.

The first half of this document presented an analysis that, although dependent on best estimates of freight flows and average emissions factors, confirms that road freight gives rise to far greater GHG emissions in South Africa than rail freight. In particular, corridor-road freight makes the largest contribution to freight GHG emissions, followed by rural-road freight and metropolitan-road freight.

PHOTO: ELSABE GELDERBLOM

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Examining the corridor-road freight on a commodity basis, it becomes apparent that the transport of processed foods makes up a particularly large proportion of this freight segment. The nature of this commodity grouping makes it suitable for intermodal transport, and given that much of it is currently transported by road, this suggests that it is a key target commodity for a road to rail shift. From an emissions perspective, we have therefore selected the processed foods commodity group as the focus of detailed freight transport modelling. The model will thus necessarily focus on the corridor-transport typology, but will also have to consider the interface with other transport typologies (most notably metropolitan).

Based on the analysis presented in the second half of the document, a selection of measures was identified that are considered to be most relevant to processed food freight. These measures, which are proposed to be included in the modelling, include:

- **SHIFT**: Processed food is transported predominantly by road along corridors but also across metropolitan and rural transport typologies as the commodity makes its way from manufacturer to retailer. As processed food can easily be palletised and containerised, and is transported in volume, it lends itself to rail transport. A road to rail shift is thus a significant opportunity for mitigation associated with the transport of this commodity and all relevant measures to support this shift will be investigated in the modelling.
- **IMPROVE**: Both operational and technological efficiency improvements applicable to road and rail freight transport are relevant to the transport of processed foods. It is likely that these efficiency improvements will be grouped together into "low cost", "medium cost" and "high cost" measures and stakeholder input used to determine what drives decision-making to implement efficiency measures. A distinction will be made between operational and technological efficiencies applicable to HGV used on corridors and the LCV used in the distribution of processed foods to retailers.

In terms of the instruments that will be used to drive the implementation of these measures, the following will be included in the modelling:

- Infrastructure planning, to improve rail infrastructure and intermodal links. This is considered the main driver for effecting a road to rail shift, which is seen as the most significant mitigation opportunity in the freight transport sector;
- A generic economic instrument, which could be a carbon or a fuel tax (the way that these will be modelled will be similar, so both can be investigated). From our preliminary engagement with stakeholders it is clear that cost signals play an important role in decision-making;
- Regulatory instruments which set standards in terms of fuels and/or vehicle specifications will be investigated in the model;
- Technological instruments in terms of vehicle and alternative fuel technology trajectories;
- Planning for low carbon electricity sources, which will be modelled as a scenario;
- Information instruments expressed through driver training and increased awareness of climate change issues.

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This is one in a series of publications produced by WWF South Africa's Low Carbon Frameworks programme, which explores the shift to a low carbon economy. We seek solutions for emitting fewer greenhouse gas emissions and enabling a flourishing South Africa, which delivers developmental outcomes and social equity.

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Commissioned by WWF South Africa from The Green House.

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WWF NEDBANK GREEN TRUST

This publication is funded by The Green Trust, a partnership between WWF and Nedbank.

100% RECYCLED

MEASURES

are implemented to reduce greenhouse gas emissions

OPPORTUNITIES

are realised by implementing mitigation measures

PROCESSED FOODS

have the highest freight carbon footprint on the road corridors

INSTRUMENTS

are used to drive the implementation of measures

PHOTO: SHUTTERSTOCK

WWF LOW CARBON FRAMEWORKS: TRANSPORT

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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