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Driver and response model for Norwegian road freight transport in the period 1993-2013.

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Samandrag

An in-depth study to understand both indirect and direct drivers behind energy use in freight transport has not been done in a Norwegian setting. The objectives of this study are to develop a theoretical model of growth in road-freight transport in Norway by identifying the likely drivers of such growth and to explain how these drivers have contributed to the growth in energy use from road-freight transport. Some of the drivers may have strongly accelerated energy use, while others have mitigated it**.** We will also consider whether there has been a shift of freight from sea and rail to road.

Andre publikasjonar frå prosjektet

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Foreword

This report is part of a main project on rebound effects involved in energy and climate policymaking financed by the Centre for Sustainable Energy Studies (CenSES); one out of 11 Centres for Environment-friendly Energy Research (FME) financed by the Research Council of Norway. The CenSES partners are NTNU, IFE, SNF, University of Oslo, SINTEF, the Regional University College of Sogn og Fjordane and Western Norway Research Institute (WNRI).

The aim of the sub-project is to develop a driver/response model for road-freight transportation in order to better understand possible rebound effects from policies and technological developments with the purpose to reduce energy use and greenhouse (GHG) emissions from road-freight transportation.

This report is dedicated to the memory of John Hille (1954–2015). This is the last report that John worked on for Vestlandforskning. John passed away in September 2015 at the age of 61. He was especially competent in processing large amounts of statistical material and combining different statistical sources in novel ways—which he did to a great extent in this report. His passing is a great loss for the environmental group at Western Norway Research Institute, and he is deeply missed.

An earlier version of this report was submitted as part of the PhD thesis “Fixing or transferring of environmental problems in the transport sector” by Hans Jakob Walnum. Carlo Aall, as supervisor of the project, has conducted a language quality check of this final version He has also included supplementary writings and has been added to the report as an author.

Sogndal, 04.11.2015

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1.0 Introduction

1.1 Objectives and research questions

The objective of this study is to develop a model of changes in road freight transport in Norway by identifying likely drivers of such growth and so far as possible to explain how various drivers have contributed to growth in road freight transport and related energy use and GHG emissions from road freight transport in the recent past. We want to use the model to analyse possible rebound effects (take-back effects) of policies and technological developments with the purpose to reduce energy-use and GHG emissions from road-freight transportation.

The long-term goal in the EU and Norway is an absolute reduction in GHG emissions from the transport sector. The goal of the EU is to reduce transport GHG emissions by 60% by 2050 (with 1990 as reference year). The goal for the transport sector is lower than what is stipulated for other sectors (80-95% reduction) due to political, economic and technologic barriers involved in the transport sector, particularly relating to freight transportation (European Commission, 2011). During the past thirty years there has been a steep increase in the demand for freight transportation, thus leading to an associated increase in energy use and GHG emissions from the freight transportation sector, especially from road-freight transportation. In Norway, GHG emissions from heavy duty vehicles in 2010 amounted to about 2.8 million tons (5% of national GHG emissions).

Road transport has for the case of Norway (as for most other European countries) the largest share of domestic freight transportation measured in ton-kilometres, and this transport work has for the case of Norway more than doubled since 1990, due both to a greater volume of freight and a strong increase in the average length of haul. Freight is transported over longer distances due to increased specialization and changes in logistic solutions with centralized production- and storage facilities. Thus, there is a large need for research to support an ambition of making freight transportation radically less carbon-intensive. Taking into consideration what is outlined above; we believe it is important to develop a better understanding of the Norwegian road freight transportation system.

During recent years several projects, both at the national level and the EU level have been started to gain a better understanding of the freight transportation system and how to achieve major reduction in energy-use and GHG emissions from freight transportation (Akyelken et al., 2012; Helmreich and Keller, 2011).

Research is emerging with the aim of gaining a better understanding of the freight transportation systems and how to achieve major reduction in energy use and GHG emissions (Liimatainen, 2013; Piecyk, 2010). This research has identified key variables for deciding energy-use and GHG emissions, and the interaction among these variables, and has presented scenarios for freight transportation development according to different policy options. Although most of this research has focused on road freight transportation, some of it has also addressed barriers and suggestions on how to achieve a switch from road to sea and rail transportation. Regarding the literature to understand determinates/causes/drivers for energy-use and related GHG emissions for road freight transport, there seem to be some differences in overarching methodology between strict quantitative models and theoretical models which involve a qualitative consideration of quantitative data. In recent years several models have been developed to understand determinates for road freight transport where quantitative data was clarified, interpreted and explained by means of qualitative analyses applying the relevant theories and research literature (Liimatainen, 2013; McKinnon, 2007a; Piecyk, 2010; Richardson, 2005).

In this project we place determinates for road freight transport into a so-called driver-response approach inspired by the logic of the OECD pressure-state-response environmental indicator model This model has recently been applied for household energy-use (Hille et al., 2011).

In our model we have distinguished between indirect, direct and response drivers (cf. figure 1). *Direct* drivers are *physical* aspects of freight transportation that directly govern the amount of GHG emissions and transport costs (e.g., transport distance, type, volume and weight of goods transported; transport mode; technical characteristics of vehicles; and type of fuel). Examples of *indirect* drivers are economic growth, import-export restrictions, transport infrastructure, energy prices, and labour costs. *Response* drivers are policy measures or technological means or other responses that may influence the direct drivers (e.g., tax on fuel and regulation of transport technologies) or on the indirect drivers (e.g., customs regulations and road pricing). In the following we will show that it is possible to quantify some of the direct drivers, but that it is somewhat more difficult to quantify the effects of indirect drivers. It is not only challenging to isolate the effect of a specific indirect driver, but also difficult to link the effect to one specific factor. What is for example "road capacity"? It could be the width of the roads (what kind of road classification?), or average transport time between point A and B in the national road network. It could also be difficult to find out how competing transport modes should be measured. "Railway supply" depends on price, time, punctuality and number of terminals i.e., how many places it is possible to ship goods to by rail.

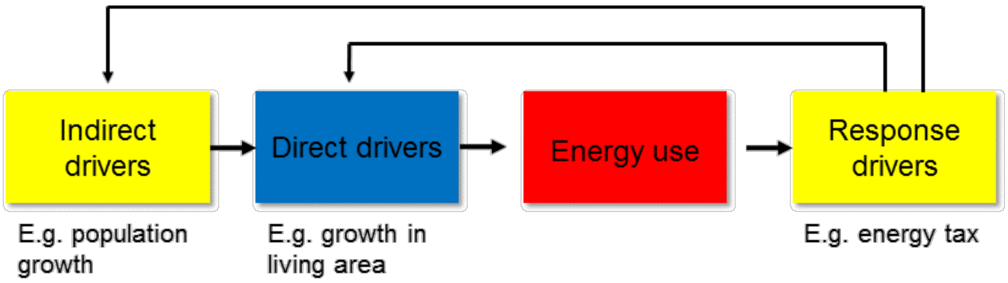

Figure 1 *The driver-response model applied in the project*

An additional aim of the project is to identify possible rebound effects connected to technology changes and climate change mitigation policies directly or indirectly addressing road freight transportation. Traditionally the research about rebound effects has been performed on energy-use within an energy economic tradition, in which the size of the rebound effect is seen as the difference between the original engineering estimate and the net energy savings after implementing more efficient technologies. An overall rebound effect of 100% means that the expected energy savings are entirely offset, leading to zero net savings. It is worth noting that rebound effects in the energy economic traditions do not treat rebound effects solely from deliberate policy, but that it could be "autonomous" rebound from technology changes (e.g. better fuel efficiency due to motor technology), logistical changes (e.g. better utilization of vehicles) or structural changes (e.g. larger supply chains because of globalisation in production processes where increased efficiency is both a driver and a response). We interpret rebound effects more broadly than merely effects after an improvement in fuel intensity, and define the rebound effect as behavioral or other systemic responses after the implementation of new technologies or to other measures that aim to reduce energy consumption or GHG emissions in freight transport (Høyer, 2011). We look at both rebound effects associated with policies as well as well as that of autonomous changes. We addressed the challenges and possibilities to address rebound effects in Norway by a critical literature review of previous research on rebound effects as well as an assessment of different policy measures taken to curb GHG emissions and the possibility to identify them based on available statistics in Norway.

The report will address the following research questions:

(1) What are the main drivers of the Norwegian road freight transportation system that decide the volume and modes of transportation and the accompanying levels of energy use and GHG emission?
(2) What are possible strategies, technological developments and policy measures for making the Norwegian freight road transportation system use less energy and GHG emissions?
(3) What are the possible environmental rebound effects and trade-offs connected to policy measures and technological improvements aimed at reducing energy and related GHG emissions in Norwegian freight transportation?
(4) What are the methodical challenges and data limitations in setting up a driver-response model for the case of Norwegian freight transportation system?

Embedded in the research questions presented above is the task to analyse how different system boundaries will affect results from the driver-respons model; for instance to see how inclusion of international transport within countries (so-called cabotage transport) and freight transportation from other countries to Norway influence transport work, energy-use and related GHG emissions. We will consider the possibilities and limitations of current statistics - for example, the kinds of aggregation possibilities associated with respect to commodities that could be done in a Norwegian setting.

1.2 Sustainable mobility and rebound effects

In this section we develop a theoretical framework for discussing the policies that are likely to decrease GHG emissions from freight transport. How can we classify strategies for curbing energy use and GHG emissions and how can we classify rebound effects? The theoretical framework aims to provide a critical understanding of the freight transport system and the effectiveness of responses by also considering potential environmental trade-off and rebound effects.

How to achieve major reductions in energy use and GHG emissions associated with transportation has been widely debated in political and scientific sustainable mobility discourses. In a 1992 green paper, the Commission of the European Union launched the concept *sustainable mobility*. The concept evoked considerable interest, both in politics and science. In his thesis, “Sustainable Mobility - the Concept and its Implications”, Høyer (1999) identified three strategies for achieving sustainable mobility: The *efficiency* strategy is about developing new and more efficient technologies to replace the old, inefficient, and polluting materials or technologies. The *substitution* strategy proposes replacing today’s dominant transportation systems with more environmentally benign and energy-efficient systems (for freight, this implies switching from road to rail or sea transport). The *reduction* strategy proposes decreasing freight volumes. According to Høyer (1999), a policy aiming at achieving sustainable mobility as well as any research aiming at analysing sustainable mobility has to include all of the three strategies.

Givoni (2013) explained three different pathways to low carbon mobility in which he also clarified the relationship between economic growth and transport. He reported that the most applied strategy is the “technological fix “pathway. In many respects, this strategy does not substantially change “business as usual” because the current way of living does not need to change. Transport speed continues to be central and therefore travel time, and not distance, is important. This pathway, which can be associated with the tradition of “ecological modernization”, assumes that environmental and economic objectives do not necessarily contradict each other. It primarily looks at the reduction per unit of transport (in the case of freight transport, emissions per tonne-kilometre) and not the underlying societal causes for transport growth.

Givoni's second pathway achieves low carbon mobility by maintaining or increasing rates of economic growth without increasing (or even decreasing) mobility. According to Givoni (2013), decoupling between freight transport and economic growth could be achieved by a change from globalisation towards `glocalisation` which implies production in self-contained local or regional markets. The production, distribution, and consumption of goods and services are then performed across much shorter distances. `Glocalisation` entails reducing the demand, and need, for the long-distance physical movement of people and goods. Globalisation can still occur under `glocalisation`; however, `glocalisation` implies a moving away from the principle of `just in time` (which is the principle of delivery a component before the assembly line needs it), as well as a change from long supply chains (transcontinental) and towards the replacing of long-distance transport by transferring of knowledge and know-how to the local level so that local production can take place (ibid.). Furthermore, another main component of this pathway is to make the full environmental cost of transport visible. The pricing of carbon and other pollutants should be at a much higher level than today because transport cost is included in the prices of all products. This strategy emphasises reducing distance rather than increasing speed.

Givoni's third pathway goes under the slogan "less can be better" and "rethinking growth". This strategy challenges gross domestic product (GDP) as an indicator of prosperity and instead focuses on well-being as a main policy objective. This implies a shift in societal values towards alternative forms of production and consumption (avoiding travel is one result of this strategy) and perhaps even towards different forms of ownership. Thus, a change towards a different economic and societal system is central to this pathway.

Table 1 *A comparison of two sets of strategies for achieving sustainable mobility and radical less carbon emission in freight transport*

	Strategies		
Term used by Høyer (1999) and Givoni (2013) respectively	Efficiency/technological fix	Substitution/glocalisation	Reduction/rethinking growth
Approach to policy	Effect oriented	Intermediate	Cause oriented strategy
Commonalities among the two sets of strategies	Main emphasis on reduction through more efficiency such as less energy use or GHG emission per tkm, either by logistical improvements or engine improvements.	Changing the transport system, a shift to more environmental benign transport forms, as well as a shift in production to shorten transport distances.	Highlighted the volume problem with transport and the need to reduce goods transport by a reorientation of societal values.
Differences between the two sets of strategies	Givoni states that this strategy does not influence our way of living and the goal of continues economic growth.	Høyer (1999) only highlight the need for shift in transport modes, Givoni (2013) main emphasis is on changing the production system so it demands less transport	Differs in the way that Givoni (2013) connects the strategy to the need for changing our thinking about economic growth.

A connection between the three sets of strategies summarised, in the table above, on how they approach changes in policy can be found. There is a difference between a “standard agenda” and a “cause-oriented” environmental policy (World Commission on Environment and Development, WCED 1987). According to WCED (1987), the standard agenda reflects an approach to environmental policy, laws, and institutions that focuses on addressing environmental effects— for instance applying the end-of-pipe solutions which could for the case of freight transportation imply using catalytic devices for cleaning exhaust. The second type of policy concentrates on the causes of those effects. For WCED, trying to reach the goal of sustainable development implies more than the standard agenda of focusing on environmental effects; policies must also address the sources of those effects. The two approaches represent “distinctively different ways of looking both at the issues and at the institutions” (WCED, 1987 p.310).

Looking more closely at the three sets of sustainable mobility strategies, the first strategy in both sets (“efficiency” and “technological fix”) has a main focus on technological solutions. However, technological fixes only addresses the negative environmental *effects* and not their underlying causes. As a result, the fixes could lead to transferring environmental problems from one sector to another or lead to the creation of new environmental problems. The second strategy in both sets (“substitution” and “glocalisation”) could be termed as an intermediate position that seeks to change the transport system and the mode of transport. The third strategy highlights the need to have an environmental policy that looks at the underlying causes as well as the need to achieve sustainable development through societal transformation.

A key question is the status of the different strategies regarding the freight transport system and road-freight transport. The EU has set a goal of decoupling road freight transport from GDP, but this has been interpreted as a relative, and not an absolute, decoupling goal. Thus, according to EU policy documents, the total energy use and GHG emissions can continue to increase even if the EU objective is met (Sorrell et al., 2012a). The lack of any EU policies in accordance with the strategies outlined by Høyer (1999) or Givoni (2013) relating to the freight transportation sector could be associated with its complexity. The sector includes many actors: haulers, shippers, and governments, as well as producers and consumers that rely on freight transportation. It is not entirely clear who should bear the responsibility for making freight transportation more sustainable, and there is little coordination between actors. Further, there is a close connection between economic growth and freight transport, where enhancing economic growth and thus transport volumes takes priority rather than curbing freight transport. Thus, there is an obvious element of goal conflicts involved in the discussion of implementing sustainable mobility policies that may lead to a reduction in the volume of freight transportation.

We will in this report investigate if rebound mechanisms can be an important explanation of why we have not managed to reverse the trend of increasing energy use and GHG emission associated with road-freight transport.

Looking at the meaning of the word “rebound,” it is something that sends you back to a state in relation to what you have been trying to achieve (Levett, 2009). In this report, we define the rebound effect (the take-back effect) as behavioral or other systemic responses to the autonomous implementation of new technologies or to policy measures that aim to reduce energy use or GHG emissions in freight transport (Høyer, 2011).

The rebound effect has been defined in several ways. Some (Alcott, 2010; Maxwell et al., 2011) have used the IPAT equation in their definition I (Impact) = P (Population) *A (Affluence)*T (Technological Efficiency). Thus, the total environmental impact depends on the population level, average products and services consumption per capita (A), and the environmental efficiency of production (T). Rebound effect refers to the fact that improvements in technological efficiency (T) could enhance production and economic growth, which could lead to an increase in per capita consumption (A)

From an energy economic viewpoint, rebound effect is defined as behavioral changes associated with a lower cost of for example transport services because of improvements in energy and fuel efficiency. A direct rebound effect occurs when improvements in energy efficiency increase the use of products and services for consumers (or increase in production rates for producers). For example, consumers who purchase a new and more fuel efficient car might drive more because it becomes cheaper to drive. The money saved can now be used on fuel for trips that were earlier made by foot, bike, or public transportation. Indirect rebound effect occurs when the money saved on reduced fuel consumption is spent on other energy-intensive goods and services, such as air conditioners or a second car in a household. Another indirect rebound effect results when energy efficiency technologies (e.g., electrical cars) need considerable energy in the production phase of their life cycle. The sum of the direct and indirect rebound effects from energy efficiency improvements is termed the economy-wide rebound effect (Sorrell, 2007).

Schneider (2008) had an alternative definition an understood it as the rebound effect can be defined as the increase of consumption linked to the reduction of limits on technology use. These limits might be monetary, temporal, social, physical, energetic, spatial, and organizational.

A key question is how resources that are freed-up through better efficiency are used. Banister (2011) points out that the dominant paradigm within transport analysis has been to focus on travel time and travel-time savings, which has led to a desire to speed up traffic. However, increased speed generates higher energy use and might in addition lead to longer travel distances. A reason for this situation to occur could be that travel has been seen as a derived demand, i.e., where travel is a means to an end, and therefore that distances and travel-time should be as short as possible. However, this hypothesis should be challenged because travel distances have increased over time.

For freight transport, it is also acknowledged that measures to increase supply-chain efficiency can reduce supply-chain costs, which can potentially result in an increased demand (since costs are lower). In the long term, this process can lead to a rebound effect that increases emissions. Throughout the supply chain improvements can be made to increase speed, such as the introduction of new vehicles and reduction of time used for load-fill. However, fast transport implies high energy consumption and increased emissions across the supply chain. So the balance between efficiency, energy use and related GHG emissions is a key issue for freight transport and the logistics industry (Liu, 2013).

During recent years there has been a growing interest in possible rebound effects for freight transportation within the energy economic understanding of rebound effects. The way of estimating these kinds of rebound effects has been by applying econometric methods, which use price elasticity to estimate rebound effects. It is based on the elasticity of demand for useful work with respect to its energy cost or to the price of energy, or the elasticity of demand for energy with respect to its price (Winebrake et al., 2012). An alternative method is that of general equilibrium modeling (Anson and Turner, 2009). Both methods define rebound effects as behavioral changes associated with a lower cost of transport caused by improvements in energy efficiency. Thus, when calculating the size of the rebound effect, it is crucial to be able to make an estimate of the fuel efficiency (or fuel intensity). Without this variable, it is not possible to estimate the rebound effect according to an energy economic understanding. The variable of fuel intensity needs to been seen in connection to vehicle-kilometers or ton-kilometers; for example developments in fuel use per ton-kilometer.

A calculation of possible rebound effects needs to control for other variables. However, it is difficult to isolate and thereby quantify all variables that we ideally need to control for from an energy economic perspective. Research on rebound effects relating to road freight transport has documented that many of the current efficiency improvements have in fact reduced fuel costs, thus also increasing the cost-effectiveness and transport range of transportation; thus in turn leading to an increased capacity for generating surplus that might be transformed into other energy consuming activities which can partly offset the initial energy savings (Anson and Turner, 2009; Winebrake et al., 2012).

Matos and Silva (2011) analyzed road freight transportation in Portugal from 1987 to 2006. They considered the elasticity of freight transportation with respect to its energy cost. According to the authors, the demand for lorry freight transport was governed by the energy cost of transportation, the economic output (GDP) at constant prices, and the price of oil[1]. They found a rebound effect of 24.1% i.e. difference between the initial engineering estimate and the net energy savings after increased fuel efficiency had emerged. De Borger and Mulalic (2012) used time regression to estimate the short- and long-term rebound effect of fuel efficiency gains for the trucking industry in Denmark from 1980 to 2007. They found a long-term rebound effect of 16.8%, which was higher than the short-term effect (9.8%) because firms rearranged their operations to capitalize on their efficiency gain, for example, by investing in more energy-efficient trucks. The use of control variables as well as choosing a method with more interaction could explain the differences between the latter study and the Portuguese one.

Anson and Turner (2009) studied the rebound effect of energy efficiency improvements which could be associated with logistics improvements and vehicle technical improvements within the Scottish commercial transport industry, and they found an economy-wide rebound effect of 36.5% in the short run and 38.3% in the long run. The minor difference between the short- and long-term effects is because the latter effect also included the disinvestment effect. The disinvestment effect may occur in domestic energy supply sectors if direct and derived demands for energy are not sufficiently elastic to prevent falling energy prices from leading to a decline in revenue, profitability and the return on capital in these sectors.

Winebrake et al. (2012) discussed terminology as well as the theory behind the rebound effect, variability in terminologies, general challenges with interpreting and comparing rebound estimates, and research in the freight sector. They also discussed the following factors which may influence elasticity estimates: Commodity type, transport region and availability of alternative modes.

From the state-of-the art within energy economic studies on rebound effects in the freight transport sector we can conclude that rebound effects are of some importance, but that most of the savings from energy efficiency are realised.

Contributions within the energy economics perspective belong to a positivistic research tradition which relies fully on quantification and modelling within strictly defined system boundaries. This perspective is embedded in methodological individualism. The sum actions of all actors constitute the totality; and energy savings and the related money and productivity gains at the micro level for households and firms contribute to changes at the macroeconomic level. Rebound effects are however difficult to isolate by means of applying positivistic research methods because such methods require extensive recording, involve having to make several assumptions, and involves having to specify very precisely the system boundaries.

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[1] A weakness in their model is that there is a close connection between fuel costs and price of oil. These two variables could not been seen as independent of each other.

In recent years, rebound research has shifted from solely being within an energy economic tradition into becoming an interdisciplinary research field which includes a number of different theoretical positions, research disciplines and methodologies (Giampietro and Mayumi, 2008; Peters et al., 2012; Santarius, 2012; Walnum et al., 2014; Weidema, 2008). One example of this process of widening out the rebound research agenda is that of applying thermodynamic theories; for example by Ruzzenenti and Basosi (2008) who have stated that an efficiency improvement may actually be used for power enhancement in a time-frame analysis. They have shown that technological improvements that were initially made to reduce consumption, such as enhanced engines and improved aerodynamics, actually led to increasing the power of the lorries during the period 1970–1995. They argued that energy conservation policies should manipulate energy costs or impose time-rate limits - e.g. by increasing the weight of trucks and decrease their speed. Increasing weight affects the efficiency process, whereas decreasing the speed reduces the power output of the process (ibid.). Other contributions to this widening-up process of the scientific rebound discourse have been from ecological economics, socio-technological perspectives, transport planning, and socio-psychological theories. New disciplines and perspectives imply that structures (e.g. physical urban structures, economic systems and political systems -) as well as dimensions other than money saved (e.g, environmental awareness, habits and lifestyles) will influence the rebound effect. Of particular interest for this report is the transport planning perspective since this perspective has dealt with how improvements in road standards could lead to traffic growth, which will also have an influence on freight transport growth.

1.3 Methods applied and methodological challenges

We have analysed a number of statistical sources connected to freight transport, concentrating on those that deals with road freight transport. In the table below we have listed our main statistics and sources and described in short how they have been applied in our study. Our approach is novel in the sense that previous studies have not made use of the same selection of statistical sources as we have, nor have they investigated the same time period (1993–2013). To our knowledge has no previous study tried to use commodities to analyse development trends in road freight transport. In our study we have tried to develop a novel model of the determinants of energy use in road freight transport in a Norway. Furthermore we have addressed methodological challenges and data limitations in available statistics.

Table 2 *Statistical sources used in our report as well as a description of how the statistics were applied*

Statistical source	Description of our usage of the statistics
“Road goods transport by Norwegian lorries”	Provide an overview in the development of commodity flows, ton-km, tons transport length of transport, and empty running and kilometres driven.
“External trade in goods”	Provide an overview of import and export and related freight trends. Also provided an overview of transport performance and the share between freight transport modes as well as commodity flows and the origin country of goods.
“Domestic transport performance”	Provide an overview of the development in transport performance for all transport modes connected to freight.
“Registered vehicles”	Analyse developments in sizes of trucks and kilometres driven.
“Transport volumes in Norway”	Analyse developments on all freight modes connected to freight.
“Industrial statistics”	Analyse business developments during the period 1993–2013 in a few industries to reflect upon how this has influenced freight transport.
“Freight transport model”	Analyse the potential of applying our model to study the handling factor (number of lifts in the supply chain); however, it was not possible due to limitations in the dataset

"Emissions of greenhouse gases"	Provide an overview of the developments in GHG emissions from road transport. Since the statistics also included buses, an estimate of the busses share of GHG emissions needs to be done.
"Waste statistics"	Provide an overview of likely developments regarding transport of waste in a Norwegian setting.

We used the different statistical sources to make a driver-response model applicable to a Norwegian setting.

In addition to reviewing statistical sources, we have reviewed the literature on models that are developed in order to explain drivers for freight transport as well as the literature on rebound effect relating to the freight transport sector. We also assessed Norwegian governmental policy documents and research reports to identify possible policy measures (response drivers) that were primarily or subordinate motivated by a goal of reducing GHG emissions. Furthermore we have done a theoretical discussion of the possibilities for rebound effects associated with the suggested and implemented policy measures. The scope of our analysis is road-freight transport, but we have also included to some extent perspectives relating to other means of transport. We look first and foremost at domestic transport, but we are also to some extent looking at freight transport to and from Norway.

A specific methodological challenge relating to our model is how to account for the effect of *indirect* drivers – this is to assess how economic development, policies, technological development (specifically that of logistics and information technology), globalization, and developments in industry influence road freight transportation. These examples of indirect drivers have all been found to be relevant in the literature (McKinnon, 2007b; Richardson, 2005); however, they are also very general concepts and thus there is a need for more precise description of the respective influence of these concepts before they can be included in a formal model. The international literature give some examples of this, such as the connection between GDP and growth in the volume of freight transport, between some categories of policy measures (such as fuel taxes and infrastructure investments) and a switch of transportation mode, and between ICT-based logistical management and capacity utilization in freight transportation. However, it proved very difficult the attain a good knowledge of the exact influence of all of the potentially relevant indirect drivers.

We defined response drivers to be autonomous technological measures (that is, mandatory technological changes implemented by the transport sector) and policy measures. However, it proved difficult to deduce whether or not a specific action, in fact is a response to the development of road freight transport. For example, implementing an increase in fuel taxes may have a fiscal reason (instead of a GHG mitigation reasoning), and infrastructure might be expanded because of person transport considerations – not that of freight transport.

In order to get a clearer picture of the actual trends in freight transportation developments we wanted to look as far back in time as availability in accessible and reliable transport statistics allowed us. We ended up looking at the period 1993–2013. We hoped to be able to split the data into specified commodity groups in order to test a double hypothesis in the international literature (McKinnon, 2007b). This double hypothesis suggests that: (1) Commodities with high values per tonne are transported over long distances, and as such, will have travelled more kilometres in general (across modes of transportation) compared to commodities with low values per tonne. (2) Lorry transport has a higher cost per tonne-km than boat or rail transport; particularly for the case for long-distance transport. If so, then these high values per tonne could still justify the extra cost if recompensed through faster and more reliable delivery.

We constructed 11 aggregated categories of goods from the statistics on domestic road goods transport. The raw data material has 101 categories, but this would have been too many categories and too many details to analyse. For some of the 101 categories the data are also based on very few observations per year, making them so uncertain that data at that level might not have been released by Statistics Norway for our use. In addition, this large number of categories would make it even more difficult to “get around” a break in the time series during 2007–2008 (see discussion below). We therefore chose to narrow the number of categories with a view to distinguish between goods with low, medium and high value densities (raw materials tend to have low value densities, with stone, gravel, sand and clay as the extreme example; food and some semi-manufactures to have medium value densities and finished manufactured goods to have high value densities). Ideally, we would have wished to delimit finished manufactured goods more precisely and perhaps split them into more categories, but this was precluded by the fact that most of these goods are shipped in containers and then disappear into the broad category of “grouped goods”, even in the raw statistical data.

Note that our chosen category of “agricultural products” refers largely to unprocessed products as delivered from the farm, e.g. un-milled cereals, raw milk or animals for slaughter. Products ready for consumption, e.g. flour, dairy products or packaged meat, are classified as “food”. “Fish”, on the other hand, includes all fish, irrespective of degree of processing. “Coal, coke and chemicals” consists *in practice* almost exclusively of chemical products, since coal and coke consumption in Norway is almost exclusively by metallurgical industries along the coast which receive these commodities directly by ship; there is very little lorry transport of coal or coke by lorry within the country. The other categories are hopefully self-explanatory – see table below.

Table 3 *Aggregated categories of goods from the Norwegian statistics on domestic road goods transport*

1.	Agricultural products
2.	Timber, sawn wood and cork
3.	Fish
4.	Food, beverages and tobacco (excluding fish)
5.	Petroleum products (including asphalt)
6.	Coal, coke and chemicals
7.	Stone, gravel, sand and clay
8.	Ores, scrap metal, raw minerals and building materials
9.	Transport equipment
10.	Other manufactured goods and grouped goods
11.	Waste

Goods could also have different requirements for transport means; bulk and general cargo or goods that need freezing and refrigeration could influence the choice between ship and lorry, but also for energy use and capacity utilization, where of course freezing of goods needs extra energy. Bulk often has a better weight per volume ratio; for example better capacity utilization.

A particular challenge is that there is a break in the statistical series for lorry transport for the period under investigation. The standard for commodity classification used from 1993-2007 was replaced by a new standard in 2008. This has made it impossible to achieve a completely coherent time-series for the period under investigation; although we have attempted, with help from Statistics Norway, to construct our 11 aggregated categories so that the consequences of the break are minimised. A major problem that we could not get around is that “waste” is a separate category from 2008 on, whereas it seems to have been spread among several categories previously, and we do not know how it was spread.

For foreign trade, we divided imports and exports into 15 commodity groups, which were aggregated from the 65 two-digit groups of the Standard International Trade Classification (SITC). As far as raw materials and semi-manufactures are concerned, we aimed for broad commensurability between the foreign trade categories and those used for domestic lorry transport, but the fit is not perfect. For instance, some commodities that are classified as “agricultural products” in the table above will be included in category 1 below, and others in category 3; also, some building materials which are grouped together with ores and minerals in the table above, will be included in category 7 below. Coal and coke are included along with oil and gas as “energy goods” below; however, there is no real problem of commensurability in this case since coal and coke are almost a null category as far as domestic lorry transport is concerned.

Apart from this, finished goods are split into more categories below than in the table above. This was possible in the case of foreign trade, since all imports and exports are specified by type in the foreign trade statistics, even if they cross the border in containers. There is no “black box” of “grouped goods” as there unfortunately is in the lorry transport statistics.

Another advantage of the foreign trade statistics compared ot that of the domestic statistics is that they give data not only on the tonnage but also on the value of imports and exports. Therefore, the average value densities of the various commodity groups can actually be calculated, and not just vaguely guessed.

Table 4 *Aggregated categories of goods from the statistics on foreign trade*

Type of goods	SITC groups	Value density of imports, NOK/kg
1. Food, fodder, beverages, tobacco	00-12	10.95
2.Timber, sawn wood and cork	24	2.52
3. Other animal and vegetable raw materials	21-23, 25-26, 29, 41-43	7.71
4. Ores and minerals	27-28	2.84
5. Energy goods	32-35	4.74
6. Chemical products	51-53, 56-59	8.37
7. Non-metallic mineral products	66	4.34
8. Metals and basic metal products	67-69	20.88
9. Paper, cardboard and paper products	64	10.89
10. Pharmaceuticals, toiletries etc.	54-55	109.31
11. Industrial machinery	71-74	107.10
12. Electrical machinery and equipment	75-77	117.63
13. Transport equipment	76-79	137.44
14. Prefabricated buildings	81	33.57
15. Other finished goods	61-63, 65, 82-89, 9x	54.43

The foreign trade statistics also include data on means of transport at border crossing by commodity group, but these figures are given in tons only. We therefore cannot say whether goods within each group that crossed the border by lorry, had a higher or lower value density than goods that crossed by other means.

1.4 Our freight transport model

There are differences in freight transport models in the international research literature with regard to degrees of resolution. Some models use only three or four factors; others use many more. We find the models applied by Richardson (2005), Piecyk (2010) and McKinnon (2007b), with their high levels of resolution to be of particular interest. One limitation of freight transport models such as those mentioned above is that they are non-specific with regard to types of freight. Some recognize changes in the average value density or value per unit weight of goods moved as a driver, but do not go beyond that to tell, say, how changes in the volume of (e.g.) construction materials, energy carriers, agricultural products or industrial consumer goods moved may have influenced the overall trend. To do so obviously require sufficient statistical data, which are not available in all countries. In the case of Norway, commodity figures are available, although the issue is complicated by a break in the statistical time series in 2007/2008, as mentioned above. However, an understanding of changes in the mix of freight being moved based on the best information available, and going beyond the dichotomy between high and low value goods, could contribute significantly to explaining overall trends. We have in this report disaggregated observed trends in Norwegian road freight transport by main commodity groups, so far as available data permit.

Rebound effects were not modelled by any of the authors mentioned above. An important differences between models used by Richardson (2005), Piecyk (2010) and McKinnon (2007b) compared to our model are how response categories are defined, They understood response primarily as government responses, however we also include autonomous changes as well as possible rebound effects associated with societal and structural changes that might have an influence on GHG emissions. Our approach is novel in that it uses a broader category of responses and includes rebound and trade-off effects.

An important methodological element of our model development has been to apply a driver-response approach inspired by the logic of the OECD pressure-state-response environmental indicator model. This logic has also been applied in a number of sustainability indicator systems (Aall and Norland, 2005). From this outset (cf. figure 1 on page 7) we have specified a model that describes how key drivers directly and indirectly affect the total transportation work of road freight transport and subsequently the accompanying GHG emissions from and energy use relating to road freight transportation. The model is set to include inland, import and export freight transportation (see table below for driver categorisation).

Table 5 *The specified driver-response model applied in our study. Inspired by drivers selected by Richardson (2005), Piecyk (2010) and McKinnon (2007b)*

Indirect drivers	Direct drivers	Response drivers
• Economic growth measured by GDP • Development in industrial activities • Globalisation • Erosion of industrial activity to other countries • Rail infrastructure investments • Road infrastructure investment • Business location	• Volumes of tons transported and length of haul • Inland transport of commodities • Foregin trade • Capacity utilization • Fuel efficiency • Degree of empty running • Transport efficiency • Cost of fuel • Cost of shipping by lorry • Distances between origin and destination • Modal split • Average length of haul	• Blending of biofuels into diesel • Level of fuel tax • Allowance of larger lorries • Measures aiming at switching from road to sea and rail • Logistical efficiency • Technical measures • Ecodriving • Dematerialization • Re-regionalisation

2.0 Indirect drivers

2.1 Economic development and transport growth

Below we discuss developments in freight transportation up against the goal of reducing GHG emissions from transportation within the EU by 60 % by 2050 compared with a 1990 level, and by 20 % by 2020.

Economic growth is closely related to freight transport, and the issue of decoupling economic growth and energy usages and related GHG emissions of freight transport has been the subject of previous research. A decoupling perspective is commonly used as a starting point in models that discuss the drivers for freight transportation. It could be argued that there is a small difference between addressing the drivers in the freight transportation sector and the gap between growth in freight transportation and GDP (which includes the inherent statement that GDP is a positive driver for freight transportation). Economic growth is closely related to freight transportation, and the possibility of decoupling economic growth and energy use and related GHG emissions has been the subject of considerable research (see e.g., Smith et al., 2010 for an overview) – and some research has also taken place specifically aiming at the transportation sector (Åhman, 2004; McKinnon, 2007b; Sorrell et al., 2012a; Tapio, 2005). It is common to distinguish between absolute decoupling — e.g. when the transport volumes decrease and GDP increases — and relative decoupling; when they grow at different rates (Sorrell et al., 2012b). Tapio (2005) refines the categorization of different forms of decoupling: According to him, for the case of transportation, negative decoupling occurs when transport volume increases faster than GDP; weak decoupling occurs when transport volumes increase more slowly than GDP; strong decoupling occurs when transport volume decreases when GDP is increasing; and recessive decoupling describes a situation in which both GDP and transport volume decrease, but transport volume decreases faster than GDP.

Some authors have found signs of absolute decoupling in freight transportation, in some countries for specific time periods (Rommerskirchen, 2005; Tapio, 2005), while others have found only relative decoupling, when taking into account the shortcomings of current statistics (Åhman, 2004; Sorrell et al., 2012b).

An important point is that there are large differences among countries and during the different times under study. Studies made by Tapio (2005) and Rommerskirchen (2005) find large differences among countries - even within Europe in the same time period - in the relationship between ton-kms and GDP. This relationship often differed across periods in time. Looking at Sweden, both Trafikverket (2013) and Andersson and Elger (2007) find that ton-kms/GDP develops differently during different stages of economic cycles. Overall, there seems to be some agreement that the tonnage transported has recently increased less than GDP in Europe, and that vehicle kilometres and emissions per ton-km have declined somewhat due to increased capacity utilization and use of larger lorries.

The dominant approach in the international research literature is to apply a relative approach in determining whether a decoupling between economic growth and freight transport work (tonne kilometre) is present. It could be argued that signs of relative decoupling are not interesting in relation to the objectives of achieving major reductions in GHG emissions from transport. The concept of decoupling has been criticized because there will always be some coupling between economic growth and energy usages (or environmental impact), even if they are growing at different rates. This coupling can, for some time and to some extent, be counteracted by gains in energy efficiency, but the coupling still exists. A better term to use is “eco-intensity reduction” (an increase in eco-efficiency) (Nørgård, 2013).

The figure below illustrates that for the case of Norway there is no sign of decoupling taking place within the freight road transport sector for the period 1990–2012 (Hille, 2014).

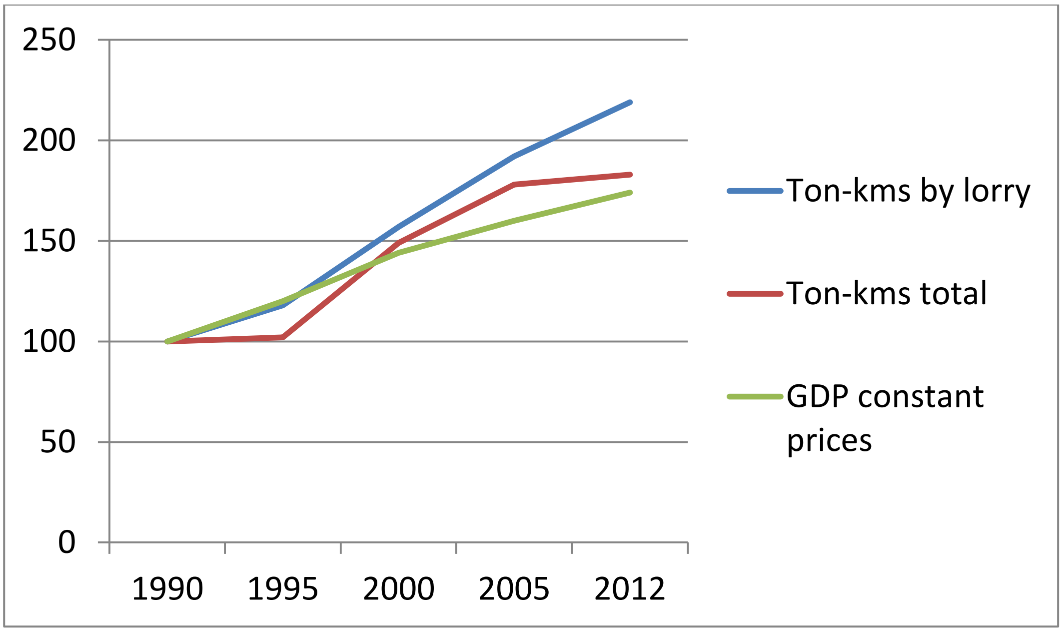

Figure 2 *Development of domestic transport performance and GDP at constant prices in Norway. Index figures, 1990=100.*

Throughout the years 1990 to 2012, total domestic transport performance has increased only slightly faster than GDP (82%, compared to 74%), and if we include cross-border hauls, total transport performance has grown by just over 83%. Obviously, there is a connection between economic growth and transport performance, but having a higher resolution of explanations of variables will let us determine which variables have accentuated and which have mitigated this effect.

We may as well immediately observe that there has been a strong positive coupling between growth in GDP (at constant prices) and road freight transport in Norway (see table below).

Table 6 *Indexes for development in GDP, road ton-km, and GHG emissions from road freight transport in the period 1990–2012 for the case of Norway (1990=100)*

Year	GDP (constant 2005 NOK)	Road ton-km		Emissions from road freight transport, index[2]
		Domestic only	Including border-crossing hauls	
1990	100	100	100	100
1995	120	117	118	132
2000	144	158	157	134
2005	160	193	192	171
2012	174	216	219	176

From the literature, we know that the type of strong coupling illustrated above for the case of Norway need not simply be the result of some positive drivers' having accentuated the effect of growth in GDP. It may just as well be the net result of some drivers' having *strongly* accentuated this effect, and others' having mitigated it. So what are the likely suspects in Norway? And why have emissions increased less than transport performance (although roughly in tandem with GDP)?

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[2] Approximate figures. Based on figures for emissions from all heavy vehicles (lorries + buses) and the assumption that buses have been responsible for a constant 400 kt/year over the whole period. Cf. data on energy use by buses from 1987-2006 in Hille et al. (2008). From 2006-2012 there was an increase of 12 % in vehicle-kms least by scheduled buses, but also an offsetting because of increase in use of biofuels by some urban bus fleets.

As exemplified by the international literature, the relationship between growth in GDP and road ton-kms can be decomposed in several ways. The three words "road", "tons" and "kilometres" already point to three separate drivers. *Road* freight transport could have evolved differently from the total of freight transport, due to modal shifts. The same goods could be moving further, which in common sense terms means an increase in *kilometres*, although it will not necessarily show up that way in freight transport statistics. If a given type of goods were moved 100 km on average in year A and 200 km in year B, but moved only once in both years, then this will appear as an increase in the average length of haul (km). However, if the 200 km in year B consisted of two trips, such that the goods were unloaded at warehouses midway and then loaded onto new lorries to travel further, then this will appear as a doubling of the number of tons transported, and no change in the length of haul. The tonnage of goods is counted anew each time they are loaded onto a new vehicle. The number of such events is called the handling factor. Finally, the *tonnage* of goods transported may have increased independently of the handling factor. As GDP grows, so will very likely the tonnage of goods produced in the country and/or that of goods imported for further distribution, but the relationships may be far from linear. They will be affected inter alia by the share of services versus primary and secondary industries in GDP, by structural changes within the primary and secondary sectors and other developments that affect the average value per ton, or value density, of goods produced. Similarly, the mix and value density of goods imported may change.

2.2 Developments in industrial activities 1993-2013

Possible explanations for the growth in average length of haul include both *concentration* and *specialization* among domestic producers of goods transported, and also increasing *competition*. The phenomenon of concentration, noted by McKinnon (2007b) with reference to the UK, implies a trend towards fewer but larger production facilities for the same goods. If each producer supplies a regional market, the size of these markets – and the average distance over which goods have to be transported to reach consumers or intermediaries – will grow as the production facilities become fewer, larger and farther between.

If we are talking of industrial producers whose raw materials are sourced from widely distributed primary producers – typically processors of agricultural products – then the average distance over which the raw materials have to be transported to reach the processing plants will also tend to increase as the latter become fewer and farther between. Such a tendency to concentration has long been evident in parts of the food processing sector in Norway. For instance, the number of dairy processing plants operated by the co-operative TINE, which enjoyed a virtual monopoly of the Norwegian dairy sector prior to 1993 and still dominates it, declined from around 100 in 1993 to 34 in 2013, and the number of slaughtering plants operated by the corresponding co-operative in the meat sector, Nortura, has shown a similar trend. Tendencies to concentration, albeit less dramatic, can also be seen in brewing and soft drink production (several major breweries which previously served regional markets have closed or discontinued soft drink production since 1993), sawmilling (the number of sawmills employing at least 5 persons declined from 194 to 138 just in the period from 1999 to 2012), and probably also in sectors such as grain milling and packaging of vegetables.

However, in the domestic sector which generates the most freight measured in tons – viz. quarries, gravel and sand pits – no such tendency to concentration is evident; on the contrary, the number of enterprises has increased somewhat since the late 1990s.

Specialization means that each enterprise, although still belonging to the same generic sector, tends to produce a narrower range of goods. For instance, of the 34 dairy plants still operated by TINE in 2013, only 15 delivered liquid milk products; some others produced, for instance, only a few varieties of cheese or ready-made desserts, of which they might be the only producers in the whole country, so that the products in question were distributed from one point to the whole of Norway.

Few of the sawmills deliver the whole range of sawn and planed products that local builders may desire. In the case of products from quarries etc., specialization may explain most of the two-thirds increase in average length of haul since 1993, as construction firms demand not just any crushed stone from the nearest quarry, but particular qualities which they may have to obtain from further away. Growing exports of crushed stone to other European countries may also be a partial explanation, as stone destined for export appears to travel a longer average distance to port than that destined for domestic consumption.

Competition also decreases the likelihood that each producer within a particular branch of industry will supply the nearest region. Within parts of the food processing sector, competition was quite limited before 1993. In the case of sectors such as milk and meat processing, this was due to the quasi-monopoly position of farmer-owned co-operatives. A near-monopolist with plants distributed over the whole country can in principle divide up his market so that each plant supplies the nearest customers. Although the co-operatives are still the biggest players in their respective markets, a number of new competitors have nibbled away at their market share since 1993, and some of these have their products distributed across the whole country, be it directly or via the distribution systems of retail chains.

Even when there are several or many independent producers in the market, regional quasi-monopolies may exist, either by tacit agreement or because transport costs give each producer a significant advantage in his regional “home” market, or simply because customers prefer the local product. Production of beer and soft drinks are a case in point. Traditionally, producers in each of the major cities tended to dominate their regional markets, with fairly limited competition from outside. To a considerable extent, this situation still prevailed in 1993. Since then, much of the national market has been gathered into the hands of two concerns, Ringnes (now owned by the Danish firm Carlsberg) and Hansa Borg. The former and larger in particular has concentrated much of its production, but the relevant point here is that both concerns now market their products across the whole country, in competition with each other.

Another tendency which can be observed not only in brewing but in a number of other sectors is a proliferation of *small* competitors – micro-breweries, micro-dairies, micro-bakeries and so on. Although these often present their products as local specialties, many do attempt to market them across much or all of the country. However, the volumes concerned are small.

There could also be cases in which domestic competition has been *reduced,* through mergers or takeovers or the simple disappearance of some firms from the market, making it easier for those remaining to “regionalize” the deliveries from their individual plants. This could conceivably have happened in the sawmilling industry where there have been a number of mergers and takeovers during the past 20 years, but we have no actual evidence of it. In the case of stone, sand and gravel this is not likely to be an issue, since markets have always tended to be as local as the quality requirements of customers permit, simply because freight represents a large fraction of total costs.

The points above have been made with reference to processing of agricultural and forestry products, and extraction of raw construction materials. For some other “heavy” products that are produced domestically, they are hardly relevant since the structure of domestic production has changed little since 1993. For instance, the number of cement plants has remained unchanged at 2, always owned by the same company; there has been only one domestic producer of bricks during the whole period;

the number of fertliser plants has also remained at 2, also owned by one company. The number of oil refineries dropped in 2000 from 3 to 2, but hardly with major consequences for lorry transport since long range distribution of refinery products is carried out by ship to depots along the coast.

Concerning finished products from manufacturing industry, the situation is simply that few of them are produced in Norway on a major scale for the domestic market, or have been at any time since 1993. Overwhelmingly, most capital as well as durable consumer goods is imported, so that lengths of haul by lorry within Norway depend mainly on the point and manner of border crossing and the structure of wholesaling or distribution centers within the country, which are discussed below.

However, there is one other “industry” in which both concentration and specialization since 1993 are likely to have had a significant effect on lengths of haul, and perhaps more than a negligible effect on transport performance by lorry. This is *waste treatment*. Unfortunately we cannot follow the trend in waste transport further back than to *2008*, since waste does not appear as a separate category in transport statistics before then (cf. discussion of trends in lorry transport by type of goods). However, we know from waste statistics that as late as 1995 over half of all household and industrial waste (52 %) either went to landfill or was disposed of in “unknown” ways, which is likely to mean that it was either dumped or incinerated locally, perhaps privately if not (yet) illegally. Moreover, most of what was landfilled in the early 1990s was disposed of locally. In 1992 there were 330 recognized landfill sites in Norway – most municipalities had their own. Today, as a result of progressively tougher regulations, only some 60 remain, so that whatever goes to landfill must on average travel much further. But by 2012 only one-sixth of waste either went to landfill or was disposed of in “unknown” ways. The remainder often travelled still further – some of it to be burnt at a district heating or CHP plant, the food waste sometimes to a regional biogas plant and other fractions to be recycled, sometimes at far distant paper mills or other factories or construction sites and sometimes even abroad (which can still involve *domestic* lorry transport, to a regional depot and/or onward to a harbor). Thus waste treatment exhibits both concentration (of landfills) and specialization (in the sense that different fractions are sent to different places for specialized treatment) – all in all leading to what is coined internationally as “waste tourism”. Several studies indicate a strong increase in waste transport within (and out of) the EU since the early 1990s. This situation to occur was predicted already in 1991 (Huelshoff and Pfeiffer, 1991) in a comprehensive study of EU environmental policies. The major reason for this to happen was that the EU in 1992 defined wastes as a good and waste treatment as a service. Thus, the free movement of wastes around Europe was defined in the same terms as the movement of services and labor. Hence, restrictions upon the free movement of wastes are banned.

3.0 Direct drivers

3.1 Volume of tons transported and length of haul

The table below shows the evolution of tons transported by road *within Norway* and the average length of haul, as imputed from Statistics Norway's surveys of lorry transport.

Table 7 *Evolution of tons transported by road within Norway and the average length of haul*

Year	Million tons transported	Average length of haul	Indices 1993 = 100	
			Tons	Average km
1993	176.3	43.1	100	100
1998	221.3	53.1	126	123
2003	226.8	60.0	129	139
2008	282.8	59.2	160	137
2013	265.7	69.0	151	160

The tonnage of goods transported between points within Norway has grown strongly since 1993, but the average length of haul has grown even more. As mentioned above, this could partly be a spurious effect in the sense that goods need not be moving that much further on average, but moving in fewer stages. For some consumer goods, this is certainly a plausible trend – that instead of being moved from a national distribution centre to regional distribution centres and then on to retail outlets in the region, goods are being moved from one distribution centre directly to outlets all over the country. However, the trend towards longer hauls is so strong that it is likely to have more causes than this. Another plausible, indeed quite obvious, explanation is that production of a wide range of goods has been increasingly centralised, and in some cases discontinued entirely within Norway, so that the products need to be distributed over larger areas (or in the case of imported goods, often from some point in the far south of the country to all parts of Norway). The centralisation of food processing, e.g. of dairies, slaughterhouses and breweries, has been widely publicised and criticised, but the trend applies equally to some other sectors, as discussed above.

Yet another reason for the increasing average length of haul could be that goods which have always tended to be transported over longer distances (i.e. goods with high value densities) could have increased their share of the total volume of goods being transported. This is also plausible, but because the high-value goods largely disappear into the broad category of "grouped goods" in the statistics on lorry transport, it is impossible to find out whether, or by how much, they may have increased their share of the transport volume. However, the *total* volume of "other manufactured goods and grouped goods" transported has actually grown less than the overall volume of lorry transport (cf. table below), which may suggest that even if the volume of high-value goods within this category has grown more strongly, the effect on overall lorry transport has not been dramatic.

Finally, a third reason may be that the average length of haul by road could have increased as a result of lorries having taken over some of the long-haul transport that was formerly done by ship or train. It is difficult to deduce from statistics whether this has actually taken place. If it has, one might, bud need not necessarily, assume that lorries would mainly have taken over some of the shorter hauls that were formerly carried out by ship or train, and that the average length of haul by these other modes would also have increased. One might perhaps also expect the tonnage of goods moved by ship or rail to have either declined or grown less than that of goods moved by road. In fact, the average length of haul both by ship and by rail has grown over the 1990-2012 period, albeit moderately (by 15-20 % in both cases). The issue of whether lorries have actually displaced ships and trains on some long hauls (i.e. longer than average for lorries, though possibly shorter than average for ship or rail transport) therefore remains moot and demands closer examination.

3.2 Domestic transport of commodities

An important issue in identifying the drivers of growth in lorry transport is of course what kinds of freight have been mainly responsible for the aggregate growth, both in the volume of goods transported and in the average length of haul.

The discussion below concerns *domestic* lorry transport only. This is due to data limitations. Although Statistics Norway also gather data on border-crossing lorry transport by type of commodity, the time series available for our purposes only extends back to 2003. Also, the number of respondents in the surveys on border-crossing transport is too small to allow the data to be broken down in the way desired for this study. Still, as shown above, domestic transport accounts for the lion's share of lorry transport on Norwegian territory.

A statistical analysis even of trends in domestic transport is – as discussed above - complicated by the fact that the classification of commodities in Norwegian transport statistics was altered in 2008, so that the time series from 1993-2007 is not strictly comparable with that for later years. The importance of being aware of this situation will be commented on below.

The statistics on lorry transport of individual categories of goods – even at the level of aggregation we have chosen– show rather large fluctuations, occasionally approaching a factor of 2 from one year to the next, which suggests considerable sampling errors. To smooth out the effect of such errors, the data below are presented as averages for five-year periods (the last covers six years, 2008-2013).

The first table below shows the evolution of goods volumes. The total volume showed a steady increase, amounting to exactly one-third from the 1993-1997 period to 2008-2013. However, there are considerable variations among categories. As shown above, the increase in tonnage was 51 % between the single years of 1993 and 2013, i.e. greater than the increase between the averages for five- or six-year periods that are shown below. Lengths of haul also increased more between 1993 and 2013 than between 1993-97 and 2008-2013.

Table 8 *Evolution of goods volumes in domestic lorry transport by type of goods, 1993-2013*

Type of goods	Goods volume, Mt (annual averages)				Growth, 2008-2013 over 1993-1997
	1993-1997	1998-2002	2003-2007	2008-2013	
Agricultural products	3.8	4.7	7.6	7.1	+85.3%
Timber, sawn wood and cork	13.4	12.2	14.0	9.8	-26.5%
Fish	0.9	1.5	1.2	1.6	+75.9%
Food, beverages and tobacco (excluding fish)	24.6	26.0	30.2	22.3	-9.4%
Petroleum products (including asphalt)	13.9	15.7	15.2	14.7	+6.4%
Coal, coke and chemicals	2.7	3.3	2.8	5.4	+98.5%
Stone, gravel, sand and clay	84.0	101.1	116.4	127.9	+52.3%
Ores, scrap metal, raw minerals and building materials	12.9	12.8	14.3	11.0	-14.6%
Transport equipment	0.9	1.1	1.2	1.1	+21.4%
Other manufactured goods and grouped goods*	38.0	40.2	40.6	42.5	+11.8%

Waste	-	.	(0.0)	16.5	-
Total	**194.9**	**218.5**	**243.4**	**259.8**	**+33.3%**

Source: Statistics Norway, Road goods transport by Norwegian lorries (data extracted for this study).

In three cases timber etc., food etc. and ores etc., transport volumes actually fell. In all three cases the drop occurred after 2008, which should alert us to the possibility that the break in the time series at that point could be partly responsible. A drop of over one-quarter in the volume of food and beverages moved seems unlikely. There is one plausible explanation for a real decline, viz. ongoing centralization of the distribution centres operated by the major food retailers, which means that more deliveries go directly from a national centre to shops all over the country, rather than being unloaded and re-loaded at regional distribution centres, in which case the volume would be counted anew in the statistics. However, the trend to centralisation of distribution centres goes further back than 2008, so one may wonder at the size of the sudden drop. Another explanation may be that some waste was counted in the “food” category prior to 2008. This is quite likely.

The drop in the volume of timber etc. after 2008 also begs explanation, since the annual Norwegian timber cut has been fairly stable at around 8 million m^3 per year since 2000, apart from a drop to 6.6 million m^3 in the single year of 2009. However, imports of timber, some of which also generate domestic lorry transport, dropped markedly at the end of the period. An increasing share of the Norwegian timber cut has also gone to export rather than domestic processing in recent years, which may have affected the volume of domestic lorry transport. Still, it is not obvious that these factors can fully explain the drop in transport volume after 2008 that the survey data indicate. It is possible that some industrial and construction and demolition waste was included in the categories of timber etc. and ores, scrap metal etc. before 2008. If so, this would contribute to explaining the drop in volume of these goods in the last period.

Apart from the categories mentioned above, there is one that shows only slight and unsteady growth, namely petroleum products. This is unsurprising, since total consumption of petroleum products has been fairly stable over the past 20 years.

All other categories of goods show a double-digit growth in volume from 1993-1997 to 2008-2013. However, it is remarkable that among the categories that count the most in total volume, the increase has been greatest for two that represent commodities with low or very low value densities, viz. unprocessed agricultural products and stone, gravel, sand and clay. Probably there was also strong growth for another very low value “commodity”, viz. waste, since the volume of household and industrial waste generated in Norway increased from 7 Mt in 1995 to over 10 Mt in 2012. Some of this was lifted more than once. However, we have no direct information on waste transport before 2008, apart from a negligible amount of waste paper which Statistics Norway could identify in their data from 2003-2007.

By contrast, the category “Other manufactured goods and grouped goods” has grown only moderately in volume. This is the category in which we should find most finished consumer and capital goods, i.e. most of the goods with very high value densities, apart from transport equipment which is a category of its own. However, we cannot deduce the increase in volume of high-value goods from these figures, for two reasons. Firstly, this category may, like several others, contain an unknown amount of waste in years prior to 2008, in which case the true increase from 2003-2007 to 2008-2013 will have been greater than the figures indicate. Secondly and more importantly, the category does not, quite apart from waste, only include finished goods, but also some semi-manufactured goods, and beyond that goods of whatever type that happen to be shipped in containers – this is what is meant by “grouped” goods. If goods are containerized, the surveys of lorry transport do not collect any information on the contents of the containers. Nor do we have other direct information on the tonnages of finished goods of various kinds that arise within the country. The best information we do have is on the volumes that either enter or leave the country, since external trade statistics are detailed by commodity. Because a very large share of the finished manufactured goods consumed in Norway is in fact imported, trends in imports can provide us with useful supplementary information. We shall return to this below.

The next table shows the evolution in average lengths of haul, for the same categories of goods as above.

Table 9 *Evolution of average lengths of haul in domestic lorry transport by type of goods, 1993-2013*

Type of goods	Length of haul, km (annual averages)				Growth, 2008-2013 over 1993-1997
	1993-1997	1998-2002	2003-2007	2008-2013	
Agricultural products	90.4	99.0	101.8	152.0	+68.1%
Timber, sawn wood and cork	67.6	90.6	101.0	99.2	+46.7%
Fish	186.5	231.8	349.7	278.6	+49.4%
Food, beverages and tobacco (excluding fish)	82.5	108.7	116.3	153.8	+86.5%
Petroleum products (including asphalt)	53.2	59.5	61.3	67.5	+26.8%
Coal, coke and chemicals	92.5	92.3	120.9	110.5	+19.5%
Stone, gravel, sand and clay	9.0	10.8	12.6	15.1	+66.9%
Ores, scrap metal, raw minerals and building materials	37.3	43.9	60.4	87.8	+135.3%
Transport equipment	103.8	85.5	105.4	123.0	+18.6%
Other manufactured goods and grouped goods*	85.2	110.8	123.2	115.6	+35.7%
Waste	-	-	-	79.8	-
Total	**46.2**	**55.7**	**61.1**	**64.0**	**+38.6%**

Across all categories of goods – without exception – average lengths of haul increased significantly between 1993-2007 and 2008-2013. For reasons discussed elsewhere, we can be fairly certain that this was also true of waste, though we have no data before 2008. Two reasons for this tendency are fairly obvious.

The *first* reason is a centralisation of distribution centres, or of wholesale storage facilities. This will tend to increase average lengths of haul but reduce the number of times goods are lifted, thus exerting a downward influence on the registered goods volumes, as noted in the case of food and beverages above. In this case, the considerable jump in average lengths of haul between 2003-2007 and 2008-2013 is consistent with significant centralisation having taken place between these two periods. Although dispensing with regional or local storage means that goods are moved in fewer but longer stages, the net effect on the total distance over which they are moved may be minor, and even the sign of that change may vary from case to case.

The *second* obvious reason for increasing lengths of haul is the concentration and specialisation of production facilities, which was discussed above. Thus concentration in food processing and sawmilling is likely to have contributed to increasing lengths of haul both for inputs (“agricultural products” and timber) and outputs (food and beverages and sawn wood). Specialisation in the quarrying sector, or rather customer demand for more specialised qualities of stone or gravel, is a likely driver of the increasing lengths of haul in this sector.

A *third* possible contributor to increasing lengths of haul in *lorry* transport is that lorries have taken over some freight that was previously moved by sea or rail. As shown previously, lorries have increased their share of goods transport within Norway since the early 1990s, albeit moderately and not monotonously. Apart from some special cases, competition between road and sea or rail transport is largely limited to hauls of 200-300 km or more. In some important cases the lower bound is even higher: for instance, containerised goods may be moved by rail between Oslo and Bergen or Oslo and Trondheim, both distances of close to 500 km, but not to points in between, since the railways operate no container terminals along the way. So in these cases competition exists only over the 500 km distance. To the extent that lorries have taken market share from ships or trains, this will mean that they are carrying out more long-distance hauls, thus increasing the average lengths of haul by lorry. A closer analysis of changes in lorry versus rail transport between points where rail terminals exist, and of lorry versus ship transport between points along the coast where there may be real competition between ships and lorries for some categories of goods, would shed more light on this issue, but remains to be done.

The next table shows the product of the two above, i.e. the evolution of transport performance in ton-kilometres.

Table 10 *Evolution of domestic lorry transport performance, 1993-2013*

Type of goods	Transport performances, Mtkm (annual averages)				Growth, 2008-2013 over 1993-1997
	1993-1997	1998-2002	2003-2007	2008-2013	
Agricultural products	346.2	460.1	771.6	1 078.9	+211.6%
Timber, sawn wood and cork	904.2	1 107.0	1 418.7	975.3	+7.9%
Fish	166.1	341.0	405.7	436.4	+162.7%
Food, beverages and tobacco (excluding fish)	2 025.3	2 828.0	3 518.1	3 422.6	+69.0%
Petroleum products (including asphalt)	739.9	931.2	931.7	997.7	+34.9%
Coal, coke and chemicals	251.6	300.8	338.6	596.9	+137.2%
Stone, gravel, sand and clay	759.5	1 090.0	1 471.0	1 930.2	+154.1%
Ores, scrap metal, raw minerals and building materials	481.3	560.1	862.1	966.9	+100.9%
Transport equipment	94.1	93.7	130.6	135.3	+43.9%
Other manufactured goods and grouped goods*	3 236.9	4 459.1	4 998.3	4 909.3	+51.7%
Waste	-	-	(3.9)	1 183.4	.
Total	**9 004.9**	**12 171.1**	**14 883.4**	**16 331.6**	**+84.7%**

Transport performance has increased for every category of goods as shown in the table above. Even where goods volumes apparently fell, the increase in average length of haul was more than enough to compensate for this. Note also that the percentage growth for some categories of goods must be somewhat too low, since waste – representing over 7 % of transport performance in 2008-2013 – was previously included in other categories.

An important point remains that the categories of “other manufactured goods and grouped goods” and transport equipment grew less, when measured by transport performance as well as by weight, than several categories of lower-value goods. Together, the two categories were responsible for only 1.7 billion tkm, or less than one-quarter of the total increase of 7.3 billion tkm in transport work between 1993-2007 and 2008-2013. It may still be that the finished goods with really high value densities within these categories increased their contribution to transport performance relatively more. In absolute terms, however, it appears that most of the growth in transport performance was due to other kinds of freight, primarily food etc. (+1.6 billion tkm) and very low-value goods such as stone, gravel, sand and clay (+1.2 billion tkm), unprocessed agricultural products (+0.7 billion tkm) and ores, scrap metal etc. (+0.5 billion tkm). Some of these figures could have been slightly higher if the respective categories had not included some waste before 2008; yet at the same time waste itself may have contributed significantly to the overall growth in transport performance.

3.3 Foreign trade

By looking at the foreign trade statistics we get an overview of which types of goods have contributed most to border crossing transport - both totally and by lorry in particular. Because imported goods also contribute to domestic lorry transport as they are distributed onward within the country, and goods destined for export may be lifted in one or more domestic stages before crossing the border, the foreign trade statistics may also shed some light on drivers of domestic transport.

As noted above, border-crossing lorry transport in connection with imports and exports is directly responsible only for a small fraction of total road freight transport performance in Norway – some 12 % in 2012. However, this does not tell us the whole story about the influence of external trade on lorry transport within Norway. Goods that are imported by ship are often sent onward from the harbour by lorry, which counts as *domestic* lorry transport; and likewise goods that are imported by border-crossing lorry or train may be unloaded at a terminal quite close to the border, for onward distribution, sometimes across the whole country, by lorry. Also, exports may be moved by domestic lorry to a harbour for shipment abroad or to a depot within Norway before onward rail or lorry transport to other countries. The domestic movement of imports by lorry is almost certainly more important than the domestic movement of exports. The lion’s share of Norwegian exports, even excluding oil and gas that are exported directly from the continental shelf, are either shipped directly from points of production along the coast with access to their own quays, or travel fairly short distances to the nearest export harbour, or are sent directly by lorry from the point of production to other countries without further handling within Norway. Some major categories of imports are much more likely to generate long domestic hauls by lorry, after first being unloaded at a harbour or a distribution centre - of which many are located in the far south-eastern corner of the country, where most goods that are imported by road enter.

The growth of imports in particular may thus be an important factor in explaining the growth of domestic as well as border-crossing lorry transport. It can be useful to take a closer look at how these imports have grown, not merely because of their importance in aggregate, but also because the external trade statistics give more detailed information on the kinds of goods that are imported, than the lorry transport statistics do on the kinds of goods moved. Quite apart from the fact that the latter statistics have fewer categories of goods, containerised goods literally disappear into one “black box” in the lorry transport statistics – there is no information on what the containers contain. The external trade statistics have no such black boxes. The contents of containers entering the country must be declared to customs. Also, external trade statistics provide data on the value as well as the tonnage of goods traded, which makes it possible to calculate, and not just guess at, their value densities.
The table below shows the development of Norwegian imports in tons from 1993-2013, split by 15 categories. Also shown are the percentages of the various kinds of goods that entered the country by lorry and their average value densities in 2013.

Table 11 *Development of Norwegian* *imports* *in tons from 1993 to 2013, split by 15 categories*

Type of goods	Imports, 1000 tons			Increase 1993-2013	Percentage crossing border by lorry*		Value density, NOK/kg
	1993	2003	2013		1993	2013	2013
1. Food, fodder, beverages, tobacco	1 645	2 395	3 824	+132%	31	33	10.95
2,.Timber, sawn wood and cork	1 491	3 493	1 457	-2%	53	79	2.52
3. Other animal and vegetable raw materials	381	1 151	1 279	+236%	34	36	7.71
4. Ores and minerals	7 250	8 069	7 735	+7%	3	1	2.84
5. Energy goods	6 012	5 757	8 202	+36%	2	3	4.74
6. Chemical products	1 941	2 494	3 493	+103%	18	25	8.37
7. Non-metallic mineral products	526	990	1 727	+238%	48	43	4,34
8. Metals and basic metal products	1 903	2 066	2 138	+12%	21	46	20.88
9. Paper, cardboard and paper products	498	666	660	+33%	69	77	10.89
10. Pharmaceuticals, toiletries etc.	92	131	160	+73%	69	80	109.31
11. Industrial machinery	200	324	571	+186%	66	68	107.10
12. Electrical mach. and equipment**	266	454	540	+103%	34	43	117.63
13. Transport equipment	191	396	600	+213%	32	35	137.44
14. Prefabricated buildings	37	96	207	+467%	75	77	33.57
15. Other finished goods	599	1 129	1 703	+184%	73	72	54.43

* Including lorries and trailers carried on ferries and trains.
** Including telecommunications equipment.
Source: Statistics Norway, External trade statistics by the Standard International Trade Classification (SITC) (Statbank, Tables 08809 and 08812).
1 = SITC groups 00-12; 2 = SITC group 24; 3 = SITC groups 21-23 + 25 + 26 + 29 + 41-43; 4 = SITC groups 27 + 28; 5 = SITC groups 32-35; 6 = SITC groups 51-53 + 56-59; 7 = SITC group 66; 8 = SITC groups 67-69;; 9 = SITC group 64; 10 = SITC groups 54 + 55; 11 = SITC groups 71-74; 12 = SITC groups 75+76+77; 13 = SITC groups 78 + 79; 14 = SITC group 81; 15 = SITC groups 61-63 + 65 + 82-89 + 9.

A couple of general points are immediately evident from the table above. The first is that there is *little* evidence of “*dematerialisation*”. The sheer tonnage of most categories of imports has risen steeply. The clearest exceptions are timber etc. and ores and minerals. The development in these cases has less to do with Norwegian consumption than with structural changes in Norwegian export industries. Specifically, several pulp and paper mills have closed since 2000, so that the need to supplement Norwegian timber with imports as raw material has diminished. Imports of ores and minerals are mainly inputs to export-oriented smelters, and this branch of industry has not expanded much over the period – there has been an increase in aluminium production, but retrenchment in other sectors including ferro-alloys. Nothing important need be inferred from the relatively moderate growth in imports of paper etc. or of energy goods, of which Norway is a major net exporter. Apart from these categories, all except “metals and basic metal goods” show an increase of 73 % or more – in most cases very much more - from 1993 to 2013.

Another point is that the *share of imports* that reach the country *by lorry* has increased, but not dramatically so. Although this share has grown for 12 of the 15 types of goods in the table, the increase is small or marginal in most of those cases, the exceptions being timber etc. and metals and basic metal goods. The share of imports arriving by lorry could be influenced by their sources, as imports from Europe are more likely to arrive by lorry than imports from other continents, even though some of the latter are unloaded at foreign European ports (e.g. Rotterdam, Hamburg or Gothenburg) and moved by lorry from there to Norway. Traditionally, most Norwegian imports in all the categories shown have originated in Europe, with a partial exception only for ores and minerals, of which about half by tonnage originated in Europe in 1993 and the remainder mainly in Africa or South America. In the age of globalisation, one might assume that imports from other continents – perhaps Asia in particular – would have increased their share in other categories significantly since then. When we measure imports in tons, however, it turns out that the changes have been quite small. Out of 14 categories (excepting ores and minerals) where 68 % or more of imports by weight originated in Europe in 1993, Europe *increased* its share in Norwegian imports of three import categories (food etc., timber etc. and transport equipment). In the case of timber etc. the European share grew from 82 % in 1993 to 95 % in 2013, which partly explains the growth in the share of lorry transport in this case. In seven other categories, the European share of imports fell, but by less than five percentage points from 1993 to 2013. Only in the cases of animal and vegetable raw materials, energy goods (which almost all arrive by sea in any case), non-metallic mineral products and electrical machinery was there a larger drop in the European share. Even in the case of "other finished goods", where imports from China have increased strongly, the European share fell only from 80 % to 77 %, while the Asian share grew from 16 % to 21 %. Had there been a greater shift in the sources of imports, then the increase in the share arriving by lorry, albeit slight for most categories of goods, would have been more notable.

As noted above, it has been suggested that the share of freight with a high value density is growing in European countries, and that this trend can partly explain the growth in lorry transport relative to other modes, since time is often at more of a premium in shipping high-value goods than is the cost per ton-kilometre. It is evident from the table above that import of goods with especially high value densities – categories 10 to 15 – have indeed grown very strongly from 1993 to 2013, and more than the average of all other imports. Large shares of most of these goods do also arrive by lorry, though this is also true of some low-value goods, especially timber. However, we are also interested in the question of how important they may be as drivers of *domestic* lorry transport. As noted in the discussion on trends in domestic transport by type of goods, the category of "other manufactured goods and grouped goods", which includes most of the high-value goods, has shown only moderate growth (12 %) between 1993-1997 and 2008-2013. However, that category also includes goods of the kinds included in categories 8 and 9 in our import table, and some other kinds as well, especially if they are containerised. Imports of high-value goods, and presumably their contribution to domestic lorry transport, have certainly grown much faster. However, they can hardly in absolute terms have made up more than of the total amount of freight in the category of "other manufactured goods and grouped goods", even in 2013. In that year the total in that category was 43.7 Mt. The volume of imports in categories 10-12, 14 and 15 was only 3.2 Mt, and some of the goods did not enter into domestic transport statistics at all, since they were delivered directly to their final destinations by border-crossing lorry. (In the case of prefabricated buildings, this is presumably the rule). On the other hand, weights in the transport statistics include packaging, which the import statistics do not; and more importantly, some of the goods will have been lifted more than once within Norway, in which case they are counted twice or several times in the transport statistics. So we cannot say for certain how much imported goods with particularly high value densities contributed to the overall growth in domestic lorry transport of "other manufactured goods and grouped goods". It may have been much more than the 7-8 % which the figures above might suggest at first glance, but hardly the major part. Another matter is that finished goods, imported or otherwise, may have contributed more to growth in *vehicle* kilometres than in ton kilometres. This is because finished goods, including packaging, often have low weight-to-volume ratios. However, available statistics do not provide any information on this.

Like imports, most categories of Norwegian *exports* grew, and many grew strongly, between 1993 and 2013 (see table below). However, the four most important categories by weight in 2013 were exported predominantly or almost exclusively by ship (or, in the case of gas, by pipeline). They therefore generated little border-crossing lorry transport, and in three of the cases did not generate very much domestic lorry transport either, since not only oil and gas installations but also most metal smelters and chemical plants are located with direct access to the sea so that raw materials can be brought in and finished products shipped with no intervening land transport. There are a few exceptions. Exports of “ores and minerals” – most of which are simply crushed stone for use in construction – do however generate considerable lorry transport to harbour, and are a driver for the increasing domestic transport of “Stone, sand, gravel and clay”.

The next two main categories of exports by weight – timber etc. and food etc. (the latter in a Norwegian context mainly means fish) - have not only grown strongly in volume since 1993; the share exported by lorry has grown significantly in both cases, so these have contributed much to the increase in border-crossing lorry transport. However, fish has only contributed modestly to the growth in domestic goods transport (see table above), since most fish that is not exported directly by lorry is exported directly by sea from the point of processing. In the case of timber etc., there may have been some increase in domestic lorry transport to harbours, but this has been compensated for by a decline in deliveries to pulp and paper mills within the country.

Exports of finished goods with high value densities have increased considerably since 1993, but the absolute quantities remain small, much smaller than Norwegian imports in the same categories. Also, the large share of most of these exports that crossed the border by lorry was probably in most cases sent directly from the point of production, in which case it generated no domestic goods transport. Therefore, goods ultimately destined for export probably only made a minor contribution to the observed growth in domestic transport of “other manufactured goods and grouped goods”. The question remains of what kinds of domestic shipments may have contributed to this growth.

Table 12 *Development of Norwegian exports in tons from 1993 to 2013, split by 15 categories*

Type of goods	Exports, 1000 tons			Increase 1993-2013	Percentage crossing border by lorry		Value density, NOK/kg
	1993	2003	2013		1993	2013	2013
1. Food, fodder, beverages, tobacco	1 337	2 146	2 796	+109%	33	47	23,19
2,.Timber, sawn wood and cork	1 005	712	3 199	+218%	56	69	0,68
3. Other animal and vegetable raw materials	901	1 288	1 192	+32%	36	37	4,87
4. Ores and minerals	12 862	16 177	25 143	+95%	1	1	0,33
5. Energy goods	129 540	203 979	156 991	+21%	0	0	3,90
6. Chemical products	5 605	10 344	10 129	+81%	12	7	3,53
7. Non-metallic mineral products	843	1 034	615	-27%	23	29	2,12
8. Metals and basic metal products	2 946	3 777	3 463	+18%	12	16	16,81
9. Paper, cardboard and paper products	1 665	1 933	1 010	-39%	19	26	4,37

10. Pharmaceuticals, toiletries etc.	73	106	103	+41%	74	66	55,88
11. Industrial machinery	100	165	238	+139%	52	50	179,69
12. Electrical mach. and equipment	41	86	316	+662%	67	16	45,74
13. Transport equipment	50	121	125	+151%	77	67	126,31
14. Prefabricated buildings	26	12	8	-69%	69	74	122,14
15. Other finished goods	293	409	331	+13%	76	86	98,33

Sources and explanations: See previous table.

3.4 Cabotage

Sorrell et al. (2012b) and Åhman (2004), when looking at freight transportation in the UK and Sweden, find that recent developments in freight transport show no sign of absolute decoupling. The reason for this could, according to the two, be found in the derivation of the statistics: Including all lorry activities within a country including transport by foreign trucks, instead of only lorries registered within that country, may strongly affect the degree to which freight transport has been decoupled from economic growth. Transport within countries done by foreign trucks (cabotage) seems to be underestimated in national statistics (McKinnon, 2007b). In a Norwegian context, Berglund et al. (2014) found that cabotage, i.e. foreign trucks doing transportation tasks within Norway, made up a minor share (0.4%) of total road freight transport performance within Norway in 2013. The numbers are obtained from Eurostat (which give statistics about EU countries, candidate countries, and EFTA countries). Thus, the quality of the data obtained would depend on the quality of the data given by only the member countries, which means that one of the neighbour countries, Russia, is not included; and because this is based on survey sampling, the uncertainty associated with these statistics could be high. Still, this relatively low share is also confirmed by a survey of Logistics and Transportation members of NHO (Confederation of Norwegian Enterprise), which also finds that the share is about 0.3 percent of driven tons in 2012. Note that instead of measuring cabotage as the percentage of inland transport performance, it is perhaps more appropriate to remove any commodity that is not attractive or natural for cabotage (e.g. transport of stone, sand and gravel, or of timber) that makes up a large share of domestic tons transported). This was taken into account by Statistics Norway (Berglund et al., 2014), in which they found that the share of cabotage increased to 1.6 percent. We therefore conclude that cabotage is not a concern in Norway based on available evidence.

3.5 Relative energy use and GHG emissions

It is clear that road freight performance has grown rapidly, as a result of increasing tonnages as well as of a modal shift, but most spectacularly is the increasing domestic lengths of haul. Yet we have noted in table 6 that GHG emissions from road freight transport have grown somewhat less than transport performance. Emissions per ton-kilometre have declined by some 20 % from 1990 to 2012. There could be several reasons for this:

- Average capacity utilization in lorries could have improved, due to higher loading factors and/or less empty running.
- The share of heavy lorries in transport performance could be increasing. There is a well-known tendency for heavy vehicles to use less fuel per ton-kilometre than lighter vehicles. If vehicle-kilometres have increased less than ton-kilometres, there is therefore reason to expect a decline in fuel consumption per ton-kilometre.
- The average fuel efficiency of lorries could also have improved for other reasons, such as better engines, reductions in aerodynamic or rolling friction or better driving techniques.
- GHG emissions could have grown less than fuel consumption due to substitution of fossil fuels with other sources of energy, e.g. biofuels.

In fact, most of these factors have been at work. From 1990 to 2012, the share of empty running in domestic goods transport has declined from 29 % to 26.4 %. This alone would explain a reduction of over 3 % in fuel consumption per ton-kilometre. The average tonnage carried by lorries on loaded trips has increased from 11.3 to 12.3 tons. This is probably a combined effect of heavier lorries and better capacity utilization, and could explain a further drop of some 6-8 % in fuel consumption per ton-km. Since 2009 almost all diesel oil sold in Norway has contained a fraction of biodiesel, now commonly 5-7 %, which would explain a corresponding drop in GHG emissions per ton-kilometre. The few percentage points of a likely drop in specific emission which cannot be explained by the three factors above may be due to more efficient engines and drivetrains, less friction and/or better driving techniques.

3.6 Transport efficiency

Two paradoxes related to the size of vehicles are associated with capacity utilization and development. The average load in Norwegian lorries increased steadily in the period from 1993 to 2002. This was as expected, and was partly because of a smaller percentage of empty driving (i.e., without any load) and partly because of an increase in the average size of vehicles. Larger lorries would increase absolute freight loads even if the capacity utilization was not increased. However, it is not possible to distinguish between the two from statistics; in theory, better logistical operations could also increase capacity utilization. The figure below shows the development in average loads in the lorries in the period 1993–2013. An average load of about 9 tons implies a loaded weight of 12 tons. Rather surprising is the development from 2002 onward. It is likely that a reduction in empty driving has nearly reached saturation but that the growth in sizes of vehicles has continued (se figure below).

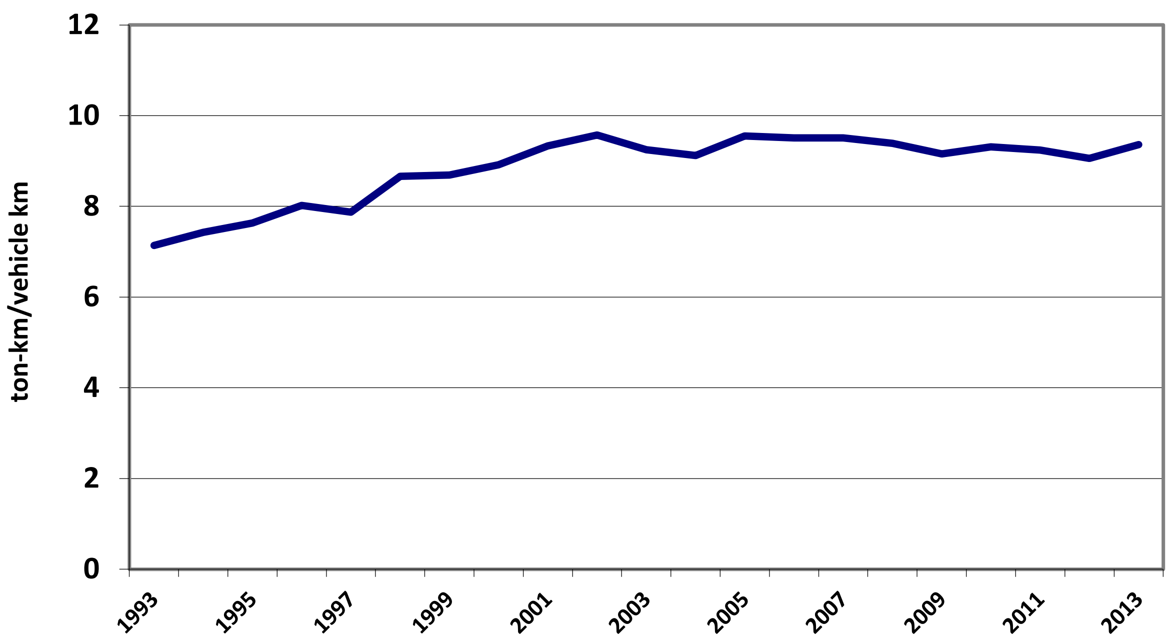

Figure 3 *Transport efficiency (ton-km/vehicle km) - including empty driving in Norwegian domestic freight road transport*

The table below shows a comparison between the after-payload percentage of Norwegian lorries that belonged to different vehicle classes in 2002 and 2013, according to the vehicle registry. The table shows a trend towards a larger share of lorries in the highest payload class. If the average size of lorries employed in domestic transport has indeed gone on increasing after 2002, then the stabilisation of average payload per lorry would suggest a drop in capacity utilisation. Unfortunately the statistics on lorry transport cannot elucidate this issue much further, because *articulated* lorries, tankers and other “special” vehicles – which together are responsible for most of the total road freight transport performance – are not differentiated by size in those statistics. So we cannot say whether e.g. heavier articulated lorries have actually increased their share of transport performance after 2002 relative to lighter articulated lorries.

Table 13 *The percentage development of Norwegian lorries that belonged to different vehicle classes after payload in 2002 and 2013 (percentage)*

Payload, ton	2002	2013
0-4,9	57,9	48,7
5-10,9	18,9	19,8
11-14,9	14,7	16,6
15-30	8,6	14,9
SUM	**100,0**	**100,0**

The *second* paradox is that fuel consumption did not increase, as one might have expected if there were actually a decrease in capacity utilization. Hovi et. al (2009) discussed whether this paradox is because of the way in which the statistics are gathered for each investigation, and pointed to the fact that large variations from year to year for specific classes of lorries are seen. However, the sample is smaller and the expected sampling error larger when looking at specific weight classes. On the other hand, if we consider all vehicles in aggregate as in the figure above, there is a clear break in the trend from 2002 onward.

4.0 Literature review of response drivers at play in road freight transport

We divide our analysis of response drivers in two: In this chapter we do a literature review with an identification of response drivers in Norway and a theoretical discussion of possible responses included empirical finding from other research. In chapter 5 we discuss of responses and rebound effects based on our analysis of national statistics.

In practical policy and sustainable mobility research, freight transport has to a large extent been neglected compared to that of passenger transport (Aall, 2005). The EU has set a goal of decoupling the development of road freight work from an increase in GDP, but this has been interpreted as a relative—not an absolute—decoupling, implying that total energy use and GHG emissions could continue to increase even if the objective was met (Sorrell et al., 2012b).The lack of policies aimed at freight transport could be associated with its complexity as well as strong interests vested in this sector. The sector includes many actors - haulers, shippers, and governments, as well as producers and consumers - that rely on freight transportation. It is not entirely clear who should bear the responsibility of reducing energy use and GHG emissions, and there is little coordination between actors. But probably even more important is the situation of competing policy goals. If an increase in freight transportation is a precondition for continuous economic growth, this situation is most likely to override any attempt to implement any policies curving down energy use and GHG emissions from freight transportation that might impose any restrictions on the total transport work load.

4.1 Policy measures for reducing GHG emissions from road freight transportation

A regulation concerning the fossil carbon intensity of fuels was introduced in Norway in 2009. Bio-blending is a legislative measure with the combined aim of increasing the renewable share of the total energy use of society and reducing GHG emissions from road transportation - the latter applying to both freight and passenger transport. This policy measure fits with what we previously classified as the technological fix approach, and does not enhance any substitution between transport modes nor address the volume of transport. The EU has set a target for increasing the share of renewables in transport fuels (European Union, 2009). One measure to achieve this target is the blending of biodiesel with fossil diesel. The B7 diesel-variety (7% biodiesel) is commonly used in large parts of the EU as in Norway. B7 was implemented in Norway in midyear 2009. Indirect energy use and GHG emissions could outstrip some of the stipulated gains of bio-blending – which in case is a rebound effect. Energy required in the making of biofuels should also be considered.

Environmental problems connected to biofuels other than that of climate change, such as direct and indirect land use change (Plevin et al., 2010; Tilman et al., 2009), have also been identified. Environmental problems connected to the blending itself have also been discovered, in which the blending could cause increased toxicological emissions (Andersen, 2013; Manzetti et al., 2011). These additional environmental impacts (from causes other-than-climate-gases) could be considered trade-off effects if they are a result of measures that try to reduce climate gas emissions but have offsetting effects by increase in other environmental indicators.

Regulation concerning the energy efficiency or size of vehicles is a measure that can reduce both GHG/tkm and energy use/tkm, but not the number of tkms in itself. An example of this kind of policy measure has been implemented in Norway. Norway allows modular lorries of up to 25.25 meters long and a weight of 60 tons in specific stretches from 15th of September 2014 (in the period 2008–2013, these lorries were allowed on a trial basis). Norway allows lorries up to 19.5 meters and a weight of 50 tons in general. Larger lorries allow for better logistical efficiency since more goods can be transported per driver and at lower costs (a reduced need for drivers, fuel, as well as payments connected to using toll roads). The energy use per transported tonne has decreased. A study by the Norwegian Institute of Transport Economics (TØI) for the period 2008-2013 found that module trucks can provide more efficient and environmentally benign freight transport on a few stretches of road with good standard (Wangsness et al., 2014). However, reduced costs could lead to increased demand as well as a modal-shift from less carbon-intensive modes of transportation from rail to road. In order to avoid such negative rebound effects, restrictions have been implemented specifying that modular lorries are not allowed on stretches where they compete with railways. This measure fits with the technological fix strategy and to some extent the substitution strategy; but not with the reduction strategy.

Fuel tax is a heated issue on the policy discourse. This measure may improve technological efficiency as well as promoting modal shifts and provide an incentive to reduce transport volumes. However, this measure may result in a rebound effect through more cabotage transport since the relative cost of domestic transport would increase compared to that of cabotage transport, thus having the potential to reduce some of the anticipated GHG mitigation effect.

Norway, as well as the EU, has applied an overall goal of shifting freight transport from road to rail and sea. The suggested policy instruments to achieve this are twofold: (1) To place more restrictions on road transport, and (2) to make a stronger price differentiation between road on the one side and rail and sea on the other side. Still, in many cases, the reduction of GHG emissions is not used as a main argument when arguing for increased public investments in “better” rail and sea transport (Klimakur 2020, 2010). From the government, this measure is first and foremost about providing investment in the form of subsidies and grants for railway infrastructure (for freight transport, this investment could be in infrastructure for crossing railway tracks and building new terminals) and should also include grants for harbours, even if they are much smaller compared to railway. Theoretically, it is possible that measures that would increase the competition from railway (for example, through rationalisation such as fewer terminals and container transport) would lead to the use of lorries for the transport of smaller amounts or shorter distances. Another possibility is that a shift away from road towards sea and to rail could lead to more liberated space on roads, since fewer lorries are on the roads. In the long run, this space could be counteracted by an increase in newly generated traffic.

The reduction of GHG emissions is seldom used as a main argument in policy documents that discusses the need to improve road standards. Arguments supporting infrastructure improvements are often about improving the conditions for trade of goods and expertise and generally to secure more efficient production and to cause economic growth (Strand et al., 2009 p.1). Improving road quality, e.g. by means of changing road gradient, curvature, and pavement type, may significantly influences fuel consumption. Traffic-related conditions as well as has an influence. Speed is an important variable that is influenced by all other factors (Demir et al., 2011, 2014). However, the effect of road improvements in an environmental policy context is a contested issue both internationally and in Norway. One study by SINTEF (Knudsen and Bang, 2007a; Knudsen and Bang, 2007b) found that on a per ton-kilometre basis, all else being equal, straighter roads (i.e., less curvy and hilly roads on a stretch A to B) lead to a reduction of GHG emissions. Furthermore, they claimed that restraining the capacity of the road network was an environmentally unsound measure for promoting lower emissions from road traffic. However, a literature study performed by TØI (Strand et al., 2009) criticised the SINTEF study for not including indirect emissions for infrastructure and for not properly understanding the role of newly generated traffic. Several studies connected to transport planning have found newly generated traffic connected to increased road capacity (Næss et al., 2012). Road improvements could remove congestion, which reduces the general cost of driving. In the short run, this reduces congestion and makes driving cheaper per kilometre with regard to time and money. Induced travel also illustrated an adjustment in the long run, as transport systems and land use patterns become more dependent on mobility and to obtain access to different activities as well as to goods and services (Næss et al. 2012, Noland and Lem 2002 (Næss et al., 2012; Noland and Lem, 2002). Strand et al. (2009) found the likelihood of increased GHG emissions would be high under the following conditions:

- When roads are builds to solve problems with traffic jams.
- When roads are built to allows for high speed (above 80kmh).

In some cases and contexts it could have an effect on reduction GHG emission:

- When new or improved roads are build where the previous situation was challenging infrastructure conditions with steep gradients and curvy roads.

When considering the environmental effects of infrastructure improvements it is central to take into account the possibility for newly generated traffic as well as the indirect energy use for construction of roads. The inclusion of a climate policy motivated argument for improving road standards can in most cases be associated with a technological fix policy mentality. This situation could, in fact, enhance road-freight transport.

There are no examples of Norwegian policy measures that is specifically aimed at reducing the volume of transportation. However, the current legislative framework in Norway for transport and land-use planning has probably contributed in reducing demands on person transportation, and thus probably also slowed down to some extent the increase in energy use and GHG emissions from transport during the last decades. The potential effects of this on freight transport is unknown, most of all because this is an under-research area, and thus very little is known about how land-use planning may influence on freight transportation. Still, it does not seem likely that current land-use practices in Norway has had any major effect on mitigating energy use and GHG emissions from freight transport as a whole – most of all because this concern has not been part of any goals involved in land-use planning. Still, partial effects of specific land-use strategies may occur. Intra-urban freight transport by vans, for example, will in principle be more extensive in low-density sprawling cities than in dense cities because of the longer average distances between origins and destinations in the latter.

Land-use planning has the potential of influencing freight transport. It might promote modal shifts (e.g. if business areas are located near railways or harbours); shorter lengths of haul (e.g. if different parts in the business value-chain are localised close to each other). Knowledge on how land-use planning may influence on freight transportation is scarce; and few policy strategies exist on how to apply land-use planning to influence freight transportation. Thus, there is a need to strengthen research on this area.

4.2 Autonomous measures aiming to increase energy and GHG efficiency

By autonomous measures we mean measures for energy saving or mitigating GHG emissions carried out by the transport industry independent of any existing policy goals and measures.

Eco-driving is a measure that is applied for both freight and passenger transport. It is about shifting behaviour of the driver, and thus fits with the technology fix strategy – and not with the substitution or the volume strategy. It promotes itself as a measure that is both environmentally and economically benign. Several studies have found that modifying driving behaviour has in fact a potential to lower fuel consumption. However, the actual reduction has been debated (Walnum and Simonsen, 2015). A difference was found for bus drivers in the short and long run. In a situation where eco-driving was reported to have saved 10–15% of fuel consumption during training, this figure had decreased to about 4–5% three months after training; and long-term savings were found to be around 2% (af Wåhlberg, 2007). Eco-driving is not a mandatory part of driving license education in Norway. However, an increased awareness about eco driving has been documented in recent years. Several EU countries have incorporated both a theoretical and a practical introduction to eco-driving into driver's education[3], and many of the largest transport companies operating in Norway use eco-driving training for drivers. Furthermore, the sale of on-board systems to monitor fuel consumption as well as eco-driving practices in the transport sector have increased rapidly during recent years.

Technical measures, such as adjustments to the type of trailer, tires, lubricants, and curb weight, as well as the aerodynamics of trailers, could easily save fuel consumption by 5–10% (Demir et al., 2014; Nylund and Erkkilä, 2005). These measures fit with the technological fix strategy and are first and foremost connected to competition between lorry producers and transport companies; to some extent it could also be influenced by vehicle as well as transport service procurement.

Better logistical efficiency and improved capacity utilization may reduce the cost per ton-kilometre connected to work, hence also reducing energy use and GHG emissions. However, as discussed above, this can also lead to increased demand for lorry transport and thus create a rebound effect.

4.3 Structural changes that might influence on energy use and GHG emissions

Globalization in the form of market integration and a shift from a Fordian to a post-Fordian mode of production (i.e., from a unique place or plant to a production chain scattered throughout an area, often in different countries) could explain outsourcing. Outsourcing, increased specialisation of activities and optimizing management costs, all of which are motivated by a hope for production cost reductions, can be considered a distinctive feature of the post-Fordian production mode. Globalization of the freight transport system, motivated by a hope for more efficient supply chains, could all together trigger a more complex system that could lead to an increase in the overall freight transportation work – thus also an increase in energy use and GHG emissions (Ruzzenenti and Basosi, 2008). More efficient logistical systems could be both a cause and an effect. Similar effects could be observed within countries where there is a tendency of concentration of production and larger distribution centres which could make the transport system more energy efficient on a per unit basis; however at the same time leading to an increase in the total transport work, energy use and GHG emissions.

Dematerialization has been discussed as a means to decouple freight transport from economic growth (McKinnon, 2007b). According to Lorek (2015), dematerialization refers to a reduction in the quantity of materials used to serve production and consumption needs. As a result, dematerialization will be evident in the sense of lighter and smaller items and products with regard to functionality.

4.4 Summary of measures

In the table below we have summarised the measures discussed in international research literature in connection to the challenge of reducing substantially the energy use and GHG emissions from freight transportation. As can be seen from the table below most of the measures we have discussed fits with the efficiency/technological fix strategy for achieving sustainable mobility, and few fits with the substitution or reduced volume strategy.

[3] http://www.ecodrive.org

***Table 14** Summary of current measures aimed at reducing energy use and GHG emissions from freight transportation*

Measure	Link with sustainable mobility strategies	Possible rebound effects	Other comments
Bio-blending	Efficiency/technological fix	Possible higher GHG emissions when taken the life cycle of the fuel into consideration.	Trade-off effects connected to toxicological emissions as well as concern for direct and indirect land use effects.
Allowance of larger size of lorries	Efficiency/technological fix	Better logistical efficiency could generate lower cost and increase the demand for road freight transport. Possible that this will make lorries more attractive compared to other transport modes.	An important addition in legislation is not to allow modular lorries in cases where there is a real competition with rail.
Increasing investment in rail infrastructure	Substitution	May increase the need for “supply” transport with lorries. Possibilities for newly generated traffic on road since more space on roads are liberated. This could lead to an overall increase in freight volumes.	GHG emissions reduction is one of many goals when reason for investment in rail infrastructure is done.
Eco driving, technical improvements and logistical efficiency	Efficiency/technological fix	Reduce the fuel cost per ton-kilometre. This could increase the demand for lorry transport. Will also have an influence the transport distance and speed of goods transport.	Long term consequences needs to be accounted for the physical infrastructure could be affected in the long run, such as localisation of distribution centres,
Re-regionalisation	Reduced volume of mobility	One possible effect is less efficient lorry transport (smaller lorries or less capacity utilization) and possibly less efficient stationary energy use.	A negative modal shift because distances become so short that lorries are the only realistic mode of transport.
Dematerialisation i.e. smaller and lighter products for the same function	Uncertain.	Longer transport distances since the relative cost of transport decreases.	Difficult to place under any of the three identifies sustainable mobility strategies
Investment in roads	Efficiency / technological fix.	Newly generated traffic.	In some cases used as a co-argument for reducing GHG emissions. Also indirect emission i.e. from building and maintenance of roads needs to be considered. Could increase the intermodal competition in favour of freight transport by road.

5.0 Possible rebound effects

In the literature review we found that it was likely that eco-driving, logistical efficiency, technical improvements, allowance of larger vehicles as well as bio-blending would increase energy use and GHG emission efficiency. From our statistical analysis we have documented that GHG emissions per ton-kilometre for the case of Norway have declined by some 20% from 1990 to 2012. However, using available statistics, it is difficult to explain why this situation has occurred; e.g. the effect of bio-blending, the effects of change in driver behaviour, compared to the effect of less empty running, infrastructure improvements or engine efficiency improvements. Furthermore, we do not know how the development in lorry size has been during the period investigated due to limitations in public statistics. The only possible explanatory factor we have been able to deduce from available public statistics is an increase in average load weight on lorries until 2002/2003, when it levelled off.

Within the energy economic tradition, the size of the rebound effect is measured through improvements in fuel efficiency (for example, per ton kilometre, tkm) and the contributions that the related operating cost reductions make to the increased demand for lorry transport. Central to that of estimating this effect is the ratio of fuel costs to other lorry costs, such as capital and wages. In Norway, this is approximately 24% - so if fuel consumption per tkm has decreased by some 15 % for the same period (an approximate since we have estimated that CO_2/tkm dropped with 20% and we have subtracted the bio-blending share which was between 5-7%). The cost of truck transport may have decreased by slightly less than 4 % per tkm for the same period, relative to what it would have been with no improvement in fuel efficiency. This could mean that, in some cases, lorry transport has gained an advantage over rail transport, or that the slightly lower cost of transport may have strengthened the incentive to centralise production and logistics facilities. However, it is not possible to explore such effects in detail with the aggregated statistics available. It is also evident that larger lorries allow for better logistical efficiency because more goods can be transported per trip, resulting in lower wage, fuel and road toll costs. This must be accounted for when economic gains in shifts to larger lorries are made. However, we could not follow up on this either due to data limitations. What still is evident is that during the period of our investigation is that the increase in fuel efficiency has not been able to counteracted the effect of increased volume of road freight transport had for GHG emissions. In the period 1993-2013 it has been a a an increase in total GHG emissions.

Taxes on fuels have been used as a policy measure to take into account GHG emissions and other externalities, such as local pollution, noise, queues and traffic accidents. We have analysed the development of fuel prices, including the proportion of CO_2 and road-use tax included in these prices. In 1995 the two taxes contributed to 21 percent of total cost for diesel, in 2013 this share had increased to 30 percent. Still we believe that the cost of externalities mirrored in the level of taxes on fuel is too low to influence the transport volume in such a way that this will help the transport sector to meet the current GHG emissions reduction targets.

It has long been a policy goal in Norway to increase sea and rail freight transportation on the expense of road transportation (Klimakur 2020). This has been one of the reasons for increased investment in railways. We have analysed the development of investment in railways since 1993. We used the actual expenditures for each year, not the amounts planned for in the national budget, and we deflated the numbers to get constant monetary units. There is no specific price index for railway construction, so we have applied the same deflator as for roads (described in detail below). It is likely that the trends in costs have been very broadly similar, and that they influence each other. Proponents of more investments in railways have been critical of high levels of road investments on the grounds that these inflate the costs of railway construction, since the two compete for many of the same resources. The table below shows that there has been a steep increase in investment in railways from 2009 onward.

This shift might have been motived by climate policy considerations. However, our investigations do not give grounds for such a conclusion – and most likely this shift is also due to other considerations as outlined under chapter 4.

Table 15 *Investments in railway in real and constant prices, 1 000 NOK (1993-2013)*

Year	Government allocations for investments in, maintenance and operation of rail infrastructure, current prices	Figures at constant 2013 prices (using a proxy deflator – see text)	Index of constant prices (1993 = 100)
1993	2 400 473	4 625 189	100
1994	2 503 638	4 759 768	103
1995	2 898 061	5 376 737	116
1996	3 409 567	6 210 505	134
1997	3 515 416	6 311 339	136
1998	3 927 970	6 989 270	151
1999	4 072 098	7 008 775	152
2000	4 012 706	6 621 627	143
2001	4 547 319	7 275 710	157
2002	4 402 630	6 900 674	149
2003	4 762 039	7 204 295	156
2004	4 856 362	7 110 340	154
2005	4 565 646	6 421 443	139
2006	4 771 767	6 430 953	139
2007	5 660 943	7 202 218	156
2008	6 057 000	7 092 506	153
2009	7 801 295	9 092 418	197
2010	9 278 148	10 424 885	225
2011	10 078 738	10 642 807	230
2012	10 706 364	10 980 886	237
2013	12 084 113	12 084 113	261

Although the increase in expenditures on construction and – not least – maintenance of railways in 2009 reflects some degree of political will to improve their competitiveness in both goods and passenger transport, it is still too early expect very visible effects when it comes to any reduction in GHG emissions from freight transportation. Stretches of new track on which work was started during the last few years of our investigation period may still not have opened in 2013, and while the immediate effect of more maintenance activity may actually be more interruptions and delays due to work in progress, the positive effects will inevitably take longer to fully materialise. Even if improved track maintenance makes goods trains run more punctually, it may take some time before businesses come to count on this as a lasting new situation, and therefore reconsider their choices between lorry and rail transport. Furthermore, passenger transportation has priority over freight transportation for most railroad tracks.

We have also included an analysis of road improvements. However, road investments is seldom used as an argument to curb GHG emissions, even if it has been argued in the political debate in Norway and internationally that better roads will reduce GHG emissions. Another argument for including an assessment of road investment is the intermodal competition between road and sea and rail transport (off course this will dependent on lengths of haul and transport corridors). The table below shows the development in national classified road investment in NOK during the years 1993 to 2013. We obtained the numbers from the annual government budget for each specific year. We included central government outlays for construction, maintenance and operation of State highways and the portion of the income from tolls on that was reinvested in road construction. Investments in county roads, some of which are also important to lorry transport, were not included due to poor data availability. There was a break in the statistical series from 2009 to 2010. From the 1st of January 2010, many State roads were transferred to the counties, so that new investments or maintenance and operating costs for these stretches of road no longer appear in the central government accounts. The large drop in outlays from 2009 to 2010 is a result of this, and not of an actual construction and maintenance activities. In some years (both before and after 2009) the central government road budget also included grants to the counties for road purposes. These have been consistently excluded from our figures, so that they refer to outlays for State roads only. The figure for 2013 has been adjusted downwards, as most of an apparent sharp increase in the central government road budget in that year occurred for a technical, fiscal reason. From 2013 road works were made subject to VAT, and the allocation for State roads was increased by 3.2 billion kroner simply to compensate for this. That compensation has been deducted from our figure. We have not found data on the amount of road toll income that was *made available for investments* in 1993 or 2002. Figures for these years are therefore lacking in the table below.

We have converted the current NOK figures to constant 2013 NOK by using a deflator that, for the period 2000-2013, is based on mean values of two price indices published by Statistics Norway: a “Construction cost index for road construction” and a “Cost index for maintenance and operation of roads”. In fact, the two indices have followed each other very closely, so the result of using a mean is almost the same as if we had used the construction index alone. To cover the 1993-2000 period we chained the index to an older one, a “Construction cost index for State and county roads” that ran from 1985 to 2004. No separate index for maintenance and operating costs is available for the years before 2000.

***Table 16** Expenditure on State roads from 1993 to 2013*

Year	Central government allocations, 1000 current NOK	Toll income made available for road investments, 1000 current NOK	Total expenditure on State roads, 1000 NOK at constant 2013 prices	Index of constant expenditure (1993 = 100)
1993	8 565 513		16 503 879	100
1994	7 857 846	1 073 000	16 978 795	103
1995	7 911 363	1 037 000	16 601 787	101
1996	9 239 072	938 000	18 537 472	112
1997	9 388 000	1 495 000	19 538 600	118
1998	9 219 308	1 998 000	19 959 623	121
1999	9 331 397	2 155 000	19 770 046	120
2000	9 959 083	1 718 000	19 269 114	117
2001	10 569 259	1 636 000	19 528 414	118
2002	11 931 712		18 701 743	113
2003	10 986 407	2 330 000	20 145 850	122
2004	12 030 562	2 520 000	21 303 898	129
2005	13 279 372	3 560 000	23 684 068	144
2006	13 411 102	3 875 000	23 296 633	141
2007	14 727 215	4 170 000	24 042 258	146
2008	16 578 873	5 400 000	25 736 385	156
2009	18 932 847	6 513 000	29 657 164	180

2010	14 943 989	4 610 000	21 970 774	133
2011	15 260 002	5 320 000	21 731 787	132
2012	16 394 172	7 365 000	24 368 382	148
2013	18 364 456	8 562 000	26 926 456	163

The effect of infrastructure improvements on energy use and GHG emissions is difficult to analyse based on our statistical material. The amount of money invested in roads does not say anything about how the money is used. If used to produce flatter roads with fewer and sharp bends, fuel consumption may decrease. On the other hand, investments to improve road quality to allow for increased speeds (above 80 kph) may increase energy use and related GHG emissions, and increased capacity, due for instance to wider roads, may invite more traffic, of lorries as well as cars. In addition the effect on intermodal competition needs to be assessed. One way to study this would be to perform a micro analysis on specific stretches of road where a tunnel or other improvements have resulted in shortened distances and eliminated vertical curves on the road; such improvements should have the potential to lead to reduced GHG emissions. Then it could be possible to measure how much the lorry traffic has increased after the improvement. In principle, such a stretch should not have any real competition with other stretches since it could be difficult to distinguish between newly induce travels and generated traffic, and other variables that affect traffic growth need to be controlled for in such a model. We have not performed such an analysis in this project because we did not have the time or resources to collect the necessary statistics. TØI has conducted a literature review and theoretical simulations on these matters and found that in most cases road building and maintenance as well as the effect of newly generated traffic increase GHG emissions (Strand et al., 2009).

We have not been able to gather data on investments in harbours. A large share of public harbours are operated by many municipal, inter-municipal and private companies, and no national statistics on their combined investments are available. The rest of the harbours are state owned.

Apart from taxes and infrastructure investments, government can, at least in principle, influence the amount of road freight transport through land-use planning or other measures designed to shorten the distances between businesses and their suppliers and/or customers. Land-use planning can have – as already mentioned above - several effects. Anyone wishing to establish a factory, warehouse or distribution centre needs planning permission. In principle, this could be used to ensure as far as possible that businesses locate as close as possible to their likely main markets or suppliers. It could also be used to ensure that they locate close to harbours or rail terminals, to encourage use of ship or rail transport (if these could be relevant options for the business concerned). However, land use planning in Norway is in the hands of local, not central government, and the local authorities have very little scope for “steering” localisation choices at the macro level; also, the majority of them do not have railway terminals or general cargo harbours within their borders. We have not examined the extent to which local authorities that might have some leverage have exploited this to make businesses locate so that lorry transport may be minimised, but assume that the effect of any such policies on the overall volume of road freight transport at the national level has been small at best.

A special case is that of businesses which do in any case mainly serve local markets and therefore generate quite a lot of transport in the shape of local (intra-city) distribution. In such cases, the average lengths of haul will be influenced by urban density, i.e. by whether the population is concentrated within a small area or spread out over a large one. This is well-known from research on passenger car transport: It has been found that dense, concentrated cities require less motorized transport and depend to a lesser extent on private cars than low-density, sprawling cities. Mainly because of the effect on passenger transport demand, it is a policy goal to increase urban densities, i.e. to provide space for new housing and enterprises by infilling rather than new development around the fringes of Norwegian cities. In this matter, the local authorities are not altogether independent, as central government guidelines actually require them to pursue such policies. However, these are slow-working policies: from 1 January 2000 to 31 December 2011 there was an increase of just 2.9% in average density (persons/km^2) in the built-up areas Norwegian towns and cities. After 2011 there is a break in the time series, so development cannot be tracked further. Also, we do not know how patterns or modes of local distribution may have changed.

6.0 Discussion

In the Norwegian statistics for road freight transport we identified main indirect drivers (GDP, industrial development, developments in commodities and goods in different categories) and direct drivers (tons transported, share of road transport, share of empty running, average length of haul, carbon intensity of fuel).

A close link exists between GDP and freight transport growth in the period 1993–2013. As such, it seems to be unrealistic in the short run to reduce the demand for freight transport in a Norwegian setting as long as the economy keeps growing. Another mitigation strategy, which is very much discussed in the European Union as well as in Norway, is to move goods from road towards sea and railway; however, development during the period has gone in the opposite direction. Barriers connected to price, speed (faster competing transport modes, such as faster boats, will make competing transport forms less environmental benign) and to make deliverables in time make such a change difficult. Although there are signs that the efficiency connected to fuels has improved somewhat since 2002, we had a rather surprising finding regarding a decline in the average ton transported since 2002/2003. One reason for decrease in ton transported could be a tendency for some of the goods to be less dense and that more air is being transported for some of the goods categories, however this hypothesis is difficult to substantiate.

Based on theories and empirical finding from the international literature, we have two rather surprising findings for road freight transport in the period 1993–2013. There are no signs of dematerialization (different functions or needs being satisfied with less material use) over this period.
We also do not see any tendency that high-value goods per ton have any influence on increasing the growth in transport by lorries. In Norway, there has been a strong increase in the transport of stone, gravel and sand (partly for export for use in European infrastructure projects), unprocessed agricultural products, ore, metal scrap, mineral raw material, and most likely waste.

A rather positive sign from an environmental policy point of view is that throughout the period there seems to be a decrease in specific GHG emissions associated with road freight transport and that logistical efficiency has, at least for part of the period, been increasing. However, this has not been sufficient to curb the increased volume of transport. Looking at theories associated with rebound effects it is likely that efficiency gains would be used to increase activities and at least partly counteract savings from the efficiency gains. And it is evident that as long as the demand for freight transport increases in a competitive market, efficiency gains would probably be used for more road transport of goods.

If the demand for freight transport continues to grow as it has over the past 20 years, it seems unlikely that efficiency measures would be sufficient to reduce total emissions; there are also currently limited possibilities for modal shifts in the sector and fuel switch options have not come as far as for passenger vehicles. The GHG emission mitigation possibilities for road freight transport seem more limited than for passenger transport since the same possibility for usages of electrical batteries do not exist, with the exception of small-size trucks in a city environment. The use of biofuels could be an alternative - however, several problems, such as an increased energy use and harmful land use, will impede this strategy. The use of fuel cells (i.e., to deliver power to onboard devices) has also been discussed; however, such measures will not counteract the need of a drastic reduction of energy use and GHG emissions from the road freight transport sector. In the short run, we see *no realistic technological measures* available for making the Norwegian freight transportation system radically less carbon intensive.

We found that that the data we gathered at the macro level had a resolution to make a calculation of rebound effects as understood within the energy economic tradition of rebound i.e. how fuel efficiency reduce cost and thereby increased demand. Even if data was available, many simplified model assumptions needs to be taken to isolate the rebound effect. Current models do not account for the complexity in the freight transport business, since the freight transport business consists of shippers, carriers, logistics providers and goods handlers. Freight parameters are dynamic; for example, payload and other operating practices can change in correlation with lower fuel cost. How are decisions made by lorry owner-operators and freight customers, and how do variables, such as fuel and vehicle capital cost, factor into decision making related to fuel consumption and demand for lorry services? Furthermore, such a calculation would be dependent on data about commodity type, distance shipped and availability of modal alternatives (Winebrake et al., 2012) which would have demanded a higher resolution than the aggregated statistics at the national level.

Our approach have been novel by making a theoretical consideration of rebound associated with self-regulative and policy measures that have had reduction of GHG emissions as primary or subordinate goal, which we have discussed against routes to achieve radical less GHG emissions in road freight transport. Interesting to observe is that many of the proposed solutions connected to reducing GHG emission in freight transport contains several goals that might be counteractive to each other, such as both to be environmental benign as well as contribute to increased amount of traffic. Even Norway's effort for increased railway investment is only partly motivated by reduction of GHG emission, but rather motivated by other issues such as increased accommodation/labour market. We will argue that it is not important to find out how the aggregated fuel intensity savings per tkm, which was about 4 percent for the period under investigation, has influenced demand for lorry transport. Our main interest has been finding out "the big picture". By applying the so-called DPSIR model we have looked at the drivers for growth in road transport, we have found that growth in the economy and increased amount of tons transported are the main drivers. We find it unlikely that the measures proposed connected to technological fix or efficiency will lead to drastic reduction in GHG emission from road freight transport, and the measures we have looked at have most likely rebound effects attached to them. The increased investment in railway will be an interesting case to follow in some years to see if it has had any effect on modal shift, however Increased road investments may partly counteract a modal shift from road to rail.

Several methodological challenges were found. We could not follow the true distances of goods moved. The goods could be moving farther, which in common-sense terms means an increase in kilometres, although that will not necessarily be shown in freight-transport statistics. Handling factors convert the physical weight of goods into freight tonnes lifted (as goods pass through the supply chain, products are lifted onto vehicles several times). If a given type of good is moved an average of 100 kilometres in year A and 200 kilometres in year B, but moved only once in both years, then this would appear as an increase in the average length of haul (in kilometres) (McKinnon, 2007b). However, if the 200 kilometres in year B consisted of two trips (that is, the goods were unloaded at warehouses midway and then loaded onto new lorries to complete their trip), then the length of haul would be unchanged but the number of tons transported will appear to have doubled. That is, the tonnage of goods is counted each time they are loaded onto a new vehicle; the number of such events is called the handling factor (Hille, 2014). We also found that it is difficult to explain why the capacity utilization of trucks increases until 2002 and then decreases. A major concern has been how changes in statistical accounting have a major influence on the comparability of data and quality of data sets for the period under investigations. Another challenge found in the statistics is that the goods transported by railway are mostly container goods and over 80% are classified as "grouped goods" or "unidentified goods" (with the exception of ore transport on Ofoten railway). It is also difficult to find numbers for railway supply, which is a function of price, numbers of terminals and delivery within time constraints, as well as the number of terminals, i.e., how many places goods could be shipped to. It is thus difficult to find a specific number for this in the Norwegian context.

It is challenging to find a quantification of the effects of drivers, and especially indirect drivers, in historical data. It is also difficult to reduce indirect drivers to one factor. Is road capacity, for example, the width of the roads or the average transport time? Unfortunately, the development for both of these indicators is not available.

In general, we see that the statistics could be improved by having more data on the contents of the containers that are transported (however this will be challenging). It could also be useful to have a coupling of data from several sources both inside and outside Statistics Norway. This could include a better accounting from Road goods transport by Norwegian lorries (from those who ship goods) of whether this is a “sent on” of goods and where the goods came from previously (in the supply chain).

7.0 Conclusion

We have looked for examples of measures that fits with three different pathways and strategies to *substantially reduce* energy use and GHG emissions from road freight transport: technological fix, substitution and reduction. Beside these three categories lies a possibility for business as usual or «no change», that involves that there is not any action that systematically seeks to reduce energy use and GHG emissions from freight road transport. Looking at the statistics and literature we can conclude that systematic policies aimed at achieving reductions in energy use or GHG emissions from road freight transportation have only to a very limited degree been implemented in Norway - with the exception of bio-blending and – possibly - increased railway investment. Nor have we been able to detect any important autonomous technology changes that might substantially contribute in the same way - although capacity utilization has slightly improved.

The volume of road freight transportation and related energy use and GHG emissions has gone in the wrong direction. Some policy and technological changes have been found. However, this has not been enough to yield an absolute reduction of GHG-emissions from road freight transport. Many of the proposed solutions do not aim to do anything about the underlying causes of increased energy use and GHG emissions from road freight transport. When the underlying causes are not addressed, we believe there will be room for large rebound effects to come into play, which again may support that freight transport volumes will continue to rise, with the probable result that no major reduction in GHG emissions will be achieved.

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