NORGES HANDELSHØYSKOLE

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THE ROAD FROM DIESEL TO NATURAL GAS

The impact of changing fuel sources in road transportation: the case of Kuehne + Nagel

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Master Thesis within the main profile of

Energy, Natural Resources and the Environment.

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ABSTRACT

With climate change abatement as an important player in the policy agenda of Norway and Europe, the transportation industry finds itself in need of finding new ways to make the industry more environmental-friendly. Fuel is not only one of their principal working tools and a significant cost in the overall equation, but it could also be a step forward towards a greener transport industry. This research explores some of the potential outcomes of changing fuel sources for the logistics company Kuehne+Nagel. With a focus on CO_2 emissions, the author compares actual and potential performance of diesel, liquefied natural gas (LNG) and compressed natural gas (CNG) for specific transportation routes as well as the costs involved.

1. INTRODUCTION

Globally, the transportation sector is expected to meet important challenges. World's population is expected to reach 9.2 billion over the next four decades. With this significant demographic growth, travel and road freight will at least double their rates in order to supply the increased demand of transportation. Consequently, the demand of fuel would also increase about 82% for all transportation modes particularly that of trucks, buses, trains, ships and airplanes. While these projections are good news for the logistics industry, the environment will suffer an increase of at least 79% of total CO_2 emissions, depending on the ability of governments' intervention and success of climate change abatement policies. (World Energy Council, 2011)

The energy sector, particularly oil production is constantly attacked because of their negative impact to the environment. Therefore, it is not unreasonable to assume that it would be in their interest work with a greener supply chain. In Norway, oil production is partly supplied by "nodes" or bases along the coast. Traffic within these nodes is mainly provided by road and it is called base-to-base logistics. Nowadays, the logistics services, base-to-base traffic included, faces the struggle of providing cost effective solutions and being subject to strict regulations and standards from climate change abatement policies. Despite the importance of road transportation both as an engine of the world's economy and as a carbon intensive activity, there is little support to find alternative solutions. Hence, this paper joins the quest of exploring the impact that switching fuels from diesel to natural gas could have for one of the specialists of the base-to-base service: Kuehne+Nagel.

Some of the limitations facing this analysis are that the market of natural gas fuel for trucks is not developed in Norway. In other words there is an insufficient infrastructure of supply of natural gas for heavy-duty vehicles. As a consequence, the market of natural gas-fueled trucks is also under development. In addition, there is uncertainty regarding the future of natural gas. Contrary to the opinion that positions natural gas as a bridge to alternative fuels (U.S. Energy Information Administration, 2013) (Brown, Krupnick, & Walls, 2009), scientists and economists argue that natural gas is a pollutant fossil fuel and some of the extraction methods are not so environmental-friendly that the fuel could be labeled *alternative* or *green* (Levi, 2013) (Stephenson & Doukas, 2012) (Howarth, Santoro, & Ingraffea, 2011). In the process of developing this research it was found that the success of switching fuel sources is not entirely up to the company subject to this study, but to a whole group of agents involved. Such agents are illustrated in figure 1 below.

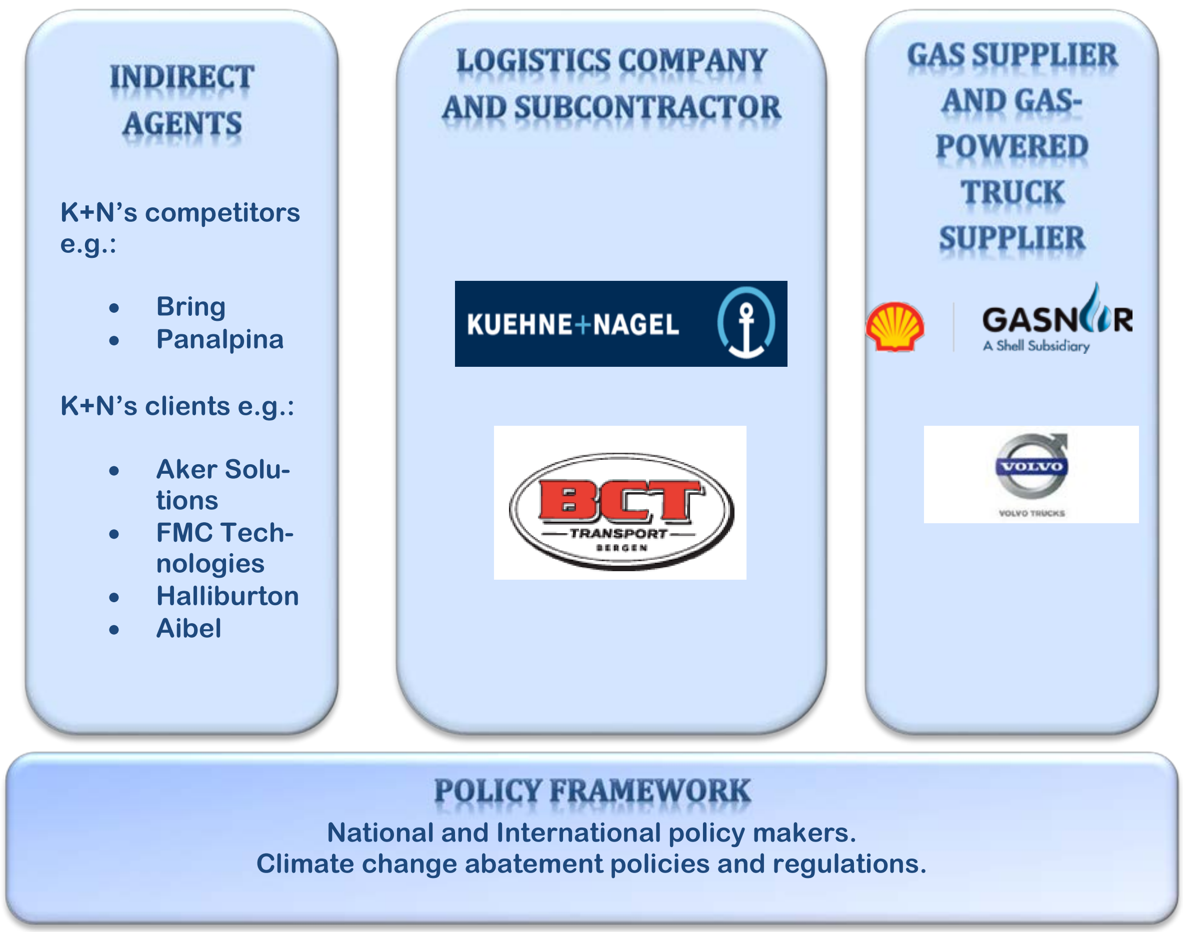


Figure 1. Main actors in the analysis of the research. Elaborated by the author.

Kuehne+Nagel's competitors and clients have been denominated indirect agents in the figure. The reason is that the close relation and cooperation between competitors is necessary to implement the infrastructure of natural gas supply. Clients play also a very important role; they need to be convinced, and willing to pay for the benefits of implementing natural gas technology to deliver their products. Kuehne+Nagel outsources truck services from subcontractors who own the vehicles. As with the gas company (GasNor), they would share

the responsibility of building the necessary infrastructure to provide natural gas fuel. Suppliers of gas-powered trucks must develop efficient technology that covers the needs of transportation of K+N's clients. Finally, all of these companies are subject to a policy framework that aspires to the achievement of ambitious environmental goals.
Considering the roles of the above-mentioned stakeholders, it is the intention of this thesis to answer the following research questions:

- *What are the costs of using Natural Gas as a fuel for road transportation for Kuehne and Nagel?*
- *What are the benefits of using Natural Gas as a fuel for transportation for Kuehne and Nagel?*
- *Is it feasible to rely on Natural Gas as a fuel for road transportation in the near future?*

The structure of this work is illustrated in the figure below (2).

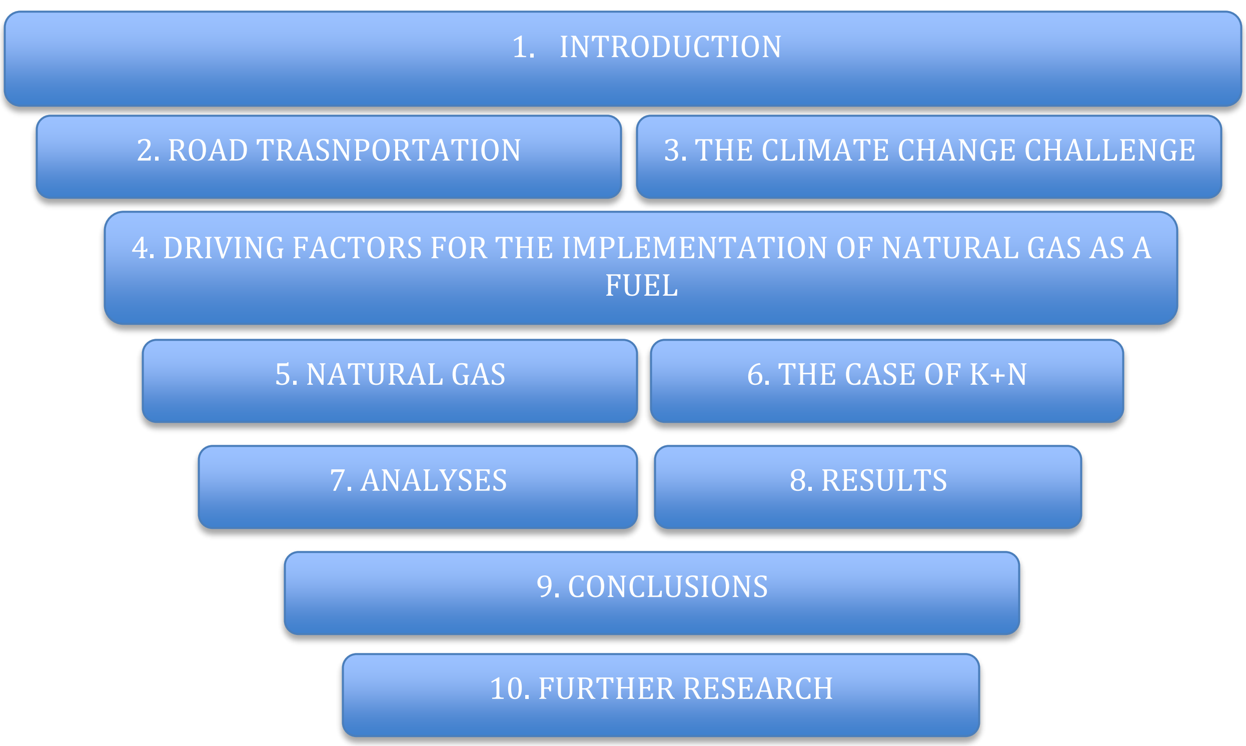


Figure 2. Structure of the thesis.

1.2 RESEARCH OBJECTIVES

The aim of this research work is to meet the following objectives:

- To describe the current situation of the transportation industry's relation to environmental and climate change issues.

- To assess the economic and environmental impact of changing from gasoline to natural gas as the fuel source for a logistics company.

- To identify and analyze the main factors that influences the change of using natural gas as a fuel for road transportation.

- To estimate whether natural gas as a fuel is more economical than diesel.

- To estimate the actual environmental benefits of natural gas as a fuel.

2. ROAD TRANSPORTATION

2.1 ROAD TRANSPORTATION IN NORWAY

The following section aims to provide the reader with an insight of the current transport situation in Norway, from a physical, industrial and political perspective.

As of December 2012 Norway had 93 822 km of public road, of which 392 km are motorways. This is by far the shortest motorway length among the Nordic countries. Tendencies for freight transportation demand in Norway have fluctuated since the economic crisis in 2008 that affected important markets in Europe. However, in 2010 Norway had an increase of 7% in the demand for this service followed by a slight decrease in 2011. (Norwegian Ministry of Transport and Communications, 2013)

Every four years, a National Transport Plan is submitted to the Norwegian Parliament. This document sets the goals and strategies to follow for the next decade. The Plan is an extensive work backed up by input from ministries, agencies, county authorities, urban municipalities, organizations and businesses within the transportation industry. The National Transportation Plan 2013-2014 is based on the improvement of the different modes of transportation, while keeping a low environmental impact and complying with the national goals for carbon reduction. As for road transportation, the plan aspires to link Western Norway throughout an upgraded and ferry-free highway E39. In addition, upgrades and important developments in Southern Norway are expected. The most significant investment will be made on road transportation, accounting for 62.46% of total investment with respect to other transportation modes. However, much effort is directed to shift more freight from road to sea and rail. The Government's strategy consists on improving efficiency through targeting infrastructure and development of all the transportation sectors and facilitating multimodal transportation through hubs[1]. (Norwegian Ministry of Transport and Communications, 2013)

[1] Hubs are defined by the Oxford dictionary as a central facility from which many services operate.

Freight transportation in Europe accounts for about 1/3 of the total energy consumption where road transportation has the largest share. (Statistisk sentralbyrå, 2013) Expressed in tonne[2] - kilometers, road transportation in Europe accounts for 74.9% of inland transport, tendencies for road transportation have not presented an outstanding change, especially compared to rail transportation which had increased by 19% in 2011. Appendix 2 shows that the behavior of goods transportation in Europe and Norway is very similar; this is dominated by road freight. (European Comission, 2013)

Statistics Norway (SSB, 2014,a) reports that in the third quarter of 2013, Norwegian lorries with a carrying capacity of 3.5 tons or more transported 4.4 billion tonne-kilometers. The report differentiates between "hire or reward" and lorries transporting for own account, concluding that transport for "hire or reward" dominates with a 76.7 %. Furthermore, 138 million km of empty driving were also accounted, representing a slight increase of 7.1% with respect to the third quarter of 2012. Empty hauling accounts for approximately the same for hire or reward and own account (25.1% and 26.1% respectively).
Groups of costs of road transportation activities according to lorry owners have been defined as (SSB, 2014,b):

1. Wage and social costs
2. Repair and service costs
3. Fuel
4. Tires
5. Administration
6. Insurance
7. Ferry costs and road tolls
8. Capital costs

[2] Tonne is defined as the metric unit equivalent to 1000 kg.

According to the source Statistics Norway, all of these groups presented an average increase of 3.7% from 2013 to 2014. When it comes to emissions of greenhouse gases (GHGs), road transportation is characterized for being an important emitter. Statistics Norway (2011) points out in its report on transportation that an increase of fuel sales is closely related to a rise of 0.4% in emissions from road traffic.

2.2 NORWEGIAN CLIMATE POLICIES

In 2013 total emissions of GHG accounted for 52,8 million tonnes, of which 10,1 % belong to road transportation. Figure 3 shows total emissions of GHG by sector in Norway. (Statistics Norway, 2013)

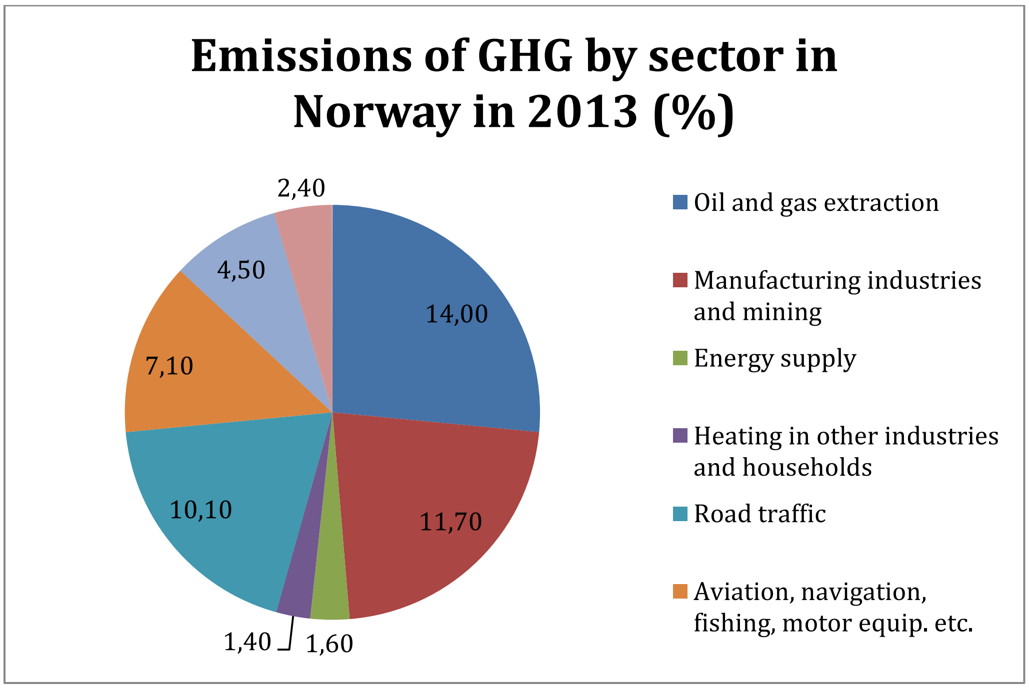


Figure 3. Emissions of GHG by sector in Norway in 2013.

According to the Norwegian Ministry of Climate and Environment (2013), the government's abatement policies include:

- To limit the average rise in global temperature with respect to pre-industrial level to no more than 2 ^{o}C.

- To reduce global greenhouse emissions by the equivalent of 30% of its 1990 own emissions by 2020 with about 66% of emission cuts made in Norway.
- To achieve total carbon neutrality by latest 2050.
- In the scenario of a global agreement with developed countries, Norway should achieve total carbon neutrality by 2030.

As seen in the figure 2 above, road transportation is the 3rd largest emissions sector in the country. A key part of the abatement process relies on the improvement of public transport and the implementation of climate-friendly technology. The Institute for Transport Economics (TØI) studies policies concerning public and freight transportation. With the purpose of providing an insight over the current taxes applicable for heavy duty trucks in the Norwegian taxation system, the following paragraphs were retrieved from the working paper "Norwegian Transport towards the Two Degree Target" by TØI. (Fridstrøm, 2013).

<u>Fuel and vehicle taxation.</u>

The Norwegian taxation distinguishes between several kinds of taxes for automobile owners. In the following paragraphs, those taxes that apply to heavy-duty vehicles are listed.

a. Fuel tax. With the objective of balancing prices among fossil fuels and alternative fuels, petrol is subject to road use tax (NOK 4.73 per liter), CO_2 tax (NOK 0.89 per liter) and value added tax (25%). Diesel has the same corresponding taxes at amounts of NOK 3.73, NOK 0.60 and 25%. An important remark on road and CO_2 taxes is that 1 NOK of any of them has the same GHG abatement effect. However, the difference is that road taxes are rather fiscal than environmental. As for biofuels[3] no CO_2 tax is levied on them and biodiesel is taxed with NOK 1.84 per liter for road use.

b. Registration fee. An annual registration fee is required on vehicles depending on several factors: class, age and weight. For heavy-duty vehicles the registration fee

[3] Biofuel is basically a fuel derived immediately from living matter. While Biodiesel is a biofuel intended as a substitute for diesel.

depends on the vehicle's weight, suspension system and number of axles. Fees range from NOK 420 per year, for the smallest vehicles and NOK 10,384 for the largest. An environmental fee is also added to this type of vehicles. The fee is charged depending on the vehicle's weight and emission standard[4] (EURO I-VI), the older the standard the more expensive the fee.

c. Road toll. Toll fees do not serve as GHG abatement. They are intended as resources for the improvement, construction and maintenance of public roads. However, tolls have also been used as schemes to hinder congestions in urbanizations.

Other policies related to the use of alternative fuels rely on the use of Biofuels. The "Blending Mandate" in Norway has been enforced since April, 2010. The mandate requires that fuel suppliers must ensure the sale of at least 3.5% of biofuels for road transportation. As a result, most oil companies have complied with the law achieving a mix of up to 7% rapeseed methyl ester (RME) in diesel. In some cases as with Statoil, the mixture contains bioethanol.

A government initiative related to the use and promotion of alternative, climate friendly fuels is the HyNor/HYOP. The project had the objectives of promoting and increasing the production of hydrogen as a fueling resource. It started in 2003 with the establishment of a highway running between Oslo and Stavanger, a route of 580 kilometers, which counted with hydrogen fueling stations. This is a national project in collaboration with the cities, or urban nodes, along the highway which would have their own hydrogen-related projects such as hydrogen production.

2.3 THE LINK BETWEEN ROAD TRANSPORTATION AND CLIMATE CHANGE

Reports and official mitigation procedures by the United Nations Framework Convention on Climate Change (UNFCCC) consider the irradiative forcing of the climate system to be dominated by long-lived GHGs, of which carbon dioxide (CO_2) is the most important anthropo-

[4] The European emission standards (EURO) establish the acceptable limits for exhaust emissions that are sold within EU member states (including Norway). This subject is further developed later in this study.

genic greenhouse gas (GHG). According to the Intergovernmental Panel on Climate Change (IPCC), global GHG emissions derived from human activity have increased 70% since pre-industrial times. In fact, the largest growth in GHG emissions from 1970 to 2004 has come from energy supply, transport and industries. Emissions of GHG from transportation in Europe, account for as much as 20.3% according to the European Environmental Agency's annual report (EEA, 2011). Among the gases expelled from transportation are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).

The link between transportation and climate change can be seen as two-directional. On the one hand there is an obvious contribution to global warming through GHG emissions from transportation. On the other hand, the change in climate threatens to alter today's transportation patterns. For instance, the projected rise of sea levels, floods and storms could potentially change the distribution of production and consumption of agricultural, manufacturing, fishery and forestry goods, and therefore the current transportation flow. Due to the possible redistribution of both the economy and demographics, transportation patterns will need to be reinvented. (Yevdokimov, 2010)

In addition to the impact that a change of temperature could have on the current transportation flow, recent studies point out the importance of considering the potential costs of climate change, such as and increase/decrease of rain, storms, and floods for paved and unpaved roads (Chinowsky, Price, & Neumann, 2013)

This study takes a closer look at the Norwegian transport sector and its GHG emissions.

3. THE CLIMATE CHANGE CHALLENGE

With the purpose of portraying the challenge of climate change from a public policy perspective the following part presents some of the findings of some of the most important scientific and analytic reviews on climate change. The text includes their definition, future and possible scenarios, mitigation and adaptation. First, what the author considers the most relevant points of the 4th Report (2007) by the IPCC will be presented. Then, an illustration of the Stern Review's most relevant points is discussed and finally, a critic to the last report by William D. Nordhaus is described.

As one of the most reliable sources to address the climate change challenge in terms of identification and quantification of data, the IPCC on its fourth report (2007) define climate change as the state of the climate that can be identified and quantified. As well as changes in the mean or variability of its properties that persists for an extended period of time. This definition does not consider whether the change is due to natural causes or human-made. Contrary to other reports presented by the UNFCC where climate change is directly or indirectly attributed mainly to human activity. However, the IPCC report also concludes that emissions of GHG due to human activity have grown by 70% since pre-industrial times. This affirmation leaves little room for questioning the anthropogenic nature of the problem.

Another conclusion is that warming of the climate system is unequivocal, due to evidence from observations of increasing global average temperatures. The phenomenon is particularly visible in the northern hemisphere, where ice melting and the loss of polar ice sheets are resulting on a 28% and 15% respectively and have contributed to sea level rise.

An important part of the report is the illustration of four Emission Scenarios, as described in the IPCC Special Report on Emissions Scenarios (IPCC, 2000). A group of four different scenarios illustrate alternative climate change development paths. The scenarios are divided into (A1, A2, B1 and B2). The storyline of scenario A1 is a very rapid economic growth, peak of global population in mid-century and introduction of more efficient technologies. B1 presents a scenario with the same population as A1 but with more rapid economic changes particularly towards a service and information economy. The scenario described in B2 has intermediate population and economic growth based on local and environmental solutions. A2 is a rather pessimistic scenario with high population grow, slow economic growth and slow technology improvement. The scenarios take into account a wide range of demographic, economic and technological driving forces that might result in GHG emissions. These scenarios exclude additional climate policies and project a warming of 0.2º C per decade. Even though no likelihood has been attach to any of the scenarios and the study differs from UNFCCC and Kyoto Protocol inclusions, the scenarios represent an effort to identify on time, possible consequences of climate change in a fast growing world.

Finally, the report points out the importance of mitigation and adaptation as a complement to each other. Both, mitigation and adaptation are necessary to reduce the risks of climate change. Risks increase under an unmitigated climate change and can surpass the capacity of naturally adaptation hence, facing a very high social, environmental and economic cost.
At the moment a Fifth Assessment Report is being elaborated and will be completed by 2013/2014. The new report will include three relevant documents, the Physical Science Basis; Impacts, Adaptation and Vulnerability and Mitigation of Climate Change.

The Stern Review (2006), hereafter called the Review, defines climate change as the greatest and widest-ranging market failure. It suggests that the economic analysis must therefore be global, with a long horizon perspective, with economic risk and uncertainty at its center. In addition, the Review takes great emphasis on an early mitigation plan. Assuring that with the right investments future climate change costs could be manageable. At the same time such investments, would contribute to the generation of opportunities, growth and development along the way. It states: "policy must promote sound market signals, overcome market failures and have equity and risk mitigation at its core". In other words, climate change policy will be reflected on costlier high emission industries as e.g. fossil fuels.
The Review uses macro-economic models to assess costs and effects of the transition to low-carbon energy systems for the world's economy. Such models are based on the four

IPCC scenarios and part from a similar basis, comparing the current and future levels and trajectories of the social costs of carbon with marginal abatement costs. (Rothengatter, 2009)

The Review and the 4th report from the IPCC coincide on the possible negative outcomes from climate change, most of them related to water. Melting glaciers increase flood risks and the reduction of water supply threats one sixth of the world's population. When it comes to mitigation plans, the Review suggests emission stabilization at 550 ppm CO2 with costs of around 1% GDP by 2050. The mitigation action plan will then consist of the following steps:

- Reduce demand for emission-intensive goods and service
- Increase efficiency
- Action on non-energy emissions
- Switching to low-carbon technologies for power, heat and transport.

Finally, adaptation is seeing through sustainable development, basically dependent on international collective action.

On his paper A review of the "Stern Review on the Economics of Climate Change" (2007) William D. Nordhaus states that the Review conclusions differ with earlier economic models using the same data. He argues that a so-called "Climate Change policy ramp" is an economically better solution than strict mitigation action. Nordhaus finds support on other economic studies whose methodology can be reproduced and use a higher discount rate than Stern. The policy ramp consists on applying stricter policies with time. The low discount rate that the Review bases its conclusions on, 0.1%, leads to an ethical problem. The lower the discount rate, the higher the symmetrical treatment towards future generations. The Review concludes that dramatic emission reduction must take place today in order to provide the possibility of a sustainable future. However, if a higher discount rate is applied, close to today's market rate, Stern's conclusion turns invalid. Nevertheless, this and other examples show how difficult it is for economists to deal with long-term unknown effects on nature (Weitzman, 2007) and define whether we must concentrate on lowering emissions (mitigation) or preparing future generations for living in a less sustainable environment (adaptation) (Rothengatter, 2009)

3.1 CLIMATE CHANGE ADAPTATION FOR PRIVATE BUSINESSES

Regulations towards climate change abatement encourage all kinds of businesses to greener practices. Among such regulations two approaches of substantial difference are found, mitigation and adaptation. Adaptation, on one hand, is defined by the IPCCC as "initiatives and measures to reduce vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist such as, anticipatory and reactive, private and public, and autonomous and planned". A climate change adaptation plan can be interpreted as only a public sector concern. It is true that the Government has the obligation to provide security to the population. However, when it comes to climate change and its reach it is necessary that the private sector have reactions on its own. The Adaptation Program of the UNFCCC has called upon private business, through the Nairobi works program on the impact, vulnerability and adaptation to climate change (NWP 2011/2012), to create and implement a strategy for the climate change impact. Many companies throughout the world have already submitted a short action plan. They describe how the organization engages and adapts to climate change in a rather sustainable way. This is by reducing business risk, in addition to reducing and avoiding the dangers posed by extreme climate events. An important aspect of the plan is the focus on the profitability from opportunities that climate change may present.

Mitigation, on the other hand, means technological change and substitution that reduce resource inputs and emissions per unit of output. In other words, it means implementing policies to reduce GHG emissions and enhance reductions. (IPCC 4AR).

One can conclude at this point that awareness of climate change is growing and taken seriously, and also that collaboration is absolutely necessary. In his paper "Successful Adaptation to Climate Change across Scales", Adger et al. (2004) suggests that adaptation can be motivated by several factors including the protection of economic well-being or the improvement of safety. Normally, there would be levels of interactions between individuals and organizations, to meet their own and collective goal regarding adaptation. The achievement of successful adaptation would critically depend on the capacity to adapt and the distribution of that capacity.

In order to build a strong and complete climate change assessment risk for an individual company, both mitigation and adaptation approaches should be taken into consideration.

4. DRIVING FACTORS FOR THE IMPLEMENTATION OF NATURAL GAS AS A FUEL

This section will present different arguments that focus on the utilization of natural gas as a fuel. Some of the most relevant works found for this purpose include, an analysis of the factors affecting the decision making process to switch fuels, the introduction of natural gas as a fuel in high dense cities like Madrid and Barcelona and finally, a discussion of actual emissions of natural gas from a well-to-wheel perspective.

4.1 GREENHOUSE GAS EMISSION REDUCTION

According to Andress et al (2011) the effective reduction of GHG emission from road transportation sector can be categorized as following:

- Improvement of engine efficiency,
- Introduction of low carbon fuels and
- Reduction of vehicular km traveled.

Andress et al., have developed a study about the potential reduction of GHG emissions in the road transportation sector in the U.S. (mainly light, medium and heavy duty vehicles, LDV, MDV and HDV). By comparing alternative and fossil fuels in a scenario where engine efficiency is increased, cost reduction targets are met and fueling structures are built. Their results show that EVs (electric vehicles) provide the greatest increase of fuel efficiency. However, costs should be lowered and adequate fueling-charging- stations should be created in order to increase the market of these. Today, EVs represent only a niche of the global vehicle fleet market (Hacker et al. 2009) due to the lack of an EV model that offers the capabilities of existing fully homologated cars. According to the EEA (2011), out of the 12.8 million new vehicles registered in 2011, 0.07% were pure electric vehicles.

In Norway, government incentives are having a positive impact over EV sales. For instance, more Nissan Leaf models were sold in Norway than in the U.S. in 2011. Also, Norway has the most reservations for Tesla Model S cars in Europe and in 2012, EVs were 5.2 % of total vehicle sales. The incentives behind the purchasing of EVs are that such vehicles are exempt of import taxes, making it relatively cheap to buy an electric car in comparison to other fuel based car. Another incentive is related to comfort. An increasing number of cities in Norway are adopting the rule of allowing EVs to drive on bus-lines cutting significantly time during rush-hour traffic. (Elbil, 2013) In spite of all the possible environmental benefits electric cars could have, there is still much to be improved. The main challenges for EVs are costs and distance traveled. Helmers and Marx (2012) after Nemry and Brons propose that, possible market segments for EVs are battery electric vehicle (BEV), plug-in hybrid vehicles (PHEV) and fuel cell vehicles (FCV). Moreover, they conclude that as today's technology, BEV can best work for small vehicles, while PHEV and FCV have vehicle packaging problems and high price is an obstacle. For medium size cars, BEV can be useful and some technology improvement is expected in oncoming years, while PHEV and FCV belong to a privileged segment and a better H2 filling station infrastructure is required. Finally, BEV concerning large vehicles can only be conceived for specific markets, such as luxury cars, due to high price and limited driving range. Electric vehicles are for these reasons not considered in this analysis, neither as a comparison point in the truck's market nor in environmental policy.

Furthermore, Andress et al. (2011) points out that the achievement of reduction of GHG emissions from using only biofuels are limited by the availability of biomass resources. Therefore, a mix of advanced vehicular technology and use of less intensive carbon fuels can help to maximize GHG reductions. The use of biofuels to displace diesel-fuels is a strategy that could trigger the success of electric propulsion technology. The uses of CNG and LNG where alternative fuels are limited have strategic advantages. For instance, reducing imported oil demand; contributing to energy security by decreasing dependency on oil and improving air quality. In addition, natural gas fuels could function as a bridge towards alternative energies.

One can then conclude that, carbon intensity depends to a great extent, to the place where the fuel is used and produced. For instance, the carbon intensity of oils derived from oil sands is 10 to 20% greater compared to conventional wells. The use of this resource will then complicate achieving GHG reductions. Such is the example of Canada and its second largest oil reserve that even if it is in the interest of many other nations to be developed, it represents a complex and controversial subject.

4.2 AIR QUALITY IMPROVEMENT

In order to comply with emission reductions, many countries are switching to less carbon intense fuels for their public transport sector. Some of those countries include the United States, India, Spain, Norway, Belgium and Brazil; the latest has the lead on using alternative fuels. Availability plays a very important role in decision making when choosing a greener fuel. The fuel itself, fueling stations and also the technology to use such fuel must be available.

In the passenger transportation context, Hans et al. (2012) explores how policy affects any future of GHG emission reduction and concludes that a significant technological change and emission reduction can only be obtained in a very ambitious policy scenario. The study takes place in Belgium and includes measures like the introduction of a kilometer charge, the concession of subsidies to replace old cars and the use of a well-to-wheel environmental indicator to define a clean vehicle. In a complementary way, the scenarios developed were examined by a selected group of stakeholders who shared their opinions and concerns about policy measures that could be quantified on environmental impacts. The importance of an ambitious and consistent policy mix that take into account the needs of the different stake holders is vital when it comes to reducing emissions in the transportation sector. As transport policy has responsibility for the demand for more mobility and concerns about traffic's side effects. In other words, if either policy intervention or technology innovation fails, transport development will continue and CO_2 emissions may even double by 2050. (Fulton, 2010)

So far in this work, emissions from GHG have been the main focus. However, when it comes to environmental influence and emissions from vehicles a difference between emissions that pollute the local environment and emissions that contribute to global warming is made. While GHG emissions contribute to the gradual raise in temperature on earth, local pollutants have a direct effect on the health of city's inhabitants. Indeed, tail-pipe emissions of NOx (Nitrogen Oxides) and PM (small particles) affect negatively health and pose a significant cost in society. GHG emissions are measured as CO2 equivalents and impact climate change. Due to the fact that the activity to be analyzed takes place outside urban areas, this research focuses only on GHG emissions. However, the following paragraphs are dedicated to review a study that deeply analyses the effect that natural gas vehicles (NGV) could have in urban areas. This is relevant for this research because ultimately, urban activities contribute to trans-boundary pollution and the increase of GHG concentration. ((Fenger, 1999) (Baldasano, Valera, & Jimenez, 2003)

Local emissions constitute a problem especially in highly dense areas. Gonçalves et al. (2009) have analyzed the impact on air quality issues from the introduction of NGV in the cities of Barcelona and Madrid. The study consisted on the creation of different scenarios where segments of the vehicle fleet were substituted for NGV. In order to evaluate the change in emissions after the introduction of NGV it was required to first, estimate the speed-dependent emission factors for the different categories of NGV (cars, LDV and HDV); and second, to define the vehicle number variation in each scenario. Since natural gas is a flexible fuel that can be used in different technologies and with different operation systems, a wide range of emissions factors can be found. This increases the difficulty of the emission selection process for the analysis. Nevertheless, the results of the analysis obtained large variations in emission levels for vehicles using CNG. Those vehicles presented lower emissions of toxic compounds than petrol and diesel equivalent engines. (Ristovski et al., 2004) Also, the results depended heavily on the specific vehicle fleet involved. The largest variation in emissions occurred in a combined scenario, when up to 26% of the vehicle fleet was changed in Barcelona and 23% in Madrid. Another conclusion drawn from this study is that NGV are useful to reduce SO2 and PM emissions, especially those coming from old LDV. All in all, Gonçalves' work shows that the introduction of NGV alone wouldn't be effective in the reduction of emissions. Instead, a combination of NGV and around 4% of substitution of conventional fuel vehicles would provide effective emission reductions. In addition, collateral impacts from NGV such as the construction of supply facilities and its emissions should be considered in the overall equation.

4.3 NATURAL GAS AS A BRIDGE TO ALTERNATIVE FUELS

In order to achieve the environmental goals established by different entities and policy makers, the balance between de-carbonization and meeting the increasing demand of energy must be in place. It has been said by key decision leaders, like the Intergovernmental Panel on Climate Change (2007) and the International Energy Agency (2011), that natural gas is where the problem meets the solution. The reason for this argument is that natural gas has been used for a long time and reservoirs and endowments at current production rates would last for 398 years (Aguilera R. , 2011). Aguilera (2011) presents a study from a Global Energy Market (GEM) model. Supported by such study he sustains that the use of natural gas, on its conventional, tight, shale and coal bed forms, has the potential to satisfy the growing energy world demand while keeping low-carbon emissions.

The reason for having a "bridge" to alternative fuels is that the transition to climate friendly fuels and technology is still in process. Although is has been indicated that natural gas is abundant and can be used to cover the gap to new technologies, non-fossil, renewable sources, technical and market research is still needed in the gas and renewable energy industries. (Aguilera R. , 2011) Today, an important incentive is that natural gas prices are relatively low, the gas burns cleaner and more efficiently than oil and coal, and it can be used as a leading option for backing up intermittent renewable sources. Stephenson & Doukas (2012) present a critic to labeling natural gas as a transition fuel when it comes to legalization of carbon-intensive natural gas development. In the research "Green-Washing Gas: Might a 'Transition Fuel" Label Legitimize Carbon-Intensive Gas Development? (2012) It is argued that exploitation of shale gas in the region of British Columbia, Canada; is unsubstantiated by the best available evidence and the impact of life cycle emissions from the activity have not been evaluated. It is therefore, suggested that decision making about natural gas development should follow a transparent engagement based on the best available evidence; in order to ensure the best utilization of the fuel and its role as a transition fuel to a low-carbon system.

5. NATURAL GAS

5.1 NATURAL GAS ENERGY CONTENT

Natural gas, oil and coal are the so-called hydrocarbons. Natural gas consists of hydrocarbons that are found in the gas phase at standard temperature and pressure (STP, 20º C and atmospheric pressure). Its main components are: methane (CH_4), ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}). Methane is the main component of natural gas (70-90%) and typically the most common component transported via pipelines and converted to liquefied natural gas (LNG[5]). The following figure (4) summarizes the major hydrocarbon components of natural gas.

Major hydrocarbon components of "typical" natural gas		
Methane	C1	65% to above 95%
Ethane	C2	2% to 15%
Propane	C3	0.25% to 5%
Butane	C4	0 to 5%
Pentane	C5+	0.05% to 2%
Non-hydrocarbon components produced with natural gas		
Nitrogen	N_2	0 to 20%
Hydrogen sulfide	H_2S	0 to above 15%
Carbon dioxide	CO_2	0 to above 20%

Figure 4. Components of natural gas.

Source: Fundamentals of Natural Gas, Vivek Chandra. 2006

Gas volumes are usually measured in in cubic meters (m^3) or cubic feet (ft^3) and the typical units of calorific value are British thermal units (Btu), joules (j) and kilocalories (kcal). The calorific or energy value of natural gas is proportioned to its hydrocarbon content. Gas from different fields, or sometimes, different reservoirs in the same field, can vary on its energy content. Conversion of gas volumes to energy equivalent values of oil (barrel of oil equiva-

[5] Cooling methane to -161.5ºC produces LNG, once in liquid form; it is transported on specially designed ships.

lent or boe) is often done, especially when oil and gas are found in the same field. (Chandra, 2006) Crude oil has a calorific value of 5.4 MMBtu (million British termal units) to 5.8 MMBtu per barrel of oil, depending on its composition, then 1 boe = 5,800 MBtu. The conversion in cubic feet, 1bbl oil= 5.8 Mcf (thousand cubic feet). In metric units will then be 1 m^3 gas = 35,300 Btu, 1 boe= 164 m^3. Table 1 presents the net calorific value of hard coal, oil, natural gas and liquefied petroleum gas (LPG) and their carbon content.

Fuel	Net calorific value (MJ/kg)	Carbon content (%)
Hard coal	29	75
Oil	42	85
Natural gas	38	75
LPG	46	82

Table 1. Net calorific value and carbon content of fuels.

(Biomass energy center, 2011)

5.3 NATURAL GAS PRICE DEVELOPMENT

Typically, prices of natural gas and crude oil have been seen as co-integrated and such conclusions have had a great impact on businesses and policy community. Analysts of the field have tried to establish statistical relationships between these two commodities that are substitutes of each other. Stephen Brown and Mine Yucel, researchers at the Federal Reserve Bank of Dallas, explain three rules of thumb that have largely been used when comparing oil and gas prices (What drives natural gas prices?, 2007).

Such rules are as follow: first, 10 -to-1 rule which indicates that natural gas price is a tenth the price of crude oil price. Second, the 6 –to- 1 rule describes the energy content of a barrel of oil where the price of a million Btu of natural gas is roughly one-sixth the crude oil price. Other economists, however, warn against valuing reserves in terms of “barrel of oil equivalent” or “gas equivalent” since the oil and gas have different costs of production, transportation, processing and storage and serve different portfolios of end users. (Ramberg & Parsons, 2012) Both 10 –to- 1 and 6 –to- 1 ratios have proven inconsistent; figure 5 shows real spot price series from the period 1991-2010 for the West Texas Intermediate (WTI) for crude oil prices and Henry Hub (HH) for natural gas prices. In the period analyzed the ratio of prices have been as low as 2.5 -to- 1 and as high as 36 –to- 1.

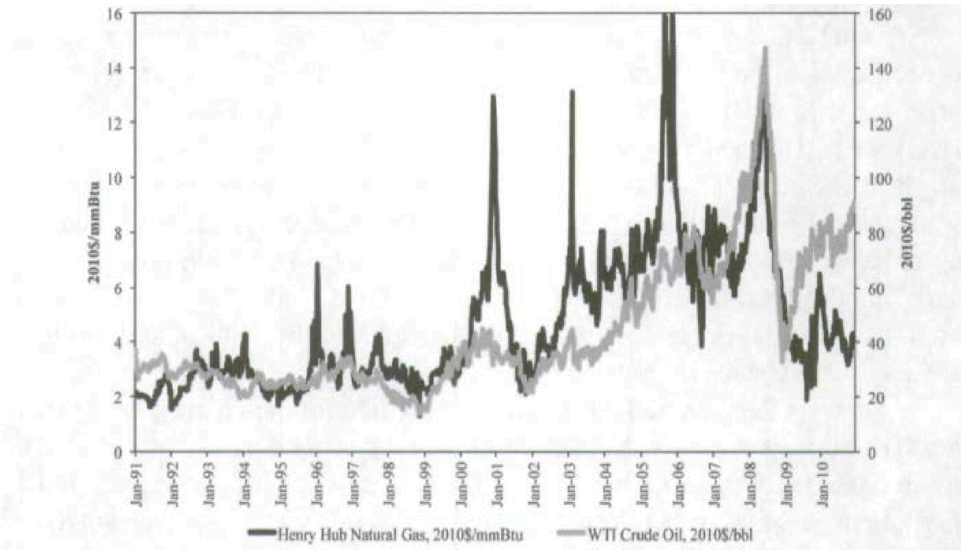


Figure 5. Real spot price series in 2010 dollars for WTI and HH. (Ramberg & Parsons, 2012)

Lastly, a more complex rule is the burner-tip parity that is generally implemented, "the rule shows natural gas pricing yielding parity with residual fuel at the burner tip, an the price at Henry Hub adjusting whatever is necessary to achieve burner-tip parity".

In their white paper Brown and Yucel also explore other factors affecting natural gas prices such as seasonality, storage and disruptions of natural gas production due to weather. They conclude then with that there exists a continuum of prices at which natural gas prices and petroleum products are substitutes and that in 85% of the cases natural gas prices show an inexplicably high volatility.

In a more recent study of the oil and gas price relation Ramberg and Parsons conclusion coincide with that of Brown and Yacel,; natural gas price's high amount of unexplained volatility at short horizons have to be taken into account. Also, the co-integrating relationship of prices does not appear to be stable through time. In other words, even though prices may be tied, their relationship can dramatically shift over time.

5.4 SUPPLY OF NATURAL GAS IN NORWAY

This section presents the points of view of one of the biggest natural gas downstream supplier in Norway, GasNor. The following information was gathered through email communication between the author and the Head of Communication and Public Relations of GasNor, in May 2014 and different Internet sources.

GasNor has been a Shell's subsidiary since 2012, as part of Shell's strategy towards the creation of a sales business of LNG and consequently expanding their commercial fuel mix. GasNor counts with an extensive pipeline network as well as CNG and LNG distribution through trailers, terminals and vessels assets. (GasNor) The gas processed at the company's facilities comes mainly from gas fields in the North Sea, one of the suppliers is Statoil, it is expected that in coming years LNG will also be imported from European LNG import terminals.

The markets GasNor serve are the industry, ship fueling, vehicle fueling and house holding. As of today, the biggest market of natural gas in Norway is the industry. However, LNG as a ship's fuel is the fastest growing market, with 42 ships LNG powered and 10 more coming during this year. House holding is a supplement to the industry market which reaches the customers through a pipeline distribution system and expectations of growth are low.

The vision of the company for the evolution of the market of natural gas as a fuel in Norway is optimistic. It is expected that the Norwegian government follow up on the proposed EU directive, Clean Power for Transport, which aims to facilitate the development of a single market for alternative fuels in Europe (European Commission , 2014) as well as to decrease oil dependency and lowered harmful emissions to the air. The plan consist on building alternative fuel bunkering stations for ships in 139 European harbors and filling stations for trucks along all European main roads. If Norway were to comply with this package, the government would need to provide with infrastructure that can supply ships and heavy-duty trucks with LNG and/or CNG along the main traffic corridors in Norway. As of today, it is possible for ships to fuel (LNG) from an onshore bunkering terminal at Halhjem (designed for ferries), Coast Center Base (Øygarden), Fjord Base (Florø), West Base (Molde) and Risavika (not commissioned yet). There are no fueling stations of LNG for trucks. When it comes to list prices, only wholesale market prices are available at the hubs, like the UK National Balancing Point.

Finally, GasNor sees four main benefits of using natural gas as a fuel:

1. Cost competitive fuel which can lower operational costs.
2. Cleaner burning fuel which can lower maintenance costs.
3. Proven and reliable LNG technology and availability improvement.
4. Natural gas meets present and future environmental regulations.

GasNor weights its focus on the growing market of LNG as a fuel for ships without completely disregarding the market of vehicle fuels which in Norway is mostly turned to CNG powered vehicles. This is reflected in the inexistent LNG fueling stations compared to CNG stations which are located on the east and west coast of Norway and one supplier in Hammerfest, in the North. There exist however, cooperation between related industries that channel their efforts towards the development of the natural gas market. An example of this is GasNor and Shell cooperating with car and truck manufacturers like Scania, Volvo, Mercedes Benz, Man, Rolls Royce and Wartsila.

5.5 NATURAL GAS VEHICLES

Natural gas vehicles are widely used in Asia, North and South America, some of these countries promote the use of such vehicles because they have their own gas resources and also as a policy to balance their dependence on oil. Other reasons for the use of NGVs are high oil prices and a need to reduce air pollution in big cities. In Europe, environmental regulations are the main motive to promote natural gas and other alternative fuels. However, the focus has been on hybrid technology and electric cars (EC) (Engerer & Horn, 2010). Such is the case of Norway, where even though gas-based fuels are becoming popular, most gas-powered vehicles have the possibility to run on gasoline or diesel as well. Gas-based fuels available in Norway are natural gas on its compressed form (CNG), liquefied petroleum gas

(LPG) and biogas. The differences between these three types of fuels are their chemical composition and their source. On one hand, natural gas is mainly composed by methane while biogas must be treated to reach 97-98% methane content in order to be used as a fuel. Natural gas is a fossil fuel and biogas can be produced from organic materials. LPG on the other hand can be a combination of propane and butane. In Norway, propane is more used because of its qualities to perform under cold conditions. (Agency for Public Management and e-Govenment, 2014)

An important disadvantage of gas-based fuels is that their energy content is lower than that of diesel. As a consequence, the driving distance of a NGV or alternative fueled vehicle is shorter than a diesel fueled vehicle. In addition a lack of infrastructure of supply stations have hindered the development of this market in Norway for private users.

The public sector in Norway has taken advantage of the environmental benefits of natural gas by introducing CNG powered public busses in cities like Trondheim, Bergen, Haugesund and recently Oslo (Enrgy Link). CNG is preferred in this context because the busses are subject to specific routes and schedules, which allow them to eventually get back to a terminal and fuel at low pressure. This system is both cost and energy efficient. The Institute for Transport Economics in Norway has developed a report on the environmental performance of the Norwegian fleet of busses (Hagman & Leiren, 2011). In such report the authors conclude that bio-methane is the most environmental friendly fuel among diesel and gasoline presenting the lowest GHG emissions (CO_2) and local pollutants (No_x and PM). The report also states that the CO_2 emissions are directly related to the consumption of a specific fuel and therefore depend on the engine efficiency to combust the fuel. Diesel engines are 25% more energy efficient than Otto engines with stoichiometric combustion. The later widely used on natural gas fuel vehicles.

As for heavy-duty vehicles in Norway, the range of option is not as wide as for passenger vehicles. During the preparation of this thesis the author has reached heavy-duty truck suppliers like TruckNor and Scania, who have expressed the lack of interest from customers towards this type of technology, possibly due to an inexistent infrastructure of natural gas supply and an increasing demand on flexibility in the transportation industry. Volvo has developed truck technology that allows the use of diesel and LNG or pure CNG. The availability of trucks with this characteristics vary in the different countries the company has a market (Volvo Trucks, 2014). As for Scania, they have focused more on methane based fueled trucks (CNG and biogas) (Scania, 2014)

6. THE CASE OF KUEHNE + NAGEL

Kuehne + Nagel (K+N) was founded in 1890 in Bremen, Germany. The company started as a traditional freight forwarder and over 120 years has evolved into a global provider of fully integrated supply chain solutions. Some of the company's logistics services are sea-freight, airfreight, contract & integrated logistics and; road and rail logistics. In addition, K+N offers specialized solutions to industries such as aerospace, automotive, fast moving consumer goods (FMCG), high tech, industrial, oil and gas, pharma & healthcare, retail, among others. K+N was established in Oslo in 1990. Today, the company operates across 15 locations with almost 500 employees. In order to strength the company's position within the oil and gas market, both in Norway and internationally, Kuehne + Nagel acquired J. Martens Holding A/S in 2009.

As for the environment, K+N is engaged on measuring the impact of its activities on the environment by re-using, recycling and reducing the use of materials in order to lessen the consumption of natural resources. In addition, they collaborate with its customers to meet their own sustainability goals and obligations by offering environment-friendly product alternatives.

A global facility emission database (GFCC: Global Facility Carbon Calculator) and a Global Transport Carbon Calculator (GTCC) were created in 2012. The purpose of these databases is to improve reliability on its emission calculations. Due to the correctness of the methodology to calculate emissions of the GFCC and the GTCC Kuehne + Nagel has been certified with international ISO standard 14064-3[6]. In the same year of its creation, the GTCC was used as a tool to prioritize the reduction of CO_2 emissions and measure its success. In 2012, the company achieved the environmental goals of reducing CO_2 emissions by 2.1% compared with the preceding year, reduction of water consumption, energy and fuel savings and recycling of waste increased by 36% compared with 2011. Furthermore, Kuehne + Nagel promotes the use of renewable energy on its locations and execution of its opera-

[6] ISO 14064-3:2006 specifies requirements for selecting GHG validators/verifiers, establishing the level of assurance, objectives, criteria and scope, determining the validation/verification approach, assessing GHG data, information, information systems and controls, evaluating GHG assertions and preparing validation/verification statements. Source: http://www.iso.org/iso/catalogue_detail?csnumber=38700

tions. However, the company is dependent on regional policies as well as client's perspective and "willingness to pay" of environmental-friendly products and services.

6.1 OIL AND GAS TRANSPORTATION SERVICES

As stated earlier, K+N organizes their services according to the needs of specific industries. The oil and gas logistics is one of the industries where K+N has more expertise and presence at a global scale. The service is divided in four core solutions:

- Supply chain management
- Rig and marine support
- Project management
- Base-to-base logistics

K+N makes use of their whole network and transportation modes to provide with efficient solutions, the modes include: seafreight, airfreight, road and rail and contract logistics.
This study focuses on the Base-to-Base logistics solution in Norway.
The information collected for this part of the thesis has been provided from Kuehne + Nagel's website and from a series of interviews with the Senior Vice President of corporate projects in Oil and Gas; and the Executive Officer (XO) of the base located in Ågotnes, in the area of Bergen.

6.2 BASE TO BASE TRAFFIC

In Norway, oil equipment transportation is mainly supplied on a Base-to-Base fashion. The bases or centers are located along the Norwegian West Coast (See Appendix 1) and both equipment and logistics suppliers share the facilities. Kuehne + Nagel has offices in 8 bases which allow their customers to contact them at any time and feel safe. K+N has identified their key success factors trough the integration of the following services:

- Control tower methodology. Such methodology allows them to make use of their transportation means at any time from any location. E.g. the trucks do not belong to any base, they can be used from any base they are.

- Established networks in major oil and gas regions.
- Multimodal integrated solutions.
- One-stop shopping for movement of assets and supplies.
- Transport of special equipment and offshore containers.

As a strategy to avoid empty haul travels, the company transports full and part loads. In a rather friendly relationship with their competitors, they share transportation means and cost in order to deliver efficiently and reduce CO_2 emissions. This example of *collaborative logistics* is developed later in this paper. In addition, transportation control centers have been interlinked. Thus, allowing them to share information and transportation vehicles, resulting in better utilization of transport capacity and minimization of empty kilometers traveled. Another communication channels between clients and organization is the ongoing contract and traffic, K+N has an express service, which is available at all times, all days a week.

6.2.1 DESCRIPTION OF THE CARGO

The cargo transported between suppliers and the bases is only oil equipment that in most cases has as last destination oilrigs. The equipment varies to a high extend in weight, volume and material. The equipment is usually transported in containers and baskets and range from (Offshore Norway):

- Drilling equipment
- Material and product handling equipment
- Pumps
- Tanks, vessels and columns
- Instruments and control equipment
- Pipes, tubes and hoses
- Valves
- Chemicals, oils, paint

The demand for transportation of this kind of products is often unpredictable and supply times are critical. This type of cargo is characterized by being highly urgent and with high renting costs..

The main clients for Kuehne+Nagel's base-to-base traffic are Halliburton, Odd Fjell Drilling, Aibel, FMC Technologies and Aker Solutions.

6.2.2 THE BASES IN THE WEST COAST OF NORWAY

The bases along the West coast of Norway are strategically located to supply with both equipment and transportation possibilities to oil companies. Kuehne + Nagel has offices in 8 bases: Ågotnes, Mongstad, Haugesund, Kristiansund, Fløro, Stavanger, Haugesund and Hammerfest. (See Appendix 1)

The general routes between the bases are as following in Table 2.

From	Destination	Distance	Frequency
Stavanger	Ågotnes	232 km	Daily
Stavanger	Mongstad	275 km	Daily
Ågotnes / Mongstad	Haugesund	254 km	Daily
Stavanger	Haugesund	81.7 km	Daily
Stavanger	Florø	438 km	Monday Wednesday Friday
Stavanger	Via Ågotnes/Mongstad Kristiansund	842 km	Monday Wednesday Friday
Ågotnes / Mongstad	Florø	321 km	Daily
Sandessjøen	Hammerfest	1,208 km	Only under request

Table 2. General routes for base-to-base transportations. Elaborated by the author with information from K+N and Google Maps.

This research focuses on the base in Ågotnes in the Bergen Area. Kuehne+Nagel's facilities are located in the Coast Center Base (CCB) in the municipality of Fjell, approximately 40 min from the city of Bergen. The base covers about 7 hectares of which 68 600 m^2 are workshops and warehouses and 20 600 m^2 are office buildings. CCB is a private owned company that supplies activities to the petroleum fields in the Tampen area of the North Sea (Statfjord, Gullfaks, Veslefrikk, Troll, Huldra and Kvitebjørn fields) (Coast Center Base).

Figure 6. Coast Center Base (CCB) in Ågotnes.

In 2013 the base in Ågotnes transported a total of 7 629 465 tons to 7 destinations (See table 3. below). Stavanger had the major trades in volumes and trips and it is the only destination with scheduled daily routes from Ågotnes. The route with the least cargo transported was Sandessjøen because the cargo to this base is mainly through seafreight (See figure 7. Distribution of total cargo transported in 2013).

From Ågotnes to	Cargo (tons)	Distance km	Tonne-km
Mongstad	480 780	92	44 231 760
Haugesund	528 879	161	101 015 889
Stavanger	2 500 000	232	580 000 000
Fløro	2 352 692	256	602 289 152
Kristiansund	847 782	544	461 193 408
Sandessjøen	96 749	1 108	107 197 892
Hammerfest	822 583	2 186	1 798 166 438
Total	**7 629 465**	**4 579**	**35 164 204 185**

Table 3. Distance and cargo transported from Ågotnes to the different bases in 2013.

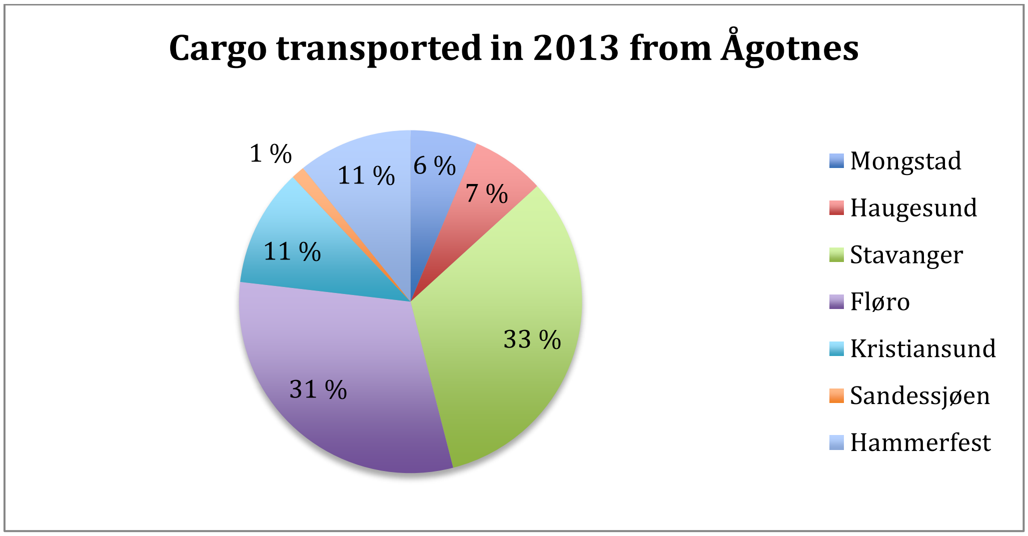


Figure 7. Distribution of total cargo transported in 2013.

6.3 KUEHNE + NAGEL'S SUBCONTRACTORS

Kuehne +Nagel does not own any vehicle used for Base-to-Base transportation. Instead, they use subcontractors who provide with vehicles that comply with the specifications from the company for this type of traffic. The reason for outsourcing truck services is that in this way, truck experts take full responsibility over delivering operations while logistics experts focus in providing logistics solutions. The following information has been collected through interviews both with Kuehne +Nagel, Ågotnes base and their subcontractor Bergen Container Transport (BCT). The interviews took place at the offices of both companies in November 07th and November 12th respectively.

Bergen Container Transport has been a subcontractor for K+N since 2009. A former K+N employee and his brother founded the company in 2002. BCT owns a fleet of 28 trucks and among the services they provide are, containers, trailers and shipments. The offices are located in the facilities of the Dokken port in Bergen. Their working place is shared with the actual owner of the company, Bring Logistics. BCT renews their trucks every five years; in this way the company complies with technical, cost and environmental requirements from their clients. For example, most of their trucks are EURO III standard and up. However, they haven't yet acquired any truck with EURO VI standards. The company measures its emis-

sions by calculating burned fuel over the km traveled. It has also been stated that their clients are aware of the environmental challenges of the transportation business and the restrictions regarding CO_2 emissions and the environment. Therefore, most clients have asked to not use a truck with lower standards than EURO III. However, in practice this seems to be a "soft rule". When there's low availability of trucks, clients prioritize getting the job done over environmental requirements.
BCT leases 5 trucks to K+N of the following specifications: all trucks have a capacity of 31 tonnes, diesel fueled and in average use 0.5 L of diesel per Km. (See table 4)

Truck	Model	Fuel capacity	Price (NOK)	HP	Range (km)
1	2013	550 L	800,000	510	1100
2	2012	500 L	1,200,000	540	1000
3	2006	600 L	1,200,000	610	1200
4	2008	600 L	1,200,000	560	1200
5	2000	600 L	1,000,000	520	1200

Table 4. Truck fleet leased to Kuehne+Nagel by BCT.

Regarding the use of natural gas as a fuel, BCT showed willingness to switch to NG driven trucks as long as there exist a good infrastructure of natural gas fuelling stations and reliable technology. During the interview with BCT, the truck supplier TruckNor was contacted in order to further explore availability of natural gas trucks. TruckNor explained that currently they only have trucks of 300 hp[7]; and that trucks of higher hp can be delivered upon request during the year 2014. As pointed out in in table 3 above, BCT uses trucks of at least 500hp. BCT then explained that in their experience is not always good to be the first company on investing on brand new technology due to potential failures in trucks' engines.
As for the operational costs, the company has price agreements with the fuel providers Shell and YX, the agreement includes a fixed discount of 24% of retail price. Furthermore, the highest expense the company has is driver's salary, followed by tolls, ferries and fuel. As for their prices, BCT charges 80% of the price K+N charges for a trip. The 80% cost include

[7] *Horsepower or hp* is a common measure for the energy needed in a vehicle's engine. Due to the weight of the transported merchandise, a minimum of 500 hp is needed by BCT.

truck and trailer leasing, driver's salary, tolls and ferries if necessary, fuel, insurance and up/unloading operations.

6.4 COLLABORATIVE LOGISTICS AS A STRATEGY FOR COSTS AND EMISSIONS REDUCTIONS

More and more companies are becoming aware of the benefits of *collaborative logistics;* the reasons are that it makes a company more competitive, profitable and efficient. At the same time it aims to reduce costs on the execution of logistics operations, protect the environment and mitigate climate change ((Rönnqvist et al. 2012; Lehoux et al. 2009). According to Rönnqvist (2012), such collaboration can be any coordinated effort between two or more partners, either from the same supply chain or from different companies, to achieve a common goal.

In the case of Kuehne+Nagel, base-to-base traffic collaboration takes place in an informal fashion. The participants are the competitors located at the base, specifically Bring Logistics and Panalpina. Under an interview conducted in December 17th by the author to the XO of the base in Ågotnes, he explained that the main reasons for collaborating between competitors are costs and emission savings and to keep long lasting relationships between companies. In addition, the close collaboration given the location of their business, right next to each other, makes everyday operations more practical.
Collaboration between the base-to-base transportation suppliers can take place under three circumstances,

1. One of the participants has free space in the trucks and asks if anyone needs the space.
2. One of the companies has a small cargo and asks other companies if they got space in their truck.
3. A truck is needed in another location and is requested to the base. If there is no cargo the operator (K+N) can accept to send a cargo from another company at a relatively low price.

As observed from such circumstances, there is a bargaining power from either party; this determines the cost of the service. There is no formal structure for the cost sharing of this service and the costs fluctuate according to what the parties consider reasonable. The informality of this transaction difficult the track of the records between cargos transported in their own fleet and the competitors'.

6.5 VISION OF FEASIBILITY OF THE USE OF NATURAL GAS AS A FUEL

As stated earlier, much of the information here confined was retrieve from interviews with the actual executors of base-to-base traffic. The interview's process was about 2 month long, from contacting the companies, waiting for their availability to provide information and finally conducting the interviews. However, the end result was worth waiting for, the author was able to get personal points of view, impressions, expectations and real concerns from the people who deal with the challenges of road transportation every day. The following paragraphs have the intention to summarize the opinions of Kuehne+Nagel and their subcontractor BCT for the feasibility of natural gas as a fuel. In general, the companies have three main reasons for switching fuels, with no specific order of preference, they are:

- Saving costs. Natural gas as a fuel is cheaper than diesel, either on its compressed or liquefied form, it could represent a cost benefit for both companies and eventually provide with a market advantage, either by increasing their revenues or lowering their prices.
- Brand strategy and customer satisfaction. Although natural gas is a fossil fuel, its environmental advantages over diesel are well known, among all the different stakeholders of the transportation business. This could have a positive impact on brand management of not only K+N and BCT but also, among the oil & gas customers for whom the environment is a concern. Even if environmental requests are not a top priority for their costumers, both K+N and BCT agree that the implementation of natural gas as a fuel for base-to-base traffic could result in a competitive advantage and satisfied customers.

- Environmental policies. As stated earlier in this research, environmental policies are having an increasing influence over companies' behavior.

Despite the benefits that switching to natural gas may bring, there are some obstacles that are beyond the companies' reach. As of today, there is a lack of infrastructure of natural gas supply both as LNG or CNG. Since the interviewed companies have little experience and contact with natural gas suppliers, they assume the process of building up fuelling stations and getting a supply network started may take very long time, or even, never happen.

Another problem facing the switch to natural gas is the lack of reliable technology regarding trucks, especially in the heavy-duty classification. The truck supplier of BCT, Volvo Truck-Nor does not have trucks with the specifications of BCT, which is over 500 hp. TruckNor however, is confident that there will be important improvements regarding this technology from the year 2014.

7. ANALYSES

This section will present the analyses conducted in the study, their methodology and application.

7.1. EMISSION INVENTORY: CALCULATING EMISSIONS OF CO_2 BY BURNING FUEL

An emission inventory is presented as a summary of the CO_2 emissions from diesel burning in the different routes of K+N from the base of Ågotnes in the year 2013.

<u>Methodology</u>

There exist many different ways of calculating emissions for road transportation. As a consequence, the results have very high variations. The author has consulted two methods and the final decision was made based on the information available and the relevance of the method for the type of activity Kuehne+Nagel has.

The first methodology consulted is "Guidelines for Measuring and Managing CO_2 Emissions from Freight Transport Operations" by the European Chemical Industry Council and the European Chemical Transport Association (ECTA & CEFIC) (2011). In such guidelines two approaches are presented:

a. Activity-based approach. These calculations are recommended for companies who outsource their transport operations to subcontractors and therefore have no direct access to energy or fuel consumption data. The formula is then (Tonnes CO_2 emissions = tonnes * km* g CO_2 per tkm[8] / 1.000.000)
b. Energy- based approach. Recommended for transport companies that record energy and/or fuel use and employ standard emission conversion factors. The formula is (Tons CO_2 emissions= liters * kg CO_2 per liter fuel/1.000)

[8] Tkm, or tonne-kilometer is a common measure to express the realized freight transport demand or supply. It is used equivalently to tonne-carried in this work.

Finally, LIPASTO traffic emission calculations have also been consulted. LIPASTO is a calculation system for traffic exhaust emissions and energy consumption in Finland developed by the Technical Research Center of Finland (VTT) (2012). The calculations take into account different factors such as EURO standard for heavy duty vehicles, urban or highway roads, load percentage and empty driving; it presents its results in tone-kilometer units.
In combination with LIPASTO's recommendations and the available data for this analysis, the method used in this work consists of the following formula:

g CO_2 per tonne carried= [(total cargo/ (gross weight * load factor))* g CO_2 per km]/1.000.000

Where,
Total cargo= total cargo transported from the base in Ågotnes to each route in the year 2013.
Gross weight = 31 tonnes, which is the carrying capacity of most trucks used by K+N.
Load factor = 31 tonnes is considered a load factor[9] of 100%
gCO_2 per km= 2580 g of CO_2 in 1 liter of diesel multiplied by fuel consumption of 0,431 liter per km.
The product is then divided by 1.000.000 in order to report the results in grams.

Data

Distances between the bases have been calculated with Google maps[10] (see table 2. Distance and cargo transported from Ågotnes to the different bases in 2013 in section 6.2.2). The data used in the calculation of emissions of CO_2 was retrieved from the UK's Department of environment, food and rural affairs (2013).

[9] Load factor is the percentage of load normally used by K+N, which ranks from 80-100%. Here is important to notice that K+N measure the loads by volume rather than weight. This represents a challenge for the calculation of emissions since the cargo transported is oil equipment, which can vary in shape and weight (see section6.2.1 Description of the cargo). In order to keep the logic of the analysis the unit factor is consider 1 m^3 = 1 ton.
[10] https://**maps**.**google**.com/

The following table (5) presents the summary of CO_2 emissions per tonne carried for the different routes of K+N, base-to- base traffic from Ågotnes.

	Emission Inventory g CO2 per tonne carried at different loading factors					
Destination from Ågotnes	80 %	85 %	90 %	95 %	100 %	Average
Mongstad	21,56	20,29	19,16	18,15	17,25	19,28
Haugesund	23,71	22,32	21,08	19,97	18,97	21,21
Stavanger	112,09	105,50	99,64	94,40	89,68	100,26
Florø	105,49	99,28	93,77	88,83	84,39	94,35
Kristiandsund	38,01	35,78	33,79	32,01	30,41	34,00
Sanddesjøen	4,34	4,08	3,86	3,65	3,47	3,88
Hammerfest	36,88	34,71	32,78	31,06	29,51	32,99
					Average	**43,71**

Table 5. Emissions of CO2 per tonne carried.

From figure 8 below it is observed that the CO_2 emissions decrease when the load factors come close to 100%. Also, with this approach, carbon emissions increase with the amount of cargo transported. For Kuehne+Nagel, Stavanger and Fløro are the destinations with the highest traffic and therefore, the highest emissions.

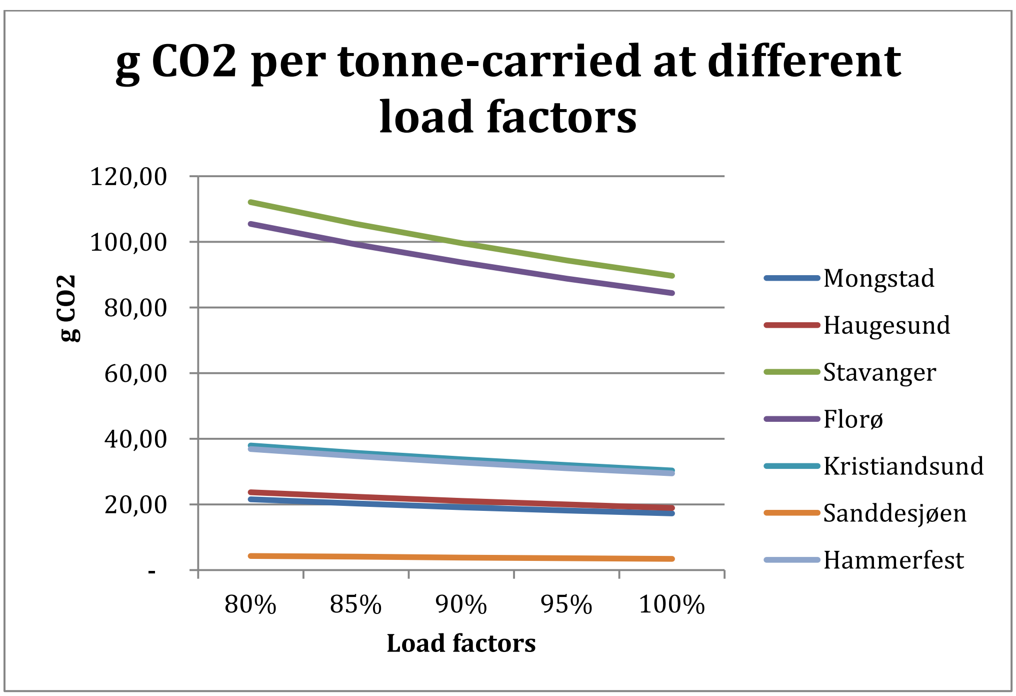


Figure 8. Carbon emissions per tonne- carried.

7.1.1 BENCHMARKING WITH EXISTING EMISSION CALCULATIONS

The benchmarking corresponds to the emissions of diesel; it allows having a general idea of the methodology applied, the necessary data and the variability of the results.

EcoTransIT on its Environmental Methodology and Data Report (2008), considers the following factors on their calculations of energy consumption of road transportation:

- Vehicle size and weight, vehicle configuration (trailer), motor concept and transmission.
- Weight of load (load factor). Appendix 4 shows an example of the energy consumption of a heavy-duty truck (40t vehicle gross weight as a function of load weight).
- Driving patter: influence of the driver and of the road characteristics (road category, number and width of lines, curves and gradient).

In addition, the EcoTransIT system takes into account the type of transported goods, according to their definition; oil equipment would be classified as volume type of cargo.

The following table shows total emission factors for lorry transport (articulated truck >34-40t) in motorway average for hilly countries. On the table it is observed that for EURO V emission standard trucks, transporting volume cargo, which would be the characteristics of the truck and cargo of K+N, the CO_2 g/ tkm is 102. The highest CO_2 factor obtained in the routes of K+N is of 110 CO_2 g/ tkm which are slightly higher than that of EcoTransIT.

Emission standard	type of cargo	CO_2 (g/tkm)	NO_X (mg/tkm)	NMHC (mg/tkm)	PM_{dir} (mg/tkm)
Euro 1	bulk	65	610	65	19
	average	72	683	75	21
	volume	111	1.051	131	37
Euro 2	bulk	63	664	47	9
	average	69	755	55	10
	volume	106	1.192	91	18

Euro 3	bulk	65	492	46	10
	average	72	553	54	12
	volume	111	856	93	22
Euro 4	bulk	63	314	50	2
	average	70	353	59	2
	volume	107	544	102	4
Euro 5	bulk	60	184	50	2
	average	66	205	58	2
	volume	102	315	100	4

Table 6. Total emission factors for diesel fueled lorry transport (articulated truck >34-40t) in motorway average for hilly countries. (EcoTransIT, 2008)

LIPASTO (2012) also presents their calculations based on the following factors:

- Engine type
- Emission standards (EURO I-VI)
- Load factors (70%-100%)
- Road and traffic conditions (highway and urban driving)
- Other calculation information:

  Diesel

  Specific weight 0.845 kg/l (Density 845 kg/m3)

  Heating value 43 MJ/kg

  Energy 1 kWh = 3.6 MJ

  Sulphur content (S) 0.001p-% = 0.0169 g/dm3 SO2

  Carbon dioxide (CO2) 2660 g/(dm3 fuel) = 3148 g/(kg fuel)

The results of the emission calculations by LIPASTO show that for a EURO V truck with 70% load, emissions of CO_2 g/tkm is 54 and fully loaded (25 tons) 41. This shows the same trend observed in the calculations of EcoTransIT for energy utilization as a function of load, energy consumption decreases as a function of weight (see appendix 4). The table below presents emission results for EURO standards (I-V) for 70 and 100% load factors.

	CO_2 [g/tkm]	
	(70% load)	full loaded (25t load)
--> 1993	52	39
EURO 1 (1994 - 1996)	53	40
EURO 2 (1997 - 2000)	54	41
EURO 3 (2001 - 2006)	55	42
EURO 4 (2007 - 2008)	54	41
EURO 5 (2009 -->)	54	41
EURO 6		
Average, year 2011	54	41

Table 7. Emission factors for diesel fueled semi-trailer combination, gross vehicle mass 40t, and pay load capacity 25t in highway driving. *Source:* (LIPASTO, 2012)

Both tools (EcoTransIT and LIPASTO) use similar factors for calculating emissions and yet present very different results.

EcoTransIT emission factors range from 60-102 for EUROV vehicles and LIPASTO presents 54-41 for the same vehicle standard. K+N's average emission factor is 43 CO_2 g per tonne carried, for loading factors from 80-100%, which is between the Lipasto tool and under the range of the Ecotransit tools. Figure 9. Shows the comparison between the existing emission factors from Lipasto in the ranges of 70 and 100% load, Ecotransit for the average and volume type of cargo and Kuehne+Nagel for the average carbon emission per tonne carried for the routes from the base in Ågotnes.

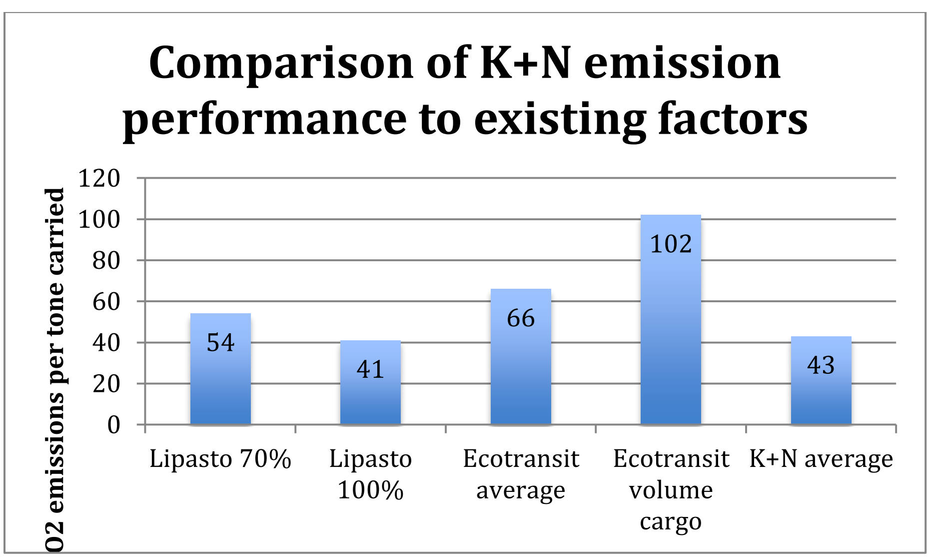


Figure 9. Comparison of K+N emission performance to existing emission factors.

7.2 CO_2 EMISSION COMPARISON OF DIESEL AND NATURAL GAS

Methodology.

The methodology used in this analysis is based on the work of McKinnon & Piecyk (2009). In order to provide with a comparable analysis for the different types of fuel an average approach has been used. It consists of calculating the following:

Average traveled distance in 1 year (km)* Fuel efficiency of the vehicle (l/km)= Fuel consumed

Fuel consumed (l)* CO_2 content on 1 liter of fuel (g) = g CO_2 emitted in an average trip.

This approach gives a partial view of the emissions of K+N's traffic but it allows a more homogeneous comparison of performance of the different fuels.

The applied method for calculating emissions of natural gas in both LNG and CNG forms follows the same method as the calculation of emissions for diesel (g CO_2 per tonne-carried). The values of emissions have been substituted for each fuel. In order to provide with a more relevant comparison the three fuels (diesel, LNG and CNG) have been calculated for the same amount of km travelled in the same routes and the same loading factors (100%).

Data

The average traveled distance is calculating for the routes from the base in Ågotnes to the different destinations, is equal to 654 km.

As for the fuel efficiency of diesel, the average of two different sources has been used. Lipasto has calculated 0,362 l/km diesel utilization for 25 tonnes trucks. K+N uses a ratio of 0,5 l/km on their calculations. The average of both sources is 0,431 l/km for diesel.

As for the gaseous fuels, Volvo Trucks have informed that natural gas fueled trucks have a consumption of 0,25-0,30 l/km. The average of those factors is 0,275 l/km.

Information on the CO_2 content of the fuels has been retrieved from Defra (Department of environment, food and rural affairs , 2013).

The fuel with the fewer amounts of emissions of carbon in an average trip is CNG, emitting approximately 20% the values of diesel, followed by LNG with emissions of 30% of that of diesel. Figure 10 summarizes the emission comparison of the fuels, for the average trip of K+N.

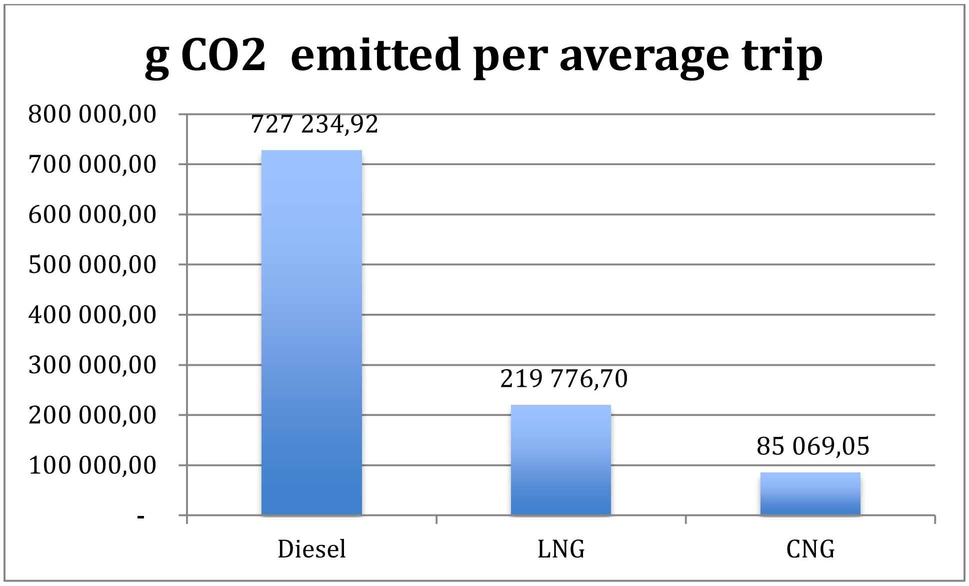


Figure 10. g CO2 emissions comparison from diesel, LNG and CNG for an average trip from the base in Ågotnes.

Appendix 3 shows in detail the data used to compare the fuels.

7.2.1 LIMITATIONS OF THE ANALYSIS

The calculations of the emission factors have been formulated according to available data from primary and secondary sources. From the primary source K+N, some data was unable to be processed for mainly two reasons, either non-existing or classified as confidential by the company. Non-existing information comprehends the amount of cargo transported in collaboration with competitors, both in K+N's used trucks and the competitors' trucks. Confidential information comprehends prices charged to competitors for the transportation of their cargo and prices for K+N's services to their clients.

As for secondary data, there are no generally used standard procedures for calculating emission of the specific truck description since the variables used in the methods can be quite difficult to quantify. Therefore, the author has used the methodology according to the available data. Such is the case of the fuel efficiency variable, the author considered appropriate to use the average between the theoretical value of Lipasto and the actual use K+N reports.

7.3 PRICE ANALYSIS

The acquisition of a truck, or eventually a fleet, is seen as a project investment. Kuehne + Nagel's subcontractor, BCT renews each truck after a 5 years period. The purpose of this analysis is to find out whether to invest on a natural gas driven truck can be profitable, given the price of the trucks themselves and the fuel price.
According to the information provided by GasNor, at this moment, there are no LNG vehicle-fueling stations for private use in Norway. It is unknown whether the establishment of such stations will happen in the near future. Due to this fact, the author has decided to compare the fuel prices of diesel and CNG of Norway and the pump price of LNG from Netherlands, where the LNG market is more developed.

<u>The price of new truck technology</u>
One of the biggest truck suppliers in the Norwegian truck market is Volvo Trucks. They are also the main supplier of Bergen Container Transport, K+N's subcontractor. The Environmental Director of Volvo Trucks was contacted for purposes of this research and he assures that even though trucks' prices are highly negotiable, a real assumption is that a methane-diesel truck is about 350.000 SEK more expensive than a diesel truck. Table 8 presents a summary of the prices.

Truck Type	Retail price (NOK)	Notes
Diesel	800.000	Average price of the trucks owned by BCT.
Methane-Diesel (LNG)	1.113.445	Diesel truck's price plus 350.000 SEK at an exchange rate of 0,90 NOK.
CNG	1.113.445	Diesel truck's price plus 350.000 SEK at an exchange rate of 0,90 NOK.

Table 8. Estimated retail prices of Volvo Trucks.

In addition to the increment in price of a natural gas driven truck, costs for maintenance and drivers' training should also be considered. According to the same source from Volvo Trucks, maintenance prices are expected to be lower than for a traditional gas engine (Otto-engine). Also, maintenance costs are highly negotiable.

An important aspect of gas-driven trucks is the concern of fuel efficiency in combination to their fuel capacity. As mentioned on table 3, truck fleet leased to K+N by BCT, the fuel capacity of the trucks range from 500-600 liters of diesel. As for the Methane-Diesel trucks[11], that run on LNG their fuel capacity is of 200 kg. As for the CNG trucks, their fuel capacity is of 80-90-diesel gallon equivalent, which would be approximately 145 liters of diesel. Using the same fuel efficiency data for diesel of 0,431 l/km as in the emission analysis, a diesel truck with a tank capacity of 550 liters would be able to travel approximately **1276 km**. While a CNG driven truck would only be able to drive a distance of **483 km** at a fuel efficiency of 0,3 l/km. A LNG fueled truck with a fuel capacity of 200 kg, approximately 145 liters of diesel (1 kg LNG= 0,426 diesel liter equivalent) with a fuel efficiency of 0,3 l/km would also reach a distance of **483 km**. This means that a natural gas fueled truck would have to stop at least 2 times to refuel in order to drive the same distance as a diesel truck. However, destinations such as Mongstad, Stavanger and Fløro could be covered in a one or round trip.

<u>Fuel price</u>

Undoubtedly, one of the main drivers to switch to natural gas trucks is the price of fuels. As stated earlier in this work, BCT has an agreement with fuel companies Shell and XY to get a discount of 24% of retail price (9,70 NOK). The price of 1 liter of diesel at XY as of June 2014, is of 14,32 NOK. The retail prices of CNG in Norway ranges from 7,22-7,50 NOK from vendors Barents NaturGass AS and SKL respectively, both of them supplied by GasNor. LNG has no distribution points for private use in Norway. However, for purposes of this research, the author uses the price of 1,195 EUR per kilogram, which is approximately 9,73

[11] Methane-Diesel trucks have the capability to run on both methane, the main component of natural gas, and diesel. Volvo's trucks run on 50% diesel, 80% methane.

NOK at an exchange rate of 8,14 NOK, from the Dutch retailer LNG24. LNG is sold in kilogram units due to the strong influence of temperature over the volume of this fuel. In order to make a fair comparison of the fuels, their prices and units the author assumes 1 kg of LNG to be equal to 0,7263 diesel liter equivalent (DLE) and 1 m^3 of CNG equals 1 liter of diesel (Horne, 2013). Taking into account, the fuel efficiency (l/km) and the prices of the different fuels (NOK/l), it is possible to evaluate that fuel cost per km. Resulting on diesel at 6,17 NOK/km, LNG **2,91** NOK/km and CNG **2,21** NOK/km.

In order to exemplify the differences in costs that the different fuel prices would have the author has selected the route of Ågotnes-Stavanger. This route is daily driven, all year round; this is 232 km one-way, 260 days a year, that would be equal to 75 920 km traveled in 1 year. Table 9 summarizes the fuel costs for this route with the different fuels. Figure 11 illustrates the potential savings on fuel costs for the mentioned route.

Fuel	Unit	DLE	Price (NOK)	Yearly cost for the route Ågotnes-Stavanger (NOK)
Diesel	Liter	1	14,32	468 572,17
CNG	M^3	1	7,36	167 631, 36
LNG	KG	0,726	9,73	220 927, 20

Table 9 .Fuel prices comparison

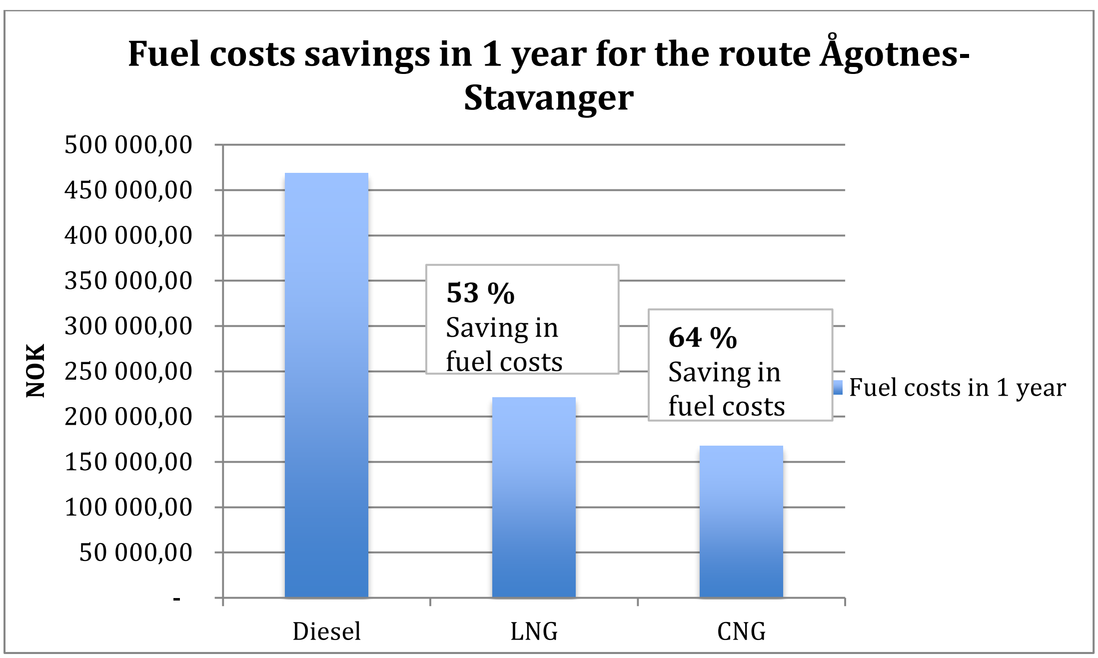


Figure 11. Potential saving costs in fuel.

As observed in the table above, switching to either one of the alternatives can make significant savings in fuel costs, even though the price of LNG is equal to the price BCT gets at a discount. In order to create a business case for natural gas fuel in Norway, the price of CNG and LNG must be considerable lower than that of diesel. From the results of t table 10 it can also be observed that at current gas prices the difference in price of the trucks can be covered. Although truck and fuel prices are important drivers to suggest a switch on truck fleet, there are other uncertainties and risks to consider.

7.4 UNCERTAINTY AND RISK ANALYSIS

The major challenge facing a switch to alternative fuels is the availability of them. It is clear that no company will switch to an alternative fuel before there is sufficient infrastructure that supports the change. At the same time, there is little motivation to build an infrastructure of natural gas supply until demands reaches desirable levels. This "chicken and egg" problem has existed even before natural gas vehicle technology reached todays' standards of engine efficiency. The uncertainty is who would take the step forward to promote the use of the gaseous fuel, when and at which scale?

As for fuels prices, it has been argued that natural gas prices can delinked from oil prices, which could mean, to a certain extend, that the gas industry can provide with more stable natural gas prices. Norway has the advantage of having significant natural gas reservoirs and technology to exploit and distribute them. From a policy point of view, it is uncertain whether policy makers will put emphasis on promoting the use of natural gas fuels, e.g. in the form of taxes on fuel prices, vehicles' price or somehow supporting the fueling infrastructure building.

From a managerial point of view, being one of the first companies to engage in acquisition of new technology can soon become a disadvantage if there is little response from the market. In this case it would be necessary that the transportation industry can be convinced of using the natural gas alternative. Also, it would be important that customers get to see the value of their goods being transported on cleaner trucks. Another potential conflict arises for companies that lease trucks, as in the case of Kuehne+Nagel, when a question of who would assume the investment risk is asked. Finally, there is a risk of not having a market to sell the trucks after their 5 years utilization, if the natural gas truck market has not to be developed by then.

8. THE RESULTS

This section has the purpose of summarizing the factors, discussed along this research and at the analysis that have an impact on the decision of switching fuel sources as well as possible further consequences and opinions. Based on the results of the analysis and the force field analysis of ActResearch (appendix 6) the following table (10) summarizes the results.

Adoption of natural gas as a fuel in the logistics industry

Factor for change	Factors against change
Total fuel cost per km. Given the current prices of diesel, LNG and CNG; the gaseous fuels have an advantage over diesel.	Higher up front cost of trucks and additional costs, e.g. drivers' training.
Natural gas delinked price from oil. This is an advantage because it provides with better price stability.	Transportation of natural gas, establishment and storage of fueling stations.
Energy independence. Not only in the case of Norway, but other countries such as U.S.A. and Canada where newly discovered reservoirs may have an important effect over the economy of those countries and the world's supply of natural gas.	Little fueling infrastructure of CNG and inexistent LNG fueling infrastructure for trucks in Norway. Little fueling infrastructure of LNG in neighbor country Sweden.
Product development and new truck suppliers. Important technology development pro-natural gas use is happening in the global trucks' market.	Engine efficiency, volume and weight of fuel tanks in trucks. In theory, the engine efficiency of the natural gas trucks is quite competitive with that of diesel. However, it is known that driving conditions such as weather, hills and drivers training, etc. play an important role in the actual efficiency of the engines.

Environmental advantage over diesel and sustainability commitment from governments and policy makers that promote the use of greener fuels.	Investment risk. Like K+N, many companies outsource truck's services and ultimately the decision of investing on natural gas trucks is on the subcontractors' hands. At the same time, conflict about defining cost beneficiaries can arise.
Green marketing and innovation from within the industry, as a strategic advantage for the user companies and their value chain, e.g. clients and final users.	Uncertain truck residual value. If the market of natural gas trucks is not developed by the time there is a need to renew the truck fleet.

Table 10. Summary of factors for and against the adoption of natural gas as a fuel.

It is not uncommon that problems arise when companies with commercial relations face risky investment and benefit-share decisions. The benefits of new technology can also bring up this dispute. A suggestion to handle this situation is to share the risk. In the particular case of switching fuel sources for K+N and its subcontractor, the subcontractor is the agent who owns the trucks and directly pays fuel costs. An expected consequence of switching to natural gas fueled trucks is that overall operative costs would sink. K+N could then be in the position of sharing the cost of the subcontractor on this new technology by implementing a diesel compensation arrangement. The compensation could cover the difference between the diesel and the gaseous fuel price used. Arrangements of this kind are often employed to motivate subcontractors and partners towards the implementation of green technology.

It was shown in the previous analysis that natural gas fueled trucks can achieve a traveled distance of up to 483 km without refueling. This is equivalent to round trips to destinations from Ågotnes to Mongstad, Stavanger and Fløro, some of the most transit bases. In an initial phase, the mentioned bases could be used as a reference to build fueling stations and have dedicated trucks between them. This suggestion may impose a limitation to the business model of K+N where trucks are indifferently used by the bases. However, given the potential saving costs of natural gas fuels and other benefits previously discussed, this solution could be the trigger of a long-term commitment between all the agents involved.

9. CONCLUSION

The current situation of the transportation industry can be described as the struggle of providing with efficient low-cost solutions to meet demand requirements and to comply with strict environmental regulations both on international and national levels. By being a carbon intensive activity, the transportation industry is constantly challenged to innovate and to channel efforts towards the implementation of environmental friendly technologies and resources. This work has discussed the alternative of switching to an alternative fuel source and the adoption of new truck technology. Certainly, natural gas is a fossil fuel and is not carbon neutral, but it represents a viable alternative to oil. Due to attributes such as lower carbon content than diesel, availability, price and well developed technology; it becomes an attractive alternative fuel for the logistics industry. This research has found that a switch to natural gas could potentially have economic and environmental advantages. Despite higher upfront costs than a business as usual scenario, low fuel prices and improved gas-fueled truck technology have the potential of providing with a competitive advantage to the business while reducing their environmental impact. Potential benefits can also be extended in areas such as marketing, brand name strategy and favorable clients' perception.

Innovation is been proved to be a great strategy to make businesses and industries more competitive. Kuehne+Nagel could make use of this advantage and even place itself a step forward to coming regulations and desires from the market. Therefore, an investment of this kind would be advisable as long as it is not taken alone. As BCT mentioned, from experience, it is not always good to be the first ones in trying out new technology. Also, taken into account that several agents play important roles as decision makers, e. g. policy makers, natural gas suppliers, technology developers, competitors, clients and subcontractors; it would be advisable to start building communication bridges between them. By doing so, "the chicken and egg problem" could have a solution. As for the role of policy makers, most of them have ambitious goals towards reducing GHG emissions. Even though road transportation emissions account for almost 11 percent of all GHG last year, there still little support in figures of taxes and infrastructure to make the industry greener. In order to reach such climate change abatement goals, it would be expected that for instance, alternative fuels had less taxes levied. Finally, in combination with minimization of risks and uncertainty, prices of natural gas fuels would need to be attractive enough to incentivize companies to switch.

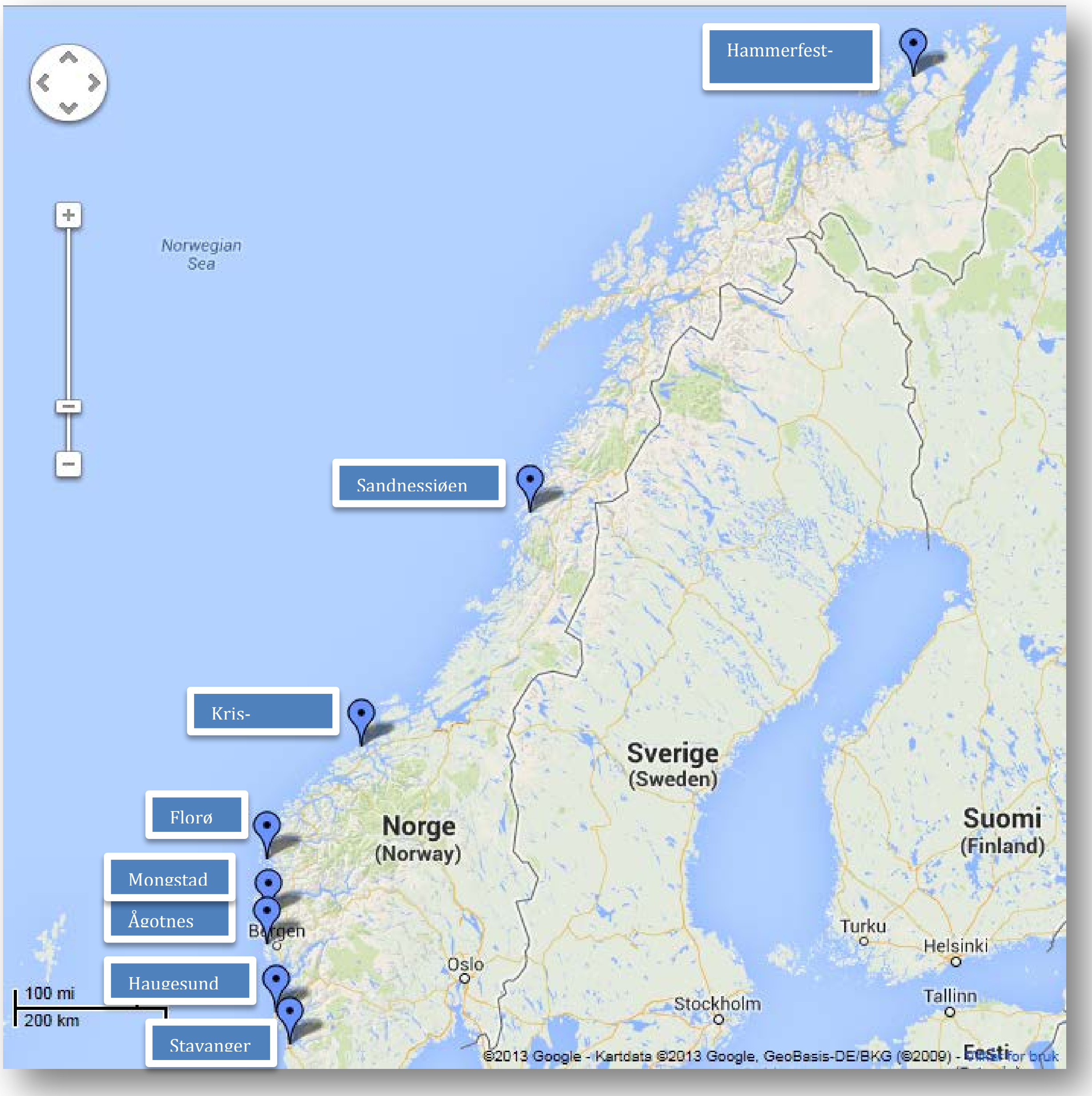
10. FURTHER RESEARCH

The field of improvement of this thesis is substantial. The results obtained in this work are not, in any case, the ultimate truth. The final decision of switching to natural gas as fuel for a specific company needs deeper and more particular research in different areas e.g. finance, marketing and eventually the evaluation of agreements with subcontractors and other agents involved. Regarding base-to-base traffic, the subject of collaboration between competitors for this particular type of service could be further investigated. In the scenario of the adoption of natural gas-fueled trucks, more research on technical aspects of the performance of the trucks would be needed. In addition, analysis of actual costs of maintenance, training and fuel efficiency would be useful in the decision making process of companies that look into this alternative. If the establishment of natural gas supply infrastructure is to happen in Norway in the near future, the author recommends at least two areas of further research. First, the investigation of strategic locations of refueling stations to supply the transportation and private sectors. Second, research using game theory[12] to analyze individual goals or preferences, and harmonic interaction among the agents involved.

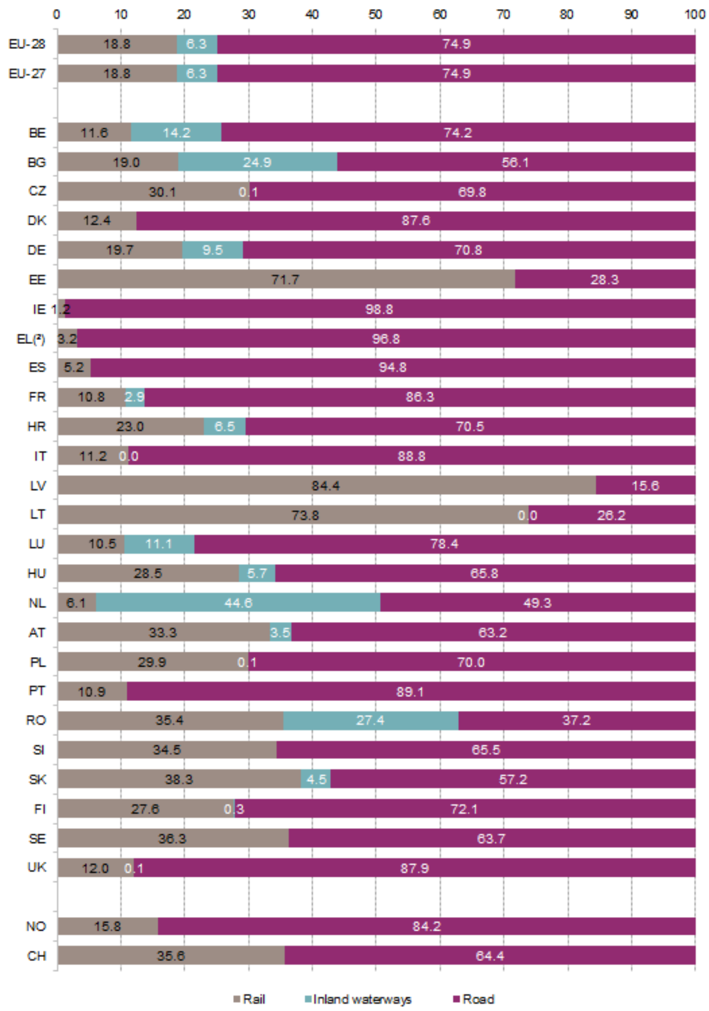
[12] Game theory is defined by Osborne & Rubinstein (A course on Game Theory, 1994) as *" a bag of analytical tools designed to help understanding the phenomena that is observed when decision-makers interact…The basic assumptions that underlie the theory are that decision-makers pursue well-defined exogenous objectives and take into account their knowledge or expectations of other decision-makers' behavior*."

APPENDIXES

Appendix 1. Map of the bases along the Norwegian West Coast, elaborated by the author with information from K+N and Google maps.



Appendix 2. Road transportation in Europe by mode.



([1]) CY and MT: no railways and inland waterways; road share is 100%.
([2]) Greece, estimated data.

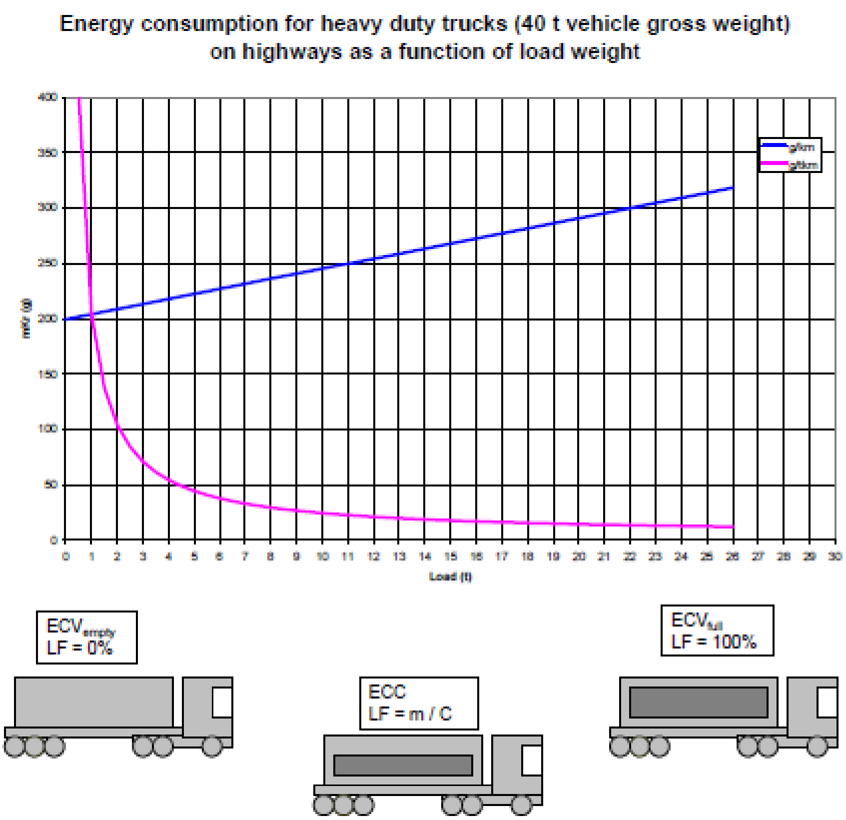
Appendix 3. Comparison of emissions for diesel, LNG and CNG.

DIESEL	
Average fuel efficiency (l/km)	0,431
0,362	l/km (Lipasto)
0,5	l/km (KN)
Average traveled distance (km)	654
Fuel consumption of the average trip =	281,87
g CO2 in 1 liter Diesel=	2580
g CO2 emitted per average trip	727 234,92

CNG	
Average fuel efficiency diesel equivalent	0,275
0,25	Volvo
0,3	Volvo
Average traveled distance (km)	654
Fuel consumption of the average trip =	179,85
g CO2 In 1 liter CNG	473
g CO2 emitted per average trip	85 069,05

LNG	
Average fuel efficiency diesel equivalent	0,275
0,25	Volvo
0,3	Volvo
Average traveled distance (km)	654
Fuel consumption of the average trip =	179,85
g CO2 In 1 liter LNG	1222
g CO2 emitted per average trip	219 776,70

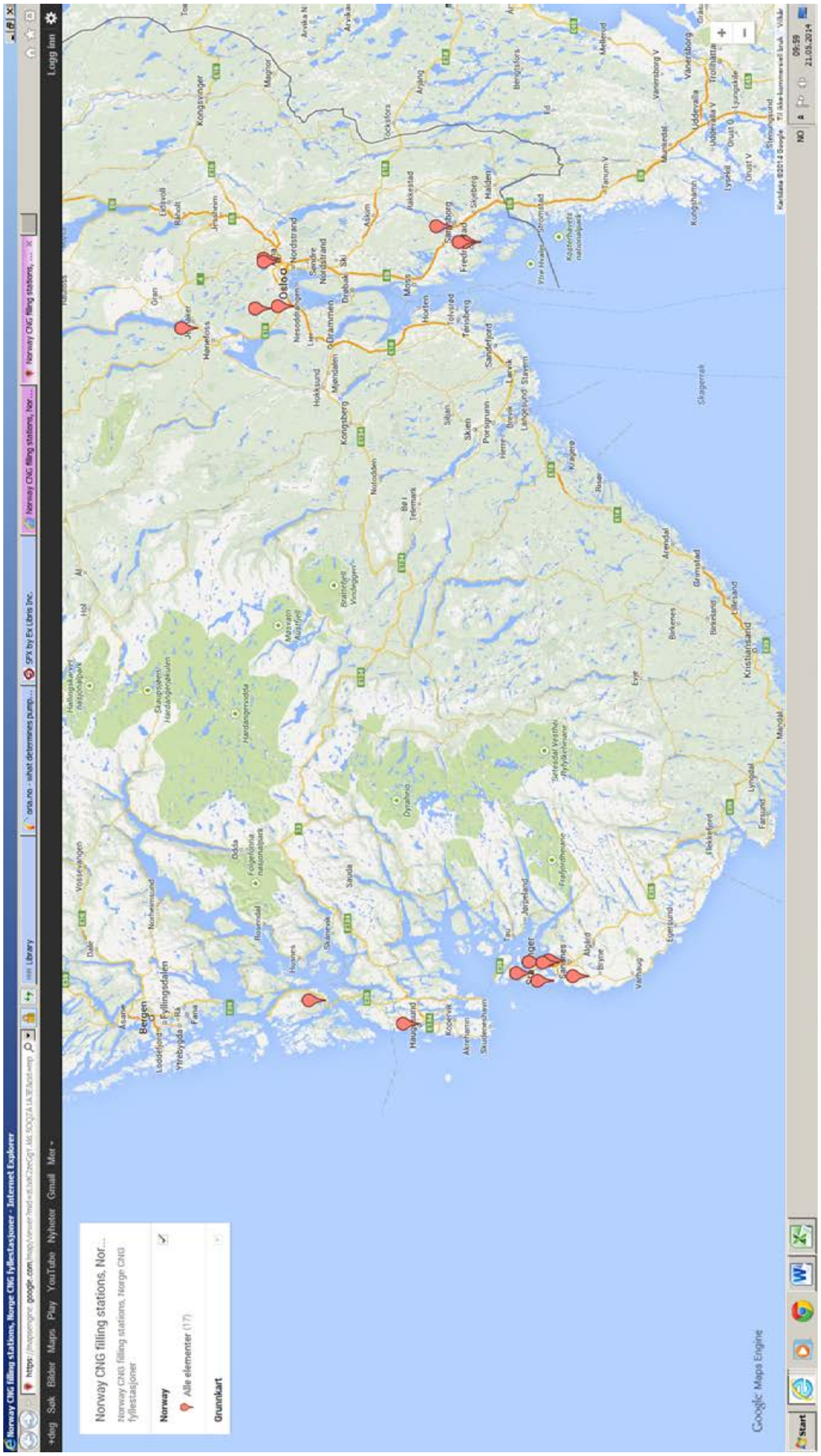
Appendix 4. EcoTransIT example of energy consumption for heavy-duty trucks (40t vehicle gross weight) as a function of load weight.



$$ECC = ECV_{empty} + (ECV_{full} - ECV_{empty}) * LF$$

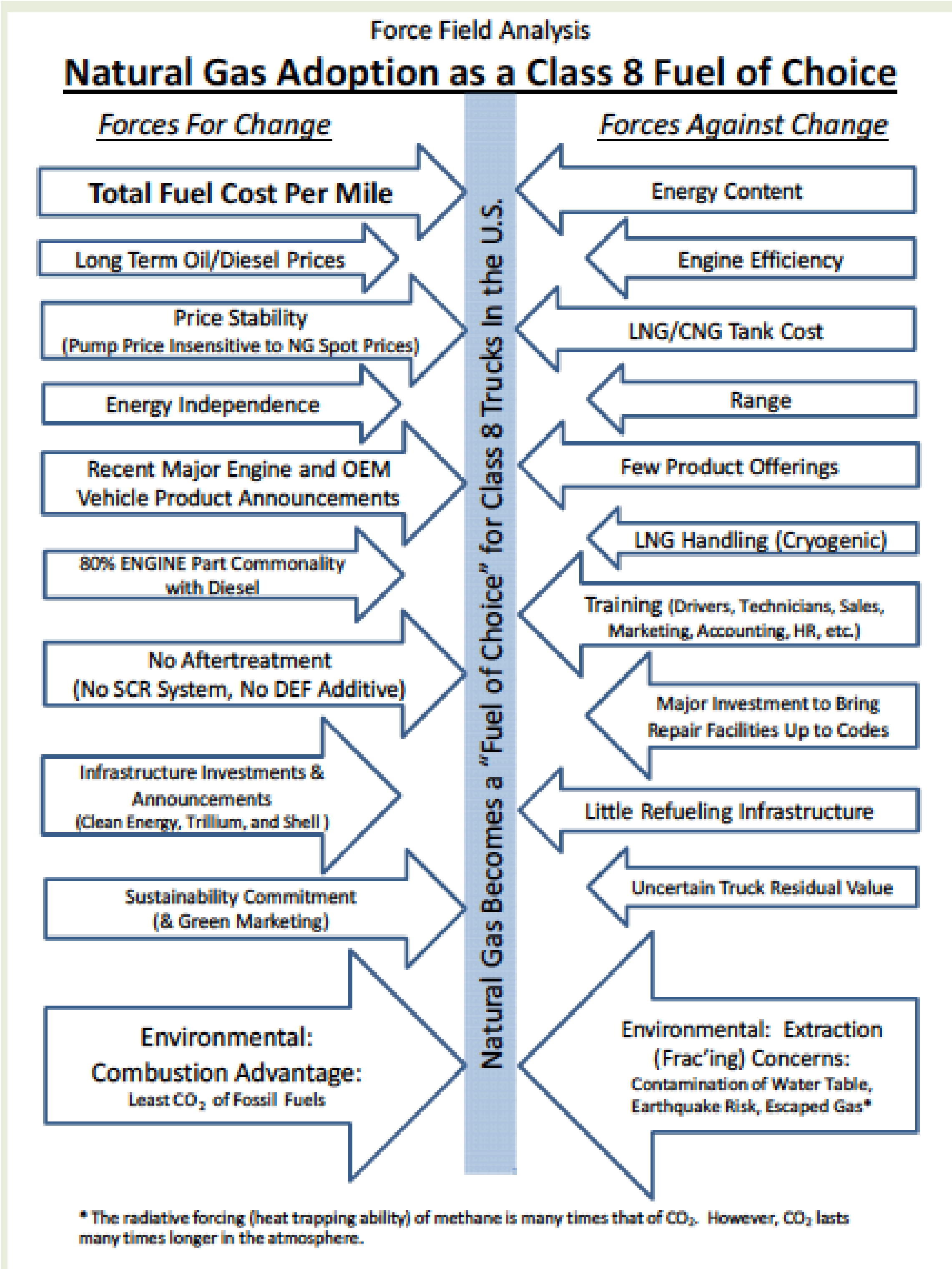
ECV	Energy consumption vehicle (g/km)
EC_{empty}	Energy consumption vehicle without load (g/km)
EC_{full}	Energy consumption vehicle with full load (g/km)
ECC	Energy consumption of specific cargo (g/km)
m	mass of specific cargo (t)
C	load capacity (t)
LF	Load factor (weight load / load capacity)

Appendix 5. CNG Fueling stations in Norway



Appendix 6. Force field analysis

Source: (ACT Research, 2012)



WORKS CITED

(2006). *The Stern Rerview on the Economic effects of Climate Change.*

ACT Research. (2012). *The future of natural gas engines in heavy duty trucks: the diesel of tomorrow?* ActResearch.

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2004). Successful adaptation to climate change across scales. *Elsevier*, 77-86.

Agency for Public Management and e-Govenment. (2014). *Direktoratet for forvaltning og IKT.* Retrieved May 1, 2014, from Difi: http://www.difi.no

Aguilera, R. (2011). World Natural gas endowment as a bridge towards zero carbon emissions. *Technological Forecasting & Social Change*, 579-586.

Alternative Fuels Data Center. (2014). *Alternative Fuels Data Center*. Retrieved March 21, 2014, from U.S. Department of Energy: http://www.afdc.energy.gov/fuels/prices.html

Andress, D., Nguyen, T. D., & Das, S. (2011). Reducing GHG emissions in the United States' trasnportation sector. *Elsevier*, 117-136.

Baldasano, J., Valera, E., & Jimenez, P. (2003). Air quality data from large cities. *Science of the total environment*, 141-165.

Biomass energy center. (2011). *Carbon emissions of different fuels*. Retrieved June 10, 2014, from Biomass energy center : http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL

Brown, S., Krupnick, A., & Walls, M. (2009). *Natural gas: a bridge to a low-carbon future?* Resources for the future.

Chinowsky, P. S., Price, J. C., & Neumann, J. E. (2013). Assessment of climate change adaptation costs fro the US road network. *Elsevier*.

Coast Center Base. (n.d.). *About CCB*. Retrieved June1 01, 2014, from http://ccb.no/index.php

Department of environment, food and rural affairs . (2013). Retrieved June 01, 2014, from https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs

EcoTransIT. (2008). *Environmental Methodology and Data Report.* Heidelberg: Institute for Energy and Environmental Research (IFEU).

EEA. (2011). *Annual Report 2011 and Environmental Report 2012.* Denmark.

Elvik, R., Vaa, T., Erke, A., & Sorensen, M. (2009). *The handbook of road safety measures, second edition.* Emerald Group Publishing.

Energi Link . (2011). *Energi Link* . Retrieved April 28, 2014, from http://energilink.tu.no/no/diesel.aspx

Engerer, H., & Horn, M. (2010, February 2). Natural gas vehicles: an option for Europe. *Elsevier*(38), pp. 1017-1029.

Enrgy Link. (n.d.). *Naturgass, tar siste bussen hjem?* Retrieved May 02, 2014, from energilink.tu.no

European Chemical Transportation Association & European Chemical Industry Council. (2011). *Guidelines for Measuring and Managing CO2 Emission from Freight Tranport Operations.*

European Comission. (2013). Retrieved from http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Freight_transport_statistics_-_modal_split

European Commission . (2014, May 20). *Mobility and Transport* . Retrieved May 21, 2014, from European Commission : http://ec.europa.eu/transport/themes/urban/cpt/

Fenger, J. (1999). Urban air quality. *Elsevier*, 4877-4900.

Fridstrøm, L. (2013). *Norwegian Transport Towards the Two-Degree Target.* Institute of Transport Economics, Oslo.

Fulton, L. (2010). Scenarios for cutting carbon dioxide in Transport 70 percent worldwide by 2050. *Climate and transport solutions: findings from the 2009 asilomar conference on trasnportation and energy policy.*, 9-23.

GasNor. (n.d.). Retrieved May 21, 2014, from http://gasnor.no/

Go with Natural Gas. (2012). *Go with Natural Gas a smart choice of transportation.* Retrieved June 13, 2014, from http://www.gowithnaturalgas.ca/getting-started/understanding-energy-equivalency/#CDLNGU

Gonçalves, M., Jimenez-Guerrero, P., & Baldasano, J. M. (2009). High resolution modeling of the effects of alternative fuels use on urban air quality: Introduction of natural gas vehicles in Barcelona and Madrid Greater Areas (Spain). *Elsevier*, 776-790.

Graham, L., Rideout, G., Rosenblatt, D., & Hendren, J. (2008). Greenhouse gas emissions from heavy-duty vehicles. *Elsevier*, 4668-4681.

Hacker, F., Harthan, R., Matthes, F., & Zimmer, W. (2009). Environmental impacts and impact on the electricity market of a large scale introduction of electric cars in Europe. *European Topic Center on Air and Climate Change*.

Hagman, R., & Leiren, M. D. (2011). *Bus emissions, biofuels and environmental impact.* Institute of Transport Economics.

Helmers, E., & Marx, P. (2012). Electric cars: technical caracteristics and environmental impacts. *Environmental Science Europe*.

Horne, D. (2013). *Proposal for CNG & LNG-DGE.* Clean vehicle education fundation. www.CleanVehicle.org.

Howarth, R., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Springer*, 679-690.

Hynor Lillestrøm. (n.d.). Retrieved from http://hynor-lillestrom.no

HYOP AS. (2011). Retrieved from http://hyop.no/om_oss/

Intergovernmental Panel on Climate Change, IPCC. (2007). *Fourth Report .*

International Energy Agency. (2011). *World Energy Outlook: Are We Entering a Golden Age of Gas?* Paris, France.

IPCC. (2000). *Emissions Scenarios (SRES).* IPCC.

Kolstad, C. (2011). *Environmental Economics.*

Lehoux, N., Audy, J., & D'Amours, S. a. (2009). Issues and experiences in logistics collaboration.

Levi, M. (2013). Climate consequences of natural gas as a bridge fuel. *Springer*, 609-623.

LIPASTO. (2012). *Lipasto Traffic Emissions*. Retrieved May 01, 2014, from http://lipasto.vtt.fi/indexe.htm

McKinnon, A., & Piecyk, M. (2009). *Measurement of CO2 emissions from road freight transport: a review of UK experience.* Logistics Research Centre, School of Management and Languagues. Edinburgh: Green Logistics.

Michiels, H., Beckx, C., Schrooten, L., Vernaillen, S., & Denys, T. (2012). Exploring the trasnsition to a clean vehicle fleet: from stakeholder views to transport policy implications. *Elsevier*.

Näslund, M. (2012). *LNG statust in Denmark- Technology and potential.* Hørsholm: Danish Gas technology Center (DGC).

Nordhaus, W. D. (2007). A review of the "Stern Review on the Economics of Climate Change". *American Economic Association*, 686-702.

Norwegian Ministry of Climate and Environment b). (2013). *Regjeringen*. Retrieved March 10, 2014, from http://www.regjeringen.no/en/dep/kld/Selected-topics/climate.html?id=1307

Norwegian Ministry of Transport and Communications. (2012). *Norwegian Ministry of Transport and Communications*. Retrieved March 6, 2014, from Regjeringen: http://www.regjeringen.no/pages/38429132/PDFS/STM201220130026000EN_PDFS.pdf

Norwegian Ministry of Transport and Communications. (2013). *National Transport Plan 2014-2023.*

Nyhammer, B. (2011). *Shifting Cargo from Road to Sea. A case study of Grieg Logistics' base-to-base transport of oil equipment.* Master thesis, Molde University College.

Offshore Norway. (n.d.). Retrieved June 02, 2014, from http://www.offshorenorway.no/event/company_prodlist?companyProducts=9790

Osborn, M. J., & Rubinstein, A. (1994). *A course on Game Theory.* Massachusetts Institute of Technology.

Pandey, D., Agrawal, M., & Shanker Pandey, J. (2010). Carbon footprint: current methods of estimation.

Ramberg, D., & Parsons, J. (2012, April 01). The weak tie between natural gas and oil prices. (33).

Ristovski, Z., Morawska, L., Ayoko, G., Johnson, G., Gilbert, D., & Greenaway, C. (2004). Emissions from a vehicle fitted to operate on either petrol or compressed natural gas. *Elsevier*, 179-194.

Rönnqvist, M., Bernstain, F., R., C., & D'Amours, S. (2012). Special issue on supply chain management and collaborative logistics.

Rothengatter, W. (2009). Climate change and the contribution of trasnport: Basic facts and the role of aviation. *Elsevier*, 5-13.

Scania. (2014). *Scania*. Retrieved April 02, 2014, from http://www.scania.no/Lastebil/miljoe/alternative-fuels/gas.aspx

SSB. (2014,a, February 11). *Statistik Sentralbyrå.* Retrieved February 24, 2014, from https://www.ssb.no/en/transport-og-reiseliv/statistikker/lbunasj

SSB. (2014,b, February 14). *Statistik sentralbyrå*. Retrieved February 25, 2014, from https://www.ssb.no/en/transport-og-reiseliv/statistikker/kilt/maaned/2014-02-14?fane=om#content

Statistics Norway. (2013). Retrieved from http://www.ssb.no/a/aarbok/tab/tab-250.html

Statistics Norway. (2013). *Emissions of greenhouse gases, 2013, preliminary figures*. Retrieved June 13, 2014, from http://www.ssb.no/en/klimagassn

Statistisk sentralbyrå. (2013, September 02). *Statistisk sentralbyrå*. Retrieved February 04, 2014, from http://ssb.no/en/natur-og-miljo/artikler-og-publikasjoner/samferdsel-og-miljo-2013

Stephen Brown, M. Y. (2007). *What drives natural gas prices?* Federal Reserve Bank of Dallas.

Stephenson, E., & Doukas, A. (2012, May 01). "Greenwashing gas: Might a 'transition label' legalize carbon-intensive natural gas development?". *Elsevier*, pp. 452-459.

U.S. Energy Information Administration. (2013, February 12). *EIA*. Retrieved May 11, 2014, from Factors Affecting Diesel Prices: http://www.eia.gov/energyexplained/index.cfm?page=diesel_factors_affecting_prices

Volvo Trucks. (2014). *Volvo Trucks*. Retrieved April 01, 2014, from http://www.volvotrucks.com/trucks/na/en-us/products/alternativefuels/Pages/alternative-fuel.aspx

Weitzman, M. L. (2007). A review of the Stern Review on the Economics of Climate Change. *American Economic Association*, 703-724.

World Energy Council. (2011). *Global Transport Scenarios 2050.* London: World Energy Council.

Yevdokimov, Y. (2010). Transportation and climate change. *InTecopen*.