Explore policies to stimulate Bio LNG using a social cost benefit analysis

The introduction of an alternative heavy road transport fuel in the Netherlands

Keywords: Bio LNG, LBM, LBG, heavy duty trucks, Social Cost Benefit Analysis SCBA, alternative fuel, transport, externalities, policy analysis

ABSTRACT

In the joint vision on the future energy mix LNG and bio LNG are being referred to as important opportunities for the Dutch economy to sustain heavy road transport fuels. New policies have to be developed to stimulate a transition to bio LNG in the Netherlands. The economic and societal effects of these new policies are unknown. This research will explore policy alternatives that will fit in the national and European context by a literature review and interviews. The effects of the policies will be examined by a social cost benefit analysis with a scope to 2050. Normally this method is used as a decision tool for infrastructure projects, in this research the value of the SCBA will be evaluated in more uncertain areas of energy transition to sustainable fuels. All the calculated alternatives score better than the reference diesel case, mainly because the forecasted increasing gap between diesel and LNG fuel prices. Different alternatives result in other distribution of effects for the stakeholders. The SCBA increases the insight in the usefulness and feasibility of policy alternatives to stimulate bio LNG. This prevents policies that have a negative effect on the welfare to be developed and. SCBA enhances discussions in the early stage of exploring policy alternatives by providing objective and independent information. Some input data for the SCBA are uncertain, further research on input variables and the connection with a transport model can make future analysis more robust.

1 INTRODUCTION

The European transport sector is facing stricter emission rules. In their fight against climate change governments try to restrain harmful emissions and improve the air quality. Transport is responsible for a quarter of the European Union’s greenhouse gas emissions (TNO ECN CE Delft, 2013). Transport in Europe is 94% dependent on oil, 84% of it being imported, with a bill up to EUR 1 billion per day (EC, 2015). The predominantly fossil fueled transport sector has to find new alternatives to meet stricter emission control measures. The need to switch to more sustainable energy sources is also triggered by depleting natural resources, concerns about increasing energy prices and desirable lower dependency on the Middle East and Russia.

Globally policy makers are searching for affordable, secure and sustainable energy sources to fuel their economies. Strategic choices are made to insure stable energy supply in the future. The Netherlands is currently facing challenging emission targets, the White Paper states that: “in order to drastically reduce world greenhouse gas emissions (...) a reduction of at least 60% of GHGs by 2050 with respect to 1990 is
required from the transport sector” (EC, 2011). At the same time transport volumes for trucks are forecasted to increase between 7% and 30% from 2015 to 2030 (RR 2012 & NEV 2014).

In 2014 a number of organizations including governments, employers, labor parties and environmental organization presented “The sustainable fuel mix of the Netherlands” (Een duurzame brandstofvisie met LEF) (SER, 2014). The document is a part of a broader Energy Agreement for sustainable growth directed by the Socio Economic Council (SER) and signed in 2013. The agreement lays out a broadly supported, robust and energy and climate policy. In The sustainable fuel mix for the Netherlands LNG and bio LNG are being referred to as important opportunities for the Dutch economy to sustain heavy transport fuels in road transport and shipment.

Bio LNG is presented as a sustainable alternative for diesel to restrict emissions, air pollution and noise nuisance, but currently there is no significant Bio LNG production capacity available. Biogas production facilities run on SDE+ subsidies and LNG is in its early development stage. Gas trucks are more expensive than diesel trucks and there is no national filling station infrastructure for LNG. It seems that Bio LNG as successor for LNG justifies the transition to another (slightly cleaner) fossil fuel. The question arises what the effects of a transition to Bio LNG will be for the Dutch economy and welfare. There are a numerous uncertainties concerning Bio LNG at the moment.

Another uncertain factor that influences the effects of Bio LNG is policy, for instance tax levels. The use of fossil fuels leads to CO2 emissions and air pollutions for which no market price is being paid (externalities). Governments can try to incorporate such externalities to a certain extend with taxes. Current tax levels for (Bio) LNG are lower than for diesel and the government uses other incentives to steer fuel demand. Biofuels are (still) more expensive than their fossil counterparts, the market is not going to make the switch to Bio LNG by itself. If the Netherlands wants to cut heavy road transport emissions, policies have to be developed to stimulate alternative clean fuels. Which policies to stimulate Bio LNG and what their effects will be is going to be researched in this article. The main question is:

*Which policies and regulations can be used to stimulate Bio LNG and can SCBA be used to provide more insight in the effects of these policies?*

This article will provide a short overview of current measures on a national and European level that influence the introduction of Bio LNG. These insights in combination with sector views on the development of Bio LNG will be used to develop policy alternatives. If the policies are set the effects on welfare are being explored using a cost benefit analysis. This method is being used to gain more insight in the effects and the distribution of the effects of more Bio LNG for the society.

### 1.1 CONTEXT

Natural Gas is a promising alternative to heavy fuel oil (HFO) and diesel in shipping and road transport. Gas engines tend to be cleaner and less noisy, and moreover, research shows limited positive environmental effects on PM, NOx and SOx emissions (TNO ECN CE Delft, 2013). CE Delft classifies the transition to gas trucks as a “no regret option” and stepping stone for the use of Bio LNG (TNO ECN CE Delft, 2014). The main disadvantage of gas is its volumetric energy content compared to oil products. In its liquid phase the volume of natural gas is reduced by a factor of more than 600, to liquefy natural gas it needs to be cooled down to -162°C (Kumar, Kwon et al. 2011). The volumetric energy density of liquefied natural gas (LNG) is 2,4 times higher than of Compressed Natural Gas (CNG) and 60% compared to diesel (Arteconi and Polonara 2013). LNG powered engines have a reasonable range
compared to diesel engines. The reduced volume of liquefied natural gas can have more advantages, for instance the ability to store the gas and transport the gas to off grid locations.

The LNG sector is in an early development stage, in the short to medium term the transition from oil based fuels to LNG can lead to lower emissions in heavy transport. On the longer term the switch from LNG to bio LNG can cut emissions further (SER, 2014). In the Netherlands there are currently around 250 LNG fueled trucks on the road (LNG Platform, 2015). To fuel LNG trucks an infrastructure is needed. In Rotterdam an additional harbor basin to enable LNG distribution for small scale LNG is build next to the GATE terminal (GATE, 2014). Private parties like Shell and Engie (GDF Suez) are planning to build successively seven plus ten new LNG tank stations in the Netherlands (TVDT, 2014). The investments in LNG infrastructure are high. Regulations and fiscal schemes are being used to stimulate the use of alternative fuels in transport. According to Brynolf the environmental profit to switch to LNG is limited (Brynolf, Fridell et al. 2014), when natural gas is being replaced by biogas the gain can become significant.

1.2 RESEARCH PROBLEM
The SER agreement about the sustainable future fuel mix is clear about the possible potential of renewable gas for the Dutch economy and society (SER, 2014). The current tax schemes and regulations will not result in a significant share of Bio LNG. If the Netherlands really wants to reduce the GHG emissions in heavy road transport new stimulation policies have to be developed. This article will elaborate on possible incentives to support the transition to Bio LNG and place them in a context.

There are numerous factors influencing the business case for Bio LNG, e.g. fossil fuel prices, production costs, taxes. The transition from diesel to Bio LNG also has external effects on greenhouse gas emissions, air pollution and safety and nuisance noise. There is no insight in the societal effects of policies yet. Before policy makers decide to stimulate Bio LNG research has to be conducted on the societal effects.

1.3 SCIENTIFIC RELEVANCE
There are many techniques for appraising policies and projects that impact the environment e.g.; Environmental Impact Assessment, Cost Effectiveness Analysis, Scenario Analysis, Risk Assessment Analysis and the Cost Benefit Analysis (Hanley and Spash 1993). CE Delft has performed LCA studies about emission reduction of different alternative fuels. In long term strategic choices for fuel sources a comparison has to be made between alternatives and their total effects on society. In an ideal world all the alternative fuels have to be compared and scored on their welfare effects. This research focusses on Bio LNG because it is appointed to be a favorable option by the SER.

The goal of this research is to explore current measures to stimulate (Bio) LNG and abstract policy alternatives from literature and interviews. These alternatives are valued and compared to a reference case using a SCBA. Traditionally CBA’s are used as decision supportive instruments in comparing infrastructure projects. The S is SCBA refers to the goal of the method to incorporate not only financial effects, but all social effects. Examples of effects that can be incorporated in a SCBA are emissions, air pollution and safety costs.
Infrastructure investments projects have different characteristics compared to environmental policies. Policies can influence consumer behavior and curtail demand. Investments or subsidies are instruments, but there is also the possibility to regulate the use of certain products. The effects of policies are inherent more uncertain than the results of investments projects.

There are more differences between infrastructure projects and environmental policies. The uncertainties on the costs and benefits differ. The benefits of environmental policies are generally external effects. There are no market prices for these external effects, what is the social cost of emitting a kilogram of carbon dioxide? With the discount rate the net present value is calculated of the interest of future generations, environmental effects can be discounted other than economic investments in for instance trucks. The challenge is to be able to conduct a CBA in a system that is surrounded by uncertainties. In the reflection of this research the method in relation to this problem is further discussed.

1.4 SOCIAL RELEVANCE
Insight in the effects of different policy alternatives regarding the transport fuel mix of the future can contribute to a more efficient policy and a higher social wellbeing. Not only economic growth will be addressed but also other public values like air quality and security of supply. If the introduction of more Bio LNG in the Netherlands results in higher social benefits than costs, policies can be adapted to actively support locally produced biogas and liquefaction units and associated investments. On the other hand, if the analysis shows more costs than benefits, the funds to support Bio LNG can be used in another way to increase social wellbeing.

The outcomes of this research can also be used to communicate the compiled complex system of effects that the introduction of more Bio LNG can have on the Dutch society. More insight in for instance noise reduction, emissions and security of supply and their distribution can lead to more efficient policy.

2 RESEARCH DEFINITION
This article provides more insight for policy makers in the long term effects of a partial transition in heavy road transport from diesel to Bio LNG for the society. Questions that will be addressed are; what are the greenhouse gas effects of Bio LNG trucks, which incentives can be used to stimulate Bio LNG and what are the projected fuel costs. In order to build the research in a structured manner, the following Main Research Question (MRQ) and sub questions are formulated:

*Which policies and regulations can be used to stimulate bio LNG and what is the value of SCBA in providing more insight in the effects of these policies?*

Sub questions:

1. Can CBA be used to valuate policy alternatives towards Bio LNG?
2. What is the current policy (status quo) of the Dutch government towards Bio LNG?
3. What are possible and feasible policy alternatives?
4. What are the social costs and benefits of different policy alternatives?
5. What is the value of SCBA in this research?
2.1 RESEARCH STRUCTURE

The research is built up as represented in Figure 1. First of all a literature review will be conducted about the subject Bio LNG. Throughout the research several meetings with the National Working Group Bio LNG are planned where the latest developments about the subject will be discussed. Interviews with pioneers in the Bio LNG sector are conducted and a few project visits to production facilities will take place to make the subject more tangible. Figure 1 shows the graphical representation of the research structure.

2.2 RESEARCH METHOD

Goal of this research is to get an overview of the feasibility of Bio LNG in the Netherlands, in a structured manner. The Cost Benefit Analysis is used as a framework to do a structured research. As a guidance the “OEI leidraad” and update (Eijgenraam, Koopmans et al. 2000) (CPB & PBL 2013) and “Leidraad MKBA in milieubeleid” (CE Delft, 2007) are being used. The steps to conduct a cost benefit analysis force the researcher to develop a broader understanding of current regulations, important actors, other project options and policy effects. Therefore a literature review in combination with interviews are conducted. The proposed policies used in the CBA are based on literature and interviews. The input variables about effects are based on sources found in literature.

A cost benefit analysis (CBA) model is used to value all costs and effects of different policy options on a systematic way. Performing a CBA can also be helpful in this early stage to select feasible alternatives and build a framework to evaluate innovation policy (SEO, 2006). “A key aspect of CBA is correctly measuring and valuing environmental and social (non-market) goods such as effects on human health and environmental integrity” (EPA, 2014). In this research the social cost benefit analysis (SCBA) will be used because non market goods like energy security of supply and clean air are important effects which are currently not valuated in Bio LNG prices. The CBA is an economic analysis which can be used for efficient decision making. Main areas where the technique is being used are; transport, environmental policy and healthcare (OECD, 2006). The cost benefit analysis dates back to the 19th century where Jules
Dupuit describes a technique to measure utility of public works in 1844, used in an infrastructure appraisal in France (Dupuit, J. 1844).

The idea of performing a cost benefit analysis is to determine the effects of different project or policies to human wellbeing (utility). In economics perfect markets have a self-regulative behavior which drives them to efficiency, which is what Adam Smith calls the “invisible hand” (Smith and Nicholson 1887). There are examples of situations where market behave imperfect for instance in the case of externalities, natural monopolies and public goods. Stiglitz points out that the invisible hand is invisible in the case of externalities (Stiglitz 1991). Clean air is an example of a public good and air pollution can be an example of an externality. The costs of the air pollution for the rest of the society is neither compensated for the producers or users of motorized transport.

Information about effects and costs of different measures can help policy makers to choose in their design for measures that have a positive total societal effect. Different alternatives can be realized against certain costs and have different effects on society. To value policy alternatives the societal effects have to be prized. Shadow prices are used to valuate external effects. Certain assumptions are made that cannot be scientifically grounded for instance; future extra investment of gas trucks, biogas production mix in 2030, discount rates and price of emissions. These assumptions result in aggregated costs and benefits that are not absolute. After the monetization of all the relevant societal effects, the net present value of these effects is calculated to a certain point in time, normally t=0.

2.3 SCALE OF THE MODEL AND DISCOUNT RATE

Along with the SER sustainable growth report the timescale will be set to 2050, in yearly steps. In environmental policies it is important to choose a timescale corresponding to environmental problems. The discount rate of environmental effects is set to 2,5% according to the advice in CE guidance (CE, 2007). Costs to restrict emissions are mostly upfront while positive effects of lower emissions can last for decades, also the longer period to calculate the effects allow a low interest rate. In the sensitivity analysis different rates will be applied to get a feeling of what the impact will be on the profitability of policies. A risk premium of 3% is set on the discount rate for investments with macro-economic risks; trucks, fuel costs and fuelling stations. The discount rate for investment other than environmental is set at 5,5%, this is in line with the Dutch CBA guidance (CPB, PBL 2013).

2.4 POLICY COSTS

The demand for fuels is strongly driven by taxation. Governments can introduce price incentives to stimulate a change in fuel mix. In the passenger car market this is already happening, gasoline, petrol and LPG can substitute each other. In the truck market LNG can substitute diesel which is currently the dominant fuel carrier. Diesel trucks cannot run on liquefied gas, but there can be a retrofit to use LNG next to diesel as a dual fuel set up. There are dedicated gas trucks which can be fueled by LNG and/or Bio LNG.

The responsiveness on policy measures is not completely rational, therefore the correlation between measures to stimulate bio LNG and the number of actual bio LNG trucks is uncertain. The calculations in the SCBA are based on number of trucks and their emission factors, predictions of the “Deelrapport wegvervoer duurzaam gasvormig” are used as input (SER, 2015). In this document several connected
actors have developed a joined view on future number of LNG and Bio LNG trucks. Policy measures that have to be taken to realize these numbers are also described.

![Diagram of policy goal, policy instruments, organisation, and effects]

Figure 2 Asses policy effects and costs (adjusted from leidraad)

2.5 DATA ANALYSIS
The input variables for the CBA are derived from several sources. Most of the data is found in literature by a desk research, for input of the CBA that can’t be found in literature some experts will be interviewed. PCM’s of TNO CE Delft and ECN, is an important data source (to be published soon). Data which is not available in literature and cannot be given by experts is being estimated by the researcher. These input variables are used to build a model in Excel.

2.6 DEMARCATION
In this research resources and time are limited, to answer the main question and sub questions within the timeframe the system needs to be simplified. It is not possible to describe all variables and their determining factors. In this research the main choices to simplify the analysis are described below. Further research can broaden the system and include more variables and sectors.

There are mainly two types of gas trucks. Dual fuel and single fuel gas trucks. Dual fuel gas trucks operate with different shares of gas and diesel mixtures. The share of LNG can be continuously adjusted from 0-75% (TvdT, 2014). To increase simplicity and overview only single fuel gas trucks and single fuel diesel trucks are incorporated in this research.
Emission factors play an important role in this research, what are the emissions of a gas or diesel truck? Not only powertrain efficiency, but also fuel production pathways have to be included. “A shift to renewable/low fossil carbon routes may offer a significant greenhouse gas reduction potential but generally requires more total energy. The specific pathway is critical” (JEC, 2014). In this research the well to tank (WTT) plus tank to wheel (TTW) emission factors are used.

The geographical demarcation is set to the Netherlands. This relates to the demarcation used in the SER energy agreement. The Dutch government acts in a European context but can design own policies to encourage the use of renewable energy. The effects of policies to encourage Bio LNG are assessed in this research.

3 BUILDING THE SCBA

From current national and international policies four possible measures are identified which are combined to alternatives that go into the CBA model. The current policies are researched with interviews and with a literature review.

- Fuel tax increase or decrease
- Regulations on minimal amount bio LNG blending in LNG for transport
- Subsidize mitigated CO2 emissions in transport
- Virtually green bio LNG through certificates

The measures are combined to build four alternatives. The Gas alternative is based on the sub report “Wegvervoer duurzaam gasvormig” of the SER, the other alternatives are adjusted from the Gas alternative (SER, 2015). Table 1 shows the alternatives and corresponding shares of (Bio) LNG trucks. These alternatives go into the CBA model where the effects are valued.

<table>
<thead>
<tr>
<th>ALTERNATIVES</th>
<th>SHARE LNG TRUCKS IN %</th>
<th>SHARE BIO LNG IN %</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GAS</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>FQD</td>
<td>25</td>
<td>32,5</td>
</tr>
<tr>
<td>DIESEL TAX</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>CO2 TAX REDUCTION</td>
<td>12,5</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 1 Shares of truck types for different alternatives in 2050

The gas alternative is built with the following measures:

- Subsidize unprofitable margin of Bio LNG production
- Stable low (Bio) LNG tax for 10 years
- Allow virtual greening of Bio LNG, but protect share of green gas grid injection

The FQD alternative:

- Stepwise growth of blending obligation Bio LNG
- Stable low (Bio) LNG tax for 10 years
- Partly virtual greening Bio LNG, but protect share of green gas grid injection
The diesel tax alternative:

- Increase diesel fuel tax with €0,10
- Higher LNG tax because of expiring refund scheme
- Subsidize unprofitable gap of Bio LNG production
- Partly virtual greening Bio LNG, but protect share of green gas grid injection

The CO2 tax reduction alternative:

- Extra tax reduction Bio LNG for mitigated CO2 emissions (8ct)
- Stable low Bio LNG tax for 10 years
- Environmental city zone: Extension Green deal zero emission city logistics to regulation
- Virtual greening of Bio LNG production, but protect share of green gas grid injection

Figure 2 shows how the alternatives are being valued, four groups of effects can be identified; direct costs, GHG emissions, Air pollution and other external cost.

Figure 3 How the CBA is build and the effects are valued
4 RESULTS

The results of the SCBA are presented below, all alternatives score better than BAU in terms of macroeconomic effect. The Diesel tax alternative has the lowest social cost, a saving of approximately €1,5 billion can be realized in the period till 2050. The governmental revenue of this alternative is higher than other alternatives, approximately €0,6 billion over the period 2015 – 2050 with the chosen input variables. These outcomes are dependent on the input variables which are forecasted and uncertain, but it gives an indication.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Net Present Value BLN €</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU (reference)</td>
<td>0</td>
</tr>
<tr>
<td>Gas</td>
<td>1,4</td>
</tr>
<tr>
<td>FQD</td>
<td>0,8</td>
</tr>
<tr>
<td>Diesel tax</td>
<td>1,5</td>
</tr>
<tr>
<td>CO2 tax reduction</td>
<td>0,4</td>
</tr>
</tbody>
</table>

Table 2 Macro economic effects of different alternatives to stimulate Bio LNG 2015-2050 in bln €

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Governmental revenue (taxes minus subsidies)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU (reference)</td>
<td>0</td>
</tr>
<tr>
<td>Gas</td>
<td>-1,4</td>
</tr>
<tr>
<td>FQD</td>
<td>-0,6</td>
</tr>
<tr>
<td>Diesel tax</td>
<td>0,6</td>
</tr>
<tr>
<td>CO2 tax reduction</td>
<td>-0,3</td>
</tr>
</tbody>
</table>

Table 3 Governmental revenue of different alternatives to stimulate Bio LNG 2015-2050 in bln €
Table 4 Graphical representation of the effects of alternatives, external effects can be distinguished and compared

Fuel cost and taxes are determining factors as can be seen in the figure above, the external effects are significant but the differences are small, except greenhouse gas emission costs. The distribution of the effects is shown in Figure 4. From a governmental point of view the “Diesel tax” alternative seems interesting, but this alternative will increase costs for transporters. The by the sector proposed “Gas” alternative brings the least tax revenues for the government. This is mainly caused by a high number of LNG trucks and lower LNG tax than diesel tax. The transport sector faces the lowest costs in the Gas alternative.
5 CONCLUSIONS

From a macro-economic perspective all alternatives score better than the BAU alternative. The benefits of the alternatives up weigh the costs. One of the main conclusions is that the business as usual (BAU) alternative scores low, the cause is increasing diesel prices and emission of greenhouse gases and other pollutants. The magnitude of the outcomes is strongly related to the discount rate chosen. The sensitivity analysis shows that changing single input variables does not have major impacts on the outcomes of the model. LNG truck and especially Bio LNG trucks can have lower CO2-equivalents emissions. The digestion of manure can even result in negative CO2-equivalent emissions, because of mitigated methane emissions.

The scenario analysis makes clear that the gap between diesel and LNG fuel price is one of the determining factors for the outcome of the model. The forecasted gap is quite high, so small changes in diesel or LNG prices do not directly lead to outcome shifts. The best and worst case scenario show complete other outcomes. The number of Bio LNG trucks becomes significant in the longer further and the discount rate on investments makes that the Bio LNG pump price does not significantly affect the outcomes.

The success of Bio LNG is very dependent on the success of LNG. Only if there is a proportional share of gas trucks on the road the introduction of Bio LNG can have significant effect. The effects of measures to
stimulate Bio LNG begin to have effect after 2020 as market shares increases. The investments are upfront and the effects come later. Discounting has a negative effects on projects with upfront investments because net present values of future effects are being decreased.

The value of SCBA in the exploration of the feasibility of a transition to an alternative fuel in this research is multiple. The SCBA increases the insight in the usefulness and feasibility of policy alternatives to stimulate bio LNG. This prevents policies that have a negative effect on the welfare to be developed. SCBA can result in a better understanding of the different effects of policy alternatives for policy makers. Decisions can be made on the basis of a better understanding of all the societal aspects of policy measures. The SCBA gives insight in the distribution and order of magnitude of different effects. The distribution shows where problems can occur when policy alternatives are implemented. SCBA enhances discussions in the early stage of exploring policy alternatives by providing objective and independent information.

In this research the method is not used as a go or no go decision tool, but more as an exploration tool to test the feasibility of a transition to bio LNG. This can lead to problems because the tool is used in an undeveloped area. The quality and bandwidth of input data is uncertain. Some variables are more certain than others, so there is a data asymmetry. Accumulation of assumptions and shortcuts can lead to biased results. The presentation of the outcomes is difficult, a generalized table only shows aggregated information and too much emphasis on the limitations of CBA will lead to a “toothless” instrument. In the exploration phase the SCBA is used as an information provider and not as a go, or no go decision tool.

5.1 Reflection
CBA was helpful to develop insight in the distribution of effects, monetization forces the researcher to make effects comparable. The process to calculate a price for all the single effects and add them up eventually makes the outcome unknown throughout the research project. Changing the input values results in other outcomes. Categorizing effects is necessary to create oversight of the subject. The CBA provides a basis to compare different policy options.

Policy alternatives are always the result of politics and are path dependent, the proposed alternatives are designed to explore the policy options and their weaknesses and strengths. The outcome of this research is not to point out one ideal policy alternative. The translation of policy measures to input variables for the CBA model is weak.

The gas sector proposed a set of measures and forecasted the number of trucks in a document, this is used as one alternative policy. The other policies are derivatives of the Gas alternative based on interviews and assumptions of the researcher. The degrees of freedom and choices that have to be made to design alternatives can make the researcher feel subjective. This can negatively influence the timeframe of the research.

Certain forecasted data points in time are used to build the CBA, between the points a simple interpolation is used to find data inputs per year. The CBA is built with several uncertain variables, if the distribution of variables were known a Monte Carlo analysis could be used to investigate the risks further. This would also result in more insight about the uncertainty of the outcome. The bandwidth is now set by a best and worst case scenario, while in reality uncertainties can also cancel out each other.
The contribution of CBA in common infrastructures will be surrounded by less assumptions, comparable projects may be realized elsewhere or scaled up or down.

The lack of a transport model for feedback on fuel prices and policies results in more uncertain outcomes. The assumptions made to forecast number of vehicle kilometers are done by the researcher. If the subject is research more extensive price elasticity’s should be included, but the difficulty is to forecast when transporters are going to switch from diesel to LNG or Bio LNG.

In this research WTW effects are used to compare alternatives, WTW effects contain the emissions of fuel production. On the other hand the demarcation is set to the Netherlands, the production of fossil fuels is mainly located outside the Netherlands. There is a tension between those assumptions.

After the CBA is being built in excel a lot of information can be extracted from the model. The presentation of results of a CBA is generalized data, the difference of the effects to the reference is presented. Results are aggregated and contain little information.

The model assumes a sort of exponential growth rates while in real life the world is changing more ad hoc. The discount rates are set for the whole period and are subjective, environmental effects can be easily valued lower with higher discount rates. The use of shadow prices is necessary to value external effects, but highly uncertain. The shadow prices can change in time, in this research the shadow prices are kept constant when for example fuel prices and vehicle efficiencies change in time.

The time horizon of 35 years is long, it is hard to make projections about the effects of alternative fuels in a context of so many uncertainties. The policies should be constantly adopted to changing environments, in this research a policy is set for 35 years which is not realistic.

Valuing safety or valuing the environment is controversial. The monetization of “ecosystems services to humans” is not the same as intrinsic value of for instance different species. The valuation is also time and place dependent.

The ability to design a national policy to stimulate Bio LNG and receive strategic benefits is uncertain. European policies to decrease emissions and air pollutants are becoming increasingly important and policies between member states are adapted to create one single market for (alternative) fuels.

Price of bio LNG production is volume dependent. If demand for biogas is high and volumes of Bio LNG are growing this will result in higher prices despite the efficiency benefits of economies of scale.

In this research the transport volume is assumed to be a given, in reality the transport volume is dependent on several internal variables. The government can also introduce strict measures to decrease transport volumes. These measures can even result in lower social costs and more benefits. This research only focusses on one fuel, but there are more possibilities to reach the policy goals.

This research focus on Netherlands but the market is more international oriented, there should be possibilities to trade biomass and biogas. The prices of Bio LNG production can drop if not only national virtually greening of Bio LNG is allowed, but also international. If for instance German green gas certificates can be used to supply Bio LNG the price can potentially drop.

Competing distribution channels for biogas. Bio LNG production can cannibalize the injection of green gas in the grid. The extent of flexibility to switch to other distribution channels is not clear. In this
research the assumption is made that for the production of Bio LNG extra production capacity for biogas will be installed. The total potential for biogas production is being used to check if the amounts are realistic (Routekaart Hernieuwbaar Gas, 2014)

5.2 FURTHER RESEARCH
The combination of a CBA with a transport model will result in more accurate forecasts of the number of trucks. Better forecasts with a feedback loop of fuel prices on number of trucks will result in more accurate predictions of effects.

Another point that can strengthen the analysis is more insight in the price elasticity of diesel versus (Bio) LNG trucks, the price elasticity of diesel trucks is low, but there are currently no real alternatives. The willingness to shift to (Bio) LNG not known. A survey can be conducted on consumer preferences, to estimate market behavior.

In the demarcation the focus is set to heavy duty road transport because of the shorter lifespan and high potential. It could be interesting to extend the analysis with a CBA on shipping, the air pollution gains can be even better in shipping. Sulphur needs to be included in the analysis because heavy fuel oil Sulphur contents are significant.

In this research the production price of Bio LNG is assumed to be fixed, while in reality the price is dependent on demand volume and biomass price. Also the relation between competing distribution channels for biogas is not clear.

The CO2-equivalent effects of biogas are determining factors in the CBA, there is discussion if the transport sector can incorporate the complete negative WTW effects, while the intensive cattle breeding is responsible for the manure surpluses.

LNG and Bio LNG are new alternative fuels, the knowledge and experience about the fuel safety is not well established yet. In this research a comparison is made with LPG, but characteristics between the fuels are quite different. A better understanding of the safety costs for gas trucks can result in better comparisons between fuel types. The safety costs of local Bio LNG production plants are also unknown.

In this research the fuel pump prices are used as an input, in these prices the infrastructure costs are incorporated. More insight in the composition of these fuel prices can strengthen the analysis.

Specify subgroups of trucks, in this research one big group is used, but the some trucks are only driving <25.000km while others drive >100.000. Because of the coldness of LNG and Bio LNG it not suitable for vehicles that are not used for longer periods.

The focus of the research was on single fuel gas trucks, dual fuel trucks can achieve higher fuel efficiencies, incorporating dual fuel trucks will make the analysis more complex, but can make the analysis more accurate.
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