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A FEASIBILITY STUDY OF USING BIOMETHANE AS AN ALTERNATIVE FUEL FOR TAXIS IN THE REYKJAVÍK CAPITAL AREA

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A 30 ECTS credit units Master´s thesis

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A Master´s thesis done at
RES | The School for Renewable Energy Science
in affiliation with
University of Iceland &
University of Akureyri

Akureyri, February 2011

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Printed in (date)
at Stell Printing in Akureyri, Iceland

ABSTRACT

Price of gasoline at the dispenser in Iceland has never been higher than today. This paper investigates the economic feasibility of using biomethane as an alternative fuel for the taxi fleet in the Reykjavík capital area. Cases of different groups of taxis were set up on the basis of existing data of the fleet and the financial feasibility evaluated. The cases were divided into separate groups based on the emission classes and various scenarios and sensitivity analysis applied. The research led to the conclusion that converting the average gasoline taxi to a biomethane fueled vehicle would have a positive return on invested capital and reduce the emission of new carbon dioxide. Carbon monoxide and hydrocarbon pollution from the fleet would be reduced; however, pollution from nitrogen oxide would be increased.

Keywords: Financial feasibility, renewable energy, alternative fuel, biomethane, compressed natural gas vehicles.

PREFACE

Iceland is an interesting case when it comes to renewable energy sources, as roughly 80% of all primary energy comes from renewables (Orkustofnun - (National energy authority), 2009). A renewable means that its source is replenished every year by the Sun (Atkins & Jones, 2007).

Most of Iceland´s primary energy comes from geothermal sources and hydropower. However, this has not always been the case. Until the end of World War II, the country relied on imported coals and oil as its main energy (Orkustofnun - (National energy authority), 2009). Fortunately, decisions were made of harnessing the energy potential the country offers and this has been a success in terms of increased living conditions, less pollution, saving money, creating jobs etc.

Although the energy potential is in place, it is easier said than done to run the road transportation fleet on domestic energy source. The whole infrastructure, including vehicle´s engines, is based on hydrocarbon liquid fuels, namely diesel and gasoline. Therefore, Iceland needs to import oil, a polluting source, using valuable foreign currency. Recently Iceland was hit hard by a financial crisis, which has led to the devaluing of the Icelandic currency, the Icelandic krona (ISK), resulting in higher prices of imported products, including petroleum products.

Concerns of greenhouse gas effects from combusted fossil fuels, as well as stricter emission standards from the European Union and stricter regulations of share of renewables in the energy mix, increase the interest in renewable fuels. Currently methane from landfill gas, a renewable fuel, is not used to its fullest potential in the Reykjavík capital area but there is enough gas presently available to fuel the taxi fleet in this area.

Taxis were specifically chosen since they are driven much more than the average passenger car in Iceland, resulting in higher usage percentage. Furthermore, they operate in one specific area and are driven between various locations from time to time, often where methane filling stations are available.

In this paper, the financial feasibility of using methane as an alternative fuel for the Reykjavík capital area taxi fleet is analyzed.

ACKNOWLEDGEMENTS

First of all I would like to express my gratitude to all members of the board of Orkuvörður Ltd., owner of RES - The School for Renewable Energy Science, for having faith in me and granting me admission to the MSc. studies at RES, although neither having proper background in engineering nor physical/natural sciences. Furthermore, I thank Landsvirkjun for granting me a scholarship for this study.

I am also very grateful to the directors and staff of RES: Dr. Björn Gunnarsson, Mr. Guðjón Steindórsson, Ms. Sigrún Lóa Kristjánsdóttir and Mr. Davíð Guðjónsson for their unchanging willingness to provide both help and assistance during my studies at RES.

I would like to address my most sincere thanks to my supervisors: Professor Páll Jensson, Ms. Ágústa Loftsdóttir and Mr. Björn H. Halldórsson. I very much appreciate their guidance and academic support during the entire course of the thesis. All the inspiration, constructive criticism and invaluable comments greatly contributed to the quality of this research.

I am very thankful to the lecturers at RES, whose effort allowed me to broaden my knowledge. I am especially thankful to Professor Paul A. Erickson, an associate professor in mechanical and aerospace engineering at UC Davis. His excellent teaching ability, as well as his outstanding course on alternative energy in transportation, was an invaluable source for a student with no background in engineering.

Furthermore, I would like to thank a number of people I contacted and obtained valuable information from in the course of this research, taxi drivers and other people in the related fields. I would especially like to thank Sigurður Ástgeirsson at Vélamiðstöðin and Steinunn Skúladóttir at The road traffic directorate for her endless patience and willingness to help, by finding the right information from the organization’s database. Furthermore, I would like to thank Marijana B. Fedoroff and John Candelaria for their assistance by proofreading the thesis.

I am also very grateful to all my colleagues and friends at RES, who have contributed both directly and indirectly to this thesis. It was an honor and a great pleasure to study and live with them in Akureyri.

Finally, I would like to dedicate the thesis to my family. Without their constant encouragement, help, support, endless patience and limitless trust I would never have reached the point that I am at now.

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LIST OF ABBREVIATIONS

CIF	Cost insurance and freight
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
EU	European Union
FOB	Free on board
Gr	Grams
GHG	Greenhouse gas/gases
GWP	Global warming potential
HC	Hydrocarbons
ISK	Icelandic krona
IRR	Internal rate of return
Km	Kilometer
MARR	Minimum attractive rate of return
NO_x	Oxides of nitrogen
Nm^3	Normal cubic meter
NPV	Net present value
OEM	Original equipment manufacturer
Yr	Year

1 INTRODUCTION

Iceland has more potential in generating energy than its population currently needs but still imports energy. Roughly, 20% of Iceland's primary energy comes from hydrocarbon-based fuels, liquids that are used as a fuel for vehicles, ships and airplanes (Orkustofnun - (National energy authority), 2009). This share of the primary energy is imported. In 2007, imported fossil fuels (CIF) accounted for approximately 12% of Iceland's total export (FOB) (Orkustofnun - (National energy authority), 2008).

Large reserves of petroleum, which is the source of liquid hydrocarbon fuels such as gasoline, exist in many parts of the world. However, although these reserves are large, they are also limited and depleted at a faster pace than they are being formed (Atkins & Jones, 2007). Around 96% of the energy consumed by vehicles worldwide are hydrocarbon-based fuels (J. Brey, Contreras, Carazo, & R. Brey, 2007). Oil is a contaminating, polluting, nonrenewable and geographically localized energy resource. If current tendency continues, the environmental problems and those of energy dependency will be even more serious. Increased interest has been in using renewable energy as a fuel.

Changing to another fuel is not an easy task. The infrastructure is in place for the conventional liquid fuel in Iceland and most of the vehicles are either using diesel oil or gasoline as a fuel. Using methane as a fuel is a recent viable alternative in Iceland. Iceland has neither any operating natural gas fields nor oil extraction sites. However, there is a potential of using biomethane coming from landfill sites (as organic waste undergoes anaerobic decomposition), sludge, manure and energy crops (Reinhart, 1994). Dicussions have also been about using hydrogen or biodiesel. In this research it was decided to look at the financial evaluation of using biomethane.

Common use of landfill gas abroad is to generate electricity or as a heat source (Deublein & Steinhauser, 2011). This is not important in Iceland as the country has its electricity and heat coming from renewable energy sources, such as hydro and geothermal. These sources fulfill the demand for this small nation. The landfill methane is a potent greenhouse gas (Brown, LeMay, Bursten, & Burdge, 2002) and it is for this reason it is collected, instead of released into the atmosphere. Using the methane as a fuel for vehicles seems therefore to be a good option. It releases energy when combusted, along with water and carbon dioxide and it becomes a less potent GHG. When considered in a global perspective it becomes carbon neutral.

A directive from the European Union (EU) established a common framework for the production and promotion of energy from renewable sources in terms of national targets and measures. By the year 2020, the share of energy from renewable energy sources in the transport sector must account for at least 10% of the final energy consumption in the sector. This is in order to promote cleaner transport and to limit greenhouse gas emissions ("Promotion of the use of energy from renewable sources," 2010).

On January 1, 2011, a legislation was enacted in Iceland which changed the way automobiles are taxed. Now it is based on CO_2 emission, instead of weight. Furthermore, taxes on hydrocarbon fuels were raised. The objective of the bill is to reduce greenhouse gas emissions, in accordance to Iceland's international obligations ("Nefndarálit um frv. til l. um breyt. á l. nr. 29/1993, um vörugjald af ökutækjum, eldsneyti o.fl., lögum nr. 39/1988, um bifreiðagjald. - (Committee: on changes on excise taxes on vehicles and fuel)," 2010). At the same time, the price of gasoline and diesel in ISK at the pump in Iceland became more expensive than ever. This will have a great effect on those that drive their cars a lot, such as taxi drivers.

Iceland has recently undergone a financial crisis and is now dealing with its consequences. One part of that, is the higher price of imported products as the country's currency, the Icelandic krona (ISK), lost a lot of its value in the aftermath of the crisis, resulting in a lower purchasing power for Icelanders. The price of gasoline set a record, 213 ISK/L on January 10, 2011. The current price of methane is 49% of the price of one liter of gasoline, when compared on same energy content basis. The number of new imported taxi vehicles has reduced drastically as well (Umferðarstofa - (The road traffic directorate), 2010a).

Taxis are on average driven more than most passenger cars (Umferðarstofa - (The road traffic directorate), 2010b). They are also operated in a specific region where methane filling stations are available. On February 1, 2010, the first gasoline taxi was converted to a bi-fuel vehicle in Iceland, in order to use methane as a fuel. Converting gasoline vehicles is a well-known and proven technology, but is the conversion of a vehicle to methane fuel financially feasible in Iceland?

This research looks into the financial feasibility of using methane for the Reykjavík capital taxi fleet. This research is unique, in that this is the first time analysis of this are provided for the taxi fleet in Reykjavík, Iceland.

2 GOAL AND SCOPE OF THE WORK

2.1 Goal

The purpose of this master's thesis is to evaluate the financial feasibility of using biomethane as an alternative fuel for the taxi fleet in the Reykjavík capital area. The overall objectives of this research is to answer the following three questions:

1. Is methane, as an alternative fuel for taxis in the Reykjavik capital area, economically feasible?
2. What is the potential national saving?
3. What is the reduction in emissions / pollution?

In order to answer these questions in a quantitative way, a model discussed in the research methodology section will be used. First, the fleet is researched and analyzed. On the basis of those findings, cases for different emission classes are formed, on which financial analysis is then applied. These research questions will be answered under different scenarios. In the end, recommendations will be formed for taxi drivers and the Icelandic government.

1. The investment is assumed economically feasible if it has a positive net present value over its lifetime.
2. National saving is defined as the value of imported liters of gasoline in USD that is saved over a period of one year, if all gasoline taxis that are found to be economically feasible for conversion would be converted. The USD currency was chosen since in international markets, oil products are traded in USD currency.
3. For greenhouse gas emission, the total new CO_2 emission over a period of one year was found. Furthermore, because of its importance in emission standards, the following pollutants were analyzed for the same period: CO, NO_x and HC pollution. In this report, HC is used for non-methane hydrocarbons.

2.2 Scope

This research looks into the financial feasibility of converting existing gasoline taxis into bi-fuel vehicles, and use biomethane from Álfsnes landfill as an alternative fuel instead of gasoline. All amounts are in real values.

As no commercial conversion of diesel passenger cars is currently provided in Iceland, this study will look into the case of gasoline vehicles. The focus is on having vehicles converted since the number of vehicles imported has seriously decreased after Iceland was hit by the economic crisis in 2008 (Umferðarstofa - (The road traffic directorate), 2010a), slowing down the rate at which the fleet is renewed. Furthermore, converting a vehicle costs less than buying a new one.

The scope of the work is the taxi driver, operating in the Reykjavík capital area, who owns his own car, buys the fuel and considers converting his vehicle to be able to use methane as an alternative fuel. This operating region was chosen because of the location of the methane filling stations within the area.

The chapter on pollution is a tailpipe calculation of how much new CO_2 is added to the environment from combustion of the fuel. It has to be kept in mind that landfill biomethane, when combusted as a fuel, is assumed carbon neutral as it is a renewed carbon, in the carbon cycle.

Summary of scope:

1. Find out the financial feasibility of converting a gasoline taxi into a bi-fuel vehicle and would be able to operate on methane as its primary fuel.
2. Analyze the financial viability from the standpoint of the taxi driver, the vehicle's owner.
3. Tailpipe emission is estimated of the pollutants and how much new CO_2 is added to the environment.

3 LITERATURE REVIEW

Literature more than 5 years old was excluded from the literature review, as it might be outdated since technology evolves fast. No comparable feasibility studies were found in the literature on converting vehicles to use methane as a fuel for taxis, applicable to this case in Iceland. However, the following studies were reviewed particularly.

Johnson (2010) applies net present value calculations on compressed natural gas vehicles (CNG). He built a CNG vehicle and infrastructure cash-flow evaluation (VICE) model to assist fleets and businesses in evaluating the profitability of potential CNG projects. Johnson presents his findings in the paper "Business case for compressed natural gas in municipal fleets" and looks into the feasibility of using CNG in fleets of diesel vehicles; transit buses, school buses, and refuse trucks, which always refuel at the same station. His calculations also include investment in a refueling station. This business case targets municipal governments and it does not cover investment for taxi fleets or on individual vehicle basis. Furthermore, it does not include any calculation of pollution nor emission saved.

In their research “Life cycle cost analysis of alternative vehicles and fuels in Thailand”, Goedecke, Therdthianwong, & Gheewala (2007) publish their findings of a life cycle cost analysis, which they applied to alternative fuels and vehicles in Thailand. Different technologies are evaluated and compared from an objective perspective, the cost of providing the function of transport and at which cost, including direct and indirect costs. Among vehicles compared are the ones that are able to use methane as a bi-fuel. This is done from the standpoint of the society. However, it does not evaluate the feasibility from the standpoint of prospective individual buyer. Net present value calculations were applied but neither internal rate of return nor various scenarios were applied. This study is not applicable to evaluate the feasibility of operating a taxi in Iceland.

The research "Evaluation of automobiles with alternative fuels utilizing multicriteria techniques" (J. Brey, et al., 2007) is a multicriteria comparison of different technologies in the automotive sector. The comparison is conducted, both of some existing technologies as well as ones under development. The variables researched are purchase cost, environmental cost, fuel cost, acoustic emissions, energy consumption well to wheel, maximum speed and acceleration. Of all the different technologies compared, the CNG vehicle, has one of the best score.

No comparable feasibility study on methane cars has been found. This research applies state of the art financial modeling on converting gasoline taxis in the Reykjavik capital area. It also finds out the emission for the fleet as well as the potential national saving.

4 BACKGROUND INFORMATION

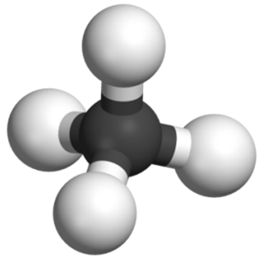
4.1 Biofuels

Of all the different fuels that are now being explored as alternatives to the conventional ones, biofuels look promising as they are renewable and carbon neutral contrary to conventional fossil fuels. Being carbon neutral means that the total quantity of CO_2 released to the environment during the manufacture and burning of a biofuel is similar to the quantity of CO_2 removed from the environment by photosynthesis during the plants growth (McMurry & Fay, 2009). Biofuels include a broad range of fuels, which are, in one way or another, derived from biomass.

4.2 Biomethane

Biomethane is the green energy equivalent of methane, which is the principal component of natural gas. The difference lies in the origin. Biomethane is odorless, colorless gas and contains four single C-H, carbon and hydrogen bonds. It has the molecular formula CH_4, as can be seen in Figure 1, and is the simplest of hydrocarbons. It is generated by anaerobic (takes place in the absence of oxygen) decomposition of organic material by bacteria (Housecroft & Constable, 2010 and Atkins & Jones, 2007). When methane is combusted in the presence of oxygen, the result is carbon dioxide (CO_2), water (H_2O) and energy.

Figure 1 - A methane molecule



(Source of image: ISSI: International Space Science Institute)

4.2.1 Greenhouse gas effect

Methane is a very potent GHG and has 21 times more warming potential than CO_2 over a 100 year period. It has a half-life in the atmosphere of about 10 years, whereas CO_2 is much longer-lived. Given this large contribution, important reductions of the greenhouse effect could be achieved by reducing methane emissions or capturing the emissions for use as a fuel, as it might otherwise escape into the atmosphere (Brown, LeMay, Bursten, & Burdge, 2002).

4.2.2 Álfsnes landfill

The biomethane sold in Iceland is obtained at the Reykjavik capital area landfill site, Álfsnes. Landfill gas has been collected from this site since 1996. According to the landfill's operating license, landfill gas has to be collected and utilized, if possible (Umhverfisstofnun - (The environment agency of Iceland, 1998).

To be fit for automotive use, its quality needs to be upgraded as close to a compressed natural gas (CNG) as possible. The treatment includes removal of carbon dioxide, water and minor contaminants in order to achieve minimum methane content, preferably 95% (National research council, 2008).

4.2.3 Methane as a fuel

The methane fuel is stored compressed in gas tanks in the vehicles, at up to 220 bars (Metan, 2010). To be able to use methane as a fuel for conventional gasoline vehicles, their engine must be modified in order to accommodate natural gas (Nersesian, 2010). A new original equipment manufactured (OEM) bi-fuel, methane and gasoline, vehicles can also be bought.

In terms of energy per unit, the methane gas coming from Álfsnes landfill site in Reykjavík is less expensive at the pump than regular gasoline or diesel. Gasoline is sold in the unit of liters but the landfill methane is sold in the units of normal cubic meter (Nm^3). One Nm^3 of biomethane sold in Iceland has more energy content than one liter of 95 octane gasoline, as 100% methane equals in energy content, 1,12 liters (Metan, 2011a). The landfill gas captured at Álfsnes landfill site is on average 50% to 60% methane but 97,5% when it has been upgraded (Mannvit, 2010).

Currently there are two filling stations in the analyzed area. One is located in Ártúnsbrekka, Reykjavík and the other in Tinhella, Hafnarfjörður both are operated by N1 (Metan, 2011b). One more is planned in Keflavík, by Metanorka in cooperation with Keilir (Metanbíll, 2010).

4.3 Emissions

Landfill methane as a fuel generates carbon dioxide when combusted. It is renewed every year for as long as the Sun shines and produces green plants (Atkins & Jones, 2007). Therefore, it does not contribute to greenhouse gas effects and global warming. This is contrary to fossil fuel which adds CO_2 to the carbon cycle when combusted.

In their research "An experimental investigation of CNG as an alternative fuel for a retrofitted gasoline vehicle", Aslam et al. (2006) found out that in the case of local pollutants, the converted vehicle had lower emissions of carbon monoxide (CO) and hydrocarbon (HC) but more nitrogen oxide (NO_x) compared to gasoline. The problematic traffic-related pollutants such as ozone precursors, particulates and benzene in particular are significantly lower compared with gasoline and diesel. Due to their importance in emission standards, the focus will be on CO, HC and NO_x.

Table 1 - Change in vehicle's emission after being converted and using methane as a fuel

Pollutant	**Change in emission (%)**
Hydrocarbons (HC)	-50%
Carbon monoxide (CO)	-80%
Nitrogen Oxide (NOx)	33%

(Source: ASLAM et al., 2006)

Table 1 lists the results from the research of Aslam et al. (2006). By using CNG instead of gasoline in a converted vehicle, the CNG produced an average 50% less emission of HC, 80% less of CO but 33% higher emissions of NO_x. These are comparable to results from another research, by Kalam et al. (2004). They found out that if compared to base petrol engine, CO and HC reduction of between 40-50% and 35-50% were achieved and NO_x emission were increased by 30% (Aslam et al., 2006). These percentage changes apply to vehicles converted into bi-fuel, gasoline and methane cars, but not natural gas vehicles originally manufactured as such.

HC is a product of incomplete combustion as well as CO. HC emissions contribute to the formation of ground level ozone, which can cause damage to human health and vegetation. CO is colorless, odorless and poisonous gas which reduces the blood's ability to carry oxygen. NO and NO_2 are collectively known as NOx. It is generated when nitrogen in the air reacts with oxygen at high temperature and pressure inside the engine. It has the potential to cause human respiratory problems at high concentrations. NOx are also one of the precursors for photochemical ozone formation.

The reason for more NO_x, is high combustion temperature (when compared to gasoline), pressure and lean mixture. Furthermore, the simple chemical bond of CNG (compared to gasoline) is also a reason of more NO_x being emitted, than in the case of gasoline. By employing exhaust gas recirculation (EGR), NO_x emission at high engine loads can be reduced, without sacrificing smoke emission and thermal efficiency (Aslam et al., 2006).

4.4 Price and taxes on fuels in Iceland

Each cubic meter of clean Icelandic landfill methane is sold for 114 ISK/Nm^3 as of January 11, 2011, including VAT. It carries no other taxes. If the methane price is put into comparison with 95 octane gasoline energy level, the price is 104,37 ISK/L (Metan, 2011a) as can be seen in Table 2. The price of one liter of 95 octane gasoline is 212,9 ISK (N1, 2011).

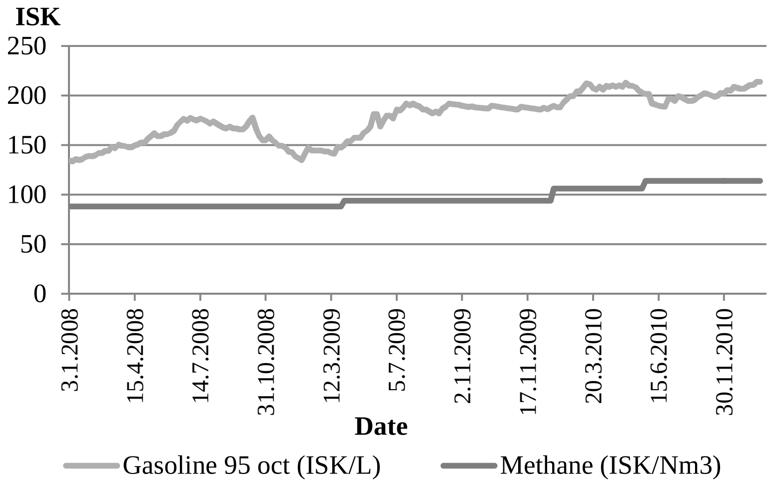
Table 2 - Price of gasoline 95 octane and methane

	Amount in ISK
Gasoline price (ISK/L)*	212,9
Methane price (ISK/Nm^3)	114
Methane price (ISK/L)**	104,37

*Self-service price at N1 filling station on 11th of January 2011 (N1, 2011). ** Energy equivalent of gasoline.

(Source of data: N1, 2011)

Figure 2 - Gasoline and methane price developments



Note: All amounts are in each year's price level. Values not adjusted for inflation.

(Source of data: N1, 2011)

The price of gasoline has fluctuated more than the price of methane and has always been higher. The price of gasoline reached its highest peak in January 10, 2011, at 213 ISK/L (N1, 2011). The price of 95 octane gasoline is similar from all fuel providers in Iceland.

Table 3 - Taxes on fuel in Iceland

	Gasoline 95 oct (ISK/L)	Methane (ISK/Nm^3)	Methane (ISK/L)
Price	212,90	114,00	104,37
Excise tax	23,9	0,00	0,00
Special excise tax	38,6	0,00	0,00
Carbon tax (ISK/L)	3,80	0,00	0,00
VAT (25,5%)	43,26	23,16	21,2
Price excl. all taxes	103,43	90,84	83,16
Share of total price to the government	109,47	23,16	21,2
% Share of total price to the government	51,4%	20,3%	20,3%

Note: All values are as of 11th of Jan 2011.

From Table 3 it can be seen that for every liter of gasoline there is excise tax, which is a fixed amount of 23,86 ISK and special excise tax also, a fixed amount of 38,55 ISK, total 62,41 ISK. The special excise tax is earmarked to The Icelandic Road Administration (ICERA) for road construction while the excise tax is a part of the government's taxation ("Lög um ráðstafanir í ríkisfjármálum - (Law: government finance)," 2010; "Lög um vörugjald af ökutækjum, eldsneyti o.fl. nr. 29 - (Law: excise taxes on vehicles and fuel)," 1993).

A carbon tax is a fixed amount, 3,80 ISK for each liter of gasoline. Both the excise taxes and the carbon taxes were raised on January 1, 2011 ("Lög um ráðstafanir í ríkisfjármálum - (Law: government finance)," 2010; "Lög um umhverfis- og auðlindaskatta nr. 129 - (Law: environmental taxes and taxes on utilization of natural resources)," 2009). A 25,5% VAT is added to the final price ("Lög um ráðstafanir í skattamálum (virðisaukaskattur o.fl.). - (Law: Taxes)," 2009; "Lög um virðisaukaskatt nr. 50 - (Law: VAT)," 1988). In the case of methane, it currently does not carry any other taxes except VAT.

The price of methane, in one liter of gasoline energy equivalent, is 49% of the price of gasoline. The total of 51,4% of the price of gasoline are taxes while taxes are 20,3% of the price of methane. If all taxes were deducted from the price of both fuels and the prices compared, methane would still be less expensive, 20,27 ISK, providing a possibility for cost savings.

4.5 Automobile taxes

Automobile taxes are due twice a year and are based on a vehicle's registered CO_2 emission, measured in grams per kilometer. Ten different emission categories exist.

Table 4 - Automobile taxes in ISK, based on CO_2 emission in grams per kilometer

Class	**CO_2 emission (Gr/Km)**	**Automobile taxes**	**Over a period of 1 year**
A	0-80	5.000 - 5.000	10.000 - 10.000
B	81-100	5.000 - 5.000	10.000 - 10.000
C	101-120	5.000 - 5.000	10.000 - 10.000
D	121-140	5.120 - 7.400	10.240 - 14.800
E	141-160	7.520 - 9.800	15.040 - 19.600
F	161-180	9.920 - 12.200	19.840 - 24.400
G	181-200	12.320 - 14.600	24.640 - 29.200
H	201-220	14.720 - 17.000	29.440 - 34.000
I	221-250	17.120 - 20.600	34.240 - 41.200
J	>250	>20.600	>41.200

Source: Calculated values, based on law on automobile taxes (2010).

Table 4 lists the emission classes and the character representing each class. Automobile taxes for each vehicle per period, which are less than 3.500 kilograms are at least 5.000 ISK, based on CO_2 emission lower than 121 Gr/Km. For each extra gram of registered CO_2 emission above the 60 Gr/Km, 120 ISK are paid. Table 4 also lists the calculated taxes, which are due yearly based on emitted CO_2. The tax increases as the vehicle emits more CO_2.

If a vehicle does not have any CO_2 emission registered, it is calculated as 0,12 grams for each kilogram of the cars dead weight as well as 50 grams added to that number. Vehicles using methane as a main fuel, either a new vehicle or one that has been converted and been certified as a methane vehicle, pay the lowest automobile tax, 5.000 ISK ("Lög um breyting á lögum nr. 29/1993, um vörugjald af ökutækjum, eldsneyti o.fl., lögum nr. 39/1988, um bifreiðagjald, og lögum nr. 87/2004. - (Law on changes of excise taxes and automobile taxes)," 2010).

4.6 Converting a gasoline taxi

Converting gasoline vehicles and using methane as a fuel is a proven technology. Spark ignition engines can be converted to CNG operation quite easily by adding a second fueling system. CNG has been used in vehicles since the 1930's (Aslam et al., 2006).

Today, a taxi driver can have his car converted in three places in Iceland; Vélamiðstöðin, Einn grænn and Megas. The cost is in a similar range for all converting workshops. The first taxi was converted by Vélamiðstöðin in February, 2010. As of January 5, 2011, three taxis have been converted, which are operating in the analyzed area.

Table 5 - Cost of converting a gasoline vehicle (in ISK)

Number of cylinders	Price
4 cl	405.000
6 cl	495.115
8 cl	510.865

Prices (including VAT) at Metanbill's website, as of January 11th 2011.
Source: (Metanbíll, 2011)

The price depends on size and type of the car, the size and number of the methane tanks, number of cylinders in the engine and how much, if anything, needs to be custom-built.

Table 5 lists the price for a vehicle with 4, 6 and 8 cylinders. The price includes the necessary equipment, installation and has a 2 year guarantee. Extra CNG tanks can be added as long as there is space available. Special loans for conversion to methane vehicles are currently available.

The vehicle becomes a bi-fuel vehicle, having separate tanks for gasoline and the gaseous fuel. The methane fuel system is an addition to the existing gasoline system and the driver can choose which fuel to use by flipping a switch. Having more than one fuel tank gives the vehicle more kilometer range than before being converted. However, the gas tanks take up storage, most often space in the vehicle's trunk, which might under certain circumstances affect a taxi driver's business, if a passenger has a lot of luggage.

After conversion, the vehicle can be operated using either methane or gasoline. However, gasoline is needed in order to start the vehicle, until certain temperature of the engine is reached, at which time it switches to methane. After that, the taxi driver can choose which fuel to use by clicking a button inside the vehicle. The gasoline consumption during start ups, depends on various factors, such as outside temperature and car type.

The cost of operating and maintaining a converted vehicle is much the same as before the vehicle was converted except for the cost of different types of fuel. Some fleets report 2 to 3 years longer service life and extended time between required maintenance as the result of a cleaner burning fuel. Conversion companies and manufacturers recommend conventional maintenance intervals (The national renewable energy laboratory (NREL), 2001).

A temporary clause is found regarding the excise tax which enables car owners that have had their cars converted to have part of their excise tax repaid, which is a maximum of 20% of the conversion cost, although not higher than 100.000 ISK. In order to qualify for that, the vehicle has to be certified as a methane primary fuel vehicle and registered as such at The road traffic directorate. The vehicle needs to be less than 6 years old and to have at least 78 liters methane tank installed. A maximum number of 1.000 vehicles can have this conversion cost repaid ("Lög um breytingu á ýmsum lagaákvæðum um skatta og gjöld - (Law on changes of various taxes)," 2010).

4.7 The taxi fleet

Total number of taxi work permits is area based. In region 1 and region 2 (listed below) there are 560 permits. Taxi drivers can temporarily turn in their work permits ("Reglugerð um leigubifreiðar nr. 397 - (Regulation on taxis)," 2003).

Region 1: Reykjavík, Kópavogur, Hafnarfjörður, Garðabær, Seltjarnarnes, Mosfellsbær and Bessastaðarhreppur.

Region 2: Reykjanesbær, Miðnes-, Gerða- and Vatnsleysustrandarhreppur.

Each taxi driver owns his car and has to finance its purchase on his own. The taxicab companies only serve as service stations for the drivers for a fee. The drivers have to belong to one of the taxi companies. Taxis are subject to yearly inspection. When inspected, their kilometer number is registered in The road traffic directorate's database. This database includes among other things information on vehicle's type approval, which is a confirmation that production will meet specified performance standards such as fuel consumption and emission of the vehicle. The directorate is the government agency that administers vehicle registration and driver licensing in Iceland. Taxi vehicles are labeled specifically in the database. If they are sold or the taxi equipment's are removed, the label is removed from the database.

Analysis of the fleet is found in chapter 6, "The existing taxi fleet analyzed".

5 METHODOLOGY AND APPROACH

This chapter describes how data for the research was collected and analyzed, as well as how the feasibility assessment model was used and constructed. To make the formulas easier to understand, a fictional case is used as an example and demonstrated when applicable.

Data of the fleet was first obtained from The road traffic directorate's database (2010) and analyzed. Based on those results, specific cases of each emission class were formed. Finally, financial models were applied to find out their feasibility. The methodology used for evaluating each financial case are net present value (NPV) and internal rate of return (IRR).

5.1 Data collection and processing

In order to have as realistic data of the taxi fleet as possible in a given period, data of vehicles listed as taxis was obtained from The road traffic directorate's database (October 28, 2010). The data included information of vehicle's type approvals as well as driving history from vehicle's previous inspections.

The data of the current taxi fleet was analyzed thoroughly. Only registered information of currently operating taxis in region 1 and 2 were used, to have reliable up to date data of the fleet. Data of taxis found not being operated were deleted. Finally, the database was cleared of obvious errors.

Total number of taxi vehicles operating in this area were found to be 534, of which 386 had information about vehicle's type approval.

5.2 Model determinants

The taxi fleet was categorized based on vehicle's CO_2 emission, based on the way the automobile tax system is set up. Ten categories were used, each represented by a letter, from A to J. The letter A represents the emission class with the lowest emission and J the most emission. The vehicles that do not have their type approval listed were scaled up in accordance to the existing share of the emission classes.

To find the number of kilometers driven over a period of one year, the difference between the last two inspections was found, as well as the number of days in between. Records having less than 150 days in between were removed. This was done to have data over a long enough period, to prevent wrongly scaled up / down data. If the kilometer readings found were not in correlation with previous readings of the vehicle, the older records were inspected further. If the last calculated driving distance was determined unusable, the one before is used.

Numbers of kilometers driven over a period of one year for each vehicle, if more than 150 days were between inspections, were calculated as following:

Equation 1 - Driving distance over a period of one year

$$\frac{Km_1 - Km_2}{D_1 - D_2} * 365 = D_{yr}$$

Source: (Author's calculations)

Where:
Km_1 = *Kilometer readings from last inspection;*
Km_2 = *Kilometer readings from the second last inspection;*
$Km_2 – Km_1$ = *driving distance between inspections*

D_1 = *Date of last inspection;*
D_2 = *Date of second last inspection;*
$D_2 – D_1$ = *Number of days between inspections;*

365 is number of days over a period of one year

D_{yr} = *Driving distance over a period of one year*

The number of kilometers difference was divided by the number of days and multiplied by 365 days. An example is provided in Appendix B – Examples.

To find out the gasoline consumption (in liters) of each vehicle, for all emission classes, kilometers driven over a period of one year was multiplied by urban driving fuel consumption. This data is listed in liters per 100 kilometers and is found in the vehicle's type approval data. Urban driving was used in the model instead of rural and mixed driving when calculating fuel consumption as these taxis operate in an area which requires mainly urban driving. Furthermore, the vehicles are often in operation, making it less needed to add extra fuel consumption i.e. in the case of the engine being cold. Average kilometers driven were found by taking the total value of driven kilometer distance for each class and dividing by number of vehicles found in that class.

To find the emission from each vehicle, stated CO_2 emission (in grams/kilometer driven) was multiplied with kilometers driven over a period of one year. The same method was used to find the pollution emitted.

The methane fuel consumption is a calculated value. It is based on the same energy content as would be needed in the case of gasoline for each vehicle. The price of methane, in one liter of gasoline energy content equivalent is used, to have the fuel prices on comparable basis. In order to find the price of methane in per liter of gasoline equivalent, as it is sold in Nm^3, it was calculated by using the following equation:

Equation 2 - Price of methane per liter of gasoline equivalent found

$$\frac{\left(\frac{P_M}{M\%}\right)}{L} = P_{GE}$$

Where:

P_M = Price of methane at the pump;

M% = The share of methane in the bio fuel sold;

By dividing P_M in M%, the price of 100% methane fuel is found;

L = The energy content of 1 Nm^3 of 100% methane, in gasoline equivalent;

P_{GE} = Price of methane in per liter of gasoline equivalent

An example is provided in Appendix B – Examples.

To find out the total emission, pollution and cost for the fleet, the value for the average vehicle found for each emission class is multiplied with the number of vehicles in that particular category.

5.3 Present value (PV)

Money is worth more today than it is in the future, as it can be invested today and increased. In order to compensate for this fact and incorporate time value of money, a discount rate has to be determined. The discount rate is often referred to as minimum attractive rate of return (MARR). It represents a rate which the investor could alternatively invest his money. That is, the return of the most preferable alternative investment. The time horizon of the investment needs also to be determined and the cash flow associated with each period (Park, 2010).

Present value is the value on a given date, of a future payment or in this case a series of future payments, using the discount rate to reflect the time value of money as shown in Equation 3.

Equation 3 - Present value (PV)

$$PV(i) = \frac{A_N}{(1+i)^N}$$

Where:

A_n = Cash flow at the end of period n;

i = Discount rate;

N = Service life of the project

An example is provided in Appendix B – Examples.

5.4 Net present value (NPV)

Net present value (NPV) is the difference between a present value of all cash in- and outflows associated with an investment project (Park, 2010). These costs and cost savings are called “cash flow”, with costs being represented as a negative cash flow (outflow of money) and savings as a positive flow (inflow of money).

When comparing these two alternative investments, the net present value of the difference in cost, from operating gasoline vehicle and converted methane vehicle is used. In this case, it includes the cost of the conversion equipment’s purchased now, along with future costs linked to this investment as well as the cost savings from fuel and operations throughout the lifetime of the project. For example, the difference in cost of fuel, switching from gasoline to methane is accounted for while the cost of insurance is not accounted for, as insuring a vehicle is not linked to it being converted and would be the same amount in both cases.

The NPV is calculated as following:

Equation 4 - Net present value (NPV)

$$NPV(i) = \frac{A_0}{(1+i)^0} + \frac{A_1}{(1+i)^1} + \cdots + \frac{A_N}{(1+i)^N}$$
$$= \sum_{n=0}^{N} \frac{A_n}{(1+i)^n}$$

Where:

A_n = Net cash flow at the end of period *n*;

i = Discount rate;

N = Service life of the project

(Source: Park, 2010)

The decision rule for NPV (Park, 2010) is as following:

If $NPV(i) < 0$, the investment should be rejected as it has greater equivalent value of outflow than inflows and therefore makes a loss.

If $NPV(i) = 0$, remain indifferent to the investment.

If $NPV(i) > 0$, the investment should be accepted as it has greater equivalent value of inflows than outflows and therefore makes a profit.

If mutually exclusive alternatives are being compared, the one with the greatest positive NPV should be selected. An example is provided in Appendix B – Examples.

5.5 Internal rate of return (IRR)

Internal rate of return (IRR) is the interest rate charged on the unrecovered project balance of the investment, such that, when the project terminates, the unrecovered project balance will be zero (Park, 2010).This means that the investment has zero NPV, when the rate of return, which is noted as i*, is used. The IRR is equal to the rate, which sets the following equation to zero.

Equation 5 - Internal rate of return (IRR)

$$NPV(i^*) = \sum_{n=0}^{N} \frac{A_n}{(1+i^*)^n} = 0$$

Where:

A_n = Net cash flow at the end of period *n*;

I^* = IRR;

N = Service life of the project

(Source: Park, 2010)

Investors want to have a higher return than only to break even for their investments. As marginal attractive rate of return (MARR) is usually defined, IRR and MARR can be used to find out if an investment is feasible or not.

The decision rule for a certain investment is as following:

If IRR < MARR , the investment should be rejected as the rate of return of the investment is lower than the marginal attractive rate of return.

If IRR = MARR, remain indifferent to the investment.

If IRR > MARR, the investment should be accepted as the rate of return of the investment is higher than the marginal attractive rate of return.

However, the decision rule becomes more complicated if the investment has a net cash flow with more than one change in sign. When that is the case the project can have multiple IRRs which makes it difficult to decide which IRR should be considered the right one to use (Kierulff, 2008). One of the drawbacks of the NPV method is that it assumes that periodic cash flow will be reinvested at the discount rate. The IRR method assumes reinvestment using the IRR as an interest rate. Both of these assumptions are not always realistic (Park, 2010). The NPV method is usually considered a superior method to the IRR one. However, the viability of IRR should be dismissed, as in some cases it may be better suited than the NPV (A. C. Lee, J. C. Lee, & C. F. Lee, 2009). An example is provided in Appendix B – Examples.

5.6 Payback period

The payback method determines how long it takes the net receipts to equal investment outlays. This means that it will find how long time it will take the investment to pay for itself, using the amount saved. This method comes in two forms, either conventional payback method which does not account for the value of money and the discounted payback method (Park, 2010). The results show a longer payback period, when discounted cash flow is used. An example is provided in Appendix B – Examples.

6 THE EXISTING TAXI FLEET ANALYZED

In order to have the research as precise as possible, information on already existing vehicles in the taxi fleet were analyzed, using data from the Icelandic road traffic directorate’s database (as of October 28, 2010) (Umferðarstofa - (The road traffic directorate), 2010a). On the basis of the calculated and analyzed data, cases were set up for evaluating the feasibility of vehicles for all emission classes.

All tables and charts in this chapter are constructed using information from this database.

Table 6 - Number of taxi vehicles in the fleet, based on fuel type

Class	CO_2 emission* (Gr/Km)	Gasoline	Gasoline/ Methane	Gasoline / Electricity	Diesel	
A	0-80	0	0	0	0	
B	81-100	0	0	0	0	
C	101-120	0	0	4	0	
D	121-140	0	1	0	4	
E	141-160	1	2	0	39	
F	161-180	4	1	0	45	
G	181-200	98	0	0	82	
H	201-220	62	0	0	61	
I	221-250	47	0	0	55	
J	>250	10	0	0	18	Total
		222	4	4	304	534

* Based on tailpipe emission.

Source: Data from the Icelandic road traffic directorate's database (2010a)

According to the analyzed data, using the vehicles' type approvals, gasoline and diesel were found to be the most common fuels used by the taxi fleet. This is listed in Table 6. Methane and hybrid electric were also used, but they were less common. Total of 222 gasoline vehicles were found to be operating, 4 methane / gasoline, 4 electricity / gasoline and 304 diesel. A total of 534 vehicles were found being operated of the 560 work permits. This makes diesel being the majority of the fleet or 57%, gasoline 42% and alternative fuel vehicles representing a small minority of less than 2%. As this is the case, potential savings in imported gasoline could be considerable.

As Table 6 is constructed based on vehicle's type approval, information on converted vehicles is not listed. Those vehicles are listed separately in the database but are listed in this table as gasoline vehicles. Converted gasoline / methane taxis were found out to be two. Therefore, the total number of taxis using methane was 6 and gasoline vehicles 220.

Most gasoline vehicles were found in emission class G, having between 181-200 grams of CO_2 emission per kilometer driven. Second most in class H and third in emission class I. This is also the case for diesel. These three are all high emission classes and account for 93,2% of the taxi fleet. However, no gasoline cars were found to be in the four lowest emission classes, A, B and C. A possible reason for this could be that smaller cars might not be suitable to be used as taxis.

What is notable regarding the classification of the methane vehicles is that they are in similar categories as gasoline vehicles. The reason they are in classes D, E and F is that this is a tailpipe emission which does not take into account whether it is a new or a carbon neutral emission, as is the case of the combustion of biomethane. These vehicles are however taxed as if they were in emission class A, according to the new legislation.

Table 7 - Number of new gasoline taxi vehicles registered from 2005 to 2010

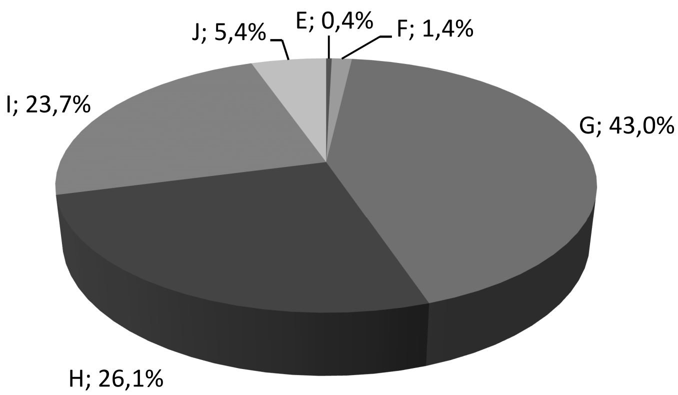
Year	Vehicles
2010*	3
2009	5
2008	29
2007	45
2006	29
2005	38

* For the period from January 1, 2010 to October 28, 2010

Source: Data from the Icelandic road traffic directorate's database (2010a)

Table 7 lists the number of gasoline taxis registered as new in Iceland, from the beginning of the year 2005 until the end of October, 2010. Most vehicles in the gasoline fleet are from the year 2007. Notably fewer vehicles were imported after Iceland was hit by a financial crisis in the late year of 2008, and the same can be seen for the 2009 and 2010 values. This might be due to a higher price on imported vehicles, and more difficulties in financing a new car.

Figure 3 - Percentage share of gasoline usage grouped by emissions class



Source: Calculated values based on data from the Icelandic road traffic directorate's database (2010a)

Total gasoline consumption was found to be 945.201 liters in one year. Three of the biggest groups accounted for 92,8% of the usage, equal to 877.238 liters. This is in accordance to the number of vehicles in these three groups. The largest one is G with a 43% share, a total of 406.507 liters. Groups H and I used 26,1% and 23,7% respectively.

Table 8 - Average kilometers distance driven by taxis over a period of one year (Km/Yr)

Class*	All vehicles**	Gasoline
A	-	-
B	-	-
C	45.655	-
D	37.075	-
E	50.767	43.717
F	38.630	33.909
G	44.453	39.118
H	41.302	32.626
I	42.578	36.010
J	43.211	34.130

* In order to specify average kilometers per emission class, vehicles having registered type approval were used. ** All types of vehicles in the fleet. Diesel, hybrid, methane and gasoline.

Source: Calculated values based on data from the Icelandic road traffic directorate's database (2010a)

According to the data, the overall taxi fleet drove a total of 22.759.945 km over the period analyzed from November 2009 to October 2010, with diesel vehicles driven 14.472.590 km and gasoline 8.069.463 km. As can be seen in Table 8, in all cases, vehicles in the overall fleet drive on average more than its gasoline counterparts.

Vehicles in emission class E are being driven on average the most, both in the case of total fleet as well as gasoline fleet. These average numbers are in all cases higher than the average value of passenger cars being driven in Iceland, both in the case of diesel as well as gasoline vehicles (Umferðarstofa - (The road traffic directorate), 2010b).

The average kilometers of the gasoline part of the fleet were used as the base for the cases in the case study as well as in the following analysis of the fleet. As no gasoline vehicles were found in emission classes A to D the focus on this analysis and following case studies will be on classes E, F, G, H, I and J.

Table 9 - Average gasoline consumption (L/100 Km)

Class	**Liters / 100 km**
E	8,60
F	10,00
G	10,60
H	12,18
I	13,26
J	14,84

Source: Calculated values based on data from the Icelandic road traffic directorate's database (2010a)

The average gasoline consumption calculated, in liters per 100 kilometers driven, was found to increase as the emission class was higher. This can be seen in Table 9. The highest consumption was found in the J category, 14,84 L/100 km, and lowest in category E, 8,6 L/100 km.

Table 10 - Average emission from gasoline vehicles for each class

	Emission class					
Emission (Gr/Km)	**E**	**F**	**G**	**H**	**I**	**J**
CO_2 emission class	141-160	161-180	181-200	201-220	221-250	>250
CO_2	158	174	193	209	229	261
HC	0,040	0,047	0,044	0,052	0,054	0,047
CO	0,240	0,628	0,445	0,364	0,428	0,221
NO_X	0,010	0,031	0,028	0,021	0,026	0,018

Source: Calculated values based on data from the Icelandic road traffic directorate's database (2010a)

Table 10 lists the emission of CO_2 calculated, for the average vehicle in each emission class, as well as the pollutants, HC, CO and NOx. It is noteworthy that pollution does not always increase at the same time the CO_2 does. Highest emission of HC is for example found in class I, not J. Furthermore the maximum emission of CO and NO_x is in category F, which has the second lowest CO_2 of the fleet.

7 CASE STUDY – CONVERTING A GASOLINE TAXI

In this chapter the results of the model are presented and analyzed first for a vehicle in each emission class and then for the overall gasoline fleet. Standard assumptions, listed below, are used unless otherwise stated. Impacts of different assumptions are discussed in the chapter scenario analysis. The cases are set up based on findings from analyzed data of gasoline taxis operating in region 1 and 2.

All monetary values are expressed in ISK unless otherwise stated.

7.1 Model inputs and assumptions for the standard case

This analysis uses multiple input variables to simulate the financial circumstances faced by taxi drivers. In this section, common or average values are used to establish a base case scenario for common operating circumstances. Several assumptions are also needed to be made. They are:

1. Cases for each vehicles class are based on the calculated average kilometers driven, found in the taxi fleet analysis chapter.
2. All calculations are based on gasoline and methane prices on January 11, 2011, including the latest changes in the taxes system.
3. The taxis regularly drive past a methane filling station to refill as they operate in this particular operating area. No extra mileage is required to fill up.
4. The discount rate was determined as the best interest rate that might be available to taxi drivers, plus a reasonable risk rate. A value of 6% annual interest rate was chosen. Same rate is assumed for all years.
5. If the vehicle is sold, the same resell value is assumed for a regular vehicle and a converted one, because as technology evolves fast, this particular equipment might be outdated. This also applies to the gas tanks. Moreover, there is limited experience in reselling converted bi-fuel vehicles in Iceland.
6. Having less space in the trunk does not affect the earning possibilities of taxi drivers. In some cases that might happen but on the other hand some vehicles get extra business as customers specially request environmentally friendly, methane vehicles. This is in accordance to taxi drivers experience.
7. The maintenance and operating cost is the same, except in the case of fuel price and automobile taxes.
8. The automobile taxes do not change during the lifetime of the investment.
9. The fuel consumption (energy content) will be the same after being converted.
10. Loan offered for conversion is an annuity carrying 8,5% interest rate. Same rate is assumed for all years.
11. Emission rate and urban driving fuel consumption are assumed to be the same value as in the type approval.
12. Quantity of gasoline needed when starting the engine in a converted vehicle is ignored as it is such a small quantity. This will not affect the economic results of the module.
13. Higher emission vehicles are assumed to be bigger, having more cylinders, as they have on average larger engines and higher fuel consumption.
    a. Emission classes: E, F, G have 6 cylinders engine
    b. Emission classes: H, I, J have 8 cylinders engine
14. No custom-built is needed when converting a vehicle.

15. The price of gasoline and methane is assumed not to change over the period of investment.
16. As most of the gasoline vehicles are from the year 2007, the lifetime of the investment was assumed to be 3 years. The vehicle would be 6 year old at the end of the investment.
17. The methane equipment will be useful during the project period.
18. The converted vehicle will be useful for at least three years after being converted.
19. Part of the excise tax is not repaid when the vehicle is converted, since the methane tanks need to be 78 liters. The tanks are assumed take up too large portion of the trunk, as well as this is a temporary clause in the legislation.
20. Converted vehicles are assumed not to apply any exhaust gas recirculation system after being converted.
21. Cost of imported metric ton of gasoline is assumed to be 800 USD and 1.200 liters of gasoline are found in each metric ton of gasoline. These values are based on recent market data.

Sometimes there is no distinctive value but a range of possible values for a parameter. In these cases, scenarios have been set up to provide a snapshot in project economics when various parameters change.

Table 11 - Summary of key assumptions

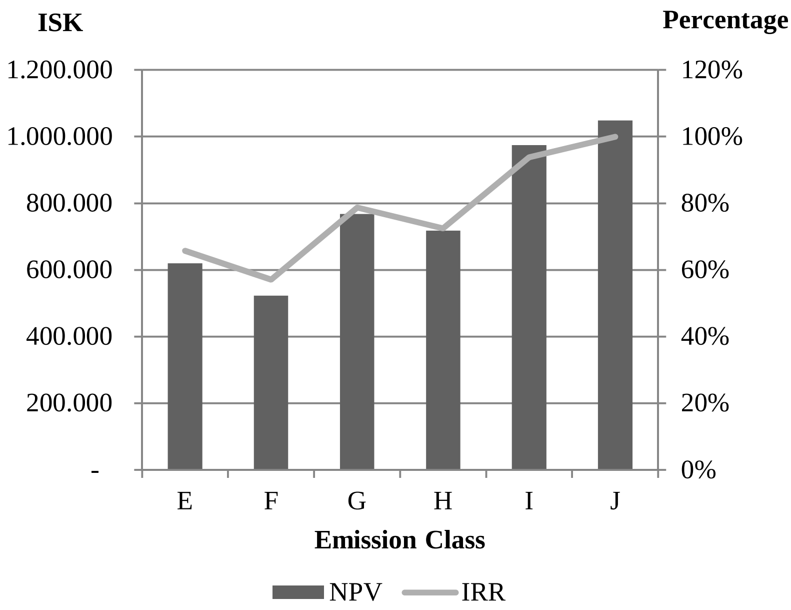
Discount rate	6% per year – Same rate all years
Loan	Available at 8,5% interest pear year. Same rate all years
Price of gasoline 95 oct (ISK/L)	212,9
Price of methane (ISK/Nm^3)	114
Price per liter in methane price eq. (ISK/L)	104,37
Excise tax (ISK/L)	23,86 – Gasoline only
Special excise tax (ISK/L)	38,55 – Gasoline only
Carbon tax (ISK/L)	3,8 – Gasoline only
VAT	25,5%
Cost of imported metric ton of gasoline	800 USD
Emission values	See Table 1
Automobile taxes	See Table 4
Investment lifetime	3 years

Table 12 - Summary of input data for each vehicle class's case

	Emission class					
	E	**F**	**G**	**H**	**I**	**J**
Emission class, CO_2 (Gr/Km)	141-160	161-180	181-200	201-220	221-250	>250
Average driving (Km/Yr)	43.717	33.909	39.118	32.626	36.010	34.130
Gasoline consumption (L/100 km)	8,60	10,00	10,60	12,18	13,26	14,84
Total gasoline usage (L/Yr)	3.760	3.391	4.191	4.039	4.877	5.064
CO_2 emission (Gr/Km)	158	174	193	209	229	261
Cost of conversion (ISK)	495.115	495.115	495.115	510.865	510.865	510.865

7.2 Vehicle per emission class

Figure 4 - NPV and IRR of all emission class cases

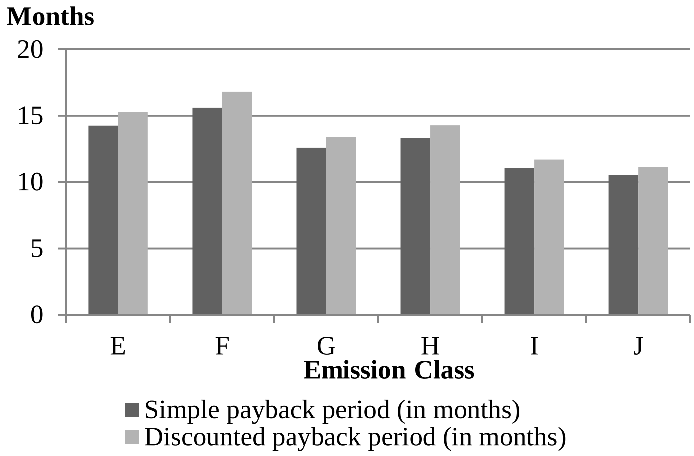


Source: Author's calculations(2011)

The main findings of the research are that under standard assumptions and input data, conversion for all emission classes would have a positive net present value (NPV) and positive internal rate of return (IRR). That means the investment pays for itself and in these cases provides a return on the invested capital, in the range of 57% to 100%. That is a high return on investment. The conversion should therefore be undertaken and methane used as a fuel.

As the vehicle classes, from E to J, have higher fuel consumption, drive more kilometers each year and have the highest automobile taxes, the savings are higher. Most savings would be incurred in emission class J and I, even though class G has more average kilometers driven. Lowest savings would be for vehicles in class F to be converted as it uses the least of gasoline of cases analyzed.

Figure 5 - Payback period of investment for all emission class cases



Source: Author’s calculations (2011)

The investment would pay for itself in the shortest range of time in the case of classes J and I. However, it would take the longest time for a vehicle in the case of emission class F. Moreover, due to the short payback time for all emission classes, a conversion is suitable in every case analyzed.

The time it takes for the investment to pay for itself, in the case of simple payback, is from 11 months in the case of J up to 15 months for vehicles in class F. This means the initially invested capital would be paid back for all cases in a period less than one year for emission class J and one year and 3 months for class F. After that time, the cost difference would be a return on investment. Having a shorter column is better as it means it takes a shorter time for the initial investment to pay for itself.

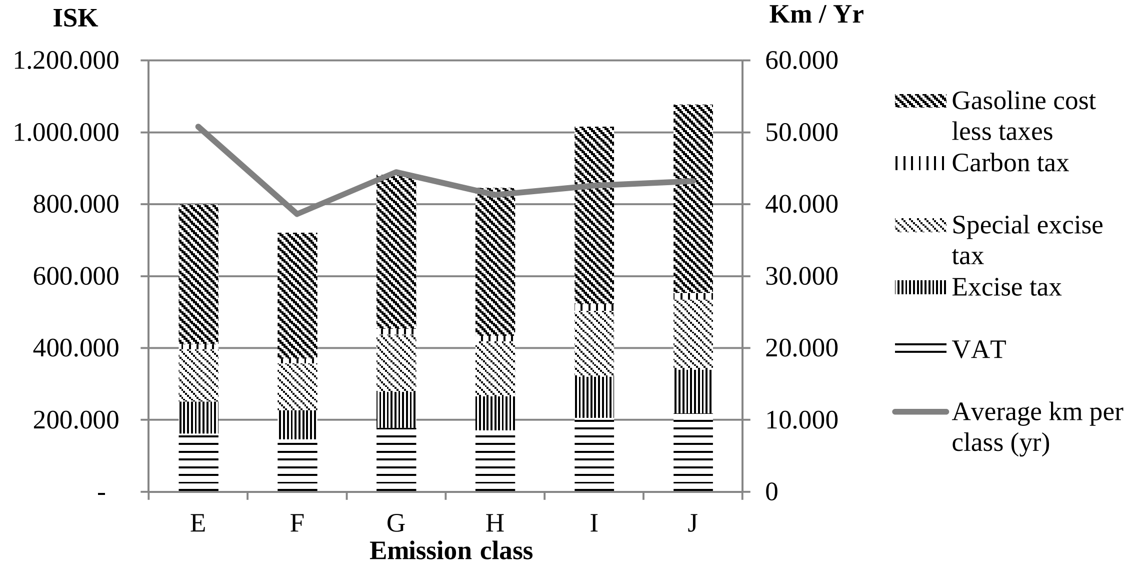
Table 13 - Automobile taxes calculated based on CO_2 emission and potential yearly savings

Class	CO2 (Gr/Km)	Automobile taxes due (ISK)	Yearly savings (ISK)
E	158	9.560	9.120
F	174	11.480	12.960
G	193	13.760	17.520
H	209	15.680	21.360
I	229	18.080	26.160
J	261	21.920	33.840

Source: Author’s caluclations (2011)

Table 13 lists up automobile taxes calculated, based on the average emission rate for each emission class. The column yearly savings, lists the potential savings by having a vehicle converted for each class. Highest yearly automobile taxes are paid by emission class J, which emits most. However, the highest emission classes also have the most potential savings.

Figure 6 - The total gasoline cost for each class and the average distance driven over a period of one year



Source: Author's calculations (2011)

Figure 6 graphs the yearly gasoline cost of each vehicle class along with the average number of kilometers driven in each share. The structure of the total fuel cost is listed in different colors.

Table 14 - Total yearly cost of fuel and fuel cost per kilometer driven (ISK/Yr) for each emission class

Class	Cost of gasoline (Yr)	Cost of methane (Yr)	Cost difference	Cost of gasoline / Km	Cost of methane / Km	Difference
E	800.430	392.391	408.040	18,3	9,0	9,3
F	721.913	353.899	368.013	21,3	10,4	10,9
G	883.115	432.925	450.190	22,6	11,1	11,5
H	845.993	414.726	431.266	25,9	12,7	13,2
I	1.016.320	498.225	518.095	28,2	13,8	14,4
J	1.078.132	528.527	549.605	31,6	15,5	16,1

Note: All amounts are in ISK

Source: Author's calculations (2011)

The average gasoline consumption per vehicle in the fleet was found out to be 4.367 liters per year. If the price of gasoline is 212,9 ISK, this cost of gasoline translates into 930 thousand ISK per vehicle. The total cost is highest in the highest emission classes J and I respectively with 1.078.132 ISK and 1.016.320. The yearly total cost does not always increase as the emission class gets higher, as can be seen by H having a lower cost than G and F being lower than E. This is the case although the latter classes have higher gasoline consumption in liters per 100 kilometers. This is due to the fact that average kilometers driven for each category is different as can be seen in Table 8.

When comparing the total cost of using either methane or gasoline as a fuel, for each emission class, highest savings in fuel cost were found in classes J and I, 550 thousand ISK and 518 thousand ISK respectively. The savings were in the range of 368 thousands ISK, for emission class F to 550 thousand for emission class J.

If the cost of gasoline is calculated based on each kilometer driven, the highest cost is found in the highest emission class J with 31,6 ISK/Km and lowest for E with 18,3 ISK/Km. The daytime taxi fare for 1 km in urban driving at Hreyfill, the largest taxicab company in Iceland, is 158 ISK (after first 2 kilometers driven) (Hreyfill, 2010). The average salary in Iceland is 366 thousands ISK (Hagstofan - (Statistics Iceland), 2011). This cost of gasoline is a considerable amount of money when these values are put in comparison.

Table 15 - Yearly new CO_2 emission, from gasoline, for each vehicle class (Kg/Yr)

	Emission class					
Single vehicle	**E**	**F**	**G**	**H**	**I**	**J**
Gasoline taxi	6.907	5.900	7.550	6.819	8.246	8.908

Source: Author’s calculations (2011)

Most new CO_2 emission can be saved in classes I and J, or 8,9 metric tons and 8,2 metric tons respectively.

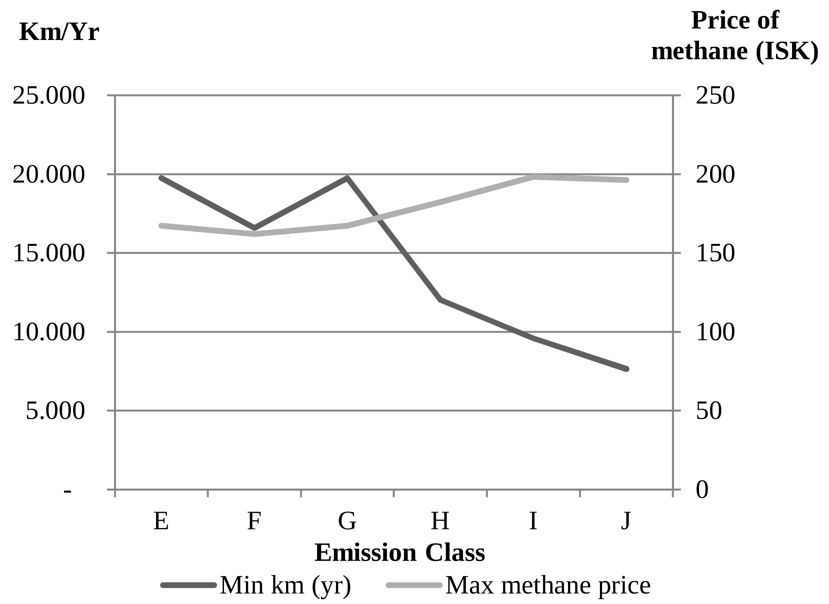
Table 16 - Pollution for each vehicle class (Gr/Yr)

	Emission class					
Pollutant	**E**	**F**	**G**	**H**	**I**	**J**
From gasoline taxi						
HC	1.749	1.594	1.729	1.692	1.927	1.604
CO	10.492	21.283	17.407	11.882	15.416	7.538
NO_x	437	1.051	1.114	674	948	629
From methane taxi						
HC	874	797	865	846	963	802
CO	2.098	4.257	3.481	2.376	3.083	1.508
NO_x	581	1.398	1.482	897	1.261	837
Difference						
HC	(874)	(797)	(865)	(846)	(963)	(802)
CO	(8.394)	(17.027)	(13.926)	(9.506)	(12.333)	(6.030)
NO_x	144	347	368	223	313	208

Source: Author’s calculations (2011)

Current pollution from taxis operating in region 1 are found in Table 16. In the same table, one can also find the estimated methane emission and the potential savings by using methane as a primary fuel for each emission class. Considerable reductions in HC and CO especially are achieved by switching a vehicle to using methane as its main fuel. Most reduction of pollution is in the case of vehicles in class F. However there is an increase in NO_x emission, the most in emission class G.

Figure 7 - Minimum number of kilometers and maximum price of methane for each vehicle class



Source: Author's calculations (2011)

Figure 7 graphs up the number of kilometers needed in a period of one year for the investment to break even for each emission class. On the same graph the highest price of methane is graphed which would set the investment break even. In order to find these values, the goal seek tool in Microsoft Excel was used. It was set to find the number of kilometers and the price of methane that would set the net present value (NPV) to zero.

Shortest distance needed was found in the case of class J and longest in the case of E and G. The highest price of methane that would set the investment to zero was found in the case of class I and the lowest in F 198 ISK/Nm^3 and in E and G, 162 ISK/Nm^3. Vehicles in emission class J need to be driven the least 7.630 kilometers per year, but vehicles found in class E and G the most or a total of 19.741 kilometers per year.

7.3 The fleet

In this chapter the part of the fleet that would be feasible to convert is used as the base for calculating the national saving as well as the potential in GHG emission and pollution reduction.

Table 17 - Number of vehicles feasible to convert

	Emission class						
	E	**F**	**G**	**H**	**I**	**J**	**Total**
In the fleet	1	4	98	62	47	10	222
Not feasible to convert	0	0	20	5	6	1	32
Feasible to convert	1	4	78	57	41	9	190

Source: Author's calculations (2011)

The vehicles that do not drive the minimum number of kilometers over a period of one year, graphed in Table 17 were found out to be 32. Most of them being in class G which are a total of 20. Out of 222 vehicles in the gasoline fleet, 190 were found out to be feasible to be converted.

Table 18 - Total gasoline cost and structure of gasoline cost for each vehicle class of the fleet

	Emission class							
	E	**F**	**G**	**H**	**I**	**J**	**Total**	**%**
Total gasoline liters (L/Yr)	3.760	13.563	323.546	226.499	195.722	44.638	807.728	
In thousand ISK*								
Total gasoline cost	800	2.888	68.883	48.222	41.669	9.504	171.965	100%
VAT	163	587	13.996	9.798	8.467	1.931	34.941	20%
Excise tax	90	324	7.719	5.404	4.669	1.065	19.270	11%
Special excise tax	145	523	12.474	8.732	7.546	1.721	31.140	18%
Carbon tax	14	52	1.229	861	744	170	3.069	2%
Taxes total	412	1.485	35.418	24.795	21.425	4.887	88.421	51%
Gasoline cost, less taxes	90	324	7.723	5.406	4.672	1.065	83.544	49%
Value of imported gasoline (USD)	2.506	9.042	215.697	150.999	130.481	29.759	538.485	

* All amounts are in thousand ISK, except the value of imported gasoline, which is stated in USD. ** The price of gasoline as of January 11, 2011 is used

Source: Author's calculations (2011)

Yearly national saving of those 808 thousand liters of gasoline imported was found to be 538.485 USD, which would be 63,2 million ISK using 117,36 ISK/USD exchange rate of January 13, 2011. This is a considerable amount of money that could be used in the local economy and to create new jobs instead. Furthermore, the share of the gasoline price that runs directly to the government is 51%.

Table 19 - CO_2 emission of the fleet (Metric ton/Year)

	Emission class						
The total fleet	**E**	**F**	**G**	**H**	**I**	**J**	**Total**
Gasoline taxis	6,9	23,6	588,9	388,7	338,1	78,5	1.424,7

Source: Author's calculations (2011)

Table 20 - Pollution from the fleet and potential reduction in emission (Kg/Year)

Pollutant	E	F	G	H	I	J
HC	(0,87)	(3,19)	(67,45)	(48,23)	(39,49)	(7,07)
CO	(8,39)	(68,11)	(1.086,20)	(541,84)	(505,65)	(53,16)
NOx	0,14	1,39	28,68	12,69	12,83	1,83

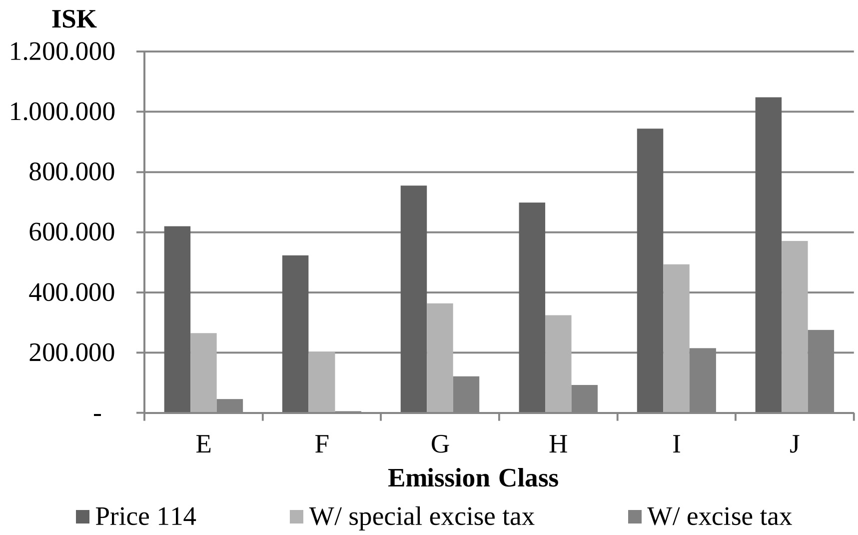
Source: Author's calculations (2011)

Total emission of new CO_2, was found to be 1.424,7 metric tons over a period of one year, with emission class G and H emitting the most, 588,9 metric tons and 388,7 metric tons. This new GHG emission could be saved by using methane as an alternative fuel. The pollution of HC and CO was found to be reduced considerably, most in class G but NO_x emission to increase, also most in class G.

7.4 Scenario analysis

In this section, the results are presented using different scenario of parameters.

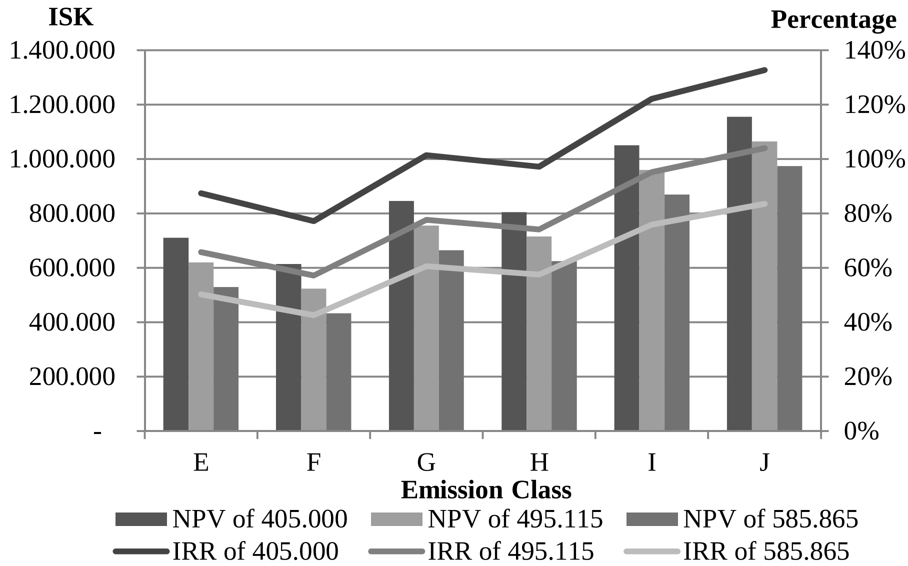
Figure 8 - NPV - Methane price and the effect of excise taxes



Source: Author's calculations (2011)

Figure 8 shows what happens to the NPV if methane were to carry the same taxes as gasoline does. Even though special excise tax was added to the investment, it would still be profitable. This is also the case if the other excise tax was added on top of the price which includes the special excise tax. This means that although methane would carry the same taxes as gasoline it would still be feasible at current methane price, 114 ISK/Nm^3. Carbon tax is not analyzed, since biomethane is not a fossil fuel and is carbon neutral when combusted. Highest return was found to be always in the case of emission class J, no matter whether the extra taxes were added or not.

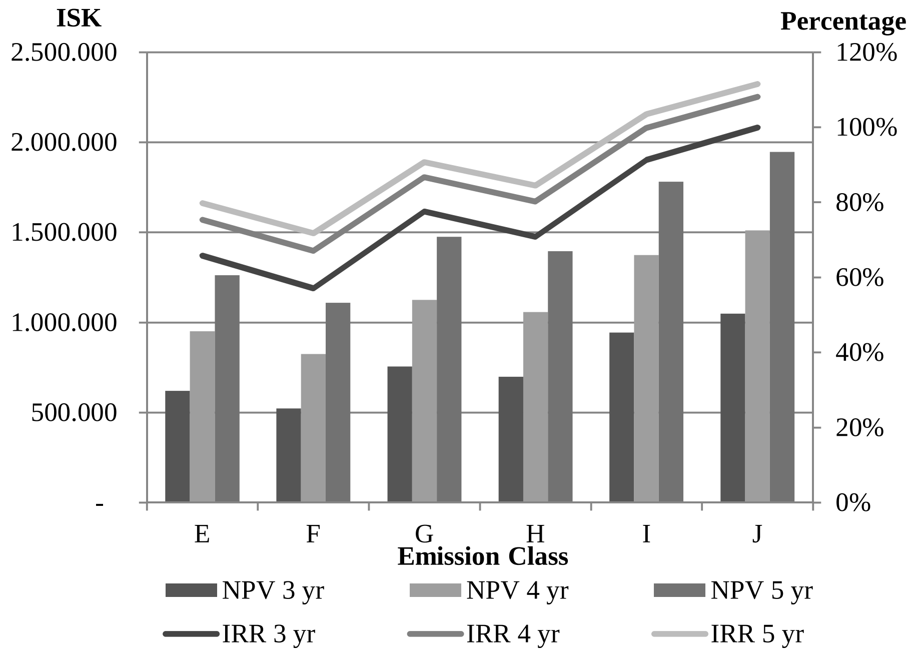
Figure 9 - Different cost of converting (NPV and IRR)



Source: Author’s calculations (2011)

Figure 9 shows graphically different net present value of investments and internal rate of return, using different scenarios of cost of conversion. The lowest case analyzed is 405 thousand ISK to 585 thousand ISK. Different costs could be incurred as vehicle owners might want more gas containers or some adjustments might be needed when the vehicle is being converted.

Figure 10 - NPV and IRR based on longer duration of investment period



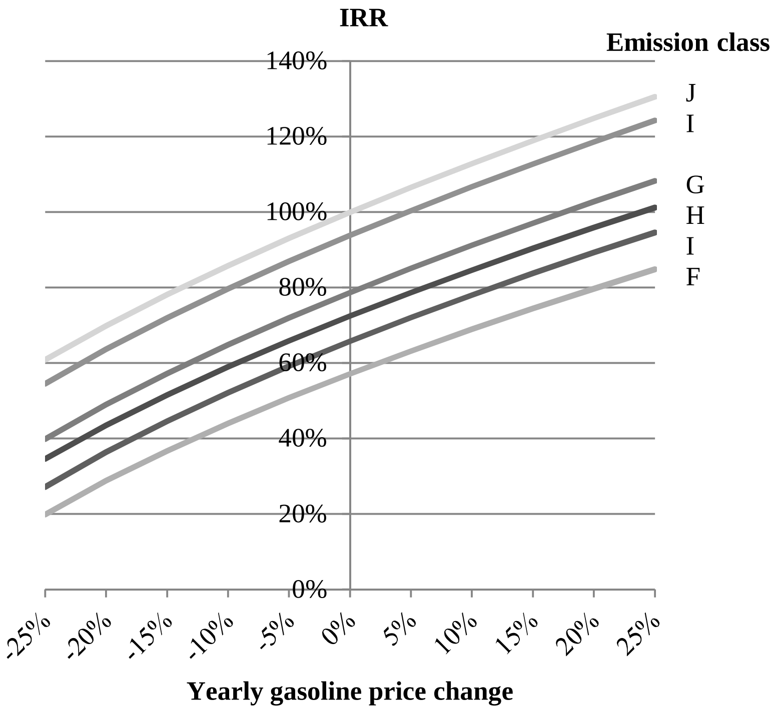
Source: Author's calculations (2011)

As the number of years increase, from three to five years, the return on investment increases and has a higher net present value. Using the equipment for a longer period of time will increase the return on investment.

7.5 Sensitivity analysis

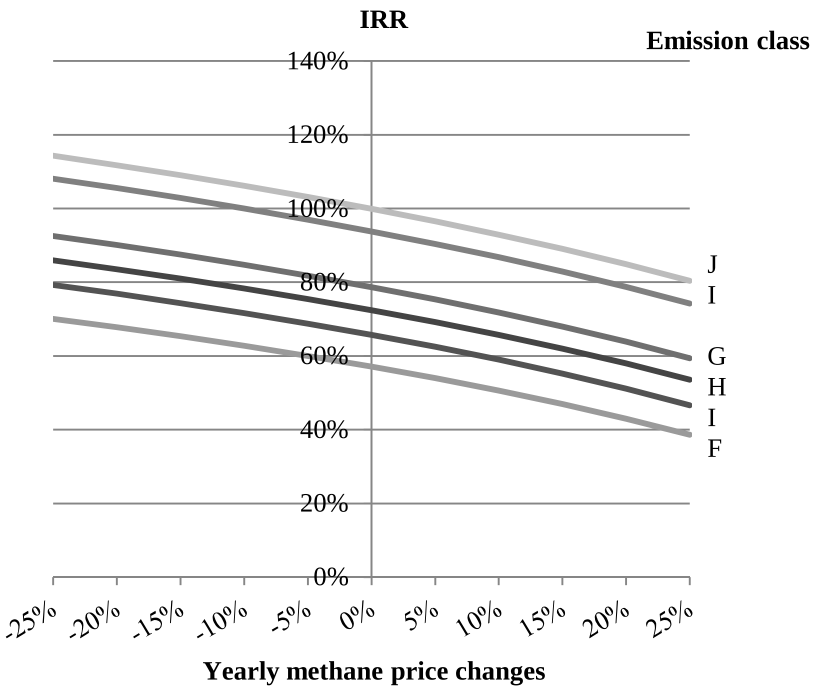
In this section, change in several parameters and its impacts on the investment are analyzed.

Figure 11 - Yearly price increase / decrease gasoline and effect on IRR



Source: Author's calculations (2011)

Figure 12 - Yearly price increase / decrease methane and effect on IRR



Source: Author's calculations (2011)

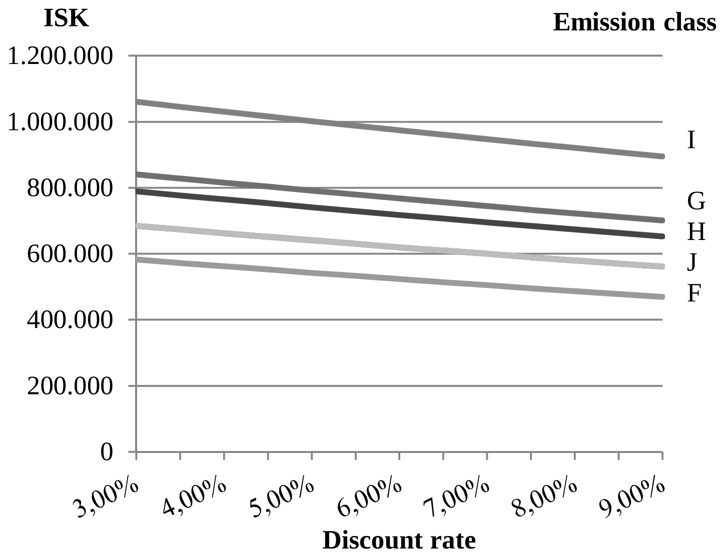
As there is no sure way to predict oil prices, sensitivity analysis is used to find out what happens if the price of gasoline changes as well as the price of methane.

Figure 11 and Figure 12 show what happens to the internal rate of return on all vehicle classes, as the price change increases or decreases of certain percentage yearly during the lifetime of the investment, from -25% to 25%, assuming the same percentage change for all the years and only one of the fuel prices changes during the lifetime of the investment. The price difference can in reality be higher or lower than this range.

It can be seen in Figure 11 that as the price of gasoline increases more and more, the investment is more and more profitable. However, if the price of gasoline steadily decreases the investment is less and less attractive. In the case of methane, Figure 12, this is the other way around. If the price of methane increases, the investment is less feasible and more feasible if the price goes down over the duration of the investment. If the yearly price change is 0% the internal rate of return is the same for both gasoline and methane, as this is the standard case.

Maximum return on investment is obtained when the price of gasoline rises at maximum rate (in the case of this graph, of 25%) and lowest return when the price decreases yearly at maximum decrease. In the case of methane, maximum return is obtained when the price of methane decreases at maximum yearly, but decreases as it increases at maximum rate.

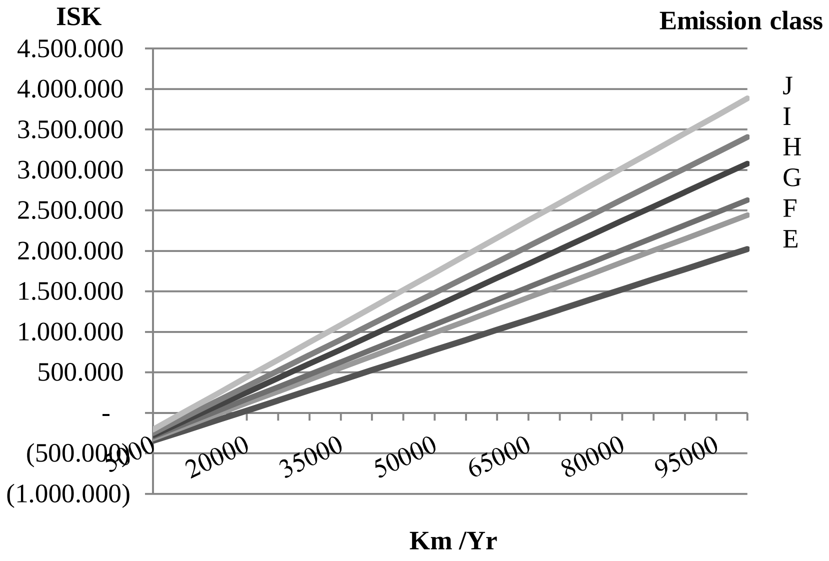
Figure 13 - Change in discount rate and effect on NPV



Source: Author’s calculations (2011)

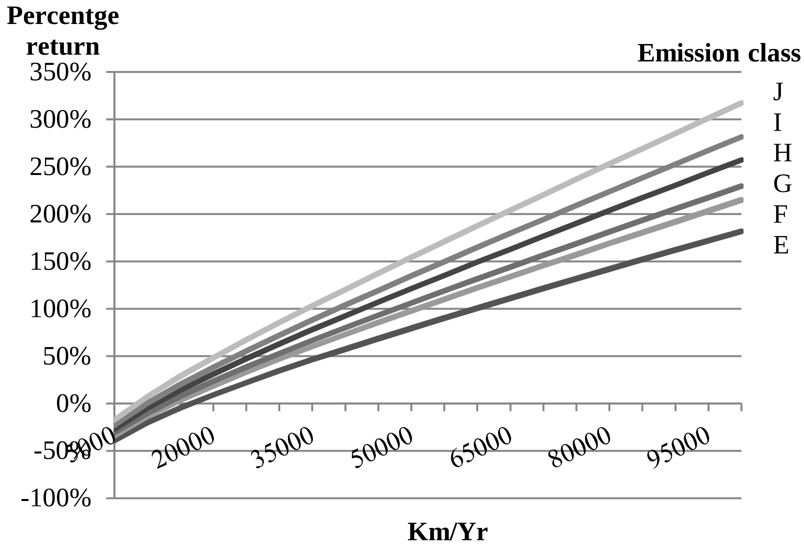
As the discount rate gets higher, there is a less return on investment. On the contrary, if the discount rate lowers, the investment will be more profitable. Although the rate will go from 6% to 9% the investment will still be feasible.

Figure 14 - NPV based on different number of kilometers driven per year



Source: Author's calculations (2011)

Figure 15 - IRR based on different number of kilometers driven per year

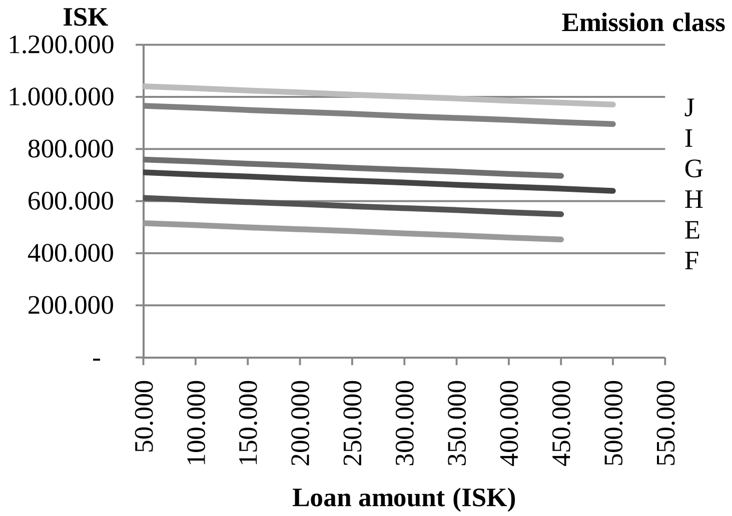


Source: Author's calculations (2011)

Figure 14 and Figure 15 graph up the net present value of the investment and the return on investment, respectively. As more distance is driven each year, the savings will be higher. The savings increase at a higher rate as the fuel class has higher fuel consumption ratio. Where each line crosses the x-axis the investment turns profitable. As can be seen, all the emission classes turn profitable when more than 20.000 kilometers are driven per year. The first vehicle class to cross the x-axis and turn into profitable investment is the J emission class and the last one is class E.

As this is a net present value and internal rate of return of investment, maintenance cost of the vehicle and other operating cost, which might increase as more kilometers are driven, are not accounted for, since that cost would be the same, no matter which fuel is used in the vehicle. Only cost incurred as the result of a different fuel is accounted for.

Figure 16 - Effect of different amount of loan on NPV



Source: Author’s calculations (2011)

If the conversion is financed initially by a loan, the net return will change. However, although it would be fully financed by a loan, it would not have much impact on the feasibility. This is because the cost of converting, using a loan, is lower than the overall fuel cost savings. Putting low initial cash up front for the conversion, financing what is left with a loan and having high fuel cost savings will return very high internal rate of return. However, interest rate could change during the investment period or some other important parameters.

The lines for emission class E, F and G are shorter than for H, I and J as one can not have a higher loan than the amount it costs to convert the vehicle.

8 DISCUSSION AND RECOMMENDATIONS

In order to prepare conducting this study, several taxi drivers were interviewed with a question list of their experience operating a methane vehicle, both converted vehicles and imported bi-fuel vehicles. Along with people who have experience in this field.

The following main advantages and disadvantages of operating a converted vehicle, were found:

Advantages	Disadvantages
• Less expensive fuel • Cleaner burning fuel	• Currently only two methane filling stations are available • The trunk has less free space available. However, those interviewed said they had not incurred any problems due to this

When asked why more vehicles have not been converted, some of the drivers stated that the reason is that taxi drivers are afraid that methane as a fuel will be taxed more in the future, as more vehicles will be converted or bi-fuel vehicles imported.

Uncertainty is not good, so if the government could give a statement that landfill methane will not be taxed as gasoline it would without a doubt increase interest in having taxis converted. This would also apply to other parts of the chain, i.e. the price charged for methane, in the case of N1 and the landfill owner. If taxi drivers were convinced that the methane fuel price would not increase considerably within a given period, they would be more confident in having their vehicles converted. They could also be provided with an agreement that they will have a fixed price of methane for a certain period of time. This also applies to the case regarding the automobile taxes; for how long will the vehicles be taxed based on CO_2 emission?

Furthermore, in order to increase the interest among taxi drivers, government organizations could point their business to taxis operating on domestic fuel, such as methane. As the excise taxes have recently been lowered for imported low CO_2 emission vehicles, the next logical step could be to lower the excise tax on the conversion equipment, which would lower the price of conversion further. The conversion companies could introduce the findings of this research to taxi drivers and offer them a guarantee. If the conversion will not save them a particular amount of fuel cost over a given period, the conversion will be partially refunded. This would without a doubt increase interest in having vehicles converted.

In the end, a technology will not be successful unless it is better and less expensive than the current one. Every journey starts with taking a first step, and that also applies to fuels. If one niche of the market would be successful in implementing a domestic gas as an alternative fuel, more people would follow in their footsteps.

9 CONCLUSIONS

According to this research, it is feasible for the average gasoline taxi to have the vehicle converted and operated on methane. This is applicable to all vehicle emission classes even if they need to finance the change with loans. The return on investment was found to be in the range of 57% to 100%. Owners of gasoline taxi vehicles should therefore, on the basis of these findings, have their vehicles converted if they drive more than the minimum kilometers needed for the investment to break even. Out of the 222 vehicles in the gasoline fleet, 190 were found to fulfill this requirement.

The fuel cost difference over a year period would be considerable, as well the cost of fuel per kilometer driven. From one of the scenarios, its findings were that the investment would still be positive in most cases, even though methane would carry excise taxes as gasoline does. As the investment would be useful for longer period of time, the NPV and IRR would be higher. If the price of methane were to increase by 25% per year for three years, the investment would still be profitable. However, one of the limitations of cost calculations and financial feasibility studies is that they can become invalid in a relatively short period of time when important input parameters change. A web based calculation model could be developed based on these findings and in depth analysis, which would calculate the results for each individual case.

It takes from 11 months to 15 months for the initial investment to pay for itself in savings. All the emission classes were found to have positive return on investment if more than 20.000 kilometers were driven yearly. The emission of CO_2 was found to be reduced considerably as well as pollution of HC and CO. However, emission of NO_x was found to increase. As for the national savings, in terms of less import of gasoline, it was found to be 538 thousand USD over a period of one year.

As this feasibility study shows, using methane as an alternative fuel on converted taxi vehicles is feasible. This is also a proven technology, using domestic and an environmentally friendly fuel. How many taxi vehicles will be converted due to these findings? How many will not be converted and why? Further researches among taxi drivers could be conducted to investigate what prevents taxi drivers from having their vehicles converted, as it is, as previously stated, financially feasible for them. This would add to the basis of these research findings.

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11 APPENDIX A – GLOSSARY OF TERMS

Air-fuel ratio: The mass ratio of air to fuel present during combustion.

Bi-fuel vehicle: Vehicles capable of running on two fuels which are stored in separate tanks. The engine runs on one fuel at a time.

Carbon monoxide (CO): A colorless, odorless and poisonous gas that is produced due to incomplete combustion. It reduces the blood's ability to carry oxygen.

Compressed natural gas vehicle (CNG vehicle): A vehicle that uses compressed natural gas as a fuel. As methane is the principal component of natural gas, "CNG vehicle" is used as well as "methane car" in the text.

Dead weight: The unrelieved weight of a heavy, motionless mass.

Discount rate: The rate of interest used in determining the present value of future cash flows.

Exhaust gas recirculation (EGR): A nitrogen oxide (NO_x) emissions reduction technique used in internal combustion engines.

Fossil fuel: Hydrocarbons, primarily fuel oil, natural gas or coal. Formed from the remains of dead plants and animals.

Hydrocarbon (HC): A product of incomplete combustion of a hydrocarbon fuel such as gasoline, and natural gas. HC emissions contribute to the formation of ground level ozone, which can cause damage to human health and vegetation.

MARR: Minimum attractive rate of return is the lowest return on an investment or a project that will make the investor accept that project.

Methane car: A car that runs on methane gas.

Metric ton: A unit of mass equal to 1,000 kilograms.

Nitrogen oxide (NO_x): NO and NO_2 are collectively known as NO_x. It is generated when nitrogen in the air reacts with oxygen at high temperature and pressure inside the engine. It has the potential to cause human respiratory problems at high concentrations. NO_x are also one of the precursors for photochemical ozone formation.

Original equipment manufacturer (OEM): Refers to the company that originally manufactured a product.

Primary energy: The energy embodied in natural resources, prior to undergoing any human made conversions or transformations.

Spark ignition engine: Internal combustion engines, specifically petrol engines. The initiation of the combustion process is ignited within a combustion chamber, by a spark from a spark plug.

The road traffic directorate: Government agency that administers vehicle registration and driver licensing in Iceland

Type approval: A confirmation that production will meet specified performance standards.

12 APPENDIX B – EXAMPLES

Example: Driving distance over a period of one year

If a vehicle has from last two inspections registered 30.000 km. and 50.000 km. and the number of days between the inspections was 250, the total driving distance over a period of one year would be 29.200 km.

Example: Price of methane per liter of gasoline equivalent found

Price of methane: 114 ISK/Nm^3.

The biogas sold is 97,5% methane.

1 Nm^3 of 100% methane in gasoline equivalent: 1,12 liters.

Price of methane in per liter of gasoline equivalent: 104,37 ISK/L

Example: Present value (PV)

You will receive 10.000 ISK in five years. How much is this amount worth today, given the discount rate is 10%?

$$A_n = 10.000;$$

$$i = 10\%;$$

$$N = 5$$

$$PV(10\%) = \frac{10.000}{(1+10\%)^5}$$

PV(10%) = 6.209 ISK

The value of 10.000 ISK received in five years, would be worth 6.209 ISK, using the discount rate 10%.

Example: Net present value (NPV)

An investor evaluates an investment with an initial outflow of 100.000 ISK and estimates that he will receive equal 35.000 ISK for three years. After comparing investments with similar risks and their discount rates, he sets the rate for this one to be 10%.

The values are:

$$A_0 = -100.000 \text{ ISK};$$

$$A_1, A_2, A_3 = 35.000 \text{ ISK};$$

$$i = 10\%;$$

$$N = 3$$

$$NPV(10\%) = \frac{-100.000}{(1+0,1)^0} + \frac{35.000}{(1+0,1)^1} + \frac{35.000}{(1+0,1)^2} + \frac{35.000}{(1+0,1)^3}$$

NPV(10%) = -100.000 + 31.818 + 28.926 + 26.296

= -12.960 ISK

This investment has a net present value of -12.960 ISK. As it has negative net present value, the investor should not invest in it.

Example: Internal rate of return (IRR)

If we take the same example as above and the investor sets his MARR to 10% the values will be the following:

$$A_0 = -100.000 \text{ ISK};$$

$$A_1, A_2, A_3 = 35.000 \text{ ISK};$$

$$i = i^*;$$

$$N = 3$$

Year 0 Year 1 Year 2 Year 3

$$NPV(i^*) = \frac{-100.000}{(1+i^*)^0} + \frac{35.000}{(1+i^*)^1} + \frac{35.000}{(1+i^*)^2} + \frac{35.000}{(1+i^*)^3} = 0$$

To find the internal rate of return, we have to find the discount rate that sets the net present value of the investment to zero.

The value of IRR is found to be 2,5%. The investor sets his MARR to 10%. As the rate of IRR is lower than MARR, the investment should be rejected.

Example: Payback period

Using the same example as before.

If the cash stream is not discounted it will be:

Year 0	Year 1	Year 2	Year 3	
Payback =	-100.000	35.000	35.000	35.000

Total cash inflow equals = *3 x 35.000 = 105.000 ISK*

This means that the investment recovers its initial cash outflow.

Number of years = $\frac{100.000}{35.000}$ = 2,85 years

This investment would take 2 years and approximately 10 months to break even and after that period turn to profit.

If we on the other hand incorporate the time value of money, the calculations will look as follows:

Year 0	Year 1	Year 2	Year 3	
Payback =	-100.000	31.818	28.926	26.296

Total cash inflow equals = 31.818 + 28.926 + 26.296 = 87.040 ISK

As the total discounted inflow, 87.040 ISK, is lower than the invested 100.000 ISK, it means the investment will not be able to recover the initial cash outflow in a given period.