Measure title: **Bio fuels in Aalborg (focus)**

City: **Aalborg** *Project:* **Archimedes** *Measure number:* **1**

Executive Summary

Within this measure the opportunities of using a high blend of bio-fuel (>B10) in standard vehicles have been explored. The Public Transport Authority of North Denmark, Nordjyllands Trafikselskab (NT) has set up requirements for the contractors to run a total of 50 buses on at least 10% biodiesel. In addition, 5 HGVs and 45 vans from the postal service in Aalborg are operated on an average of 15% biodiesel. A fuelling station was established to ensure the supply of bio-diesel to the demonstration fleet.

There is a slight indication of increased NO_x and a tendency to reduced CO, which is in line with most previous studies. At the same time there is a small reduction in PM and Fuel Consumption (BSFC). However, these differences are too small to be significant. The change in HC is also too small to be significant. The conclusion is therefore that emissions are practically unchanged.

The use of bio-diesel will lead to less consumption of conventional diesel, and since the used bio-diesel product is saving the environment from a relatively high amount of CO_2, the overall conclusion, is that, local emissions are practically unchanged, while CO_2 emissions are reduced corresponding the use of bio-diesel. It is hence demonstrated that 2nd generation bio-diesel, AFME, made from animal fat can be used without major problems in public transport fleets and delivery vehicles.

It is possible to reduce CO_2 emissions and fossil fuel consumption from vehicles without increasing other emissions significantly, without moderating vehicles and without encountering major problems in vehicle performances. In total 1,000 tonnes of CO_2 has been saved as a result of this measure.

The overall conclusion is that the capitalised benefits, when compared to the capitalised maintenance costs, are not enough to yield satisfactory returns on the Biofuels project's capital costs. The project has an NPV of approximately -€1,300,000.

In order to test the robustness of the conclusion a sensitivity analysis on select key impacts has been carried out. If the benefits from increased perceived image were monetarised to €100,000 and any one of the following bullets were to be realised, the NPV of the project will turn positive:

1. The initial additional costs of using biofuels are reduced to approximately €121,000.
2. The price of CO_2 quotas is increased to €186.

Based on this sensitivity analysis it is argued that the overall conclusion, as laid out above, is robust.

Aalborg has launched a shuttle bus line, the City Circle, free of charge, which runs between parking areas, and key places in the city as tourist attractions and the new waterfront. The City Circle was in 2010 operated by a hybrid bus with 30% lower fuel consumption and hence lower CO_2 emissions than regular buses. In 2011 a bus operating on 30% 2nd generation bio-diesel was used and in 2012 a bus operating on 100% sustainable diesel was used. The season 2012 has just ended.

Main barriers met in the project are technical and especially concerning the establishment of a fuelling station at one of the involved companies. Main driver for the Postal Service and the Public Transport Authority has been to investigate how this measure can help them to meet their corporate objectives for carbon dioxide reductions.

A Introduction

A1.1 Objectives

The measure objectives are:

1. High level / longer term:
    - To reduce pollution in the city.
2. Strategic level:
    - To increase the number of bus passengers
    - To improve the image of public transport
3. Measure level:

    (1) Reduction of CO, NO_x and Particulate emissions of the involved vehicles in the demonstration. Of the public transport fleet 50 diesel buses will be operation on at least 10% bio-fuels blend. In addition Danish Mail will include 5 HGVs and 45 vans on an average of 15% bio-diesel. Emission control schemes have been set up for 2 buses and 1 vehicle from the Postal Service.

    (2) Provided that fuel consumption remains the same the 10% substitution of diesel with CO2 neutral bio fuels in public transport in the CIVITAS corridor is expected to lead to 140t less CO_2 emissions annually. For HGV and vans the figure will be around 175 t.

    (3) To design and implement a tourism shuttle bus with target on 7,500-15,000 passengers using the shuttle bus line per year of the project.

A1.2 Target groups

- Bus passengers travelling in the City of Aalborg – mainly in the CIVITAS Corridor. The image of public transport will be improved by the implementation of bio-fuels.
- Potential users of public transport in the City of Aalborg. With an improved image of public transport, road users, who are not familiar with public transport, might be encouraged to use public transport.
- HGV operators, which have been involved in the planning of this measure, including the bus operators and the national postal service.
- Tourists visiting the City of Aalborg are target group of the shuttle bus. Hopefully, tourists can be encouraged to use the bus instead of private car.
- Citizens in Aalborg who wish to experience their city in a new way by using the shuttle bus as transport to tourist attractions, or as a way to see the city or to talk to the host and get information about the city. In this way, public transport contributes positively to the citizens' impression of both public transport and the city in general.

A2 Description

Within this measure the opportunities of using a high blend of bio-fuel (a 10 % bio-diesel blend or more) in standard vehicles have been explored. The analyses comprise buses, HGV and distribution

vehicles with a new tourist bus line as a visible showcase. First experiences in developing a supply infrastructure for bio fuels were gathered.

Task 11.1.1 Aalborg has established a subcontract with Danish Technological Institute[1] to carry out a study on 1st generation and 2nd generation bio-fuels to determine state-of-the-art and find the best sources for the full scale demonstration in task 1.1 and 1.2. Important criteria are the environmental impacts, impacts or requirements to vehicle engines and up-scaling potentials.

Task 1.1 As part of a tender in 2010 for operating the city buses in Aalborg, and based on the inputs from research report 11.1.1 (Study of impact using 1G and 2G bio fuels in Public Transport and Delivery Service vehicles) Nordjyllands Trafikselskab (NT) set up requirements for the contractors to run a total of 50 buses on at least 10% biodiesel. NT has reported on fuel consumption and impacts on vehicle reliability. The link to task 11.1.1 has enabled the assessment of environmental impacts.

The winning contractors have been given the responsibility to establish the required supply infrastructure in co-operation with oil suppliers as part of ARCHIMEDES task 1.3. It was included in the tender that a second generation bio-diesel should be used. Both companies have chosen to use a 10% blend of DAKA bio-diesel, which is bio-diesel made from animal fat, mainly waste from slaughterhouses that cannot be used for any other purposes (e.g. food or pet food).

Through **Task 1.2** 50 postal service vehicles in Aalborg are operated on an average of 15 % biodiesel. The demonstration project was started the 1st of April 2011. The Postal Service has reported on fuel consumption and impacts on vehicle reliability. The link to task 11.1.1 has enabled the assessment of environmental impacts. The Postal Service Company has chosen to use a 10% blend of DAKA bio-diesel in the winter, 15% in spring and autumn and 20% in the summer period.

Task 1.3 included establishing fuelling stations to ensure the supply of bio-diesel to the demonstration fleet. In total, three fuelling stations were established; one for each of the two bus operators and one for the postal service. Different approaches are used by the companies. At the bus operators, the bio-diesel is blended on location, whereas the Postal Service is receiving the fuel already blended by the oil company.

Task 2.1 Aalborg has launched a shuttle bus line, the City Circle, free of charge, which runs between parking areas, and key places in the city as tourist attractions and the new waterfront. Different green technologies have been tested in the three seasons of the shuttle bus. The goal has been to inform visitors in the city about Aalborg and green public transport. The aim has been to encourage as many people as possible to use the bus; hence the number of passengers will be evaluated through countings.

The City Circle was operated by a hybrid bus with 30% lower fuel consumption and hence lower CO2 emissions than regular buses in 2010, in 2011 diesel buses running on a 30 % bio-diesel blend were used and in 2012, a bus running on 100 % sustainably produced bio-diesel has been operated. A host is on board the buses every day between 10.00 and 14.00, providing the passengers with information about Aalborg, sustainable initiatives in the city and facts about the bus.

A3 Person in charge for evaluation of this measure

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[1] http://www.dti.dk/

B Measure implementation

B1 Innovative aspects

The innovative aspects of the measure are:

- **Use of new technology/ITS** – The use of biodiesel based on animal fat is new in Denmark. A few research projects have been going on in other parts of the country. Not more than a 5 % biodiesel blend is tested among regular customers.
- **New mode of transport exploited** – A shuttle bus service for tourist at the new harbour front is a new initiative locally and regionally.
- **Targeting specific user groups** – This measure is targeting tourists among others, which is a new target group to address regarding transport.
- **New organisational arrangements or relationships** – Various stakeholders, including oil companies, public transport operators, and the national postal service are involved in a public private partnership as part of this measure.

B2 Research and Technology Development Tasks

Aalborg has had the Danish Technological Institute to carry out a study on first generation bio-fuels (e.g. made of foodstuff) and second bio-fuels (made from waste products, such as animal fat) to determine state of the art and find the best sources for the full scale demos in task 1.1 and 1.2. The study is named R1.1 Study of 1st and 2nd Generation Bio-fuels and has been approved by the EC and the key findings are:

About 2.500 m3 of Tallow Methyl Ester (TME) based B10, B15 and B30 has successfully been used in Denmark so far.

Cold temperature properties of biodiesel are very different from fossil diesel. Tallow biodiesel typically requires heated tank installations for handling in pure form (B100). The problem is reduced when mixing with ordinary diesel or with additives. The B5Next project has shown that it is possible to produce a tallow-based B5 that is usable under the same conditions as standard Danish winter diesel. B10 and B15 should be limited to approx. -10°C, whereas B30 should not be relied on during winter. Low temperature stability is not consistently dependent on base fuel cold properties. It is absolutely necessary to measure cold weather properties in the ready mixture, not only in the base components. While B10 and B15 TME can be derived from domestic diesel qualities, B30 TME requires a special low density base-diesel to comply with the density requirement of the Fuel Quality Directive. This makes B30 significantly more expensive.

Biodiesel might need heating before the admixing process with diesel. Tallow biodiesel requires heating at approximately 25 ºC when mixed; otherwise a deposition in the finished mix could result.

The need for two-stage mixing could arise in the case of long transport distances where, for example, due to the cold temperature properties, neat TME must be diluted to B50 before transportation.

A diesel engine is an internal combustion engine with a high compression ratio that brings about a fuel dilution of the engine lubricating oil – especially in the engine warm-up period – because the fuel seeps down past the piston and dilutes the engine oil. Biodiesel has been shown, according to various international experiences, to increase this dilution. When using B30 or lower blends however, no significant deterioration of engine oils is likely to occur, when service intervals are adapted according to the manufacturer's specifications. Typically this means that engine oil has to be changed twice as often. In the Biodiesel DK project analyses of the motor oil in the vehicles have regularly been made –

partly to protect against engine failure and partly to test possible engine oil change intervals. No critical fuel/oil dilution has been detected.

Fuels like B10 and B15 TME are not likely to damage factory mounted or retrofit exhaust after treatment equipment.

Power and torque can be expected to drop consistently with volumetric energy content in the fuels. This was not noticed by most drivers. Laboratory tests indicated a slight improvement of engine thermal efficiency. Emissions of CO, HC and PM decreased while NO_X was slightly increased.

The cost of TME is not the only cost issue. Also to be considered is the cost of extra service, base diesel price and fuel logistics. A surplus consumption due to lower volumetric energy content may also be expected.

Approval of new tank installations is a time consuming process. The two pilot projects that for the past year have worked with centralized admixture have spent seven and ten months respectively on the design and completion of the mixing plants.

Special requirements on equipment, pumps, gaskets, coating etc. are often the result of rubber materials that lack compatibility with B100 biodiesel. The problem is not so predominant for concentrations below B30 and can therefore often be neglected in the vehicle when using a lower admixture. However, the mixing plants that are in contact with B100 must have the appropriate hose and gasket material.

For biodiesel it is particularly important to consider the storage and mixing temperatures, which for tallow biodiesel in particular is, a critical parameter. Therefore, it is even more important that the mixing takes place under controlled conditions. On the other hand the ready-mixed B10 or B15 will be rather unproblematic to transport – also by ship if needed.

B3 Situation before CIVITAS

The first demonstration projects using 2nd generation bio fuels were initiated in 2008 with a new product manufactured from slaughterhouse fat waste. In parallel to this, the CIVITAS ARCHIMEDES measure was developed to take the experiences even further on a larger scale.

Compliance with EURO IV was required at the latest tender for bus services in Aalborg, but operation is on standard diesel as bio-diesel is not currently part of government policy and thus not available on the Danish market.

In regards to tourists, they have not specifically been catered for by the current public transport system in Aalborg.

B4 Actual implementation of the measure

The measure has been implemented in the following stages:

Stage 1: Study in 1st and 2nd generation biodiesel. (September 2008 – September 2009) – Danish Technological Institute has carried out this study as a sub-contract to the project.

Stage 2: Tendering stage (January 2009 – December 2009) – The next tender for bus operation was written and was evaluated from January 2009 to December 2009. The tender made it possible to require buses to use bio-fuels during the ARCHIMEDES project.

Stage 3: Infrastructure development – (April 2009 - September 2010) in cooperation with stakeholders, the infrastructure and the bio-diesel were developed and implemented. This stage

included: organisation of stakeholders, positioning of stations, development of bio-fuel product to be used and mounting of bio-fuel stations.

Stage 4: Operation of bio fuelled vehicles. (October 2010 – September 2012) – Bus operators and national postal service operated their fleets on the agreed blend of bio-diesel. The buses started operating on 10 % bio-diesel 1st of October 2010, and the Danish Mail started operating on Bio-diesel (10, 15 and 20 %) from 1st of April 2011.

Stage 5: Planning of shuttle bus – (November 2009 – May 2010) The City of Aalborg and NT specified the shuttle bus route in order to operate the shuttle bus from M20. The route for 2011 was changed slightly compared with the route in 2010 due to evaluation of the first season. In 2012 the bus route was the same as in 2011.

Stage 6: Operation of shuttle bus – (May 2010 – August 2012) The City of Aalborg and NT operated the shuttle bus in the summer months during 2010, 2011 and 2012.

B5 Inter-relationships with other measures

The measure is related to other measures as follows:

Measure no. 52 City Bike Scheme in Aalborg – Many stops on the Clean Fuelled Tourism Shuttle Bus route are located near city bike scheme stations (as described in Measure 52) to provide an eco-friendly transport system covering the central area of the city within the CIVITAS corridor.

Measure no. 63 Efficient Goods Distribution in Aalborg The partnership of stakeholders in this measure is also linked to the environmental zone as some of the stakeholders are the same.

C Planning of Impact Evaluation

C1 Measurement methodology

C1.1 Impacts and indicators

C1.1.0 Scope of the impact

The high level / long-term objective are to reduce pollution in the city of Aalborg. The pollution level is measured through indicators describing the level of emissions from each involved vehicle of CO_2, CO, NO_x and Particulate emissions. Since, the demonstrating fleets are relatively small it will be difficult to use indicators concerning air quality. However as part of measure 63 – environmental zone in Aalborg, air quality modelling has been carried out based on one measurement in the City Centre.

On the strategic level, the objectives are to gain more passengers to public transport by improving the image of public transport. During the last decade public transport has experienced a decrease in the number of passengers. This measure will implement technologies, which potentially will lead to an improved image of public transport. Awareness and acceptance of the implemented technologies such as the shuttle bus and the bio-fuelled busses will be measured and so will the number of bus passengers before and after the implementation (For results concerning number of passengers please refer to Appendix A ACRHIMEDES corridor - Number of passengers).

C1.1.1 Selection of indicators

NO.	EVALUATION CATEGORY	EVALUATION SUB-CATEGORY	IMPACT	INDICATOR	DESCRIPTION	DATA /UNITS
	ECONOMY					
		Benefits	Company Image Improvements	Image Value	Improvement in company image due to the implementation of bio-fuels	Euros, quantitative, estimated
1			Operating Revenues	Operating revenues	Revenues per pkm	Euros/pkm, quantitative, derived or measurement
2a		**Costs**	Operating Costs	Operating costs	Costs per pkm	Euros/pkm, quantitative, derived or measurement

NO.	EVALUATION CATEGORY	EVALUATION SUB-CATEGORY	IMPACT	INDICATOR	DESCRIPTION	DATA /UNITS
2b			Capital Costs	Capital costs	Project costs	Euros, quantitative, derived or measurement
2c			Maintenance costs	Maintenance costs	Costs for maintenance in project period	Euros, quantitative, derived or measurement
	ENERGY					
3		**Energy Consumption**	Fuel Consumption	Vehicle fuel efficiency	Fuel used per vkm, per vehicle type	G/kWh, quantitative, derived or measurement
4				Fuel mix	Percentage of fuel used by type	Percentage, quantitative, derived or measurement
	ENVIRONMENT					
8			Emissions	CO2 emissions	CO2 per vkm by type	G/kWh, quantitative, derived
9				CO emissions	CO per vkm by type	G/kWh, quantitative, derived
10				NOx emissions	NOx per vkm by type	G/kWh, quantitative, derived
11				Particulate emissions	PM10 and/or PM2.5 per vkm by type	G/kWh, quantitative, derived
	SOCIETY					
13		**Acceptance**	Awareness	Awareness level	Awareness of the policies/measures	Index (%), qualitative, collected, survey
14			Acceptance	Acceptance level	Acceptance of the policies/measures	Index (%), qualitative, collected, survey
	TRANSPORT					
			Occupancy	Number of passengers	Number of passengers on specific bus routes	Number

Indicators 1, 2a, 2b, 2c: The cost benefit analysis is based on measure implementation, hence, there will not be made any cost/benefit analysis as part of the baseline data collection.

C1.1.2 Methods for evaluation of indicators

No.	INDICATOR	TARGET VALUE	Source of data and methods	Frequency of Data Collection
	Image Value		The image value has not be quantified in .this evaluation. How the demonstration projects have a long term corporative level impact has been described.	Summer 2012
1	Operating revenues		Financial accounts from bus operator with revenues for increased number of passengers (PT only)	Annually 2009-2011
2a	Operating costs		Financial accounts from bus operator or postal service with operating costs related to more expensive fuels	Annually 2009-2011
2b	Capital costs		Financial accounts from public transport authority on increased costs for using bio-fuels including construction of new fuelling stations for bio-fuels or postal service with costs related to investment in bio-fuelling infrastructure and capacity.	Annually 2009-2011
2c	Maintenance costs		Financial accounts from bus operator or postal service with costs related to more frequent service of vehicles.	Annually 2009-2011
3	Vehicle fuel efficiency		To determine the fuel efficiency and the impact from the use of bio diesel, it has been chosen to get the data through vehicle measurements.	Through measurements
8	CO2 emissions	315 tonnes CO2 saved annually	The emissions from the vehicles have been calculated based on vehicle performances along with concrete measurements on a few vehicles in the demonstration project.	Data collected from 2010 and onwards
9	CO emissions	Reduced C O emissions	The emissions from the vehicles have beencalculated based on vehicle performances along with concrete measurements on a few vehicles in the demonstration project.	Data collected from 2010 and onwards
10	NOx emissions	Reduced NOx emissions	The emissions from the vehicles have beencalculated based on vehicle performances along with concrete measurements on a few vehicles in the demonstration project.	Data collected from 2010 and onwards
11	Particulate emissions	Reduced particular emissions	The emissions from the vehicles have beencalculated based on vehicle performances and product specifications along with concrete measurements on a few vehicles in the demonstration project.	Data collected from 2010 and modelled in spring 2012
13	Awareness level	Increased knowledge of the use and concept of	Interviews or questionnaires on shuttle bus campaign and bio-fuels. The questionnaire survey has been carried out in the shuttle bus. In 2010 100	Summer 2011

No.	INDICATOR	TARGET VALUE	Source of data and methods	Frequency of Data Collection
		bio-fuels	passengers participated and in 2011 232 passengers participated. The survey was conducted through handout of paper questionnaires.	
14	Acceptance level	Increased acceptance of the use and concept of bio-fuels	Acceptance level is based on feedback from drivers and media coverage.	Summer 2011
	Number of passengers	7,500 - 15,000 passengers using the shuttle bus line pr. year	Manual bus passenger counts on the shuttle bus route. The bus driver counted each passenger entering the bus with a manual counter and registered the number of passengers per hour.	Annual bus passenger counts in the shuttle bus 2010 and 2011

C1.1.3 Planning of before and after data collection

EVALUATION TASK	INDICATORS INVOLVED	COMPLETED BY (DATE)	RESPONSIBLE ORGANISATION AND PERSON
Analysis of financial accounts from bus operators or postal service. The accounts will be traced 2 years back in time to provide baseline data.	1, 2a, 2b, 2c	M20, M32, M44	Aalborg, Gustav Friis NT, Finn Larsen
Collection of vehicle performance data from selected vehicles in the measure.	3, 4, 8, 9, 10, 11	Continuously from M14 to M42	Aalborg, Gustav Friis
Quantitative Survey to identify awareness and acceptance towards shuttle bus service campaign and use of bio-fuels	13, 14	Month 36	Aalborg, Gustav Friis
Licence plate registration in M3 and M26 will be the basis of modelling emissions using the TEMA2000 model.	25	M3 and M26	Aalborg, Gustav Friis
Manual passenger count in the shuttle bus		M22-24 and M34-36	Aalborg, Gustav Friis
D12.2 Baseline and first results from data collection	All indicators	Month 36	Aalborg, Gustav Friis
D12.3 Draft results template available	All indicators	Month 42	Aalborg, Gustav Friis
D12.4 Final version of results template available	All indicators	Month 49	Aalborg, Gustav Friis

C1.2 Establishing a baseline

The baseline of this measure, where applicable, is the result of the tests on vehicle performance performed by Danish Technological Institute on three vehicles, which afterwards started operating on bio-diesel. The baseline data covers vehicle performance, and emissions from the vehicle. The test is described in detail below as well as the results prior to the trial.

With regards to the other indicators involved, no baseline data has been collected as already foreseen in the evaluation plan.

C1.3 Method for Business as usual scenario

The business as usual scenario contains more energy efficient vehicles, but no change towards using bio-fuels in vehicles.

The trend towards cleaner vehicle technology has been taken into account by the evaluation of the environmental zone (measure 63) in which a number plate registration has been carried out in 2005, 2008 and 2010 to determine the development in vehicle technologies.

The registrations of license plates coupled to the Motor Registry were conducted in 2005, 2008 and 2010. The Motor Registry includes data to determine the emission category (Euro emission standard) of each vehicle.

The purpose of the license plate registration in December 2010 was to investigate and analyse vehicle composition 1.5 years after the environmental zone in Aalborg was introduced and the new requirements in the environmental zone have been a reality for 4 months.

The analysis is then compared with a similar analysis conducted in autumn 2008, shortly before the introduction of the LEZ as well a feasibility study from 2005.

The next step was to link the license plate data to the Central Motor Registry (CMR). This showed that between 82% and 93% of the entering vehicles are diesel driven and thus subject for the LEZ. The share of diesel vehicles is very similar to the share in 2008.

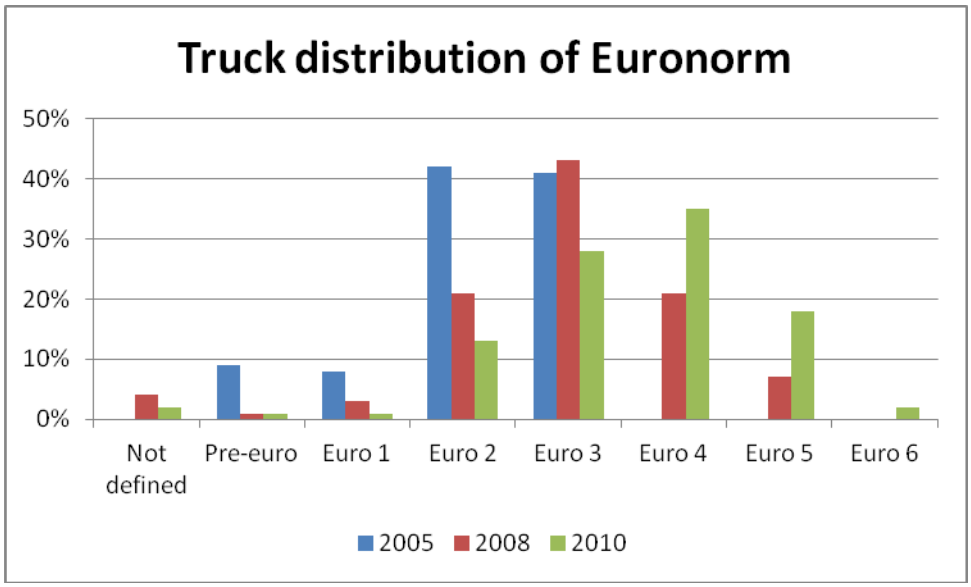

Figure 1: Truck distribution of Euro norm

Figure 1 above shows the percentage distribution of the Euro-norm, and thus reflects trends in vehicle age from 2005, 2008 and 2010.

A total of 215 trucks representing 45% of the trucks that were registered in the environmental zone do not comply with Euro IV standard in 2010. This does not mean that the vehicles do not comply with the requirements of the environmental zone, as vehicles retrofitted with particulate traps also are compliant. It is not possible to get information on whether the vehicle has a particulate filter from the CMR.

The share of trucks with Euro IV or better increased from 28% in 2008 to 54% in 2010. The trucks with engine standard Euro II or earlier have been reduced from 26% to 15%. There has been a replacement of both Euro II and Euro III vehicles. Euro II vehicles are having an age where they are normally replaced rather soon. The registered trucks are on average 6 years old. According to Statistics Denmark, the average age for the entire car park in Denmark in 2010, is 8.2 year for trucks. The average age of the Danish fleet in recent years remained fairly stable.

Age composition of vehicles operating in the environmental zone in Aalborg is significantly lower than the composition of Denmark as a whole. We also see to special trucks and buses are considerably younger than the national level. This supports the conclusions that the LEZ requirements have helped to stimulate a trend towards the purchase of newer vehicles.

However, vehicles can also meet the LEZ requirements by having mounted particle filters, which are not registered in the CMR.

The business as usual scenario hence provide that vehicles will be more cleaner and more efficient over time as concluded in the evaluation report for measure 63: Environmental zone in Aalborg. In terms of the cost indicators, this will not have any effect compared to the baseline. In terms of emissions the business as usual scenario will not be applicable, since vehicles tested before and after are the same (and by this the business as usual scenario has been bypassed to see the exact results of the use of bio-diesel). On a higher level, the effect of the low emission zone, resulting in newer and less polluting vehicles can be added to the results of the bio-diesel demonstration.

C2 Measure results

C2.1 Economy

The CBA and economic impact analysis is carried out based on the implemented measure. The economic impact is concerning implementation of bio-diesel in buses only.

The baseline for this measure is operation of the buses on pure diesel. Evaluation of the costs and benefits from changing fuel from pure diesel to a 10% blend of bio-diesel are the extra costs in regards to establishment of fuelling facilities, higher costs of the bio-diesel product compared to pure diesel and higher maintenance costs, meaning that the change in technology leads to a more careful examination of the engines.

In terms of benefits it is the saved emissions of CO_2 by substituting fossil fuel diesel with bio-diesel. This means that we have CO_2 emissions before, and fewer emissions after. The benefit is the costs of the reduced amount of emissions[2].

The key impacts of the project are:

1. Capital costs of the facilities
2. Operation costs of the facilities
3. Benefits from reduced emissions
4. Image value

Concerning bullet 2, operation costs (which comprise additional costs from using biodiesel), were initially estimated to €215,000 per year, but after the end of the project, they are estimated to decrease. The additional costs from using biodiesel are estimated to decrease from €0.13 to €0.05 per litre. In this CBA this decrease to approximately €85,000 has been introduced as of 2013.

The capital costs of 54,000 € is concerning the establishment of fuelling facilities for bio-diesel in buses.

Table C2.1.1: Costs for implementing Bio-diesel (10%) in 50 city buses in Aalborg

Indicator	Before Prior 2008	B-a-U (date)	After 2011	Difference: After –Before	Difference: After – B-a-U
1 Operating revenues	Baseline (0 €)	n/a	n/a	n/a	n/a
2a Operating costs	Baseline (0 €)	n/a	215,000 € pr. year	+ 215,000 € pr. year	n/a
2b Capital costs	Baseline (0 €)	n/a	54,000 €	+ 54,000 €	n/a
2c Maintenance costs	Baseline (0 €)	n/a	Included in the operating costs	n/a	n/a

[2] Only CO_2 emissions are taken into account. Based on measurements other pollutants are not significantly reduced by using the bio-diesel blend. This is further described in section C2.3 Environment.

C2.2 Energy

The Danish Technological Institute has performed Stationary Chassis Dynamometer Test on three vehicles, one Danish mail delivery van and two buses.

The vehicles were examined on an AHS ELP 500 A/D chassis dynamometer.

The test procedure was a simplified 88/77/EEC procedure known as a 5-mode test. Similar to 88/77/EEC, the result of the test is obtained as a weighted average of the 5 modes, only with different weighing factors.

Measurements included engine output, specific fuel consumption, CO, NO, NO_2, HC and PM were first made with ULSD (Statoil EuroDiesel10®) for reference, and then repeated after 16 months running on biodiesel blend.

Table 2.2.1: Selected modes and weighing factors

Mode	Weight	Load	Speed
1	25%	0%	Idle
3	16%	25%	Max. torque
4	16%	50%	Max. torque
6	25%	100%	Max. torque
8	18%	100%	Max. power

The 5-mode method has previously been shown to give similar results to 88/77/EEC (Hansen, Ken Friis; Ezerman, Niels; "Verifikation af rullefeltsmålinger (Verification of chassis dynamometer measurements)"; Danish Technological Institute, September 30th 1992; File no. 140 2 4224; For the Danish Ministry of Road Traffic 8th office; Journal no. 92-817241-006). However it was not the purpose of the study to produce results directly comparable with 88/77/EEC. The purpose was to detect any positive or negative changes in the emissions or performance of the vehicles as a result of running on bio diesel.

Figure 2: The tested vehicles in the 5-mode test.

The Ford Transit was a 2.2 litre Euro IV turbo diesel with 85 BHP. It has no particle filter or NOx reducing catalyst on board. The air emissions per kWh are relatively high for this type of vehicle.

The Volvo is a Euro III type B10BLE bus with a DH10B engine. It is equipped with a retrofit diesel particulate filter to comply with local particle mass reduction requirements. With correct maintenance of the filter it can be assumed that the particle mass emission is below 20 % of engine-out level and the number of emissions is at Euro VI level.

The Scania is a EURO IV / EEV Omnilink with a DC9-29 engine. It has no particulate filter, but still fulfils the EURO IV and EEV requirements on particle mass emission. The particle number emission, however, is unknown.

Table C2.2.2: Fuel consumption for the three vehicles performing the test

Indicator	Before 2010	B-a-U 2012	After 2012	Difference: After –Before	Difference: After – B-a-U
3 Vehicle fuel consumption – **Ford**	217 g/kWh	217 g/kWh	205 g/kWh	-5.5%	-5.5%
3 Vehicle fuel consumption – **Volvo**	220 g/kWh	220 g/kWh	216 g/kWh	-1,8%	-1,8%
3 Vehicle fuel consumption – **Scania**	239 g/kWh	239 g/kWh	243 g/kWh	+1,7%	+1,7%
4 Fuel mix	0 %	0 %	10 %	+10 %	+10 %

The measurements indicate that the fuel consumption has decreased for the Ford whereas the picture is unclear for the buses, respectively increasing fuel consumption and decreasing fuel consumption. It is not possible to draw conclusions on the whole fleet for this.

The bus operators have explained that they cannot see any changes in fuel consumption on the road and that many other factors are more important in terms of fuel consumption than the use of bio-diesel.

C2.3 Environment

The fuel consumption has been registered for vans and trucks for the Danish Postal Service and for the 50 buses included in the trial.

Table 2.3.1: Fuel consumption in the demonstration project and CO_2 savings.

Fuel consumption	Fuel mix				
	B0	B5	B10	B15	B20
Truck	0	0	0	155,441	0
Bus	0	65,070	3,274,557	3,024	65,824
Van	0	0	0	46,335	0
Fuel consumption	Pure bio diesel consumption				
Truck	0	0	0	23,316	0
Bus	0	3,254	327,456	454	9,874
Van	0	0	0	6,950	0
	Kg of CO_2 saved				
Truck	0	0	0	62,954	0
Bus	0	8,784	884,130	1,225	26,659
Van	0	0	0	18,766	0
Total	**0**	**8,784**	**884,130**	**82,944**	**26,659**

For the postal service, the consummation has been registered, and been distributed to an average of B15. As described above, the postal service vehicles have been operating on 10%, 15% and 20% depending on the time of year. This leads to an average of 15% over the year.

The registered fuel consumption is transformed into consumption of pure bio-diesel. This sub-result shows that in the demonstration period, a total of 371,000 litres of pure bio-diesel has been used. In other words, the demonstration has saved the equal amount of fossil fuels. Calculated into carbon dioxide, the demonstration has saved 1,000 tonnes of CO_2.[3]

The calculation behind this is that for each litre of fossil diesel 2.7 kilos of CO_2 are emitted. Using a (close to) carbon dioxide neutral product, this means that for each litre used, 2.7 kilos of CO_2 have been saved.

[3] The bus operators have explained that they cannot see any changes in fuel consumption on the road and that many other factors are more important in terms of fuel consumption than the use of bio-diesel. Therefore the consumption of bio-diesel is the considered the same as ordinary diesel.

The chassis dynamometer measurements were supplemented by an ON ROAD METHOD known as the periodic emissions inspection (DA: Miljoesyn).

The vehicles were periodically inspected by means of a portable field measuring system (Figure 3) consisting of a 5-gas-analyzer Bosch BEA Mobile (CO, HC, CO_2, O_2, NO), opacimeter[4] (Bosch Opacimeter RTM 430) and a hand held pressure gauge (Ametek PPC 15 bar) for measuring the backpressure upstream of the filter if present. The system is specially designed for on road measurements.

The measurements were done at full engine load during full acceleration of the vehicle on a plane surface.

Emissions were measured downstream of any emission abatement system, such as filter etc.

Figure 3: Mobile testing equipment. Left picture shows 5-gas analyser with battery box and PC. Right picture shows the opacimeter with sample tubes directed through the cabin floor to the exhaust.

The accelerations were repeated until stable results. The result value is the maximum instantaneous value read during the acceleration. The stated values are averages of 3 such maximum values.

[4] Opacitet: flue gas darkness (soot and other particulate content) measured by means of light penetration

The cars inspected are listed in Table 2.3.2.

Table 2.3.2 Periodically inspected vehicles

Owner	Model	Nr
Arriva	Scania Omnilink	3051
	Scania Omnilink	4428
	Volvo B12 BLE	8482
City-Trafik	VDL Jonckheere	2467
	VDL Jonckheere	2468
	VDL Jonckheere	2469
Post Danmark	Ford Transit 300 M	713779
	Ford Transit 330 L	716011
	Ford Transit 350 M	713045
	Opel Movano6G	717780

As shown in Figures 4-5 the periodic measurements seem quite stable but with some uncertainty. Therefore, it cannot clearly be concluded from these measurements if the emissions have actually increased or decreased. The chassis dyno results are much more accurate in that respect.

On the chassis dynamometer values were obtained from the 5-mode test as mentioned in Section C2.2 Energy. Results from the periodic inspections are summarized below.

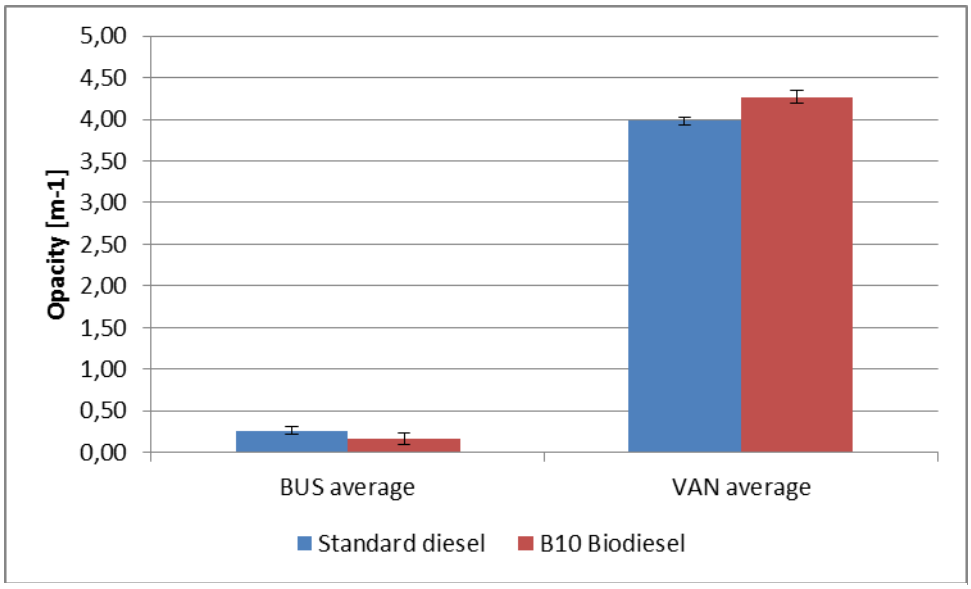

Figure 4: Opacity measured in periodic inspections

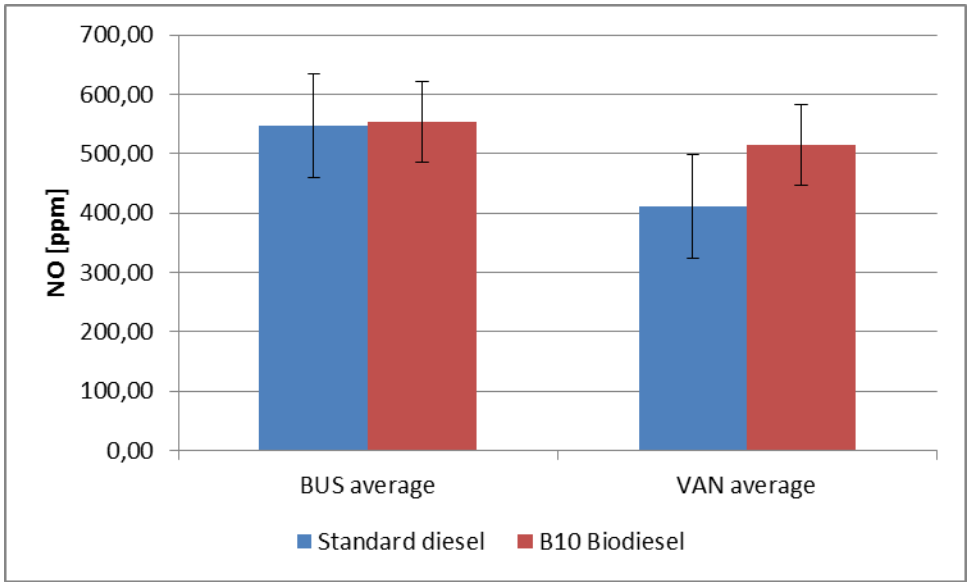

Figure 5: Flue gas NO measured in periodic inspections

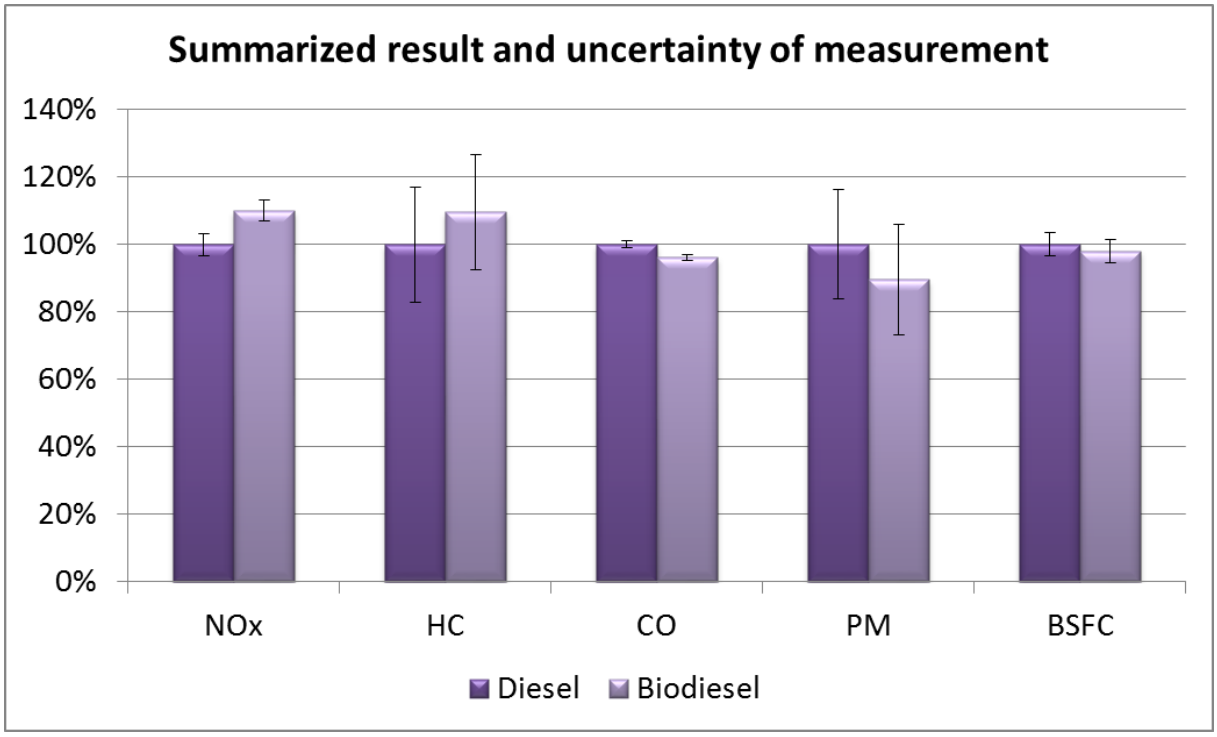

Figure 6: Summarized chassis dyno results

The uncertainty for each parameter of the 5-mode test was obtained from a Type B evaluation according to ISO-GUM. Type B evaluations are based on aggregation of all known tolerances of each instrument used in the test. The combined uncertainty for the group of three vehicles tested was also evaluated according to ISO-GUM assuming constant parameter uncertainty. This accounts for the fact

that the combined uncertainty of three tests is less than the uncertainty of each single test. A standard coverage factor of k=2 was used in all uncertainty evaluations.

Since, the three vehicles do not constitute a representative sample of all vehicles in the region, the stated uncertainties should not be interpreted as a confidence interval for all vehicles. The uncertainties only cover the ability of the laboratory to determine the mean of a given sample.

In the diagram above the overall change is shown along with the combined uncertainty of before- and after-measurements. *Only when the before-after change is larger than uncertainty the result is considered to be significant.*

There is a slight indication of increased NOx and a tendency to reduced CO, which is in line with most previous studies. At the same time there is a small reduction in PM and Fuel Consumption (BSFC). However, these differences are too small to be significant. The change in HC is also too small to be significant.

The conclusion is therefore that emissions are practically unchanged. Further details are attached as Appendix A (Measure 1) – 5-Mode Test Data Sheets.

Table C2.3.1: Summarisation of changes in Emissions between standard diesel and bio-diesel from the measurements carried out on selected vehicles.

Indicator	Before 2010	B-a-U (-)	After (2012)	Difference: After –Before	Difference: After – B-a-U
8: CO2 emissions	-	-	- 1,003 tonnes	-	-
9: CO emissions **Ford**	1.47 g/kWh	1.47 g/kWh	0.67 g/kWh	-55%	-55%
9: CO emissions **Volvo**	0.28 g/kWh	0.28 g/kWh	0.47 g/kWh	+66%	+66%
9: CO emissions **Scania**	0.35 g/kWh	0.35 g/kWh	0.27 g/kWh	-24%	-24%
10: NOx emissions **Ford**	10.65 g/kWh	10.65 g/kWh	9.54 g/kWh	-10%	-10%
10: NOx emissions **Volvo**	8.47 g/kWh	8.47 g/kWh	7.34 g/kWh	-13%	-13%
10: NOx emissions **Scania**	1.87 g/kWh	1.87 g/kWh	2.87 g/kWh	+54%	+54%
11: Particulate emissions **Ford**	0.17 g/kWh	0.17 g/kWh	0.22 g/kWh	+31%	+31%
11: Particulate emissions **Volvo**	0.04 g/kWh	0.04 g/kWh	0.03 g/kWh	-5%	-5%
11: Particulate emissions **Scania**	0.06 g/kWh	0.06 g/kWh	0.02 g/kWh	-57%	-57%

C2.4 Transport

Table C2.4.1:

These results are the results of the counts made in the shuttle bus. The number of passengers has been counted in 2010 and 2011. The objective was to have between 7,500 and 15,000 passengers during the eight weeks the bus is operating. Both years just about 10,000 passengers were counted.

Indicator	Before before 2010	B-a-U	After	Difference: After –Before	Difference: After – B-a-U
Occupancy 2010	0	0	10,000[5]	10,000	10,000
Occupancy 2011	10,000	10,000	10,172	172	172

C2.5 Society

2.5.1 Shuttle bus awareness

To emphasise that Aalborg is working with alternative fuels and clean vehicles, a show case shuttle bus has been operating for three summer seasons during the ARCHIMEDES project. The objective of this show case has been to broaden this message. Two surveys among the passengers have been carried out in the shuttle bus in 2010 and 2011 to determine which audience the message has been delivered and to determine whether the clean technology is in the passengers' awareness.

In 2010, 100 respondents were participating in the survey, which was a paper questionnaire in the bus, and in 2011, 232 respondents were participating. In 2010 the survey was conducted at the end of the period (medio August) whereas it in 2011 was conducted over the full season, from 1st July to medio August.

In 2010, 64 % of the respondents stated that they are living or working in Aalborg. This number has decreased in 2011 to 51 %. 23 % of the passengers were tourists in 2010, while this number was 28 % in 2011. The remaining respondents have given other purposes for their stay in Aalborg.

Each day both years, between 10am and 14pm, there were a host on board the shuttle bus. The host would inform about the city and also about the technology used in the bus. Information about green bus technology has reached both visitors and inhabitants of the city both years. In 2010, 18 out of 100 respondents state that one of the reasons to try the shuttle bus was to try to travel by a hybrid bus. This reason is mostly mentioned by people living or working in the city. For tourists the main reason for using the bus was to see the city, while the inhabitants used the bus to get around the city.

In 2011, 17 out of 232 respondents stated that one of the reasons for going with the bus was to try it. The bus in 2011 was an ordinary diesel bus, and if you didn't know that it was using 30 % bio-diesel, you couldn't tell. That people were more aware that they were driving in a hybrid bus in 2010 is therefore explainable. In 2010, 5 out of 100 appreciated that the bus is silent (when switching to electrical power) and 9 state that the bus is a good choice as what they appreciate. This indicates that some people are appreciating the new technology. In 2011, 11 out of the 232 respondents state that the environment friendly issue was something that they appreciated during the trip. 3 hybrid buses were later put in regular service in Aalborg.

No negative feedback has been given for the route in the questionnaires. In 2010, people were encouraged to come up with good ideas for the route, and the suggestions were used to improve the route in 2011. In 2012 the same route was used as in 2011.

[5] Some numbers were missing in the count, and the number is build on estimation from the existing numbers.

2.5.2 Bio-diesel tasks awareness

To create awareness of the demonstration tasks, bread rolls were handed out along with information flyers about the bus trials to passengers the day the demonstration started. This was followed up by information at the entrance of every bus operating on bio-diesel and information about the trial on the bus monitors. At the beginning of the trial, posters in the city were informing that the buses were beginning to operate on bio-diesel.

In April 2011 a competition was launched on the bus monitors. The participants had to answer the right bio-diesel blend that the buses are using. The options were 10 % and 100%. More than 150 people participated in the competition and only very few (<5) answered the question wrong.

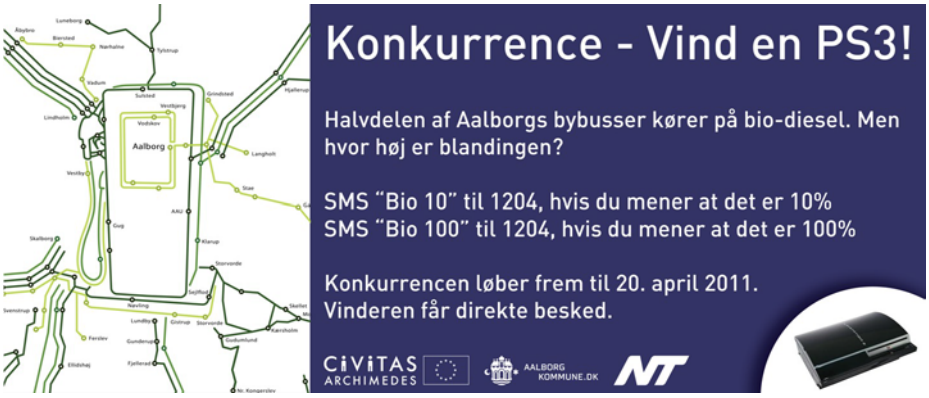

Figure 7: Awareness raising competition in the buses

At the launch of the bio-diesel trial at Post Danmark (Postal Service), main stakeholders, including people from different units in Post Danmark were invited to get information about the trial. Their job was to tell the drivers about the trial in order to get their acceptance.

2.5.3 Environmental targets

Post Danmark has set up ambitious environmental objectives, and aims at reducing the emissions of carbon dioxide in 2020 by 40% compared to 2009. One step to reach this is to test bio-diesel in the ARCHIMEDES project. According to the webpage of PostNord (owner of Post Danmark), one of the measures to ensure the objective is to have a greater proportion of biofuel consumption.

The reason for joining the project for Post Danmark is hence more to meet the environmental objectives, rather than generate a local image value. By fulfilling the corporative objectives PostNord (and Post Danmark) wants to be the environmentally right choice for customers. On the long term, this measure can, with other initiatives, improve the image of the company. However at this point, it cannot be assessed. It has not been finally determined whether Post Danmark will continue the project, but it is most likely that the project will end with the ARCHIMEDES project in December 2012. This indicates that the value gained on the project (at least at the local level) does not counterbalance the extra costs that Post Danmark will have to pay for the bio-diesel to continue the project.

The external image value towards the customers has not been a focus, however, in co-operation with other sustainable measures to reduce the carbon dioxide emissions from transport, the company will improve its environment profile to attract more customers on the long run.

The Public Transport Authority has a long term objective for CO2 emission reduction on 60% in 2050. In the Public Transport plan 2013-2016, a range of measures have been included, including bio-diesel, but another way of reducing the carbon dioxide emission from transport is also to have more passengers on public transport instead of in the cars. Getting more passengers does not necessarily have anything to do with a green image. In a focus group interview, performed in March 2009, the users state that the environmental benefits from more people using public transport is a spin-off-benefit rather than a real reason for using public transport. To get more people to take the bus, other measures than bio-diesel will be more effective – also in terms of added image value.

In the Public Transport Plan, calculations on the costs from reducing CO_2 are included. Reduced fuel consumption in the buses reduces the costs for operating, whereas introducing hybrid buses and using bio-diesel will increase the costs for reducing CO_2. Since the Public Transport department in Aalborg has decided not to continue using bio-diesel after the end of the ARCHIMEDES project, it is indicated, that the image value from using bio-diesel does not counterbalance the extra costs used for bio-diesel.

2.5.4 Acceptance

There are two aspects within this indicator:

1. Driver's acceptance of a new diesel product. In terms of this, no negative feedback has reached the municipality. At meetings in the working group with the postal service, it has been mentioned that the drivers are satisfied with the product and that it would be raised as an issue if they were not. This has not been done within the project.
2. Public acceptance of the product. Some previous trials of bio-diesel have had the public against it, because they were using first generation bio-fuels. In this demonstration project, a second generation bio-diesel product has been used. When the projects (bus and postal cars) were started up, press releases were also submitted. Local press has had interest in this, but only positive stories have been written.

To read more about the media coverage for these projects, please read the technical deliverables: T1.1 T1.3 and T1.2 T1.3.

C2.6 Cost benefit analysis

The following conducts a cost benefit analysis (CBA) of the project Biofuels in Aalborg as it is described above. The overall objective of this CBA is to evaluate costs and benefits of the projects and be able to indicate whether the investment that is made into this project results in satisfactory returns.

C2.6.1 Evaluation period for CBA

In order to evaluate the project its key impacts have been compared to a "before" scenario, since this project Biofuels is the first of its kind in Aalborg.

Project life is estimated to 15 years corresponding to the expected life time of the fuelling facilities purchased for the demonstration project.

The European Commission (EC) suggests that non-cohesion countries apply a social discount rate (SDR) of 3.5 %. Furthermore the base year for discounting, and the price base, will be set to 2008. Finally, an exchange rate of 750 DKK/EUR is applied when relevant, all externalities are discounted using a GDP deflator and all other prices are discounted using the consumer price index (CPI).

C2.6.2 Method and values for monetarisation

As described above the key impacts of the project are:

1. Capital costs of the facilities
2. Operation costs of the facilities
3. Benefits from reduced emissions
4. Image value

Concerning bullet 2, operation costs (which comprise additional costs from using biodiesel), were initially estimated to €215,000 per year, but after the end of the project, they are estimated to decrease. The additional costs from using biodiesel are estimated to decrease from €0.13 to €0.05 per litre. In this CBA this decrease to approximately €85,000 has been introduced as of 2013.

With regards to bullet 3, the available data concerns CO_2 reductions. The benefit from reducing CO_2 is best estimated using the price of CO_2 quotas, which at present is €15.3 per tonne CO_2.

C2.6.3 Life time cost and benefit

Table C2.6.1 illustrates the timing of capital costs of the project:

Table C2.6.1 Capital cost in the evaluation period (not discounted)

	Cases for comparison	Cost
2011	CIVITAS measure	-€54,000
	Reference case (or BAU)	€0
2012	CIVITAS measure	€0
	Reference case (or BAU)	€0
2013	CIVITAS measure	€0
	Reference case (or BAU)	€0
2014	CIVITAS measure	€0
	Reference case (or BAU)	€0
2015	CIVITAS measure	€0
	Reference case (or BAU)	€0
2016	CIVITAS measure	€0
	Reference case (or BAU)	€0
2017	CIVITAS measure	€0

	Reference case (or BAU)	€0
2018	CIVITAS measure	€0
	Reference case (or BAU)	€0
2019	CIVITAS measure	€0
	Reference case (or BAU)	€0
2020	CIVITAS measure	€0
	Reference case (or BAU)	€0
2021	CIVITAS measure	€0
	Reference case (or BAU)	€0
2022	CIVITAS measure	€0
	Reference case (or BAU)	€0
2023	CIVITAS measure	€0
	Reference case (or BAU)	€0
2024	CIVITAS measure	€0
	Reference case (or BAU)	€0
2025	CIVITAS measure	€0
	Reference case (or BAU)	€0

As it is seen from the table above the capital costs that are directly linked to the project Biofuels in Aalborg accumulate to €54,000. These costs cover the following:

1. Deployment of facilities

Table C2.6.2 below illustrates the timing and magnitude of the maintenance costs required to keep the project Biofuels running:

Table C2.6.2 Operation cost in the evaluation period (not discounted)

	Cases for comparison	Values
2011	CIVITAS measure	-€215,000
	Reference case (or BAU)	€0
2012	CIVITAS measure	-€215,000
	Reference case (or BAU)	€0
2013	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2014	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0

2015	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2016	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2017	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2018	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2019	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2020	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2021	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2022	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2023	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2024	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0
2025	CIVITAS measure	-€85,149
	Reference case (or BAU)	€0

It is seen that operation costs amount to €215,000 in the years 2011 and 2012 and €85,149 in the subsequent years of the project. These costs cover:

1. Additional costs from using biodiesel.

Table C2.6.3 in the following shows timing of the realisation of the monetarised value of reducing CO_2 through the project Biofuels:

Table C2.6.3 Value of CO_2 reductions in the evaluation period (not discounted)

	Cases for comparison	Values
2011	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2012	CIVITAS measure	€6,440

	Reference case (or BAU)	€0
2013	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2014	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2015	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2016	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2017	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2018	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2019	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2020	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2021	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2022	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2023	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2024	CIVITAS measure	€6,440
	Reference case (or BAU)	€0
2025	CIVITAS measure	€6,440
	Reference case (or BAU)	€0

The project Biofuels results in an annual reduction of 420 tonnes of CO_2 at a value of €15.3 per tonne. The result is a monetarised benefit of €6,440 per year.[6]

[6] The reduction of 420 tonnes of CO_2 used for the calcultation is the savings in the first year of the demonstration project.The total reduction for the buses is around 890 tonnes over two years (table 2.3.1). This indicates that the calculation may be conservative.

C2.6.4 Compare the lifetime costs and benefits

There are three measurable key impacts from the project Biofuels in Aalborg; capital costs, maintenance costs and value of reduced CO_2 emission. Capital costs are only incurred in the project's first year, whereas the benefits and operation costs are incurred in every year of the project. From an economic perspective there is a disadvantageous relationship between investments, operation costs and benefits.

Table C2.6.4 Lifetime cost/benefit of CIVITAS measure (discounted)

	Capital cost	Operation cost	Benefits	Total cost	Total Benefit	Cumulated cost
2011	-€52,174	-€207,729	€6,222	-€259,903	€6,222	
2012	€0	-€200,705	€6,012	-€200,705	€6,012	-€253,681
2013	€0	-€76,799	€5,809	-€76,799	€5,809	-€448,374
2014	€0	-€74,202	€5,612	-€74,202	€5,612	-€519,365
2015	€0	-€71,693	€5,422	-€71,693	€5,422	-€587,955
2016	€0	-€69,268	€5,239	-€69,268	€5,239	-€654,225
2017	€0	-€66,926	€5,062	-€66,926	€5,062	-€718,255
2018	€0	-€64,663	€4,891	-€64,663	€4,891	-€780,119
2019	€0	-€62,476	€4,725	-€62,476	€4,725	-€839,891
2020	€0	-€60,363	€4,565	-€60,363	€4,565	-€898,523
2021	€0	-€58,322	€4,411	-€58,322	€4,411	-€958,886
2022	€0	-€56,350	€4,262	-€56,350	€4,262	-€1,069,382
2023	€0	-€54,444	€4,118	-€54,444	€4,118	-€1,125,732
2024	€0	-€52,603	€3,979	-€52,603	€3,979	-€1,180,177
2025	€0	-€50,824	€3,844	-€50,824	€3,844	-€1,232,780
Total	-€52,174	-€1,227,369	€74,172	-€1,279,542	€74,172	-€1,283,604

Table C2.6.12 Lifetime cost/benefit of the reference measure/case (discounted)

	Capital cost	Savings from transferring bus passengers to the Cycle Motorway	Total cost	Total Benefit	Cumulated cost
2011	€0	€0	€0	€0	€0
2012	€0	€0	€0	€0	€0
2013	€0	€0	€0	€0	€0
2014	€0	€0	€0	€0	€0
2015	€0	€0	€0	€0	€0
2016	€0	€0	€0	€0	€0
2017	€0	€0	€0	€0	€0
2018	€0	€0	€0	€0	€0
2019	€0	€0	€0	€0	€0
Total	€0	€0	€0	€0	€0

C2.6.5 Summary of CBA results

The overall conclusion is that the capitalised benefits, when compared to the capitalised maintenance costs, are not enough to yield satisfactory returns on the Biofuels project's capital costs. The project has an NPV of approximately -€1,300,000.

Finally, it can be argued that Aalborg's image as an environmental conscious city is improved which might increase its population's feeling of pride and it's satisfaction with its local government. And furthermore it might increase, or be a prerequisite for, the migration of people, companies and students the Aalborg. These impacts are not easily quantified, but should none the less be taken into account when evaluating the success of the measure.

C2.6.5.1 Sensitivity analysis

In order to test the robustness of the conclusion a sensitivity analysis on select key impacts has been carried out. If the benefits from increased perceived image were monetarised to €100,000 and any one of the following bullets were to be realised, the NPV of the project will turn positive:

3. The initial additional costs of using biofuels are reduced to approximately €121,000.
4. The price of CO_2 quotas is increased to €186.

Based on this sensitivity analysis it is argued that the overall conclusion, as laid out above, is robust.

C3 Achievement of quantifiable targets and objectives

No.	Target	Rating
1	Increase the number of bus passengers[7]	★★
2	Improve the image of public transport	NA
3	Reduction of CO, NOx and Particulate emissions of the involved vehicles in the demonstration	O
4	Reducing fossil fuel consumption and thereby also CO2 emissions. Providing fuel consumption remains the same the 10% substitution of diesel with CO2 neutral bio fuels in public transport in the CIVITAS corridor is expected to lead to 140t less CO2 emissions annually. For HGV and vans the figure will be around 175 t.	★★★
5	Tourism shuttle bus with target on 7,500-15,000 passengers using the shuttle bus line per year of the project	★★
NA = Not Assessed O = Not Achieved ★ = Substantially achieved (at least 50%) ★★ = Achieved in full ★★★ = Exceeded		

[7] Changes in modal split have been measured within the effects of the package of measures related with this is reported in appendix A.

C4 Upscaling of results

Assumptions for up-scaling and how to deal with them:

1. **Every bus or HGV in the city centre would be able to perform on a biodiesel blend of 10 %**. Based on the licence plate count and measured emission for the involved vehicles in the demonstration project, a model describing the emissions in this scenario will be developed.
2. **Demonstration vehicles would be able to perform on a higher bio-diesel blend**. Models of emissions on higher blends will be developed.

The results show that emissions are not significantly changed by the use of bio-diesel (10%). In terms of letting all vehicles in the city centre operate on biodiesel, this should not create any changes in this respect.

In terms of CO_2 reduction this will increase with the number of vehicles. However, it is not possible to restrict vehicles to use bio-diesel currently.

For the second upscaling scenario, this has been done as part of the demonstration project without any problems. As of the end of the CIVITAS ARCHIMEDES project it does not seem realistic that the trials will continue after the end of the project.

C5 Appraisal of evaluation approach

For this measure a very scientific evaluation approach has been chosen in order to investigate the actual impacts of the demonstration in terms of emissions and carbon dioxide reduction. The test procedure was a simplified 88/77/EEC procedure known as a 5-mode test and in line with European standards, making it possible to compare results across cities and projects.

C6 Summary of evaluation results

There is a slight indication of increased NOx and a tendency to reduced CO, which is in line with most previous studies. At the same time there is a small reduction in PM and Fuel Consumption (BSFC). However, these differences are too small to be significant. The change in HC is also too small to be significant.

The conclusion is therefore that emissions are practically unchanged.

The use of bio-diesel has lead to less consumption of conventional diesel, and since the used bio-diesel product is saving the environment from a relatively high amount of CO_2, the overall conclusion is that, emissions are practically unchanged, while CO_2 emissions are reduced corresponding the use of bio-diesel. It is hence demonstrated that 2nd generation bio-diesel, AFME, made from animal fat can be used without major problems in public transport fleets and delivery vehicles.

It is possible to reduce CO_2 emissions and fossil fuel consumption from vehicles without increasing other emissions significantly, without moderating vehicles and without encountering major problems in vehicle performances.

C7 Future activities relating to the measure

The bio-diesel trials will be on-going throughout the CIVITAS ARCHIMEDES project. As of the end of the CIVITAS ARCHIMEDES project it does not seem realistic that the trials will continue after the end of the project.

One new public transport route on bio-diesel has been introduced in the region outside the CIVITAS ARCHIMEDES project. It is operated by one of the operators in the CIVITAS ARCHIMEDES project. This route is benefitting from the established infrastructure and other experiences from the ARCHIMEDES project.

Whether the postal service will continue using bio-diesel is not yet clear. The product is still more expensive than conventional diesel, and as the EU funding will end, the postal service will have to decide whether bio-diesel is one of the strategies to achieve their objectives on green transport.

D Process Evaluation Findings

The process evaluation has been elaborated on the part of the measure which is concerning the operation on bio-diesel in the vehicles at the postal service, bio-diesel in buses and the implementation of fuelling facilities.

D.0 Focused measure

	1	Most important reason: *The measure fits into the city policy towards sustainable urban transport and / or towards sustainability in general.*
	2	Second most important reason: *Participation of a range of different actors*
	3	Third most important reason: *The measure fits into the EU policy towards clean urban transport and it is possible to make a Cost-Benefit analysis on the experiences in Aalborg.*

D.1 Deviations from the original plan

The implementation timeline as described in the DoW was almost followed. Due to some barriers in the implementation process, the start of the demonstration of bio-diesel in the postal fleet had to be postponed from October 2010 to April 2011. These barriers, however, were mainly due to the establishment of the fuelling station, and the experiences from this process are difficult to compile into useful recommendations for other cities.

Efficient project management is required to implement the project and the time to establish a fuelling station, even though it is only of minor scale, should not be underestimated. Teaming up with relevant stakeholders and professionals in the field of bio-diesel is of high importance. Still, the technology is relatively new, and bodies involved in the implementation are not necessarily aware of bio-diesel technology. This can have a negative impact on the application process of establishing the fuelling station.

D.2 Barriers and drivers

D.2.1 Barriers

Preparation phase

- **Barrier 1 (Spatial)**; One of the main barriers for implementing this measures has been to find a feasible fuelling solution, finding the right spot for the fuelling station and to get the required permissions to build.

    i. This is a barrier because it might prolong the implementation process, making the time for operation and evaluation shorter. It has resulted in more work and the fuelling station was not in place at the time when planned. However, the demonstration period has been long enough to do a proper evaluation of the task.

- **Barrier 2 (Costs):** – during the preparation phase more options for fuelling stations appeared. The fact that purchasing a new fuelling station was considerable more

expensive than lending an existing one, slowed down the process in order to find the best and most feasible solution.

i. The fact that more options should be searched has slowed down the process of implementing the fuelling station.

Implementation phase

- **Barrier 1 (Construction):** Due to the delay in getting the permission to set up the fuelling facilities for the trial, the construction work was delayed. This meant that when construction was to happen, it was too cold. In 2010, the cold weather came early to Aalborg, and the construction of the fuelling facilities was further delayed.

Operation phase

- **Barrier 1 (Technical)** At the bus facilities, a few operation problems with the fuelling stations were discovered early in the operation phase. The provider of the fuelling station solved the problem, but it was clear that technical barriers can occur.

D.2.2 Drivers

Drivers have been similar in all three phases; preparation, implementation and operation;

- **Driver 1 – (Objectives)** – For both the Postal Service and the Public Bus company, it has been a driver to be part of the demonstration project in order to meet corporative targets on carbon dioxide reductions. Even though the projects will most likely not continue, due to the extra costs, Post Danmark and the Public Transport Department has experienced that the use of bio-diesel is a way to meet the objectives.

- **Driver 2 – (Organisational driver)**; The City of Aalborg has benefited from the involvement of the key stakeholders in the process, in addressing problems and challenges.

  i. The work load has been divided between the stakeholders, making the process smoother.

  ii. The postal service has been able to work directly with the construction application with input from the City of Aalborg and using the network of the City of Aalborg.

- **Driver 3 – (Communication) Involvement, communication driver;** the motivation among the stakeholders has been high which has been a driver for the process.

  i. The process has been smoothened through motivation among the stakeholders.

D.2.3 Activities

Activities have been the same in all three phases; preparation, implementation and operation;

- **Activities 1** – (organisational) co-operation between stakeholders, including frequent meetings. The meetings continued into the implementation phase.

D.3 Participation

D.3.1. Measure Partners

- **Measure partner 1** – ARCHIMEDES partners (City of Aalborg and Public Transport Authority) involved in this project is The City of Aalborg as leader of working group.
- **Measure partner 2 - Post Danmark (National Postal Service)** – Participant in the working group for implementation of the low emission zone and efficient freight solutions in Aalborg.

D.3.2 Stakeholders

- **Q8 – Oil Supplier** – The oil company has being delivering the bio-diesel product for the demonstration project. At the beginning of the project, Q8 was attending the working group meetings and a study tour was carried out to the oil company facilities in September 2009. After this the negotiation of the delivery of the fuel has been carried out between the Q8 and Post Danmark.
- **The Danish Technological Institute**: Research Study on availability and usability of bio-diesel has been carried out by this stakeholder. The Danish Technological Institute also performed evaluation on the performance of the vehicles.

D.4 Recommendations

D.4.1 Recommendations: measure replication

- In the beginning of the project it is very important to investigate what kind of fuel product that should be used. The issues about 1st and 2nd generation bio-diesel have been taken prior to this project. Choosing first generation bio-diesel made from food stock can cause some ethical discussions and bad will from the public and stakeholders. 2nd generation biodiesel on the other hand can give some technical challenges and lead to higher costs. This has been explained in the assisting documents, the research report R11.1.1 and the technical deliverables T1.1-T1.2 and T1.2-T1.3.

- During the trials it has been proven that using a second generation bio-diesel product made from slaughterhouse waste (animal fat) in blends between 10% and 20% can be done without causing any operational problems. This measure is in that respect easy to replicate. Challenges in the preparation phase about warranties and extra maintenance due to the use of bio-diesel can occur and might have to be addressed. During the operation phase these challenges did not turn out to be a concern.

- Use existing fuelling facilities if possible. It has proven to be very time consuming to set up a fuelling station for this use. Use professional assistance to deal with this is necessary in order not to be delayed.

- Do a big scale demonstration. Starting up the project, including installing the fuelling facility is expensive and not worth it for only a few vehicles. In this project a total of 100 vehicles were participating.

D.4.2 Recommendations: process

- Close co-operation with partners: Make sure that all partners are working for the same objective. In this demonstration project we had a very close co-operation with the postal service in order to ensure that they also saw the benefits from this project.

- Setting up a large scale demonstration task takes time. Be prepared for this.