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Promoting alternative automotive technologies in urban areas: Lessons learned from international cases

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ABSTRACT: The core objective of this paper is to document criteria for successful case studies of pilot projects implemented in urban areas and to derive lessons learned which can be transferred to other cities or regions.

The successful case studies are analyzed from economic, energetic and ecological point of view, taking into account three success criteria: low costs, CO_2-reduction and multiplicity (easy transferability of lessons learned).

The major conclusion of this work is that there is a wide range of possibilities to introduce alternative, low emissions automotive technologies and fuels in urban areas. Most of analyzed case studies are successful from technological and ecological point of view and well accepted from final users. Experiences in local areas are a very good basis for further dissemination of alternative technologies and fuels as well as successful policy measures. In some cases due to the missing infrastructure, as well as regulatory framework the transferability of knowledge and technology is limited.

However, bad economics is still the major problem for a broader dissemination of alternative fuels and alternative automotive technologies in urban areas. This problem can be solved by means of public procurement policies e.g. regarding fuel switching for public busses and introduction of emission-free zones.

INTRODUCTION

Since over 70% of the European population live in urban areas[1], cities need efficient transport system. Developing efficient transport systems in urban areas has become an increasingly complex task for public authorities, which have an essential role in providing the planning, the funding and the regulatory framework.

The adverse impact of continuously increasing traffic in urban areas result in greenhouse gas emissions, noise, air pollution, road accidents, and congestions causes every year a loss to the European economy of about 100 billion euros[2] (corresponding to about 1% of the EU's GDP).

This enormous damage to humans, economy and the environment points to the fact

[1] United Nations, World Urbanisation Prospects: The 2007 Revision.
[2] COM(2007) 551 final, Green Paper, Towards a new culture for urban mobility

that we urgent need more sustainability in urban mobility. For decades the social needs for mobility was misunderstand to be equivalent to enhancing car transport infrastructure.

European Commission has recognised the problem of urban mobility which has been presented in Green Paper: Towards a new culture for urban mobility (2007) as well as in the Action Plan on Urban Mobility (2009). The urbanisation and its impacts on transport have been identified as one of the main challenges in making the transport system more sustainable. Since the responsibility for urban mobility policies lies primarily with local, regional and national authorities it is important to help them to attain the goal of more efficient transport system from an economical, ecological and social point of view.

Urban transportation is organised basically in three broad categories: individual, collective and freight transport. In the last decades rapid urban developments implies increased quantities of passenger and freight traffic within urban areas leading to a scramble to provide transport infrastructure often in an inadequate way, which has often not been able to keep up with the grow of mobility. Increasing motorization and energy consumption by urban transportation have become a serious impediment to the quality of life and the health of urban populations.

It is clear, that urban areas as a driver of the European economy need mobility but also better quality of life, lower greenhouse gas emissions, noise and air pollution. One of the possibilities to solve or at least to reduce some of theses problems is use of alternative fuels and alternative more efficient technologies. In the most of EU countries the share of alternative fuels (AF) and alternative automotive technologies (AAMT) is relatively small, but continuously increasing due to implemented policy measures and EU targets. The major reason for the low share of AF and AAMT is that their costs are still very high comparing to conventional fuels and technologies.

The core objective of this paper is to document criteria for successful case studies of pilot projects implemented in urban areas and to derive lessons learned which can be transferred to other cities or regions.

The successful case studies are analysed from economic, energetic and ecological point of view, taking into account three success criteria: low costs, CO2-reduction and multiplicity (easy transferability of lessons learned).

This paper is part of the analysis done in the scope of the ALTER-MOTIVE project funded within the Intelligent Energy-Europe (IEE) programme[3].

METHODS OF APPROACH

At first in this session the method of approach is documented.

Energy conservation analysis

We analyse the savings in fossil energy consumption. This investigation is either based on a direct comparison of energy consumption before and after introduction of the case if reported so or based on estimations using typical or average figures e.g. for vehicle kilometres driven and for fuel intensity. The estimation uses the following equation:

[3] ALTER-MOTIVE: Case Studies evaluation report: www.alter-motive.org

$$\Delta E_{FOSS} = (FI_0 vkm_0 - FI_t vkm_t) \cdot V_{subst}$$

With:
FI (fuel intensity); vkm (kilometres driven per car and year); V_{subst} (number of vehicles substituted)

Moreover, for biofuels also the gross savings are calculated by taking into account the fossil energy for production:

$$E_{BF} = E_{\mathrm{Re}n} + E_{FOSS_{\mathrm{Re}n}}$$

So total energy balances are:

$$E_{FOSS_{\mathrm{Re}n}} = (f_{e_{FOSS}} FI\ vkm) \cdot V_{subst}$$

With:
f_{eFOSS} (factor of fossil share in biofuels)

Economic analysis

The economic analysis is based on identifying the additional costs of alternative cars, costs for new infrastructure and administrative costs[4].

In estimating the additional costs we used the principle of "additional marginal costs". E.g. for cars or buses we considered only the difference in investment costs of the new alternative vehicles in comparison to a new version of the conventional (e.g. diesel) vehicles. Or otherwise, if no new vehicles are purchased the cost difference is due to adaptation costs.

The costs per year are:

$$C_y = C_{IS} + C_{CV} + C_{Ad\min} = IC_{IS} \cdot CRF_{IS}(r, t_{IS}) + IC_V \cdot CRF(r, t_V) + C_{Ad\min}$$
[€/yr]

With:
IC_{IS} (investment costs in infrastructure); t_{IS} (depreciation time for infrastructure-about 20 years); C_{Admin} (yearly administrative costs); IC_V (investment costs in vehicles); CRF (capital recovery factor); t_V (depreciation time for vehicles - about 12 years).

Ecological assessment

This considers mainly the reduction in CO_2-emissions equivalents (comprising methane and other gases with global warming potential):

[4] Note, that not for every case study data were available for all of these cost categories.

$$\Delta CO_{2_{equ}} = E_{FOSS_{0j}} f_{CO2_j} - E_{FOSS_{tj}} f_{CO2_j} - E_{Ren_{tj}} f_{CO2_j} \qquad [\text{ton } CO_{2equ}]$$

j…….. fossil fuel type
f_{CO2j}…….specific CO_2 emission factor (e.g. 2.36 kg CO_2/l biodiesel)

Finally, costs of CO_2 (C_{CO2}) are calculated as:

$$C_{CO_2} = \frac{C_y}{\Delta CO_{2equ}} \qquad [€/\text{ton } CO_{2equ}]$$

Definition of success criteria

The success criteria for case studies are defined as follows:

- The target of 100% **low costs** is reached, when CO_2 reduction costs are lower than 1 EUR/ton CO2.
  Correspondingly, costs of about 30 EUR/ton CO_2 are related to 50% of the "low cost" goal and 0% target is reached when costs are higher than 1,000 EUR/ton CO_2.
- With respect to the **CO_2 reduction**, the target of 100% CO2 reduction is reached, when the reduction of CO_2 emission due to the analysed case study are higher than 10,000 tons CO_2.
  CO_2 reduction of 50% correspond to the CO_2 saving of about 3,000 tons per CO_2. 0% means there was no emission reduction.
- With respect to "**multiplicity**" a figure 100% means that this case study is possible in every location in every (EU) country and the fuel is available everywhere. 80% applies if is possible in every corresponding area, e.g. in every city without fuel limitation.
  If the measure is possible in most areas, but there are restrictions of fuel availability, then multiplicity is defined as 50%. If the case described is virtually unique, and cannot be duplicated anywhere the target reached is 1%.

ECONOMICS, ENERGETIC AND ECOLOGICAL ASSESSMENT OF ANALIZED CASE STUDIES

In this section the major groups of case studies by fuels, such as CNG-, electricity-(battery electric vehicles) and biofuels-projects are documented and analysed from an economic, energetic and ecological point of view.

CNG (compressed natural gas) case studies

The share of CNG projects represent about one quarter of the show cases collected and analysed in the scope of the ALTER-MOTIVE project. The main reasons for the investments in CNG-fleets are:

- Responsibility for the environment and improving company's green image
- The price comparison of CNG and diesel, possibility to save money
- The necessity to avoid driving bans in cities because of increased limits in relation to particulate matter

- Noise reduction

Most of the analysed CNG-case studies have been successful. The technology used is already mature and works without any major problems. Beside dedicated CNG vehicles in use are also bi-fuel (CNG/diesel) vehicles. By CNG vehicles more time for refuelling (approx. 8 minutes) is necessary. This usually causes no extra costs, but the changes in driver's work time management die to longer refuelling time is possible. Some of the disadvantages of CNG vehicles in comparison to conventional diesel engine are:

- Lower engine durability (about 140,000 km)
- Lower weight capacity (due to gas cylinders)
- Lower performance of engine (but for running in city centres the performance is usually not important).

The biggest problem so far of the CNG pilot projects was the low developed network of service stations. Since the CNG-infrastructure is limited, CNG vehicles are usually used in urban areas in public fleets e.g. buses with determined operating ranges. Trips into the outskirts require the ability to switch to a conventional fuel. Dual fuel capability is mostly used in CNG passenger cars or vans. On one hand advantage is that duel-fuelled CNG vehicles could be used across the country or region in spite of limited infrastructure. On the other hand in this case most of the time diesel is used as a main fuel, so that all economic and ecological advantages of CNG vehicles are significantly reduced.

Due to relatively good experience with CNG and good acceptance by all involved groups most of the CNG projects are extended. In some cases CNG is already a part of regular fleets.

However, the missing or low density of CNG refuelling stations is the major obstacle in extending the fleets operations.

The impact of municipal policies as well as financial support from public institutions is mostly very relevant. Although the CNG vehicles have lower operating costs, due to the lower fuel costs, in most of cases due to the low operational performance (from 10.000 to 45.000 km per year) and the small number of vehicles, only relatively low part of the extra costs for CNG vehicles can be compensated by fuel costs savings and user benefits. In these cases financial support is very important.

Most of cases (about 95%) were public buses initiated by municipalities.

As a matter of fact CNG is not a renewable energy carrier, but it ensures great environmental virtues: lower level of noise and lower air polluting emissions. The CNG vehicles have proven to be low-emission alternative to diesel vehicles. The emissions usually go below the requirements of the EEV standard. However, the results regarding the reduction of greenhouse gas emissions are different from case to case (dependent from mileage, vehicle type – dedicated or articulated bus etc.). Thanks to the catalytic converter CNG vehicles emit about 90% less PM_{10} and about 70% less NO_x in comparison to conventional diesel vehicles.

Additionally, by using CNG vehicles the level of noise could be reduced for about 4 dB in comparison to diesel vehicles, which is big advantage for vehicle use in cities.

As an example we have shown energy- and GHG–balances of a fleet with 100 CNG buses, see Figure 1 and Figure 2. It is assumed that conventional diesel buses are

replaced with dedicated CNG buses with an operating range of 40.000 km per year.

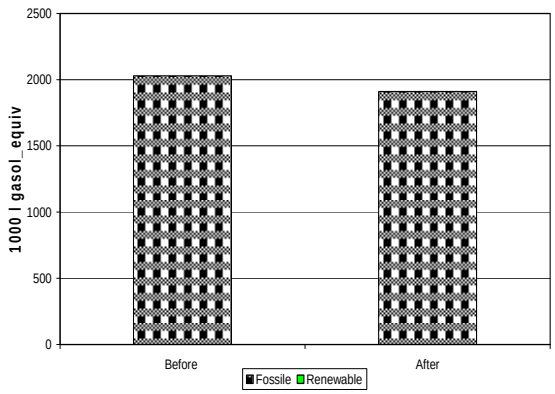

FIG. 1. Average energy balances of CNG projects

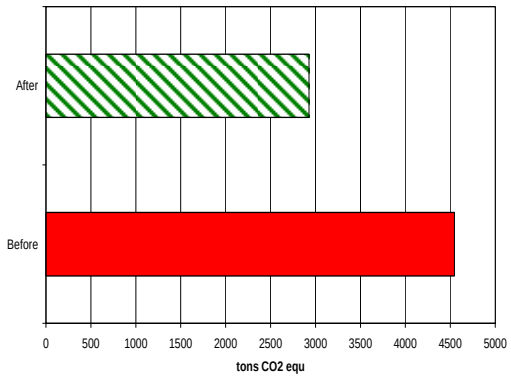

FIG. 2. Estimated average of GHG emissions of CNG projects

Along the environmental benefits, the CNG vehicles have lower operating costs, due to the lower fuel costs. In some cases the fuel costs could be reduced by 25% - 50%. Maintenance costs are more or less steady, but repair costs could be partly higher.
Using CNG vehicles operating costs are lower, but it will take time to recapture the initial investment costs. In some of the projects beside acquisition or adaptations of vehicles it was necessary to build CNG refuelling station, which, of course, increased costs of the project. The investments in fuel station were up to 800.000 EUR. Yet filling stations only (no building included) are about 190.000-350.000 EUR.

In some projects CNG cars or vans are leased. The costs of leasing are not exceptionally different compared to those of conventional fossil fuels vehicles. The project costs are different from project to project and from country to country. In some cases project costs are not available for public. However, the CNG vehicles have proven to be economic, especially dedicated CNG vehicles.

The fuel consumption of CNG vehicles is significantly lower than that of old diesel engine, but the initial investment costs are higher. By bi-fuel vehicles the conversion costs are approximately 10.000 EUR per bus. But in this case operation costs are higher. The costs of dedicated CNG buses are about 315.000 -385.000 EUR.

The most of the CNG case studies could be classified as successful. Using CNG operating costs could be reduced as well as noise and greenhouse gas emissions. A big advantage is also relatively easy transferability of knowledge and technology.

Examples of CNG case studies

Some interesting examples in this fuel category are[5]:

- ***EBRD loan for CNG bus fleet in the city of Plovdiv (Bulgaria)***
  The European Bank for Reconstruction and Development (EBRD) extended a loan of 6 millions Euro for renewal of the bus fleet and for launching of e-ticketing in

[5] For further information and more examples see www.alter-motive.org

Plovdiv, the second biggest city in Bulgaria. The loan has been used to purchase 30 new buses running on natural gas to replace the old diesel buses, used in the city.

- ***Biogas as fuel for transport in Linköping (Sweden)***

  Biogas (biomethane) made from wastewater or solid biological material is a very clean commercially available vehicle fuel. There are almost no hazardous emissions at all and very little greenhouse gas emissions. Using biogas is a way to reduce the vehicle emissions and simultaneously reducing municipal waste problem. Biogas is especially well suited for city fleets as it is normally available in all cities from the water treatment plants. Svensk Biogas AB in Linköping is a successful example of the biogas concept having 13 filling stations and 7 more to be opened. In addition to the public transport company's 67 buses one train and more than 500 cars are fueled by biogas in Linköping.

Battery electric vehicle (BEV) case studies

In the last few years interest in battery electric vehicles is rapidly increasing, so that about one quarter of analysed case studies in ALTER-MOTIVE project is related to electro mobility.

The motivation for most of electro mobility case studies is to:

- Learn about economic, technical and social viability of electro mobility as well as about requirements, charging technology and practical aspects of operating charging infrastructure
- Test consumer behaviours and demonstrate acceptance
- Reduce noise, air pollutions and greenhouse gas emission in urban areas.

Most of analysed case studies have been successful. Big public interest in electro mobility can be also noticed.

The electric vehicles used in the case studies are still not fully technically mature and not completely comparable with conventional gasoline or diesel vehicles. Some of the disadvantages of electric vehicles in comparison to conventional ICE engines are:

- Very long charging time (8-10 hours to fully charge)[6]
- Lower operating range (about 50-100 km) in real life
- Lower maximal speed (40-70 km/h) especially for retrofitted electric power trains
- Restricted servicing possibilities due to limited infrastructure.

Since the number of charging points is limited, electric vehicles are usually used in urban areas in public fleets e.g. garbage trucks or tourist vehicles with determined operating ranges.

In some cases this problem is solved by using bi-fuel vehicles. Dual fuel capability allows the vehicles to run on two different types of fuels – one alternative and one conventional. Of course, by using bi-fuel vehicles ecological advantage of electric vehicles is reduced.

Due to relatively good experience and acceptance by all involved groups most of the case studies related to BEV will be extended.

However, the number of charging points have to be increased and the operating range

[6] Recent fast charging facilities do promise a replenishing to 80% in half an hour or even less.

of electric vehicles have to be improved.

By BEV case studies the impact of municipal policies as well as financial support from public institutions is mostly very relevant. Since the prices of the electric vehicles are higher than those of combustion engine vehicles, different kinds of measures are necessary to make this vehicles more attractive. E.g. in some cases charging of electric vehicles is free as well as parking space, or the electric vehicles are allowed to enter restricted traffic zones.

However, to provide these benefits to users of electric vehicles in the most of the cases financial support is very important.

Electric vehicles are zero-emission at their point of use. However, emissions are being produced during the generation of electricity, the amount depending on the method of generation and art of primary energy which is used for electricity generation. Therefore, the emissions need to be considered on a lifecycle basis. Best option is to use 100% renewable energy for electro mobility. In any case, electro mobility can significantly reduce noise, air pollution and CO_2 emissions in the city.

As an example we have shown energy- and GHG–balances of a fleet with 100 electric vehicles, see Figure 3 and Figure 4. It is assumed that conventional ICE vehicles are replaced with electric vehicles with an operating range of 14000 km per year. In case studies mostly used electric vehicles are Th!ink, Renault Twingo, Fiat Panda, Fiat 500 and Mazda 2. In some cases the larger electric vehicles provided by Mercedes did give some technical problems (not properly working battery). Due to this problem some of the cars have been out of service for longer period. This had a negative impact on the reputation of electric vehicles.

Actually, the best experience is with the small electric vehicles which use is limited to the certain urban areas, e.g. narrow streets in the city centres.

Electric vehicles are significantly more expensive to buy than conventional ICE vehicles. Typically for new electric car the price is about 30.000 EUR higher. The batteries are very expensive and have to be exchanged every 2 to 5 years. However, the acquisition costs of small electric vehicles are in the range 14.000 (2-seat model) and 16.000 (4-seat model).

In spite of high investments costs, in some countries with low electricity prices e.g. Norway, electric cars are largely an economic success (cost saving per electric vehicles is about 1 EURO per 10 km travelled). For example, in Denmark the governmental taxes on cars are the highest in the world, but there is no tax on electric vehicles until the end of 2011. This tax exception makes electric vehicles much more competitive with the conventional vehicles.

In some of the projects beside acquisition of electric vehicles it was necessary to build new charging infrastructure, which, of course, increased costs of the project.

In some pilot projects electric vehicles could be used free of charge.

The project costs are different from project to project and from country to country. They are highly dependent of the type of vehicle used e.g. small or large electric cars, motorbikes, bicycles etc. In some cases project costs are not available for public.

The most of the case studies related to the electro mobility are successful. Note that the large CO_2-reduction figure is only reached assuming electricity generation from renewable energy sources. Using electric vehicles local air pollution and greenhouse gas emissions could be significantly reduced as well as noise. A big advantage is also

relatively easy transferability of knowledge and technology. Important task for the future is international standardisation of the interface between the vehicles and the charging point.

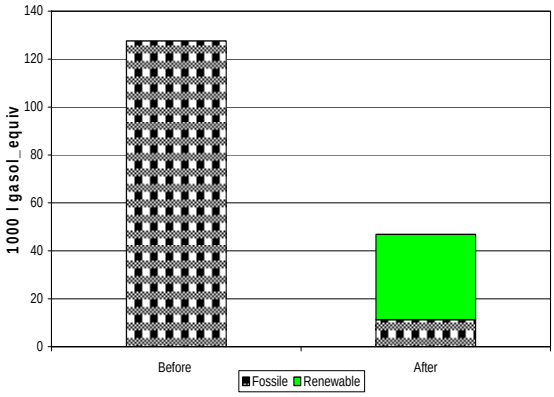

FIG. 3. Energy balances of BEV projects

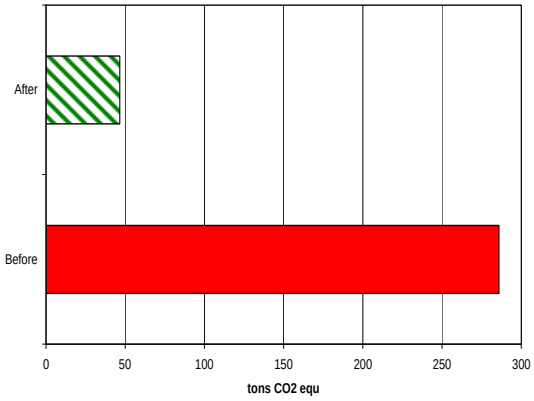

FIG. 4. Estimated average of GHG emissions EV projects

Examples of BEV case studies

Some interesting examples of BEV case studies are[7]:

- ***Electric Mini-Buses in Portugal***
  21 Electric Buses "Gulliver" (11/2010) are running regular urban bus lines in 6 capital of districts in Portugal right now. The introduction of electric Bus in Portugal was promoted by several years of events and demonstrations at local authorities. This was crucial to the acceptability of EV´s. Surveys of quality of service show very high rates of acceptance in every city.
- ***VLOTTE - a large electric mobility demonstration project in Vorarlberg (Austria)***
  The utility company of the federal state of Vorarlberg started an initiative to become a model region for electric mobility. The project covers the setup of an infrastructure of charging points and the availability of electric vehicles. The slogan is to provide fair mobility in accordance with the nature.

Biofuels case studies

In the last decade interest in biofuels, especially bioethanol and biodiesel was continuously increasing in all European countries. Many countries have set the goal to replace a significant part of fossil fuels by biofuels. In the European Union by the end of this year (2010) 5,75 percent of the energy used for transportation should be biofuels. Biofuels are considered to have the potential to reduce at least to some extent problems in the transport sector, such as growing consumption of fossil fuels, growing import dependency from political instable countries and increasing greenhouse gas emissions.

In most cases biofuels in transport sector are fully implemented, after successful pilot projects. The biofuel projects are usually driven by:

[7] For further information and more examples see www.alter-motive.org

- ecological aspects
- interest in technological progress (to test the use of biofuels in practice)
- image improvement
- the wish to support local biofuel production

Most of analysed case studies have been successful. They have made it possible to gather information about repair, maintenance and service needs when using biofuels.
Usually, a diesel/biodiesel mixture with a percentage between 5% (B5) and 30% (B30) biodiesel was mainly used. Small percentage of biodiesel does not require technical adaptation of the vehicles. In some analysed case studies also pure biodiesel (B100) has been used. The goal was to test pure biodiesel use in conventional ICE vehicles (e.g. Volkswagen LT) without modification. The first experience was positive, without any extra maintenance or other problems.

Bioethanol is usually used as E5 to E10 in conventional vehicles without any additional modification of engine. Higher percentage of bioethanol (E85) is used in flex-fuel vehicles (FFV). The experience with FFV has been good so far, without problems reported.
Some of the disadvantages and problems related to biofuels use in some cases were:

- the number of refuelling stations is limited
- flex-fuels vehicles require about 25% more fuel per kilometre to run on bioethanol
- lack of general regulations and safety rules, no classification and excise duty rates for bioethanol fuel.

Some specific features of analysed biofuels projects are shown in Figure 5. As shown the impact of municipal policies as well as financial support from public institutions is very relevant. Most of the tests with biofuels use in vehicles were successful, so that public acceptance is relatively high.

Yet, most of the biofuel case studies are successful, see Figure 6. Using biofuels local air pollution and greenhouse gas emissions could be significantly reduced. In some countries biofuel use in transport sector has already long tradition, so that transferability of knowledge and technology is relatively easy. In the future it will be important to improve WTW energy- and CO_2 balances and to make biofuels more competitive on the market.

One of the main reasons for the use of biofuels in transport is to reduce greenhouse gas emissions. Some case studies have shown that the effect of a particulate catalyst in connection with the use of biodiesel is even better compared to the use of fossil diesel.
The emission tests have shown that today's standard ethanol engine together with standard emission cleaning equipment can achieve emissions significantly lower than Euro 5. Particle emissions could be 10 times lower than Euro 5.

However, it is important that biofuels are produced in sustainable way. Therefore, total emissions need to be considered on a lifecycle basis.
Tested flex-fuel vehicles have also shown good CO_2 emissions performance. Flex-fuels car's emissions are under 100 g/km.

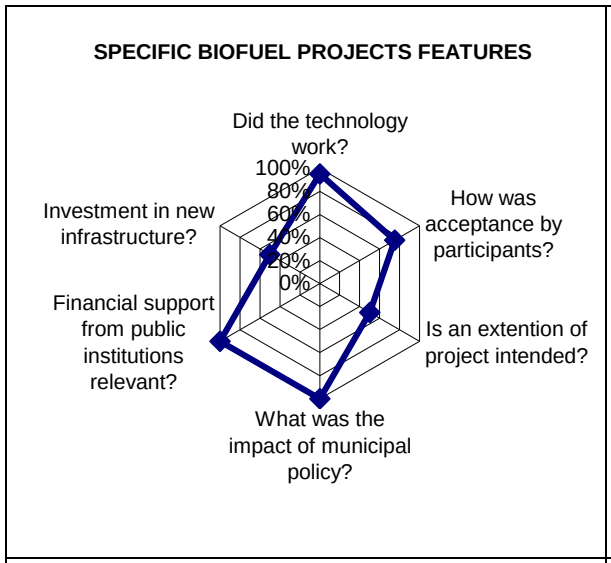

FIG. 5. Specific biofuels projects features

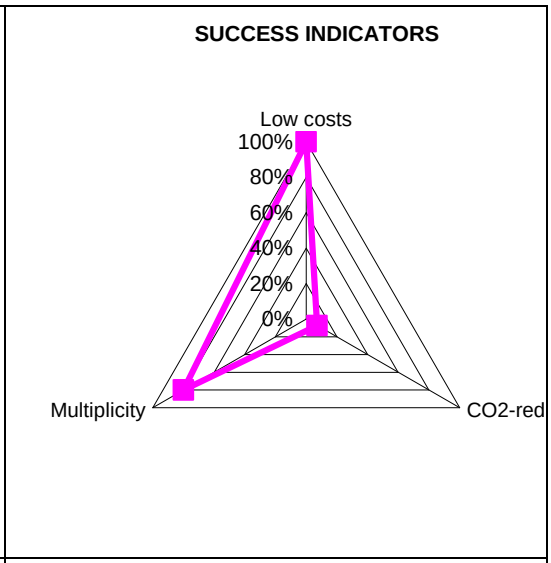

FIG. 6. Success indicators of biofuels projects

In some cases reduction of CO_2 emissions was lower than expected, which was the reason to switch to natural gas.

As an example we have shown energy and CO_2 balances of a fleet of 100 biofuels vehicles (50 E20 capable vehicles and 50 B20 capable vehicles), see Figure 7 and Figure 8. It is assumed that biofuels are used in conventional ICE vehicles with an operating range of 15.000 km per year.

Since the prices of the biofuels are higher than those of conventional fuels, fuel duty rebates on biofuels, as well as reduction in vehicle excise duty for environmentally friendly cars (such as E85 vehicles, FFV) are needed.

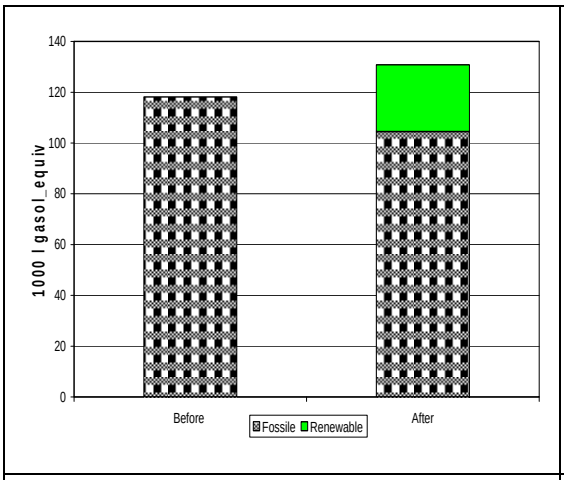

FIG. 7. Energy balances of the biofuel project

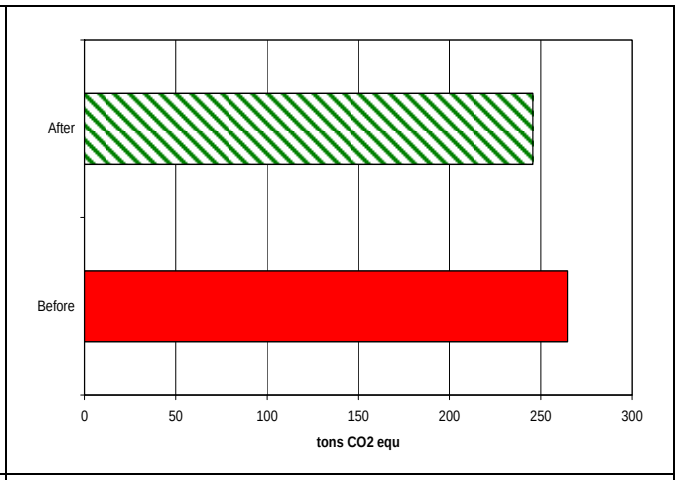

FIG. 8. Estimated average of GHG emissions of the biofuel project

Basically, there is no financial benefit of using biofuels. In most of case studies total costs of operation were slightly higher than planned.

In some of the projects beside acquisition of vehicles (e.g. FFV) it was necessary to

invest in infrastructure – in biofuel refuelling stations. This, of course, increases costs of the project.
However, the additional project costs are very low.

Examples of biofuels case studies

Some interesting examples in this fuel category are[8]:

- ***More than 400 ethanol buses in Stockholm (Sweden)***
  Sweden has a long and good experience of ethanol buses. The Stockholm Public Transport Authority introduced ethanol buses in the city bus fleet in the middle of 1980's. Since then, diesel buses have successively been replaced with ethanol buses, and the Stockholm fleet has now expanded to over 400 ethanol buses. The aim is that at least 50% of the two thousand buses should run on renewable fuels in 2011 and 100% in 2025.
- ***City of Graz - biodiesel from waste oil for public bus fleet***
  For ecological reasons and in view of an efficient environmental protection the Grazer Verkehrsbetriebe (GVB) have seen its obligation in analysing, testing and implementing the currently existing possibilities of alternative fuels in its daily use in the line operation for many years.

CONCLUSIONS

The major conclusion of this work is that there is a wide range of possibilities to introduce alternative, low emissions automotive technologies and fuels in urban areas. Most of the analysed case studies are successful from technological and ecological point of view and well accepted from final users. Experiences in local areas are very good basis for further dissemination of alternative technologies and fuels as well as successful policy measures. In some cases due to missing infrastructure (e.g. lack of proper filling stations), as well as missing regulatory framework conditions (e.g. security standards or international standardisation of the interface between electric vehicles and charging point) transferability of knowledge and technology is limited.

However, bad economics is still the major problem for a broader dissemination of alternative fuels and alternative automotive technologies in urban areas. This problem can be solved by means of public procurement policies e.g. regarding fuel switching for public busses and introduction of emission-free zones.

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[8] For further information and more examples see www.alter-motive.org