Promoting alternative automotive technologies and alternative fuels – major insights from the EU-project "ALTER-MOTIVE"

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Abstract

Increasing the market shares of alternative fuels (AF) – like hydrogen, biodiesel – and of alternative and more efficient automotive technologies (AAMT) – like electric vehicles and fuel cell cars – is considered as a major policy measure for reducing energy consumption and CO_2-emissions in the EU. To find strategies and to derive an action plan for how to promote AF and AAMT in a least-cost manner up to 2020 and how to link them to other policy measures like taxes and standards was the core objective of the project ALTER-MOTIVE funded within the Intelligent Energy-Europe (IEE) programme.

In this paper we summarise the major results and conclusions of this project.

The major (preliminary) over-all conclusion is that measures that focus on reduction of transport (like fuel taxes) and enhancement of efficiency (like fuel economy standards) are of superior relevance for reducing energy consumption and CO_2 emissions. They are superior to the promotion of any alternative fuels.

In detail the major recommendations to bring about a remarkable CO_2 emission reduction by 2020 are:

(i) Strive for harmonised fuel taxes at the upper level of current overall fuel price range in Europe; (ii) intensify R&D in efficiency and tighten standards of conventional cars; (iii) introduce a well-tuned registration and ownership tax system based mainly on specific CO_2 emissions per km. This system should provide a clear incentive to buy smaller cars; (iv) regarding AF: avoid subsidies and focus on (justified) tax exemption based on CO_2 relief; (v) regarding AAMT (e.g. electric vehicles and fuel cell vehicles) invest in and emphasize R&D, strive for minimum standards regarding technical reliability (e.g. range, battery quality), promote field tests reasonably and moderately but avoid subsidies for vehicles of any type of technology! (vi) remove incentives for the purchase of larger cars as very often exist in commercial enterprises.

1. Introduction

Increasing the market shares of alternative fuels (AF) like hydrogen, biodiesel and of alternative and more efficient automotive technologies (AAMT) – like electric vehicles and fuel cell cars – is considered as a major policy measure for reducing energy consumption and CO_2 emissions and to head towards a sustainable transport system. The core objective of the project ALTER-MOTIVE is to derive effective least-cost policy strategies to achieve a significant increase in innovative alternative fuels and corresponding alternative more efficient automotive technologies to head towards a sustainable transport system and to derive an action plan for how to promote AF and AAMT up to 2020 and how to link them to other policy measures like taxes and standards.

The objective of this paper is to present some of the major results of the project ALTER-MOTIVE funded within the Intelligent Energy Europe (IEE) programme.

This paper is organized as follows: In section 2 the ecologic and economic assessments of AF and AAMT is described. Section 3documents the investigations of case studies. The analysis of government policies is documented in section 4. The ALTER-MOTIVE Action plan is presented in section 5.

2. Ecologic and economic assessments

To meet the above-stated target of the project ALTER-MOTIVE it is necessary to use a proper dynamic modelling framework. This framework must be based on a sound database for the various considered AFs & AAMTs for passenger transport. This work focuses on providing a fundamental database for biofuels, natural gas, electricity and hydrogen and AAMTs including technical, ecological and economic characterisations of each relevant technology. The ecological assessment is conducted along the whole Well-to-Tank (WTT) and Tank-to-Wheel (TTW) chain for selected AFs and AAMTs (see also Toro et al., 2010).

The database is organised in Excel files that contain relevant technical, environmental and economic data delivering specific costs, carbon emissions and where possible also NOx emissions for all relevant electricity, hydrogen and biofuel technologies in the sub-systems production, distribution, conditioning, storage, refuelling and conversion. The main results of this database with respect to AFs and AAMTs are presented below[1].

Additional analyses are made to identify the most promising pathways to supply biofuels, hydrogen or electricity for transport based on their combined WTT and TTW cost and environmental performance.

The major results for AF are illustrated in Figure 1. In Figure 1a the production costs are documented in comparison to the WTT emissions for 1st and 2nd generation biofuels. In Figure 1b the corresponding figures are compared for hydrogen from renewables as well as for electricity in battery electric vehicles (BEV) for various sources of electricity generation regarding their economic and environmental performance. It should be noted that all these figures correspond to a snapshot in time of their performance in 2010 based on average input values along the WTT chain.
Finally specific production costs (C_{AF}) of alternative fuels are calculated as follows:

$$C_{AF} = C_{FS} + C_{Ei} + CC + OM - R_{BP} \qquad [€/MJ_{fuel}]$$

where

C_{FS}.........Feedstock costs

C_{Ei} ……Other energy inputs costs (e.g. electricity, heat etc)

CC ……Annual capital costs

OM …..Operations and maintenance costs

BP …….Total by-product credit

No fuel taxes are considered.

With respect to the biofuels the best performing option corresponds to biogas with lowest specific emissions and costs per delivered Gigajoule (MJ) of fuel. 2nd generation bioethanol performs better than biomass-to–liquid (BTL) chains in terms of delivered costs but not in terms of CO_2 emissions per Megajoule (MJ), however, not higher than 1st generation Bioethanol (sugar beet) with very similar performance in emissions but higher costs. This is very

[1] This database is available for download from www.alter-motive.org

arguable as 1st generation technologies are already at commercial level and their economic performance depends highly on feedstock cost management and by-product value. The values provided here for 2nd generation are still arguable as they are based on R&D or demonstration figures, but still no scalable experience has been obtained. Biomass-to-liquids (BTL) have the prospect to offer lower emissions in this case due to the co-generation assumption covering high energy inputs; however, the capital requirements observed are very high. Along the whole chain biodiesel from rapeseed and bioethanol from wheat are exhibiting the higher CO_2_eq. emissions per delivered MJ of fuel due mostly by cultivation and fertilizers use as well as the use of fossil based inputs.

For all pre-selected pathways, by-products were considered in all cases as they result to have a positive influence in costs and emissions performance. However, the use of by-products and the way they are characterized in analysing biofuels production from WTT is not always comparable with other studies, as assumptions regarding their use and value differ greatly.

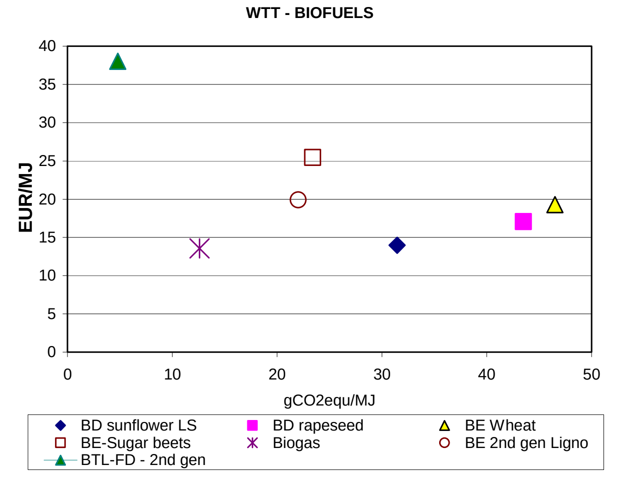

Figure 1a. Biofuels – State of the Art: WTT-emissions [gCO_2eq/MJ] and production costs as of 2010 [€/MJ]
BD: Biodiesel, BE: Bioethanol

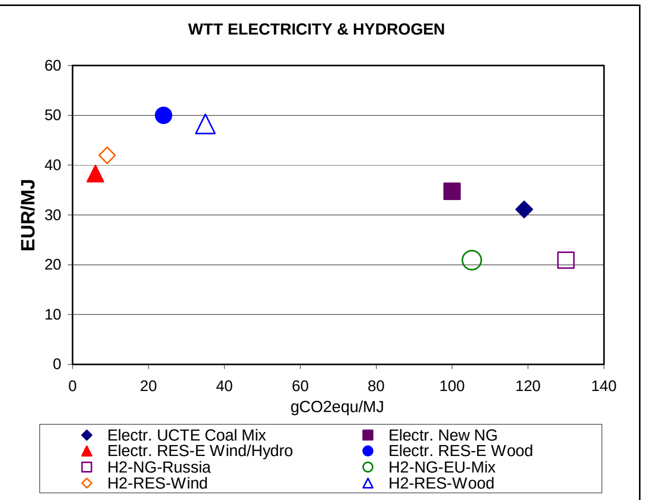

Figure 1b. Electricity and Hydrogen – State of the Art: WTT-emissions [gCO_2eq/MJ] and production costs as of 2010 [€/MJ]
H2: Hydrogen, RES: Renewable energy sources

With respect to a State of the Art assessment of AAMT, the modification of the existing internal combustion engine to run on alternative fuels, able to be blended with fossil diesel and gasoline or natural gas performs differently in terms of emission reductions stating better for biodiesel and biomass-to-liquids than for gasoline or flex-fuel vehicles running on ethanol mixtures.

The costs per km driven C_{km} in Figure 2 are calculated as:

$$C_{km} = \frac{IC \cdot \alpha}{skm} + p_f \cdot FI + C_{O\&M} \qquad [€/km]$$

where:

IC…….Investment costs [€/car]

α……..Capital recovery factor

skm…… specific km driven per car per year [km/(car.yr)]

p_f……..fuel price [€/litre]

$C_{O\&M}$….operating and maintenance costs

FI……..fuel intensity [litre/100 km]

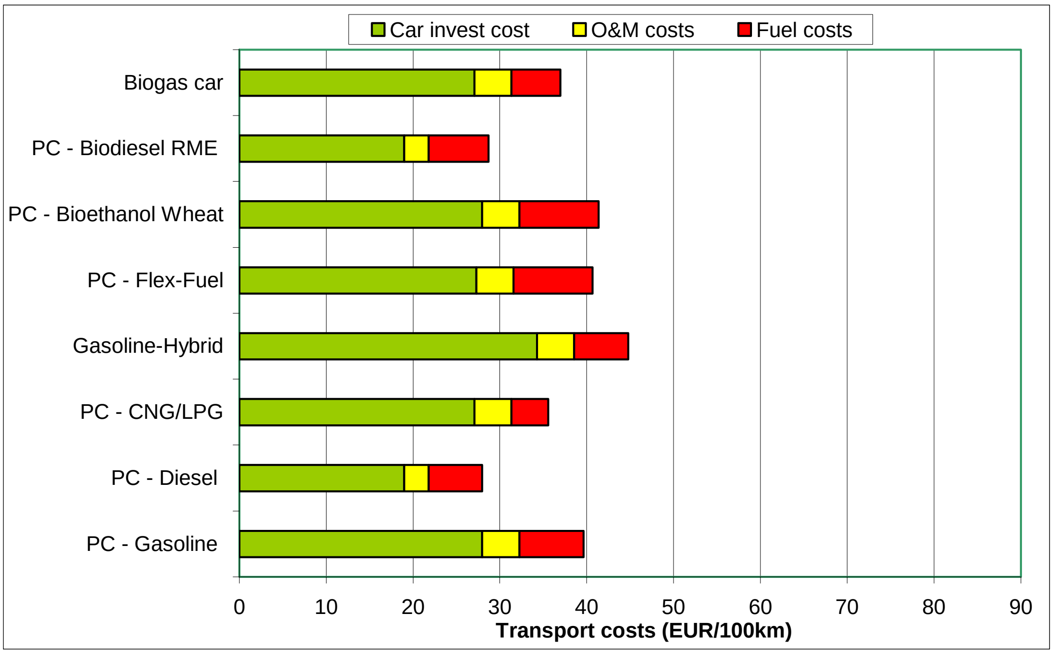

Figure 2. State of the art assessment of driving costs for fossil fuels vs biofuels [€/100km]
PC: Passenger Car

Moreover, AAMTs including hybrids, plug-in hybrids, battery electric vehicles (BEVs) and hydrogen technologies combined with ICEs have been assessed on their economic performance and partially on their environmental performance as per data availability, see Figure 3.

The specific capital costs are the highest component of the driving costs for all technologies. Hybrids, battery electric vehicles and plug-in hybrids take into account the actual costs for batteries as well as for fuel cells. However, these costs can be reduced until 2020 based on technical improvement potentials. The objective for batteries reaches the 500 €/kWh for Li-Ion batteries while fuel cells for transportation until 2020 exhibit higher figures. The small BEV is the only one exhibiting closer driving costs to gasoline or diesel references followed by PHEV, BEV and Hydrogen FC.

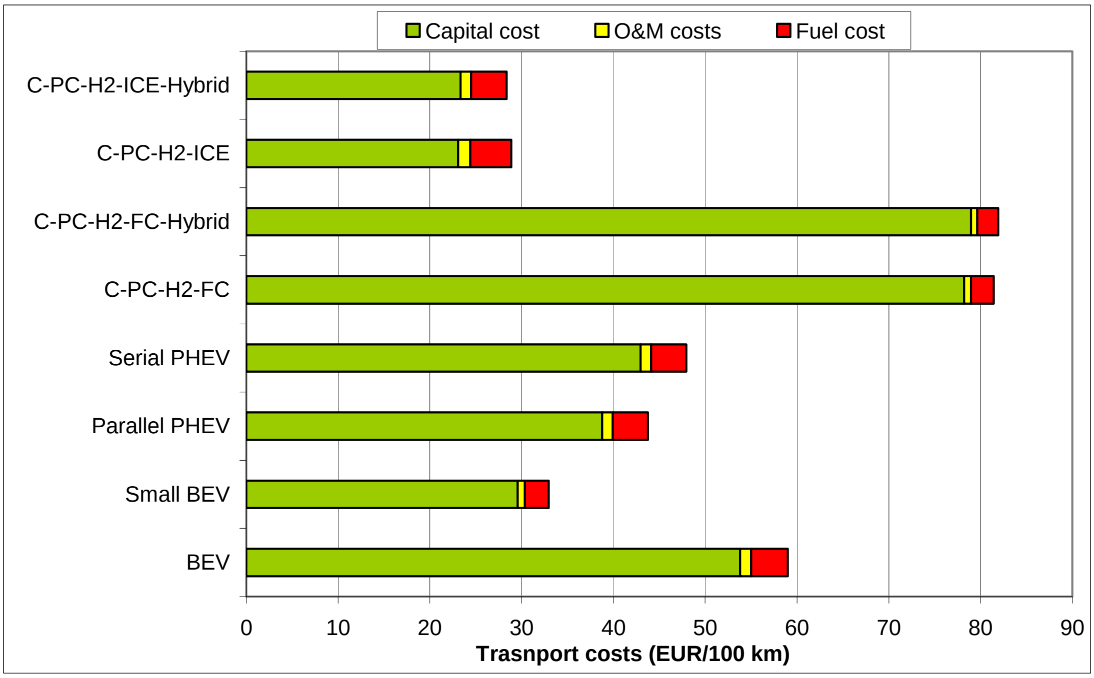

Figure 3. Hydrogen and Electric vehicles – State of the Art of economic assessment of driving costs 2010 (Size of vehicle: 80 kW except small BEV: 47 kW)
(*C-PC: Conversion Passenger Car, H2: Hydrogen, ICE: Internal Combustion Engine, FC: Fuel Cell, PHEV: Plug-in Hybrid Electric Vehicle, BEV: Battery Electric Vehicle*)

A broad summary of the reviewed main technical improvement potentials for both AFs and AAMTs – see Toro et al (2010) for further details – include:

- Developments of biodiesel and bioethanol processes and product specifications to better perform at combustion. Feedstock availability and competition issues put pressure to research further in expanding biomass feedstock and including waste streams.
- Advanced fermentation and thermal conversion for 2nd generation research and development are expected to gain further actions as they move from pilot to demo to early commercial stages. The potential to contribute are high but several economic and energetic bottlenecks need to be solved.
- Biogas offers a high potential as AF and upgrading needs to be made more competitive and technically feasible in order to gain further momentum and market share as a transport fuel. Further bottlenecks relate to infrastructure expansion and coordination with natural gas networks.
- Until 2020, the contribution from hydrogen as a transport fuel remains limited and several technical improvements remain at research and demonstration with an important potential after 2020. Major challenges are to reduce losses in over-all conversion chains for H2 and to make it cheaper; to enhance the reliability and life-time of fuel cells and to bring the learning curve of costs.
- The internal combustion engines exhibit important technical improvements with the potential to increase efficiency and reduce emissions with moderate extra costs. Several of these technologies are highlighted and include among others the application of engine test bed, optimised fuel injection and electronic systems, modern valve controlling and innovative gear drives (e.g. duplex clutch, continuous automatic gearbox, hydraulic impulse store).
- Further improvements include chassis suspension and brake technology, reduction of rolling resistance of tyres (e. g. innovative materials or optimised tyre profiles), enhanced aerodynamics, weight saving constructions (e. g. substitution of steel by plastics and carbon fibres, substitution of conventional headlights by light-emitting diodes) and material grade from renewable raw materials and optimisation of the power train. In addition, driving styles exhibit substantial fuel saving potentials.
- Additional modification on ICE include the adaptation of motors to run on biodiesel or bioethanol low or high blends with a potential to reduce emissions further while making less changes in technology.
- Battery electric vehicles (BEV) is still an immature technology and major R&D and demonstration activities relate to the further development of the batteries technologies and technology improvements indicate a wide range of weight and costs reductions until 2015 and until 2020 probably explained by the different scaling factors for battery and cell sizes.
- Across the review several experts in Europe and Worldwide foresee battery costs in 2015 and onwards varying between 370 and 580 €/kWh – see Toro et al (2010) for further details – while others consider possible a factor 5 in cost reduction based on the developments.
- Fuel cell research and development (R&D) is aimed at achieving high efficiency and durability, low material and manufacturing costs of the fuel cell stack and in addition is currently being considered for hybrid electrics as E-Mobility is expected to gain larger shares.
- Technical improvements for fuel cells include power density and platinum loading which are necessary to go on commercial scale. A cost evaluation on fuel cells for automotive power trains suggests that in future for high production significantly lower costs for fuel cell systems vary between 26 to 100€ per kW by 2020 following mass production and technology learning.

3. Case study analysis

One very important part of the project ALTER-MOTIVE is documentation and analysis of about 130 case studies of pilot projects for marketing alternative fuels and alternative automotive technologies, see ALTER-MOTIVE website.

The core objective of this task is to analyse successful case studies of pilot projects implemented in different European countries and to derive lessons learned, which can be transferred in other countries or regions. The analysed cases cover various kinds of alternative fuels (e.g. compressed natural gas (CNG), biofuels, pure plant oil (PPO), hydrogen) and alternative automotive technologies (e.g. battery electric vehicles (BEV), fuel cell vehicles), for more details see Cebrat et al, 2010.

The case studies are analysed from economic, energetic and ecological point of view, taking into account three success criteria: low costs, CO_2-reduction and multiplicity. Regarding the scaling: we have made the following definitions for the single categories:
- ***Low costs:*** The target of 100% low costs is reached, when CO_2 reduction costs are lower than 1 EUR/ton CO_2. 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.
- **CO_2-*reduction:*** With respect to the CO_2 reduction, the target of 100% CO_2 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[2].
- ***Multiplicity:*** 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 it 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%.
In this paper some of the results of our analysis of case studies in 24 European countries related to CNG (23 pilot projects), BEV (21 pilot projects) and biofuels (9 pilot projects) are presented.

3.1 Analysis of projects with fuel-switching to CNG

The share of CNG projects represent about one quarter of the show cases collected and analysed in the scope of the ALTER-MOTIVE project.

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 due 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 the 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. Some specific CNG features from the analysed projects are depicted in Figure 4.

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[2] On purpose, we do not use a relative scale because from our point-of-view case studies with total larger emission reductions are preferable to those with smaller. E.g. if a fleet of 500 buses is substituted by environmental benign fuels it is preferable to a case study where one bus is switched.

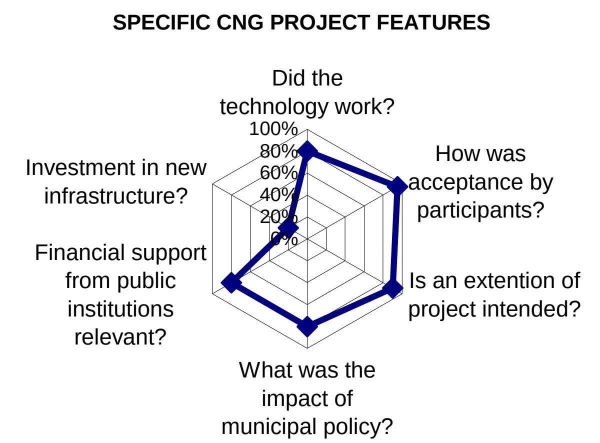	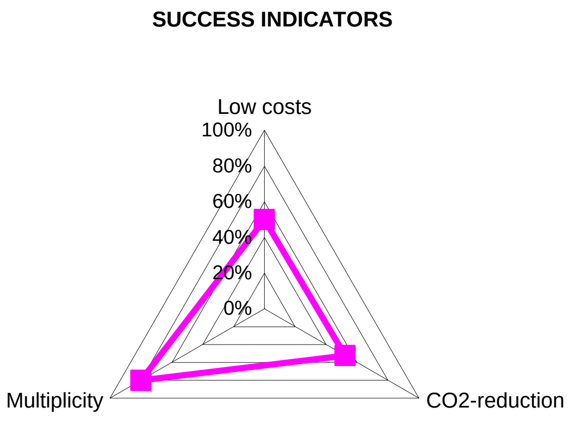
Figure 4: Specific features of CNG projects	Figure 5: Success indicators of CNG projects

As shown the impact of municipal policies as well as financial support from public institutions are 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. A big advantage is also relatively mature technology and high acceptance by all participants. Most of cases (about 95%) were public buses initiated by municipalities and could be classified as successful, see Figure 5.
As a matter of fact CNG is not a renewable energy carrier, but it ensures great environmental virtues: lower level of noise (noise could be reduced for about 4 dB in comparison to diesel vehicles) 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 (Enhanced Environmentally Friendly Vehicle) 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 PM10 and about 70% less NOx in comparison to conventional diesel vehicles.
A big advantage is also relatively easy transferability of knowledge and technology.

3.2 Analysis of projects with switching to battery electric vehicles (BEV)
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.

Most analysed case studies have been successful. Big public interest in electro mobility can also be 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)
- 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 of electric vehicles has to be improved.
From the analysed projects some specific electric vehicles features are shown in Figure 6.

As shown in Figure 6, 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.

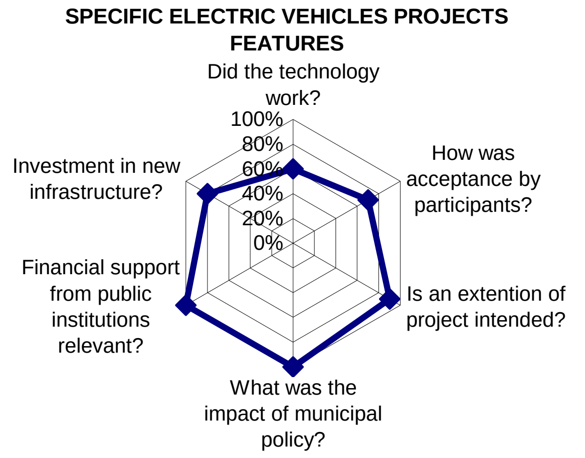

Figure 6: Specific features of battery electric vehicle projects

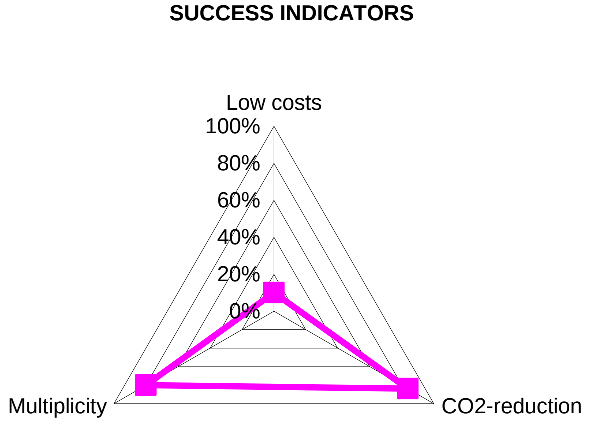

Figure 7: Success indicators of BEV projects

However, the most of the case studies related to electro mobility are successful, see Figure 7. 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.

3.3 Analysis of projects with fuel-switching to biofuels

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.

Most of the 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 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 8.

As shown in Figure 8, 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.

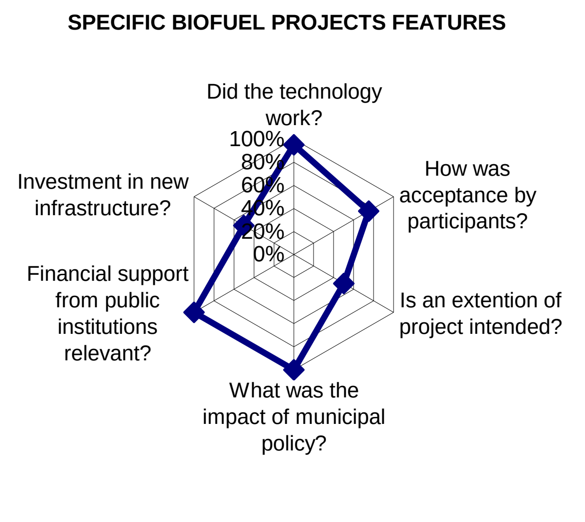

Figure 8: Specific biofuels of projects features

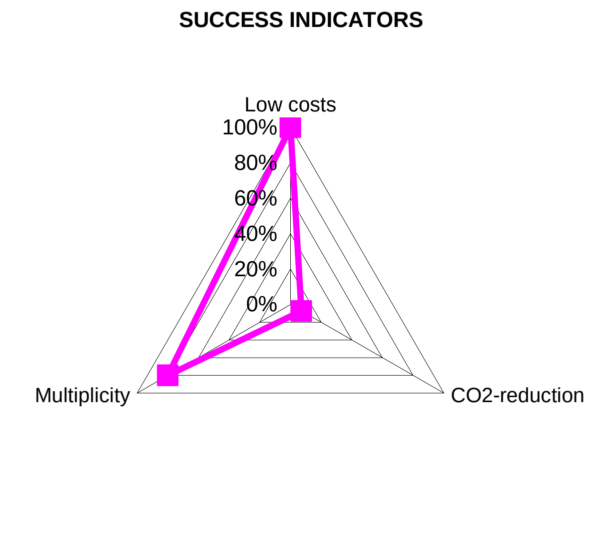

Figure 9: Success indicators of biofuels projects

However, most of the biofuel case studies were successful, see Figure 9. 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.

The major conclusion of this work is that there is a wide range of possibilities to introduce alternative, low emissions technologies and fuels in urban areas. Most of analysed 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 basic for further dissemination of alternative technologies and fuels, as well as for step-by-step construction of missing infrastructure.

4. Analysis of governmental policies

Another important issue was to analyze the effect of Top-Down policies implemented by national governmental or EU-level. The recommendations for policy makers derived from these comprehensive analyses of countries' fiscal policies are:

- Policy measures to support the introduction of an alternative fuel or technology need to be well-timed according to their current technological status. Therefore, the technology status should be carefully analysed before the introduction of measures. As sometimes the technological development and learning curve move ahead fast, close technology monitoring and flexible policies are suited best. The biggest pitfall from a policy maker perspective is tax exemptions without budget restrictions which become (very) expensive when the market share of the technology or fuel in case grows quickly.
- Each of the fuels under consideration in ALTER-MOTIVE needs a tailored approach, but also different framework conditions in the EU member states need to be considered in the choice of the policy instruments. E.g. due to the specific role of car manufactures in Germany the development of more efficient cars, BEV and FCV plays an important role in designing polices. On the other hand, due to a high share of agriculture in Poland, biofuels developments are much more important.
- The key stakeholders involved in introducing a particular alternative fuel should develop a common vision. Policy measures should result from this common vision and offer enough perspective to the other stakeholders for a viable future market.
- Generic policies like CO_2-based fuel taxes are effective to achieve an overarching goal such as CO_2 emission reduction, however the market will decide upon the cheapest technological option that not necessarily entails the biggest abatement potential in the long-term.
- Biofuels (1st gen.): Main barrier for the first generation of biofuels is cost and debate on environmental impact. The scope for cost reductions in the first-generation of biofuels is limited, so policy measures to increase the market share of biofuels are likely to be expensive. The basic choice is which stakeholder is going to bear these

costs. When tax exemptions are applied, the costs are borne by the national government and eventually all tax payers. When an obligation is applied, the costs are born by the fuel providers and eventually all fuel consumers. To increase the amount of biofuels beyond the blend limits that currently apply, measures are required to stimulate the uptake of flex-fuel vehicles (FFV). Basically, the same basic choice applies: the extra costs will be borne by all tax payers (tax exemption, vehicle subsidy) or by all car buyers (obligation to include flex-fuel capability in new models).

- Biofuels (2^{nd} gen.): The costs of the second generation of biofuels are currently too high to allow the development of an early market. Policy should for now focus on support for R&D and demonstration projects.
- LPG: LPG requires a significant fuel price discount over conventional fuels to be successful, but is only triggered when market players see a market perspective and act on that. Markets for LPG have been developed in the past without other support measures in place.
- CNG: CNG requires a significant fuel price discount over conventional fuels and a shared vision by the relevant market actors that a viable market for CNG can be developed. Since CNG is currently more popular in new vehicles than in conversions and because CNG infrastructure is relatively expensive (compared to LPG), measures aimed at direct support for vehicles and infrastructure development may be considered to accelerate early market development.
- Hybrid electric vehicles (HEV): Main barrier is high vehicle costs. Support measures that bring the costs of vehicles down are successful, especially measures that make the private use of company cars (lease) more attractive.
- Hydrogen: Main barriers are the initial cost of fuel cell vehicles (consumers) and high upfront investments in infrastructure (industry). The costs of vehicles can be brought down by (i) R&D and learning-by-doing in demonstration projects and (ii) reaping scale advantages of mass production. This requires support for R&D and demonstration projects on the one hand and direct support to bring down the costs of the first batches of vehicles on the other hand. Infrastructure investments can be triggered by implementing measures that offer a viable long-term perspective to fuel providers, but also by more direct measures such as investment subsidies and accelerated depreciation. Locally initiated hydrogen implementation projects (bottom-up) can provide first experiences with technology and grow out into corridors (links) to other hydrogen application centres. With limited availability of hydrogen passenger cars, public transport buses or niche applications such as materials handling can be a starting point.
- BEV: Main barriers are high initial vehicle cost (battery cost) and infrastructure roll-out cost. Support should aim to lower cost through battery R&D and demonstration projects (learning by doing and volume effects). More experiences need about what coverage of charging infrastructure is required by end-users. Consumer incentives are suitable to provide a financial relief to reduce initial high vehicle cost (due to battery cost), either in form of tax incentives or a direct subsidy.

For more details about effective policy instruments see Bunzeck et al, 2010.

5. Development of a dynamic Action plan

The Action Plan is based on the work done in the scope of the ALTER-MOTIVE project, but also on the feedbacks from policy makers, experts and stakeholders from different European Member States. The results documented and the recommendations derived in the Action Plan are based on the method of approach depicted in Figure 10.

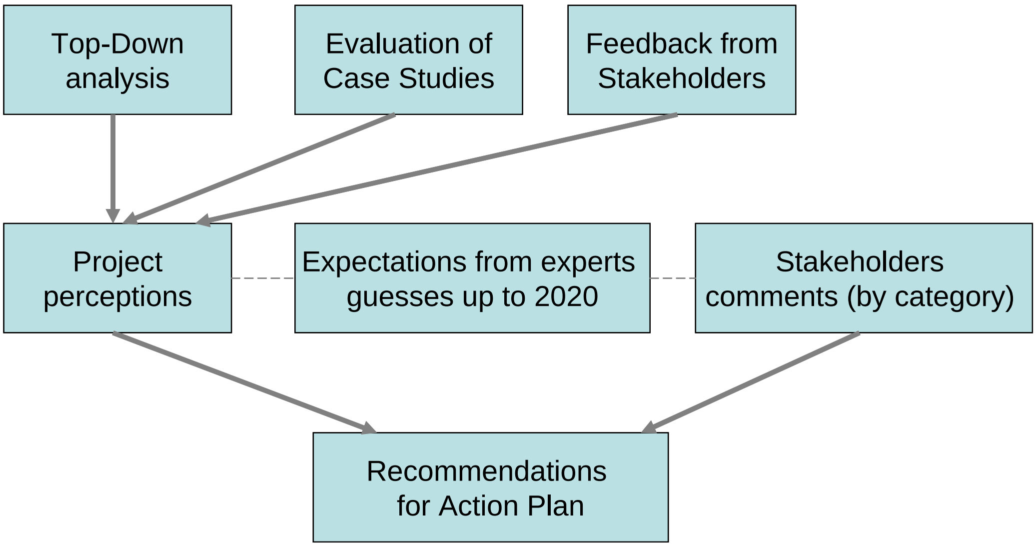

Figure 10. Action Plan: Method of approach

Its purpose is to serve as a "living document". It will be continuously updated and completed until the end of the project taking into account comments and suggestions from interactions with stakeholders, policy makers and experts.

The major results of our analysis in the project ALTER-MOTIVE are:

- ***Implement a burden-free effective portfolio of standards and fuel taxes***
  An important policy measure to reduce fuel consumed per km driven is the enforcement of standards. For km-specific CO_2-emissions (and implicitly fuel intensities) the EU aims to meet a target of 95 g CO_2/km for 2020. The scenario analysis in ALTER-MOTIVE shows that an improvement of standards for the aggregate of all segments of sold vehicles in every country linked to an emission target of 75 g/km CO_2_equ (based on the test cycle monitoring) cuts CO_2 emissions by about 12% up to 2020. It is important to state that a large share of this effect could mainly come about from switch to smaller cars!
  A very important aspect in this context is that accompanying to standards the introduction of fuel taxes is forced. This is important because of the following aspect: Due to the introduction of standards the service "km-driven" becomes cheaper. This leads to a rebound effect leading to more km driven. This rebound can be compensated at least partly by the simultaneous introduction of a fuel tax. In this case with a suggested overall tax increase of 20% we reduce the rebound at least by about the half and for customer the service still remains cheaper.
  So in this policy portfolio, despite the introduction of the fuel tax there is no additional burden put on customers. On contrary: They benefit finally from cheaper service prices and can afford to travel more kilometres with the same budget!

- ***Develop infrastructure for "emission free" vehicles***
  Battery electric vehicles and fuel cell vehicles may to some extent contribute to a relief of over-all CO_2-emissions and may especially in cities contribute to improve air quality.
  Yet, the overall ecological performance of BEV strongly depends on how electricity is generated, how the battery performs ecologically and whether actually conventional passenger cars are substituted or additional transport is triggered. Hence, it is recommended that the electricity supply industry and municipalities design joint roadmaps for an efficient development of infrastructure.
  Moreover, in parallel to the market introduction of emission free vehicles the corresponding deployment of new renewable electricity capacities must be ensured and proven by certificates.

- ***Biofuels first generation: tighten standards – ensure better performance!***
  Biofuels are expected in many policy directives and scientific papers to have the potential to contribute significantly to reducing fossil fuel consumption and corresponding CO_2 emissions.
  Indeed, in recent years biofuels 1^{st} generation (BF-1) – Biodiesel, bioethanol, biomethane – have entered the fuel market in significant amounts, see Ajanovic ed., 2009.

Yet, they are still under discussion mainly because of their currently poor ecological and energetic performance. In 2010 BF-1 had overall about 40% lower CO_2-emissions (on a WTT basis) than fossil fuels (FF) (EC, 2008), see Figure 11.

To cope with this problem measures must be implemented that ensure that the ecological performance and energetic of these BF-1 improves and net specific CO_2-emissions are reduced significant up to 2020. One strategy to cope with these problems is to pursue a strict path towards an improvement o BF-1 to "Renewable fuels" (see EC, 2009) leading to 60% less CO_2-emissions of BF-1 by 2020. This is strongly recommended along with certification and monitoring schemes!

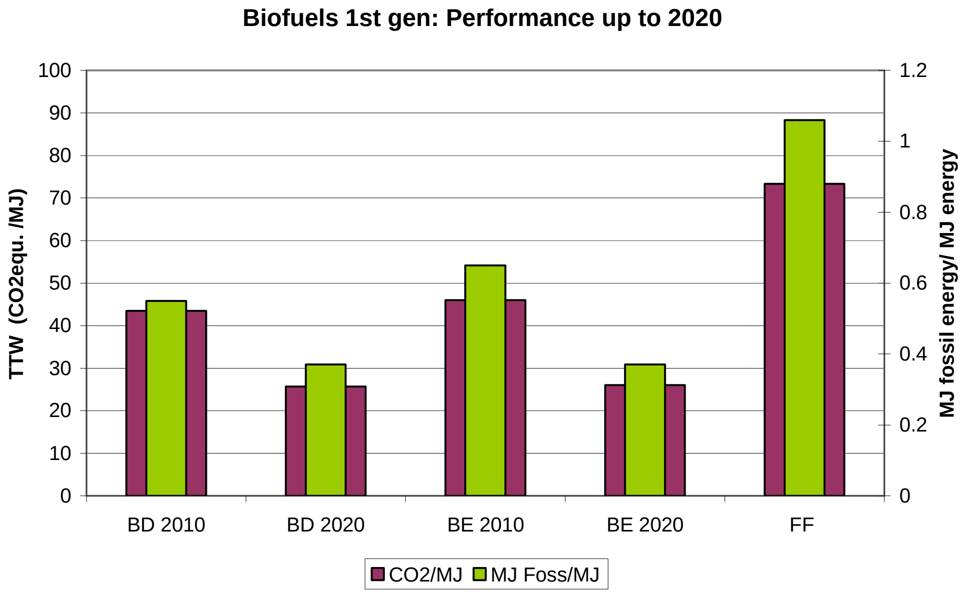

Figure 11. Necessary development of performance of biofuels first generation to meet "Renewable fuel standards" (EC (2008), EC (2009))

In addition passenger cars might not be the priority target for biofuels, freight transport could make more sense!

- ***Emphasize efficient R&D for second generation biofuels and hydrogen***
  The time horizon of this project is 2020. Within the remaining period it is very unlikely that either 2nd generation biofuels or hydrogen enter the market in a significant quantity. Yet, to harvest the benefits of these fuels it is important to undertake the necessary steps in the next years.
  For hydrogen it is important that the preparation of the ideal infrastructure is planned and forced continuously. Moreover, it is very important that R&D is intensified focussing especially on a more efficient conversion of feedstock and primary energy carriers into these alternative fuels. This should finally also lead to more cost-effective production paths and market competitiveness beyond 2020.

6. Conclusions

The major conclusions of this project are:

(i) Case studies for AF and AAMT are successful in the sense that they achieve local CO_2-reduction and receive high local acceptance. But from a global point-of-view they are of minor relevance if no effective additional dissemination mechanism is implemented;

(ii) With respect to alternative fuels, biofuels have the potential to gain significant market shares of about 20% up to 2020. However, due to the moderate ecological performance CO_2-reduction will only be small. Hence, it is important to ensure that specific CO_2-emission of 1st generation biofuels are decreasing continuously to a level of 40% of fossil fuels in 2020;

(iii) With respect to AAMT the potentials for market penetration and CO_2-reduction up to 2020 are very limited for all three major technologies (BEV, fuel cell cars and flex-fuel vehicles). In an optimistic scenario the number of BEV in EU-15 will grow to a stock of about 650.000 cars in 2020 leading to less than 1% CO_2-reduction (because the overall stock of cars is about 200 millions).

(iv) Finally it is important to state that in the future a very broad portfolio of policy instruments (taxes, standards, quotas, emissions free-zones…) will be necessary to reduce energy consumption and straightforward CO_2 emissions significantly. There is no "one size fits all" measure or technology that has the capability to solve all problems alone.

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[3] All reports used for the paper are available for download from www.alter-motive.org