ALTER-MOTIVE

Strategies for the introduction of alternative fuels and automotive technologies

Analysis of effective policy instruments

A report compiled within the European research project

Deriving effective least-cost policy strategies for alternative automotive concepts and alternative fuels-ALTER-MOTIVE

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Introduction

Alternative transportation fuels and automotive technologies are one key element to reduce GHG emissions from the transport sector and contribute to the achievement of limitation of climate change targets such as the -80% overall emission reduction in 2050 compared to 1990 levels for developed countries as indicated by the UNFCCC. The present report provides new insights regarding the available policy options that can support the introduction of non-conventional fuels such as biofuels (1st and 2nd generation), CNG/LPG, and the role of electric vehicles. Within the Alter-Motive project horizon until 2020, it is expected that the impact on emission reductions from the various non-conventional technologies differs and substantial reductions are still expected from conventional fuels due to efficiency improvements and hybridization of drive trains.

Aim and approach of this report

This report is part of the Alter-Motive project and analyzes the potential of different policy measures to facilitate the introduction of sustainable fuels in the EU up to 2020 and beyond. Due to the variety of fuels, technical solutions and technical and market maturity, particular attention needs to be paid to their stimulation by means of policy support. The aim of the study is to provide recommendations to policy makers about the potential policy solutions. The methodological approach takes into account the technological development status of each fuel/technology by applying the S-curve approach that defines the current technological development status and measured market penetration. Our research is based on literature research and expert interviews and supplemented by insights from 40 alternative transport case studies during the course of the project.

General results

Through the analysis of the current technological status of the respective technology, specific barriers for each technology could be identified. Barriers (such as market readiness, cost or fuel supply) can be tackled and overcome through different policy measures. Basically, policies to facilitate the introduction of alternative fuels e.g. to overcome barriers can be divided into four categories named after their objective: Protection, Competition, Regulation and Obligation (see figure 1). In each of the technological development phases, different policy measures exist that can help the specific technology overcome barriers that prevent their increased market penetration or to regulate the market towards a more environmental friendly technology. In reality, the policy measures cannot sharply be divided and will have an overlap between the phases. It is therefore of high importance to closely monitor developments and design policies in a way that they can respond to a new situation. Also, technical mature technologies are more prone to be stimulated by means of top-down (mostly generic) approaches such as vehicle taxation, while technologies in an early development stage can benefit from bottom-up (on national level) approaches such as local applications.

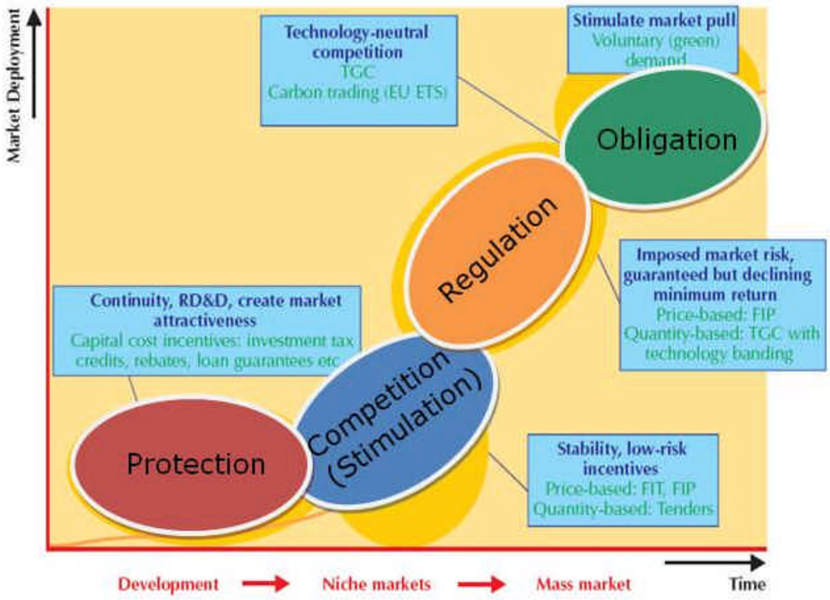

Figure S.1 *Policy objectives and measures along the technological development curve [IEA 2008, adapted by ECN]*

Fiscal policies, such as vehicle and fuel taxation are widely applied with today's conventional fuels, with the objective of increasing overall energy efficiency of the transport sector. Those policies can be either levied on the vehicle or the fuel. A recent case study on Scandinavian countries showed that one-time measures such as a vehicle purchase tax do have an influence on the car sales and the choice of the model. Further on, the calculation basis of annual vehicle taxes changed from being previously based on weight or cylinder volume of the engine towards a model that is based on the vehicle's CO_2 emissions. This method is seen as a more direct way to influence consumer car purchase decisions based on its emissions performance, but that depends on the cap put in place, i.e. whether it provides a benefit or imposes an additional penalty for the consumer.

A stricter limit compared to today's targets (EU: 130g/km CO_2 in 2015), e.g. <100g CO_2/km could trigger the shift to more energy efficient and environmentally friendly cars more rapidly. The case study also concludes that taxation on transport fuels influences the overall mileage driven per car and also the choice of the car itself during the car purchase process. Another type of fiscal measures can be applied to the use of the road infrastructure, e.g. by means of congestion charge. Currently, such charges are levied in London, Stockholm and Oslo. This instrument can be particularly effective in decreasing local pollution, but needs to be introduced in tandem with public transport improvements.

Measures that in their design are not specific towards any type of alternative fuel ('generic policy') can help to overcome barriers (e.g. high costs) that prevent alternative fuels to enter the market by themselves. In that sense, this type of policy provides a backdrop for measures that do target specific alternative fuels ('specific policy'). The aim of specific policy is to provide extra incentives that render these fuels so attractive that they can overcome their barriers and enter the market.

Specific/General policy
Specific policy can be successful in stimulating the uptake of alternative fuels. Biofuels, liquefied petroleum gas (LPG), compressed natural gas (CNG), and hybrid-electric vehicles HEVs have all been successfully stimulated by specific policy measures. Generally, the success of these measures is to a large extent dependent on whether the incentive they provide is

sufficiently large enough to become economically competitive[1]. However, promoting alternative fuels is only worthwhile if there is sufficient perspective that the barriers that these policies tackle are solved permanently in the longer run. The costs and other implications of specific policy measures are typically acceptable in the short run and with relatively low market shares, but become infeasible to sustain in the longer run and/or with larger market shares. There are two situations in which the application of specific policy measures is justified: to 'kick-start' a market and to trigger learning-by-doing.

In the previous case, a combination of barriers exists that makes private actors hesitant to start commercial activities with respect to an alternative fuel. The chicken-and-egg dilemma is an excellent example for this. Specific policy measures may provide incentives for a first batch of consumers to switch to an alternative fuel and convince stakeholders that a viable market exists. After this first introduction, the policy measures should be gradually phased out. Note that this requires that the alternative fuel is in principle competitive with conventional fuels, e.g. have intrinsically lower cost or comparable to that conventional fuels (excluding taxation)[2].

In the latter case, cost reductions, technological improvements and information required to enter the early market phase (e.g. consumer behaviour) should be collected through learning-by-doing. Support for demonstration projects, but in some cases (e.g. HEVs) also support to create an early market, are warranted, since these measures offer the perspective that the cost and other aspects (e.g. move to sustainable fuel production) of the alternative fuel can become competitive with conventional fuels.

At any rate, policies need to adapt over time to changing conditions. Once measures aimed at creating an early market (primarily tax exemptions and subsidies) become successful, they will become very budget-intense and should be phased out. In case the alternative fuel has now reached competitiveness, the measures have to be adjusted to avoid overcompensation. In case the alternative fuel is not (yet) competitive, measures such as an obligation to supply (a certain percentage of sales) the alternative fuel could be introduced instead[3]. Following this procedure is in line with the approach that the S-curve framework suggests.

The S-curve approach also suggests that proceeding through the various innovation stages is a linear process. In practice, this is not always the case. EVs are a case in this respect. A major barrier for EVs is their limited driving range in combination with long charging times (compared with conventional refuelling). This can be solved in various ways, e.g. the development of batteries with higher specific capacities (through R&D), the development of battery exchange programmes (R&D/demonstration), the development of fast charging solutions (R&D/demonstration) or the willingness on the part of consumers to only use EVs for relatively short trips (demonstration/early market). Hence, even though a barrier may seem to require correction in a particular phase, it may be overcome by new solutions of developments in the next phase. Therefore, it makes sense in some cases to support an innovation moving into a next phase even before all barriers have been solved, provided there is a perspective that the barrier can be solved in the next phase. In the case of EVs, it makes sense to support R&D programmes, initiate demonstration projects and stimulate early (niche) markets, all at the same time. Another approach are to support business developments that can later more easily make use of market dynamics to tackle further barriers.

1 Note that economic competitiveness may differ between countries/regions and between technologies/fuels.

2 It is unclear to which extent this is the case for the alternative fuels that have been studied in this report. In general, even fuels that are not more expensive than conventional fuels (e.g. CNG, LPG) proved not competitive with conventional fuels after support measures were reduced.

3 In the latter case, the costs of subsidizing the alternative fuel are shifted from the government budget to the consumers of the fuel (via the fuel providers).

Next to being balanced over time, policy packages should be comprehensive in the sense that all major barriers relating to a particular technology need to be addressed. Not all of these barriers are equally important, however. LPG can be taken as example. In some countries, only an incentive that keeps the cost of LPG fuel low (e.g. a very low excise duty in the Netherlands) was in place. Nonetheless, this incentive has provided sufficient market perspective for entrepreneurs. Consequently, the development of infrastructure was triggered in the absence of dedicated policy support by market forces. It is therefore wise to only address the major barriers in each technology and leave solving the remaining barriers to the market.

However, it is not guaranteed that a policy measure that brings down the cost of LPG to the consumer will trigger a market for LPG. In many cases, the entrepreneurs have to undertake (risk) investments that enable the provision of the alternative fuel to consumers. The willingness of private parties to undertake these investments can be enhanced by the appropriate policy measures. The role of the government is to bring the relevant stakeholders[4] together and to develop a common vision on what is required to make the introduction of the alternative fuel a success. This includes common identification of major barriers and actions to be undertaken by all stakeholders involved to overcome these barriers. The result of this approach can be that only a subset of barriers is to be addressed by specific government policy measures[5]. Finally, some measures are clearly the most effective when applied at a certain policy level.

Table S.1 provides an overview the role various levels of government could play in selected specific policy measures.

Table S.1 *Appropriate levels for implementation of specific policy measures*[6]

European level	
Standardisation	Codes, regulation and technical standardisation should be designed for an application as broad as possible to ensure interoperability across borders. Preferably, these should be set at global level. If that is not feasible, they should be set at European level.
R&D	Supporting R&D at a European level allows for programmes that are large enough to tackle major barriers. Another role for the EU is to coordinate the various national R&D programmes.
Large-scale demonstration & rollout	Some technologies (such as fuel cell vehicles) require a (costly) rollout on a large scale. The EU level is therefore the most appropriate to coordinate the rollout of these technologies.
National level	
Fiscal measures	Although the discussion for more fiscal harmonisation is ongoing, fiscal systems are currently still defined at national level. Hence this is the most appropriate level for this type of policy measure.
Local/regional level	
Demonstration projects (execution)	The practical implementation of demonstration projects takes place at the local level. Demonstration projects are often introduced with accompanying measures as support.
Accompanying measures	Measures such as reduced parking tariffs and exemption of congestion charge are related to local circumstances. These measures may even help solve local issues such as air quality problems.

4 Typically, these will include stakeholders with an interest in the vehicle (car manufacturers, car dealers, car lease companies, maintenance companies) and stakeholders with an interest in the fuel (fuel producers, fuel distributors, fuel providers).

5 The approach suggested here is comparable to the approach called 'network management' (Kleindienst Muntwyler et al, 2010).

6 The overview of policy measures in this table is not exhaustive, but only includes those policy measures that are more effective when applied at the level that is indicated in the table.

More than 40 case studies from alternative transport case studies have been analyzed with respect to their policy measures and successes. Most of the case studies took place on a city or regional level, only a few cases looked into the country wide deployment of new transport fuel or technology (mostly delivery companies that operate in a wider environment or maintenance companies). The technological focus of the cases is more into mature technologies such as CNG/LPG and biofuels, which have the highest number of case studies. The reason to focus on mature technologies is low upfront investment costs for the operators. In most cases, the alternative fuel was applied in the public bus fleet or other, municipality related fleet such as cleaning or waste collection.

Less mature technologies with currently low market penetration and little or no available infrastructure such as hydrogen fuel cells and electric vehicles are introduced via projects financed by the European Commission, due to their high upfront investments. One of the examples is the HyFleetCute project that deployed 47 hydrogen buses in 10 European cities to demonstrate their everyday feasibility. However, after the end of the project the technology could not be continued due to non-availability of vehicles.

Key recommendations for policy support to introduce alternative fuels:

- 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 are 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.
- 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 are effective to achieve an overarching goal such as CO_2 emission reduction, however the market will decide for 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 (2nd 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.

- 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. However, HEVs may not offer the most cost-effective option to reduce vehicle emissions.
- 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.
- EV: 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.

1. Introduction

1.1 Alter-Motive project

This report is part of the ALTER-MOTIVE project financed within the Intelligent Energy Europe program of the European Commission. Our objective is to analyze policy effectiveness in the context of the introduction of alternative fuels and alternative automotive technologies. By means of our analysis, we aim to provide policy makers with the necessary tools in selecting the right policy for their specific goals, e.g. the facilitation of a certain clean technology or overall environmental policy objectives.

It is the goal of the Alter-Motive project to create an action plan for the application of effective policies that can help to increase the uptake of new and sustainable transport technologies, e.g. biodiesel, LPG or electric vehicles. During the project, it is also planned to establish scenarios for the future uptake of alternative fuels up to 2020. Therefore, one first needs to know what effective policies are and how they can be characterized in the context of alternative fuels. Based on this, recommendations can be given on how each technology might be supported best by policy measures. It is expected that quite different measures have to be applied for each of the technologies as their stage of market introduction varies significantly, meaning that some are already widespread while others still remain in R&D stage.

Overview of the alternative fuels and alternative automotive technologies investigated in the Alter-Motive project:

Alternative Fuels (AF):
- Bioethanol
- Biodiesel (FAME)
- Synthetic Fuels
- Biogas
- Hydrogen
- Renewable Electricity
- Compressed natural gas (CNG)
- Liquefied petroleum gas (LPG)

Alternative Automotive Technologies (AAMT):
- Electric vehicles, including battery-electric (BEV) and plug-in hybrid (PHEV)
- Hydrogen fuel cell
- Hybrid systems (HEV)

1.2 Objectives

Within Alter-Motive, ECN is leading the analysis of the policy effectiveness for the introduction of alternative fuels and alternative automotive technologies in the market. The core objective of the current report is to analyze and evaluate which policies instruments are most appropriate to facilitate the introduction or dissemination of the above listed AF and AAMT technologies.

The various technologies in question are in a different stage regarding their technological maturity and market position and have different barriers that have to be tackled by policies. For new technologies it is hard to enter the market and compete with the existing and established reference technology. High initial cost, start up problems, lock-in, are just some barriers which have to be overcome for the new technology to succeed. Governments are in the unique situation to address these barriers by means of policy support. However, due to the variety of technologies and there specific characteristics there is no such thing as *'one policy fits all'*. This report should be considered as main outcome of work package 5 of Alter-Motive in which the effectiveness of policy measures related to the introduction of alternative fuels (AF) and alternative automotive technologies (AAMT) will be evaluated.

1.3 Research questions

The research question to be answered can be summarized as follows:

- What are potentially the most effective policy support mechanisms stimulating the various technologies in the different development phases over time?

The main research question is broken down in a number of sub-questions:

- What are the different technology development stages and what are their characteristics?
- In what stage of technology development are the different technologies focused upon in the Alter-Motive project?
- Which policy instruments exist and are most effective to stimulate technology development at the various market stages?
- Which policy instruments should be used in each stage of the technology diffusion process of the different technologies?

The report is structured in six chapters. After the explanation of the objectives, the second chapter will explain in detail our conceptual framework for the report, based on innovation policy and putting each technology on a development curve. In the next chapter, we will briefly explain in which phase each of the technologies is at the moment and what measures can be undertaken to support their introduction. We first discuss policies on conventional fuels, which form the backdrop for measures targeted at specific alternative fuels. These specific measures per technology are discussed next, including an assessment of their effectiveness. As a support for the policy effectiveness, we will try to provide a picture about policies on conventional fuels. To strengthen our approach we will also research the outcomes of 80 recently introduced policies that supported the introduction of alternative fuels. Through our theoretical framework, it should be possible to evaluate the policies later on.

2. Conceptual framework

2.1 Research approach

The framework represents our methodology to address the research questions and provides a solid basis for the further analysis in the project.

In the first step, the AF & AAMT technologies that are in the focus of the Alter-Motive project will be linked with available policies measures that aim to facilitate their introduction in the market or increase their overall share by tackling barriers. Secondly, we will introduce the different development stages of technologies and discuss the status of each technology in question.

Our methodology consists of a two-step approach. First, a theoretical framework will be created that provides insights about technology development and available top-down policies, see Chapter 3. It is important to mention that policy effectiveness will be evaluated on the basis of their correct application along the technology stage. Therefore, it needs to be closer analyzed which relationship between the technology development and policy instruments exist. Policy instruments are not necessarily universally applicable, thus it needs to be differentiated between generic and technology specific instruments. The theoretical framework will already provide us with insights on the relationship between technology development and policies. In addition, it provides a 'baseline' scenario what can be expected to be used in practice for the stimulation of technology development.

In the second step, we perform an evaluation of current policies on alternative fuels and automotive technologies in Europe. The discussion includes European policies and a number of representative case studies per fuel. From the evaluation, we extract conclusions and recommendations on policy measures per fuel. The evaluation also provides insight to what extent the theoretical framework is useful as a guide in designing policy measures.

Additionally, our theoretical framework is also tested against the outcomes of 80 case studies that will be studied in the Alter-Motive project. The case studies are recent examples of introduction of alternative transport technologies or fuels and provide data on the mechanisms used and their impact. By means of real-life experiences the theoretical framework is further calibrated. Policy effectiveness can also be influenced by other external factors such as location characteristics that have contributed to the success of the project. We have therefore also performed a thorough analysis of impact factors that have played a role in the projects, see Alter-Motive report: *'Copy-Paste Policies. Analysis of transferability of successful policies related to alternative fuels and alternative automotive concepts in transport'* (ECN, 2010).

The outcomes of this research are translated into a toolbox with recommendations for policy makers on EU, national and local level as well as decision makers in companies and investors. In this short paper we describe our methodology for this work package including the research questions we want to answer. As an outcome of phase one, an overview of technologies as well as general or technology-specific policies will be created. This is only the result of the theoretical exercise and still needs to be verified with the data from the real-life samples in the second phase of the workpackage.

We determine effective policies for new technologies, review literature, evaluate existing policies and test with case studies in the second part . Our two-step methodology has a number of relevant subtasks: the classification of technologies and policies, the S-curve of technology development, evaluation of policy effectiveness and interdependency of policy effects and location and the build-up of the policy toolbox as final outcome. The required input on the policy level will be provided as result of the country-specific data evaluation originating from earlier review work within Alter-Motive ('D3 Country review report'). The overview will consist of detailed data on the respective technology and policies that have been applied. In addition, literature research will be carried out to complete the policy overview. Projects that have been researching particular fuels or technologies such as Refuel or HyWays [Refuel 2008, HyWays 2007] will also be taken into account to refine the technology-policy linkage.

Additionally, the effects of various transport taxation schemes (registration tax, car owner tax) and the effects of fuel taxes on the energy efficiency of cars are analyzed to cover the period once a technology has reached maturity.

2.2 Rationale for policy support to introduce alternative fuels

Currently, passenger road transport is still very much dependent on fossil fuels derived from crude oil. Yet, the use of fossil fuels has adverse effects, ranging from energy security issues to a contribution to global warming through raising levels of GHG emissions. In 2008, the share of total emissions in the EU originating from the transport sector was about 19 percent[7], of which the largest share comes from land transport [EEA 2010]. Furthermore, the amount of passenger kilometres travelled in the EU-27 grew by 1.2 percent in 2007. Of all road transport modes, passenger cars remain the preferred mode in the EU-27 by 72 percent of all passenger kilometres, this percentage being virtually unchanged since 1995 [EEA 2010].

To keep global warming below 2°C the concentration of CO_2 in the atmosphere needs to be stabilised at 450 ppm[8] by the end of this century. This 2°C target has been adopted by the European Community and many other governments, and is a strong guidance in discussions with respect to post-2012 climate goals and policies.

Although a global GHG reduction target for the longer term has been defined by the Intergovernmental Panel on Climate Change (IPCC) with emissions 50% below 1990 levels in 2050, a specific global reduction target for the transport sector remains missing.

Given the future growth in transport volume (even higher growth expected in developing countries) it is nevertheless clear that the required reduction relative to future emissions in the baseline scenario is much larger even than the reduction target set relative to the 1990 reference situation. It is likely that all sectors in the EU-27 will have to reduce total GHG emissions by 50 – 80% compared to 1990 in order to contribute to meeting this overall target, see Figure 2.1. Given the expected continuing growth in transport volume the required reductions per kilometre travelled are even higher.

7 Excluding aviation and maritime transport

8 ppm = parts per million

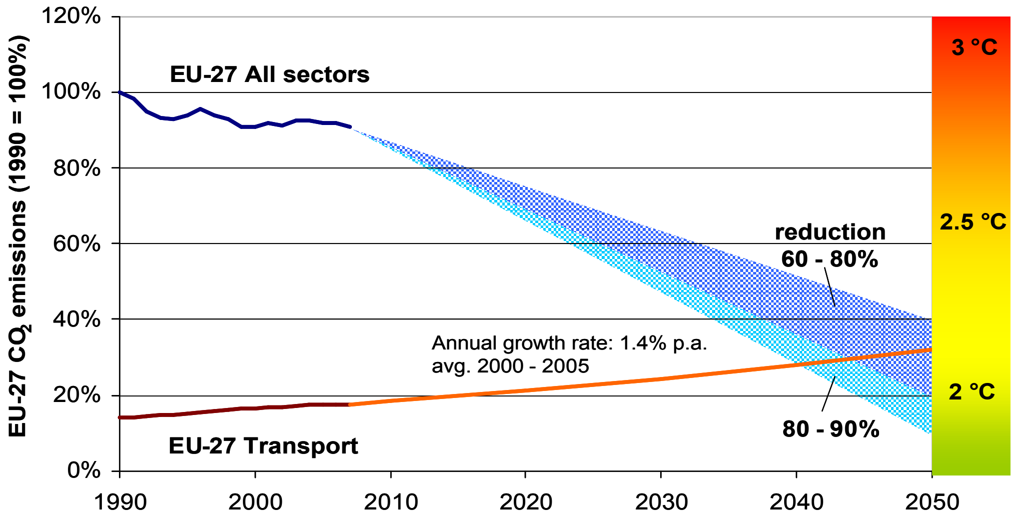

Figure 2.1 *Comparison between EU-27 emissions of all sectors and transport [graph adapted from EEA 2009]*

A reduction of passenger kilometres travelled (e.g. demand reduction, modal shift) and an improvement of efficiency (e.g. vehicle efficiency, driver efficiency) can also provide some reduction of the dependence on fossil fuels and thereby increase security of supply. However, substantial reductions, such as necessary to meet ambitious climate policy targets, amongst other options, require the introduction of AFs and AAMTs [King 2010, OECD/ITF 2010].

The problem with alternative, low or less carbon-emitting transport fuels is that most of them still need to overcome certain market barriers before they can compete with conventional technologies. Those barriers are mostly related to cost of the new technology. After a new technology has left the R&D phase it still faces a number of barriers that prohibit its widespread market adoption. In this respect a distinction can be made between incremental innovations that fit better with the existing system and disruptive innovations that have to build up a completely new system (e.g. refuelling infrastructure) to work. In the case of incremental innovation the barriers that a technology faces are mostly investment cost. Disruptive innovations such as electricity in transport and hydrogen fuel cells face even stronger barriers since they also require a dedicated infrastructure (although home recharging of electric vehicles (EV) is also a possibility, especially in the early years with low EV market penetration rates). Over time the cost of the technologies is expected to go down through two effects: technological learning effects and improvements through economies of scale.

Policy measures may help to address these barriers and help to introduce a desired technology faster into the market. Basically, a distinction can be made between 'demand-pull' and ' supply push' measures. In a perfect market, the effect will be the same, production will follow demand. In practice, stakeholders will respond differently to incentives from both sides.

Demand-side measures such as feed-in tariffs, obligations and standards can help to establish a long-term demand framework that incorporates environmental cost. However, it is a known problem that those measures are (mostly) not very effective in stimulating additional R&D spending. Supply-side policies such as investment grants and access to cheap capital have a more direct impact on companies innovative efforts. Both supply and demand measures will have an effect on the overall competitiveness of the technology. This report will analyze and present supply/demand policy measures that support the introduction of AFs and AAMTs.

2.3 Measuring policy effectiveness for AF and AAMT

The evaluation of policy effectiveness raises the question about environmental policies; are they working and are the contributing to certain goals and targets? How does this need to be taken into account in terms of alternative fuels?

Further on, the question arises what do we exactly understand by the term policy effectiveness. Hereby, a first distinction must be made between efficiency and effectiveness. Policy efficiency is mostly related to costs associated with a policy. This will not be the focus of our research undertaken in the scope of Alter-Motive. Effectiveness is related to the effects that the respective policy has induced. These can be defined in different criteria, for example (lasting) changes, market growth, rebound effects, consistency of measures, flexibility of policy to changes, etc. Thus, in order to evaluate the effectiveness of the different policy instruments, we firstly need to identify criteria to measure the effectiveness.

How we are measuring the effectiveness of policy instruments of AF and AAMT?
1. Comprehensiveness
2. Timing
3. If applicable, market shares in an early market environment (data availability)

Although policy instruments (for example subsidies, taxes, tradable permits, covenants, environmental standards, economic incentives, etc) play an important role in the technology development and diffusion, literature also says that the latter "are not a simple response to a regulatory pressure" (Kemp, 2000, p.36). Policies and other regulations are thus often an extra stimuli for the exploitation of environmental friendly technologies but cannot be considered as the "be-all and end-all" of innovation. According to Kemp there is no best policy instrument to stimulate clean technology and therefore it is best to combine instruments and benefit from the synergistic effects. The OECD comes to similar conclusions and writes that there is a large potential for improvement in policy design via policy mixes and only a limited number of renewable energy technology policies so far are effective (OECD, 2003 and 2008).

The effectiveness of a deployed policy support depends on the market stage of the respective technology. The policy measure needs to be exactly timed on the specific barriers that the technology faces at that very moment. If policy measures are applied too early, unrealistic goals can be set (e.g. targets for market penetration of electric vehicles in the demonstration phase, limited vehicle availability). On the other hand overstimulation (i.e. policy measures that aim on problems that have been solved in the meantime) is a poor solution in terms of cost-effectiveness.

3. Technology development and related policies

The characterization of the different stages that each technology goes through during its development from laboratory to mass market is a widely studied field and we will briefly summarize the status of discussion for our report. Commonly, the distinction of market stages is done through application of the S-curve approach describing the evolution of the different stages (or phases) of technology development together with market penetration over time.

3.1 The S-curve of technology development

Before a new technology enters the market, it has to pass through different stages of growth and development, ultimately leading to broad mass market penetration. This theory also holds for new technologies in road passenger transport. Already in 1934, Schumpeter developed a distinction of different technology development phases. *Invention* is hereby the very first phase of an idea that could lead to a new product or process, followed by the *Innovation* phase that further develops the product towards a first application. After the first tests, the new technology is typically employed in a niche market environment, where the new technology has substantial advantages over the reference technology. After successful introduction in niche markets the technology is exposed to a broader environment in an early market setting in the *diffusion phase*. But, also market (demand) will be *saturated* at some point in time. Then the cycle starts from the beginning when a new, superior product enters in the senescence phase [Gruebler et al 1999; IEA 2008]. Considering time and market share as factors, the development takes the form of an S-curve, see Figure 3.1 .

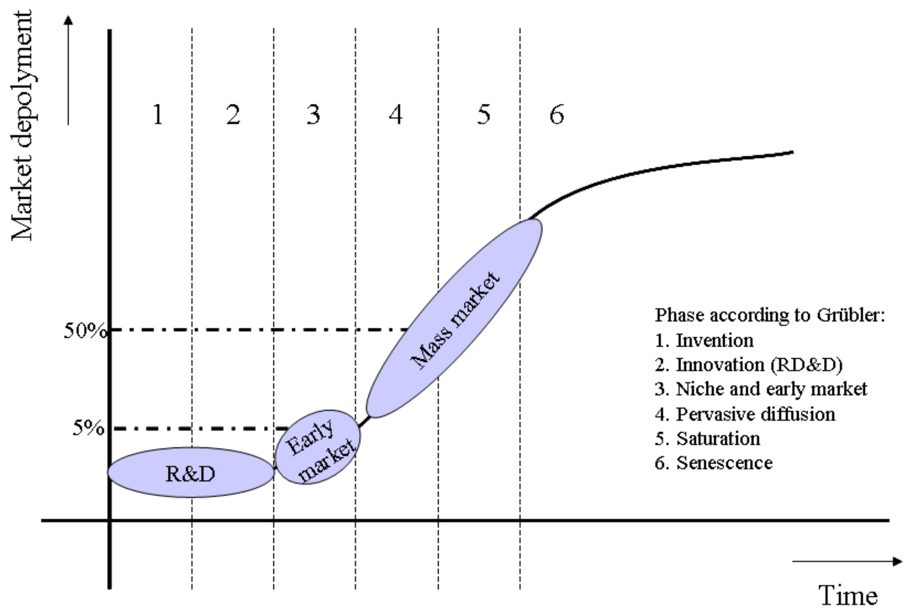

Figure 3.1 *Stages of technology growth and development [adopted from Gruebler, adopted with market stages by ECN]*

The S-curve divides the development trajectory in roughly three phases. In our framework the technology development theory is used to describe each technology since each phase has its unique characteristics. Each of the Alter-Motive AF and AAMT technologies will be located on the curve through an assessment of their current technological status.

3.2 Policy support schemes

During the technology innovation process, policy measures can stimulate and push a technology through each of the stages. For each technology stage, different policies are required as also different (technology-specific) barriers have to be tackled. The objectives of policy support measures are aligned with four different stages (R&D, Demonstration, Early commercialisation, mass market) of the technology development curve, briefly elaborated in the following. In reality, the policy measures cannot sharply be divided and there will be an overlap between the phases.

The evolution of policy support measures can be aligned on the stages of technology evolution as depicted in Figure 3.1. As a general principle, less mature technologies that are still away from economic competitiveness require very stable low-risk incentives next to continued R&D support.

In the first phase, invention, or R&D phase it is mainly important to provide an investment relief to the manufacturer for the further up-scale of the technology. Therefore, incentives in this stage are mainly to provide financial support to develop and test the technology further. As the technology moves to demonstration and subsequently to pre-commercialisation the policy focus should shift to reaching cost-competitiveness with the reference technology and provide incentives to be taken up by the end-consumer through provision of incentives, mainly fiscal ones. As the mass market comes along with higher production numbers, this also positively influences the unit price due to economies of scale effects. Once the technology is fully commercialized also cost-competitiveness with the reference technology should be reached. In this stage, the policy instruments should predominantly have a regulatory character. Further on, technologies can be nurtured through e.g. setting of quotas.

Combination framework of policy incentives as a function of technology maturity

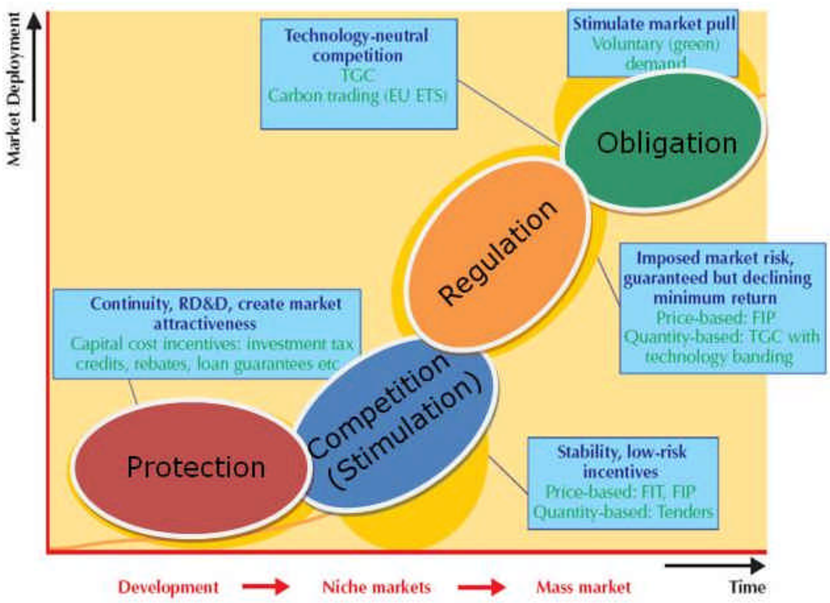

Figure 3.2 *Policies on development curve [IEA 2008 adapted by ECN]*

As demonstrated above, policy measures need to follow the technological development and therefore different measures have to be applied accordingly. On a broader level, the policy measures can be grouped into four categories: Protection, Competition, Regulation and Obligation, see Figure 3.2. It should be taken into account that in reality, the phases (and thus, the type of measures) cannot be sharply separated and most often there will be a seamless transition of technology through phases. In the following, we will present a (non-exhaustive) list of policy measures that can typically be applied in the selected policy category.

3.3 Protection

When a new technology is in its early phase of R&D and has barely left a laboratory environment, it is primarily important to provide an investment relief for the further upscaling of the technology. The incentives in this stage should therefore focus on financial support to the developer/producer to further improve and test the technology.

3.3.1 R&D subsidy

An R&D subsidy should ideally cover all cost involved in conducting R&D. This includes labour cost and cost related to the purchase of new equipment and dissemination cost. National programmes mostly directly support R&D for technologies that are far from commercial implementation and focus on basic research. Within the EU community the R&D subsidies are limited to 100% of eligible cost so that any support cannot lead to a profit for the technology developer. An advantage of R&D policies are the relatively low costs for the government (relative to e.g. tax breaks and direct subsidies), as most cost occurs for labour cost.

3.3.2 Investment subsidy

Usually an investment subsidy is handed out in the form of a grant that can help to overcome the high initial investment cost for manufacturing equipment. It is a commonly used instrument to stimulate investments in less cost-effective technologies. Investment subsidies can be differentiated in the amount over time. From a governmental perspective, investment subsidies allow governments to steer the direction of technology deployment and development.

3.3.3 Zero interest loan

One of the biggest obstacles in new and innovative energy technology projects is the high initial capital cost of projects (producer). Thus, the cost of borrowing money plays a major role in the realization of such projects. Financing assistance in the form of low-interest, long-term loans and loan guarantees can play an important role in overcoming this obstacle. For e.g. based on government funds the banks can issue low-interest loans and guarantees.

3.4 Competition

Once the technology is solid enough to be introduced in an early market environment, the focus of policy support has to be more on bringing down the cost of the technology in comparison to the reference technology. That means that the measures should aim on balancing out initial higher cost and provide incentives for the end-consumer to take up the new technology. Most commonly, this is done through the application of fiscal measures. Yet, this assumes that the price premium is on a manageable level as fiscal measures have only a certain bandwidth to influence overall cost.

3.4.1 Fiscal measures

A wide range of different fiscal measures is applied in road transport in the EU. Most countries have some form of direct vehicle taxation, based on weight or engine size. Recently, many countries have introduced direct vehicle taxation schemes based on the CO_2 emissions of the vehicle. Fiscal measures can be categorized as taxes on vehicles, taxes on the fuel and charges for the use of infrastructure.

3.4.1.1 Vehicle related taxes

Taxation on vehicles involves one time measures such as taxation during the purchase and registration, and annually levied taxes such as annual circulation taxes (road tax) and a surcharge on income taxation for private use of company cars. All EU-15 countries except France levy road taxes. The basis for the annual circulation tax varies from country to country (e.g. Germany bases it on a mixed calculation of engine size and CO_2 emissions)

3.4.1.2 Fuel related taxes

One problematic aspect of introducing alternative fuels can be their purchase price that can be significantly higher than the reference technology. Fuel tax incentives can therefore be a very effective tool to change the 'playing field' for alternative and conventional fuels. Particularly in the early stages incentives can be useful to push a technology into the market. Higher demand will stimulate the available supply that will ultimately result in lower prices.

Fuel taxation is a very direct means of stimulation because it sends a direct signal to the consumer. As taxation constitutes a significant part of government revenues, it needs to be taken account for lost revenues. Fuel tax exemptions should be reviewed from time to time and adjusted for price reductions that may have taken place.

3.4.1.3 Infrastructure charges

Instruments that charge for the use of public roads are aimed at collecting dedicated funding for construction and maintenance of the road network infrastructure. In particular heavy-duty trucks are a target for those schemes as they are supposed to have the highest damaging impact on roads. In Austria, this toll system applies to all vehicles above 3,5t, in Germany it starts from 12t. Toll roads also exist in Norway. London introduced a congestion charge in 2003 that can be understood as toll. Each vehicle needs to pay the congestion charge except some vehicles like emergency vehicles, but also alternative fuel cars and bicycles.

3.4.2 Public procurement

The government can support the deployment of new technologies by tendering the demand for it. By this, the government basically becomes a customer, raising demand and reducing uncertainty for industry. Public demand creates an advantage for the supplier as production volumes can be increased in times when private demand is not so high, ultimately leading to cost reductions. Besides, public procurement can also lead to increased awareness as the overall exposure level is raised.

The advantage of public procurement is that it stimulates early market demand, however front-runners will most benefit from it. The success also depends on whether the good example will find enough followers from the private sector.

3.4.3 Accompanying measures

Besides measures that improve the economic competitiveness of e.g. electric vehicles, further measures exist that increase the attractiveness of the vehicle via non-monetary measures. From such accompanying measures, particularly car drivers in urban areas can benefit from switching to an alternative fuel vehicle. Some examples are the use of free parking in inner cities (possibly combined with free charging nearby), the use of taxi and bus lanes or similar systems. In the US, high occupancy lanes (HOV) which normally require at least two persons in the car could be opened to electric vehicles without achieving the occupancy objective.

3.5 Regulation

When a (formerly) new technology has reached the phase of being able to compete with the (existing) reference technology, e.g. that it has reached a stage of (near) cost competitiveness, the support schemes should become more generic and open up competition between technologies.

Competing technologies that contribute to the same policy objective should receive the same (or no) support and in the end, it is left up to the market to decide which technology will be the preferred choice. So the application of technology specific or generic support also depends on the technology development stage.

3.6 Obligation

After a technology has established a foothold in the market and proven its technical (and preferably economical) feasibility the government can further facilitate the introduction by mandate the production and use of a certain technology that requires the technology producer, but ultimately also the end-user to switch. As these measures can have serious effects on the market, it should be carefully considered whether supply can satisfy the demand that will be created by the mandate.

3.6.1 Quota obligations

A quota system introduced by the government obliges all market actors to achieve these quota. The EU Directive on the promotion of the use of biofuels[9] or other alternative fuels in transport is an example of an obligation. Under this directive, the EU Commission mandates EU countries to blend a certain amount of biofuel with gasoline and diesel.

From the governmental perspective obligations promise almost certain fulfilment of policy goals as obligations are mandatory. Nevertheless, too ambitious or costly obligations can cause resistance among market players.

3.6.2 Standards

By the setting of standards, a minimum amount of a technology will be required to be utilised in the market. The standard can either be technology based, but it can also be the requirement of information provision to the end-consumer. The general idea behind a standard is that the consumer is forced to buy the most efficient technology on the market and pushing an (environmentally) inferior product out of the market. One example is the EU regulation to phase out incandescent light bulbs until 2012 in favour of more energy efficient fluorescent bulbs[10].

In Europe, the fuel quality directive (FQD), which was adopted in 2008, sets a 10% target to reduce greenhouse gas emissions (GHG) from transport fuels by 2020 compared to 2010 Achieving a 6% reduction is mandatory, while the other 4% are voluntary.[11]

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9 Directive 2003/30/EC

10 Ecodesign Directive (2009/125/EC)

11 Directive 2009/30/EC

Introducing a standard can have effects on the producer: if his products do not meet the standard he will be forced to switch technologies. Also, standards are hard to set. It should be strict enough to speed up the innovation process but at the same time not request unrealistic targets. Usually the market already anticipates the introduction of standards (through the political debate) and then the situation can occur that the standard is already outdated once introduced.

A softer approach to standards is when the mandate is to provide information to the consumers rather than set limits on manufacturing. This often takes the form of labelling. Due to the extra information of consumers, labels directly address the market failure arising from the lack of information. Labels have already proven effective for several appliances that have swept the inferior ones out of the market. In the European Union, legislation exists that requires car dealers to display information about the potential car's energy consumption and CO_2 emissions.[12] The commission has also published a communication stating that in 2010, a review of the existing directive will be undertaken. The presence of innovative technologies and their impact on the vehicle specific CO_2 emissions should be communicated properly to the member states responsible for the monitoring and reporting in accordance with the regulation. The commission also plans to introduce requirements for fuel economy meters as means to encourage energy-efficient driving.

3.7 Policy measures on the technology development curve

The policy measures that have been discussed briefly can be allocated along the S-curve of technology development, see Figure 3.3. This gives an impression on how the measures can be allocated during the development, however to choose the measures properly one would still need to know more details about the current status of development for the respective technology.

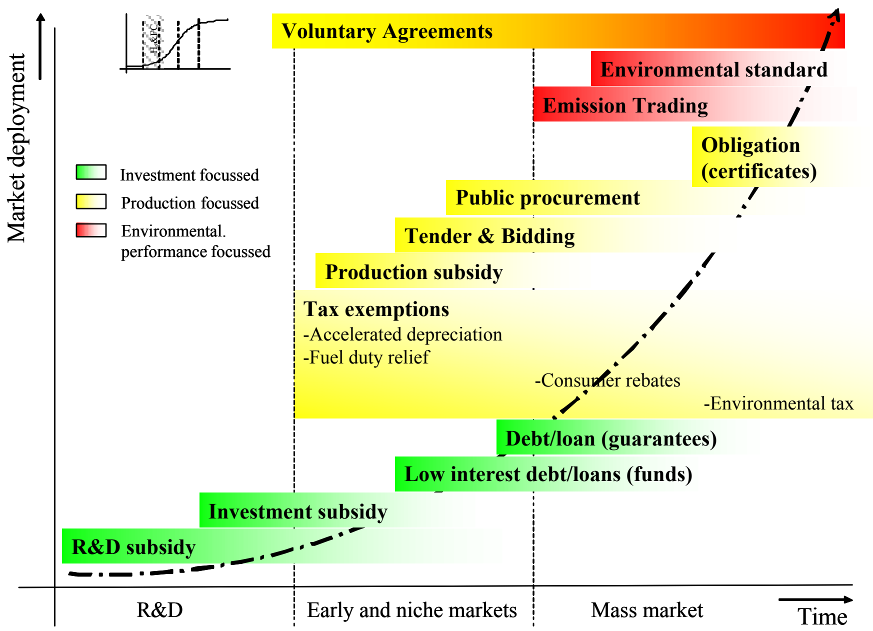

Figure 3.3 *Policy measures along the S-curve (adapted from Ros, 2006)*

12 Directive 1999/94/EC of the European Parliament and of the Council.

3.8 Levels of implementation for policy measures

Policies to reduce GHG emissions from road transport by means of alternative fuels and technologies can be implemented on several political levels, generally locally or regionally, through the national government, or through the European Union and their respective institutions. Regulations at EU-level, such as the emission limits of passenger cars, are gaining importance. Nevertheless, the member state level is still a prominent level in the introduction of alternative fuels with regard to policy support measures, as the EU is not supporting technologies beyond their innovation stage, further explained in the following. Also, interests and motives for the implementation of legislation and measures by institutions on the different levels differ quite substantially.

3.8.1 Local/regional level

The local transport policy maker will balance between environmental objectives (e.g. improving air quality, reduction of congestion) and regional industry objectives to facilitate innovation and create jobs. That's why usually demonstration projects are perfectly suited for local policy makers because they can already contribute to air quality improvements in confined spaces, while on the national level there is generally no significant impact yet. Also, it helps local industry to overcome initial barriers for deployment of the new technology and can support creation of new jobs. Yet, for technologies that are still in a very early phase it requires high upfront investments (e.g. in infrastructure or expensive vehicles) which usually cannot be afforded by local governments. Also, local policy makers need to be aware how a technology can grow further (beyond the local level) once it is tested and demonstrated on local level. It is important to have strategic plans ready early on, otherwise there is a high risk of stranded investments.

3.8.2 National level

National governments are concerned about CO_2 and other emissions (e.g. particulates) as well as solving security of supply, congestion and safety issues in the most cost-efficient way and preferably on short notice. As most cabinets try to achieve results within their elected period, this means that politicians will often favour the 'low-hanging' fruit, meaning the cheapest, but not necessarily best technological option in the long-run. Other options might promise a much higher abatement potential but face the obstacle that results will only become visible in later stages. Only cabinets that manage to achieve a consensus across the political spectrum can achieve long-lasting support for certain technologies. One example is the German feed-in-tariff for photovoltaic energy which has been often debated to be abolished, but it remains virtually untouchable even with cabinet changes. This stable horizon has provided a lot of investment security for industry and resulted in high growth rates.

High cost effectiveness can only be achieved with options that fit well into the current energy system as no substantial no upfront investments in retrofitting of vehicles and/or infrastructure investments are necessary, thereby favouring incremental innovation over disruptive ones.

3.8.3 European level

EU R&D policy for new technologies only covers the initial phases until the technology is ready to enter the early market, as mass-market support is not an objective of the EU. EU research policy focuses on the early stages of technological development and on medium to long-term benefits. Therefore, measures that aim to improve cost competitiveness and make a new technology attractive to the consumer are still widely a field of the national member states.

Once the technology is more mature and widely available, the EU can intervene through e.g. EU wide standards, such as the Fuel Quality Directive (FQD)[13] or the emission limits for passenger cars.

[13] Directive 2009/30/EC.

4. Determining the current position of AF/AAMT technologies on the development curve

The various transport fuels and technologies that are in focus in the Alter-Motive project (see 1.1) will be assessed concerning their state of technological development to determine their current position on the development curve. Ultimately, we will locate each of the technologies along the development curve which forms the basis for our policy suggestions. In Table 4.1, the current status of each AF/AAMT is summarized, together with their main barriers for market introduction that the currently face.

Table 4.1 *List of alternative fuels and drive train technologies with market barriers*

No.	Alternative fuel/drive train technologies	Innovation type[14]	Current status[15]	Main barriers for broader market introduction[16]
1	Liquified petroleum gas (LPG Natural gas (CNG)	Incremental	Mass commercialisation	None (LPG) Infrastructure (CNG)
2	2nd gen. biofuels	Incremental	Demonstration	Sufficient fuel supply OEM[17] engine approval Infrastructure
3	Hybrid electric vehicles (HEV) Mild hybrid (e.g. Toyota Prius) Full hybrid (Daimler S400)	Incremental	Mass Commercialisation (mild hybrid) Pre-commercialisation (full hybrid)	None (HEV) Cost of battery Limited availability of models
4	Electric vehicles (BEV/PHEV)	Radical	Pre-commercialisation	Vehicle cost (related to battery) Battery lifetime Lack of public infrastructure Standardization
5	Hydrogen fuel cell vehicles (FCV)	Radical	Pre-commercialisation	Vehicle cost (fuel cell stack, storage) Lack of refuelling infrastructure

4.1 Overview of technologies

4.1.1 Compressed natural gas (CNG)/liquefied petroleum gas (LPG)

Natural gas and liquefied petroleum gas used as fuel in road transport has a long history in a number of countries, notably the Netherlands, Argentina and Italy. Also today, it enjoys some popularity and has above all a high availability on refuelling stations. Recently, it has undergone some revival due to biogas.

[14] For a typology of innovations, see Tidd, J. et al. (2005).
[15] Classification according to Toro, F.A. et al.
[16] Technology specific barriers, see Toro, F.A. et al.
[17] OEM – Original equipment manufacturer, i.e. automotive industry.

LPG, initially introduced as a by-product from oil refining, it was one of the only alternatives to gasoline in the 50s and 60s of the previous century. The use of diesel in passenger cars was not widespread at this time. A dense refuelling network was established in several EU and other countries due to the help of some critical events that pushed the price of oil and subsequently gasoline. In the 70s, LPG had a rather big price advantage compared to gasoline due to its low production cost and the high oil price.

Most automotive manufacturers (OEM) also offer new LPG models ex-factory. Yet, also retrofit kits for LPG storage are cheaply available on the market. Over the last decades, diesel has become the main competitor for LPG/CNG as all three technologies offer high vehicle/low fuel price, making them attractive for high mileage drivers. Nevertheless, the constant improvements in energy efficiency of diesel car technology have come to the disadvantage of CNG/LPG since they have to compensate for a lower energy content, meaning that they effectively require more fuel for the same mileage. Also, diesel cars outperform LPG/CNG cars in terms of acceleration and range.

Depending on the country, the share natural gas vehicles can be still quite high as in Argentina were 25% of the total passenger car market are propelled by CNG. In a case study from the Netherlands, it becomes apparent that even a continued fiscal stimulus did not help to avoid the share of LPG cars to drop further. Currently, the share of LPG cars is about 2% of the total market (Backhaus & Bunzeck, 2010).

4.1.2 Biofuels

Different kinds of biofuels exist that can replace fossil fuels such as gasoline and diesel. For example, bioethanol, bio-MBTE[18] and bio-ETBE[19] are substitutes for gasoline, while biodiesel, pure plant oil (PPO) and synthetic biodiesel are substitutes for diesel. Currently, biodiesel and bioethanol have the highest market shares and are expected to dominate the biofuels mix up to 2020.

First generation biofuels are produced mainly from dedicated food crops that can be grown in subtropical climates (rapeseed, sugar beets, cereals) and regions with tropical climates (palm oil, sugar cane). Growing concerns of using such feedstocks for fuel production while they are also used as food have led to increased attention for second generation biofuels. Feedstocks for this new generation of biofuels are not associated with food production (non-food crops e.g. jatropha) or waste streams (wet waste or wood waste) and forms of lignocellulosic biomass. Second generation biofuels cultivation and processing is not yet as developed as the first generation.

Both generations of biofuels can be used as fuel in internal combustion engines with or without adaptations, depending on the blend and endorsement by the car manufacturer. Low-percentage blends can be used in unmodified conventional engines. Blends with conventional fuels containing higher percentages of alternative fuels require dedicated engines that are offered by the automotive industry as flex-fuel or biofuel models (basically still the same car with some engine adaptations).

4.1.3 Electric vehicles and electricity

This category consists of pure battery electric vehicles (BEV), but also hybrid electric (HEV) and plug-in hybrid vehicles (PHEV). PHEVs and HEVs combine an electric drive system

[18] Methyl Tertiary Butyl Ester, produced using bio-methanol.

[19] Ethyl Tertiary Butyl Ester, produced using bio-ethanol.

with a conventional engine and can run on electricity and fuel. Recently, electric vehicles enjoy growing popularity at policy maker and industry level.

Hybrid electric vehicles have received an initial push through the introduction of the Toyota Prius and other hybrid vehicles such as the Honda Civic. Hybrid systems are now becoming much more widespread. Even so, their overall market share remained on a low level, i.e. around 1% of light-duty car sales in EU countries in 2007 and 2.79% in the US in 2009. For the first half of 2010, the US reported falling sales figures for HEV leading to a overall market share of 2.24%. However, the market is expected to tripe by 2012 compared to 2007 [IEA IA HEV 2008, 2010].

Hybrid electric vehicles show improved fuel economy compared to conventional vehicles, especially in city traffic with high shares of stop-and-go traffic. When driving in electric mode, HEVs produce zero tailpipe emissions. Hybridization is seen as the major trend in the automotive industry to lower the overall vehicle emissions with relatively low cost effort, although other options such as downsizing the engine exist. The all electric range of an HEV is limited since the battery is not designed for a long-range mode on battery power (usually the combustion engine kicks in at a certain speed). By adding a larger battery or the possibility of recharging the battery by plugging it into the electricity grid it becomes a plug-in hybrid vehicle (PHEV) the range can be extended. Battery electric vehicles (BEV) operate constantly on zero tailpipe emissions because they have an electrical engine as the only source of power. Nevertheless, from a well-to-wheel (WtW) perspective emissions can be substantial depending on the method of generating electricity. WtW emissions for EVs can be in a range from 117g/km CO_2 if the power is generated from coal power plants to 2 g/km CO_2 if the power comes from low-carbon sources such as renewable or nuclear [RETRANS 2010].

Initially the electric vehicles are going to suffer from higher cost for the end-consumer compared to conventional cars. High battery cost and low production numbers are the main reasons for this, and they also need to design specific cars. Nevertheless, the high purchase costs for the end-consumer are partly compensated by expected lower operating cost. Other uncertainties exist about the impact of frequent battery charging on the battery lifetime and safety of batteries. The range of most vehicles is currently limited to 100 to 200 km which is already sufficient to cover the daily needs of a large user groups. The driving range of EVs in reality will be also determined by a number of other parameters. It depends on the overall characteristics of the route that is taken (going up the hill needs more battery power), the way it is driven (higher speed needs uses more battery power and vice versa) and the operation of ancillary services such as air-condition. Nonetheless, recharging time is another issue. With a normal household plug it takes between 5 to 10 hours to recharge. For faster charging, special infrastructure is necessary that allows higher electricity throughput. At the same time, novel approaches are emerging. Better Place, a company implementing EV mobility solutions is looking into battery swapping systems. Those should work in a way that you drive your car into a battery exchange station located along the road and the floor-mounted battery is swapped to extend the vehicle range instantly. Better Place claims that this process does not take longer than a conventional refuelling, but also requires substantial investments for the battery changing stations as well as the batteries kept in stock.[20]

Availability of vehicles is one of the key issues towards a broader market introduction. The product range of electric and plug-in hybrid vehicles available is still very small compared to the overall product portfolio of car manufacturers. Most of the major automotive companies neglected electric transport for quite some time and are now rushing to introduce new models. The range of vehicles that is available today is manufactured by small manufacturers with low volumes or niche specialisation (Aixam, Th!nk, Reva, Smith). Most of the established OEMs have announced electric vehicle sales across the board, led by Mitsubishi, Nissan-Renault,

[20] Better place, see www.betterplace.com.

Toyota and Mercedes. Still, announced prices at market introduction are high, such as the Mitsubishi i-MiEV with a price tag of €32,000 or the GM Volt with US$ 40,000.

Unless such hard factors as battery cost and lifetime will be solved, mass-market introduction is still some time away, not to mention additional factors such as standardization and system integration, not speaking of electrical grid adaption. Automakers worldwide are joining with battery producers to improve the overall performance of the vehicles. From an innovation perspective electric transport has just left the R&D stage and is now in the position to demonstrate its abilities on a larger scale.[21]

The International Energy Agency (IEA) has analyzed the future perspectives and market shares for several energy technologies, among them electric vehicles. In the most ambitious GHG emission reduction scenario, that assumes high policy support for electric vehicles, combined EV/PHEV sales would arrive at around 34 million in 2030, compared to a worldwide estimated vehicle sales of 120 million light-duty vehicles (LDV) at the same time. By 2050, about 50% of all LDV sales worldwide should be EV or PHEV. Other sources have also published estimates based on varying assumptions. McKinsey has tested the outcomes of three scenarios with a varying strong breakthrough of electric vehicles, that estimate vehicle sales ranging from 17 million (combined PHEV/EV) to 29 million in 2030. [IEA 2010, McKinsey 2009]

4.1.4 Hydrogen fuel cells

Hydrogen is an energy vector, not an energy source and therefore has to be produced first from other sources, either fossil (natural gas, coal) or non-fossil (renewable electricity or biogas). Hydrogen is then used as a fuel in vehicles, converted to electrical energy using fuel cells. Such vehicles have zero tailpipe emissions, however the production method determines the chain emissions. Fuel cells and hydrogen for transport have been long expected to make zero-emission transport a reality. However, the introduction of such an disruptive technology is characterized by a fierce dispute over the investment cost for the necessary refuelling infrastructure. Only a few manufacturers have vehicles operating and they are deployed in demonstration projects, mainly in Europe (Berlin, Scandinavia), the US (California) and Japan.

Several OEMs maintain a high level of R&D efforts for hydrogen fuel cell vehicles, with some of them already having presented detailed roadmaps how and when to make the step towards mass production starting around 2015 [NextHyLights 2010]. Regarding the vehicle supply to the end consumer, further cost reductions depend to a large extent on the achievement to deploy a larger number of vehicles beyond the demonstration (10,000 vehicles) phase [HyWays 2007]. Forecasts made in the EU HyWays[22] project predict that vehicle cost will only come down (assuming retail prices of 23 k€ for compact cars) once 100,000 vehicles are produced. Not reaching the necessary vehicle production numbers could further postpone mass introduction later than 2015 due to insufficient technology learning effects and remaining high cost. In addition, currently only a small number of OEMs (Daimler, Honda) have made concrete announcements to start up production in the area of hundreds of thousands, while a greater number of first movers is necessary. The availability of adequate refuelling infrastructure is directly linked to a successful introduction of hydrogen vehicles. Some OEMs have intensified collaborations with utilities and infrastructure suppliers, resulting in the establishment of the 'H2 Mobility Initiative' that will prepare the roll-out of a national hydrogen infrastructure in Germany.[23]

[21] From a historical perspective, there have been many attempts to create a(n) (early) market for EVs. Some of these attempts have at least been partially successful. However, these markets have disappeared, hence the current characterization of EVs leaving the R&D stage.

[22] The European Hydrogen Energy Roadmap, http://www.hyways.de

[23] http://www.daimler.com/dccom/0-5-658451-1-1236356-1-0-0-0-0-0-13-7165-0-0-0-0-0-0-0.html

4.2 Allocation of technologies on the development curve

From the analysis of their development current status, each of the technologies can be placed on the development curve and the respective stage, see Figure 4.1.

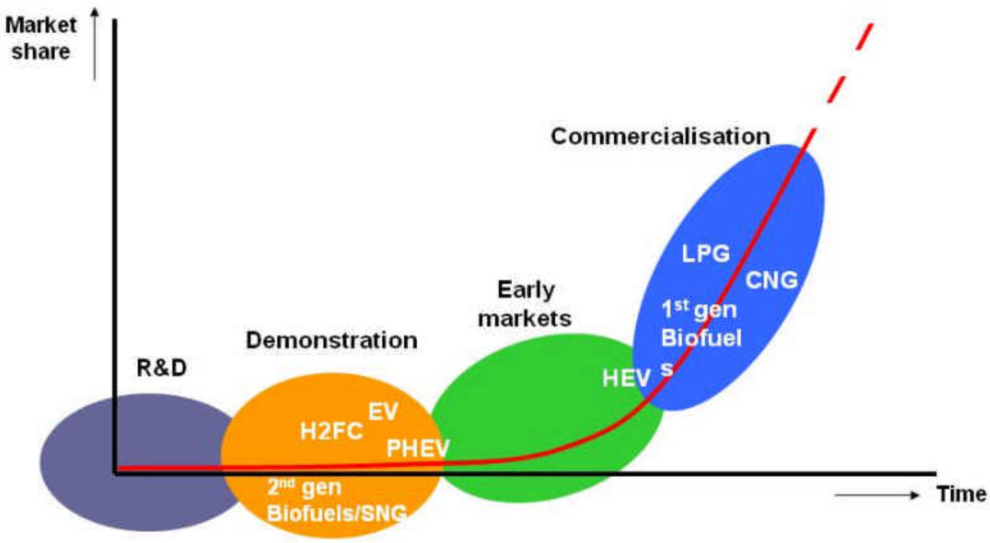

Figure 4.1 *Current position of AF and AAMT technologies*

5. Fiscal instruments related to conventional fuels

A large-scale introduction of alternative fuels and technologies requires an increase in their competitiveness. In the innovation process different kinds of activities (R&D, demonstration projects, mass production to enter early market phase) help to improve competitiveness. As pointed out in Chapter **Error! Reference source not found.**3, these different activities require different forms of policy support. It is therefore important that policies are applied at the right moment in time.

In the early market phase, alternative fuels will enter direct competition with conventional fuels. In this phase, policy on alternative fuels aims to change the competitive playing field in the advantage of alternative fuels. The playing field is to a large extent defined by fiscal policy. This chapter will discuss how current fiscal policy can influence the playing field for conventional fuels.

A broad range of fiscal instruments is applied to road transport in the EU. Conventional fuels (e.g. gasoline, diesel) have been already for some time the target of policy makers with the aim to increase vehicle efficiency and, in the last years also to reduce GHG and other emissions. Policy measures that have been applied in this context can therefore be also a source of experiences that could be applied in an alternative fuel scenario.

5.1 Taxes on vehicles

Most EU countries levy some kind of vehicle registration tax, either based on price or engine capacity. The basis for the calculation of the registration tax can be the vehicle weight or cylinder capacity, although a number of countries switching of a CO_2 emission based scheme (see Figure 5.2). Generally, the Nordic countries (e.g. Denmark and Norway) have very high registration taxes (purchase taxes) that in some cases nearly double the initial sales price of the vehicle, see Figure 5.1 .

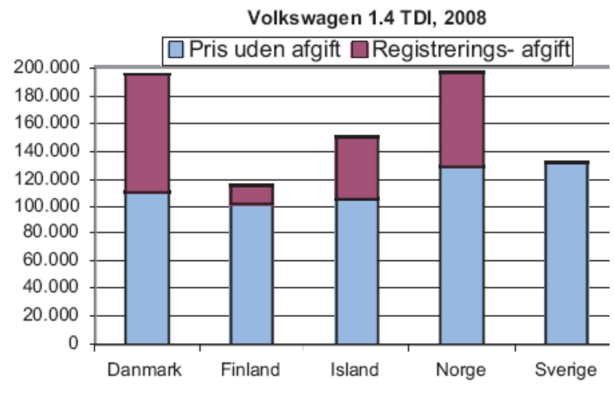

Figure 5.1 *Comparison of VW vehicle prices (in Danish krone DKK) with and without registration tax in the Nordic countries (from 1.4.2008, Nordic Council of Ministers, 2008)*

A case study on the impacts of registration taxes conducted in the Nordic countries of Denmark, Sweden, Norway, Finland and Iceland has found out that policy instruments that are applied with the car purchase have a clear effect on the overall number of vehicle purchases and also the particular model choice [Nordic Council of Ministers, 2008]. Therefore, taxes

that are levied in connection to the purchase are an effective instrument to guide car purchases towards more energy efficient and thus more environmental friendly vehicles.
In Figure 5.2, a comparison between car price levels and purchase price shows the impact on the overall vehicle stock per capita. Still, in countries that have a similar level of registration tax (e.g. DE, ES, FR, IT and UK) a wide spread of car ownership levels can be found. Hence, also other factors seem to influence car ownership levels in society (e.g. operational cost or favourable company car schemes for private individuals).

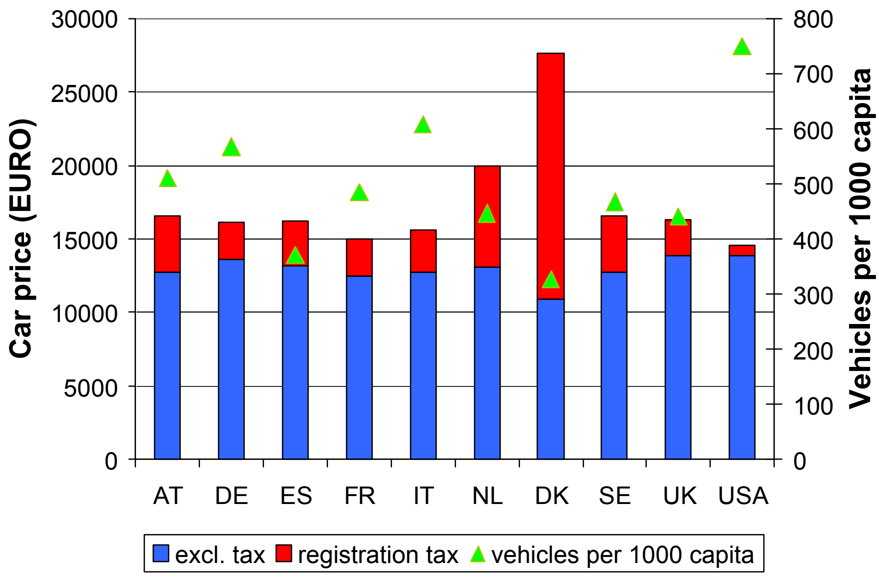

Figure 5.2 *Car prices (incl. and excl. registration taxes) in EU countries and the USA in 2007 (Ajanovic et. al. 2010)*

Besides one-time instruments, road taxes are annually levied by most EU countries. Again, the base value for calculation of the tax varies depending on cylinder capacity, vehicle weight or CO_2 emissions (e.g. Germany). Based on research conducted in Scandinavia it was found that annual levied taxes do not have significant influence on the overall car sales nor the choice of the car model. [Nordic Council of Ministers, 2008]

In the case of Sweden however new evidence shows that through the change from a weight-based to a CO_2 emission based vehicle taxation, it shows significant road tax reductions for smaller, energy efficient vehicles. A CO_2 based taxation system linked to vehicle weight takes away an incentive for vehicle light weighting. Therefore, the car's footprint should be used as a proxy. This has been already adopted in the US. [T&E, 2010]

New regulations for vehicle emission limits on the EU level (130g CO_2 by 2015, likely 95gCO_2 by 2020) lead to a higher availability of supply of new models [Sprei, 2009]. Annual road taxes are a useful instrument for CO_2 reductions if it would entail a component that favours low-emissions vehicles (e.g. <100gCO_2/km) over more emitting vehicles (e.g. more >140gCO_2/km). An overview about the calculation basis for registration and road taxes for EU countries can be found in Table 5.1..

Table 5.1 *Passenger car taxation schemes (adapted from ACEA, 2009)*

Country	Registration tax	Road tax
Austria	Based on fuel consumption Maximum 16% + bonus/malus	Kilowatt
Belgium	Based on cc + age	Cylinder capacity
Bulgaria	None	Kilowatt
Cyprus	Based on cc + CO2	Cylinder capacity, CO2 emissions
Czech Republic	None	None
Germany	None	Cylinder capacity, exhaust emissions CO2 emissions (as from July 2009)
Denmark	105% up to DKK 79,000 180% on the remainder	Fuel consumption, weight
Estonia	None	None
Finland	Based on price + CO2 emissions Tax % = 4.88 + (0.122 x CO2) Min. 12.2%, max. 48.8 %	Time fuel, weight
France	Based on CO2 emissions From € 200 (161 to 165g/km) to € 2,600 (above 250g/km)	None
Greece	Based on cc + emissions 5% - 50%	Cylinder capacity
Hungary	Based on emissions	Weight
Ireland	Based on CO2 emissions max. 36%	CO2 emissions
Italy	IPT + PRA + MCTC	Kilowatt, exhaust emissions
Lithuania	None	None
Luxembourg	None	CO2 emissions
Latvia	€ 373	Weight
Malta	Based on price, CO2 emissions, vehicle length	Cylinder capacity
The Netherlands	Based on price + CO2 emissions 40% - € 1,394 (petrol) 40% + € 290 (diesel)	Weight, province
Poland	Based on cc 3.1% - 18.6%	None
Portugal	Based on cc + CO2 emissions	Cylinder capacity, CO2 emissions
Romania	Based on cc + emissions + CO2	Cylinder capacity
Slovenia	Based on price 1% –13%	None
Slovakia	None	None
Spain	Based on CO2 emissions From 0% (up to 120g/km) to 14.75% (above 200g/km)	Horsepower
Sweden	None	CO2 emissions, weight
United Kingdom	None	CO2 emissions/ cylinder capacity

5.2 Taxes on transport fuels

All road transport fuels are taxed to a certain degree varying by the respective EU member country. Main objective of fuel taxation is for fiscal reasons, although some taxation schemes also entail environmental components. The increased level of fuel taxation over the last years has provided incentives for more efficient vehicles and less travel (EEA, 2005). Most commonly used is a tax differentiation between gasoline and diesel that originally dates back from the time when diesel was widely used only by commercial vehicles. As the number of diesel vehicles grew, some countries have reversed the trend and set a higher fuel tax for diesel than for gasoline. For an overview of gasoline fuel prices across selected OECD countries please see Figure 5.3 . The level of fuel taxation can be differentiated to encourage the use of more sustainable alternatives to gasoline and diesel, e.g. biofuels.

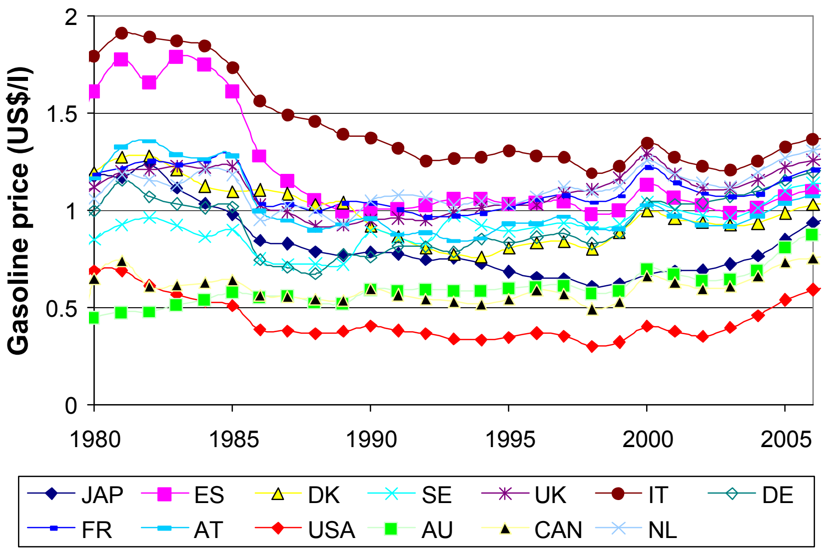

Figure 5.3 *Historical development of fuel prices (in real terms, including taxes) [Ajanovic et. al. 2010]*

Fuel prices vary greatly, especially between most European countries and the US, Australia and Canada, were they have been historically always lower than in Europe. Over the last decade however, fuel price levels have increased across the board but in total levels still Europe is leading in terms of overall price levels for fuels

A study commissioned by the Nordic Council of Ministers found out that higher fuel taxation, resulting in high fuel prices is a successful policy instrument that influences overall mileage driven and also partly the choice for a particular car model. [Nordic Council of Ministers 2008, Sprei 2009]. Car drivers remain price sensitive as high fuel prices have an immediate effect on the expenses.

Nevertheless, large improvement potential remains in the commercial vehicle sector with regard to taxation schemes that favour low CO_2 fuels. The higher energy yield of diesel comes together with higher non-CO_2 pollution such as particulate matter, thus external cost are higher per litre diesel than gasoline which should be reflected in the taxation levels.

5.3 Congestion charge

From the initial idea of toll roads to raise fiscal revenues for the purpose of infrastructure extension and maintenance, the congestion charge scheme was first introduced in London in

2003 with the aim to reduce traffic congestion and improve local air quality in the city. A number of EU cities have followed and currently congestion charges are also levied in Stockholm and Oslo. Further cities in the EU cities have shown interest to introduce such schemes.

Within the congestion charge scheme, vehicles (usually there are numerous exemptions e.g. cabs, buses, emergency services) will be charged when entering a certain city zone (e.g. London inner city area from 7am to 6 pm Mon-Fri.). Within the London scheme, drivers have to pay £8 per day, although monthly and annual discount schemes exist. Residents from within the congestion charge zone are subject to up to 90 percent reduction of the fee.[24]

The examples from London and Stockholm show that these kind of fees might reduce CO_2 pollution considerably if combined with an improvement of public transport. The height of the fee needs to be 'sufficiently' high to influence consumer behaviour. A review of the London congestion charge scheme found out that congestion in the zone was reduced by 30% and overall traffic by 15% (in 2005), although the figures have since deteriorated which can be partially explained by substantial changes in the overall covered road network by the system, the addition of new zones but also the introduction of new, uncharged passages through the city. [TfL 2008]

Most congestion charge schemes entail a favourable component for drivers of alternative fuel or zero-emission vehicles, meaning that they are exempted from paying the fee. In Sweden, 'Green cars' are exempt from the Stockholm congestion charge[25]. Parking is also free for 'green cars' in the city area.

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24 http://www.tfl.gov.uk/roadusers/congestioncharging

25 Exempted from congestion charge are the following fuels: E85, biogas, electricity, hydrogen, natural gas but not LPG. For the complete list of exempted fuels see http://www.transportstyrelsen.se/en/road/Congestion-tax/Congestion-tax-in-stockholm/Exemptions/, last accessed 06/07/10

6. Alternative fuel policies

Fiscal policies are an important instrument to form the playing field for conventional and alternative fuels. Specific policy measures can be deployed to further change the playing field. Specific measures can help alternative fuels overcome barriers that put them at a disadvantage vis-à-vis conventional fuels and are not sufficiently addressed by more generic policies. An example is provided by the differentiation of taxation with respect to (tailpipe) CO_2 emissions. Fully differentiated acquisition taxes (i.e. no tax for vehicles that do not emit CO_2) will provide a stimulus for any technology that emits no CO_2, such as electric vehicles. However, lack of infrastructure is another barrier for electric vehicles. Therefore, policy specifically directed at the installation of charging infrastructure for electric vehicles may be required to enable their introduction.

Per alternative technology, this chapter will provide an overview of the barriers that can be expected, categorized by the innovation phases that have been introduced in chapter **Error! Reference source not found.**3. Next, it will describe how policy measures have been applied across Europe to overcome these barriers. Also, the effectiveness of the various approaches is discussed, highlighting interesting cases. Finally, conclusions and recommendations are provided.

Assessing the effectiveness of policy measures requires an approach that depends on the innovation phase that a technology is in. The R&D and demonstration phases are primarily aimed at resolving technological issues. It is hard to determine exactly how and to what extent policies contribute to this aim. Therefore, the effectiveness of policies supporting BEVs, PHEVs, and FCVs is studied by assessing to what extent policy support covers all barriers that hamper market introduction. Also, a brief outlook is given on which policy support measures should be introduced in the future to enable a successful market introduction.
Effectiveness assessment of policies for the support of technologies in the (early) market phase (biofuels, LPG, and CNG) is done on a semi-quantitative basis. Policy support measures are listed and related to the market share that the technology has obtained in a particular country in a certain timeframe. The extent to which market share developments are due to policy or due to other factors is determined as well as data availability allowed.

For each alternative technology, the discussion of policy effectiveness is based on the analysis a selection of EU-countries. These countries have been selected because they are each representative for a particular policy approach that has been taken to introduce a particular alternative fuel. and because sufficient data was available for these countries. Studying other countries has not resulted in detailed additional information, and hence only a limited number of cases is presented in-depth.

6.1 Biofuels

6.1.1 Barriers

The barriers for biofuels differ somewhat according to the type of biofuels considered. Low biofuel blends encounter the lowest number of barriers in their introduction. These are biofuels (bio-ethanol, biodiesel) that are blended with conventional fuels. The biofuel content in the fuel is kept relatively small (typically less than 10%), so that conventional engines run on these fuels without modifications.

Nonetheless, barriers for the introduction of these fuels do exist. The most prominent barrier (by far) are costs, which are significantly higher than for conventional fuels. For consumers, biofuels do not offer more value than conventional fuels, which implies that fuel providers are unlikely to be able to charge a premium. Other barriers include:

- the lack of fuel standards, which prohibits the use of certain biofuel types (e.g. E10)
- sustainability, including the impact of biofuels on greenhouse gas emissions, food prices and biodiversity
- the availability of feedstock and the protection of the environment as the amount biofuels used in transport increases.

Higher blends and biogas require the adaptation of conventional vehicles and infrastructure. This leads to additional barriers, which characterise a chicken-and-egg dynamic:

- the coverage of filling stations offering the high-blend fuel or biogas
- the availability of vehicle models that can run on high-blend fuel or biogas

The price premium of a vehicle that runs on high-blend biofuels (flex-fuel) or biogas also adds to the dynamic, although the additional costs of a flex-fuel vehicle are moderate.

For biogas, the barriers are comparable to the barriers to the introduction of CNG (see section 6.3).

The existence of these additional barriers implies that additional policy measures are required to overcome this so-called 'blend wall'.

Finally, biogas vehicles tend to depreciate quickly, because there is a perception that the high combustion temperatures cause the engine to wear down quickly. Consequently, they have a low residual value, which makes them unattractive for new car buyers.

As explained in Chapter 3, different barriers are more prominent in different innovation phases. Table 6.1 summarises how barriers and innovation phases are related for biofuels. It indicates for instance that high fuel production cost is a barrier (and is worked on) during the R&D, demonstration, and early market phases. In each of these phases, different instruments will be deployed to lower production costs. Biofuels will only be used on a large scale when they are (almost) cost competitive with conventional fuels, implying that high costs are no longer a barrier in the mass market phase.

Table 6.1 *Barriers for biofuels and biogas per innovation phase*

Barrier	R&D	Demo	Early market	Mass market
Biogas & High biofuel blends & Low biofuel blends				
High fuel production cost	■	■	■	
Lack of standards			■	
Sustainability			■	■
Feedstock availability				■
Biogas & High biofuel blends				
Filling station coverage			■	
Vehicle availability			■	
High vehicle price			■	
Biogas				
Low residual vehicle value			■	

6.1.2 Policies to support the introduction of biofuels

6.1.2.1 EU policy

The following elements of EU policy relate to biofuels (Pelkmans et al, 2008):

- The *Common Agricultural Policy (CAP)*. This policy has two pillars: (1) direct spending to farmers, and (2) rural development. In the former pillar, set-aside requirements were in place until 2007, for which a premium was received. Farmers were allowed to produce energy crops on set-aside land without loss of the premium. These measures have stimulated feedstock production, but have been abolished in 2008.
    - In the other pillar, measures are in place that support feedstock production as well as conversion.
- Although not restricted to biofuels, the requirements of the Renewable Energy Directive (RED) and Fuel Quality Directive (FQD) are expected to be fulfilled to a large extent through the increased use of biofuels. The RED requires that the transport sector uses 10% renewable energy by 2020. The FQD requires fuel providers to reduce the well-to-wheel greenhouse gas emissions of their fuels by 6% in 2020.
- Additionally, Regulation (EC) No 443/2009, which sets CO2 emission performance standards for new vehicles, includes a provision that discounts the specific emissions of FFVs capable of running on E85 by 5%[26, 27].
- Sustainability. There are several concerns relating to the sustainability of biofuels, notably their effective greenhouse gas reductions, impacts on biodiversity, and impacts on food prices. Both the RED and FQD include sustainability criteria that biofuels must need in order to count towards the requirements of both directives.

In sum, the EU policy on biofuels has shifted from incentives based on premiums (mainly in the CAP) to obligations in directives.

6.1.2.2 National policies

The requirements in EU Directives need to be implemented in national settings. The fact that costs are the major barrier for low biofuel blends is reflected in the portfolio of national policy measures (Table 6.2). All countries in the overview have tax reductions for biofuels in place, an obligation to sell a certain percentage of biofuels, or both. Countries that have additional policy measures (e.g. vehicle subsidies, public procurement) in place do not outperform countries that have only measures in place that reduce biofuel costs.

Furthermore, the following observations can be made:

- A number of countries anticipate the introduction of second-generation biofuels through support measures specific for these fuels, typically R&D subsidies. Some countries also stimulate the purchase of flex-fuel vehicles (that can run on high biofuel blends or biogas) and the construction of infrastructure for high-blend biofuels and biogas.
- A few countries directly support the production of biofuels, typically through subsidising the construction of biofuel production facilities.

[26] Provided that at least 30% of the service stations in the member state where the vehicle is registered sells E85.

[27] However, it is possible that the requirements of this regulation will be fulfilled at lower costs by (other) efficiency improvements to conventional vehicle technology (IEA RETRANS, 2010).

Table 6.2 *Policy measures and biofuel market shares in selected EU countries*

POLICY SUMMARY for 2009	Market share	Tax reduction	Obligation	Vehicle Subsidies	Public Procure-ment	Production support	Support for 2nd gen.	Other support policies
Germany	7.7%	X	X				X	
Sweden	3.8%	X	X	X	X	X	X	X
France	3.4%	X		X				
Austria	3.1%	X	X					
Netherlands	2.6%		X				X	
Lithuania	2.6%	X	X					
Luxembourg	1.6%	X	X					
Greece	1.2%		X					
Spain	1.1%	X	X			X	X	
Belgium	1.0%	X						
United Kingdom	0.8%	X	X					
Slovenia	0.8%	X	X					
Poland	0.8%	X	X					
Hungary	0.7%	X						
Czech Republic	0.5%	X	X			X		
Ireland	0.5%	X						
Italy	0.4%		X					
Bulgaria	0.1%	X	X					
Latvia	0.1%	X						
Denmark	0.1%	X					X	
Cyprus	0.1%	X						
Finland	0.0%		X					

Note: Market shares are from 2007, selected measures are from 2009. Market shares based on energy content.

6.1.3 Policy effectiveness

The two generations of biofuels that are currently distinguished are in different stages of innovation (see Section 4.2). This implies that different policies are appropriate for the two generations, with different policy objectives. Hence, the evaluation of policy effectiveness is different as well.

First-generation biofuels are in the early market phase. Consequently, policy aims to increase the market share of this generation of biofuels. Policy effectiveness of the various policy packages aimed at first-generation biofuels is therefore based on semi-quantitative assessment of the market share development of biofuels and factors that may have contributed to this development.

Policy packages come at a cost. Policy packages in many countries include tax reductions for biofuels. It has been attempted to quantify the cost associated with tax reductions as much as possible. Figure 6.1 provides a first indication of the effectiveness and efficiency of policy packages in selected countries. It shows that there are some differences between the effectiveness and efficiency of the various policies. In the next sections, we explore four national policies in more detail.

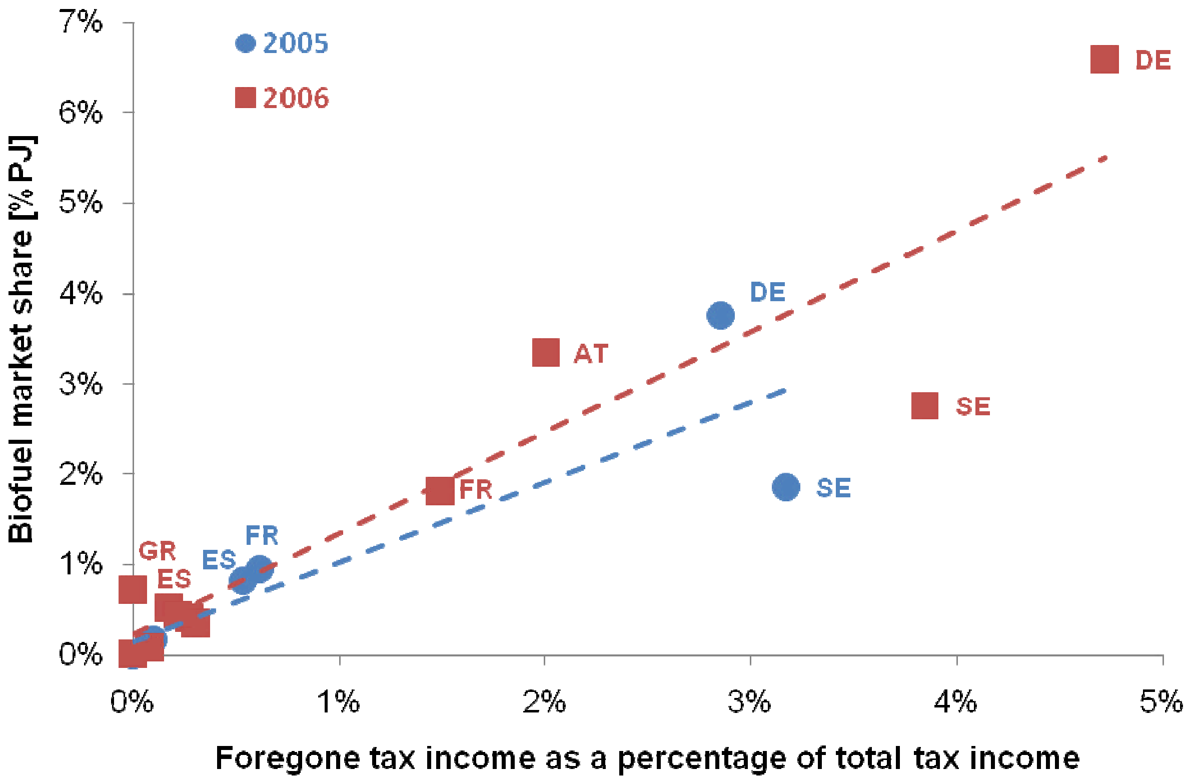


Figure 6.1 *Plot indicating effectiveness (expressed in market share as measured by energy content) and efficiency (expressed as foregone tax income) of excise tax reductions for biofuels in selected countries (selection based on data availability). The blue series (dots) represents 2005 data, the red series (squares) represents 2006 data. Sources: (Kutas et al, 2007), ACEA, IEA.*

Second-generation biofuels are in the demonstration phase. Progress in this phase is determined by a number of factors, including cost reductions and the extent to which second-generation biofuels and biofuels production can resemble the performance of first-generation biofuels and conventional fuels. Assessing policy effectiveness is more difficult in this phase and requires an in-depth analysis of R&D programmes and research outcomes, which is beyond the scope of this report.

6.1.3.1 Germany

Figure 6.2 shows the development of biofuel market share in Germany. The CAP reform of 1992 sparked the introduction of biofuels in Germany. Idealistic entrepreneurs and other stakeholders started the production and sales of pure biodiesel (Pelkmans et al, 2008). In 1995 Volkswagen announced that it had certified its engines for the use of biodiesel[28].

Government supported the initiative by exempting pure biodiesel (B100 and pure plant oil, PPO) from excise duties in 1993. Pure biodiesel requires dedicated infrastructure and a considerable proportion of filling stations was equipped with dedicated pumps from 1993 onwards. A subsidy that covered 40% of investment costs was put in place in 2000 has accelerated this development.

The policy measures resulted in a favourable price for biodiesel. Price data are available for the period 2000-2006 and indicate that biodiesel enjoyed a discount of around 10% compared

[28] In 2004, Volkswagen announced that it would not allow the use of biofuels in Euro-4 compliant engines.

to conventional diesel. The market share of biodiesel increased to over 1% in 2003. Supporting infrastructure was installed at a far larger proportion of filling stations, covering 12.5% of stations in 2005, the latest year for which data are available.

Additional policy measures were introduced in 2004. Biofuel blends are also exempt from fuel tax, proportional to the biofuel content of the fuel. Both pure biofuels as well as biofuel blends were now cost competitive with conventional fuels on an energy basis (Bomb et al, 2007). The market share growth of biofuel blends (biodiesel and ethanol) added to the continuing growth of pure biodiesel, resulting in an acceleration of the growth of total market share of biofuels (Pelkmans et al, 2008).

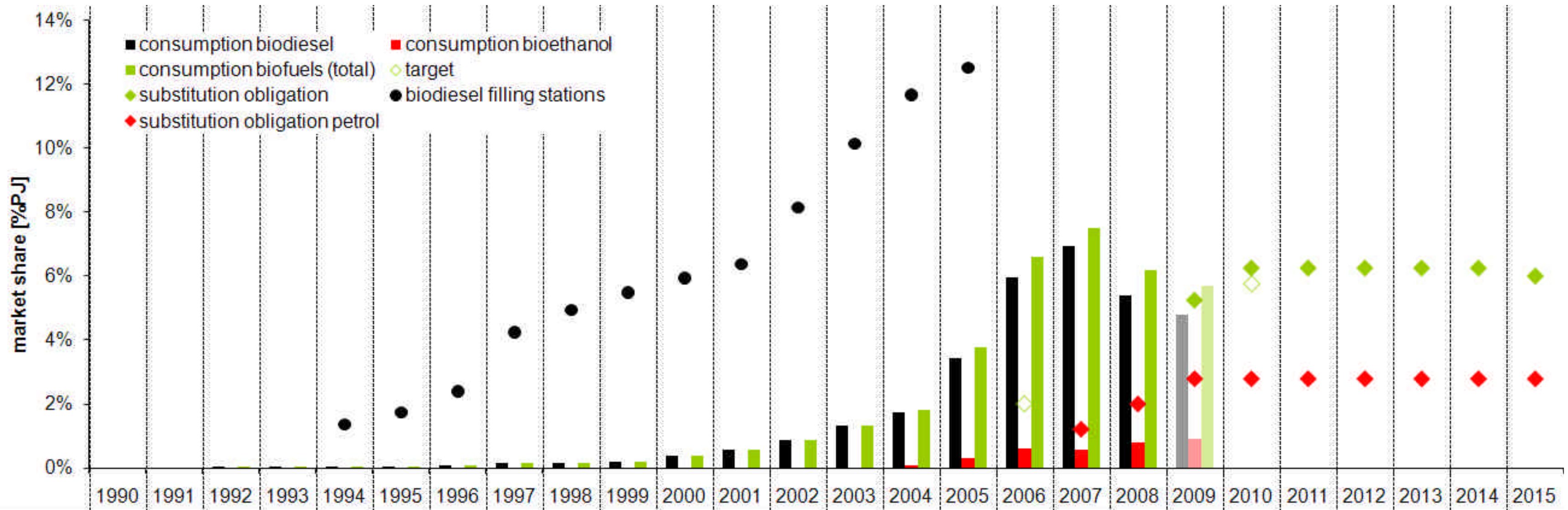
Although the policy proved effective – biofuel market share approximately doubled in 2005 and 2006 – it also proved expensive. The market share of biofuels directly translates in foregone tax income. It is estimated that foregone tax income amounted to €1.2bn in 2005 and €2.0bn in 2006 (Table 6.3).

Table 6.3 *Foregone fiscal income in Germany due to tax exemptions. Sources: ACEA, (Kutas et al, 2007)*

Year	Fiscal income from motor fuels	Forgone fiscal income
2005	€41.1bn	€1.2bn (2.9%)
2006	€39.0bn	€2.0bn (4.8%)

This prompted another revision of the biofuels policy. In 2007, the exemptions for biodiesel blends were scrapped, while tax exemptions for B100 and PPO were gradually reduced. Instead, an obligation for fuel providers to include a percentage of biofuels in their sales was introduced in 2009. Additionally, a separate obligation to include a percentage of bioethanol in petrol was instituted, effective 2007. Note that biofuels sold in excess of the quota are still tax exempt, as is E85.

Scrapping the tax exemptions has eliminated the discount that biofuels enjoyed compared to conventional fuels. Consequently, growth has tapered off. In 2007, growth was 20% (down from 70% in 2006), and in 2008 the biofuel market share declined. Data for 2009 are incomplete, but indicate a further decline in the biodiesel market share, while there is still a moderate growth in the share of bioethanol. It is expected that the biofuel share will slightly exceed the obligation. The separate obligation for ethanol will most likely not be met. .



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
diesel taxation										€ 0,32	€ 0,38	€ 0,41	€ 0,44
tax reduction B100				€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
tax reduction PPO				€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
tax reduction B5/B7													
subsidy for filling stations											40%	40%	40%
tax exemption BTL													
tax reduction E5/ETBE													
tax exemption E85													
substitution obligation													
substitution obligation petrol													

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
diesel taxation	€ 0,47	€ 0,47	€ 0,47	€ 0,47	€ 0,47	€ 0,47	€ 0,47	€ 0,47					
tax reduction B100	€ -	€ -	€ -	€ 0,09	€ 0,09	€ 0,15	€ 0,21	€ 0,27					
tax reduction PPO	€ -	€ -	€ -	€ -	€ 0,02	€ 0,15	€ 0,21	€ 0,26					
tax reduction B5/B7		€ -	€ -	€ -									
subsidy for filling stations	40%	40%	40%	40%									
tax exemption BTL					€ -	€ -	€ -	€ -					
tax reduction E5/ETBE		€ -	€ -	€ -	€ 0,66	€ 0,66							
tax exemption E85					€ -	€ -	€ -	€ -					
substitution obligation							5,25%	6,25%	6,25%	6,25%	6,25%	6,25%	6,00%
substitution obligation petrol					1,20%	2,00%	2,80%	2,80%	2,80%	2,80%	2,80%	2,80%	2,80%

Figure 6.2 *Development of biofuel market share and infrastructure in Germany. 2009 data are indicative. Monetary amounts reflect taxes per litre. The subsidy for filling stations in place from 2000-2006 covered 40% of investment. Tax exemption for biofuel blends (E5/ETBE and B5/B7, 2004-2007) is proportional to the biofuel content of the fuel. Sources: IEA, (UFOP, 2009), (Pelkmans et al, 2008), (Pelkmans et al, 2007).*

The quota were revised downward to the percentages pictured in Figure 6.2 in 2009. Reasons for this revision include the fact that a larger proportion of biofuels will be imported with increasing market share. Imported biofuels typically have a poorer greenhouse gas reduction performance, which raised concerns on the effectiveness of biofuels in reducing greenhouse gas emissions . Second-generation biofuels – with better greenhouse gas reduction performance – are currently not available yet. Hence, the obligation is kept constant until 2015, when it will be replaced by an obligation based on CO_2 emission reduction (UFOP, 2009).

Germany actively pursues the development of (second-generation) biofuels. A research programme has been in place since 1993. In 2005, support for bioenergy demonstration projects was put in place (which is set to end in 2010).

6.1.3.2 United Kingdom

Figure 6.3 provides an overview of the use of biofuels in the United Kingdom. Marketing of biofuels was triggered by a reduction of the fuel taxation on biodiesel (both pure biodiesel and blends) in 2002, followed by a tax reduction of ethanol in 2005. These tax reductions initially provided very little incentive. In 2004, only certain types of biodiesel were cost competitive on an energy basis (Bomb et al, 2007). In 2006 and 2007, sales of biofuels nevertheless picked up, possibly due to the approximately 12% higher pump prices of petrol and diesel in 2006 and 2007 compared to 2005.

In 2008, the tax reduction was complemented by the Renewable Transport Fuels Obligation (RTFO). Sustainability of biofuels is a major concern in the UK. Hence, the RTFO includes a carbon and sustainability assurance scheme. Only biofuels that fit this scheme count towards fulfilment of the obligation. Credits obtained under the RTFO can be traded. The RTFO includes a buyout option.

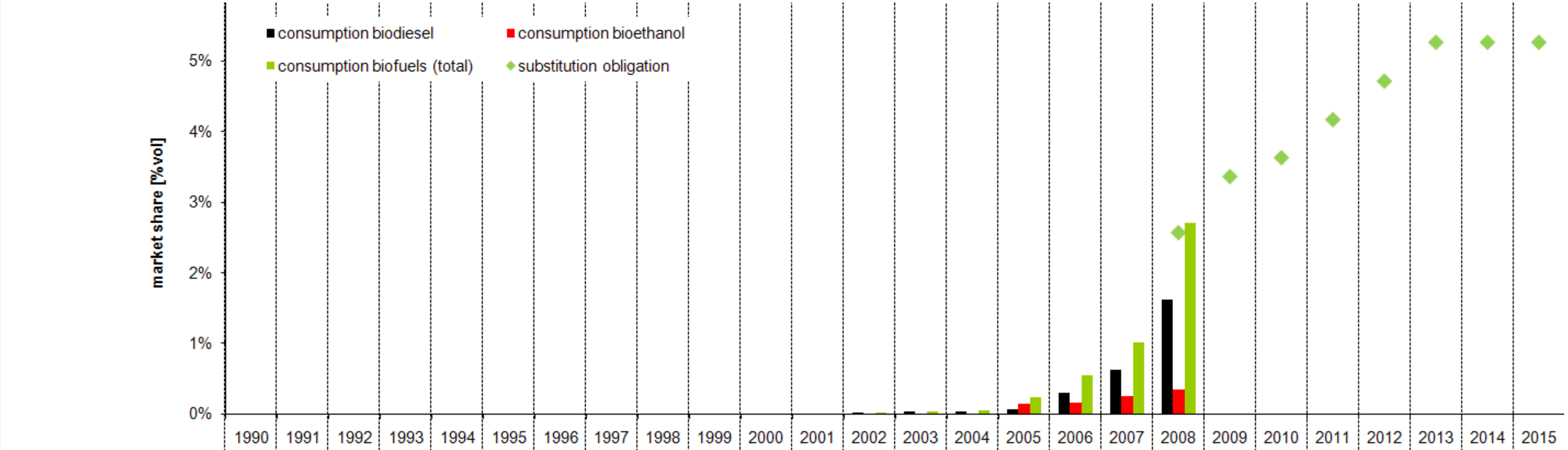
In July 2008, critical notes on the sustainability of biofuels were published in the Gallagher review. Subsequently, the targets in the RTFO were revised downwards. With the establishment of the £27m Biofuels Research Centre, the UK intends to accelerate the introduction of more sustainable second-generation biofuels.

The RTFO has been effective in driving the market for biofuels. The 2008 share was slightly over the target, with none of the fuel suppliers exercising the buyout option (RFA, 2010b). Provisional data show that the 2009 obligation has also been met (RFA, 2010a).

Starting 2010, tax exemptions were scrapped and the RTFO remains the only mechanism for stimulating biofuels. Phasing the tax reductions for biofuels out has kept the cost in terms of foregone tax income relatively low. Data are only available for 2005 and 2006 (Table 6.4). Yet even in 2007 and 2008, in which the biofuel market share doubled two years in a row, it is unlikely that biofuels took away more than 0.5% of excise duty tax income.

Table 6.4 *Foregone fiscal income in the United Kingdom due to tax exemptions. Sources: ACEA, (Kutas et al, 2007)*

Year	Fiscal income from motor fuels	Forgone fiscal income
2005	€34bn	€0.03bn (0.1%)
2006	€34bn	€0.07bn (0.2%)



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
diesel taxation	£ 0,48	£ 0,50	£ 0,50	£ 0,50	£ 0,52	£ 0,54	£ 0,52	£ 0,56						
tax reduction biodiesel (B5-B100)	£ 0,26	£ 0,27	£ 0,27	£ 0,27	£ 0,28	£ 0,30	£ 0,32	£ 0,36						
petrol taxation				£ 0,53	£ 0,55	£ 0,57	£ 0,52	£ 0,56						
tax reduction bioethanol				£ 0,27	£ 0,28	£ 0,30	£ 0,32	£ 0,36						
substitution obligation							2,56%	3,36%	3,63%	4,17%	4,71%	5,26%	5,26%	5,26%

Figure 6.3 *Development of biofuel market share in the United Kingdom. Monetary amounts reflect taxes per litre. Tax exemptions for biofuel blends are proportional to the biofuel content of the fuel. Note that the substitution obligation is formulated by volume rather than energy content – the vertical axis is labelled accordingly. Sources: IEA, (RFA, 2010b), HM Revenue and Customs.*

6.1.3.3 Sweden

As in many other countries, the main instrument for the introduction of biofuels in Sweden has been a tax reduction. As early as 1992, Sweden has exempted ethanol blends from excise duties. Biodiesel has been exempt since 1999. Figure 6.4 shows the development of the market share of biofuels in Sweden. A significant uptake of biofuels did not take place until 2001, implying that tax exemptions did not provide a sufficient incentive to provide biofuels to the market. Since 2002, the taxation of conventional fuels has risen quite steeply, with a CO_2 tax instituted in 2002 and an energy tax added in 2004. Biofuels are exempt from these taxes.

Initially, biofuels in Sweden concerned primarily ethanol, since the majority of passenger cars in Sweden is fuelled by petrol. The use of biodiesel blends has only been allowed since 2006 and the use of biodiesel blends has increased sharply directly afterwards.

The majority of biofuel sales in Sweden take the form of low blends. The market share of ethanol has increased to the point that Sweden has hit the 'blend wall': since 2004, all petrol sales are mixed with 5% of ethanol[29], and the Fuel Quality Directive does currently not allow the use of higher blends (Pelkmans et al, 2008). Consequently, sales of ethanol may only increase through the use of higher blends (in this case, E85).

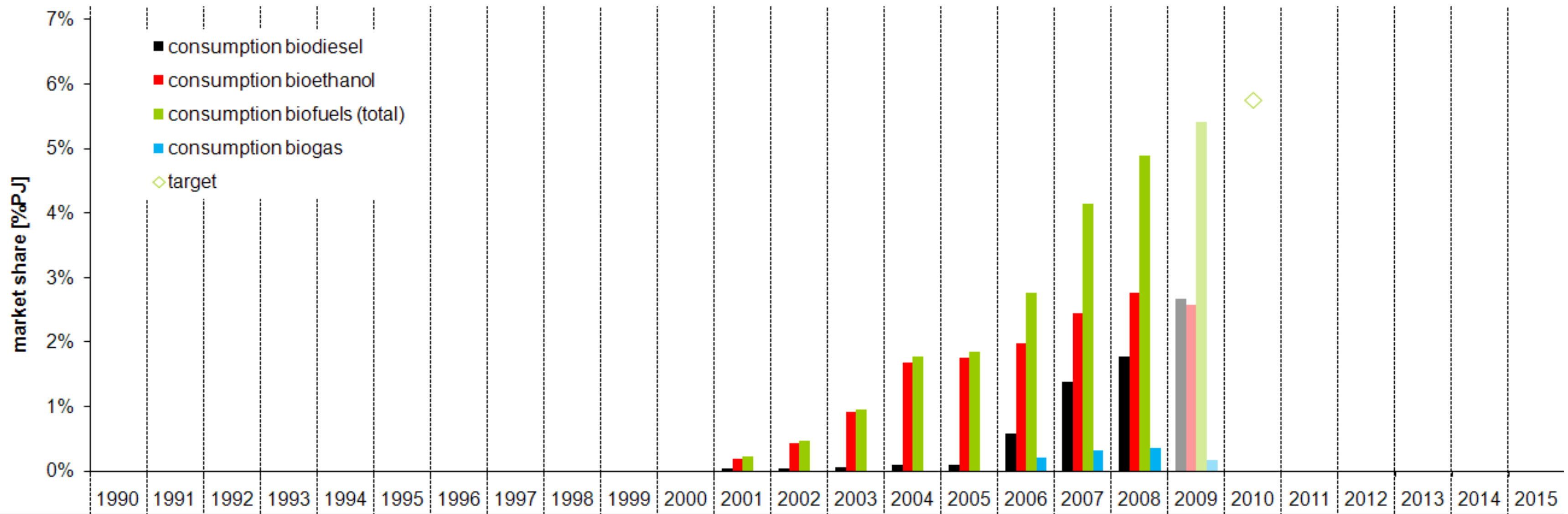
Sweden has anticipated this development and has introduced policies to stimulate the uptake of flex-fuel vehicles (FFVs). Figure 6.5 shows the development of stock of FFVs and the number of ethanol filling stations in Sweden.

The first significant sales of FFVs take place in 1998. In this year, the Swedish government procured 3000 FFVs. Additionally, grants were made available for investments in environmentally friendly vehicles. These measures have triggered initial sales of FFVs. Sales again increase somewhat with the introduction of the Ford Focus FFV to the market in 2001. However, a steep increase in sales occurs only from 2005 onwards. This development can be ascribed to a number of factors, although it remains difficult to draw conclusions on the relative importance of each. Starting 2004, the taxation of company cars is reduced for ethanol-powered cars and parking fees are reduced for FFVs. In 2005, Saab and Volvo introduced new FFV models, and the government adopted a policy that increasing shares of government vehicles must be 'eco-friendly' – FFVs qualify as such. From 2006 to 2009, FFVs have been exempt from the Stockholm congestion charge. Share of FFVs in sales further increased with a cash bonus in the period 2007-2009.

In 2008, FFVs made up over 3% of the car stock. At the current sales rate (over 20% in 2008), the share of FFVs in the Swedish car stock is set to increase further over the coming years. The full potential of FFVs can only be reaped when E85 infrastructure is available. In Sweden, policy measures to stimulate the construction of infrastructure have been implemented at the same time as the measures to stimulate uptake of FFVs. From 1998 to 2002, grants for the construction of infrastructure have been in place.

In 2006, the government implemented an obligation for filling stations that sell more than 3000 m^3 of fuel annually to offer at least one renewable fuel. The large majority of fuel stations opted for the construction of E85 pumps, as that is the option with the lowest cost of the available alternative fuel options. Although the measure was presented as technology-neutral, in practice it obviously favoured E85.

[29] Note that Figure 6.4 measures market share in terms of energy content. Due to the lower energy content of ethanol compared to petrol, the ethanol market share is lower than 5% in this figure.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
diesel taxation						2,89 kr	3,01 kr	3,20 kr	2,67 kr	2,65 kr	2,92 kr	3,04 kr	3,12 kr	3,18 kr	3,33 kr	3,65 kr	3,67 kr	3,72 kr	4,16 kr	4,34 kr						
tax reduction B2/B5/B100										- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr		
petrol taxation						4,01 kr	4,27 kr	4,47 kr	4,47 kr	4,43 kr	4,47 kr	4,50 kr	4,62 kr	4,71 kr	4,79 kr	4,96 kr	4,99 kr	5,06 kr	5,29 kr	5,52 kr						
tax reduction E5/E85/E95			- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr		
tax exemption for pilot projects						- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr						

Figure 6.4 *Development of biofuel market share in Sweden. 2009 data are indicative. Monetary amounts reflect taxes per litre. Tax exemptions for biofuel blends are proportional to the biofuel content of the fuel. Sources: IEA, EC Oil Bulletin, Eur'observer.*

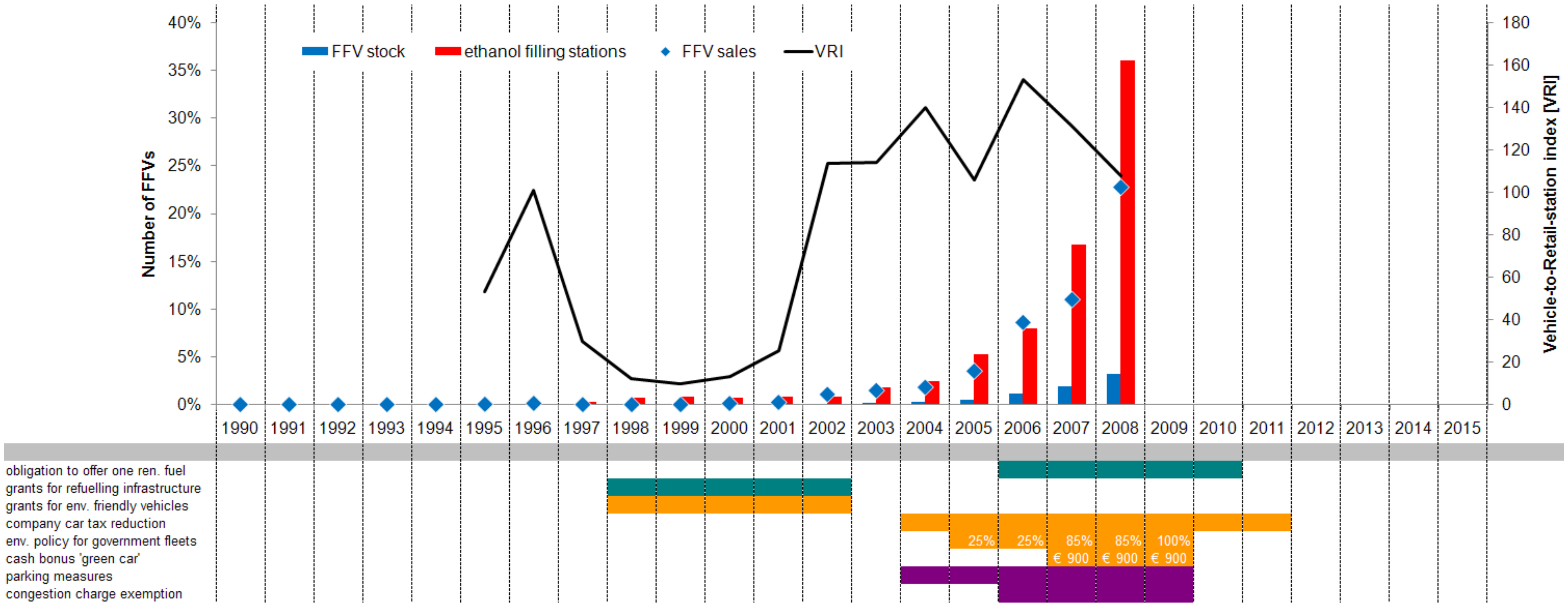


Figure 6.5 *Development of the stock of flex-fuel vehicles and ethanol filling stations in Sweden. Percentages reflect the share of vehicles procured by the government that need to be 'eco-friendly'. Monetary amounts reflect the sum that buyers of 'green cars' receive in cash. Sources: (BEST, 2009), Eurostat.*

Although the chicken-and-egg problem is not really prominent with FFVs – which can use petrol as a fuel as well as E85 – it is more attractive to purchase an FFV when sufficient E85 filling stations are available. On the other hand, the underutilisation of infrastructure represents costs to fuel providers. This trade-off can be measured using the vehicle-to-retail-station index (VRI) (Yeh, 2007). This VRI represents the ratio of the number of vehicles to the number of retail stations.

A low VRI implies that there is a good availability of refuelling infrastructure for consumers. However, a low VRI also implies that the refuelling infrastructure is underutilised and is relatively costly for fuel distributors. Trivially, a high VRI represents the opposite situation.

The VRI is plotted in Figure 6.5 . In Sweden, the VRI was very volatile during the first period of the rollout, in which the numbers of both vehicles and filling stations were small and changes were by definition large in relative terms. From a peak in 1996, the VRI fell to the range of 10-30 vehicles per filling station until 2001. During this period the stock of FFVs stayed around 300, while the number of filling stations increased to 35. From 2002 onwards, the introduction of both FFVs and infrastructure experienced a major acceleration. The number of FFVs and the number of filling stations doubled almost every year. Consequently, the VRI was relatively constant, averaging approximately 120 over the period. In 2008, the expansion of infrastructure took place more rapidly than FFV sales, and the VRI drops to 108.
From these observations, it appears that the installation of infrastructure and FFV sales have happened at approximately the same rate. There is some evidence that the construction of infrastructure has started to outpace FFV sales, possibly due to the obligation for fuel providers to offer one renewable fuel. Given the fact that the VRI for conventional fuels and vehicles has averaged approximately 1000 over the period 1990-2008 and shows an increasing trend, the FFV sales rate needs to increase relative to the rate of construction of infrastructure to mitigate the underutilisation of E85 infrastructure.

A growing FFV stock does not guarantee an increased market share for ethanol. Indeed, FFVs can also use petrol for a fuel. E85 sales are strongly dependent on the pump price of petrol and, consequently, on the oil price. E85 sales tend to be strong in times of high petrol prices (Fenton & Carlsson, 2010). The decrease in ethanol sales in Sweden in 2009 may be explained by the decrease in the oil price.

The Swedish policy has been effective in stimulating the introduction of biofuels, including the infrastructure and vehicles required for the use of high blends. Table 6.5 gives an indication of the efficiency of the policy.

Tax exemptions have been the main policy instrument. The costs of tax exemptions for fuels amounted to 3.2% and 3.8% lost tax income in 2005 and 2006 respectively. Since 2006, market shares of biofuels (especially biodiesel) have increased further, implying that the foregone fiscal income has increased further as well. Obviously, measures to stimulate FFVs and E85 infrastructure have also added to the costs of stimulating biofuels.

Table 6.5 *Foregone fiscal income in Sweden due to tax exemptions on fuel. Sources: ACEA, (Kutas et al, 2007)*

Year	Fiscal income from motor fuels	Forgone fiscal income
2005	€4.9bn	€0.16bn (3.2%)
2006	€5.0bn	€0.20bn (3.8%)

Finally, Sweden anticipates the use of second-generation biofuels. It intends to use its large potential of woody biomass as feedstock. Since 2002, Sweden has invested more than €50m in support for R&D and demonstration projects for biofuel production (Pelkmans et al, 2008).

6.1.3.4 France

The market development of biofuels in France is shown in Figure 6.6 . As in Germany, the CAP reform of 1992 triggered the production and use of biofuels. Actors in the various links in the biofuels production chain (feedstock producers, biofuel producers, fuel distributors) teamed up to develop the market for biofuels (Pelkmans et al, 2008). Tax reductions (for biodiesel blends and blends of ETBE in petrol) were the main policy instrument to support this development. The biofuels market developed quickly (especially biodiesel), more than doubling in the first years. In 1998 and 1999, prices for conventional fuels hit a low, dealing a blow to the biofuels market share.

The year 2000 saw a change in policy designed to limit the impact of the biofuels support on government budget. From 2000 onwards, tax breaks only applied to a limited annual quantity of biofuels. Consequently, the biofuels market share did not exceed the annual quota and hovered around 0.8%, indicating that the tax reductions were essential for the competitiveness of biofuels. In 2004, blends of ethanol in petrol were also granted a tax reduction. The amounts of all tax reductions were subject to annual revision from 2003 onwards.

In 2005, production quota were increased. Furthermore, the 'Taxe Générale sur les Activités Polluantes' (TGAP) was instituted for fuel providers. The TGAP is diminished by the biofuel content of the fuel sold. The system is therefore equivalent to an obligation with penalties in the form of a tax. Starting 2006, biofuel market share has followed the TGAP rate closely.

In 2006, an initiative was started to promote E85. A task force has been created, car manufacturers announced plans to introduce flex-fuel vehicles and a goal to have 500 E85 pumps by the end of 2007 was launched. Since 2008, flex-fuel vehicles receive a premium of €2000. However, the plan has not been very successful – mid-2010, the number of E85 filling stations was 600.

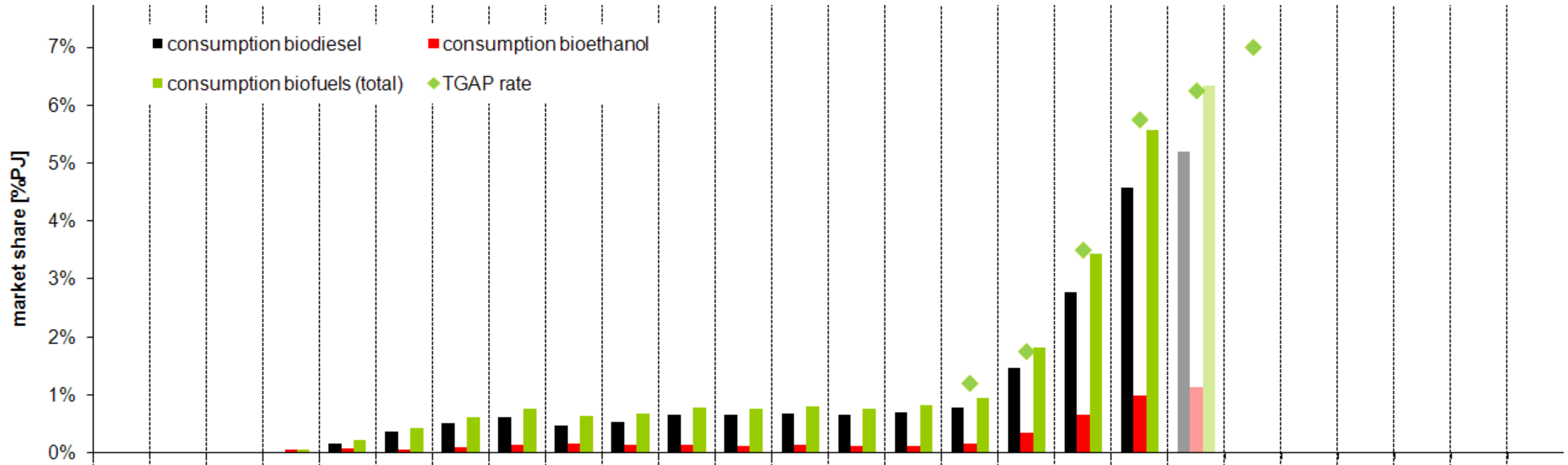
Policy has been effective in developing a market for biofuels in France while limiting the impact on government budget.. Table 6.6 shows that the foregone tax income in 2005 and 2006 was rather limited. However, in 2007 and 2008 the biofuels market share grew by 80% and 60% respectively, implying that the impact on government budget was larger in these years[30].

Table 6.6 *Foregone fiscal income in France due to tax exemptions. Sources: ACEA, (Kutas et al, 2007)*

Year	Fiscal income from motor fuels	Forgone fiscal income
2005	€32.1bn	€0.2bn (0.6%)
2006	€33.1bn	€0.5bn (1.5%)

France anticipates other forms and higher blends of biofuels. A national research programme on biofuels is in place and the government-sponsored scientific interest group AGRICE monitors R&D on biofuels and bio-additives (Kutas et al, 2007). Furthermore, demonstration projects in captive fleets are ongoing to determine the feasibility of the widespread use of B30.

[30] In 2007 and 2008, the tax reduction for biofuels were lowered by 12% and 32% respectively. Consequently, actual foregone excise tax income by the government rose by approximately 70% in 2007 and 41% in 2008.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
diesel taxation			€ 0,31	€ 0,31	€ 0,32	€ 0,33	€ 0,35	€ 0,36	€ 0,37	€ 0,38	€ 0,39	€ 0,37	€ 0,38
tax reduction B5/B7/B30			€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
petrol taxation			€ 0,49	€ 0,49	€ 0,51	€ 0,55	€ 0,56	€ 0,58	€ 0,59	€ 0,59	€ 0,59	€ 0,57	€ 0,57
tax reduction ETBE			€ 0,10	€ 0,10	€ 0,10	€ 0,11	€ 0,11	€ 0,12	€ 0,12	€ 0,12	€ 0,12	€ 0,11	€ 0,11
tax reduction E5													
tax reduction E85													

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
diesel taxation	€ 0,39	€ 0,42	€ 0,42	€ 0,42	€ 0,43	€ 0,43	€ 0,43	€ 0,43					
tax reduction B5/B7/B30	€ 0,04	€ 0,09	€ 0,09	€ 0,17	€ 0,18	€ 0,21	€ 0,28	€ 0,32					
petrol taxation	€ 0,59	€ 0,59	€ 0,59	€ 0,59	€ 0,60	€ 0,60	€ 0,60	€ 0,61					
tax reduction ETBE	€ 0,21	€ 0,21	€ 0,21	€ 0,26	€ 0,27	€ 0,33	€ 0,39	€ 0,43					
tax reduction E5		€ 0,21	€ 0,21	€ 0,26	€ 0,27	€ 0,33	€ 0,39	€ 0,43					
tax reduction E85					€ 0,27	€ 0,33	€ 0,39	€ 0,43					

Figure 6.6 *Development of biofuel market share in France. 2009 data are indicative. Monetary amounts reflect taxes per litre. Tax exemptions for biofuel blends are proportional to the biofuel content of the fuel. The TGAP is an extra tax, from which fuel providers are exempt for the percentage of biofuels they blend in their fuels. Sources: IEA, (Pelkmans et al, 2008), Ministère de Développement Durable*

6.1.3.5 Greece

The market development of biofuels in Greece is shown in Figure 6.7 .

The very low market shares of biofuels are due to the high gasoline consumption in the transport sector, while at the same time, the only biofuel/bioliquid used in the Greek transport sector is biodiesel. In 2005 the gasoline consumption in the individual passenger cars was 4,160 ktoe and the relevant for diesel was 2,508 ktoe.

The high gasoline consumption in the transport sector is due to the particularities of the Greek diesel market. Automotive gasoline is mainly used in passenger cars, whereas diesel is mainly used in taxis and private fleet cars. Diesel is also used in passenger cars registered in the country with the exception of Athens, Piraeus and Thessaloniki, which are inhabited by almost the half of the Greek population.

Until 1992, Greece was the only European country that restricted the use of diesel driven vehicles, apart from taxis. The reason for this restriction was the high air pollution in Athens, mainly due to fumes and small particles emitted by busses, tracks and taxis of old technology and bad maintenance. In 1992, the Greek government issued the Law 2052/92 that allowed diesel engine passenger cars and light commercial vehicles cars up to 3.5 tons in the country with the exception of the urban areas of Athens, Piraeus and Thessaloniki because the emissions are damaging the ancient monuments. Only taxis and private companies light vehicles are permitted to circulate in these cities.

Therefore, the demand for diesel and consequently also for biodiesel for individual passenger cars is lower than in the EU average.

The harmonisation with the EU Directive 2003/30/EC and the introduction of biofuels in the Greek market was made through integration of biofuels into the existing institutional framework for petroleum products. The Law **3423/2005** "Introduction to Greek Market biofuels and other renewable fuels", was actually an appropriate supplement and amendment of Law 3054/2002 "Organization of the oil market and other provisions" and allowed the smooth introduction of biofuels, namely biodiesel into the energy market in Greece. According to this Law, only blends up to 5% for both biodiesel and bioethanol were allowed to be distributed in the biofuel market.

Marketing of biofuels started thus only in 2005 and was triggered by a tax exemption of biodiesel and bioethanol that lasted until the end of 2007, combined with an obligation for fuel providers (oil refining companies) to include a certain percentage of biofuels (initially up to 5%) in the refined crude oil. The quota allocation of pure biodiesel is decided and announced annually, after the call for tenders.

The low investment costs for building and operating a biodiesel plant – compared to a bioethanol plant – coupled with the tax exemption and obligation policy measures provided very strong incentives for the development of the biodiesel market in Greece. As a consequence, up to 10 biodiesel production plants were built and operated in Greece with a total capacity of around 400,000 tons. Plant capacities ranged from as low as 5,000 tons up to 40,000 tons, while there was a biodiesel plant starting to operate in 2006 with a capacity of 230 tons.

In the years 2006 and 2007, approx. 52,000 tons and 94,000 tons of biodiesel respectively were distributed in the biofuels market in Greece. The vast majority of these quantities (93% and 97% for 2006 and 2007 respectively) were locally produced. This tremendous biodiesel development could be also due to the approximately 11% higher pump prices of petrol and diesel in 2006 and 2007 compared to 2005, as in the case of UK.

From 2008, by the new **Law 3653/2008**, biodiesel was no more subjected to the special tax status meaning that practically the distributed biodiesel was no longer tax exempted. This Law also regulated the quota allocation, the call for tenders, and the final decisions, especially for the year 2008. A year later, **Law 3769/2009** allowed the distribution of biofuel blends with refined crude oil beyond the limit specified in the Decisions of the Supreme Chemical Council (ACHS), if the other specifications of these blends lie within the limits of standards. In these cases a special mark in the fuel tanks had to be displayed.

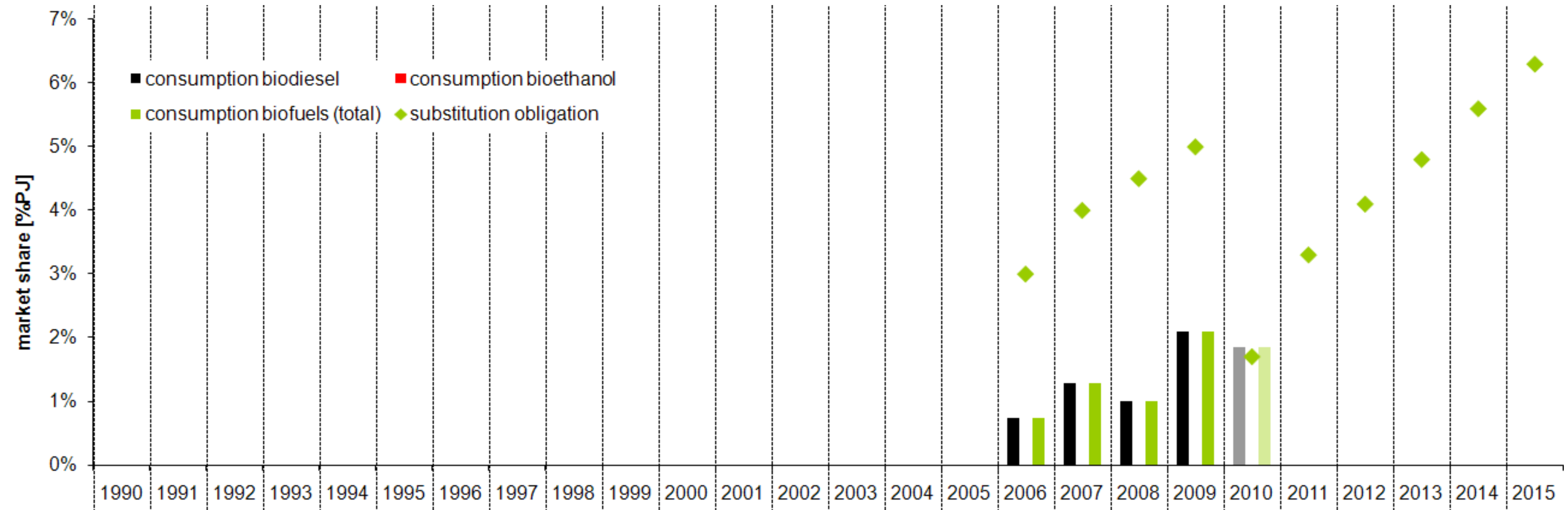
Specific issues, like the amount of quota allocation every year, call for tenders and evaluation criteria are managed through Joint Ministerial Decisions. For instance, for the annual quota granted to every eligible product, a formula is used (also utilized for the 2009 quota specification), which includes criteria with specific weighting factors for each type of raw material (vegetable oils, used/fired oils and animal fats).

In the year 2008, there was a drop in the biodiesel production (and relatively biodiesel consumption) because of the very late announcement of the 2008 quota (announcement in August 2008). Thus only 69,000 tons of biodiesel were produced. Biodiesel production in 2009 is expected to be at the same level as in 2008, or even lower, because of the very late announcement of the 2009 quota (again in August 2009) which delayed even further because of the elections and change of the Governing party in September 2009.

From one biodiesel plant operating in 2005 there are currently 13 biodiesel plants in operation with a total capacity of up to 700,000 tons of biodiesel, and another 4 biodiesel importing companies. Capacities are expected to have only but marginal increase if current market conditions persist (no tax exemption, late annual quota allocation. Limited market options for higher blends or pure biodiesel).

On the contrary, bioethanol is neither produced nor imported in Greece, thus the biofuels target is only met by biodiesel.

Currently the harmonisation of the new Directives 2009/28/EC and 2009/30/EC is being prepared with focus on the sustainability criteria and certification systems.



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
diesel taxation		€ 0,26	€ 0,28	€ 0,29	€ 0,35	€ 0,30					
petrol taxation		€ 0,30	€ 0,34	€ 0,35	€ 0,41	€ 0,53					
tax exemption biodiesel	€ -	€ -	€ -								
tax exemption bioethanol	€ -	€ -	€ -								
substitution obligation		3,00%	4,00%	4,50%	5,00%	1,70%	3,30%	4,10%	4,80%	5,60%	6,30%

Figure 6.7 *Development of biofuel market share in Greece. 2010 data are indicative. Monetary amounts reflect taxes per litre. Tax exemptions for biofuel blends are proportional to the biofuel content of the fuel. Sources: IEA, EC Oil Bulletin.*

6.1.4 Conclusions and recommendations

The examples of the previous section show some similarities and differences that make it possible to draw up conclusions and recommendations. Biofuels have been pioneered in a limited number of countries in the early 90s, in some cases triggered by the CAP reform of 1992 (as in Germany and France). These countries have paved the way for biofuels in Europe.

Market shares remained modest in this period, however. Significant increases in market shares only took place with direct support to mitigate the high cost of biofuels, mainly in the form of tax exemptions. As market shares increased, these measures proved costly and many countries moved to an obligation for fuel distributors to include a minimum share of biofuels in their sales. In recent years, concerns over the sustainability of biofuels have led to the downward revisions of targets in various countries.

Based on the cases analysed, the following are conclusions and recommendations for policy to introduce biofuels:

- *Provide incentives that are sufficiently large to overcome the cost barrier*
  In all the countries studied, biofuels have only taken off once the incentive that was provided was sufficiently large. This implies that the costs for biofuels must be equal to or below the costs for conventional fuels.

- *Tax reductions and obligations are the main instruments to overcome the cost barrier*
  Tax reductions have been the main instrument to reduce costs of biofuels. However, without additional measures to curtail the associated costs, tax exemptions become too expensive[31]. As many countries have now done, an obligation for fuel providers to include a certain percentage of biofuels in sales is an option to sustain the market share of biofuels without losing tax income. An obligation transfers the additional cost of biofuels from the government budget to motorists.

  Both tax reductions and obligations should provide a sufficient incentive to supply biofuels. In the case of obligations, this implies that the penalty for not meeting the obligation should be sufficiently high. Note that the appropriate amount depends on the cost of conventional fuels, and consequently on volatile factors such as the oil price.
  The difference in costs associated with policies in various countries suggest that tax reductions have been more generous than necessary in some countries. However, these differences can also be caused by cost differences for conventional fuels and biofuels between countries, or by preference differences between motorists in various countries. Further research is required to establish which of these (or other) factors has been most significant.

- *Take care of boundary conditions*
  To start the introduction of a particular biofuel, some boundary conditions should be met. For low biofuel blends, these include:
  - -Authorisation of the sale of the fuel through the institution of the appropriate fuel quality standard.
  - -Certification of vehicles to use the fuel – this implies cooperation on the part of vehicle manufacturers.

  For pure biodiesel, a dedicated infrastructure is required. The German example shows that determined entrepreneurs can be successful in rolling out this infrastructure themselves.

[31] Tax exemptions are nonetheless useful to create an early market. Tax exemptions should be accompanied by measures to curtail the costs, such as France has done by instituting quotas. Tax exemptions are also justified as a means to induce cost reductions by increasing economies of scale and learning-by-doing effects. Yet, this has not proven to be (very) effective in the case of biofuels, and it is difficult to determine the correct level of the tax reduction, so that windfall profits for fuel producers are avoided.

Government support (e.g. in the form of investment grants) may however accelerate this development.
All measures should be applied at the most appropriate level. Fuel quality standards and certification should be done at the highest possible level, i.e. in EU regulation. Due to national differences, support for infrastructure is best applied at national level.

- *Support for both FFVs and infrastructure is required to anticipate the 'blend wall'*
  Increasing the use of biofuels beyond the percentage that can be applied in conventional vehicles requires the introduction of dedicated infrastructure and FFVs. The French example shows that this is not an easy challenge and that policy support is required both for vehicles and for infrastructure.

  Although the relative importance of the portfolio of measures that has been introduced to stimulate the uptake of FFVs in Sweden is not entirely clear, the tentative conclusion is that the introduction of subsequent FFV models has had a fairly large and positive impact. Depending on generic policy, e.g. differentiation of fiscal measures with respect to CO2 emissions of vehicles, specific measures may be required to stimulate FFV uptake.
  The French example shows that the installation of dedicated infrastructure does not take place without policy support. The oil price is a major factor that renders the attractiveness of installing dedicated infrastructure uncertain. Measures to stimulate the construction of infrastructure should be designed in such a way that the underutilisation of infrastructure is minimised. To this end, policy measures could be coupled to the VRI[32].

- *Anticipate future limitations: sustainability and second-generation biofuels*
  Possible future limitations are the limited availability of feedstock and sustainability issues. These are interlinked: additional supplies of biofuels, triggered by increasing demand, tend to come from less sustainable sources. Their source is more difficult to trace, which renders their impact in terms of greenhouse gas reductions more opaque as well. Also, first-generation biofuels may drive up food prices.

  Biofuel policies should take note of these concerns and include elements in their design that address these concerns. On a national level, incentives for first-generation biofuels should be coupled with sustainability criteria, such as in the British RTFO. Additionally, R&D and demonstration projects for second-generation biofuels should be put in place. As development of second-generation biofuels is of supranational concern, this is ideally addressed at a European level.

6.2 LPG

6.2.1 Barriers

LPG is a mature technology that has been in use for decades. There is no more need to demonstrate the feasibility of LPG in passenger cars. Hence, all barriers for LPG relate to creating and sustaining an early market (Table 6.7). Once these barriers are solved and LPG moves into the mass market phase, no more barriers are expected.

LPG requires a dedicated infrastructure (i.e. pumps, distribution system) and vehicles that can run on it. On the infrastructure side, the geographical coverage of infrastructure is therefore a barrier. On the vehicle side, there are a number of barriers. LPG vehicles can be bought as new vehicles or existing vehicles can be converted to (also) run on LPG. In the former case, a

[32] The VRI could for instance be used as an indicator to determine the number of filling stations that fuel providers are required to open over the next period, or the amount of investment grant that will be available. The VRI should strike a balance between the availability of high-blend fuels for consumers and the utilisation of the associated infrastructure.

barrier in the early market phase is the availability of LPG car models. In the latter case, conversion costs may form a barrier. Conversion may cause more rapid deterioration of certain (engine) components, which increases maintenance costs and harms durability. Consequently, the residual value of converted vehicles tends to be lower.

LPG vehicles are typically also able to run on petrol. Therefore, an introduction of LPG does not really entail a chicken-and-egg dynamic – LPG vehicles can always make use of the existing refuelling infrastructure. Of course, minimum infrastructure coverage should still be available to make the switch to LPG attractive.

Table 6.7 *Barriers for LPG per innovation phase*

Barrier	R&D	Demo	Early market	Mass market
Filling station coverage				
Vehicle availability				
Vehicle (conversion) cost				
High maintenance costs				
Retrofit vehicle durability				
Low residual vehicle value				

6.2.2 Policies to support the introduction of LPG

6.2.2.1 EU policy

There is no specific EU policy to stimulate the use of LPG in passenger cars. Regulation 443/2009, which sets CO_2 performance standards for new cars, theoretically provides an incentive for car manufacturers to include LPG-powered cars in their sales mix, because the specific CO_2 emissions of LPG vehicles are lower than that of conventional vehicles[33].

6.2.2.2 National policies: LPG

On a national level, LPG almost universally enjoys a low excise tax compared to conventional fuels, even in terms relative to the cost of the fuel (i.e. excluding taxes) and taking into account the lower energy content of LPG. Apart from that, there are little specific incentives for LPG (Table 6.8).

[33] However, it is possible that the requirements of this Regulation will be fulfilled at lower costs by (other) efficiency improvements to conventional vehicle technology (IEA RETRANS, 2010).

Table 6.8 *Policy measures and LPG market shares in selected EU countries*

POLICY SUMMARY for 2009					
	Market share	Low excise tax	Vehicle tax reduction	Vehicle Subsidies	Other support policies
Bulgaria	15,8%	X			
Lithuania	15,3%	X			
Poland	13,8%	X			
Netherlands	3,3%	X	X		
Italy	2,6%	X		X	
Latvia	2,5%	X			
Czech Republic	1,4%	X			
Belgium	0,8%	X			
Hungary	0,7%	X			
Germany	0,5%	X			
Portugal	0,4%	X			
United Kingdom	0,3%	X			
France	0,3%	X	X	X	X
Austria	0,2%	X	X		
Greece	0,2%	X			
Spain	0,1%	X			
Denmark	0,1%	X			
Luxembourg	0,1%	X			

Note: Market shares are from 2007, selected measures are from 2009. Market shares are based on energy content.

6.2.3 Policy effectiveness

Three cases have been selected to examine policy effectiveness in more depth, based on the list presented in Table 6.8. Three (South) East European countries top this list by some distance. Poland will be discussed as an example of the developments in these countries. The Netherlands and Italy are examples of countries that have a long history in LPG use, but in which the market share of LPG is under pressure. The Netherlands is studied as an example of this situation. Finally, contrary to other countries, France has a portfolio of measures in place, and will also be discussed.

6.2.3.1 Poland

Poland has witnessed a strong growth of LPG consumption for transport in the period 1993-2005. In 2005, the market share of LPG peaked at almost 15%, after which a decline has set in. Data for the LPG vehicle stock are only available for 2003-2008 and indicate a trend of slowing growth. Interestingly, this implies that the consumption per vehicle has dropped, because vehicles are driven less on LPG or have a higher efficiency. Data on LPG filling stations is very scarce. In 2008, there were about 6700 LPG filling stations in Poland, implying that the VRI[34] for LPG is approximately 320.

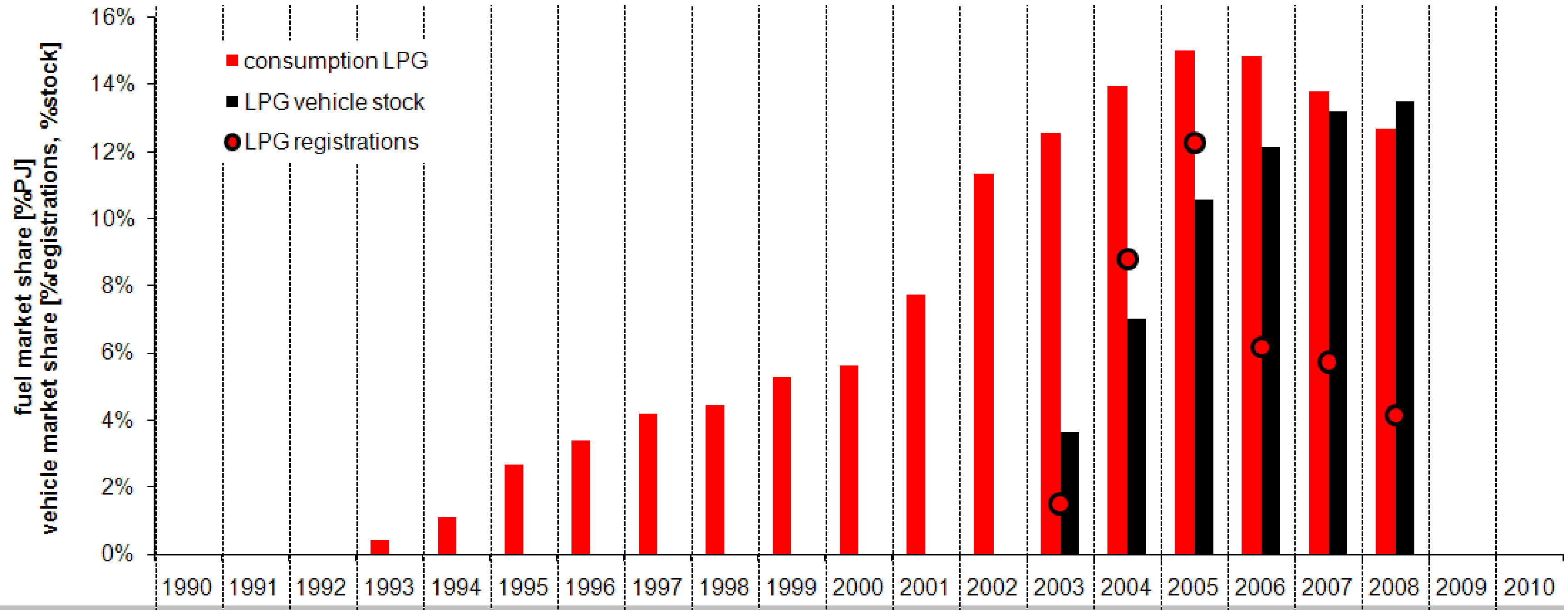
The only policy measure that has been in place in support of LPG is a low excise duty[35]. The favourable situation for LPG in Poland cannot be entirely ascribed to this, however. The boom in LPG consumption was primarily fuelled by an inflow of second-hand vehicles from Western Europe that could be converted to LPG cheaply, partly due to the low labour cost in

[34] A low VRI implies that there is a good availability of refuelling infrastructure for consumers. However, a low VRI also implies that the refuelling infrastructure is underutilised and is relatively costly for fuel distributors. Trivially, a high VRI represents the opposite situation.

[35] The excise duty is also low compared to that of conventional fuels. Depending on the oil price, excise duties make up about 23% of the price of LPG, 43% of the price of petrol and 34% of the price of diesel.

Poland (World LP Gas Association & Menecon Consulting, 2005). This added to the low cost of using LPG as a fuel.

Although the low excise duty has certainly contributed to the favourable situation for LPG in Poland, it only offers a partial explanation. The declining trend in LPG consumption has set in after an increase of the excise duties for LPG, but the discount that LPG has compared to conventional fuels increased in most of the years after 2004. This indicates that policy cannot fully determine market developments.



	2004	2005	2006	2007	2008	2009	2010
low excise duty	0,41 zł	0,45 zł	0,45 zł	0,45 zł	0,45 zł	0,46 zł	0,46 zł
excise duty as %pump price		23%	21%	23%	20%	28%	22%
cost advantage vs. petrol		1,64 zł	1,59 zł	1,68 zł	2,03 zł	1,25 zł	2,16 zł
cost advantage vs. diesel		1,49 zł	1,57 zł	1,64 zł	1,85 zł	1,23 zł	1,77 zł

Figure 6.8 *Development of LPG and LPG vehicle market share in Poland. Data on vehicles are only available for the period 2003-2008. Excise duties are per litre. Cost advantage is expressed as the discount on the pump price that LPG enjoys compared to conventional fuels.*

Sources: IEA, Eurostat, EC Oil Bulletin

6.2.3.2 Netherlands

LPG has been in use for decades in the Netherlands (Backhaus & Bunzeck, 2010). The use of LPG was initiated in the 1950s by a single company that saw a market opportunity for LPG. This company was very active in establishing LPG infrastructure. Consequently, the right circumstances were in place when prices of conventional fuels soared in the 1970s, leading to the real breakthrough of LPG.

There has never been really strong government support for LPG, although the government implemented some rule changes that enabled the a more widespread use of LPG. Most importantly, in the 80s the rule that LPG and conventional fuels were not allowed to be sold at the same filling station was suspended (Backhaus & Bunzeck, 2010). Currently, two fiscal measures are in place to support LPG. The excise duty on LPG is low relative to the excise duty on conventional fuels. Furthermore, there is a reduction in the ownership tax for vehicles that meet certain emission standards.

The use of LPG in the Netherlands has peaked in 1985 and has been in decline since. In recent years, the LPG market share has stabilised (Figure 6.9). Since 2005, the market share of LPG in vehicle registrations has been on the rise.

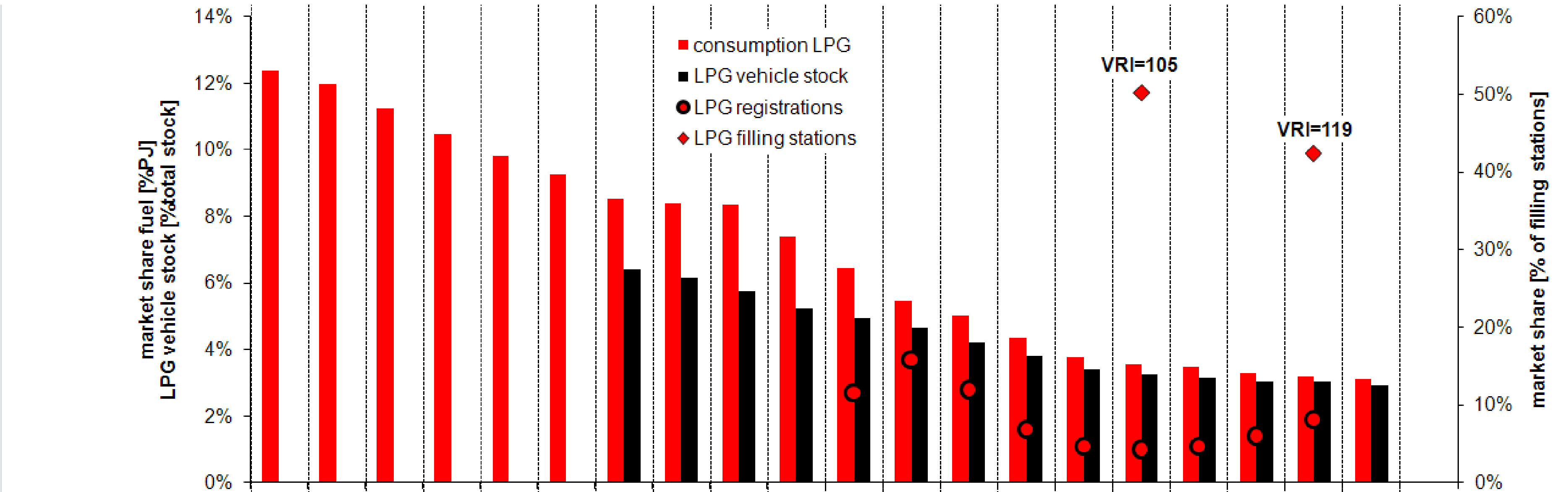
In the period 1985-2005, the incentives in place for LPG have been insufficient to draw more consumers to LPG. Apart from that, LPG enjoyed a bad image. Cars that had been converted to LPG tended to require more maintenance and break down more often. Some companies that owned large fleets implemented a policy not to purchase LPG vehicles (Backhaus & Bunzeck, 2010). Although technical progress has improved the performance of LPG vehicles, the image of LPG is still not very good.

Since 2005, the cost advantage in relative terms has been relatively constant – implying that the cost of both LPG and conventional fuels move in tandem with the oil price – but it has been growing in absolute terms. This has made LPG relatively more attractive.

The long history of LPG in the Netherlands has resulted in a very good geographical coverage of infrastructure. The decline in the use of LPG has caused the LPG vehicle stock to drop more quickly than the number of LPG filling stations. In 2008, still more than 40% of the filling stations offered LPG. The VRI[36] has dropped from more than 200 in the 80s to 119 in 2008.

In sum, the use of LPG in the Netherlands was triggered by entrepreneurial activities. Government support only entered later. Recent development of LPG market share has been determined by developments of the oil price. An extensive infrastructure network is in place that could enable a swift revival of LPG.

[36] A low VRI implies that there is a good availability of refuelling infrastructure for consumers. However, a low VRI also implies that the refuelling infrastructure is underutilised and is relatively costly for fuel distributors. Trivially, a high VRI represents the opposite situation.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
low excise duty				€ 0,03	€ 0,03	€ 0,03	€ 0,03	€ 0,03	€ 0,03	€ 0,04	€ 0,06	€ 0,07	€ 0,07	€ 0,05	€ 0,05	€ 0,05	€ 0,05	€ 0,05	€ 0,07	€ 0,07	€ 0,09
excise duty as %pump price				12%	11%	10%	9%	8%	9%	11%	14%	16%	16%	13%	12%	11%	10%	9%	10%	14%	13%
cost advantage vs. petrol	€ 0,45	€ 0,45	€ 0,53	€ 0,56	€ 0,60	€ 0,61	€ 0,62	€ 0,61	€ 0,65	€ 0,59	€ 0,60	€ 0,71	€ 0,67	€ 0,73	€ 0,72	€ 0,74	€ 0,84	€ 0,75	€ 0,82	€ 0,75	€ 0,73
cost advantage vs. diesel	€ 0,22	€ 0,24	€ 0,23	€ 0,34	€ 0,36	€ 0,35	€ 0,37	€ 0,37	€ 0,35	€ 0,29	€ 0,33	€ 0,40	€ 0,34	€ 0,37	€ 0,36	€ 0,40	€ 0,47	€ 0,41	€ 0,50	€ 0,52	€ 0,38
ownership tax reduction																					

Figure 6.9 *Development of LPG fuel, LPG vehicle and LPG filling station market share in the Netherlands. Data on vehicles are only available for the period 1996-2008. Excise duties are per litre. Cost advantage is expressed as the discount on the pump price that LPG enjoys compared to conventional fuels.*

Sources: IEA, Eurostat, EC Oil Bulletin, (Bovag, 2010)

6.2.3.3 France

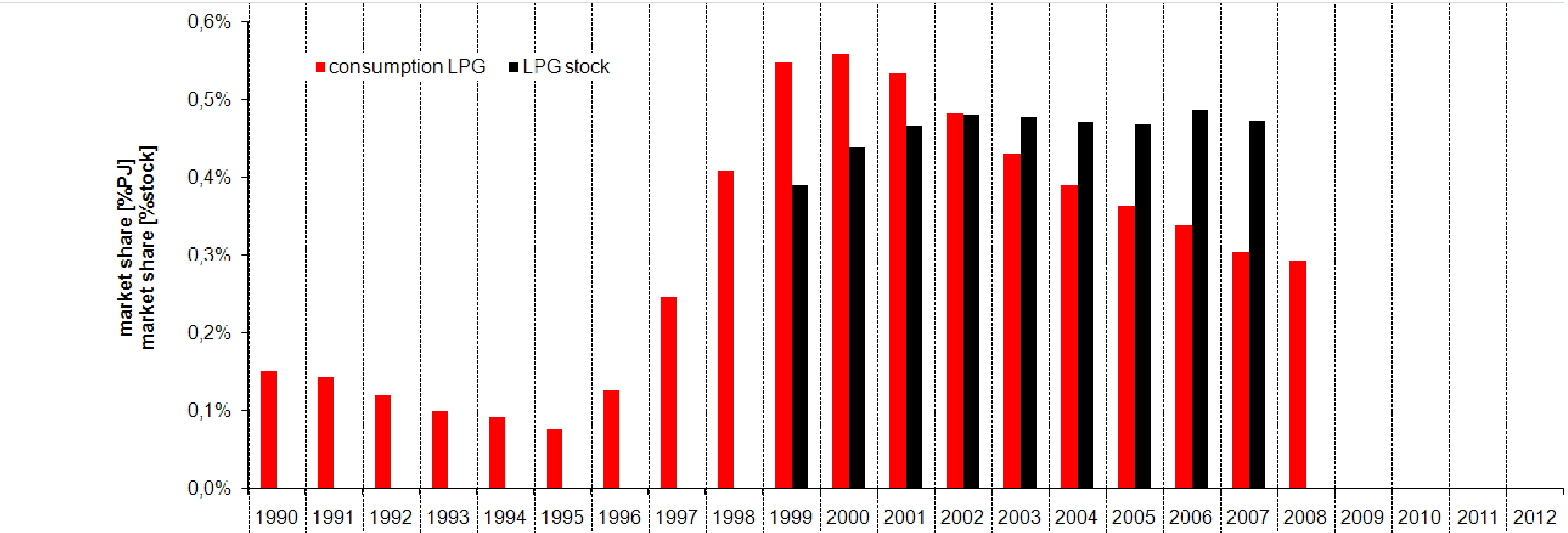
There is a very clear trigger for the development of LPG in France: the fiscal reforms of 1996 that slashed the excise duties from €0.23 to €0.07 per litre. Following this measure, LPG market share quadrupled to a peak in 2000. However, at the peak, LPG only reached a market share of just over 0.5%.

Since 2000, the market share of LPG has shown steady decline. This decline is hard to explain. Although the cost advantage of LPG over conventional fuels has declined in the period 2000-2003, it has increased from 2004 onwards. In 2008, the cost advantage was actually higher than in the boom period. This lends credibility to the idea that the reduction of excise duties has had a one-time effect that has not lasted.

Since 2001, France has introduced many vehicle-related subsidies. The conversion grant that was offered was large enough to cover the entire cost of conversion (World LP Gas Association & Menecon Consulting, 2005). The reduction of registration tax differs between 50% and 100%, depending on the region. Arguably, these generous measures have had their effect in stimulating the LPG vehicle stock, which has seen a lesser decline than the consumption of LPG itself.

The data on the market share of LPG filling stations in France are sparse. In 2007, the VRI can be calculated as approximately 76, which is very low[37]. Interestingly, there are no specific policies to stimulate the development of LPG infrastructure. A possible explanation is that the development of LPG is concentrated geographically, so that the VRI is higher in selected areas.

[37] A low VRI implies that there is a good availability of refuelling infrastructure for consumers. However, a low VRI also implies that the refuelling infrastructure is underutilised and is relatively costly for fuel distributors. Trivially, a high VRI represents the opposite situation.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
low excise tax						€ 0,23	€ 0,07	€ 0,07	€ 0,06	€ 0,06	€ 0,06	€ 0,06	€ 0,06	€ 0,06	€ 0,06	€ 0,06	€ 0,06	€ 0,06	€ 0,06	€ 0,06	€ 0,06		
excise duty as %pump price								16%	15%	14%	11%	12%	12%	11%	11%	9%	8%	8%	8%	9%			
cost advantage vs. petrol								€ 0,51	€ 0,50	€ 0,52	€ 0,57	€ 0,53	€ 0,52	€ 0,48	€ 0,49	€ 0,52	€ 0,53	€ 0,57	€ 0,59	€ 0,53			
cost advantage vs. diesel								€ 0,24	€ 0,22	€ 0,26	€ 0,32	€ 0,29	€ 0,28	€ 0,26	€ 0,32	€ 0,38	€ 0,37	€ 0,38	€ 0,50	€ 0,33			
vehicle premium (low CO_2)																			2.000	2.000	2.000		
conversion grant																							
registration tax reduction																							

Figure 6.10 *Development of LPG fuel, LPG vehicle and LPG filling station market share in France. Data on vehicles are only available for the period 1999-2007. Excise duties are per litre. Cost advantage is expressed as the discount on the pump price that LPG enjoys compared to conventional fuels.*

Sources: IEA, Eurostat, EC Oil Bulletin, Ministère de Développement Durable

6.2.4 Conclusions and recommendations

The main conclusion is that the fuel costs of LPG relative to conventional fuels are by far the major driver of the uptake of LPG. LPG prices are less volatile than conventional fuel prices, implying that the relative cost difference is larger in times of high oil prices. Nonetheless, a minimum cost difference is necessary to convince consumers to switch.

The analysis shows two distinctive groups of cases. In a group of (primarily) Eastern European countries, LPG enjoys a cost advantage – partly due to low conversion costs – that provides sufficient incentive for a large group of motorists to switch to LPG.
Furthermore, there is a group of countries that have witnessed a growth of the use of LPG that dates back many decades. In these countries, LPG consumption is declining and inversely coupled to the oil price. With a rising oil price, the price difference between LPG and conventional fuels increases in absolute terms, making the use of LPG more attractive.

These conclusions lead to the recommendations below.

- *Cost-lowering measures can get the market started…*

The most obvious measure to stimulate LPG is a low excise duty. Most countries have a very low excise duty in place. These measures serve to provide entrepreneurs with sufficient perspective that a market for LPG can be successfully developed. Note that swings in the oil price influence the price difference between LPG and conventional fuels.

- *…but avoid policy to become 'too successful'*

This problem is the same as for biofuels. Since the excise duty on LPG is much lower than on conventional fuels, a large market share for LPG leads to a large decline in excise duty income.
There is also a major difference, however. The cost of LPG (without taxation) is less than the cost of conventional fuels (without taxation). The cost differential required to induce consumers to switch to LPG might decrease when the critical mass of consumers using LPG is smaller. This may trigger more infrastructure development. Perhaps even more importantly, the image of LPG might improve if more consumers use LPG vehicles without too many issues. Decreasing barriers like these might decrease the cost differential required to induce consumers to use LPG, leading to a larger scope to increase the excise duty again. Therefore, it can be expected that the impact on government budget decreases over time.

- *Vehicle support is optional*

Some countries have implemented measures aimed specifically at vehicles, and there is some evidence that they have had effect. However, there is also evidence that LPG development can take place without such support.

- *There is no need for dedicated infrastructure support*

In all of the cases studied, there have been no dedicated measures to support LPG infrastructure. Once the cost differential between LPG and conventional fuels triggered LPG use, fuel providers installed the required infrastructure by themselves. Apparently, the investment barrier for an LPG pump is by no means insurmountable.

6.3 CNG

6.3.1 Barriers

The barriers for CNG are listed in Table 6.9 . CNG faces the requirement to provide a decent geographical coverage of refuelling infrastructure. The infrastructure required for

CNG is relatively expensive, e.g. compared to the infrastructure required for LPG. Therefore, rolling out infrastructure for CNG is quite a significant barrier.

CNG vehicles are generally also capable of running on petrol, which reduces the chicken-and-egg dynamic. However, using CNG as a fuel is typically cheaper than using petrol. Therefore, the availability of refuelling infrastructure is still an important factor for the successful introduction of CNG.

Conversion of existing vehicles to use CNG as a fuel is not very common. Instead, car manufacturers typically offer separate versions of their models that are capable of using CNG as a fuel. These versions are typically significantly more expensive than the conventional versions. Moreover, due to the relative unfamiliarity of these values, their residual value is low compared to conventional vehicles. Finally, car manufacturers only offer a limited range of models that are capable of using CNG as a fuel.

Table 6.9 *Barriers for CNG per innovation phase*

Barrier	R&D	Demo	Early market	Mass market
Filling station coverage				
Vehicle availability				
High vehicle cost				
Low residual vehicle value				

6.3.2 Policies to support the introduction of CNG

6.3.2.1 EU policy

As for LPG, there is no specific EU policy to stimulate the use of CNG in passenger cars. Regulation 443/2009, which sets CO_2 performance standards for new cars, theoretically provides an incentive for car manufacturers to include CNG-powered cars in their sales mix, because the specific CO_2 emissions of CNG vehicles are lower than that of conventional vehicles[38].

6.3.2.2 National policies

Table 6.10 provides an overview of national policies on CNG in a selection of countries. In the majority of countries, CNG is supported by low taxation (as for LPG). Many countries also have additional measures in place. The purchase of CNG vehicles is supported by fiscal measures such as the reduction of acquisition tax and by direct vehicle subsidies. Some countries have direct incentives in place to support the construction of filling stations. Other support policies are often regional (e.g. reduced parking fees).

[38] However, it is possible that the requirements of this directive will be fulfilled at lower costs by (other) efficiency improvements to conventional vehicle technology (IEA RETRANS, 2010).

Table 6.10 *Policy measures and CNG market shares in selected EU countries*

	Market share	Low taxation	Acquisition tax reduction	Vehicle Subsidies	Filling Station Subsidy	Other support policies
Bulgaria	1,7%	?	?	?	?	?
Italy	1,4%	?		X		X
Sweden	0,3%	X			X	X
Greece	0,2%	X			X	
Germany	0,2%	X	X			
France	0,2%	X		X		X
Czech Republic	0,1%	X				
Austria	0,0%	X				
Netherlands	0,0%	X	X		X	X
Belgium	0,0%	X				
Poland	0,0%	X				

Note: Market shares are from 2007, with the exception of Germany (2006). Selected measures are from 2009. Data on policy measures in Bulgaria and taxation in Italy are lacking.

6.3.3 Policy effectiveness

Based on energy content, the market share of CNG is highest in Bulgaria. For that reason, it would be interesting to see to what extent this development was policy-driven. Unfortunately, accessible data on Bulgaria is extremely scarce, making it impossible to draw conclusions on the Bulgarian case. Instead, the developments in Italy and Germany have been analysed. In Italy, CNG has been in use for a long time, whereas the development of CNG in Germany is of more recent date.

6.3.3.1 Italy

The use of CNG as automotive fuel in Italy dates back several decades. Data are available since 1973 and indicate that the use of CNG peaked in 1975, most likely due to the oil crisis. CNG use dropped a bit until the early nineties and has been on the rise since.

Unfortunately, it is difficult to pinpoint the factors that underlie the development of CNG use in Italy, partly because there is no good account of the policy measures that have been applied over time. A prime driver has been the price difference between CNG and conventional fuels, at € 0.55 compared to petrol and € 0.61 compared to diesel (GVR, 2010). A patchwork of (relatively unrelated) policy measures has been applied, both at a national level and at a regional level. Policies have included investment subsidies for CNG filling stations, subsidies for new NGVs and vehicle conversions, and the institution of zones in which only vehicles fulfilling certain European emission norms (e.g. euro-2 and higher) and NGVs were allowed. Next to policy measures, Italy has an active industry on natural gas. Both fuel providers and car manufacturers have actively promoted the use of CNG. Sales of NGVs and CNG typically increase after the release of new vehicle models powered by CNG.

Figure 6.11 summarises the available data on the market shares of CNG as a fuel, NGVs, and CNG filling stations since 1990. The data show a relatively high VRI: a filling station serves a average of about 600 to 700 vehicles[39]. The recent growth in NGVs is accompanied by a growth in filling stations, indicating that the market is well able to cater for the growing demand for CNG.

The tentative conclusion is that policy and an active industry have started and sustained the market for CNG and NGVs in Italy, aided by external developments such as a high price for

[39] A low VRI implies that there is a good availability of refuelling infrastructure for consumers. However, a low VRI also implies that the refuelling infrastructure is underutilised and is relatively costly for fuel distributors. Trivially, a high VRI represents the opposite situation.

conventional fuels. Currently, the prerequisites for a further growth of the use of CNG are in place. The most important policy measure is to ensure that CNG keeps enjoying a cost advantage compared to conventional fuels, maintaining the circumstances that provide industry sufficient incentive to invest in CNG as a fuel.

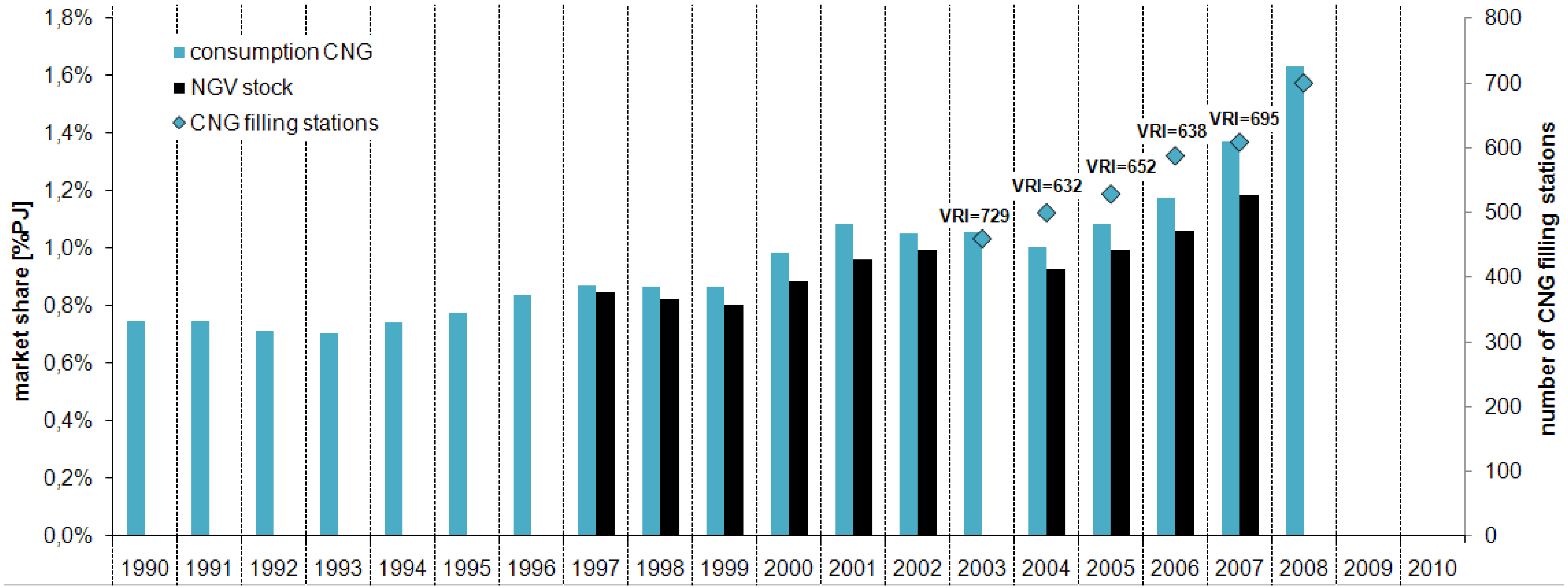


Figure 6.11 *Development of CNG fuel, NGV and CNG filling station market share in Italy. Data on vehicles are only available for the period 1997-2007, with 2003 missing.*

Sources: IEA, Eurostat, (GVR, 2010), Natural Gas Vehicle Association Europe

6.3.3.2 Germany

The use of CNG is relatively recent in Germany. Data are available since 1998 and show that the market share of CNG by energy content has increased from less than 0.05% in 1998 to over 0.2% in 2006 (Figure 6.12).

The major incentive for stimulating CNG has been the low fuel taxation. Taxation has been such that CNG has always enjoyed a significant cost advantage over conventional fuels. Currently, CNG enjoys a cost advantage of € 0.57 per litre petrol-equivalent and € 0.23 per litre diesel-equivalent (GVR, 2010). Current taxation levels have been fixed until 2018. As in Italy, other incentives are regionally dispersed, making it hard to judge their effects. In many regions, the purchase of vehicles is subsidised. In 2000, the federal government ran a large-scale information campaign to increase awareness of the possibilities of CNG as an automotive fuel.

Industry has acted on the conditions that are created by government policy, that the government has created a stable climate for investments in CNG. Interestingly, it seems that especially fuel providers have been active. The VRI in Germany has been extremely low since 1998, reaching as low as 41. A low VRI implies a low utilization of refuelling infrastructure and a low return on investment for fuel providers. On the other hand, it implies that there is a relatively good availability of refuelling infrastructure for the consumers that have adopted CNG vehicles.
The German fuel providers have agreed to introduce 1000 CNG filling stations. The fact that fuel providers have opened so many CNG pumps illustrates the fact that they anticipate future growth of the market for CNG as an automotive fuel.

In recent years, the growth in the NGV stock has caught up, and the VRI has reached approximately 100 in 2009. Nonetheless, an increased uptake of NGVs would be welcome to bring the VRI to an acceptable level. In Germany, as in Italy, the introduction of new NGV models is visible in the sales of NGVs. Cooperation of the car manufacturing industry is therefore essential for a successful introduction of NGVs.

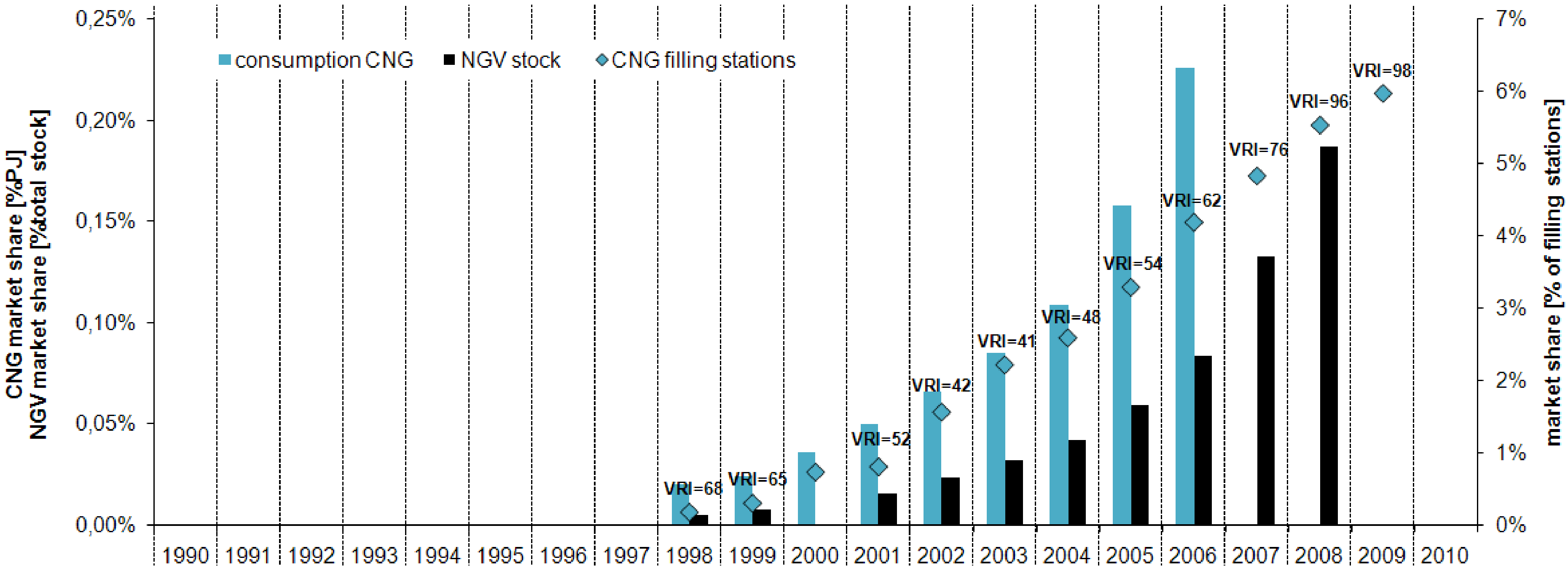


Figure 6.12 *Development of CNG fuel, NGV and CNG filling station market share in Germany.*

Sources: IEA, NGVAE

6.3.4 Conclusions and recommendations

The technology associated with the use of CNG as an automotive fuel is mature and has been used for many decades. Nonetheless, market shares of CNG vehicles are low with the market share by energy content not exceeding 2% in any country in Europe.

It seems that the chicken-and-egg barrier is relatively prominent for CNG, e.g. more prominent than for LPG, which can be explained by the relatively high investment cost for infrastructure and the relatively high price of CNG vehicles. The recommendations below are therefore (partly) aimed at tackling this barrier.

- *Provide an incentive to keep fuel cost low*

A lower fuel price is a prime incentive for consumers to switch to CNG. The German example shows that a low taxation of CNG can provide a powerful incentive for consumers to switch, but also for industry to start the construction of infrastructure required for CNG and the development of CNG vehicles.

In some countries, the cost of CNG (excluding taxes) is lower than the cost of conventional fuels. In the Netherlands, the cost of CNG without taxes is about 60% of that of conventional fuels. In these countries, it is relatively cheap to introduce and sustain policies that keep the price of CNG at a level at which competition with conventional fuels is possible. On the other hand, in Germany the cost of CNG before taxation is about equal to that of conventional fuels. Keeping the cost of CNG at a competitive level is significantly more expensive in countries like Germany.

- *Stimulate cooperation between key stakeholders*

The fuel providers and car manufacturing industry need to tackle the chicken-and-egg problem jointly. A good geographical coverage of infrastructure and a broad range of NGV models are required to convince consumers to switch to CNG. The latter aspect is illustrated by the fact that the introduction of new NGV models causes peaks in NGV sales.

In Italy and Germany, these industries have joined forces in associations. Governments could stimulate these developments and e.g. try to sign a covenant with these associations. In such covenants, each actor should commit undertake actions to make the introduction a success:

- Government should at least commit to measures that keep the price of CNG at a competitive level for a fixed period and possibly offer incentives to reduce the price of CNG vehicles and the costs of CNG infrastructure.
- Fuel providers should commit to the construction of a number of CNG pumps that jointly offer a good geographical coverage.
- Car manufacturers should commit to the introduction of CNG vehicle models that jointly cover a significant number of vehicle segments.

- *Provide incentives for vehicles and infrastructure to 'kick start' introduction*

Additional incentives may 'kick start' the market. On the infrastructure side, investment subsidies may be applied to increase the number of available refuelling stations. On the vehicle side, tax breaks in acquisition and road tax, as well as direct vehicle subsidies can stimulate the uptake of vehicles.

The necessity of these additional measures must be critically assessed. In the German example, infrastructure has been built up quickly – perhaps even more quickly than necessary – without such additional measures. It seems to be harder to convince consumers to purchase a NGV, so measures on the vehicle side seem more appropriate. It is recommended to discontinue these incentives after the market has taken off.

- *Establish broadly accepted standards*

Broadly accepted standards for infrastructure and vehicles are a requirement for interoperability and prevent the formation of isolated networks between which no travel is possible. A worldwide standard is preferable, which implies that there is a role for the European Commission to push for such a standard at the global level.

6.4 Hybrid-electric vehicles

6.4.1 Barriers

Hybrid-electric vehicles (HEVs) are in the early market phase. The technology has been on the market on a significant scale for approximately two decades and has proven itself. Hybridisation is an 'add-on' to existing technology and does not require dedicated infrastructure to be rolled out. Consequently, HEVs are very similar to conventional vehicles. The major barrier for HEVs is that they come at a cost that is higher than conventional vehicles[40].

The availability of vehicle models can be a problem in the early market phase. However, car manufacturers operate globally and are bringing an increasing number of HEV models to the market. In the mass market phase, scarce resources may form a constraint. The supply of rare metals that are used in the batteries in HEVs may be too limited to serve too large a fleet.

Table 6.11 *Barriers for HEVs per innovation phase*

Barrier	R&D	Demo	Early market	Mass market
High vehicle cost			■	
Vehicle availability			■	
Scarcity of raw materials				■

6.4.2 Policies to support the introduction of hybrid-electric vehicles

6.4.2.1 EU policy

There is no specific EU policy for HEVs. Regulation 443/2009, which sets CO_2 performance standards for new cars, theoretically provides an incentive for car manufacturers to include HEVs in their sales mix, because the specific CO_2 emissions of HEVs are lower than that of conventional vehicles[41].

6.4.2.2 National policies

An overview of policies on HEVs in a selection of EU countries is provided in Table 6.12. Virtually all measures all of a fiscal nature, some with an emphasis on reducing the purchase price of HEVs, some with an emphasis of reducing annual taxation (road tax). In the UK, HEVs are exempt from the London congestion charge.

[40] Whether these costs can be recovered through lower fuel consumption depends on factors such as annual mileage, driving style and driving patterns. However, consumers tend to be reluctant to purchase a vehicle with a higher price even when the additional costs can be recovered during the lifetime of the vehicle.

[41] However, it is possible that the requirements of this Regulation will be fulfilled at lower costs by (other) efficiency improvements to conventional vehicle technology (IEA RETRANS, 2010).

Table 6.12 *Policy measures and HEV share in new vehicle registrations in selected EU countries in 2008*

	Share of registrations	Registration tax reduction	Vehicle Subsidies	Road tax reduction	Company car tax reduction	Other support policies
Netherlands	2,3%	X		X	X	
Sweden	1,4%			X	X	
United Kingdom	0,5%			X	X	X
France	0,3%		X			
Belgium	0,3%		X			
Germany	0,1%					
Poland	n/a					
Denmark	n/a					
Italy	n/a					
Austria	n/a	X				
Luxembourg	n/a					
Finland	n/a					
Ireland	n/a	X				
Greece	n/a	X		X		
Bulgaria	n/a					
Estonia	n/a					
Hungary	n/a					
Latvia	n/a					
Lithuania	n/a					
Malta	n/a					
Slovak Republic	n/a					
Slovenia	n/a					

Note: n/a = no data available

6.4.3 Policy effectiveness

Table 6.12 reveals a quite clear picture: HEVs make up a larger share of vehicle registrations in countries that have (significant) fiscal measures in place. These measures lower the main barrier: high vehicle cost.

The developments in the country that features the highest share of HEVs in registrations, the Netherlands, confirms this picture. Figure 6.13 shows the development of the HEV market share in the Netherlands. It shows that acquisition tax and road tax exemptions coincided with some initial sales, but that the tax exemptions granted to private users of company cars have really triggered the high sales numbers of recent years. Sweden and the UK (numbers 2 and 3 in Table 6.12) have similar incentives for users of company cars in place.

The downside of this kind of stimulus is that it can easily become too expensive. In the Netherlands the costs of the policy measures have exceeded the budgeted amount for 2010. Nonetheless, it has been decided to continue the measures in 2011.

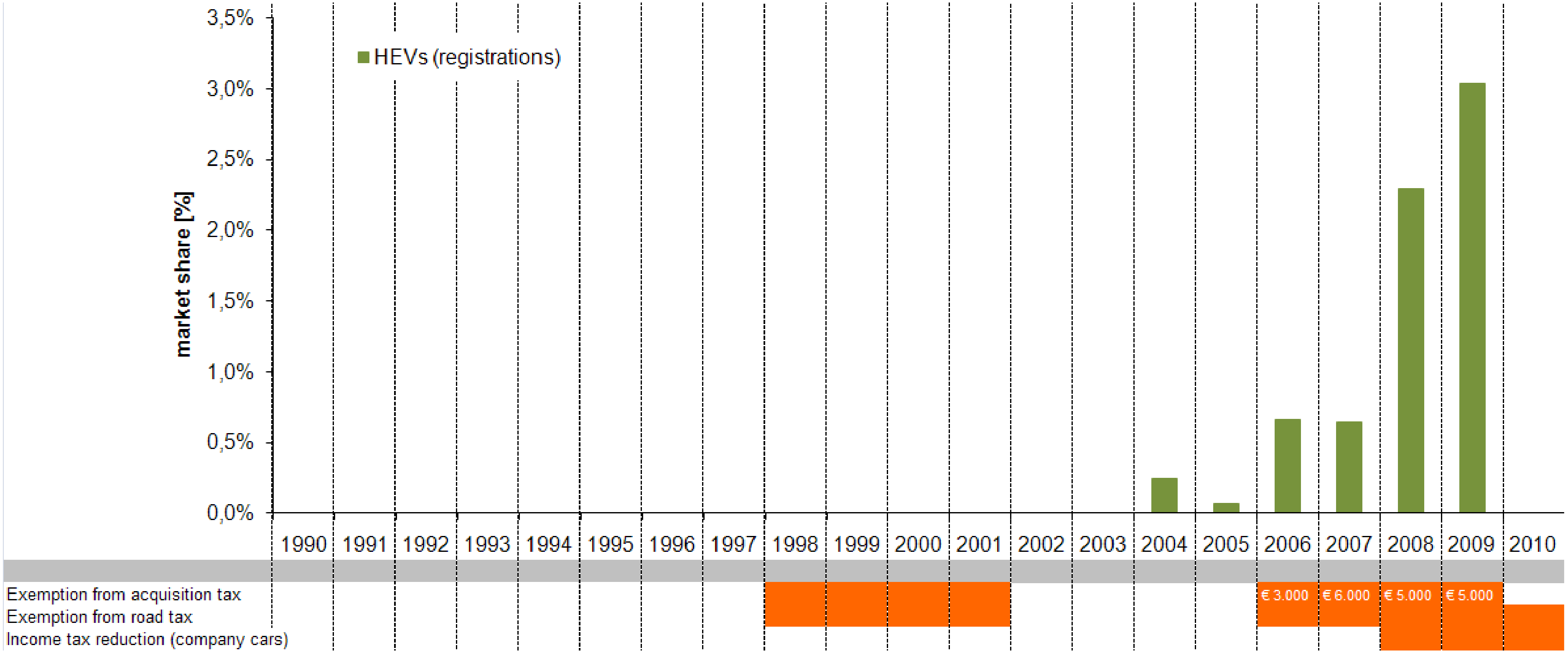


Figure 6.13 *Development of the share of HEVs in vehicle registrations in the Netherlands. Monetary amounts represent the maximum amounts for which exemptions are granted.*

Sources: Eurostat, ACEA, Jato Dynamics

6.4.4 Conclusions and recommendations

There are no major barriers for the introduction of HEVs other than the higher vehicle purchase costs. Fiscal measures are effective measures to stimulate the uptake of HEVs - especially a reduction of company car taxation has proven effective. However, this type of policy directly affects government budget and may become too expensive when sales of HEVs increase significantly.

Therefore, it is recommended that the fiscal measures described above are complemented by measures that reduce the cost difference between HEVs and conventional vehicles, e.g. by raising the costs of conventional vehicles. CO_2 norms such as stipulated by Regulation 443/2009 are an example of this type of policy. It can be expected that the norms set by this Regulation require adaptations that will raise the cost of conventional vehicles.

6.5 Battery-Electric Vehicles and Plug-in Hybrid Electric Vehicles

Battery-Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) will be discussed together. The two vehicle types are similar because they both use an electric motor to drive the wheels and can be recharged using grid electricity. The major difference is that a PHEV also has an internal combustion engine that drives a generator which recharges the battery. This allows for a much larger vehicle range and a smaller battery.

A major reason to include BEVs and PHEVs under the same header is that policy measures often benefit both technologies. In fact, many countries do not distinguish between the two vehicle types in their policy[42].

6.5.1 Barriers

BEVs and PHEVs are in the demonstration phase. Additionally, BEVs have moved into some (small) market niches (e.g. small cars primarily used in cities).

BEVs and PHEVs still have a number of barriers to overcome before they can enter the early market phase (Table 6.13). The R&D phase is primarily concerned with improving battery safety and durability to a level that will allow BEV and PHEV performance that is comparable to conventional vehicles. Additionally, BEVs and PHEVs are more expensive than conventional technologies, largely due to the costs of the batteries. Cheaper battery technology is a solution for this barrier – however, it is expected that BEVs and PHEVs can be brought to the market before the technologies are fully cost competitive with conventional technology. Hence, the barrier is likely to persist through the demonstration and early market phases. A lack of standards (e.g. for charging infrastructure) is a problem to be solved before the technology can move into the early market phase. Also, a good availability of vehicle models in the various segments of the car market is important during the early market phase. As with HEVs, scarcity of raw materials may pose a problem in the mass market phase, when BEVs and PHEVs achieve very significant market shares.

In addition, BEVs currently have a limited range compared to conventional vehicles. Since charging batteries takes a long time, this implies that the use of BEVs is markedly different (and perhaps less convenient) than the use of a conventional vehicle. This problem may be solved by R&D into batteries with a larger specific capacities. However, it may also be solved in the demonstration phase by experimenting with battery exchange stations or fast charging, or in the early market phase by customers who are willing to change their behaviour and use

[42] Typically, policy is primarily targeted at BEVs. However, PHEVs also benefit from (part of) the measures, such as charging infrastructure support.

BEVs only for (relatively) short trips. (A change in) user behaviour could therefore speed up the introduction of BEVs. Finally, the limited range of BEVs also requires the rollout of a charging infrastructure, since vehicles need to be recharged at travel destinations (e.g. work) as well. However, the rollout of this infrastructure can take place very gradually and only needs to provide places to charge vehicles in addition to charging that takes place at home.

Table 6.13 *Barriers for PHEVs and BEVs per innovation phase*

Barrier	R&D	Demo	Early market	Mass market
BEVs & PHEVs				
Battery safety				
Battery durability				
High vehicle cost				
Lack of standards				
Vehicle availability				
Scarcity of raw materials				
BEVs				
Limited vehicle range				
Long charging time				
High infrastructure investment cost				
Unknown user behaviour				

6.5.2 Policies to support the introduction of BEVs and PHEVs

It is typically not very clear whether policies are aimed at BEVs or both BEVs and PHEVs. Therefore, we will not distinguish between the two types in the policy discussion below and refer to EVs instead, unless policy is clearly aimed at either BEVs or PHEVs.

6.5.2.1 EU policy

The focus of EU strategy is twofold. Firstly, several measures are aimed at creating framework conditions that are favourable for the introduction of EVs, including type-approval requirements (e.g. electric and crash safety requirements) and the creation of standards, e.g. for charging infrastructure. Secondly, the EU will launch the Green Cars Initiative in 2011, a program that includes a large-scale demonstration project aimed at assessing consumer behaviour and usage patterns and increasing awareness on electric mobility. The total public budget for the Green Cars Initiative amounts to €4.5bn.

Additionally, in Regulation 443/2009, which sets CO_2 performance standards for new cars, supercredits[43] have been included for cars that emit less than 50 gr/km. As BEVs have no tailpipe emissions at all, they are eligible for these supercredits. The Regulation thus provides an extra incentive for the introduction of BEVs.

6.5.2.2 National policies

Table 6.14 provides an overview of policy measures that are currently in place to support the introduction of EVs in a selection of EU member states.

[43] In the regulation, the emissions of vehicles are averaged over the total sales of a producer per year. In this calculation, each vehicle that emits less than 50 gr/km is allowed to count as 3.5 cars in 2012 and 2013, 2.5 cars in 2014 and 1.5 cars in 2015, potentially compensating for extra emissions from other vehicles.

Table 6.14 *Overview of policy measures for EVs in the EU and selected EU countries by innovation phase*

	R&D	Demonstration	Early market
European Union		Green Cars Initiative [€4.5bn]	Definition of type-approval requirements Crash safety requirements Charging infrastructure standard
Austria			Registration tax exemption Vehicle subsidies (regional)
Belgium			Company car taxation exemption (income tax) [max. €9000]
Cyprus			Vehicle subsidy [€700/vehicle]
Czech Republic			Road tax exemption
Denmark		Pilot project subsidy [€15m over 3 years]	Registration tax exemption Road tax exemption
France	Battery R&D support [€7.5m]	Demonstration project support [€70m]	Vehicle subsidy [€5000/vehicle] Public procurement of vehicles Mandatory construction of charging points in new buildings [starting 2012] Subsidy for construction of charging points [€1.5bn] Grid-strengthening measures [€750m] Development of charging infrastructure standard [jointly with Germany] Investment in battery production [€125m]
Germany[44]	Support for the Lithium-Ion Battery Alliance [€60m over 8 years] Storage Battery Programme	Demonstration project support [€105m over 4 years]	5-year exemption from road tax Development of charging infrastructure standard [jointly with France]

44 On top of the measures listed, Germany has earmarked a large part of its second economic stimulus package (total amount €500m until 2011) for electromobility.

	[€35m over 4 years] Energy Management in Vehicles [€100m over 5 years] E-energy (grid integration) [€60m over 4 years]		
Greece			Registration tax exemption Road tax reduction
Ireland		Pilot project support [€0.5m]	Registration tax reduction [max €2500] Vehicle subsidy [€5000] Rollout of 3500 charging points
Italy			Vehicle subsidies (regional)
Netherlands[45]	Vehicle R&D support	Demonstration project support [€10m over 3 years]	Registration tax exemption Road tax exemption Company car taxation exemption (income tax) Rollout of infrastructure Public procurement
Portugal			Registration tax exemption Company car taxation exemption (income tax)[46] [max. €796] Vehicle subsidy [€5000] Rollout of 1350 charging points in 2010 Public procurement [20% of vehicle purchases] Priority for EVs & parking places
Romania			Registration tax exemption
Spain		Infrastructure development (project MOVELE) [€1.5m]	Tax incentives on purchase [€6000[47]]

45 The Netherlands has a combined budget of €55m for infrastructure support, vehicle R&D support and public procurement.
46 Only if the vehicle is recharged with renewable electricity.
47 In most regions – in Andalucia, 70% of the investment is subsidised.

	Vehicle subsidies (project MOVELE) [€8m]	
Sweden		Road tax exemption Company car taxation reduction (income tax) [40%]
United Kingdom	Demonstration & Infrastructure project support [£20m]	Road tax exemption 5-year company car taxation exemption (income tax) Vehicle subsidies (in 2011 and 2012) [25% of purchase price, max. £5000/vehicle, max. £230m in total]

Legend:

Vehicle-related measures

Infrastructure-related measures

6.5.3 Policy effectiveness

The EV models that are currently on the market do not offer a performance comparable to conventional vehicles and are therefore not yet serious competitors for conventional vehicles. Consequently, EV market share is negligible and not a suited indicator to evaluate policy effectiveness. Instead, policy effectiveness will be based on a qualitative assessment of the current policies.

The overview of Table 6.14 shows that different countries take a different approach to stimulating EVs. Firstly, only a few countries have measures in place that offer focused support to R&D and demonstration projects[48]. Other countries have only deployed measures that stimulate the early market of EVs. These countries then depend on the initiatives in other countries as well on the EU's Green Cars Initiative to tackle barriers in the R&D and demonstration phases.
The R&D programmes are primarily aimed at vehicle development, in particular battery development. Only Germany has a programme in place that does R&D work on grid integration. On the other hand, all demonstration programmes cover infrastructure-related aspects.

Most countries have incentives in place that are aimed at creating an early market, but Germany is a notable exception. The focus of German policy is on R&D and demonstration of vehicles.
In contrast, France has many vehicle-related subsidies. Interestingly, France also has a number of measures in place to ensure a quick rollout of infrastructure, including an obligation to include charging points at new buildings from 2012 onwards. In addition, France has a large budget of a demonstration programme.

For instance,
Denmark, the Netherlands and Ireland are examples of small countries that aim to be frontrunners in creating an early market. They have specific characteristics that make them rather attractive for EVs (e.g. high population density and short driving distances, (intermittent) availability of wind power). By investing in demonstration programmes and measures that make the purchase of EVs attractive for consumers, they hope to attract a relatively large share of the first batches of EVs that will come to the market.

The extent to which the various measures will be successful to create an early market for EVs can only be evaluated when more EV models will be released. Policy success will depend on to what extent the measures employed will render EVs competitive with conventional vehicles, as well as consumer willingness to pay for EVs. This will also depend on generic policies that have been adopted in various countries. For instance, the registration tax exemption for EVs that Denmark has in place is very generous, since registration taxes are very high in Denmark (typically over 100% of the price without tax).

Success is also likely to be dependent on the extent to which all barriers are addressed. A number of countries have no measures in place that relate to infrastructure. Especially for BEVs, the availability of charging infrastructure at typical travel destinations (e.g. offices, public places) might significantly increase the convenience for future users. With limited public charging infrastructure, only a subset of consumers might be persuaded to adopt EVs[49]. Although a charging infrastructure might develop without stimulus by the national government, policy support for infrastructure is likely to at least accelerate the uptake of EVs.

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[48] In other countries, R&D on EVs may be funded from programmes that are broader than just EVs. These programmes than typically have no budget earmarked for EVs and are therefore not part of Table 6.14.

[49] As yet, it is unclear how much infrastructure users require. Demonstration projects can shed more light on this issue.

The (fiscal) measures that form the core of the policy in many countries amount to benefits of several thousand euro per vehicle. If EVs capture a significant market share (e.g. 5-10% of vehicle sales), these measures may become very expensive. Not all measures currently in place are designed in a way that limits the total amount spent in stimulus of EVs.

6.5.4 Conclusions and recommendations

As BEVs and PHEVs are not deployed in significant numbers, it is not yet possible to assess the effectiveness of current policy. Nonetheless, the barriers that EVs and PHEVs face on their way to commercialisation and the observations in the previous section provide the basis for some conclusions.
The first target for policies for the introduction of EVs is EV competitiveness compared to conventional vehicles. EV costs can be reduced by R&D and by increasing production volumes of EVs, both of which require separate policy measures.

The second aim is to create the preconditions for the implementation of EVs. This includes e.g. standards, but also the construction of charging infrastructure in strategic places. Working on these two aspects will allow the introduction of limited numbers of EVs. Much uncertainty surrounds the impact of larger numbers of EVs on the electricity grid, partly due to uncertainties related to consumer behaviour with respect to EVs. These uncertainties can be studied in the demonstration phase. Demonstration projects are thus instrumental to the success of EVs in the early market phase.

These conclusions lead to the following recommendations.

- *Implement R&D programmes aimed at making EVs competitive with conventional vehicles*

R&D is one way of reducing the costs of EVs. R&D can be effective if sufficient resources are made available, so that a sizeable R&D programme can be put in place. R&D is efficient if individual R&D programmes are complementary, i.e. there is little overlap between programmes.

Coordination of R&D on European scale is therefore desirable. The Green Cars Initiative and the FP7 programme are coordination mechanisms that are already in place. Additionally, Europe could benefit from the harmonisation of national R&D programmes.

- *Provide incentives that make EVs competitive with conventional vehicles*

The mainstay of policy is to implement measures that make EVs competitive with conventional vehicles. These measures can be in the form of direct vehicle subsidies, but will more often take the form of tax reductions. Since taxes are collected at a national level and since fiscal systems differ throughout Europe, such measures are best implemented at this level. Exemptions from regional taxation, as well as direct vehicle subsidies, could also be applied at a regional level.

The main intent of these measures is to induce cost reductions by increasing production volumes and to reduce investment uncertainty for industry and consumers in the early market phase. There should be sufficient perspective for EVs to become competitive with conventional vehicles or else there is a risk that the early market will collapse when the measures are discontinued[50,51]. The risk that measures will become too expensive can be managed by introducing a cap on the total (annual) budget that is available. A standard is an efficient way to

[50] Of course, competitiveness of EVs vis-à-vis conventional vehicles can also be achieved by implementing changes in existing policy aimed at making conventional vehicles more expensive.

[51] This argument could render implementing incentives at a regional level less attractive. However, it is unlikely that car manufacturers will introduce EVs if support measures do not create a market that is sufficiently large to provide a positive long-term perspective.

raise the cost of other technologies compared to EVs. Such a standard is effectively applied at a European level.

- *Provide incentives for the construction of infrastructure*

Possibly, a large share of potential EV adopters will require sufficient coverage of infrastructure as a prerequisite for adoption. Therefore, governments should engage with grid operators to develop a plan for the (initial) infrastructure development, possibly partly publicly financed.

- *Establish preconditions at the appropriate level*

Adoption of new standards and adaptation of existing standards are preconditions for the introduction of EVs. Standards are best addressed at the highest level possible (i.e. globally) to ensure uniformity and interoperability.

- *Use demonstration projects to clarify uncertainties*

Finally, demonstration projects fulfil an important role to clarify uncertainties such as battery durability under real-life conditions and consumer behaviour. For the effectiveness and efficiency of demonstration programmes the same recommendations as for R&D programmes hold. Resources should be made available that allow for demonstration projects of a scale that is sufficiently large to be effective, i.e. to clarify all uncertainties. To be efficient, there should be as little overlap as possible. For efficiency, European coordination is therefore important.

6.6 Hydrogen vehicles

6.6.1 Barriers

The barriers for Fuel-Cell Vehicles (FCVs) are summarised in Table 6.15. In the R&D phase, fuel cell durability and the capacity of hydrogen storage systems are issues to be worked on. High vehicle cost is also a barrier that can be addressed in the R&D phase, but demonstration projects are possible despite this barrier. The cost of FCVs may decrease further in the early market phase as the vehicles are produced in larger volumes.

In the early market phase, hydrogen filling station coverage is a major issue. FCVs require hydrogen as a fuel. Consequently, a low coverage of filling stations is a serious barrier for the adoption of FCVs. The construction of the required infrastructure to allow broad coverage until 2030 e.g. in Germany is expected to cost €1bn per year[52]. The low availability of FCV models is a further barrier in the early market phase. Initially, only a handful of vehicle models will be available, which will only address a limited number of consumer segments. An expansion of the number of models available is required to increase market share.

The development of infrastructure and the introduction of FCV models is prone to the chicken-and-egg problem. Since both infrastructure and FCV production require significant investments, both infrastructure providers and car manufacturers will require guarantees that their counterparts are equally willing to invest.

The perception of the risks of hydrogen is a potential barrier, although it is unclear to what extent this is really the case. Possibly, consumers will perceive hydrogen as a risky technology, although the overall conclusion from a number of studies is that consumers will expect hydrogen to be engineered to be safe (Ricci et al, 2008). Finally, a number of preconditions needs to be fulfilled before FCVs can move into the early market phase. Most importantly, standards need to be formulated, e.g. type-approval and safety regulations. Scarcity of raw

[52] See final report of the GermanHy Study, http://www.germanhy.de/

materials that are critical components may form a barrier for further expansion of the FCV market share.

Table 6.15 *Barriers for FCVs per innovation phase*

Barrier	R&D	Demo	Early market	Mass market
Fuel cell durability	■			
Hydrogen storage capacity	■			
High vehicle cost	■	■	■	
Infrastructure investment		■	■	
Filling station coverage			■	
Lack of standards			■	
Vehicle availability			■	
Safety perception			■	
Scarcity of raw materials				■

6.6.2 Policies to support the introduction of hydrogen vehicles

6.6.2.1 EU policy

The EU activities on Fuel Cells and Hydrogen (FCH) are bundled in a Joint Technology Initiative (JTI). The JTI has been implemented in a Joint Undertaking (JU), which brings together the EU, industry, and research organisations in a public-private partnership. The EU contributes €470m to the FCH JU, industry will at least provide a matching amount of funding for projects until 2013.

The activities of the FCH JU cover both R&D (short-term and long-term) and (large-scale) demonstration projects. Preconditions for the introduction of FCVs and associated infrastructure, such as the development of regulations, codes and standards are also part of the activities of the FCH JU.

6.6.2.2 National policies

FCVs are still distant from commercial market availability, which is reflected in the policies in place in various countries (Table 6.16). The mainstay of policies in many countries are R&D and demonstration programmes. Some countries have measures in place that are aimed at creating an early market. However, as FCVs are not expected to enter the market in large numbers in the coming years, these measures are for now largely symbolic. None of these measures target the build-up of infrastructure.

Table 6.16 *Overview of policy measures for FCVs in the EU and selected EU countries by innovation phase*[53]

	R&D	Demonstration	Early market
European Union	Fuel Cells and Hydrogen Joint Undertaking (2008-2017) [€940m]		-
Austria	R&D Programme (2008-2009) [€5.68m]		Registration tax reduction [€500]
Denmark	R&D and Demonstration Programme (2008-2025) [€800m]		Registration tax exemption National filling station coverage by 2011[54]
France	R&D and Demonstration Programme (2005-2016) [€344m]		-
Germany	National Innovation Programme (2008-2016) [€1140m]		-
Italy	R&D and Demonstration Programme (2005-2016) [€100m]		-
Netherlands	R&D Programme [€?m]	[o] Demonstration Programme [€5m]	Excise tax exemption Registration tax exemption Road tax exemption
Poland			Excise tax exemption
Sweden	R&D and Demonstration Programme (2005-2011) [€315m]		
United Kingdom	R&D and Demonstration Programme [€8m]		Low VAT on hydrogen Road tax exemption

Legend:

Vehicle-related measures

Fuel-related measures

Infrastructure-related measures

Sources:(Bünger et al, 2010), FuelCells.org, (Ajanovic, 2009), various tax agencies

[53] The amounts in R&D and demonstration programmes may include the contributions of industry partners.

[54] It is unclear whether what public funds are available to achieve this target.

6.6.3 Policy effectiveness

It is not yet possible to evaluate which policies are effective in stimulating FCVs on their way to the market, since no FCVs are currently available on a commercial basis yet. Based on the barriers that FCVs face, some considerations on what aspects should be part of effective policies can nonetheless be given.

Costs of FCVs are currently still prohibitively high. Broadly, these costs can be reduced in two ways: through additional R&D and through the economies of scale in mass production.
On the infrastructure side, using hydrogen as an automotive fuel requires large investments. In the initial phase of the rollout, this infrastructure will be underutilised. Hence, the initial phase is the most costly phase of the rollout.
The introduction of FCVs is therefore less costly if numbers of FCVs increase quickly, both from the perspective of the vehicle manufacturers as well as from the perspective of the fuel distributors,

The investment perspective for car manufacturers and fuel providers is best when policy measures are in place that enable a quick rollout. This requires close coordination between the various stakeholders, including an organisational form that fits such close collaboration. The policy measures that are adopted in the framework of this collaboration need to provide each actor with sufficient perspective to implement large investment in the early stages of rollout. Also, it requires coordination on a European scale, as only few European countries are large enough to sustain such a rollout by themselves.

The above considerations are mirrored in the current approach. Most R&D and demonstration programmes integrate the stakeholders involved. The FCH JU, which is relatively large compared to most national R&D and demonstration programmes, operates on a European scale, and also provides a platform for the mutual coordination of national R&D and demonstration programmes.

6.6.4 Conclusions and recommendations

The following are recommendations for the introduction of hydrogen as an automotive fuel.

- *Involve all relevant stakeholders and formulate a strategy at a high level*

The expected dynamics of the rollout of FCVs and the associated infrastructure require close cooperation between all relevant stakeholders, in particular the automotive sector and the fuel distributors. A public-private partnership is a good form for organising this cooperation, because it offers the opportunity to formalise the agreements that are required between all stakeholders involved. The first task of the partnership is to define the barriers that need to be overcome to make the introduction of FCVs possible and divide tasks and responsibilities. It is recommended that these partnerships are established at a high level, preferably supranational.

- *Put incentives in place that create an early market, while limiting impact on government budget*

R&D and demonstration projects can realise cost reductions and overcome other barriers for FCVs. At some point, FCVs will have improved to the extent that they will be (almost) competitive with conventional vehicles. At that point in time, policy measures need to be put in place that can create an early market for FCVs. It is likely that in this early market phase, costs for FCVs will further decrease through learning-by-doing. Measures could take the form of vehicle subsidies and tax exemptions (vehicle and fuel).

Simultaneously, the extent to which the construction of infrastructure will be taken care of by the market must be evaluated. If, e.g. due to investment uncertainty, industry is reluctant to invest, measures such as investment subsidies and accelerated depreciation may help to stimulate the construction of an initial network of filling stations. However, it is advisable to phase such measures out once an acceptable coverage is in place. If further extension of the network is not taken care of by the market, an obligation to install hydrogen pumps could be a cost-effective measure (from the government point-of-view) to stimulate densification of the network, if the cost to be supported by retailers is not too important, not speaking of the grid costs. Many of these measures relate to fiscal policy and/or require budget outlays of a type that are only available at a national level. The measures are therefore best implemented at that level.

7. Evaluation of case studies

7.1 Methodology

The Alter-Motive project also provides an opportunity to test and, if the need emerges, update the theoretical findings from the previous chapters with real-life case studies. This chapter has the aim to validate the previous findings about effective policy measures for alternative fuel introduction by comparing them with measures that have been applied in a set of case studies from all over the EU. It is also of interest to find out which measures need to be introduced on which level, either local, national or EU-wide.

In total, 84 different case studies on alternative fuel deployment have been reviewed by another project partner of the Alter-Motive project (WP4) and information on the used measures have been collected.[55] The case studies have been selected by the individual project partners for their respective country. Criteria for selection were the presence of the introduction of a previous not existing, sustainable fuel or automotive technology as described in Alter-Motive.

The following questions are sought to be answered by the evaluation of case studies:

- Which policy instruments have been used for which technology and at which level?
- What were the policy impacts?
- Are there any differences that can be detected in comparison to the recommendations from our theory?

7.2 Case studies on alternative fuel deployment

The evaluation will be carried out in three steps. First, a list of case studies will be created for each of the AF/AAMT technologies based on information from questionnaires collected in workpackage four. Secondly, we will look for each technology if there are specific characteristics in terms of used policies. It is then checked what the theory has recommended as instrument to be used at the specific technology stage. If there are deviations, it will be analyzed were the reasons for it. In Figure 7.1 , an overview of the used technologies is presented, while Figure 7.2 shows the distribution of case studies per country.

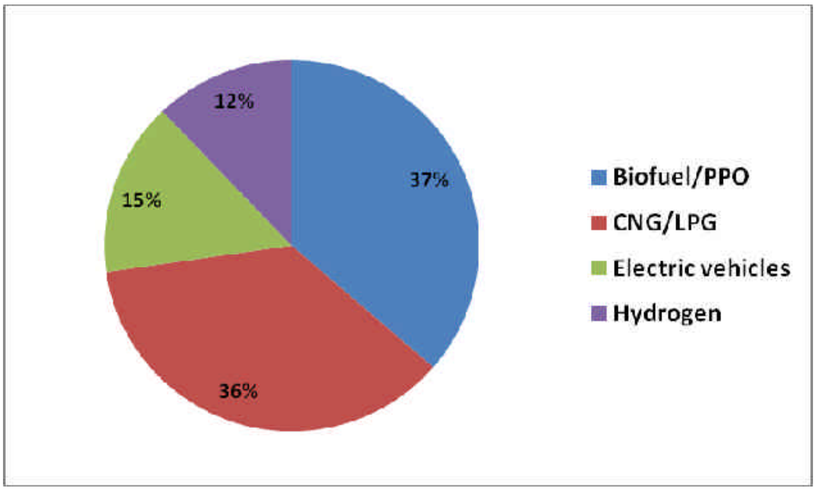

Figure 7.1 *Deployed AF/AAMT technologies in the case studies*

[55] For a full overview of case studies please see Deliverable 6, work package 4 of the Alter-Motive project.

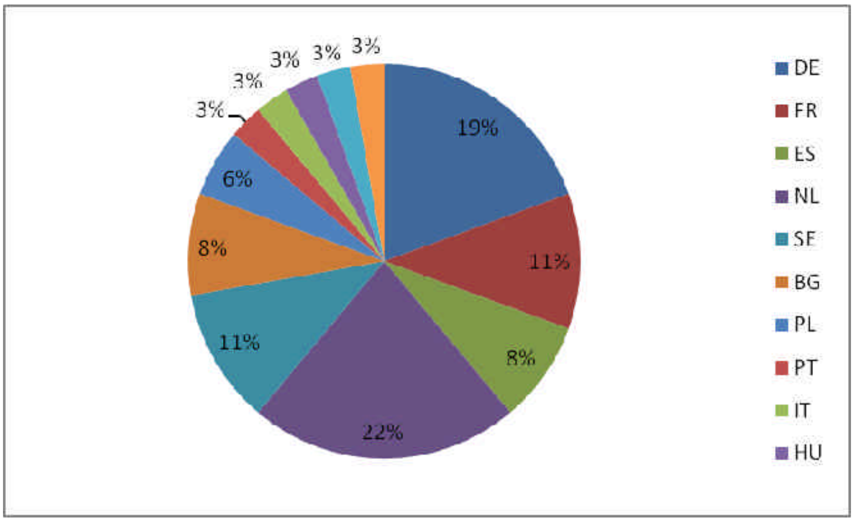

Figure 7.2 *Overview of case study country of origin*

7.2.1 Biofuels and Pure plant oil (PPO)

Table 7.1 *Biofuel and PPO case studies*

Project/ Country	AF/AAMT technology	Vehicle class	Policy instrument	Deployment level	Result	Long-Term change
TNT fleet (Germany)	Biogas	Delivery vans	Vehicle procurement subsidies, Access restrictions for other vehicles	National	100 new vehicles	
City of Lille (France)	Biogas	Buses	Direct Investments	Local/Regional	128 out of 450 vehicles converted	
City of Seville (Spain)	Hybrid Biodiesel/Electric vehicle	Compactors	Vehicle procurement subsidies[56]	Local		
City of Ede and Wageningen (Netherlands)	Biodiesel/PPO	Waste collection trucks	None		2 adapted trucks	Switch to CNG vehicles
TPG Amsterdam (Netherlands)	Biodiesel	Delivery vans	None	Local	56 vans	Positive, but switch to Euro V engines with soot filters
Vitoria-Gasteiz (Spain)	Biodiesel/Electric hybrid	Buses	Vehicle procurement subsidies[57]	Local	90 biodiesel, 4 electric hybrid	
City of Breda (Netherlands)	Biodiesel	Vans and waste collection truck	None	Local	4 modified vehicles	10 new vehicles have been

[56] Of the total investment, 80% were financed from the EU cohesion fund and 20% from the City of Seville.
[57] The buses are co-financed from the CIVITAS initiative, 35% of the overhead cost.

						bought after the trial
City of San Sebastian (Spain)	Biodiesel	Buses	Vehicle procurement subsidies[58]	Local	120 existing buses on blends	
Gothenburg area (Sweden)	Biodiesel	Waste trucks	Vehicle procurement subsidies	Local/regional	50 new trucks	
Stockholm (Sweden)	Ethanol (E95)	Buses	Filling station subsidy[59]	Local	420 buses	
La Rochelle	PPO		Direct Investments			
Eindhoven	PPO		Fuel tax exemption		Adapted vehicles	

In the case studies on biofuels the use of biodiesel and biogas is clearly most favoured by the stakeholders. Biodiesel is already widely available and supply issues are not a problem for most municipalities. A further advantage is that usually procurement of new vehicles is not necessary as existing vehicles can be modified through measures on the fuel injection system. As cost are not that high, it also means that some private companies have started initiatives without any support and bear the cost by themselves, mostly motivated by corporate responsibility targets. Regarding the policy measures the measures are mostly related to the procurement of the vehicles and financial support for refuelling stations.

Although most of the projects aim on the local deployment of vehicles, some case studies were involved in EU project which provided funding from EU projects such as the CIVITIAS initiative[60] or BEST that aim to facilitate sustainable urban mobility projects. Particularly the bus trials have led to a permanent consideration of alternative fuel use. Two smaller projects in the Netherlands (Ede-Wageningen and TPG Post) have decided to abandon the test and switch to alternatives that satisfy them more than biodiesel.

7.2.2 Compressed natural gas/Liquefied petroleum gas

Table 7.2 *Overview of CNG/LPG case studies*

Project/ Country	AF/AAMT technology	Vehicle class	Policy instrument	Deployment level	Impact	Long-Term change
City of Burgas (Bulgaria)	CNG	Buses	None	Local	10 diesel buses modified	
City of Sofia (Bulgaria)	CNG	Buses	Filling station subsidy	Local	13 new CNG buses, 55 diesel buses adapted on CNG	Continuation towards ‘Green buses’
City of	CNG	Buses	Vehicle pro-	Lo-	10 new	Start with

58 CIVITAS
59 Stockholm is lead partner of the BEST project and has received financial support for procurement http://www.best-europe.org
60 http://www.civitas-initiative.org

Gdynia (Poland)			curement subsidies[61], Filling station subsidy	cal/Regional	CNG buses	biogas
City of Slupsk (Poland)	CNG/ Bioethanol (E95)	Buses/vans/passenger car	Subsidies procurement buses/ Subsidies procurement filling stations	Local	5 new CNG buses, 5 new bio-ethanol buses, 3 used bio-ethanol buses, 1 van CNG, 1 car CNG	
City of Augsburg (Germany)	CNG	Buses	Subsidy procurement vehicles	Local	100 modified buses	Planned to convert all buses and municipal vehicles to CNG by 2010
City of Porto (Portugal)	CNG	Buses	None	Local	255 CNG buses	
City of Frankfurt/Oder (Germany)	CNG	Buses	Vehicle procurement subsidy[62]	Local	22 CNG buses	
DHL (Germany)	CNG	Delivery vans	Vehicle procurement subsidy	National[63]	170 Iveco vans	
Hamburg Wasser (Germany)	CNG	Maintenance cars	Corporate social responsibility	Local	80 Opel combo	
CWS-Boco (Germany)	CNG/gasoline bi-fuel	Diverse	Vehicle procurement subsidy	National	175 CNG vehicles	
City of Skopje (Macedonia)	CNG/diesel bifuel	Buses	Vehicle procurement subsidy	Local	30 adapted buses CNG and 2 leased	
Gothenburg Sweden)	Multiple: Electric/Ethanol /Biodiesel/ CNG	Municipal vehicles	Vehicle procurement subsidies			

Most projects around the implementation of CNG are taking place in cities since the application is on local transport buses. It is possible to convert existing buses to CNG requiring relatively little finance. In other cases also old diesel buses have been replaced by CNG buses. Some large companies that maintain a large national fleet of vehicles also have started trials to convert parts of their fleet. Once CNG has been introduced successfully, a further step could be done towards the use of green gas. General, CNG as a local application faces low implementation barriers both from the vehicle and infrastructure side. To further increase the

61 At the time of the survey, application for vehicle procurement subsidies was still in progress.
62 The city of Frankfort/Oder won a competition by the federal ministry of environment that allowed for procurement of CNG buses. Without the competition, diesel buses would have been purchased.
63 Augsburg, Berlin, Bonn, Bremen, Dortmund, Düsseldorf, Duisburg, Dresden, Essen, Frankfurt am Main, Hamburg, Hannover, Leipzig, Mainz, Munich, Nürnberg, Regensburg, Stuttgart, Würzburg

flexibility of CNG buses, some cities have decided for bi-fuel alternatives, such as CNG with biofuel.

7.2.3 Electric vehicles (HEV, BEV, PHEV)

Table 7.3 *Electric vehicles*

Project/Country	AF/AAMT Technology	Vehicles	Policy instrument	Deployment level	Change	Long-Term change
Green Post (Italy, Hungary, Belgium and Bulgaria)	Electric vehicles	Quadricycles	Reduced parking fees, access restrictions for other vehicles	Local	67 new vehicles leased	Project ends in 2010
City of Apeldoorn (Netherlands)	Electric vehicle	Bus 'Whisper'	Vehicle procurement subsidies/Filling station subsidies	Local	5 new buses	
City of Rotterdam (Netherlands)	Electric vehicles	Delivery vans	None[64]	Local	7 MB Sprinter	Not continued due to technical problems (reliability) and high initial vehicle cost
Gothenburg area (Sweden)	Electric/CNG (biogas) Hybrid vehicles	Waste trucks	Vehicle procurement subsidies	Local	15 new procured trucks	Field trial with producer, 2010 decision for series production
La Rochelle car sharing (France)	Electric vehicles	Passenger cars and vans	Free parking	Local/Regional	50 small cars and 6 vans	

Although there has been only a renewed interest in electric vehicles since the last years, some municipalities have already studied possibilities for electric vehicle deployment since longer time. Main benefit of EV's deployed in inner city areas is their zero tailpipe emission, silent mode of operation, therefore directly impacting on the most pressing problems of crowded cities: local air quality and noise. Discussions about tightened access restrictions for inner city areas further trigger the implementation of EV plans. The analyzed case studies still had to cope with early technology barriers (see Table 7.2) due to the reliability of vehicles and their high procurement cost. Therefore, not many positive examples of (long-term) deployment of EVs exist to date.

As the technical maturity of the vehicles has improved significantly over the last years, many municipalities currently announce new plans to stimulate deployment of EVs in the cities. As an example, the initiative 'Amsterdam electric' has the aim to deploy 200 vehicles and 200 charging stations in the inner city zone by 2012. To support early adopters, the municipality co-finances vehicles bought by local businesses with 50%. Further on, the city provides re-charging infrastructure for cars, scooters and boats and stimulates EV ownership by means of free parking.[65]

[64] Vehicle deployment took place with the EU project 'CITIVAS TELLUS', but no financial support has been provided.

[65] http://www.nieuwamsterdamsklimaat.nl/amsterdam_electric/amsterdam_electric

7.2.4 Hydrogen fuel cells

Table 7.4 *Hydrogen fuel cell technology*

Project/Country	AF/AAMT Technology	Vehicles	Policy instrument	Result	Long-Term change
Amsterdam GVB (Netherlands)	Hydrogen fuel cells	Buses	Vehicle procurement subsidy66	3 hydrogen buses	Continuation awaited for 2010
Province of South Holland (Netherlands)	Hydrogen fuel cells	Buses	N/A	1 bus	Not continued, problems with regulation
City of Dunkerque (France)	Hydrogen (used in internal combustion) (Hythane hydrogen-natural gas mix)		Vehicle procurement subsidy/Filling station subsidy	2 leased vehicles	Problems with regulation in the beginning, therefore most of the time no passenger transport possible, fund required for continuation
Berlin BVB (Germany)	Hydrogen fuel cells	Buses	Vehicle procurement subsidy	10 buses	The bus supplier has stepped out, but Berlin plans to continue with hydrogen buses within a national funded project.

Vehicles operating on hydrogen fuel cells are still significantly more expensive than comparable vehicles. In the case of urban transport they have to compete with regular diesel buses. Most of the projects analyzed use hydrogen buses because they are easier to supply with hydrogen from the bus depots, hydrogen filling station. The trials in Amsterdam and Berlin were part of the HyFleetCute project that financed the additional cost of a hydrogen bus as compared to a diesel bus. Without this subsidy, the procurement would not have been taken place. The customers were satisfied but the buses remain expensive. The Hydrogen bus alliance (HBA) plans to bundle procurement power of several EU cities to achieve a better negotiation position against the bus manufacturers.[67] Some projects could not be finished successfully or experienced major problems due to a lack of common regulations in the EU (e.g. Dunkerque and Delft)

7.3 Initial conclusions

The analyzed projects represent a wide range of different alternative fuel technologies, although technologies that are more close to the market dominate. Disruptive transport technologies that do not rely on the internal combustion engine and therefore require also a complete different drive train such as electric and hydrogen fuel cells are in the minority due to high upfront investments that are necessary for vehicle procurement and, in the case of hydrogen fuel cells, refuelling infrastructure. EU programs have helped to initiative some dem-

[66] In the framework of the HyFleetCute project, the overhead cost for the buses were payed.
[67] http://www.hydrogenbusalliance.org/about.html

onstration project such as HyFleetCute[68] to test and validate the everyday feasibility of hydrogen fuel cells in public transport.

Most commonly the projects take place at a city level, although due to sometimes the scope of the project is also extended to the adjacent region, mostly in the case of public transport outreach. Favourite applications are public transport buses, but also vehicles that are deployed in inner city areas such as waste collection trucks. That kind of vehicles have the advantage of a standard single point of refuelling – public buses are refuelled over night in the bus depot that reduces the dependence on an extensive refuelling network for alternative fuels.

By choice of technology the most common is of biofuels in different sorts, either as biodiesel, bio-ethanol or biogas. One of the reasons for this is might be cost – no significant upfront investments are necessary in the case of biodiesel or bioethanol. Also, the supply situation for biofuels is quite developed already in most parts of Europe, with the additional benefit of local production possibilities. If locally available, also the use of biogas is foreseen. The low initial cost barrier to the use of biofuels also makes those projects independent from necessary subsidies on the vehicles. Projects that decided for more innovative vehicles such as hybrid biodiesel-electric (Seville, Vitoria-Gasteiz) or biogas (TNT fleet) are more prone to use subsidies due to the increased cost of vehicles or installations.

Vehicles that run on natural or liquefied petroleum gas do not necessarily require the purchase of new vehicles because they can also be adapted. However, in case there was anyway the decision for new buses then usually it was easier to buy new vehicles instead. Still, some cases still relied heavily on subsidies for the procurement of the vehicles (e.g. Frankfurt/Oder). For most the cities CNG is seen as a relatively cheap way to reduce their emissions. Also, CNG vehicles can be adapted to be used with biogas. Two large corporate organizations also decided to change parts of their fleet to CNG which has probably to do with the large fuel availability.

Electric vehicle technology has been more in the focus in the last years, nevertheless the projects are all somewhat older than that. Most of the projects are small scale with the deployment of a low number of vehicles. The Projects depended on some sort of subsidy to finance the procurement of vehicles (e.g. Apeldoorn). Other projects finished or were not continued since the technology has been proven not reliable enough for daily business (e.g. vans in Rotterdam). Another method of integrating electric vehicles are bi-fuel vehicles such as the trucks running on electricity and CNG (biogas) in Gothenburg.

Sustainable transport technologies that have already moved in their development phase (see Figure 4.2.) are currently the preferred choice by cities/fleet operators to be utilized in large numbers. There are a number of reasons for this, mainly cost and reliability. Public transport buses with a diesel engine can be low-effort retrofitted for the use of biodiesel, with some higher effort also to biogas. Those technologies are also much more reliable because they have no undergone higher road testing. Fuel supplies are not a problem in most parts of Europe.

Projects with electric and hydrogen fuel cell vehicles are, to a certain extent expectedly, limit in terms of size. Without public support for the purchase of vehicles it is mostly not feasible to purchase those vehicles as they are 2-3 times more expensive (if available at all). Sometimes the overhead cost of a technology to the conventional technology is subsidized (e.g. hydrogen to diesel buses). For most hydrogen fuel cell projects, the analyzed projects relied on funding from EU level that supports demonstration projects, i.e. once the financial support stops also the project had to stop.

68 http://www.global-hydrogen-bus-platform.com/

8. Conclusions and recommendations

This report provides an overview and new insights regarding the policy options that can support the introduction of non-conventional fuels such as biofuels (1st and 2nd generation), CNG/LPG and the role of electric vehicles. Since the time horizon of the Alter-Motive project is until 2020, the impact on emission reduction of the various technologies differs and substantial reductions are also expected from conventional fuels due to efficiency improvements and hybridization of drive trains. Nevertheless, it should be clear that the bigger challenge in the reduction of emissions up to 80% is until 2050 which will require drastic measures in the transport sector. Accordingly, framework conditions for the long-term market roll-out of alternative transport fuels or technologies with a high carbon abatement potential need to be put in place already now.

Due to the variety of fuels and technical solutions and technical and market maturity, particular attention needs to be paid regarding their stimulation by means of policy support. Our methodology takes into account the technological development status of each fuel/technology by applying the well-known S-curve approach that defines the development status and market penetration. Through the analysis of the current technological status of the respective technology, specific barriers for each technology could be identified. Barriers (such as market readiness, cost or fuel supply) can be overcome through different policy measures. Basically, policies can be divided into four categories named after their objective: Protection, Competition, Regulation and Obligation. In each of the phases, different measures exist that can help the specific technology overcome barriers that prevent their increased market penetration or to regulate the market towards a more environmental friendly technology. In reality, the policy measures cannot sharply be divided and will have an overlap between the phases. It is therefore of high importance to closely monitor developments and design policies in a way that they can still respond to a new situation. Also, more technical mature technologies are more prone to be stimulated by means of top-down (mostly generic) approaches such as vehicle taxation, while more innovative technologies that still need to go through the stages can benefit from bottom-up (on national level) approaches such as local applications.

Key recommendations for policy support to introduce alternative fuels:

- 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 are 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.
- 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 are effective to achieve an overarching goal such as CO_2 emission reduction, however the market will decide for 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 exemp-

tions 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 (2nd 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.
- 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. However, HEVs may not offer the most cost-effective option to reduce vehicle emissions.
- Hydrogen: Main barriers are the initial cost of fuel cell vehicles (consumers) and high up-front 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.
- EV: 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.

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