STIMULATION OF THE USE OF BIOFUELS IN EUROPE BY MEANS OF BIOFUELS CORRIDORS ON THE TEN-T NETWORK

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ABSTRACT

The article first defines the current framework of the biofuels development with respect to their technology, policy, controversy and market conditions in order to provide insight into the current and future characteristics of the biofuels industry, main markets, policies and trends. A case study on the feasibility of one possible EU biofuels corridor, from Rotterdam to Constanta, is further described. Four potential biofuels corridor designs (under different scenario's), in which high-blends were determined as vital for achieving EU targets, are compared. The case study includes interviews with key stakeholders on the corridor (including freight operators, oil companies and policymakers at the national and EU level), and data analyses on the transport flows, refuelling infrastructure and biofuels policy in the Member States that are involved in the corridor. Economic feasibility analysis places the concept of biofuels corridors into the wider context, extrapolating the results into a general evaluation of the biofuels corridor approach as a measure of stimulating the use of biofuels in EU road transport. Conclusions and recommendations are finally presented.

Key words: biofuels, biofuels corridor, transport corridor Rotterdam – Constanta, EU sustainability policy

INTRODUCTION

Awareness of the consequences of using petroleum-based fuels in transport is increasing for various reasons. Firstly, the literature widely discusses 'inevitable and imminent' limitations in oil production growth (see, for example, Hirsch et al, 2005 and Hanlon and McCartney, 2008: 649). The rapid increase of global energy demand in the transport sector intensifies this problem. Secondly, many EU Member States (MSs) are highly dependent on crude oil originating from regions which are often politically unstable (such as the Middle East) which makes the EU transport sector vulnerable. Currently, well over 80 percent of the oil used within the EU is imported and 70 percent of that is used to power transport (EC, 2009). Thirdly, the negative environmental and health effects of using petroleum-based fuels are becoming more visible and debates how to overcome them currently rank high on the policymaking agenda.

The EU has applied several measures to increase the sustainability of the transport sector in relation to fuel dependency and environmental effects. The foundation of sustainable transport policy can be found in the 2001 EU White Paper – 'European Transport Policy for 2010: Time to Decide' – and its 2006 Mid-Term Review. Furthermore, the 2003/30/EC and 2009/28/EC Directives (accompanied with a comprehensive strategy) were introduced, being now the key pieces of EU legislation regarding the use of renewable energy in transport. The Directives require MSs to set targets for the share of renewable energy in transport which is to replace petroleum-based fuels, up to the mandatory level of ten percent in 2020.

Biofuels are considered to be one of the most viable options to meet renewable energy targets set by the EC. Their share in the EU total fuel consumption is constantly growing (almost 3% in 2009), but this progress is still not sufficient to achieve the established targets. The next chapter describes in detail the current state of play and main tendencies in biofuels market, gives an overview of the main EU policy developments in order to promote the development of biofuels and finally presents the concept of biofuels corridors.

1. TRANSPORT BIOFUELS: THE STATE OF PLAY

Main Characteristics of Biofuels

Biofuels are all fuels produced from renewable biological resources referred to as biomass (e.g. plants and organic waste). Energy from biomass is promising and currently represents approximately 14 percent of world's total energy consumption (Demirbas, 2009). There are several other ways in which biomass is used in the EU: for heat production (66 percent), electricity production (31 percent), in chemical products typically made from petroleum (e.g. plastics), and for conversion into gas-like or liquid fuels (e.g. ethanol) (3 percent) (USDA, 2008). The latter are referred to as biofuels.

A distinction is made between so-called first generation and next generation biofuels. First generation biofuels refer to biofuels made from food crops, such as sugar, starch, vegetable oils or animal fats. These biofuels currently dominate the global biofuels market and it is expected that, at least over the next decade, food crops will continue to provide the bulk of biofuels feedstock (see, for example, Worldwatch, 2007). Second generation biofuels are produced from lignocellulosic biomass, such as agricultural residues and wood, and waste residues. Also algae, referred to as the third generation, may serve as next generation biofuels feedstock. Second and third generation biofuels are still at the experimentation or demonstration phase, as they have not yet succeeded in becoming economically viable (Worldwatch, 2007).

Ethanol[1] and biodiesel[2] are the two most commonly used biofuels (first generation) which currently represent over 95% of the EU biofuels market (USDA, 2009). Several experts (research interviews, 2009) share opinion that these biofuels will most likely remain the most dominant biofuel types in the near future, possibly with some variations in form of consisting of different feedstocks.

Biofuels produced from plant material are renewable and offer various advantages compared to other sustainable energy sources. First among these advantages is that, in comparison with petroleum based fuels, biofuels show a reduction of net GHG emissions which is key to tackling climate change (OECD, 2008). Secondly, biofuels – whether blended with conventional fuels or in pure form – generally burn more cleanly in terms of air pollutants (Demirbas, 2009 and Worldwatch, 2007). Air polluting emissions, such as nitrogen oxides, sulphur dioxides and particle matter, are associated with negative effects on public health. Thirdly, biofuels have the ability to reduce countries' dependency on crude oil for powering transport. Well over 80 percent of the EU's crude oil is imported, often from politically unstable regions, which makes the transport sector vulnerable (EC, 2009a). Fourthly, compared to other sustainable transport options, such as electrical or hydrogen-powered vehicles, biofuels can be implemented without major changes to the current methods used for distributing and consuming petroleum-based fuels. They can easily be blended with gasoline or diesel, which makes the transition almost unnoticed for the vehicle users (Worldwatch, 2007). Finally, the production of biofuels may indirectly stimulate rural development in terms of income and employment.

Along with these advantages, the use of transport biofuels is currently surrounded by global controversy. There is an ongoing discussion on the extent to which biofuels, in particular the first generation, are sustainable, from an economic, environmental and societal perspective. Production of biofuels requires the harvesting of crops such as sugar, oil and starch, and there are concerns that the secondary effects of this process could be to drive up food prices, ruin biodiversity and increase soil erosion. In addition, there are doubts to which extent biofuels are energy efficient: it is argued that the amount of (fossil) energy needed for the cultivation, harvesting, refinery and delivery of biofuels may outweigh the potential benefits of using biomass as a renewable energy source in the transport sector and that biomass can be used much more efficiently for heat and electricity generation (Reijnders and

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[1] Ethanol is an alcohol derived from carbohydrates. It can be used in Otto motors and thereby serves as a replacement for gasoline. The EU standard for bioethanol is EN 15376. The energy content of one litre of ethanol is approximately two-thirds of the energy content of one litre of gasoline (Worldwatch, 2007). It can be blended with gasoline or used in its pure form, but the use of high ethanol contents in gasoline (more than 10 percent) or pure ethanol requires adaptations to vehicle engines (Bomb et al, 2006). The use of highly concentrated ethanol blends also requires different distribution equipment, such as special tanks and separate refuelling systems. Currently, ethanol is largely used in Brazil and Sweden, by the means of Flexi-Fuel Vehicles (FFVs). FFVs are vehicles which can run on pure gasoline or any ethanol-gasoline blend and are becoming 'increasingly popular' (Worldwatch 2007: 17).

[2] Biodiesel is derived from lipids and is broadly used (particularly in Europe) to replace petroleum-based diesel fuel. The most commonly-used type of biodiesel is referred to as FAME (Fatty Acid Methyl Ester). Other types of diesel substitutes, such as FT-Diesel, Biomass-to-Liquid (BtL), Bio-DME and Bio-SNG, are currently in the developmental stages and are thus not yet commercially available (Worldwatch, 2007). Biodiesel is produced by chemically combining vegetable oils and fats with an alcohol, mostly methanol, in the presence of a catalyst (e.g. NaOH or KOH). It can be easily blended with petroleum-based diesel or used in its pure form. The use of FAME in diesel engines can improve lubrication due to the higher viscosity of the fuel, which may extend the life span of vehicles. However, in most cases, the use of high biodiesel contents or pure biodiesel in conventional diesel engines (more than 20 percent) requires adaptations to vehicle engines (Worldwatch, 2007).

Huibregts, 2009). The ability of first generation biofuels to reduce GHG emissions also appears to be less positive as initial evaluations suggested. It is expected that most of these problems will be solved when second generation biofuels, made from cellulosic biomass, become commercially viable. The production of these products will smooth some of above-mentioned effects (see, for example, CE, 2006a and Refuel, 2008).

In response to the critique regarding the environmental and societal sustainability of biofuels, the EU has developed regulations and certification schemes. The sustainability criteria are presented the EU Renewable Directive 2009/28/EC (RED). These criteria include minimum requirements for GHG emission savings, limited allowance of land-use changes and various monitoring rules regarding social sustainability (EC 2009b: Article 17).

Biofuels Market

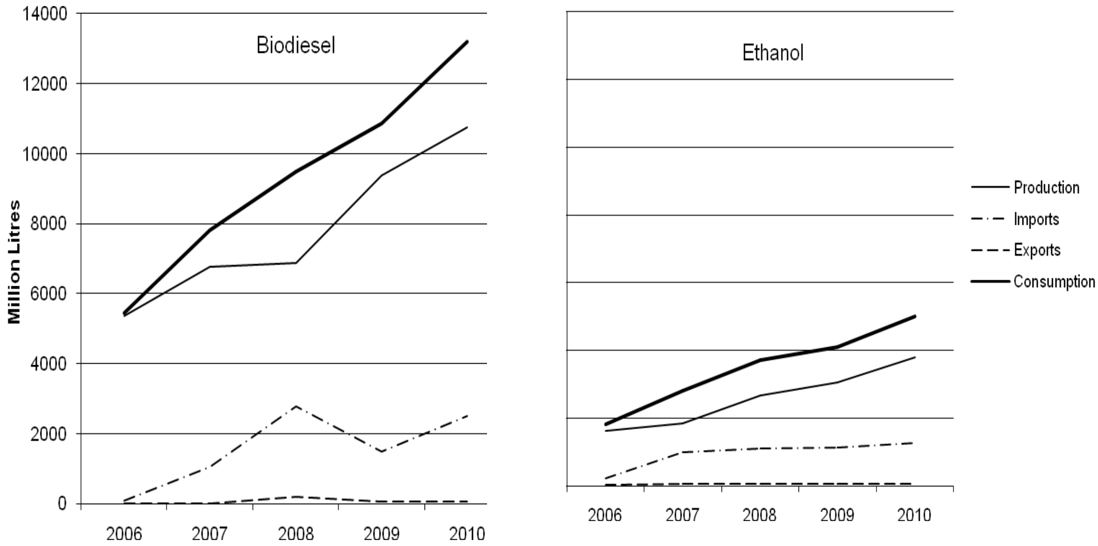
Currently, the biofuels industry is booming and biofuels are widely supported by governmental bodies and international organisations as means to replace petroleum-based fuels. Ethanol production as a replacement for gasoline is mainly concentrated in Brazil and the United States, and biodiesel is mostly produced in Europe to replace diesel. The EU is rapidly expanding production capacity and represents approximately over 70 percent of the total biofuels supply. EU ethanol and biodiesel production accounted for approximately 4 and 80 percent of the world total in 2007, respectively (Monfort, 2008 and USDA, 2009). Due to the land availability the potential for biofuels production is high especially in Central and Eastern European countries (Van Dam et al, 2007).

Currently just under 10 percent of all biofuels are traded internationally (which is a rather low figure compared to the trade in conventional fuels; Worldwatch Institute, 2007). This number can grow, considering the comparative advantage of biomass production in tropical areas, such as Brazil. Figure 1 shows the EU ethanol and biodiesel production, exports and imports in millions of litres between 2006 and 2010, respectively.

Consumption of EU biofuels (Figure 1) is strongly oriented towards biodiesel, accounting for 77 % of the market (USDA, 2009). This can be explained by the high share of diesel engines in road transport. In addition, EU oil companies tend to favour biodiesel, due to the fact that in this region, there is generally a shortage of conventional diesel and an oversupply of gasoline (Bomb et al, 2006 and EU, 2006). The high share of biodiesel is in contrast to other countries, such as Brazil and the US, as their biofuel markets mainly consist of ethanol (OECD, 2008).

Almost all EU biofuels are currently sold as low-level blends with petroleum-based fuels. Only Germany and Sweden have developed a significant market for blends with a high biofuel content: for B100 (100 percent biodiesel) and E85 (85 percent ethanol, 15 percent gasoline), respectively (see, for example, Ethanol Producer, 2008). These 'high-blends' often require adaptations to vehicle engines and only a very small amount of refuelling stations offer these biofuels. In Europe, blends up to 5 volume percent of ethanol in gasoline or biodiesel in diesel are covered under warranty by vehicle manufacturers (Wiesental et al, 2008). This is also the maximum according to the European standards for gasoline (EN228) and diesel (EN590). Blends with a higher biofuel content may not be sold as conventional gasoline or diesel and thereby should meet the EN 15376 and EN 14214 certifications, respectively. However, it is obvious that the mandatory 2020 target of 10 percent cannot be reached by the further stimulation of 5 percent blends alone.

Figure 1. EU Ethanol and Biodiesel Market Developments (2009 and 2010 figures are based on predictions)



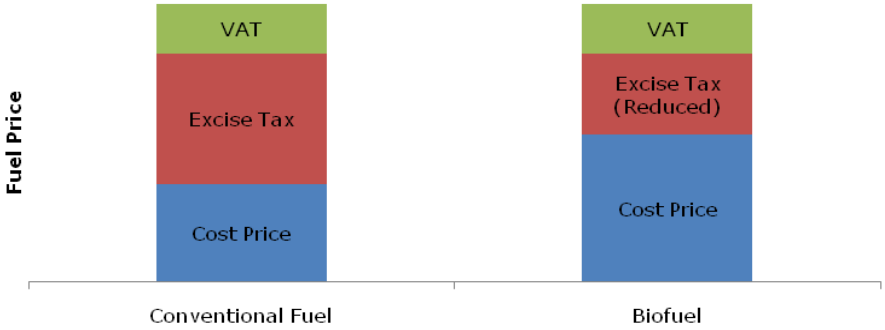
Source: Data from United States Department of Agriculture (USDA), 2009

The EU is currently revising the fuel standards in order to allow higher volumes of biofuels in gasoline and diesel, up to 10 volume percent for ethanol and 7 volume percent for biodiesel (SenterNovem, 2008). Another option is to make high-blends more easily available at refuelling stations. In this article we argue that the aim of the successful biofuel policy should be a replacement of the petroleum-based fuels rather than supplementing them. Therefore, we prefer to focus on the latter option.

Biofuel retail prices depend on government policy and on their competitiveness with conventional fuels. As biofuels are generally more costly than petroleum-based fuels[3], the price also relies heavily on government (e.g. tax) policy. This is illustrated by the indicative fuel price outline in Figure 0, in which granting a partial tax reduction makes up for higher biofuel costs.

[3] It should be noted that the positive externalities of biofuels compared to conventional fuels, such as a reduction in GHG emissions, are not taken into account, and that these benefits may well make up for the higher biofuel costs.

Figure 0. Petroleum-Based and Biofuels Price Outline



The literature indicates that the high costs for biofuels is particularly true for Europe because of higher production costs, freight rates and border protection (see, for example, Reijnders and Huibregts, 2009). Only Brazilian ethanol, made from sugar cane, comes close to competing with the low price of gasoline. The competitiveness of biofuels with conventional fuels, in turn, mainly depends on crude oil and biomass feedstock prices and their fluctuations, as well as on the efficiency of biofuel production. Measures proposed by different Member States are detailed in the section below.

EU Biofuels Policy

The 2003/30/EC and 2009/28/EC Directives are the key pieces of EU legislation regarding the use of renewable energy in transport and fall under the broader EU policy which aims to increase the overall share of renewable energy used in the region to 20 percent in 2020 (EC, 2008). The Directives aim to promote the use of biofuels in order to contribute to "…meeting climate change commitments, environmentally friendly security and promoting renewable energy sources" (EC 2003: 3). They are also referred to as the 'Biofuels Directives', as biofuels are considered as the most viable solution to meet these targets in the short-term. The Directives require MSs to set targets for the share of renewable energy in transport which is to replace petroleum-based fuels. Inital objective to MSs was to replace 2 percent of the energy used in road transport with biofuels by 2005. This was then to grow by 0.75 percent annually in order to achieve a share of 5.75 percent by 2010. The 2005 target has not been met and the 2007 progress report indicated that it is 'not likely' that the 2010 target will be achieved either (EC 2007a: 6).

In 2008, the Commission proposed new targets for the use of renewable transport energy to the Council of the European Union. The target of 10 percent was accepted as a mandatory target to be achieved by all EU MSs and is stated in the Renewable Energy Directive (RED) 2009/28/EC. The Directive falls under the broader 'EU Energy and Climate Change Package' (EC, 2008). This package is commonly referred to as the '20/20/20 package', as the objectives for 2020 are to reduce greenhouse gas (GHG) emissions by 20 percent, to improve energy efficiency by 20 percent, and to have an overall share of 20 percent of renewable energy in the EU energy mix.

Even though this politics has led to an increase in biofuels use, they currently account for only 3 percent of EU total fuel consumption. The implementation progress of the Directive must be accelerated in order to meet the EU targets. Therefore, MSs apply various policy instruments – incentives, mandates and trade barriers (see, for example, USDA, 2009) - in order to stimulate the development of the biofuels market. OECD (2008) models confirm that, without this support, the use of biofuels in the EU would be radically reduced.

At the EU level, the production of biomass feedstock has been stimulated by the so-called Energy Crop Aid, which falls under the Common Agricultural Policy (CAP). The CAP provides incentives for using crops for energy production. Furthermore, the EU domestic biofuel market is protected by import tariffs on ethanol and biodiesel. Duty free ethanol imports are allowed from Least Developed Countries under the so-called 'Everything But Arms' initiative, as well as from various African, Caribbean and Pacific (ACP) States, under the Cotonou Agreement (Bamiere, 2007).

The majority of the policy instruments have been adopted at MS level. These measures predominantly focus on stimulating biofuels demand and supply. Demand for biofuels has mostly been supported by granting (partial) fuel excise tax exemptions for ethanol and biodiesel, which is allowed by Article 16 of the EU Directive 2003/96/EC on energy taxation. These incentives lead to a reduction in retail biofuel prices, as average biofuel taxation is about 50 percent lower than for conventional fuels (OECD, 2008). Although this has been proven to be effective for establishing an early-stage biofuel market, there is a recent trend in moving towards or combining tax incentives with biofuel obligations. This is due to the fact that the application of tax incentives alone leads to significant revenue losses for governments. By setting mandatory blending targets on fuel suppliers, the additional costs are, in most cases, directly passed on to the consumers. The main drawback of biofuel obligations is that strategies for lowering costs will be adopted by fuel suppliers, which might contradict the underlying EU objectives of stimulating and using domestic and sustainable biofuels, as these are more expensive. The supply of biofuels has been strengthened by promoting domestic biofuel production, which is done by way of subsidy systems as well as through incentives originating from the CAP (OECD, 2008). In addition to stimulating demand and supply, MSs have applied various other policy instruments, such as investments in research and development and introducing user incentives.

The Concept of Biofuels Corridors

The concept of biofuels corridors as analysed in this article is one of the potential instruments to provide more internationally coordinated approach to the promotion of the biofuels in transport sector. This concept, which involves clean transport fuels being offered at specific locations on long-distance road routes, could help to facilitate EU ambitions regarding clean transport fuels and help MSs to achieve the biofuels targets. More concretely, an EU biofuels corridor is defined as a long-distance (minimum length 1000 kilometres (km)) and cross-border route on the TEN-T Network roads on which high-blends of ethanol and biodiesel are offered regularly along the entire length of the route.

An example of a biofuels corridor can be found in the United States, in the form of the so-called Interstate 65 (I-65) Biofuels Corridor. This 886-mile stretch of highway from Lake Michigan to the Gulf of Mexico, offers E85 ethanol and B20 biodiesel along the entire route. The project concept, originating with the United States Department of Energy (DOE), called for an increase in the biofuels fuelling infrastructure along the Interstate to be upgraded, giving drivers the opportunity to travel along the entire corridor using high-blends only. The Indiana Office of Energy Development was awarded $1.3 million from the DOE to fund E85 and B20 fuelling stations along Interstate. The funding was made available by the DOE through the Clean Cities Programme. The grant provided funding to 31 refuelling stations.

The idea of implementing high-blends by means of biofuels corridors has not yet been adopted in the EU. Nevertheless, it is believed for various reasons that EU biofuels corridors could effectively promote and stimulate the use of biofuels, and could thereby contribute to achieving the EU renewable energy targets. Firstly, the implementation of EU biofuels corridors could lead to a more coherent strategy and international cooperation on the promotion of biofuels, instead of individual MSs struggling to achieve their own biofuel targets. Their development may be a first step towards an EU refuelling network for high-blends, which would facilitate refuelling over large distances. Moreover, biofuels corridors could strengthen the EU vision on sustainability in transport and could serve as a catalyst for the transition to renewable and sustainable transport fuels. Secondly, it is generally argued that the long-term potential of biofuels lies in the field of long-distance and heavy goods transport. Other alternatives, such as electric- and hydrogen-powered vehicles would, because of their restricted action radius, be more suitable for short-distance and urban transport. The fact that freight transport uses a lot of fuel relative to the total road transport sector could make it easy to obtain a large market share for biofuels. Thirdly, the biofuels corridor approach would immediately increase the visibility of the use of biofuels in transport, as opposed to low-level blending. The latter remains regularly unnoticed by road users. High visibility of biofuels would likely increase the environmental awareness among society and in turn stimulate their use.

The principle is that there would be several EU biofuels corridors being established gradually over time and that, by 2020, when the RED targets are due to be achieved, the use of high-blends on the TEN-T Network roads would have risen considerably.

The aim of our research is to assess the potential of EU biofuels corridors as a means to stimulating the use of transport biofuels in the EU. The following section presents the methodology used to design and assess TEN-T biofuels corridors.

2. METHODOLOGY: DESIGN AND ASSESSMENT OF THE TEN-T BIOFUELS CORRIDOR

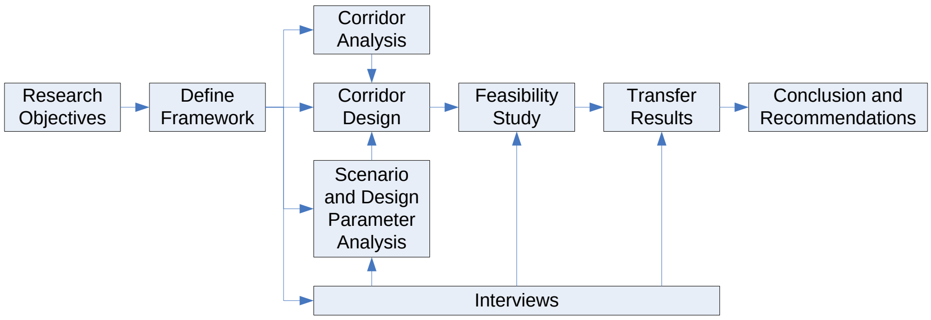
General Approach

The potential and feasibility of EU biofuels corridors is assessed by means of a case study for one specific corridor on the TEN-T Network roads; the highway from Rotterdam (Netherlands) to Constanta (Romania). A three steps approach was used: firstly, three biofuels corridor design parameters were determined and detailed; secondly, a scenario analysis was used to narrow down the amount of possible corridor configurations; finally, the predefined parameters were applied on to specific corridor selected based on various criteria.

The statistics and other quantitative information used in this study have mostly been obtained from publicly accessible documents from various institutions, including the EC, sector- and business associations active in the field of transport biofuels and other relevant sources. Information regarding transport flows on corridors was enriched with data from TRANS-TOOLS model. Finally, valuable input was obtained from interviews with key stakeholders closely associated to the concept of biofuels corridors. These stakeholders include oil companies, the EC, governments, transport companies, sector and business associations active in the field, and research institutions.

The general methodological approach to the study is presented on a figure 3.

Figure 3. Overview of the Overall Research Methodology



Description of Corridor Design Parameters

One can systematically create and distinguish between different biofuels corridor designs by changing the input value of various design parameters. In this research we assume some of them like, for example, “MS biofuels policy” and “biofuel-compatible vehicle fleet” as unchangeable. Other design parameters have a certain input range which can vary. When applied to a specific corridor, any input from these design parameters results in a biofuels corridor design. In our study we decided to concentrate on the following parameters: (1) market access, (2) product supply diversity, and (3) station coverage. Below each of these parameters are detailed more precisely.

(1) Market access represents the percentage of corridor users that is permitted or able to refuel with biofuels on the corridor. Varying the market access would impact on the potential of biofuel sales on the corridor, as well as the scale of implementation and thereby the respective strategy. As the effects of changing market access could influence the potential of the corridor both positively and negatively, it is considered to be an important parameter in the development of biofuels corridors. Lower market access, for example, could decrease biofuel sales on the corridor, meaning the corridor would then contribute to the EU policy objectives to a lesser extent. However, restricted market access could also benefit biofuels corridors, as this would allow increased control of possible financial support for the corridor project. The provision of incentives to biofuel-users would be easier to manage, and, as fewer fuel stations would be able to offer biofuels, the project's infrastructure investments could be controlled more tightly.

A distinction is made between four levels of market access: (a) a dedicated user group (also referred to as 'captive fleet'), (b) freight transport, (c) passenger transport, and (d) all road transport using the corridor. In practice, various methods can be used to distinguish between these different market segments: for example, the provision of refuelling cards to a specific user group; fiscal incentives provided to a specific user group to encourage their use of biofuels; and varying the biofuel types which are offered on the corridor.

(2) Product supply diversity represents the different biofuel types and corresponding blends offered on the biofuels corridor. The parameter level increases with the amount of biofuel products that are offered and with the content of the biofuel in the blend. Diversification of products could impact the potential of biofuels corridors, as it is directly linked with infrastructure adaptations which may be required and additional logistic costs. Moreover, diverging interests among stakeholders may favour the provision of certain blends on the corridor.

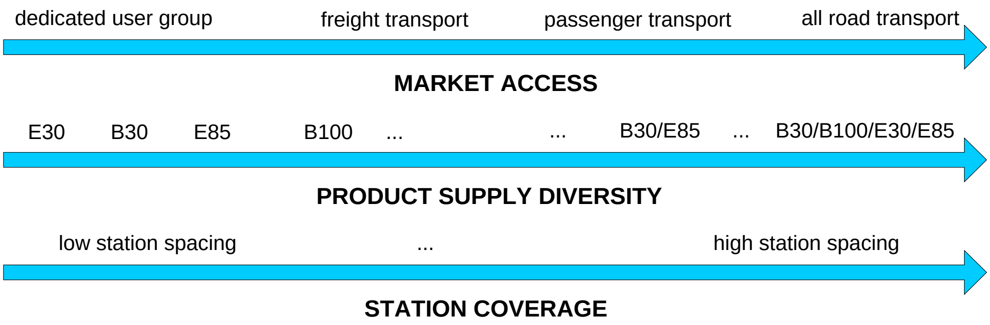
Only ethanol and biodiesel blends are taken into account, as they now represent over 95 percent of the total biofuels market in the EU and, moreover, they will most probably remain the most dominant transport biofuels available on the market in the upcoming decade. In our article we focus only on the promotion of high-blends, and this is why biofuel blends with an ethanol or biodiesel content lower than 20 percent are not included here. It is further assumed that there will be no diversification of product supply among individual biofuel stations on a certain corridor. Four high-blends are considered in these designs: E30 ethanol, B30 biodiesel, E85 ethanol, and straight B100 biodiesel. E85 and B100 offer the highest content of biofuel per litre which is practically possible in the EU. Mid-level blends generally vary between 20 and 40 volume percent biofuel, and a wider range of vehicles could handle these fuels. An average of 30 percent mid-level biofuels has therefore been chosen for the purpose of this study.

(3) Station coverage defines the intensity of stations that offer biofuels on the corridor. The parameter level increases with the number of stations per unit distance, referred to as 'station spacing'. Only stations directly on the corridor are considered (i.e. motorway stations). It is to be expected that possible detours, in order to refuel with high-blends at local stations slightly away from the corridor, will cause a significant user disutility. Station coverage influences the scale and complexity of the corridor project. It will also influence implementation and logistic costs, and market access. Minimum station spacing applies for all biofuels corridors in order to avoid occurrences of vehicles running out of biofuel while driving on the corridor. Although vehicles can also use conventional fuels, this is not considered as an optimal design solution since the aim is to encourage the use of high-blends specifically.

The station spacing is dictated by the vehicle range and depends on the supply reliability of biofuel stations. The vehicle range, in turn, depends on the vehicle's tank size, the engine's fuel efficiency, and on the type of biofuel considered. The supply reliability is taken into account by applying a safety factor of two, as travellers should be able to make it to the next station in case one station on the corridor runs out of biofuels. We have estimated necessary minimum station spacings for different combinations of fuel and market demand, ranging from 200km up to 800km. Minimum station spacing would be lower if freight transport alone is considered.

All the above-mentioned parameters are closely interrelated. The choice of market access is interrelated with station coverage: a lower degree of market access will naturally lead to reduced station coverage and vice versa. Market access for diesel vehicles alone would reduce product supply diversity, and, likewise, a less diverse product supply could impact on the market access. The product choice for the biofuels corridor has consequences on the user group (market access), the logistic supply complexity and adaptations to fuel station infrastructure. A wider product variety would increase infrastructure and logistics costs and vice versa. Station coverage is closely linked with the level of market access and with the various stakeholders that would be involved in the biofuels corridor. Increasing station coverage, and thus biofuel supply, would naturally increase demand on the corridor, which would mean a higher level of market access. The opposite is also true. Therefore, for an open market including short distance traffic, station coverage should be high. Furthermore, a high station coverage could limit the participating stakeholders to only multinational fuel distribution companies. Figure 4 provides an overview of the different design parameters.

Figure4. Three Design Parameters for the Creation of Biofuels Corridors



Different biofuels corridor configurations are analysed with the help of a scenario analysis.

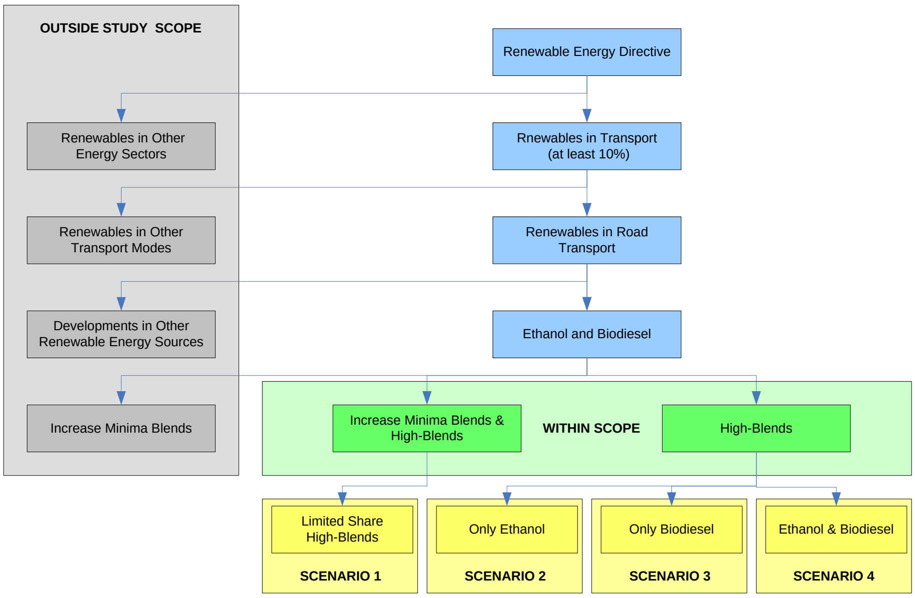
Scenario Definitions

A scenario analysis is used to narrow down the amount of possible design configurations with regards to their future viability. The analysis anticipates the interpretation of the RED and defines four policy scenarios which would be conducive to the development of biofuels corridors.

The RED is the key piece of legislation regarding the use of renewable energy in the EU. The implementation of the RED, however, is open to interpretation by MSs and could therefore take various directions. Biofuels corridors would become very interesting for the stimulation of the use of biofuels if high-blends in road transport are required or preferred for the sake of achieving the RED targets. The fact is that, aside from achieving the targets by implementing high-blends, there are also other alternatives which could lead to an achievement of the RED targets. It is likely that the role of high-blends will become clearer in one or two years, when the transport targets have been set and national strategies to achieve these targets have been defined. It will also depend on future developments in the production efficiency of second generation biofuels.

Figure provides an overview of the various directions that the realisation of RED could possibly take. The diagram follows a hierarchical setting.

Figure 5. Scenario Overview of the Future Role of High-Blends in the EU



The possible steps are each described in the following paragraphs.

Step 1. Every country has an individual overall 2020 target for the use of renewable energy, based on their Gross Domestic Product (GDP). MSs are free to allocate different targets across the various energy sectors, under the condition that its share in transport meets the minimum of 10 percent. This could then change the perspective on the promotion of transport biofuels, as going beyond 10 percent could be seen as an opportunity to achieve less in the other sectors.

Step 2. Once the renewable energy shares in transport have been defined by the MSs, various options exist for the implementation of these targets within the transport sector. Aside from implementing the biofuels in road transport alone, other transport sectors, such as aviation, rail and inland shipping, could also make a contribution towards these biofuel targets.

Step 3. The question remains as to what extent MSs deploy present-day biofuels, ethanol and biodiesel, or focus on developments in other forms of renewable energy. It has been previously argued that almost all renewable transport energy in 2020 will be provided by biofuels, as other alternatives (e.g. hydrogen-powered and electric transport modes) are either not mature enough, need more time to develop, or are too costly at this stage. However, second generation biofuels could also be a realistic option. Most of these biofuels, such as BtL and hydrogenated vegetable oil, would allow blending of biofuels with conventional fuels in higher volumes, up to the targets which have been set, for example, without the need for engine adaptations. In addition, second generation biofuels count double towards the RED targets to stimulate their use. This means, for example, that the overall target of 10 percent can also be achieved by 5 percent of second generation biofuels alone. Both aspects would then reduce the need for further measures, as, naturally, an infrastructure for high-blends, such as biofuels corridors, would no longer be necessary.

Step 4. The question particularly relevant for this study, is how the remaining share of renewable transport energy that is not achieved by low-blends or any other alternative that has been mentioned above, would be accommodated. Two main options exist. First would be to change the gasoline and diesel fuel specifications in such a way that the allowable percentage of ethanol and biodiesel to be blended with these fuels is increased. This option is referred to as 'increasing the minima'. As noted earlier, the percentages are currently limited to 10 and 7 percent of ethanol and biodiesel, respectively, but one might decide to increase these values up to E20 ethanol and B15 biodiesel, for example. This would, however, also require engine manufacturers to produce new vehicles compatible with these blends. The second option would be to offer high-level ethanol and biodiesel blends. A middle course would be the incorporation of both solutions. A focus on just high-blends is not to be expected without strong government support, due to a lower efficiency of the supply chain brought about by offering more products. If high-level ethanol and biodiesel blends become an important part of MSs' RED strategy, biofuels corridors could have the potential to make a contribution to these targets. There would then be a need for an infrastructure for high-blends, which defines the scope for the biofuels corridors study. This scope is marked green in Figure .

Step 5. Within this scope, various scenarios can be defined, as, if high-blends become important, the implementation could take various directions. These developments depend on the type of biofuel which becomes most popular, and on the required level of contribution from high-blends towards the targets. Four future scenarios are defined for the promotion of high-level ethanol and biodiesel blends.

It should be mentioned that, although other and more specific scenarios could be developed, it was not within the scope of this research to do so. The scenarios that are chosen follow logically from the literature and from stakeholder interviews and cover a wide and sensible spectrum range of the future role of high-blends in EU road transport. Developments which could lead to these scenarios will certainly become clearer when the national action plans are published.

Definition of Corridor Scenarios

The input values of the design parameters are chosen in such a way that they are able to accommodate each of the future scenarios. This results in the definition of so-called 'Corridor Scenarios' (Table 3). These values can be applied to any TEN-T Network road corridor to develop EU biofuels corridor designs. This has been done for the corridor selected for the case study; from Rotterdam to Constanta. In addition, fuel use by corridor users, biofuels policy in the MSs involved, and this corridor's refuelling infrastructure are examined.

Table 1. Definition of Corridor Scenarios

Parameter	*Corridor Scenario 1*	*Corridor Scenario 2*	*Corridor Scenario 3*	*Corridor Scenario 4*
Focus on high blends	Limited	High	High	High
Product Supply Diversity	B100 Biodiesel	E85 Ethanol	B30 Biodiesel	E85 Ethanol B30 Biodiesel
Market Access	Restricted Freight	All Gasoline	All Diesel	All Transport
Targeted group	Long distance transport companies	Both freight and passenger gasoline vehicles	Freight and in less proportion passenger diesel vehicles	Both long and short distance trips, with adapted vehicles
Station Coverage	Low coverage	High coverage	High coverage	High coverage

3. RESULTS: THE FEASIBILITY OF THE EU BIOFUELS CORRIDORS

The specific corridor for the feasibility study was chosen with respect to several requirements and criteria. Requirements include, for example, that the corridor should be part of the TEN-T network roads and should be at least 1000km in length. The potential of biofuels sales was an important criterion, which is why the current transport flows, expected developments of the transport flows, EC attention to the biofuels development, average trip length upon the corridor were taken into consideration. As because of data availability, the preference was given to corridors originating from the Netherlands. The Rotterdam – Constanta transport corridor was chosen to conduct the further analysis.[4]

A Rotterdam – Constanta Biofuels Corridor

The corridor from Rotterdam to Constanta consists of two corridor routes which are frequently driven in a southerly direction via Mannheim in Germany and in a northerly direction via Hanover and Dresden. The total length of the corridor (i.e. including the two sections) is just over 4000km. Corridor is running through seven EU MSs: Austria, Czech Republic, Germany, Hungary, the Netherlands, Romania, and Slovakia.

To estimate the fuel consumption on the corridor, the transport flow shares on the corridor (as a percentage of total transport activity) are multiplied by the national diesel and gasoline

[4] The first analysis with regards of the current transport flows resulted in the selection of the four TEN-T corridors: Rotterdam – Barcelona, Rotterdam – Warsaw, Rotterdam – Constanta, Rotterdam – Venice. Further the analysis of the expected transport flows indicated that the East – West corridors to Poland and Romania offer highest potential for the future growth (traffic forecasts TRANS-TOOLS for 2030; NEA, 2009). Taking in consideration that transport growth on the Romanian corridor is expected to be higher than on Polish corridor and that potential of biofuel production in East European countries, such as Ukraine and Romania, is high (which provide an easier access to the domestic biomass supply) the final choice was done to the Rotterdam – Constanta corridor. Moreover, this corridor is a part of the Pan-European corridor IV which makes it more attractive to the policymakers. Because of the data availability the focus was made on the freight transport flows upon the corridor.

fuel consumption[5] at MS level. The results which are provided include all transport activity on the corridor, and not only traffic running from Rotterdam to Constanta. TRANS-TOOLS has been used to determine the transport flows on the corridor as a percentage of the total transport activity in the respective countries. Taking the assumptions and limitations into consideration, the following result was obtained (Table 4). Total fuel use is on this transport corridor in 2020 is estimated to be approximately 8280 million litres annually.

This table illustrates as well that on average approximately 8% of national fuel use originates from the specific corridor traffic. This indicates the national importance of main corridors in terms of transport flows and a potential for the biofuels usage.

Table 4. Fuel consumption on Rotterdam – Constanta corridor, million litres

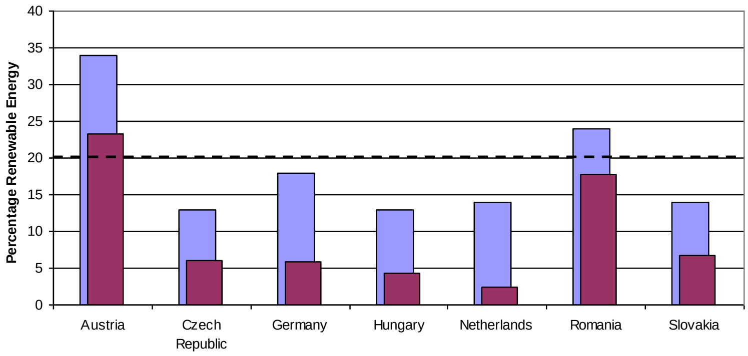
Consumption of fuel in million litres	2010	2015	2020	% of national driven-km on corridor
Gasoline consumption by passenger cars	2978	2893	2823	8.5%
Diesel consumption by passenger cars	1628	1962	2306	8.5%
Diesel consumption by freight trucks	2336	2707	3151	7.6%
Total	**6942**	**7562**	**8280**	

Policy, targets and progress related to the Biofuels Directives vary significantly among the seven MSs that are involved in this corridor (Figure 5). As follows from the National Reports on the biofuels Directive 2003/30EC, by 2008 Austria and Germany were forerunners in the fields of biofuels consumption and, already have roughly achieved their indicative 2010 EU targets. By now all the involved MSs, with the exeption of the Netherlands, make use of excise duty tax exemptions in order to promote the use of high-blends.

Figure 6 shows the mandatory targets for renewable energy in 2020 per country and the 2005 shares of countries' renewable energy. A minimum of 10 percent applies for the transport sector. The overall target share of 2020 is indicated by the dotted line. We can see that countries like the Netherlands and Germany, due to their high GDP, have relatively tough targets compared to Eastern European MSs. It can be anticipated that in order to meet their overall targets Western MSs will consider more ambitious targets for renewable energy in transport (higher than 10 percent).

[5] The national diesel and gasoline fuel/energy consumption follow from the MS progress reports of the 2003/30/EC Directive. Each MS is required to provide information regarding the annual quantities of diesel and gasoline fuel being brought on the market. These figures count for the entire transport sector, and therefore, various assumptions are made to derive the specific quantities for the passenger and freight road transport sectors.

Figure 6. Member State 2005 Renewable Energy Shares (Purple) and 2020 Renewable Energy Targets (Blue) (>10% Transport)



Source: EU Renewable Energy Directive 2009/28/EC

As regards refuelling infrastructure, the total number of fuel stations, except Romania, has been obtained from the road maps of the Royal Dutch Touring Group (ANWB, 2009). Density of fuel stations along the corridor varies and is higher in Western European countries, e.g. up to once every 20km in the Netherlands. Therefore, even the minimum station spacings for E85 infrastructure can easily be met by existing refuelling infrastructure. A 10% increase in the amount of fuel stations on the corridor is expected by 2020.

The paragraphs below present the biofuels corridor designs. These designs were made by applying each of the corridor scenario parameters to the specific Rotterdam – Constanta corridor.

Corridor Design 1: Biodiesel B100 is offered at freight pumps. Minimum station spacing applies for long-distance transport, which is estimated to be one station every 732km. Considering the corridor length of just over 4000km, this results in a total of approximately 12 biofuel stations (both sides of the corridor). Freight transport companies that regularly refuel at these stations are selected for the captive fleet. The number of participating freight companies depends on the required biofuel sales as a percentage of total fuel sales. It is assumed that, in this design, the total of these freight transport companies will account for 5% of the total freight transport on the corridor. This results in a total diesel consumption on the corridor by the specific market of around 158 million litres in 2020 annually.

Corridor Design 2: Ethanol E85 is offered. The minimum station spacing of once every 185km applies, which would result in a total of approximately 44 biofuel stations. However, due to the high access market, including local short-distance passenger transport, many more stations on the corridor would need to offer biofuels. Therefore, over 50 percent of the total number of stations will offer the high-blend. The exact number of stations depends on the market and oil companies. The total fuel use of gasoline passenger cars on the corridor will account for approximately 2823 million litres annually in 2020.

Corridor Design 3: Biodiesel B30 is offered, both for freight transport and for passenger transport. Minimum station spacing for freight is almost 800km and for passenger around 250km, which results in a minimum of 32 biofuel stations on the corridor. One in every four stations must also have a biodiesel pump for trucks. However, the high access market also includes short-distance transport, which therefore would require more stations. The exact number depends on the market and the oil companies, and will be over 50 percent of the total number of stations on the corridor. The total fuel use of the market on the corridor (i.e. all diesel vehicles) accounts for approximately 5457 million litres annually in 2020.

Corridor Design 4: Both biodiesel B30 and ethanol E85 are offered at the corridor. Many fuel stations would need to offer the biofuels, which is over 50 percent of the total number of stations. The exact number depends highly on the market analysis and on the oil companies. The potential market includes all traffic on the corridor, which account for approximately 8280 million litres annually in 2020.

The Feasibility of the Biofuels Corridor

In order to estimate the feasibility of the biofuels corridor, we have analysed biofuels consumption in each of the four corridor designs for the corridor Rotterdam – Constanta. This was done on the basis of two input variables: percentage of corridor users that actually refuel at stations along this corridor and percentage of fuel sold that will be replaced by biofuels in each of the corridor designs. For this, several assumptions were made: the availability of the various types of biofuels, the number of biofuels compatible vehicles available over time, and, the price of biofuels.

The total fuel use on the Rotterdam-Constanta corridor, as estimated in the previous chapter (8280 million litres annually), is based on the total amount of km being driven. However, the actual fuel consumption at fuel stations along the corridor (i.e. motorway stations) could well be different. There are many alternative places to refuel. The relatively high fuel cost along motorways compared to at other locations is the main reason for road users to adopt a certain ‘refuelling behaviour’.

The freight transport market is very competitive and truck companies mostly refuel at predefined locations to reduce costs. Most haulage companies have their own refuelling infrastructure or have special price agreements with specific stations, particularly the larger ones. The TLN (2008) study indicates that on average only approximately 10 percent of all freight transport refuelling takes place at random (i.e. motorway) stations. This aspect, therefore, will significantly impact upon the effectiveness of biofuels corridors for freight transport, as, with biofuels corridors, access to high-blends is restricted to fuel stations on the corridor only.

Passenger car users refuel more often at local stations because of the fact that fuel prices on motorways are generally higher. Most business users having a refuelling card could well be an exception to this rule. Clear data on passenger cars ’fuelling behaviour”’ has not yet been found.

It is indicated by interviewees that the average total fuel sales at EU motorway stations is approximately 5 million litres per year. Some reports, however, estimate this throughput to be slightly higher or lower; e.g. ECORYS (2009) estimates an annual throughput of approximately 7 million litres at large Dutch motorway stations, while the Union of European Petroleum Independents (2008) points to a maximum of approximately 4 million at Swiss motorway stations. Due to the lower traffic intensity on corridor section in the Eastern

European countries, an average annual throughput of 5 million litres has been assumed for fuel stations on the Rotterdam-Constanta corridor.

Given the fact that there will be approximately 230 fuel stations on the corridor in 2020, a simple calculation shows that total fuel sales on the corridor would be approximately 1150 million litres annually by 2020. This is a rather small figure when considering that the total fuel used by vehicles driving on the corridor has been estimated at 8280 million litres and this severely impacts on the potential of the corridor as a means to sell high amounts of biofuels. Given that the freight transport trucks will refuel approximately 315 million litres at corridor stations (i.e. 10 percent of their total use) per year, this would leave approximately 835 million litres for passenger transport. In turn, this indicates that only 16 percent of passenger vehicles using the corridor would actually refuel at stations on the corridor.

The total amount of fuel (gasoline or diesel) that will actually be consumed in each of the corridor designs is now calculated as follows. Firstly, the total fuel used by the specific market is calculated. The total fuel used on the corridor was calculated to be approximately 8280 million litres annually. For the open market designs, as the market is defined by the product type, these figures follow from Table 4. For Design 1, the potential market is 5 percent of the total freight diesel consumption. Secondly, the fuel used by the specific market is multiplied by the percentage of users that actually refuel on the corridor. Thirdly, the fuel use at corridor stations is multiplied by the share of biofuel-compatible vehicles in 2020 for the specific market. This leads to the volumes of conventional fuel that could be displaced by high-blends. Fourthly, to obtain the amount of conventional fuel that will be replaced by biofuels, this value is multiplied by the percentage of biofuels (based on energy content) in each specific high-blend. This is 79, 28 and 100 percent for E85, B30 and B100, respectively. And, to calculate the amount of specific high-blend(s) in litres required to realise this shift, the total fuel consumption at the corridor stations by the respective market is divided by the energy content of this high-blend relative to that of the specific conventional fuel. This is approximately 0,71; 0,97; and 0,90 for E85, B30 and B100, respectively. The total displacements of conventional fuels by biofuels in each of the Rotterdam-Constanta biofuels corridor designs are provided in Table The table also indicates the displacements as a percentage of the total fuel use on the corridor.

Table 5. Expected Displacements of Conventional Fuels by Biofuels in each of the Rotterdam-Constanta Corridor Designs in 2020

	Design 1	*Design 2*	*Design 3*	*Design 4*
Displacement by biofuels in millions of litres	158	179	140	319
Percentage of total fuel use on the corridor	1.9%	2.2%	1.7%	3.9%

This analysis indicates that, despite the enormous transport flows on the corridor, the overall effect of offering high-blends on the corridor are strikingly low. Demand would be the highest in Corridor Design 4, accounting approximately for 4% of the total energy use on the corridor.

The theoretical maximum amount of fuel being displaced by biofuels on the Rotterdam-Constanta corridor will, taking the corridor approach, be limited to the fuel sales at the corridor stations. This is only approximately 14 percent of the corridor's total fuel use. Due to the fact that high-blends also contain a certain share of conventional fuel, the actual maximum displacement by biofuels will be even lower. Although these consumption rates may rise post-2020, due to an expansion of the biofuel-compatible vehicle fleet, the displacements by means of this biofuels corridor alone will, because of this, remain limited.

Furthermore, we made an overview of the costs involved in the development and operation of the biofuels corridor. One can distinguish between three types of costs: costs related to the vehicles using biofuels; distribution and refuelling infrastructure costs; and the costs of biofuels compared to those of conventional fuels.

SenterNovem (2008) provides price indications for vehicle adaptations. The price of Flex-Fuel technology for gasoline vehicles largely depends on economies of scale. The cost of building the technology into present-day cars is estimated to be approximately €500 per vehicle. However, these costs go down significantly to just €100, if the Flex-Fuel is built into newly sold cars and produced in large quantities. In countries in which FFVs are very popular, such as Brazil and the United States, costs of FFVs are similar to those of baseline gasoline cars (Worldwatch, 2007). For the purpose of this study, an additional cost of €100 per vehicle is taken into account. For diesel vehicles, the adaptation costs to make them compatible with B30 or B100 are considered to be negligible. However, in the case of biodiesel trucks which drive long distances, a one-year maintenance interval would not be sufficient. Additional maintenance costs for B30 and B100 trucks are estimated to be €250 and €850 per year, respectively. The cost estimates adapted to each particular scenario are presented in a table below (Table 6).

Table 6. Estimation of Annual Vehicle Costs in Each Corridor Design

Rotterdam-Constanta	*Design 1*	*Design 2*	*Design 3*	*Design 4*
Biofuel-compatible vehicles needed (x1000)	6	25,000	28,540	53,540
Estimation of annual costs (€ million)	5	208	135	343
Cost-effectiveness: Cost per litre of fuel (€)	3 cents	116 cents	96 cents	108 cents

The cost estimates indicate that offering high-blends to the open market (i.e. as in Corridor Designs 2, 3, and 4) on a single corridor not a cost-ineffective way to stimulate the use of biofuels. Despite the fact that various assumptions have been made to make estimates, the numbers give a clear signal that the annual vehicle costs of the corridor designs in which E85 ethanol is offered are most significant and may reach over €200 million annually. Corridor Design 2 in particular might seem as an expensive way to go, as the average vehicle costs per litre of gasoline fuel replaced by ethanol is highest. These costs could be even higher as costs reductions due to economies of scale (i.e. 'only 25 million' vehicles) could also be limited in this case.

This observation confirms that the development of the corridor for the open market would only be feasible if the future focus is on high-blends, as then, the vehicle costs will not be allocated to just the biofuels corridor alone. In the scenario in which high-level ethanol and biodiesel blends become vital for achieving EU targets, the biofuels corridor will be accompanied by other support measures to stimulate the use of high-blends (e.g. local stations offering high-blends). These initiatives will also require biofuel-compatible vehicles, reducing the average additional vehicle cost. Design 1 could however also be interesting without a focus on high-blends as it concerns a niche market. Money spent on vehicle maintenance can be allocated much more effectively, as the market is selected in such a way that users do refuel regularly at the corridor stations.

Distribution and refuelling infrastructure costs also need to be taken into consideration. The literature and oil industry experts point to various aspects which require special attention when distributing high-blends. E85/B30/B100 require separate pumps at fuel stations, as they may not be sold as conventional diesel and gasoline. The materials used in these pumps need to be compatible with the characteristics of ethanol and biodiesel, which react differently to certain types of plastics and rubbers (Biofuel Cities, 2009). In addition, the handling of E85 ethanol requires a special authorisation for stations and a different tank for its distribution and storage may be required due to its instability when in contact with air and/or water (SenterNovem, 2008). Although biodiesel faces similar aspects, its distribution is easier, as the conventional diesel infrastructure can generally be used (Worldwatch, 2007 and Biofuel Cities, 2009).

The fact that high-blends require a separate pump is important to oil companies. Filling stations mostly have limited space, especially in Western European countries. For this reason, most fuel stations cannot afford to have more than two pumps, one for each product type (i.e. gasoline and diesel). These pumps, therefore, have to be used as efficiently as possible. Presently, for example, stations often offer a basic type and premium type (e.g. Shell V-Power). Motorway stations could accommodate more pumps, but to offer more fuel types would be more complex to organise logistically. In short, for high-blends this means that there must be a large enough amount of road users ready to use the fuel before the fuelling technology will be adjusted. The demand analysis indicates that in 2020 there will most likely be enough demand for high-blends in all corridor designs to make offering high-blends attractive.

The additional tank infrastructure costs are low. Depending on the station lay-out, two options exist. One can either change an existing storage tank and pump (which was formerly being used for gasoline, for example) to accommodate the new biofuel blend, or one can decide to install a new pump and storage tank. In the first and latter cases, costs for retrofit are estimated to be approximately €830 and €18,000, respectively (SenterNovem, 2008 and Worldwatch, 2007). The installation of new tanks will be rare, as, due to space and logistical restrictions at fuel stations, an additional tank is not viable. This means that, even when all stations on the corridor would offer high-blends, the total costs for refuelling infrastructure will remain well below one million euros.

In sum, distribution and refuelling infrastructure costs are low and can be covered by oil companies if there is a high enough demand of high-blends on the corridor stations. Since the analysis indicates that this would be the case by 2020, this would most likely make it feasible to offer high-blends.

Contribution of Biofuels Corridors to EU Targets

In order to determine the potential contribution of biofuels corridors to the RED targets we have analysed the potential displacement of conventional fuels by biofuels by means of implementing EU biofuels corridors on the entire TEN-T Network roads.

The RED requires MSs to have a share of at least 10 percent of renewable energy in transport, and in the corresponding scenarios a certain percentage must be achieved by high-blends. In Corridor Scenario 1, this would only be a small share of the total renewable transport energy targets, which is presumed to be one percent. The remaining share will be met by increasing the minima of low-blends as well as by other alternatives. In Corridor Scenarios 2, 3 and 4, high-blends would entirely complement low-blends, which implies that, based on the minimum ten percent target, approximately 4 percent of total EU transport energy should be achieved by high-blends. It should be mentioned again that MSs may decide to adopt higher targets, which means that the scope of high-blends could be increased.

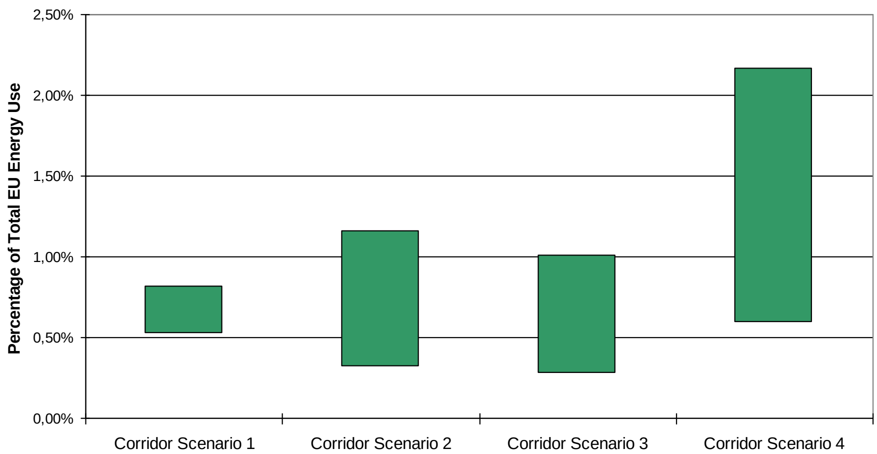
The maximum potential contribution of EU biofuels corridors in 2020 is, therefore, expressed as the total share of transport energy that could be replaced by biofuels. This share for each of the corridor scenarios is calculated as follows. To obtain the maximum contribution of EU biofuels corridors, the average use of high-blends (in energy terms) per km of biofuels corridor is multiplied by the total length of the TEN-T Network roads. Subsequently, this figure is divided by total EU transport energy use.

This calculation requires three input values: the total length of the TEN-T Network roads; the total EU transport energy use; and, the replacement of conventional fuels by biofuels per corridor-km. Firstly, the TEN-T Network roads are expected to comprise approximately 90,000km of motorways and high-quality roads by 2020 (EC, 2009c). Secondly, the total EU transport energy use in 2006 was 15.5E9 Gigajoules (GJ) (Eurostat, 2008). As transport energy is expected to grow by 0.75 percent annually between 2005 and 2030 (EC DG TREN, 2008), the total transport energy use would be 17.2E9 GJ in 2020. Thirdly, the biofuels use per corridor-km can be obtained from the Rotterdam-Constanta corridor demand analysis. The total length of this corridor is just over 4,000km. The RED is based on energy terms, which means that the biofuels use must also be expressed in energy terms (GJ).

However, the biofuels use per corridor-km on the Rotterdam-Constanta corridor could be slightly different than for other TEN-T Network routes. Nevertheless, thanks to the many and diverging countries involved in this particular corridor, the Rotterdam-Constanta corridor is considered to be very representative for other corridors on the TEN-T Network roads. In addition, in order to provide an estimate of the demand per corridor-km, a certain deviation interval regarding transport flows and refuelling behaviour on this specific corridor have been assumed. Firstly, transport flows on other TEN-T road corridors may be different than for the Rotterdam-Constanta corridor. As this specific corridor was selected on the basis of high transport flows, it is likely that average transport flows might be slightly lower if implemented on the entire TEN-T Network roads. Therefore, a deviation interval of between 70 and 110 percent of total Rotterdam-Constanta transport flows has been assumed. Secondly, approximately 10 and 16 percent, for the freight trucks and passenger transport respectively, of the total fuel use on the Rotterdam-Constanta corridor will actually be obtained at corridor stations. Yet, this share may be slightly higher or lower for other corridors, because of different refuelling behaviour (e.g. due to toll roads). Therefore, a deviation interval of between 60 and 140 percent from the Rotterdam-Constanta corridor values has been assumed. Both assumptions apply to all markets, including freight and passenger transport alike, and lead to maximum and minimum values for the energy displacement on EU corridors per corridor-km. It is important to bear in mind that, because of these assumptions, the true results could be slightly different, yet it does allow a first indication to be made of the effect that biofuels corridors could have if implemented at the EU level. It also should be emphasized that by taking these aspects into account, the final results of this study are not directly influenced by the initial choice of the case study corridor.

Figure 7. presents an estimate of the maximum contribution of EU biofuels corridors in 2020 under each of the four corridor scenarios. The green bars represent the sensitivity of the calculations, i.e. the contribution of Corridor Scenario 4 is estimated to be between 0.5 and just over 2 percent.

Figure 7. **Estimation of the Maximum Contribution of EU Biofuels Corridors to the RED Targets in 2020**



From the figure follows that EU biofuels corridors in Corridor Scenarios 2, 3, and 4 as a measure on its own does not come close to complementing low-blends in 2020 (i.e. 4 percent). Moreover, it is assumed that biofuels corridors are implemented on the entire TEN-T Network roads, which can already be considered as very ambitious. The maximum contribution of biofuels corridors in Corridor Scenario 4 would increase the amount of biofuels as a percentage of total energy consumed in transport by just one or two percent. The other scenarios would be much less powerful.

4. SUMMARY AND CONCLUSIONS

Biofuels are considered by EC policymakers as a viable alternative which could replace fossil transport fuels in the short run. The biofuels industry is booming, owing to strong government support, and first generation ethanol and biodiesel dominate the existing market. Biofuels in EU road transport could theoretically contribute to a significant reduction in fossil-fuel dependency and GHG emissions, and thereby deliver a substantial contribution to the overall EU sustainability policy objectives. Although biofuels are considered as one of the most viable solution to contribute to EU sustainable transport policy objectives, it remains questionable whether they have the potential to become competitive with petroleum-based fuels in the short-term. Therefore the main objective of our research was to understand to what extent can biofuels corridors on the TEN-T Network roads function as a catalyst for the biofuels usage in the EU.

The case study on the Rotterdam-Constanta biofuels corridor has indicated that the effect of a single corridor in terms of increasing use of biofuels would be low. The market analysis shows that demand for high-blends on the corridor, as a percentage of total fuel use by corridor users, is limited to a maximum of 4%. The main reason is that corridor users mostly refuel at local fuel stations instead. The vehicle and infrastructure technology required for the use of high-blends is available, but their large-scale implementation would face economic barriers. The economic analysis indicated that a single biofuels corridor for an open market (i.e. Corridor Designs 2, 3, and 4) would not be cost-effective, because of high vehicle-related costs. A low share of biofuel-compatible vehicles would reduce demand, which, in turn, would be insufficient to make fuel companies offer high-blends. Corridor Design 1, however, which focused on a captive freight fleet, would be easier to implement and its corresponding scenario is more realistic. Although the concept would still require additional policies and certain conditions to be met (wider coverage of the network and incentives for high-blends, for example), the implementation would be more cost-effective as opposed to the open market designs. Moreover, the biofuels demand could rise if the number of participating haulage companies were to be increased or if the focus were on other market segments than corridor stations alone (e.g. business stations).

The results of the Rotterdam-Constanta corridor can be further transferred to other corridors on the TEN-T network roads when taking in consideration the differences in transport flows and refuelling behaviour specific to each corridor.

The results have shown that **the overall extent to which biofuels corridors alone can increase the use of biofuels and contribute to the EU sustainability targets is limited**. Even if biofuels corridors were implemented on the entire TEN-T Network the maximum contribution to the RED targets would be just between 1 and 2 percent. The main reason for this is that the enormous transport flows and corresponding fuel use are not representative of the actual fuel sales at stations on the network: the corridor users refuel mostly locally.

Most of all freight vehicle km are **fuelled at the transporters' home base**, leaving only about 10 percent that actually refuel at stations on the corridor. This does imply, however, that **transport companies could take action on an individual basis**. Here, one can note that a truck suitable for high blend biodiesel can also fuel regular diesel in case if somewhere on the route biofuels are not available yet. Therefore, the demand for biofuels can be already generated by individual transport companies. In order to promote this, MSs can always support these measures along main TEN-T routes.

For passenger cars, a good network of fuelling stations where biofuels are available is essential for a proper implementation. As private users mostly refuel locally, **high-blends should also be made available at local stations**. Most passenger movements are short distance, and each country can implement this alternative in its own pace, independently from any EU contribution. For example, in the Netherlands, recently a simulation package was launched to improve biofuels availability.

The viability of biofuels corridors for an open market seems to depend on a future public policy focus on high-blends, which, according to the analyses, would be rather ambitious. The scenario analysis points to many other alternatives to stimulate the use of biofuels, including increasing the allowable percentage of biofuels to be blended in conventional fuels and second generation biofuels. These would, from the perspectives of various stakeholders, be more favourable than focussing on high-blends alone. The future role of high-blends, however, will presumably become clearer when national RED action plans are presented. In these scenarios, biofuels corridors could still be implemented and would mainly serve to increase the awareness of biofuels among road users. Furthermore, they could encourage international cooperation in fuel standards and taxation.

Several recommendations can be elaborated from the above-discussed results. First of all, it is **necessary to reconsider the implementation of biofuels corridors for the open market once there is more certainty regarding the future role of high-blends**. The study indicates that the development of biofuels corridors is very much dependent on the national support policy for high-blends. However, it should be emphasised that the scenario analysis has pointed to several other ways in which the implementation could be realized, focussing on second generation biofuels, for example. This MSs plans would provide a significant amount of additional data which would assist in assessing whether or not the implementation of biofuels corridors is realistic and viable.

Secondly, the conclusions show that **biofuels corridors for the freight transport truck market could be a promising development**. A scenario in which high-blends would be required to contribute to just a small percentage of EU targets is a realistic one, and it was shown that targeting this market (i.e. captive fleet of freight trucks) could help to achieve this contribution in an effective way, from both a cost and future policy perspective. Preferably, the initiative would not only include corridor stations, but also business and home-based fuel stations to increase demand and thereby produce the corresponding effects. The ultimate aim would then be to create a kind of bunker fuel[6] consisting of large biodiesel components for the EU freight transport market. This fuel, e.g. B30 or B100 biodiesel, would then become one of the standard truck fuels in the EU and would be available at most fuelling locations for trucks. Therefore, if the future corresponding scenario becomes reality and MS policy promotes the use of high-blends, **further research should be undertaken into realising a high-blends refuelling network for freight transport trucks.**

[6] Bunker fuel refers to standard fuels that are used by international shipping and which are present in most harbours.

Thirdly, **the corridor approach could be transferred to other modes of transport as well as to other sustainable transport alternatives**. One could, for example, investigate the opportunities of a biodiesel refuelling network for inland shipping. Or, alternatively, for hydrogen or electric-powered road transport.

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