Sustainable alternatives for land-based biofuels in the European Union

Assessment of options and development of a policy strategy

Report
Delft, December 2012

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Publication Data

Bibliographical data:
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Sustainable alternatives for land-based biofuels in the European Union
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Delft, CE Delft, December 2012

Publication code: 12.4593.55

CE publications are available from www.cedelft.eu

Commissioned by: Greenpeace European Unit
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Summary

Background and aim of this study
The Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD) are important steps on the road towards decarbonisation of EU transport, as they directly affect the energy used in this sector. The first sets a target of 10% renewable energy in transport in 2020, the second states that the average life cycle greenhouse gas (GHG) emissions of transport fuels should reduce by a minimum of 6%, between 2010 and 2020.

Both targets are expected to be met mainly by increasing the use of biofuels. The Directives defined sustainability criteria for these biofuels, but these have proven to be insufficient to effectively prevent undesired impacts. The main omission is currently the exclusion of impacts of indirect land use change (ILUC); these can nullify GHG emission savings of biofuels and even increase overall emissions in some cases. Efforts are ongoing to improve the criteria, but these have not yet led to improvements. Recently, the European Commission submitted a proposal to limit the use of biofuels whose production competes with that of food and feed product, but no final decision has been taken.

This study aims to develop a more robust and sustainable approach to meeting the RED and FQD targets. Scenarios were developed with which EU Member States can meet these targets without or with limited use of biofuels from cultivated biomass, and without biofuels from waste and residues with other useful applications. The study was commissioned by Greenpeace and BirdLife Europe, with support from Transport & Environment and the European Environmental Bureau (EEB).

Renewable energy is crucial, but only part of the solution
When comparing long-term EU climate goals for the transport sector with business-as-usual scenarios, it becomes clear that the GHG emission targets can not be met with current policies. Very significant additional efforts are required. These may be aimed at four types of measures:
- reducing transport demand;
- improving transport efficiency (including modal shift);
- improving fuel efficiency;
- reducing the GHG intensity of fuels.

The RED and FQD focus on the latter, within the 2020 timeframe, but should be seen in the context of the first three types that determine energy demand: the lower the energy demand, the less renewable energy and other CO_2 mitigation measures are necessary to meet the targets. As renewable energy for transport is likely to remain costly and scarce in the future, energy demand reduction will be at least equally important in the future transition towards sustainable transport.

Sustainable alternatives to land-based biofuels
A range of alternatives to the current land-based biofuels were identified that are typically more sustainable, able to contribute to both the RED and FQD targets, and lead to overall, real CO_2 reduction as well:
- an increase of energy efficiency and reduction of fossil energy consumption in transport;
- a shift towards electric transport, with an increasing share of electricity from renewable sources;

– biofuels and biogas that meet strict sustainability criteria (i.e. biofuels or biogas from waste and residues with no other useful applications);
– hydrogen from renewable energy sources.

These can be complemented by measures such as reducing flaring and venting during oil production and processing. These contribute to the FQD target and overall CO_2 reduction, but not to the RED target.
The potential contribution of each of these measures towards the policy goals depends on the effectiveness and timing of the policy measures implemented in the coming years and on the success of technological developments. Estimates were derived for their maximum realistic contribution in 2020.

Meeting the targets sustainably

Based on these findings, a number of EU-level scenarios were developed for 2020. The potential policy implications were assessed, for both EU and Member State level. For the latter, five countries were taken as case studies: Denmark, Finland, France, Germany and the Netherlands.

Three examples of EU-level scenarios are shown in Figure 1 below, where an overview of the contributions of the various measures towards the RED target is shown. Here, the 10% RED target is met by

1. An **energy demand reduction** of 15%, compared to business as usual.
2. The **level of land-based biofuels** ranges from zero in the left column, to the 2008 biofuels demand level in the middle (421 PJ, or 10 Mtoe) and the 2010 level in the most right variant (582 PJ, 14 Mtoe).
3. **Renewable electricity** (RE) in non-road and road transport; a total of 152 PJ or 3.6 Mtoe renewable electricity is assumed.
4. **Biofuels from waste and residues** (W&R), which will consist mainly of biomethane from agricultural waste and biodiesel from waste fats; their contribution varies from 342 PJ (8.2 Mtoe) in case no land-based biofuels are used, to 51 PJ (1.2 Mtoe) in case 2010-levels are included[1].

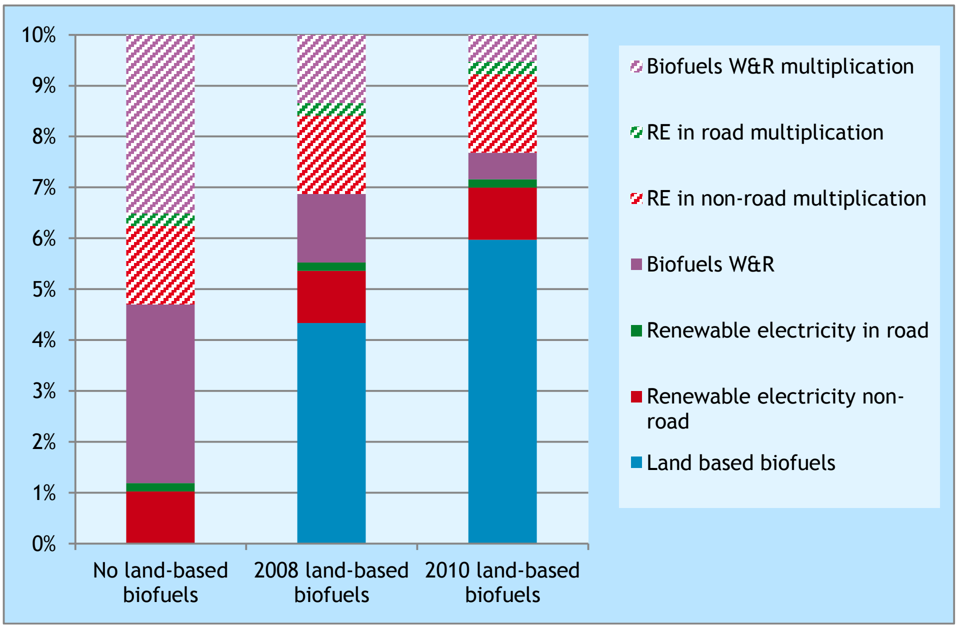
In addition, **renewable electricity in non-road transport** is multiplied with 2.5, to ensure equal treatment of electricity in non-road and road applications.

The shaded parts in the graph are administrative contributions of the renewable energy towards the RED target: all renewable electricity is assumed to be multiplied by 2.5, biofuels from waste and residues are double counted. For comparison: if the National Action Plans would be realised, land-based biofuels would increase to 8.7% of road transport fuels in 2020.

All scenarios achieve the 10% RED target in 2020. The contribution of the renewable energy options to the FQD target is 3.1-4.3%. The remaining 1.7-2.9% will have to be achieved by other CO_2 reduction measures such as reducing flaring and venting.

[1] For comparsion: the total volume of biofuels from waste and residues used in EU transport in 2010 is estimated to be between 3 and 4 PJ (less than 0.1 Mtoe).

Figure 1 **Scenario 2: Renewable energy mix to meet the 10% RED target**



The overall CO_2 emission reduction achieved in the scenarios is about 205 Mton CO_2, of which 75% is due to the 15% reduction of energy demand. The scenario without any land-based biofuels can be expected to be the most sustainable way to decarbonise domestic transport in the EU, provided that environmental safeguards are put in place for biofuels from waste and residues. It is the only scenario which potentially excludes both direct and indirect land use changes.

The way forward: change of policy strategy and focus

This analysis clearly illustrates that meeting the RED and FQD targets will not be met sustainably unless a number of new policy measures will be agreed upon by Member States and Parliament at EU level. Policies need to be aimed much more at curbing energy demand, increasing energy efficiency and speeding up the development of sustainable fuel alternatives, while land-based biofuels are phased out.

To achieve this change of focus, action is required by both the EU and the Member States. Important first steps are the phase-out of direct and indirect support for land based biofuels and the adoption of a trajectory from current consumption levels towards near-zero use in order to prevent further environmental and social damage. In addition, ILUC emissions should be accounted for in the life cycle analysis of biofuels under both the RED and FQD, and sustainability criteria for land-based biofuels and biogas should be improved (see Section 1.2).

Secondly, the transport sections of the National Renewable Energy Action Plans by the Member States should be redrafted to adjust them to these changes in EU policy. Furthermore, the EU and Member States need to put a robust policy framework into place that speeds up energy efficiency developments, as well as the production and use of biofuels from waste and residues with no alternative uses. This biofuel strategy should be part of a broad biomass and bioenergy strategy, as the sustainable feedstock is limited and other applications will also need sustainable bioenergy to meet their climate goals.

1 Introduction

1.1 Introduction

At the end of 2009, two EU Directives were issued that affect the types of energy used in the transport sector: the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD). The first sets a target of 10% renewable energy in transport in 2020, the second states that the life cycle greenhouse gas (GHG) emissions of the transport fuels should reduce by a minimum of 6%, between 2010 and 2020 (another 4% reduction is optional).

It was (and still is) expected that an increasing use of biofuels would contribute significantly to both targets. Both Directives define sustainability criteria for biofuels to be counted towards the targets, including a minimum GHG emission reduction requirement, and a number of provisions, for example to prevent biofuels to be cultivated on land with high carbon content or high biodiversity although many of these criteria are not yet fully defined and implemented. However, potential impacts of indirect land use change (ILUC) are not included in the 2009 Directives, even though emission due to ILUC will, in some cases, nullify GHG emission savings or even increase emissions when used instead of conventional fuels. Since then, the EU is working on a means to include ILUC effects and thus improve the regulations. However, so far, this has not led to a concrete proposal or amendment of the Directives.

The Member States' National Renewable Energy Action Plans (NREAPs), submitted as part of the RED requirements, outline the way in which the Member States intend to meet the 10% renewable energy target in transport in 2020. From these NREAPs, it can be concluded that all Member States expect to meet this target with mostly land-based biofuels, of which biodiesel has by far the largest share. Implementing these plans would result in very significant increases of global land use for biofuels, and thus GHG emissions due to both direct and indirect land-use change effects. Various studies now conclude that quite a large share of these biofuels is not sustainable, and is not likely to meet the sustainability criteria once ILUC is included[2].

This now leads to the key question that is addressed in this report: how can the 10% target in transport and the 6% FQD target be met sustainably? This study therefore aims to review how unsustainable biofuels can be phased out and what implications this has for the 10% and 6% targets. This aim will be achieved by developing one or more scenarios with which EU Member States can meet their 10% renewable energy target of the RED and at the same time contribute to the 6% GHG decarbonisation target in the Fuel Quality Directive in a sustainable way, without further increasing the use of biofuels grown on lands, and within the ecological limits of the planet.

The focus of the study is the period until 2020, but developing these sustainable alternatives it could also prove to be a significant and effective step in the continuing transition to sustainable transport after 2020. Actions in the coming years should be in line with a sound and robust, sustainable renewable energy and decarbonisation strategy for transport. The options that are to be developed in the coming years should thus have the potential to be

2 See, for example: IFPRI, 2011; JRC, 2011b; Öko-Institut, 2011.

scaled up further in the future, to eventually contribute to the long-term decarbonisation goals of the transport sector.
The study was commissioned by Greenpeace, BirdLife Europe, Transport & Environment and the European Environmental Bureau (EEB).

1.2 What are sustainable biofuels?

There is some debate on the criteria that determine whether or not a biofuel is 'sustainable'. The biofuels sustainability standard defined by the EU under the RED and FQD covers some of the criteria typically mentioned, but it does not capture indirect effects on GHG emissions and biodiversity, and it does not prevent negative social impacts[3].

In consultation with the client, it was decided that in this report, a **sustainable biofuel** is considered to comply with the following criteria:

1. Any bioenergy project which replaces energy produced from fossil fuels must, considering the whole production chains and any indirect land use changes (ILUC), **reduce total GHG emissions and disaggregated CO_2 emissions each by at least 60%** in comparison to the fossil energy production. Bioenergy production is not carbon neutral and always creates a carbon debt, since carbon is released to the atmosphere when burning biomass. This carbon debt has to be integrated in the GHG calculation methodology using a carbon payback time based on science and consistent with the objective to limit average temperature increase with 2° Celsius.
2. Crops and plantations for bioenergy **must not cause direct or indirect destruction or conversion of natural forests and other natural or valuable ecosystems** nor should they have negative effects on biodiversity (e.g. forests, peatlands and grasslands which are important carbon stores and have high biodiversity).
3. **Biomass from natural ecosystems is sourced according to environmentally responsible and socially just standards**. Additional criteria for the use of wood and wood residues from forests and grass from grasslands do not yet exist and therefore must be developed and applied.
4. **Social conflicts are avoided and food security, livelihoods and land rights are not undermined.** Production and use of bioenergy should not widen social inequalities, especially between developing and developed countries. Local needs should take priority over global trade and production. In addition, international trade in biomass or biofuels must not result in negative social impacts, nor undermine food security. Land use conflicts are avoided and indigenous peoples and local communities have the right to free and prior informed consent for the use of their land.
5. **No deliberate release of genetically engineered (GE) organisms to the environment is permitted**. Any bioenergy crops, including trees, must not be GE. GE microbes must only be used in contained facilities.
6. **Crops and plantations for bioenergy promote biodiversity on plantation level**, which means that they must not concentrate on monoculture plant and tree plantations.
7. **Sustainable agricultural practices are applied** that do not pollute the biosphere by accumulation of agrochemicals like synthetic fertilizer, pesticides and herbicides in the soil, water or air. The use of these agrochemicals is minimised, which means that they are only used when there is no biological or organic alternative and only in the most-efficient and non-polluting way.

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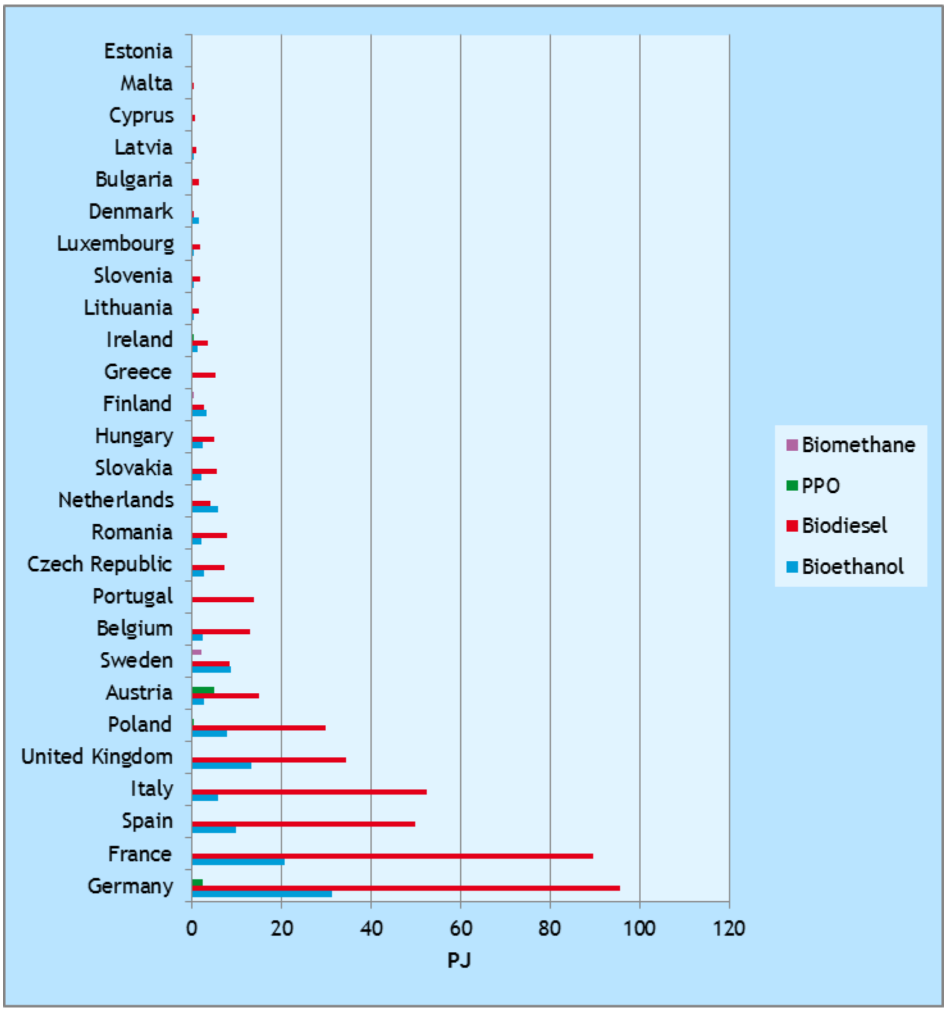
[3] These are to be monitored and reported by the European Commission (RED, Art. 17.7). This may lead to corrective action at a later point in time.

8. **The production of bioenergy crops maintains** soil fertility and soil organic carbon; avoid soil erosion, promote conservation of water resources and have minimal impacts on water availability, quality, nutrient and mineral balances.
9. **The expansion and development of new bioenergy crops, plantations and/or tree plantings, does not introduce any invasive species**. Where there is doubt, the precautionary principle should be applied.

1.3 Land-based biofuels: the issue of land use change

The current biofuel pool in the EU consists mainly of biodiesel and bioethanol from food crops. The types of crop used as feedstock have not yet been reported in the statistics (reporting of feedstock has only been obligatory for suppliers from 2011 onwards), but consumption of the various types of biofuels is known, see Figure 2. Biodiesel is the biofuel that is mostly used, followed by bioethanol, biomethane and pure plant oil.

Figure 2 Biofuels consumption in the EU Member States, in 2010



Data source: EurObserv'ER, 2011a.

If the NREAPs are implemented as planned, the total biofuels consumption will almost double by 2020 compared to the 2010 level. In the current policy framework, this further growth will be met mainly by further increasing biodiesel and bioethanol demand and production volume. Member State's plans suggest that the biofuels from agricultural commodities, the so-called 1st generation biofuels, will have a share of about 8.7% of EU road transport fuels in 2020, of which 22% is bioethanol, and 78% biodiesel (JRC, 2011). For comparison, the biofuel share was 4.7% in 2010 (EurObserv'ER, 2011a).
These biofuels are produced from agricultural food crops such as vegetable oils (palm, soy, rapeseed, etc.), sugar cane and sugar beet, wheat, maize, etc. Cultivating these commodities requires land, so that an increasing demand of these biofuels will lead to expansion of global agricultural land. IFPRI (2011) estimates that globally, the biofuels EU mandate leads to an increase in cropland area by about 1.8 million hectares - an area equivalent to 60 per cent of the total area of Belgium. It is this process of land use change that has attracted a lot of attention in recent years, both scientifically and politically, as it can lead to very significant GHG emissions. In some cases, this land use change can be directly attributed to specific biofuel batches, for example in case a palm oil plantation is started on land that used to be forest or grass land the year before. However, these effects can also be indirect, when the oil is taken from existing fields or from plantations that have been in place for many years. The land conversion will then be somewhere else, perhaps even in a different region, country or even continent. The complexity of global agricultural markets and trade, adjustments of supply to demand, potential shifts in demand for specific crops, etc. makes it practically impossible to determine a direct link between a certain biofuel batch and this kind of indirect land use change (ILUC). For this reason, the extent of land use change that will follow EU biofuel policies is determined by modelling.

Direct land use change emissions have to be included in most biofuels life cycle (i.e. well-to-wheel) analyses and also in the EU biofuels sustainability criteria of the RED and FQD, in case they occur. However, indirect land use change emissions are not (yet) included. As these can not be determined in practice, their impacts can only be determined using computer modelling of the global agricultural markets.

A number of modelling studies have been carried out in recent years, the most recent and elaborate study that specifically looked at the ILUC impact of EU biofuels policy and demand was carried out by IFPRI for the European Commission (IFPRI, 2011). This study confirmed the findings of earlier assessments that the current biofuel demand already requires significant land area, and this will further increase as demand increases in response to the target of the RED.

This land use change then causes significant GHG emissions. Increasing the current biofuels demand level to the 2020 demand outlined in the NREAPs was found to cause around 500 Mton of CO_2 per year, which is about 38-40 grams of CO_2 equivalent per MJ of biofuels on average – more than two-thirds of the emission savings attributed to the use of biofuels (IFPRI, 2011). These emissions equal almost half of the current GHG emissions of the transport sector in the EU (see Section 2.1)[4].

[4] Note that because most of the biofuels feedstocks are cultivated outside the EU, most of these land use changes do not add to the EU and IPCC emission statistics, where only direct emissions are included and the emissions of biofuels burning are considered to be zero.

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The studies on ILUC also find that there can be very significant differences between the various types of biofuel, and even between the various crops used to produce a biofuel. Biodiesel typically scores much less positive than bioethanol. IFPRI (2011) concludes that the total GHG emissions of biodiesel from soybeans and rapeseed are higher than of the diesel that the biodiesel replaces, and net savings from palm fruit and sunflower are very limited (less than 10%).

Apart from GHG emissions, large-scale land use change for biofuel production also has other environmental and potential socio-economic impacts. For example, the land use change (both direct and indirect) will have a significant impact on biodiversity. In a recent study of the JRC, it is estimated that the land use change caused by the biofuel demand increase for the RED target will reduce the Mean Species Abundance (a measure for biodiversity) of the areas converted on average by about 85% (JRC, 2011b). This estimate was based on the land use change estimates of IFPRI (2011) and the biodiversity work carried out by PBL under the framework of the UNEP Convention on Biological Diversity (Alkemade, 2009). Negative socio-economic impacts occur, for example, when land is taken from local communities to be converted to large-scale plantations.

1.4 The need to develop alternative pathways to sustainable transport

Clearly, there are quite a number of risks associated with land-based biofuels: they may only lead to limited GHG savings on average (some may even increase emissions), they have negative impacts on biodiversity and there are socio-economic risks involved with increasing large-scale biomass production. Furthermore, there is competition with food production thus leading to higher prices for food commodities.

There are significant differences between the impacts of different types of biofuels and even between individual pathways – some score quite well while others are worse than the fossil fuels they replace.

It proves to be difficult and expensive to effectively prevent these undesired effects with EU and national policies. Direct environmental effects are insufficiently covered in the RED sustainability criteria for biofuels, while indirect impacts and socio-economical effects are not included at all. At the time of writing this report, the decision process on how to include GHG emissions due to ILUC in the EU policies has been going on for some time now, but has not yet resulted in a concrete proposal by the Commission. Global policies that may effectively prevent these impacts are not yet in place nor expected in a foreseeable future.

The on-going research and debate on the actual life cycle impacts of the various biofuels (i.e. including indirect effects) provides reason to be careful not to overestimate the potential future volume of sustainable biofuels for the European transport sector. In a world with global population increase, economic growth and an increasing need to prevent carbon emissions and biodiversity loss, the availability of sustainable biomass may be much more limited than originally expected. Furthermore, road transport will have to share this with other sectors such as shipping, aviation, the chemical industry, heat and electricity production. All these sectors will also be looking for low-carbon and sustainable alternatives to their current fossil feedstock, in response to policies such as the overall renewable energy target defined in the RED, national policies and consumer demand.

Hence, it is becoming increasingly clear that:

a There is a real risk that only a relatively modest volume of truly sustainable biofuels can be produced globally. And

b Current policies do not guarantee that the biofuels that are being used are really sustainable.

The current focus on land-based biofuels for GHG emission reduction in the road transport sector has thus proven to be largely ineffective, decarbonisation of the road transport sector clearly requires refocusing on other options. Other, safer and more sustainable GHG mitigation options should be implemented instead, to speed up the process of and thus meet the longer-term goal of achieving 60% GHG reduction in transport sector by 2050 set in the White Paper on Transport (EC, 2011b) and the Energy Roadmap 2050 (EC, 2011a).

The key questions addressed in this study are therefore:

– What alternative means are there that could be sustainably deployed instead of the land-based biofuels?
– Is it possible to reach the 10% renewables target under the RED and the 6% fuel quality target under the FQD in a sustainable way? With focus on solutions that after 2020 can also be scaled up to deliver the savings needed by 2050? What actions should be taken to steer the developments in the right direction?

1.5 This project: aim and scope

The main aim of this project is to develop a number of scenarios which investigate if and how EU Member States can meet the 10% renewable energy target (RE) and at the same time contribute to the 6% GHG decarbonisation target in the Fuel Quality Directive in a sustainable way, within the ecological limits of the planet.

The term sustainability is defined in a broad sense of the word and implies that a variety of goals are aimed for, including

– minimising GHG emissions (taking a life cycle perspective);
– reducing energy use and improving energy efficiency;
– preventing or minimising negative impacts on biodiversity and other environmental issues;
– preventing or minimising negative socio-economic effects, including negative impacts on food prices and supply;
– development of long-term solutions that can significantly contribute to decarbonisation of transport.

In the context of this study, it was decided to explore the feasibility of greening the EU road transport system without expanding further the use of biofuels grown on land. It is assumed that increasing the use of land-based biofuels by 2020 will inevitably breach some of the above-listed sustainability criteria because of the impact of most existing agricultural systems on the environment (emissions, biodiversity, water, agrochemicals) and because of the difficulties and cost to design and implement effective policies to distinguish between those that meet the criteria and those that do not. It was thus decided to take a precautionary approach and not accept any additional land-based biofuels in the sustainable scenarios for green road transport. It is also assumed that land-based biofuels under the cap gradually improve their environmental performance with the introduction of ILUC factors and stricter sustainability criteria.

The scenarios in this report will thus focus on the following alternatives to the land-based biofuels:
– reducing overall energy use in road transport, by improving fuel efficiency of vehicles and/or reducing transport demand;
– increasing the use of renewable electricity in road and non-road transport;
– increasing the use of biofuels from waste and residues that do not cause additional land use change.

Furthermore, the study will also look at the pros and cons of adjusting the RED and FQD methodology for counting the contribution of various options towards the target.

1.6 This report

The report is structured as follows:
– Chapter 2 describes the overall context of the study, in particular the long-term climate goals, the relevant EU policies and the opportunities for and barriers to change in the sector.
– Chapter 3 provides an overview of the sustainable alternatives to land-based biofuels. Estimates are derived for the potential contribution of the various options in 2020.
– Chapter 4 then explores the extremes of the playing field and assesses how the various options may contribute to the RED and FQD targets and overall CO_2 emissions.
– In Chapter 5, a number of realistic and sustainable scenarios are developed in which the sustainable alternatives are combined to meet the RED and FQD targets in 2020.
– Chapter 6 then assesses which policy strategies and measures would be required to achieve these scenarios.
– Chapter 7 explores what these policy strategies could mean on a Member State level, with five country case studies.
– The conclusions and recommendations that follow from this study can then be found in Chapter 8.

2 Moving towards sustainable transport: sustainability issues and the political context

2.1 Introduction

Moving the transport sector towards sustainability is a very tough challenge. It is feasible but requires very effective and focussed actions in the coming years and decades. In the past, the sector has been characterised by significant growth of both passenger and goods transport, in all modes. When comparing past trends towards future decarbonisation goals, it becomes clear that the transport sector needs significant structural change, ranging from a drastic change of its energy supply to a strong increase of transport efficiency and probably even in the way that economical growth seems to be strongly linked to growth of transport demand.

Starting point of this analysis is the long-term goal of at least **60% GHG emission reduction of the transport sector in 2050**, compared to 1990. This goal is set by the EU in the 2011 White Paper for Transport, and represents the lower range of what can be considered necessary to meet the overall 80-95% emission goal of the EU by 2050, as agreed by European Heads of State and governments. This goal is set in order to limit average global temperature increase to no more than 2° Celsius.

The White Paper also sets an interim target of -20% below 2008 levels for 2030. This represents an 8% increase above 1990 levels and is thus only a relatively modest step towards the 60% reduction target of 2050. Even so, it clearly indicates that past trends of GHG emission growth can not be maintained, and urgent action is required to move the sector into a much more sustainable future. 2030 and 2050 may still seem far away, but it will undoubtedly take several decades to develop the right technologies, replace vehicles with much more energy-efficient ones and drastically modify the energy infrastructure in the sector. Clearly, by 2020 the shift toward a transport system using much less energy, a significant part of which comes from renewable sources, should have been initiated.

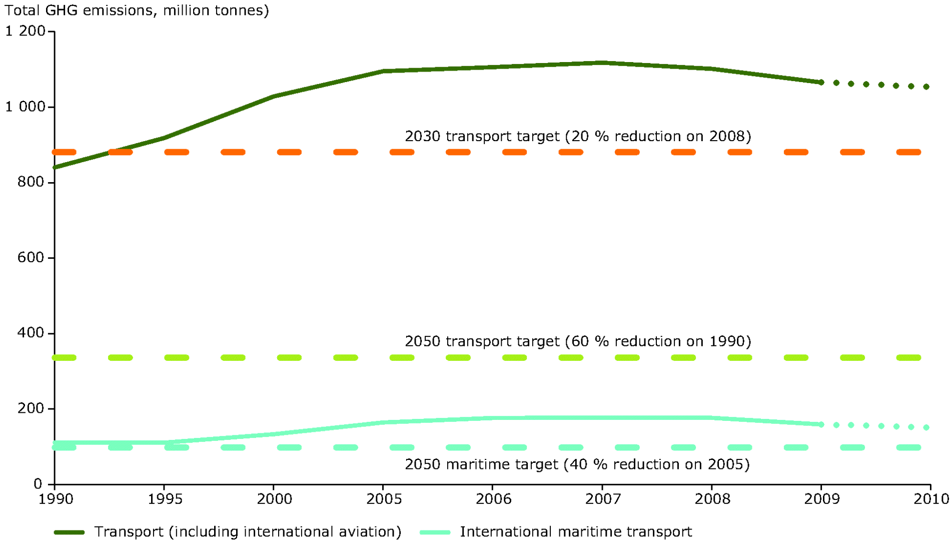
2.2 Transport emissions: trends and forecasts under current policies

In Figure 3, the GHG transport emission trends over the past 20 years are shown, compared to the targets mentioned above (domestic tank-to-wheel emissions, including international aviation)[5]. After many decades of GHG emission increase, they seem to have stabilised in 2005 and even decrease from 2007 onwards. The EEA concludes that the decline in GHG emissions from road transport over the past two years can be mainly explained by a decline in freight transport demand related to the economic recession and to higher fuel prices. This implies that under current policies, emission growth will continue once the economic growth picks up again or fuel prices reduce. Despite the

[5] Source: EEA (2011), data for the EU-27.

emission reduction in recent years, transport GHG emissions were 27% above 1990 levels in 2009.

Figure 3 **Transport GHG emission developments in the EU versus the targets of the EU White Paper for Transport**

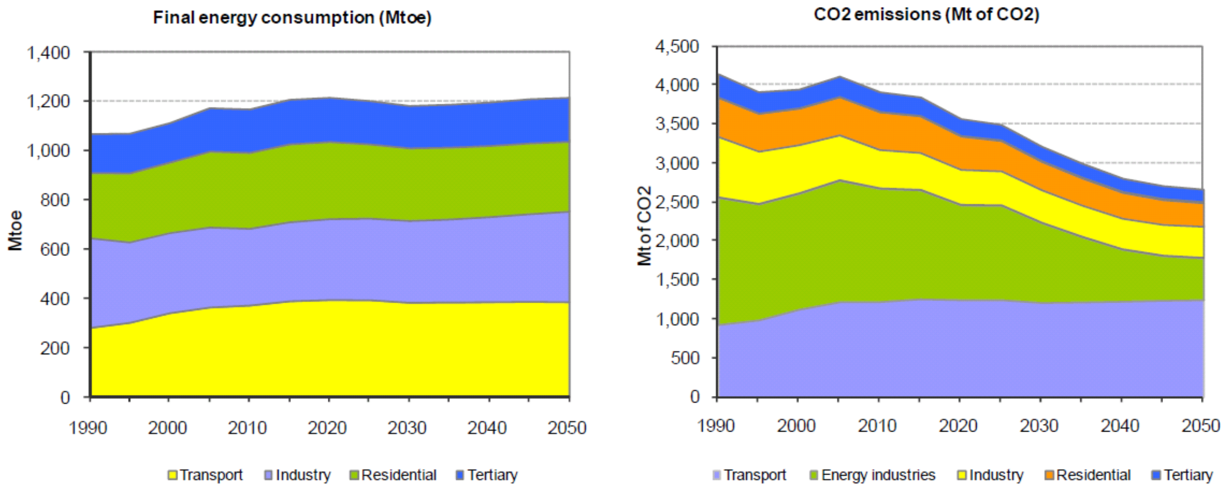


Source: EEA, 2011.

Future transport emissions will strongly depend on government policies, economic growth both within and outside of the EU, oil price, etc. Recent European Commission (EC) forecasts for both energy consumption and CO_2 emissions in the EU as a whole and in the transport sector are shown in Figure 4. These forecasts include the effects of policies currently implemented. The share of GHG emissions of the transport sector is expected to increase over the years as especially the GHG emissions of the energy sector will reduce, whereas transport emissions continue to grow. Transport demand is expected to continue to grow, in line with economic activity: passenger transport activity by 51% between 2005 and 2050, freight activity by 82%. Mainly because of fuel efficiency regulations for passenger cars, transport energy demand increases at a lesser rate, by 5% by 2030 and an additional 1% by 2050 (EC Impact Assessment, 2011). CO_2 emissions of the transport sector would remain at more or less current levels.

This means that despite the Renewable Energy Directive, Fuel Quality Directive, CO_2 regulation of cars and vans, etc., GHG emissions of the sector are, in the absence of further measures, expected to be about 30% higher in 2030 when compared to the 1990 level, increasing to 35% in 2050. Actual reductions compared to 2010 levels (let alone 1990 levels) require much more stringent policies and effective actions.

Figure 4 Evolution of total final energy consumption and CO_2 emissions between 1990 and 2050 in the EU Reference scenario



Source: EC White Paper Impact Assessment, 2011. Transport emissions include international maritime and aviation but exclude combustion emissions from pipeline transportation, ground activities in airports and harbours, and off-road activities.

2.3 The need for change

Taking the EU goals as a starting point, another 12% reduction in transport GHG emissions needs to be achieved in 2030 - on top of on-going policies - and the expected 35% emission increase in 2050 needs to be turned around to a 60% reduction. This is a challenge that requires a drastic change of current practises in the sector, affecting transport cost and demand, energy efficiency in the sector, the modal split, the energy used for the various modes, etc.

Quite a number of technical and policy options exist to reduce GHG emissions of the transport sector. An extensive overview of mitigation measures can be found, for example, in AEA (2010) and the individual reports that were written in the context of that study on the project ‘EU Transport GHG: Routes to 2050’[6].

The technical GHG reduction options can be roughly divided into three different categories:

1. **Reduce transport demand**, i.e. the number of passenger or ton kilometres driven.
   - This can be achieved for example with pricing policies (e.g. increasing taxes or road charging, ETS), spatial planning, modal shift from road transport to rail, shift from passenger car transport to bicycles, etc.
2. **Improve fuel efficiency** of transport, i.e. reduce the energy consumption per kilometre (which can be a passenger kilometre or a ton kilometre).
   - This can typically be achieved with improving the fuel efficiency of vehicles, or by shifting transport towards modes that emit less GHG per kilometre.

6 See www.eutransportghg2050.eu.

3. **Reduce GHG intensity of fuels** and energy carriers.
   – This can be done by shifting towards renewable fuels with low GHG intensity such as renewable electricity, sustainable biofuels, etc., or by reducing GHG emissions of existing fuels (e.g. by reducing flaring and venting during oil production, reducing GHG emissions of refining, etc.).

Decarbonisation scenarios such as those developed in the project on 2050 GHG reduction mentioned above typically conclude that all available technological mitigation options are required to meet future GHG emission targets. In addition, they lead to the conclusion that it will be very difficult (if not impossible) to reduce GHG emissions from transport by 50% or more through the uptake of technical options alone (AEA, 2010). Non-technical options such as speed and transport demand reduction also need to be deployed.

In the follow-up project on the 2050 GHG reduction study, a more detailed assessment of risks and uncertainties stressed even more the need to also develop GHG mitigation options other than technical options (AEA, 2012). Especially the risks and uncertainties of the future GHG reduction contribution of biofuels and electricity call for an approach that does not overly rely on these options. The analysis shows that under pessimistic biofuel savings assumptions – taking into account risks and uncertainties related to issues such as actual versus calculated GHG savings of biofuels, future availability of sustainable biofuels, etc. - there is a very substantial gap opened compared to the White Paper Target. When biofuels savings turn out to rather follow a pessimistic scenario than the more optimistic baseline scenario, GHG emissions could be 43% higher. This could further increase to 54% (~300 MtCO_2e per year) if the contribution of electric vehicles to GHG savings are also low, for example if the share of electric vehicles is lower than estimated. The only way to close these gaps would mean that all three identified mitigation options are implemented to their maximum levels. This requires very significant increases in technical efficiency, operational efficiency and the application of measures to further shift and ultimately reduce net transport activity (AEA, 2012).

Fuel efficiency, GHG intensity and transport demand: three communicating vessels

Given a certain GHG reduction target, these three options can be envisaged as communicating vessels: if one delivers less GHG reduction than expected, the others will have to achieve more.

The following (simplified) examples can illustrate this. In both cases, a GHG emission reduction of 60% is assumed in 2050, compared to 1990 levels.
– if in 2050 the average GHG intensity of transport fuels is reduced to 20% of that of transport fuels in 1990;
– and fuel efficiency of transport is 50% of that of 1990;
– transport volume in 2050 can be about 6 times as much as in 1990.

This example would probably mean that most road and rail transport will have to be powered by renewable and carbon-free electricity, and aviation and shipping will use low-carbon biofuels or hydrogen and perhaps some fossil fuels. Fuel efficiency will be key in all modes.

However, if
– the GHG intensity is reduced to 50% on average;
– and fuel efficiency is 60% of that of 1990;
– transport volume in 2050 can be about two times as much as in 1990.

Compared to the previous example, in this case the transport sector would either still use a relatively large share of fossil fuels, probably in aviation and shipping and heavy duty trucks. This could happen, for example, if the volume of biofuels with low GHG intensity is relatively limited, and renewable electricity and hydrogen only have a relatively limited (though still significant) share in the sector. Fuel efficiency will still be key in all modes, as a 40% efficiency improvement is still an ambitious goal (on average, i.e. also taking trucks, planes and ships into account).

Note that In these examples, it is likely that passenger cars have achieved much more reduction than the average, but heavy duty trucks, shipping and aviation have probably reduced less as there is less technical potential in these modes.

The main starting point of this study is the question if and how the Renewable Energy Directive transport target can be met in a sustainable way and at the same time contribute to the 6% GHG decarbonisation target in the Fuel Quality Directive in a sustainable way, within the ecological limits of the planet.
As described in the next paragraph, both the RED and FQD focus on the GHG mitigation category 'reduce GHG intensity of fuels', but transport demand reduction and transport and fuel efficiency improvements can also contribute to meeting the targets.

- As the RED sets a relative target (10% of total energy use in the sector should be renewable), reducing the energy consumption will lower the renewable energy required to fulfil the target.
- The FQD target, however, is strictly about the GHG intensity of fuels, and transport demand reduction and fuel efficiency improvements will not help to achieve the target. On the other hand, options within the fossil fuel chain are available here.

2.4 Relevant EU policies

A number of EU policies are relevant to this study, and it is important to understand the basics of these policies when assessing alternatives to land-based biofuels. The following provides an overview of the relevant key characteristics, goals and definitions of the EU regulatory policies that play a role in this study. Note that this overview is limited to the items relevant to the transport sector and this study. In most cases, the regulations are much broader than described here.

Renewable Energy Directive (RED)

The RED (EC, 2009a) covers all types of energy in the EU, as it sets an overall target of renewable energy use for the EU (20% in 2020) and individual targets for the various Member States. It also regulates quite a number of issues concerning renewable energy in electricity and heat production. Articles 3(4) and 17–21 are relevant for the transport sector.

The key issues relevant for transport are the following[7]:

- Each Member State shall ensure that the share of energy from renewable sources in all forms of transport in 2020 is at least 10% of the final consumption of energy in transport in that Member State.
- For the calculation of the denominator, i.e. the amount of fuel of which 10% should be renewable in 2020, the total amount of petrol, diesel, biofuels and electricity consumed in road and rail transport shall be taken into account.
- For the calculation of the numerator, i.e. the amount of renewable energy in transport, all types of energy from renewable sources consumed in all forms of transport shall be taken into account.

7 For details, please refer to the Directive itself.

– For the calculation of the contribution from electricity produced from renewable sources and consumed in all types of electric vehicles, Member States may choose to use either the average share of electricity from renewable energy sources in the Community or the share of electricity from renewable energy sources in their own country as measured two years before the year in question. The Commission is asked to present, by December 31st, 2011, if appropriate, a proposal permitting, subject to certain conditions, the whole amount of the electricity originating from renewable sources used to power all types of electric vehicles to be considered. In September 2012, however, the Commission decided not to publish a proposal at this time, and keep the current methodology in the RED[8].
– Furthermore, for the calculation of the electricity from renewable energy sources consumed by electric road vehicles, that consumption shall be considered to be 2.5 times the energy content of the input of electricity from renewable energy sources.
– The contribution made by biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels.
– Although its focus is mainly on reducing CO_2 intensity of transport fuels the RED also recognises the need to improve fuel efficiency[9].

The RED furthermore defines a number of sustainability criteria for biofuels that need to be met if the biofuel is counted towards the 10% target, in Articles 17-19. These define the methodology to determine the GHG emissions of biofuels and set minimum GHG reduction levels, exclude biofuels from biomass that is cultivated in areas with high biodiversity or high carbon content of the soil, etc. However, as discussed in Section 1.2, this report applies more stringent sustainability criteria.

In October 2012, the Commission published a proposal to modify the RED directive, as a result of a debate on how to include ILUC emissions in this directive. These modifications were not taken into account in this report as it was written prior to this proposal.

Fuel Quality Directive (FQD)

The FQD (EC, 2009b) is concerned with technical standards for transport fuels, but also requires fuels suppliers to gradually reduce the average life cycle GHG emissions of the transport fuels that they sell in the EU. The targets were set in the Directive, but the methodology to calculate the contribution of various fuels and GHG mitigation measures towards the target has only been partly defined so far.

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8 See: Communication to the Commission on communicating outcome of the Impact Assessmnet related to requirements of Article 3(4) of Directive 2009/28/EC', European Commission, C(2012) 6287 final.

9 See: RED, Preamble (5): In order to reduce greenhouse gas emissions within the Community and reduce its dependence on energy imports, the development of energy from renewable sources should be closely linked to increased energy efficiency. Preamble (17): The improvement of energy efficiency is a key objective of the Community, and the aim is to achieve a 20 % improvement in energy efficiency by 2020….Preamble (28): The Community and the Member States should strive to reduce total consumption of energy in transport and increase energy efficiency in transport. The principal means of reducing consumption of energy in transport include transport planning, support for public transport, increasing the share of electric cars in production and producing cars which are more energy efficient and smaller both in size and in engine capacity.

And also RED, Annex V, C2+3: Greenhouse gas emissions from fuels, E, shall be expressed in terms of grams of CO_2 equivalent per MJ of fuel, g CO_2eq./MJ. By derogation from point 2, for transport fuels, values calculated in terms of g CO_2eq./MJ may be adjusted to take into account differences between fuels in useful work done, expressed in terms of km/MJ.

The most relevant parts of this Directive are the following[10]:

– From January 1st, 2011 onwards, suppliers shall report annually on the greenhouse gas intensity of fuel and energy supplied within each Member State by providing, as a minimum, the following information:
  a The total volume of each type of fuel or energy supplied, indicating where purchased and its origin. And
  b Life cycle greenhouse gas emissions per unit of energy.
– Member States shall require suppliers to reduce life cycle greenhouse gas emissions per unit of energy from fuel and energy supplied by up to 10% by December 31st, 2020, compared with the fuel baseline.
  - 6% of this reduction is mandatory;
  - the remaining 4% can be met by, for example, the use of carbon capture and storage and credits purchased through the Clean Development Mechanism of the Kyoto Protocol, for reductions in the fuel supply sector.
– 'Suppliers' are, in general, the entities responsible for passing fuel or energy through an excise duty point.
– The scope of the Directive are the fuels used by road vehicles, non-road mobile machinery (including inland waterway vessels when not at sea), agricultural and forestry tractors, and recreational craft when not at sea.
– The calculation methodology to determine the life cycle GHG emissions of biofuels is the same as the one used in the RED (and thus does not yet include ILUC emissions).

The FQD can only function when all relevant fossil and renewable transport fuels are differentiated according to their well-to-wheel GHG emissions. However, the FQD did not define a baseline for the GHG emissions, nor a calculation methodology to determine the GHG intensity of various fossil fuels and other energy carriers such as electricity. It also did not define which non-biofuel GHG mitigation options (e.g. reducing flaring and venting, reducing GHG emission of refineries, etc.) can be used to meet the FQD target sustainably. In October 2011, the Commission published a draft proposal to fill these gaps, but that has not been agreed on yet[11].

Some of the main points of this proposal were:

– Different default GHG intensity values apply to different types of fossil fuels, depending on the origin of the oil (e.g. conventional, tar sands, CTL, etc.) and the type of fuel (petrol, diesel, LPG, CNG).
– Each Member State can use its own national average GHG intensity factor for electricity production – depending on the electricity generation mix of the Member State, these values can be much lower than the GHG intensity of conventional fuels.
– The contribution of electricity towards the overall GHG intensity of fuels is multiplied by 0.4, to compensate for the higher energy efficiency of electric power trains[12].

10 For details, please refer to the Directive itself.

11 End of April 2011, it was decided that the Commission would first carry out an Impact Assessment before submitting a new proposal; http://www.upi.com/Business_News/Energy-Resources/2012/04/23/EU-pushes-back-oil-sands-decision/UPI-81101335107688/.

12 Note that the actual energy use of electric vehicles is already about 40% of the energy use of conventional cars (in MJ). This is also taken into account in the calculation methodology as actual energy use data are multiplied with the GHG intensity of the energy type to calculate the total emissions. The additional multiplication factor of 0.4 thus increases the incentive to use electricity, but will lead to an underestimate of the actual GHG intensity – this effect will be small, though, as long as the share of EV is small.

– Greenhouse gas emission reductions at oil production and extraction sites can also be counted towards the target, if they comply with certain conditions and standards.

CO_2 regulation for cars and vans

The fuel efficiency of cars and vans is regulated in separate EU regulations. Both provide mandatory targets to car manufacturers, ensuring a gradual decrease of the CO_2 emissions per kilometre of newly sold cars and vans in the EU. The CO_2 emissions of cars and vans are measured during type approval, using a strictly defined measuring protocol. Emissions in real life are typically significantly higher for a number of reasons, and this difference has increased quite strongly in recent years, from 8% in 2001 until 21% today (ICCT, 2012).

The CO_2 regulation is currently based on vehicle tailpipe emissions only. Electric vehicles (and hydrogen vehicles) are thus counted as zero emission cars.

EU Emission Trading System (ETS)

The EU ETS sets a cap on the GHG emissions of a number of sectors within the EU, including electricity production, industry and, since beginning of 2012, aviation. Without going into detail, the ETS works as follows: parties in the ETS need to submit emission allowances (EUAs) for their emissions, which are partly supplied free of charge and partly auctioned. These EUAs may be traded between parties, or banked for future use. Over time, the number of available EUAs are reduced, ensuring that the overall emissions of the parties involved are gradually reduced.

As CO_2 emissions from European electricity generation are included in the EU ETS, emissions from power production for electric railway transport and electric road vehicles are automatically part of the EU ETS, and under the cap.

Other policies

Apart from these key regulatory policies, there are quite a number of other relevant EU programmes, publications and Directives. For example, the recently published Roadmap 2050 and White Paper for Transport (EC, 2011a and b) set long-term goals and describe a way forward, the Clean Vehicles Directive regulates that energy and environmental impacts are taken into account in all purchases of road transport vehicles through public procurement[13]. Effort sharing and the Taxation Directive also have an impact on the use of biofuels.

Options to meet the RED target sustainably

Looking at the RED, a number of options can be identified with which the transport target can be met. In this report, the following options are considered to be sustainable:

– **Increasing energy and transport efficiency, reducing energy consumption in the sector**[14]. With a certain volume of renewable energy, this will increase the share of renewable energy in transport consumption.
– **A fuel shift from conventional fuels towards electricity,** where the share of RE rises over time, or **a shift toward additional electricity from renewable sources.**

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13 See http://ec.europa.eu/transport/urban/vehicles/directive/directive_en.htm.

14 To be precise: reduce petrol, diesel and biofuel consumption in road and rail transport.

- **A shift from conventional fuels towards liquid or gaseous fuels produced from biomass, which meet the strict sustainability criteria as defined in Section 1.2**. Note that these are much stricter than the criteria currently implemented in the RED.
- **A shift from conventional fuels towards hydrogen from renewable energy sources** – a methodology how to calculate the contribution of hydrogen towards the RED target is not yet given in the 2009 regulation, but is expected to be published by the EC in the coming months.

Options to meet the FQD target sustainably

As explained above, it is not yet clear yet which GHG mitigation options can be used to meet the FQD target sustainably, since a significant part of the calculation methodology has not yet been defined. It was therefore decided to use the draft proposal of the Commission of October 2011 as a starting point for this study, and assume that the mitigation options included in that proposal will count towards the FQD target in 2020.

The shift to renewable energy sources that is promoted by the RED will also contribute to the FQD target, albeit to a different extent as the calculation methodologies differ. Transport demand reduction or efficiency improvements do not contribute to the FQD. In addition, the following measures can also be implemented to meet the FQD target in a sustainable way:
- reducing GHG emissions of flaring and venting;
- shift from petrol and diesel to fossil fuels with lower GHG intensities, for example CNG or LNG;
- not using high-carbon fossil fuels (like from tar sands and coal to liquid), which may offset any savings that would be achieved by other measures.

Only correct carbon accounting for both fossil fuels and biofuels will ensure that the GHG intensity reductions are really achieved. It is important to note that contrary to the RED, the FQD approach rewards additional GHG savings for biofuels that go above the minimum threshold.

2.5 Opportunities and barriers for change

Any change of plans and strategy can be expected to be faced with barriers, for example in the form of existing policies that are geared towards the existing strategy, or by resistance from industry that is negatively affected by these changes or fears that the new situation could harm their interests. Consumers are used to the current vehicles and energy carriers, and may be hesitant to switch to alternatives, because of cost or a (perceived) lack of fuelling infrastructure, or because they do not yet know or trust the new technology.

At the same time, the changes that are discussed in this report will create opportunities for innovative businesses to develop and market new products and thus gain market share. They also provide much broader benefits to society, ranging from reduced climate change to improved air quality and less noise, with associated heath and wellbeing benefits.

When assessing any changes to the current policies, it is thus important to also take into account the wider impact on the various stakeholders, and the possibilities and potential difficulties of modifying existing policies. In the following, the most relevant opportunities and barriers for the changes addressed in this study are identified.

Policy related opportunities and barriers

On EU level, the RED and FQD that determine the key policies in this field until 2020 are in place, and Member States have made significant progress in implementing them in national policies. These Directives are not easy to modify, but they do provide room for changes in the coming years, either because of scheduled reviews or because of obligations for the Commission that are included in the Directives. A number of opportunities exist that can be used to implement the changes towards sustainability that are discussed in this report.

- **ILUC implementation**: The Commission was obliged to submit a report by December 31st, 2011 with a review of the impact of ILUC on GHG emissions, and addressing ways to minimise that impact. The report shall, if appropriate, be accompanied by a proposal containing a concrete methodology for emissions from carbon stock changes caused by ILUC (EC, 2009a, Art. 19.6).
- **Other sustainability issues:** By December 31st, 2012, the Commission shall report on the effectiveness of the system in place for the provision of information on sustainability criteria and on whether it is feasible and appropriate to introduce mandatory requirements in relation to air, soil or water protection. If appropriate, the Commission shall propose corrective action (EC, 2009a, Art. 18.9).
- **Impacts on food prices and other socio-economical issues:** The Commission shall, every two years, report on the impact on social sustainability in the Community and in third countries of increased demand for biofuels, on the impact on availability of foodstuffs at affordable prices, land-use rights and a range of other socio-economical issues. The first report is due in 2012. If appropriate, the Commission shall propose corrective action, in particular if biofuel production is found to have a significant impact on food prices (EC, 2009a, Art. 17.7).

Implementing effective ILUC policies can be a powerful incentive to further develop and produce biofuels that do not use land, and provide a clear signal to everyone involved that efforts need to be redirected towards other, more effective and sustainable GHG mitigation options. The other two potential revisions can further strengthen this development.

Financial interests of industry

Especially the biofuel-producing industry has significant financial interests in the current situation and in the current demand for biofuels. In recent years, they have based many of their investment decisions on government policies, and it will take time to recover the cost and achieve a positive return on these investments.

Large-scale biofuels policy started in the EU in 2003, with the Biofuels Directive (2003/30/EC) of the European Commission. This Directive set an indicative target for Member States of 5.75% biofuels, for 2010, and was an incentive for many EU countries to implement biofuels tax reductions, subsidies or obligations. The RED was published at the end of 2009, together with the FQD, providing a clear signal to both Member States and industry to continue these developments and increase production of renewable fuels, albeit with (incomplete) boundary conditions regarding their sustainability. The NREAPs that were published in the context of the RED then led to expectations regarding biodiesel and bioethanol growth in the coming years, on which industry based their developments and investment decisions.
A recent study by Ecofys (2012) estimates the average pay back time for an installation to be 5 to 10 years. About 95% of the existing biofuels installations will therefore have had positive returns on investments by 2017.

A second sector that has financial interest in land-based biofuels production is agriculture. Part of this sector has benefitted from the increasing demand for vegetable oils and sugar crops, and increased the production of biofuels feedstock as demand increased. However, the sector can respond to changes in demand and price quite rapidly by switching crops, and it will benefit from the continuously increasing food demand due to an increasing global population. It can also benefit financially from an increasing demand for organic waste and residues, useful feedstock for the production of much more sustainable biofuel or biogas, or for electricity/heating production. This can turn currently unsellable waste streams into a valuable product.

A third sector that could be affected by a reduction of the support to land-based biofuels under the 10% target are the fuel suppliers that have to meet the FQD target. If the alternative options to meet the RED target do not contribute towards the FQD target as the current biofuels, they will have to invest in other options to meet the FQD target. We will discuss the potential of reducing flaring and venting emissions in the upstream part of the oil production chain in more detail in the next chapter.

Changes of policy strategy will also create interesting business opportunities for stakeholders that are at the forefront of new and sustainable developments. New markets for new products will develop, with positive economical impacts in those markets. Looking at the options discussed in the next chapter, quite a number of businesses are likely to grow and benefit, for example those that develop technology for 2nd generation biofuel production, biomethane producers, electric vehicle and battery developers and producers, car manufacturers that offer fuel-efficient vehicles, etc.

The role of consumers

Until now, the role of consumers in the uptake of renewable transport energy or increasing fuel efficiency of vehicles was quite limited. EU and national policies were mainly aimed at fuel and car suppliers, and only a limited number of interested consumers have been aware of the changes that have taken place. Fiscal policies are probably the most well known measures to consumers. In the coming decades, however, consumers are likely to become more important stakeholders in the decarbonisation process. Their support will thus become much more important than we have seen in the past.

Biofuels when used in low percentage can directly be used in the existing car fleet, at least up to a certain blend percentage: 7vol% in case of conventional biodiesel, FAME, and 5 or 10vol% in case of ethanol. All diesel vehicles can drive on the 7% FAME (often depicted as B7), all petrol vehicles can drive on a 5% ethanol (E5), and most modern cars can use a 10% ethanol blend (E10). B7 is already in use in a number of EU Member States, E10 has been put on the market in three EU countries so far. As not all cars can use E10, filling stations have to also offer E5, at least until 2013 (according to the EU FQD, but this period is likely to be extended in most if not all Member States).

The increasing use of biofuels increased fuel costs, however, as biofuels cost are higher than that of their fossil counterparts. This cost increase has not been perceived by consumers, though, as blend percentages are still low and consumers are used to fuel prices changes because of oil price volatility. Also, a number of Member States provide fuel tax reductions for biofuels that defer the extra cost of using biofuels to the taxpaying public.

Some of the alternatives to land-based biofuels would not impact consumers either. Liquid biofuels from waste and residues are comparable to the land-based biofuels. Since biofuels from non-food biomass count double in the RED, their share need not be increased as much to comply with the Directive, which reduces the need for high blend biofuels and modifying existing vehicles to adapt to these higher blends, at least in the coming years. In the longer term, if biofuels shares increase further, consumers will have to be actively convinced to buy cars that can run on higher blends, and buy these high blend fuels rather than the standard low blends.

Other options, mainly electric vehicles (EVs) and gas-powered (biomethane) vehicles, require involvement of consumers right from the start. A transition to electric vehicles requires that consumers buy, rent or share an EV, in a situation where EVs are typically (much) more expensive than conventional cars and have a shorter driving range. In addition, a charging network has not yet been developed. Reduced energy cost will partly compensate the higher purchase price, but in the current situation, this compensation is not yet sufficient in most cases. This may change, of course, when cost of EVs reduce over time, and government policies may also help make EVs more attractive. Increasing biomethane use is faced with similar barriers: consumers need to buy vehicles that can run on this fuel and a fuel distribution network has to be developed.

Options to reduce energy use in transport might require policies that increase the cost of car use, for example if it is achieved through road pricing, increasing fuel taxes, reducing tax benefits for company cars, etc. This will affect consumer choices and cost, and may thus lead to public resistance – depending on the way these polices are designed and implemented: public resistance may be overcome by, for example, differentiating fuel taxes to CO_2 emissions rather than simply increasing all taxes, or by implementing attractive alternative measures such as improved public transport.

National legislation and taxation

National policies may be very effective in supporting the transition to the sustainable alternatives to land-based biofuels that are discussed in this report. For example, differentiation of energy and vehicle taxes can play a strong role in increasing the sales of biomethane or electric vehicles. Fuel taxes, road charging and spatial planning policies can reduce transport and energy demand. Differentiated vehicle registration and circulation taxes can discourage the sales of cars with high CO_2 emissions, and promote the sales of fuel-efficient cars.

On the other hand, national exemptions from fuel or excise taxes given to land-based biofuels can reduce or nullify the development of more sustainable types of waste-based biofuels. Tax reductions for company cars or commuting by car are an incentive for more car transport rather than less.

3 An overview of sustainable alternatives to land-based biofuels

3.1 Introduction

As explained in the previous chapter, this study focusses on the following options to meet the RED target sustainably:
- increasing energy and transport efficiency, reducing energy consumption in the sector;
- a fuel shift from conventional fuels towards electricity with increasing share of renewable energy, or a shift towards additional electricity from renewable sources;
- a shift from conventional fuels towards liquid or gaseous fuels produced from biomass, which meet the strict sustainability criteria as defined in Section 1.2;
- a shift from conventional fuels towards hydrogen from renewable energy sources.

Most of these measures also contribute to the FQD target, but in addition, the FQD target can be met by:
- reducing GHG emissions of flaring and venting;
- shift to fossil fuels with GHG intensities lower than that of diesel or petrol.

In the following, these different types of measures will be explored further. Only the last option, the shift to low-carbon fossil fuels is not considered here, its potential is probably quite limited compared to the other options[15].

Where possible, estimates are derived of the potential contribution of these options towards the RED and FQD targets in 2020. These estimates are then used in the following chapters, as input for scenario calculations.

3.2 Reducing energy use

Reducing energy use in the transport sector has a number of positive effects related to the RED, even though it does not directly add any renewable energy. First of all, less renewable energy is required to meet the RED target – a 10% reduction of transport energy use means that 10% less RE has to be deployed. This reduces cost and risk of indirect effects. Secondly, the reduced energy use directly reduces CO_2 emissions of the sector, one of the key aims of the RED policy.

It can be achieved in various ways:
1. Improving fuel efficiency of vehicles (cars, vans and trucks).
2. Improving transport efficiency (including modal shift and optimisation of vehicle use).
3. Reducing the kilometres driven, i.e. reducing transport volume.

15 For example, 6% of diesel used in road transport would have to be replaced by CNG or LNG to reduce the average GHG intensity of transport fuels by 1%.

4. Shift to a more energy-efficient mode, for example from car to train or bike, from truck to ship and from plane to train.
5. Reducing speed limits, shift to a more fuel-efficient driving style, etc.

3.2.1 Improving fuel efficiency of vehicles

The CO_2 and cars regulation is in place, and sets a target of 95 g CO_2/km for new passenger cars, for 2020. A similar regulation is in place for light commercial vehicles, with a target of 147 g CO_2/km in 2020. Further improving fuel efficiency between now and 2020 could be achieved through the following options:

- Reducing the targets for cars and vans, at times of interim reviews of the polices. NGOs advocate a target of 80 g CO_2/km for cars and no more than 110 g CO_2/km for vans.
- Setting fuel efficiency targets for heavy duty trucks. As AEA (2012) concludes, various GHG measures in this vehicle segment have higher savings than cost (from a societal point of view).[16]

CO_2 regulation is not the only means to improve fuel efficiency of vehicles. Other options are, for example, CO_2 differentiation of vehicle taxation and CO_2 labelling, as well as – indirectly - increasing fuel excise duties. These are important supporting policies to the CO_2 regulation, and may even encourage a shift to fuel-efficient cars that goes beyond what is asked of the car manufacturers.

Note that increasing fuel efficiency creates a risk of a rebound effect: if fuel efficiency improves, the cost per kilometre reduces as well. This can lead to an increase of the kilometres driven. These effects can be mitigated if they are combined with increased fuel taxes or road charging.

For our scenario calculations of the next chapter, we need to derive a realistic estimate of the extent in which these policy options might reduce overall energy use and CO_2 emissions of the transport sector. The potential impact of the policy measures listed above is relatively high, but depends on the extent and effectiveness of the policy measures that are implemented.

A simple calculation can illustrate the impact of reducing fuel efficiency of vehicles by another 5% yearly from 2013 onwards, through tightened target or other measures affecting the market:

Between 2013 and 2020, more than half of the EU passenger car, van and heavy duty fleet will be replaced. New vehicles have, on average, much higher annual mileage than older vehicles, so these vehicles will use about 70% of the road transport fuels in 2020. Therefore, if the measures listed in this section would lead to a 5% improvement of real life fuel efficiency of the road vehicle fleet from 2013 onwards, and no rebound effect would occur, this would reduce total road energy use and CO_2 emissions by about 3.5% in 2020, compared to business as usual. These benefits will increase further after 2020, as the current vehicle fleet is gradually being replaced by more fuel-efficient alternatives.

[16] A package of cost-effective reduction measures was identified for medium heavy goods vehicles (~12 tonne) that can result in about 16% lower CO_2 emissions. For heavy duty vehicles, (~40 tonne) even a larger CO_2 reduction could be realised at negative abatement costs. Note that cost and cost effectiveness are defined here from a societal cost point of view.

3.2.2 Improving transport efficiency, reducing transport volume and energy use

This can typically be achieved with pricing policies such as road pricing, fuel excise duties, etc. In addition, there are many other options such as reducing transport distances through spatial planning (increasing population density, for example), encouraging working from home, etc.

Spatial planning measures typically take a long time to reach full potential, although measures such as encouraging development of office buildings near railway stations rather than motorways could have some effect in 2020 already.

Pricing policies are often quite effective in reducing energy use or transport demand or both – depending on the type of pricing and its design. Increasing fuel taxes are a very direct means to encourage the sales of more fuel-efficient vehicles, reduce transport demand and improve transport efficiency. In good transport, the effects, often expressed in terms of price elasticity, are relatively limited, as fuel cost are only a relatively small part of overall transport cost. Significance (2010) concluded that for goods transport, a 10% fuel price increase leads to about 3% fuel demand reduction – due to changes in fuel efficiency, changes in transport efficiency and changes in road freight transport demand. Passenger car transport is much more responsive to price increases: PBL (2010) determined that in the Netherlands, a 10% fuel price increase will reduce fuel demand of passenger cars by about 2-3% in the short term (after 1 year), but this increases to 6-8% in the longer term (5-10 years).

Road charging schemes also reduce transport demand, and thus energy use, depending on the tariff level and potential compensating measures. Based on an extensive review of literature and existing road charging schemes, Significance (2010) finds that road charging has a significant impact on fuel use, vehicle and tonne kilometres: if cost per kilometre increase by 10%, this represents a tariff of about 9 €cent per kilometre, both fuel use and vehicle kilometres reduce by 9%, and tonne kilometre by 6%. This is due to a number of responses by hauliers and shippers that result in modal shift (e.g. from road to rail or inland shipping), transport demand reduction (due to reduced demand for the transported products) and transport efficiency improvements (by increasing the load factor, changing routes and shipment sizes, etc.). In the Netherlands, it was estimated that conversion of the vehicle taxes to a road charging system would reduce overall transport demand by 4-6% in the first 10-15 years, but even by 10-15% in the longer term (PBL, 2010).

Other examples of pricing policies that can reduce transport volume and energy use are charges on tickets for aviation and parking fees.

3.2.3 Shift to a more energy-efficient mode

People do not always choose the most energy-efficient mode for a certain trip or transport of goods: time, reliability and comfort typically play a much larger role when choosing a transport mode than energy efficiency. Even in goods transport, where hauliers and shippers are usually much more cost-conscious than in passenger transport, energy cost is only a limited part of overall cost and considerations.

The theoretical potential of modal shift options is typically very significant. Energy savings can be achieved if people replace part of their long distance car travel with train journeys, and rather take the bicycle, bus or tram instead of their car in case they make a relatively short trip. Part of passenger airplane transport over medium distances could be replaced by high-speed train. A shift of goods transport from trucks to inland shipping or railway transport also saves energy, as well as choosing maritime transport rather than aviation to transport goods over long distances. In many cases, there are quite pertinent reasons why a given mode is used: a car or a truck may be the most time- and cost-effective solution for a given transport demand.

Promoting a shift to a more energy-efficient mode can be achieved with pricing policies such as road charging, aviation ticket charges, parking fees, etc., as discussed in the previous paragraph, as long as they result in increasing the cost of the modes with higher emissions (or, alternatively, reduce cost of the energy-efficiency modes). Measures that improve the performance (e.g. speed, reliability, comfort) of the more energy-efficient modes can also be effective. Examples are investments in pedestrian and cycling infrastructure in bicycle-racks for cycling, park-and-ride-facilities near railway stations, or in railway and tram infrastructure. Also, car or pedestrian areas in city centres can be implemented (or enlarged), and the efficiency of goods distribution in urban areas can be promoted by local regulations or measures. Examples of other spatial planning measures that can reduce the need or attractiveness of car transport are promoting the location of office buildings near public transport hubs such as railway stations, and ensuring adequate combinations of functions, for example adequate shopping facilities in or near residential areas. Many of these measures and policies can also have a positive impact on the liveability and accessibility of cities.

The potential of these measures can be significant but depends on the local situation and often also on the details of the policies.

Other options

There are a number of other options to reduce energy use in transport, the ones with the highest potential are probably the following:

- reducing average speed of vehicles on roads, for example by lowering (or imposing) speed limits;
- promote ecodriving training, to reduce fuel use per kilometre – a very cost-effective measure (see, for example, AEA, 2012);
- using fuel-efficient tyres;
- ensuring tyre pressure is correct.

Many of these options can be promoted with national policies and correct enforcement, in the case of speed limits and tyres.

3.2.4 Maximum potential in 2020

Reducing energy use in transport has a lot of potential, but many of the measures listed here are typically not very popular with politicians and the public, even if studies show that they can have both economical and environmental benefits. A detailed discussion on the realistic potential and cost effectiveness of these measures is outside the scope of this report.

Since energy efficiency improvement and general energy demand reduction is a very important part in any effective decarbonisation strategy, we will also include it in the scenario calculations in the following chapters. Looking at the range of policy measures listed above, we assume that an energy reduction of 15% would seem feasible in 2020. This requires implementation of a mix of these measures, in many cases sooner rather than later as implementation takes time and many measures will gain effectiveness over time. Fuel efficiency improvements of cars, for example, will only affect new vehicles, it will take a number of years before a large part of the fleet is replaced with these more fuel-efficient cars.

3.3 Increasing renewable electricity use in transport

Electricity use in transport is currently mainly limited to railways, trams and metros (source: NREAPs). Electricity demand of electric road transport is still negligible, but this may change in the future.

Looking at the RED methodology, the contribution of renewable electricity towards the 10% transport target can be increased via three routes:
- increase electricity use in non-road modes;
- increase electricity use in road transport;
- increase the share of renewable electricity in the Member State or in the EU;

The most promising and potentially significant measure of the first option is electrification of railway transport. In some Member States, the potential of this measure is significant, and it is already planned for and included in the NREAP (see ECN, 2011). According to the action plans, the non-road renewable electricity use is expected to increase from the current 54 PJ to **100 PJ** in 2020. This is partly due to an increasing renewable energy share (from about 21% on average in 2010 to about 30% in 2018, the reference year for the RED), and partly due to an increase of electrification of railway transport.
Because of the cost of this measure, however, we do not expect this to be a route with much additional potential for 2020.

The second option, electrification of road transport, is starting to take off in various Member States, although the current contribution towards the RED and FQD target is still negligible. Compared to conventional cars, electric vehicles have a number of advantages:
1. Low CO_2/km, albeit depending on the type of power production, and a large potential for further reduction in the coming decades. The well-to-wheel CO_2 emissions of EVs are much lower, unless the power is produced in coal plants.
2. Electric drive trains are much more energy-efficient than conventional drive trains, they can deliver the same transport work with much less energy input – about 2.5 times, which explains the multiplication factors in the RED and FQD. On a well-to-wheel basis, when looking at primary energy input, this comparison depends on the energy used to produce the electricity. When the electricity is produced in large-scale coal or gas power plants, the well-to-wheel efficiency is somewhat comparable to that of conventional cars. EVs perform much better in this respect if renewable energy such as solar or wind energy is used.
3. With the share of renewable electricity increasing, EVs can contribute to stabilise the power supply system and adapt electricity demand to renewable electricity supply. This requires smart charging and a significant share of EVs.
4. Energy costs are lower than in conventional cars, mainly because of the high energy efficiency. Insurance and repair costs are expected to be lower as well because the EV motor is so much simpler than the ICE engine[17]. There are simply fewer things that can break. Therefore, once the vehicle and batteries are paid and the battery lifetime is more than that of the vehicle[18], the running costs are low. Note that this also creates a risk of rebound effects: low cost per kilometre may increase transport demand, especially in the future when the driving range is not restrictive anymore.

[17] Reliable data on these costs are currently lacking due to the limited number of EVs.

[18] In the current situation, battery lifetime is typically expressed as a number of charging cycles. This means that battery cost will effectively depreciate with use, adding to the cost per kilometre. Experience with battery lifetime is still limited, though.

5. Air quality improves, and noise levels are much lower in urban environments (at higher speeds, noise levels are dominated by tyre noise, and EVs become almost comparable to conventional cars).

EVs also have a number of disadvantages, mainly related to battery cost and capacity. R&D and increasing production volumes in the coming years are expected to reduce cost of the battery and increase capacity (per kilometre) and lifetime at the same time (CE, 2011c and b). In addition, various types of plug-in hybrid vehicles are being developed that combine the advantages of electric driving with the driving range of conventional cars. Despite their more complex drive train technology, the cost of these plug-in hybrids is expected to be lower than that of full electric vehicles at least in the short to medium term, as they need less (expensive) battery capacity (CE, 2011c).

Electric vehicles are being promoted quite strongly, both at the EU level (e.g. via the CO_2 and cars regulation) and in various Member States, cities and regions. An increasing number of electric vehicles is coming on the market, ranging from full electric vehicles (FEVs) to extended range electric vehicles (EREVs) and plug-in hybrid electric vehicles (PHEV).

In CE (2011), a number of EV market uptake scenarios were developed for the EU, based on expectations regarding cost developments, oil price, government policies, etc. Three scenarios were developed: most realistic, ICE (conventional car) breakthrough and EV breakthrough, and impacts on energy demand, electricity production, GHG and air pollutant emissions, etc. were calculated.

These scenarios also provide estimates for electricity consumption of electric vehicles in the EU in 2020, as shown in Table 1 below. Renewable electricity consumption is also included in the table, assuming that renewable electricity will be on average about 30% of electricity production in 2018. With that assumption, EVs can be expected to contribute about **5-16 PJ** renewable energy[19]. In the RED methodology, these figures can then be multiplied by 2.5 to determine the contribution of EVs to the target[20].

Table 1 **Estimated electricity demand of electric vehicles in 2020 in the EU-27, for three scenarios and their potential contribution to the RED target in 2020**

Scenario	Total number of EVs in the EU fleet (million)	EV electricity consumption (PJ)	Renewable electricity consumption (30% of total consumption, without RED multiplication) (PJ)
Scenario 1: 'Most realistic'	3.3	28	8.4
Scenario 2: 'ICE breakthrough'	1.9	17	5.1
Scenario 3: 'EV breakthrough'	5.5	52	15.6

Source: (CE, 2011b).

[19] Even though these scenarios are quite ambitious regarding EV uptake, the NREAPs are even more ambitious: in the EU-27, it is expected that road transport contributes about 30 PJ renewable electricity towards the target.

[20] This is only true for road transport, the RE of electric railway transport only counts once.

The question is now, to what extent can these developments be accelerated further, to ensure that the EV breakthrough scenario is met, or even surpassed? Car manufacturers, the EU and local and national governments throughout the EU have increased their efforts to develop and promote electric vehicles and their charging infrastructure in recent years, and growth rates are significant, but absolute sales numbers are still low in the EU: only 5,222 in the first half of 2011 versus about 500 in the same time period in 2010, according to a report by JATO (2011). Total passenger car sales in the first half of 2011 were more than 9 million.

The limited driving range and high cost of the vehicles (especially of the batteries) are currently the main barriers to their market uptake. One of the main drivers is probably the CO_2 and cars regulation, a policy aimed at vehicle manufacturers, encouraging them to invest in R&D and EV production. In addition, national and local EV targets and support policies are an essential part of EV policies as they can directly target consumers and potential vehicle buyers, and thus help to overcome the current barriers. Several EU countries are investing in EV infrastructure and compensate consumers fully for the extra cost of purchasing EV. For example: Estonia aims to have EV charging stations for every 50 km; Germany has a target of 1 million EV by 2020; the UK target is 1.7 million EV by 2020, a € 5,800 subsidy is given to purchase EV plus free access through London payment ring, etc.; France has a target of 2 million EV, and a € 5,000 subsidy to purchase EVs; Denmark has no target but EVs are exempt from high DK car taxes, which makes cost of buying EVs the same as conventional ICEs.

It may thus be reasonable to assume that the EU sales of EVs are still highly uncertain, and depend strongly on both technology development and government policies. EU sales are currently still very limited, and increasing the number of EVs to 1 million and up will take time and effort. It is also not yet clear if the EVs will actually replace conventional cars, or if part of the benefits are lost because they are rather used as additional, second cars for short-distance use. It may well be that the EV market uptake continues to vary between countries, with countries where strong policies are in place will have significantly higher market shares than others. The contribution of EVs to the RED target (and CO_2 reduction as a whole) would be optimised if the EVs are mainly sold in Member States with a green electricity mix: high shares of renewable electricity production and low share of coal.

The third option to increase the contribution of renewable electricity to the RED target, increasing the share of renewable electricity in the electricity mix, is a development that will take place in the coming decade irrespective of the transport target of the RED: Member States have to put a lot of effort into this in order to meet the overall target of the RED, which is on average 20% renewable energy in 2020 – including energy for transport, electricity and heat. As it is easier (i.e. less costly) to increase the share of renewable energy in electricity than in transport and heat, it is expected that this means that the average share of electricity from renewable sources will be about 30-35% in 2020 (this explains the 30% renewable electricity in 2018, assumed in the calculations above). Each Member State has its own individual overall target.

In conclusion, the 2020 contribution of renewable electricity to the RE transport target is expected to be about 100 PJ in non-road, and no more than about 16 PJ in road (to be multiplied by 2.5 for the RED), assuming a 30% share of renewable electricity.

This is only a relatively small share of the renewable energy needed to meet the RED target in transport in 2020, as can be seen in the next chapter.

Especially electricity use in road transport is, however, still in its infancy, and probably in 2020 it will still only be at the beginning of its growth in many countries. The main benefits will only be achieved after 2020. If the EV developments are, however, accelerated in selected Member States, especially those with high renewable electricity shares, the share of EVs and their contribution to the RED transport target may well be much more than average in these countries already in 2020.

3.4 Biofuels that do not require land

Biofuels produced from waste and residues that can not be used in alternative applications are currently the only type of biofuel that does not require land, cause emissions due to land use change or reduction of carbon stock. In some cases, they can even prevent GHG emissions from decay of the organic waste or residues. These types of biofuels thus typically score very well in a life cycle analysis, and achieve significant GHG reduction when used to replace fossil fuels. In addition, they have the significant advantage that they do not compete with the food sector, as they use biomass feedstock that can not be used as food or feed and do not require land.

The RED and FQD recognise that biofuels from waste, residues, non-food cellulosic material and ligno-cellulosic material are both more beneficial and more expensive to produce. For this reason:
- they count double towards the target in the RED;
- the default GHG savings of these biofuels are relatively high in both the RED and the FQD and they will even be more advantageous compared to other options once ILUC factors are included in the GHG calculation methodologies;
- as long as the biofuels are produced from waste and residues other than agricultural, aquaculture, fisheries and forestry residues, suppliers only need to fulfil the minimum GHG savings requirement, they do not need to explicitly demonstrate the rest of the sustainability criteria.

It is important to realise, however, that not all waste and residues can be considered to be land-free and without sustainability impacts. There are a number of conditions for the good environmental performance of biofuels from waste and residues that are not yet included in the RED and FQD sustainability criteria. These will be discussed in Section 3.4.2.

In the current biofuels market, biofuels from waste and residues only have a limited share within the EU. Experience shows that specific incentives are needed to allow these routes to compete with the conventional, 1st generation biofuels. Double counting has so far only been implemented in a limited number of Member States, even though this is required by the RED.
There are currently three types of biofuels produced from waste and residues:
- FAME (Fatty Acid Methyl Ester), the most common type of biodiesel, produced from used cooking oil (UCO) or animal fat.
- HVO (Hydrogenated Vegetable Oil), an alternative to FAME, is also produced from waste oils and fats, for example from UCO or waste streams from the meat industry (fat or tallow mainly)[21].

[21] Hydrogenated Vegetable Oil concerns vegetable oil from which the oxygen is removed by treatment with hydrogen (hydrogenation). The products of hydrogenation are water, CO_2, propane and a hydrocarbon product that is very similar to conventional diesel.

- Biomethane for transport is being produced from sewage treatment plants, organic waste or fermentation (of manure, for example) in various countries. Note that co-fermentation of manure with a commodity such as maize is not land-free, as the maize will have to be cultivated.

The role of UCO and similar by-products of meat processing[22] will always remain limited because of limited supplies. Sale prices of UCO have increased in recent years, and are moving closer towards the prices of the pure plant oil[23]. As FAME production from UCO is more costly than from rapeseed oil, the cost of UCO-based FAME is currently higher than those of rapeseed-based FAME in countries where double counting is implemented (for example, the Netherlands). Because of these higher cost, they are typically only used in Member States with specific incentives for these biofuels.

Current non-food feedstocks for EU biofuels are thus mainly used cooking oil, organic waste (incl. the biogas from sewage treatment plants), manure, animal fat and tallow from the meat industry. Other options are being explored and tested, with the aim to expand on the waste and residue streams that can be used as feedstock for biofuels. A lot of effort (financial support and R&D) is put into developing processes that can convert ligno-cellulosic biomass into biofuels, mainly with the aim to use agricultural and forest residues as feedstock in the future. These routes are generally considered to have significant potential, but this will be discussed in detail in the following sections.

Research into biofuels from algae cultivation is also on-going, as this would not require fertile, agricultural land. However, as these developments are still very much in an R&D stage, with relatively limited yields and high costs and possibly involving releases of GMOs, this option is not considered here further: it is not expected that this route could provide significant biofuels volumes in 2020. Next to this, it is not yet clear how sustainable algae-based biofuels would be. Algae cultivation requires significant amounts of energy for pumping around the cultivation medium as well as nutrients. For example, in the Netherlands, algae production in closed tubular systems is found to require three times more energy than is sequestered in the produced algae.

3.4.1 Estimate of availability of sustainable biomass and biofuels

Based on a number of authoritative studies[24] an indicative overview was produced of the potentially available amounts of probably land-use free biomass feedstocks and the biofuels volume that could be produced from them. The feedstocks that were considered and identified comprise a variety of primary (agricultural/forestry), secondary (food industry, wood industry) and tertiary (consumer) by-products and residues.

22 Meant are C1 an C3 fats from rendering.

23 http://www.slideshare.net/ralphbrieskorn/120313-wb-mpresentationrotterdam2012.

24 EEA, 2006; JRC, 2009; RENEW, 2009; ECN, 2008.

Estimates for their theoretical, long-term potential are given in Table 2, together with some background information on alternative uses of the biomass (competing function), cost of the biomass, potential processing technology, etc. These feedstocks and potential sustainability risks associated with them are discussed in more detail in the following paragraphs.

The colours in the table indicate the perceived risk level for ILUC, adverse effects on biodiversity and carbon stocks:

Green: Good, using this biomass has few negative environmental effects.
Red: Not good, using this biomass is associated with high environmental risks and impacts.
Orange: Questionable: significant environmental risks associated with the use of these wastes and residues or they would be more efficiently used in other industry sectors.

To put the data in the table into context: assuming business as usual development of transport energy demand, about 1,150 PJ of fossil fuel need to be replaced in order to fulfil the RED target of 10%. As the biofuels discussed here count double towards the RED target, about 575 PJ biofuel or biogas from waste would meet the whole target.

Table 2 Overview of waste and residues suitable for biofuels production for transport - long-term EU potential (Abbreviations: see next page)

	Competing function	Functionality combinable?	ILUC risk at functionality loss?	ILUC free feedstock available PJ/year	Biofuel production routes	Biofuel produced potential PJ/year	Cost of feedstock €/GJ
Consumer waste							
- Sep. collected green waste	Compost, A.D.	Yes	No	166	A.D.	99	-1
- Mixed municipal solid waste	Landfill gas, Waste incineration plant	No	No	776	A.D.	466	-1
- Verge grass	Compost	Yes	No	46	A.D.	28	1
- Used cooking oil	Co-combustion	No	No	88	FAME, HVO	83	20
Agricultural by-products							
- Straw	Bedding, cogeneration,fibre board	No	Yes (hay, peat)	0		0	
	Feed		Yes (roughage)	0			
	SOC + nutrients	Yes	No	3,224	2nd generation ethanol	1,612	5
- Crop residues	Feed		Yes (roughage)	0			
	SOC + nutrients	Nutrients yes, SOC no	No	4	A.D.	2	5
- Prunings	SOC + nutrients	Yes	No	392	Various (2nd generation)	196	5
- Manure	SOC + nutrients	Nutrients yes, SOC no	No	1,456	A.D.	728	0
By-products food industry							
- Various	Larger part as feed, potential surplus for energy?	Yes for pot. surplus	Not for surplus	63	A.D.	38	5
- C1 fats (i.e. fats unsuitable for human consumption)	Co-combustion	No	No	11	FAME, HVO	10	15

	Competing function	Functionality combinable?	ILUC risk at functionality loss?	ILUC free feedstock available PJ/year	Biofuel production routes	Biofuel produced potential PJ/year	Cost of feedstock €/GJ
By-products pulp industry							
- Paper sludge	Landfill, WIP	No	No	65	A.D.	39	
Woody biomass: felling, by-products from forestry and landscape care and consumer waste							
- Landscape care	Compost additive, SOC + nutrients	Yes	No	380	Various (2nd generation)	190	5
- Additional felling	C-storage	No	No - no alternative	1,529	Various (2nd generation)	765	5
- Felling residues (Tops, branches excluding stumps)	SOC + nutrients, biodiversity	Biochar	No - no alternative	1,002	Various (2nd generation)	501	5
- Saw mill residues	Board, fuel	No	Partly (additional felling)	687	Various (2nd generation)	344	5
- Consumer waste wood	Particle board, fuel	No	Partly (additional felling)	371	Various (2nd generation)	186	0
Total technical potential of biofuels/biogas from waste and residues (in brackets: with low environmental risks)				**10,260 (3,004)**		**5,287 (1,651)**	
Of which - Biogas - FAME, HVO - 2nd generation (see below)						 **1,400 (1,362)** **93 (93)** **3,794 (196)**	

Based on (IEE, 2012)

For total 2nd generation feedstock, the range for risk free feedstock and feedstock including feedstocks carrying a risk of negative impact (additional fellings, felling residues) is given.

AD = Anaerobic Digestion (biogas production, can be upgraded to biomethane)

SOC = Soil Organic Carbon;

FAME = Fatty Acid Methyl Ester

HVO = Hydrogenated Vegetable Oil

DME = Dimethyl Ether, can be used in retrofit diesel engines, requires separate infrastructure

Various (2nd generation) = pyrolysis + gasification + methanol production + DME production from methanol + BTL + 2nd generation bioethanol.

As it appears Table 2, biogas production represents ca. one third of the total potential. Biogas feedstocks also stand out from a sustainability point of view because a significant part of these are largely uncontested. In contrast, 2nd generation biofuel processes will have to compete for most its feedstocks (straw and wood) with other uses, both within and outside of the energy sector. These other applications are often more efficient from CO_2 reduction and cost point of view. FAME and HVO can only contribute relatively limited land-free biofuels volumes, with a total EU potential of less than 100 PJ.

Looking at production technology and capacity, only FAME, HVO and biogas from waste production plants are currently in operation in the EU. Wood gasification, ethanol production from ligno-cellulosic feedstocks are still under development (see the overview in Section 3.4.3).

Prices per GJ have been adopted from Wageningen UR (2010). The values are indicative and can vary from time to time and region to region and can be significantly affected by policies. For example, current prices for used cooking oil and C1 fats are triple to quadruple compared to a few years ago because of the surge in demand for these feedstocks after RED (Art 21(2)) promoted double counting of biofuels based on these feedstocks (see footnote 23).

3.4.2 Sustainability risks associated with biofuels from waste and residues

In the RED and FQD, and in various research publications, biofuels from waste, residues and ligno-cellulosic biomass are considered to be sustainable and ILUC-free by default. However, unfortunately, in many cases this is not really the case. This is due to the fact that this biomass would (or could) otherwise be used elsewhere – and in many cases at higher efficiencies than in transport.

Many of these biomass streams have other useful applications, for example as soil improver, fodder, in the chemical industry, for electricity and heat production, etc. If these feedstocks are then diverted to biofuel production, these other applications will have to resort to other feedstocks – perhaps from cultivated biomass, or from fossil fuels. This may then lead to indirect emissions elsewhere, which should be taken into account in assessments of the sustainability of the biomass and biofuel.

Also the indirect effects may be very significant, as can be illustrated with a number of examples. Ecometrica (2009) assesses these indirect effects for a number of cases in the UK situation. For example, using UK tallow for biodiesel production will lead to 85% emission reduction according to the RED methodology. Taking indirect effects into account, Ecometrica finds that the net effect will be between about 55% reduction and 15% additional emissions. Producing bioethanol from sugar beet molasses[25] also shows that whereas the GHG reduction is more than 50% without indirect effects, the net effect ranges between about 30% savings and 35% additional emissions. The ranges are relatively large, mainly because of the different alternative uses. Ecometrica concludes that the use of materials which have existing uses (in the absence of biofuels/bioenergy usage) is likely to create negative indirect GHG effects currently not accounted for in the RED and FQD methodology. Alternatively, the use of materials which are disposed of (in the absence of biofuels/bioenergy usage) can create large positive greenhouse gas effects which are not yet accounted for. On the other hand, when genuine waste

[25] This is the syrup left from the final crystallisation stage of sugar beet, typically used as an animal feed component, but also as a growth medium for yeast, in lactic and citric acid production, and in niche applications including dust suppression, food flavouring and colouring.

streams are used to produce biofuel or biogas, meaning materials with no existing use, large greenhouse gas reductions can be achieved.

This is confirmed in an assessment of different applications of biogas from sugar beet leafs in the Netherlands, as reported in CE (2011a). Upgrading the biogas to biomethane and then using it as a transport fuel will reduce emissions by about 88 kg CO_2 per GJ biogas, whereas using the biogas directly for electricity production in a gas engine will save 95 kg CO_2 per GJ biogas, in the Dutch situation and depending on the methane leakage in the production process[26]. Therefore, even though the biogas use in transport is extremely beneficial from a GHG savings point of view, even higher GHG savings could be achieved if the biogas would be used for electricity production. The reason for this is the higher efficiency of using the biogas in a gas motor – using it as bio-CNG in transport require additional energy input to first upgrade it to the quality needed as a transport fuel and then compressing it to be used in the vehicles. Shifting biogas from electricity to transport thus effectively increases emissions, unless other types of renewable electricity production are increased to compensate for this loss of biogas. If the biogas production replaces land fill, however, GHG emissions are strongly reduced.
Nevertheless, as some parts of the transport sector have few alternative renewable energy options, use of biogas in transport may still be the most effective application – the electricity sector has much more sustainable options and can resort to, for example, wind and solar energy (see Section 3.4.5 for further discussion on where to use biomass).

Therefore, looking at the ‘bigger picture’ significantly limits the potential supply of waste and residues that do not cause land use change elsewhere, or have other undesired environmental impacts. This assessment is complicated, though, as the alternative uses can vary and the impacts can be difficult to predict.

Another issue that should be kept in mind is that the limited availability of sustainable biomass in the EU may also induce undesired initiatives from suppliers. The past two years witnessed the dumping of subsidised US biodiesel on the EU market. Efforts were made to get around imposed EU anti-dumping legislation by, for example, the trans-shipment of US biodiesel in third countries (in particular Canada) to conceal its US origin or the export of artificially designed blends containing less than 20% biodiesel and not covered by the EU measures adopted in 2009 (typically B19, B7, etc.)[27].
In a situation with limited intra-EU availability of sustainable biomass similar initiatives of trying to get around legislative constraints may be taken, such as the creation of inefficient production process to generate more waste for biofuels. Also, incentives for waste-based biofuels increase the likelihood of fraudulent activities that may be difficult to detect, for example cooking palm oil to sell it as waste oil to the biofuels sector, at a higher price. Policy makers may want to anticipate such initiatives.

3.4.3 The potential of land-free biofuels and biogas in 2020

The potential of land-free biofuels and biogas depends on:
a Potential availability of the feedstock (at reasonable cost).
b Availability of technology and production capacity to convert the feedstock into a high-quality transport fuel or gas.

[26] See, for example, http://www.esu-services.ch/fileadmin/download/publicLCI/stucki-2011-biogas-substrates.pdf.

[27] http://www.thebioenergysite.com/news/8691/biodiesel-antidumping-measures-welcomed.

Feedstock

In the literature, a number of estimates are available regarding the potential waste and residues available in the future, but these typically result in a large range. Many of these estimates are broader assessments, where studies also look at the potential future availability of biomass including biomass cultivation (i.e. land-based biofuels) given certain sustainability boundary conditions. These studies do not specifically answer the question what part of this potential will be available for the EU transport. Biomass is often used locally, especially in non-OECD countries, but it can also be traded and transported all over the world – as is also the case for most biofuels. Furthermore, as explained before, there are quite a number of other sectors that are also very interested in using these biomass waste and residues in their development towards a sustainable future. The feedstocks can often also be used for electricity and heat production or for chemicals and materials production – sectors that will also have to achieve very significant GHG reduction targets to meet overall GHG targets in the future.

The future potential of these land-free biofuels for EU transport thus depends on quite a number of factors, including:

- availability of organic wastes and residues from environmentally and socially sustainable sources (globally, if imports are considered, otherwise within the EU);
- demand from other regions and countries;
- demand from other sectors and for other applications.

Production technology and capacity

The potential of land-free biofuels also depends on production technology and capacity, and operational cost. A number of biofuel production technologies from waste and residues are mature and in large-scale operation, such as FAME production from used cooking oils, HVO production from animal fats and biomethane production through anaerobic digestion of organic waste and manure. Other biomass waste and residues, notably the woody biomass types, can not yet be processed into biofuel or biogas on significant scale, so far only pilot scale plants have been operational. A number of technologies are specifically being developed in order to expand the potential biomass types that could be processed into a biofuel:

- **2nd generation bioethanol** production from woody or ligno-cellulosic biomass;
- **Biomass-To-Liquid processes** (**BTL**, i.e. first gasification of biomass, followed by Fischer-Tropsch synthesis);
- **Gasification** of biomass, resulting in **biomethane** or **bio-DME.**

Ligno-cellulosic and woody waste and residues from forestry, agriculture, etc. are often thought to have a significant potential, although using some of these streams of waste and residues result in high risks for the natural environment, which will be hard or nearly impossible to mitigate. These issues will be discussed further in the following section, where the various types of residues are discussed.

Note that some developing technologies for this conversion of woody biomass involve the use of genetically modified (GM) bacteria, or ‘synthetic’ organisms. There are concerns over whether GM bacteria can be kept in safe and secure contained use, when used on such a large scale. There would be concerns regarding leakage and escape of GM bacteria, especially if they were designed to digest lignin.

These three processes are not yet deployed on a commercial scale, although gasification has been operational in a large-scale plant in the 1980s, and especially the 2nd generation bioethanol R&D seems to be quite successful in recent years. The first commercial 2nd generation bioethanol plants are scheduled to start operating in 2013 in both the USA and the EU. The main driver of this initiative are US regulations (The Energy Independence and Security Act of 2007 and the Renewable Fuel Standard) which requires an annually increasing supply of cellulosic biofuels to the automotive fuels market from 2013 onwards.

Wood-gasification-based methanol production has been demonstrated on a commercial scale at the HT Winkler gasification-based plants in Oulu and Berrenrath (in the 1980s), but they are not currently in use. BTL research and development is on-going in the USA and, until about a year ago, in the EU. A leading developer in the EU, Choren, has declared insolvency last year. Its gasification technology has recently been sold to Linde Engineering Dresden[28]. Stora Enso and Neste on the other hand are planning commercial operations in 2015[29].

For these technologies to significantly contribute to the RED target of 2020 would require a very rapid development path in the coming years: successful further development of the technology, including optimisation of the processes, enzymes, etc. to reduce cost and make the technology sound and mature enough to invest in large-scale production plants and gradually expand processing capacity. As the first large-scale production plants are only now being built or in the planning phase, potential contributions to the 2020 target are not likely to be significant on EU scale. The situation might be different for specific Member States, though.

Literature estimates of biofuel and biogas potential from waste and residues

A number of recent publications have estimated the potential supply of biofuels from waste and residues in the EU in 2020. These estimates typically relate to biofuels from waste, residues and ligno-cellulosic biomass, in line with the definition of double-counting biofuels in the RED (Art. 21(2)). As discussed above, this may also include biomass that is already in use or would otherwise be used in other sectors. Using these streams for biofuels production will then force these other sectors to use other feedstock, thus leading to indirect effects that may reduce or eliminate environmental benefits.

In the context of the RED, all Member States had to submit National Renewable Energy Action Plans in which they elaborated on how they planned to meet the RED targets. Part of this report was to provide an estimate of the use of biofuels that meet the Art. 21(2) criteria, i.e. are produced from waste, residues, etc. Aggregating these data lead to a total of **109 PJ** of these biofuels expected to be used in the EU in 2020[30]. This is about 8% of total biofuels demand in 2020, or 0.7 % of total energy consumption in transport, according to the NREAPs.

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28 http://www.the-linde-group.com/en/news_and_media/press_releases/news_120209.html.

29 See e.g. http://www.nesteoil.com/default.asp?path=1,41,540,10793,10795,11601 and http://www.storaenso.com/investors/presentations/Documents/0928_Bioseminar_Stockholm.pdf.

30 The NREAPs specify the expected volumes for various types double-counting biofuels (biodiesel, bioethanol or other), but they do not provide information on the basis for these expectations.

JRC developed a number of biofuels scenarios for the EU in 2020 (JRC, 2011). This study includes some estimates for potential (feasible) biofuels volumes from waste and residues in 2020: 42 PJ of FAME/HVO from waste oils (used cooking oil), 10 PJ BTL and 27 PJ 2nd generation bioethanol. In total, this would amount to almost **80 PJ** 2nd generation biofuels. The report does not further specify the basis for these estimates.

In a recent study by the Netherlands Environmental Assessment Agency (PBL) and CE Delft, a literature scan was carried out to estimate the potential availability of sustainable biomass. Restricting this to biomass from waste, it finds that EEA estimates arrive at about 4.0-4.3 EJ of potential EU organic waste for 2030. Global estimates that are reported in PBL (2012) are less detailed, but the study concludes that for 2030, 100 EJ would seem a realistic estimate for sustainable biomass potential. Potential EU supply is then estimated to be between about 8 and 18 EJ - depending on the share of the total that the EU would use. A significant part of this potential will be cultivated, though. The study does not make a choice in what sector this biomass should be used, but it does provide a number of considerations about the best applications. It thus concludes that it can best be applied in sectors with limited potential alternative renewable energy sources, such as in heavy duty vehicles, shipping, aviation, in existing buildings and small industries and for fossil-free production of plastics. Therefore, despite the large potential that this study gives, it lacks detailed data on which share would be land-free and usable for biofuels production in 2020.

3.4.4 An assessment per biomass category

In the following, the various biomass categories of Table 2 are discussed in more detail. Focus is on the assessment whether a feedstock is indeed available for transport fuel production, and whether there are environmental risks involved. In some cases, options are identified with which the biomass could be used for biofuel or biogas production without losing the alternative functionalities, or at least significantly reducing the environmental impacts.

Consumer waste

Part of the food products that is produced is lost in wholesale, retail or at the consumer. The resulting waste is partly collected as a separate fraction for recycling or composting. The rest ends up in municipal waste and is landfilled or burned. The landfill gas and heat produced during these processing operations is partly utilised for generation of heat and power. However, the ban on using catering waste for pig swill is coming under increased scrutiny amid calls for it to be lifted, both because of the amount of food waste going to landfill and the huge imports of animal feed. This may create a competing use for food waste.

In case of landfilling and incineration there is no competing use apart from heat and power generation. In case of composting, biofuels production can be combined with production of compost. For example, in Germany and increasingly also in the Netherlands composting installations have been or are extended with an anaerobic digestion facility. However, in both cases it is possible (and highly desirable!) that the amount of food waste available for energy production will decrease in the future.

For recycling of paper and wood there is a risk of ILUC, as outlined for recycled by-products from wood processing below.

By-products from agriculture

By-products from agriculture are for example manure, crop residues, prunings from orchards and vineyards, and straw. The following only provides a broad overview of the topic, of the potentially sustainable feedstocks and routes. However, determining the overall sustainable potential of these biomass streams for biofuel more accurately, and in particular to fully assess the possibilities (and associated risks) to develop these streams sustainably, require a much more detailed assessment of these systems and biomass.

Part of these by-products find use in high(er) value applications in animal husbandry, such as feed (crop residues, straw) and bedding material (straw) or other applications (e.g. straw used for fibreboard production). For these applications the alternative would be growing dedicated feed crops or crops providing bedding material, which would require additional land, inducing the risk of land use displacement effects (ILUC).

The total amount of straw produced on a European scale is however higher than required for these high(er) value applications. The part not utilised as feed or bedding material is usually left in the field and provides nutrients and carbon to the soil. This function could be retained if the lignin rich residue of straw-based ethanol production is returned to the field as fertilizer. As an alternative the residue can possibly be applied as a peat substitute in e.g. potting soil. US bioethanol producer POET is considering this option and is currently studying costs involved[31].

Residues of crops other than cereals and oilseed plants – such as sugar beet and potato leaves – may also be left in the field as a source of carbon and nutrients to the soil. In this case biofuels production and maintaining soil fertility could be combined by collecting and anaerobically digesting these residues and returning the digestate to the field. This option is indicated as 'S.O.C + nutrients' in the table, since the digestate then has a function of bringing the nutrients and fibres (carbon) back into the soil. Such a configuration could probably be realised at low costs if the agricultural machinery was to become available that would harvest the entire plant instead of separating the crop in products and by-products at the field. An alternative route might be to mow the leaves prior to crop harvesting[32]. According to studies by Alterra, removing crop residues would have the additional advantage of significantly reducing N_2O emissions from the field[33]. Unfortunately, it is not clear yet how much of these crop residues are left in the field. Furthermore, is clear that a shift to more ecological farming methods with less industrial inputs, like synthetic fertilisers, will require a careful approach in using these residues as they are also needed to remain and improve soil quality including soil organic carbon.

Implementation of these advance production routes that combine biofuel production with carbon and nutrient recycling will require changes in legislation concerning manure and green manure, at least in the Netherlands but maybe also in other EU Member States. In the Netherlands, current legislation seems to frustrate centralised digestion and manure processing, it is

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31 See: http://www.eere.energy.gov/golden/ReadingRoom/NEPA/1628/DOE%20EA-1628_Supplement_Analysis-FINAL.pdf.

32 See e.g.: http://edepot.wur.nl/5357, http://www.boerderij.nl/Akkerbouw/Nieuws/2011/11/Onderzoek-naar-nieuwe-toepassing-bietenblad-AGD576872W/, http://www.akkerwijzer.nl/artikel/n/386/bietenblad-beter-benutten.html, http://www.boerderij.nl/Home/Foto-Video/2011/11/Bietenblad-hakselen-in-Valthermond-BOE019054W/.

33 See: http://edepot.wur.nl/16496.

not legally possible to reuse digestate that is produced in centralised digestion plants.
Pruning wood is usually cut and left in the field as organic mulching[34]. The function of providing nutrients and carbon to the soil could be maintained and combined with biofuel production if the wood biomass is first pyrolysed with a pyrolysis technology producing separable biochar (see, for example, the Dynamotive technology[35]). The biochar, which also contains the nutrients, could be returned to the orchards and spread as a fertilizer[36]. The produced pyrolysis oil could be utilised as a boiler fuel or a feedstock for gasification.

Comparable to straw, manure is applied in agriculture as a source of nutrients and carbon for the soil. As with straw, in this application part of the substances in the manure – hydrocarbons not contributing to humus formation - are ‘wasted’. Therefore, the opportunities for optimising manure utilisation are similar to those for straw.

For manure, optimisation could be achieved by anaerobic digestion and subsequent separation of the residual digestate in a wet and a dry fraction. During digestion decomposable organic components are converted into biogas, a mixture of CO_2 and CH_4. This biogas could be utilised for:
- heat and/or power generation;
- natural gas substitution, by separating the methane and injecting it in the natural gas pipeline system;
- diesel substitution in automotive applications;
- feedstock for e.g. methanol or ammonia.

Nutrients in digested manure are better available to plants, hence can substitute fertilisers to a higher degree. Residual digestate separation allows for separately managing the nitrogen (liquid fraction) and phosphorus (solid fraction) present in the manure. Note that transportation of heavy and fermenting manure over large distances may not be economical and will reduce the environmental benefits of manure digestion.

By-products from food industry
By-products from the food industry in particular find high value applications, mostly as feed. As with crop residues, the alternative for the utilisation of these by-products as feed would be growing dedicated feed crops, which would require (additional?) arable land.

Some residues may be produced in surplus – e.g. potato peelings - allowing utilisation as a feedstock for biofuels production, but this potential is probably limited in view of the sizable animal husbandry sector in the EU. For most of these residues anaerobic digestion is the most appropriate conversion technology.

Waste fats from animal and meat processing are categorised within three quality categories:
- suitable for human consumption (e.g. tallow);
- C3 quality – applicable in oleochemical processes and products (e.g. cosmetics), feed and pet food;
- C2 and C1 – high risk materials, obligatorily co-combusted or converted into biodiesel/HVO.

The first two by-products compete with primary fats and fatty acids. Diverting them to biofuels production could result in additional crop cultivation and

[34] See e.g. http://www.biomasseverband.at/uploads/tx_osfopage/PSI_Silvestri.pdf.

[35] See http://www.dynamotive.com/.

[36] See: http://en.wikipedia.org/wiki/Terra_preta.

associated land use. C2 and C1 fats however are obligatorily burned in power generation or as a transportation fuel. In these applications these fats primarily compete with fossil fuels.

Woody biomass: felling, by-products from forestry and landscape care and consumer waste

This category includes both wood from forests and by-products and waste from wood-applying sectors. Resources are discussed following the wood production and application chain.

Pruning wood

Landscape care pruning wood is often mulched or used in composting to give structure to the compost heap. The function of providing nutrients and carbon to the soil could be maintained if the wood is first pyrolysed with a pyrolysis technology producing separable char, which is subsequently recycled to the landscape.

Felling residues

Felling residues such as tree tops, branches and stumps in general are left in the forest and contribute to carbon stocks and nutrient concentrations in the soil, while at the same time help maintaining biodiversity and providing protection against erosion. Stumps, dead and dying trees in particular play a crucial role in maintaining biodiversity within forest ecosystems.
In Scandinavia however stumps are increasingly harvested for utilisation as boiler fuel. Again, the function of providing nutrients and carbon to the soil could be maintained if felling residues excluding stumps are first pyrolysed and the produced char is subsequently recycled to the forest. However, the function of maintaining biodiversity and protecting against erosion would be lost. How much of these ecosystem services are lost as a function of the percentage of residues removed and whether harvesting a limited fraction could be acceptable – as for corn stover - is unknown. In view of these losses of ecosystem services felling residues are an uncertain resource of biomass at best. The use of this resource should be clearly defined and strictly limited.

Additional felling

Next to these different categories of by-products and residues, there is at least theoretically a potential for producing an additional amount of wood from European forests.
One definition of 'sustainable forestry' is that annual felling should not exceed net annual increments in standing wood volumes in the shape of trees. This would give no changes in sequestered amounts of carbon. In a number of European countries annually felled volumes of wood are smaller than net annual increment. So theoretically more wood could be produced and made available for applications as for example a fuel.
However, the effects of additional felling can have very different impacts on forest biodiversity and the availability of providing ecosystem services, depending on the type and maturity of forest in which the additional felling is done and how felling is done:

- Additional felling in mature and unmanaged forests that are still sequestering carbon will have a significant negative impact on biodiversity and carbon stocks and should be avoided.
- In managed forests, increased wood production should be realised carefully, rather by increased thinning than by clear felling of the neglected forest.

– The restoration of management in neglected and overstocked tree stands on the other hand is considered to provide many benefits apart from serving as a source of biomass. For example, this may result in improving the general quality of woodlands, improving access for recreation and potentially meeting biodiversity objectives through changes to stand structure and light regime[37].

As indicated in the EFSOS II report (UNECE, 2011), a sharp increase in wood supply is probably not attainable in a sustainable way:

> *"The main concern is for biodiversity, as increased harvest pressure in all scenarios, except for the* "Priority to biodiversity" *scenario, lowers the amount of deadwood and reduces the share of old stands. The* "Promoting wood energy scenario" *shows a decline in sustainability with regards to forest resources and carbon, due to the heavy pressure of increased wood extraction to meet the renewable energy targets".*

How much biomass can be produced in a sustainable way from neglected tree stands is not completely clear. The potentials mentioned in the literature consulted may serve as a first indication, but further research in this matter is necessary.

Sawmill residues

During processing of wood and – to a lesser extent – crops, part of the processed material is converted into by-products or residues, e.g. sawdust, bark and shavings during wood processing.

By-products from wood processing such as sawdust, shavings and bark are already partly applied as raw material for board production or are utilised as a fuel, substituting fossil fuels.

In case the by-products are utilised as a raw material for e.g. board production, there is a risk of ILUC when these raw materials would be redirected to biofuels production. This risk depends on the total demand and availability for wood on the EU market and will become a fact when demand requires felling of additional wood from pristine forests or felling more wood than the net annual increment (see also subparagraph additional felling).

Consumer waste wood

Consumer waste wood includes both bulky refuse and waste wood from industrial sources, such as demolition and construction. Approximately 60% of the produced waste wood is collected and sorted for application as fuel or raw material for panels.

As with chips and shavings from saw mills and other wood processing industries there is a competition between the energy sector and board producers for high quality waste wood.

3.4.5 Biomass: in which sector?

Sustainable biomass can be used to replace fossil fuels and thus reduce GHG emissions in transport. However, it can also be used in electricity and heat production, and in the chemicals industry. These sectors also need to significantly reduce their GHG emissions in the coming decades, and biomass is a convenient means to achieve this. In some cases, the biomass can be used in

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[37] See e.g.: AEAT, 2011. 'Including UK and international forestry into $BEAT_2$': http://publications.environment-agency.gov.uk/dispay.php?name=SCHO0311BUAD-E-E. Johanneum, 2010. 'The upfront carbon debt of bioenergy ': http://www.birdlife.org/eu/EU_policy/Biofuels/carbon_bomb.html.

more than one sector via cascade utilisation, e.g. if woody biomass is first used for fibreboard, and in a later stage as a feedstock of electricity production. This typically leads to the highest added value and environmental benefits.

The choice in which application the biomass should be used depends on the assessment criteria – each application has its pros and cons. The following can serve as a rough guideline, although specific situations should be assessed individually:
- Using waste and residues for electricity and heat production is typically a very efficient means to reduce GHG emissions, if it replaces fossil power or heat production (coal, natural gas, etc.).
- Use in transport as a replacement for petrol or diesel can significantly reduce GHG emissions, but less than in electricity and heat production as described above. Cost, in terms of €/ton CO_2 reduction, is also typically higher in transport than in the other energy applications.
- On the other hand, part of the transport sector has only few alternative renewable energy options. Renewable electricity may be successful in the medium to longer term, but its use is probably limited to only part of the sector. Aviation, shipping and probably also long distance heavy duty transport have few alternative options. Liquid biofuels might even be the only sustainable energy option for aviation, whereas shipping and long distance HDV transport could also use gaseous biofuels (e.g. bio-LNG). Only hydrogen from renewable sources could also be envisaged as future sustainable alternative in these sectors.
- The same holds for some of the other potential biomass users such as the chemical industry and some industrial heat applications. For example, biomass is probably the only feasible renewable option to produce plastics. As mentioned above, options for cascading use could help to increase the efficiency of biomass use and reduce this competition between sectors.
- The electricity sector can also use biomass for power production, but has a range of other alternatives: wind, solar, hydro, etc.

Looking at this overall picture, it seems justified to use a reasonable amount of sustainable biomass available in transport especially from a long-term perspective.
For the same reason, the chemical industry and high-temperature heat production will claim part of the sustainable biomass supply. They also have few alternatives. Other users may also join this future ‘battle for biomass’, depending on the development of alternative renewable energy options.
From a more short-term GHG reduction perspective, however, the land-free sustainable biomass can best be deployed in the power sector. This saves more GHG emissions than using it in the transport sector.

Clearly, a balance has to be found between these short-term and long-term considerations. This requires building a strategy on the best use of the available sustainable biomass waste and residues, which takes into account all sectors, cost, potential alternatives, technological barriers, etc.

3.4.6 Land-free biofuels and biogas in transport - a prognosis for 2020 (and beyond)

The most promising routes for increasing biofuel and biogas production volumes from waste and residue streams in the period until 2020 are those based on the **anaerobic digestion** of the waste streams and by-products with low economic value that were identified above as having low environmental risks. The main reasons for this conclusion are:
- anaerobic digestion is a well known technology;
- there are a multitude of technology suppliers;

– the technology can be combined with current residue processing, such as composting or even landfilling and waste incineration – mechanical treatment and anaerobic digestion could be implemented as a pre-treatment for landfilling or incineration, see e.g. respectively Aterro Groningen and Aterro Wijster;
– it can be combined with nutrients recycling if recycling of stabilised digestate as a fertilizer is ensured by e.g. collection and processing methodology[38]; but returning digestate to soil will not return organic matter;
– for part of these residue streams (manure, consumer waste) there is reduced competition with alternative uses/functions of this biomass although possible negative effects on soil organic carbon should be carefully assessed;
– there is no alternative technology applicable for energy extraction from this biomass;
– depending on national policies and incentives, double counting can make biogas utilisation in transport more attractive than competing options (for biogas producers);
– for manure, anaerobic digestion for biogas production can be combined with manure processing.

Just how much additional anaerobic digestion capacity can be implemented before 2020 depends on government policy, e.g. on budgets for investment subsidies or fees for produced biogas, or waste processing legislation (for example, by requiring anaerobic digestion of digestible organic waste, providing it is not possible to use it as animal feed).

The biogas can then be upgraded into biomethane, and be used as bio-CNG in gas-powered cars or buses, or as bio-LNG in heavy duty trucks or shipping. Both types of applications require specific vehicles and engines (with higher manufacturing and purchase cost), and distribution infrastructure. The technology is mature and some EU Member States (e.g. Sweden, Germany and the Netherlands) have policies in place to promote the increasing market share of these vehicles in transport, but the share in overall transport fuels is still negligible. This can also prove a barrier to large-scale deployment of biogas in the transport sector, in 2020. So, national policies targeted at increasing the sales of gas-powered vehicles and the distribution infrastructure are also essential to realise the potential of these biogas routes.

The actually achievable 2020 potential for sustainable biomethane in transport therefore depends on
– the successful increase of anaerobic digestion throughout the EU;
– a large-scale increase of gas-powered vehicles sales and filling points; and
– the question which part of the biomethane will be used in transport, and which will be used for power and/or heat production.

All three issues depend significantly on national policy conditions.

Starting with the maximum technical potential estimated in Table 2, it can be concluded that the technical potential for sustainable biofuels from waste and residues is about 3,500 PJ, of which 1,450 PJ can be produced using current commercial production technology. Most of this, about 1,360 PJ, is biogas potential. Part of this technical potential is already being produced, but current production data can not be compared to these estimates because EU biogas production statistics do not distinguish between different feedstocks.

[38] For example by separate collection and processing of biomass residues with low concentrations of polluting components (e.g. heavy metals) from which remaining digestate can be reused as a green fertilizer.

Current biomethane use in transport is still very low, 2 PJ in the EU in 2010 (EurObserv'ER, 2011a), but increasing. Assuming that this route is strongly promoted in the coming years, it is estimated that sustainable biomethane use could increase to about 300-500 PJ in 2020. This would imply growth rates of 80 to 90% per year – very significant indeed, but comparable to the recent growth rates of photovoltaic electricity production in the EU (EurObserv'ER, 2011b).

Another sustainable fuel option that can be easily implemented is **biodiesel (FAME, HVO) production from used cooking oil and C1 fats**. The biodiesel production sector has already discovered these feedstocks and is actively pursuing increased collection of this kind of feedstocks. For example Rotie –a waste fat collection and processing company in the Netherlands - has recently begun offering a € 32 fee per 240 litre container of waste fats to sporting clubs and similar organisations to stimulate used cooking oil supply[39]. These fuels can then be blended into diesel (up to certain limits), and therefore do not require the additional investments and policies needed for the biogas routes described above. However supply of C1 and recycled HVO is limited: true waste oil is estimated to be able to contribute only about 100 PJ to the 2020 RED target, without significant potential for scaling up.

How much production capacity can be realised in 2020 for **ethanol from straw** or **DME from woody biomass** is difficult to estimate. In both cases it concerns large-scale and capital-intensive production technologies which can probably be financed only by a limited number of initiators. In addition, DME can only be used in adapted vehicles, and therefore requires both dedicated vehicles and infrastructure. Next to this the number of technology providers that can offer proven-off-the-shelf-technology at industrial processing capacity is still zero for the pre-treatment, enzymatic hydrolysis and C5 fermentation utilised in ethanol production from lingo cellulosic biomass and just one for pyrolysis (Dynamotive) and gasification (Krupp Uhde).
The large investments and the limited availability of the technology will probably limit production capacity to a maximum of several industrial-scale installations before 2020. These may significantly contribute to some Member State's biofuel mix, but overall EU production capacity will remain limited.

Summarising, the technical potential for biofuels from waste and residues is considerable but only a share of it can be used without generating some adverse environmental effects or depriving other industry sectors that need to reduce CO_2 emissions from an essential source of raw materials. Looking at ready technology, the FAME/HVO production routes are likely to require the least effort to deploy, resulting in a maximum realistic potential of about 90 PJ in 2020. If the biogas routes are strongly promoted in the coming years – increasing biogas production but also increasing the share of gas-powered vehicles in the EU fleet and ensuring adequate infrastructure to fill up these vehicles - the maximum realistic potential might be as high as 300–500 PJ. New, 2nd generation production routes are also likely to grow in the coming years, and may also start to contribute to the RED target in 2020, but production capacity will be relatively limed.
It is thus concluded that a total sustainable biofuel/biogas potential of about 400 to 500 PJ might be feasible in 2020, if the necessary drastic policy changes are made in the short term.

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[39] http://www.rotie.net/nl/news/gebruikt-frituurvet-levert-extra-inkomsten-voor-clubs-en-verenigingen.

In the longer term, biogas use in transport could further increase, as well as the 2nd generation biofuel production. Once the latter technology becomes operational and their production capacities are expanded, a total potential of more than 3,500 PJ of biofuels from waste and residues with low economic value comes into sight. However, it is still unclear what effects the large-scale use of residues to produce 2nd generation biofuel will have on nutrient and soil organic carbon cycles in agriculture. Furthermore, this would require that all biomass waste streams would be gathered and processed throughout the EU, and then used for fuel production in transport – conditions that are not likely to be met even in the future.

3.5 Hydrogen from renewable energy sources

This option is still in the R&D phase, and costs are high compared to conventional driving and electric vehicles. It is generally expected that hydrogen in transport might be an interesting alternative for the longer term, but it will not yet have a significant share 2020.

Hydrogen can be produced from a broad variety of energy sources. Currently, hydrogen is mainly produced via natural gas reforming, and used in refineries However, it can also be produced from sustainable and renewable energy, for example from renewable electricity. Hydrogen can be used in any type of vehicle, typically in combination with a fuel cell. The main barrier to its market uptake are the cost of the cars, and the investments needed to build a hydrogen fuelling infrastructure. R&D is on-going to develop this technology further and reduce cost. In the EU, much of this work is being coordinated through the Fuel Cells and Hydrogen Joint Undertaking (FCH JU, see www.fch-ju.eu)

As hydrogen is an energy carrier with great flexibility regarding energy source, it has the potential to contribute significantly in the decarbonisation of the transport sector, if the cost become attractive. In some respects, it competes with battery electric cars. For example, both can use renewable electricity to achieve zero-emission transport and both can be used for energy storage in case of temporary overproduction of renewable electricity. Battery electric cars have the advantage that they can be rolled out without up-front large-scale investments in charging infrastructure, whereas hydrogen may be a better option for heavy duty and long-distance transport due to its higher energy density.

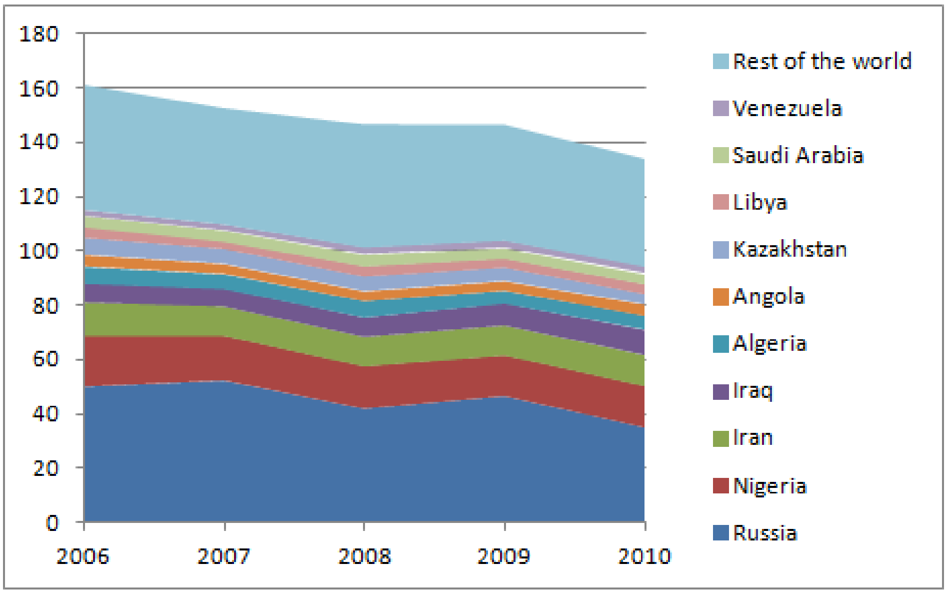
Most experts will agree that it will take quite some time before it could achieve significant market shares in transport. Significant investments are required to roll out a large-scale hydrogen distribution network in the EU. First steps in this development are made in R&D programmes, but it will take time before its potential can be predicted with any certainty. As the focus of this study is 2020, this option is not further considered in this report.

3.6 Reducing emissions from oil and gas flaring and venting

One of the means to reduce the GHG intensity of fossil fuels is to reduce GHG emissions of flaring and venting in the upstream part of the oil production industry.

Every year oil producers flare and vent a volume of natural gas and associated equivalent to the combined gas consumption of Central and South America. Developing countries and economies in transition account for more than 85% of gas flaring and venting, with Russia, Nigeria, Iraq, and the Islamic Republic of Iran being the largest contributors (see Figure 5).

Figure 5 **Overview of flared volumes**



Source: See footnote[40]. All figures in BCM/year.

The associated greenhouse gas emission related to the flared volumes of gas can be estimated assuming a specific emission of 2.4 Mtonnes CO_2eq./BCM[41] of gas (see IPIECA/API, 2009) to 2.9 Mtonnes CO_2eq./BCM of gas (E.ON Masdar, 2011).

3.6.1 Technological options for reduction of flaring

In theory several different technical options are available or will become available in the short term for reducing flared volumes of associated gas (see Figure 6 and Figure 7). All options require gas treatment in which heavy metals, sour components and condensable components are removed.

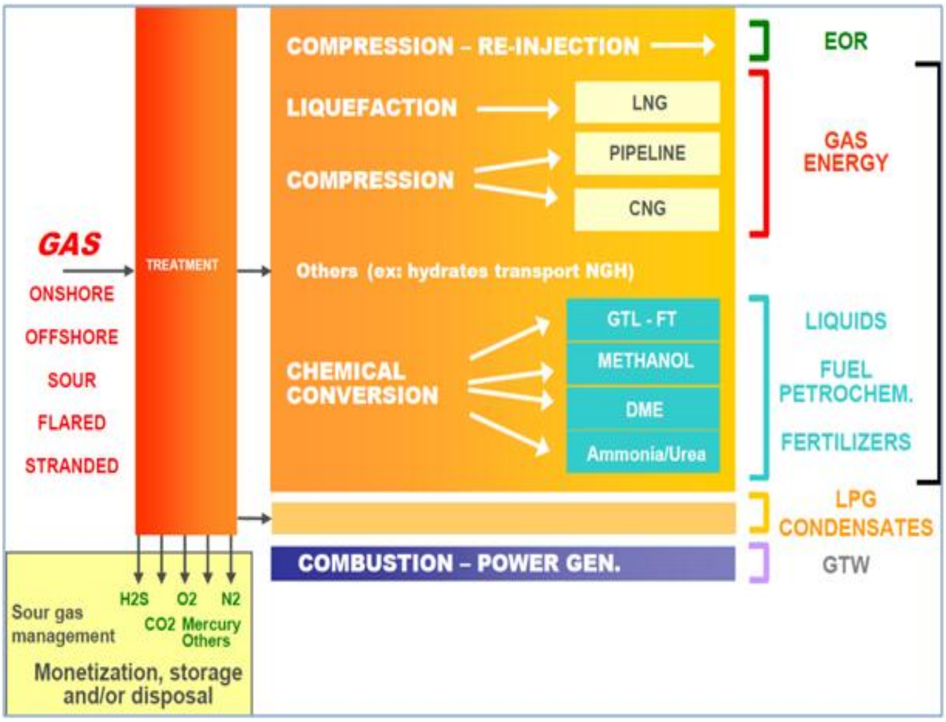
The available technical options and options under development are designed for both (very) large flows of gas that will be available for a long period of time and for small volumes that may be depleted within a limited period of time.

40 http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTOGMC/EXTGGFR/0,,contentMDK:22137498~menuPK:3077311~pagePK:64168445~piPK:64168309~theSitePK:578069,00.html.

41 BCM = billion cubic metres.

In general large-scale conversion technology already has proven to be technologically mature, while for most conversion routes miniaturisation is under development. The exemption is LNG production, which is already available as a containerised technology.

Figure 6 **Potential future and existing routes for utilisation of natural gas and associated gas**



Source: Total, 2008.

Figure 7 **Technical maturity of the different technologies for processing of natural gas and associated gas**

Paper study	Pilot unit (lab)	FEED	Demo unit	Industrial units	Standard technologies
Floating LNG Floating GTL		Floating (mini)LNG CNG	DME (direct)	FT-GTL MeOH DME (indirect)	Onshore/offshore pipelines, LNG, onshore mini LNG

Source: Total, 2008.

Mini LNG has recently been developed and has become available as container-sized units applicable even for small off shore sources. Suppliers are e.g. Hamworthy, Linde and others. A 20 tkpy plant is shown in Figure 8. For ammonia, too, container-sized equipment is commercially available and is offered e.g. by Proton Ventures in the Netherlands. There are also efforts of miniaturising methanol production technology. Methanol could become a new intermediate for the production of olefins but could also be an alternative for kerosene or a more environmental-friendly alternative for wood fuel in domestic applications such as cooking in developing countries.

Another option is power and/or heat production on site with decentralised combustion engine or gas turbine skids. This option is already applied for small gas fields in the Netherlands such as Schagen and Donkerbroek, for which investments in pipeline infrastructure would be unprofitable.

Figure 8 Snurrevarden Mini LNG plant in Norway

Source: http://www.hamworthy.com/PageFiles/177/Onshore%20Brochure%20%20Small%20Scale %20and%20Mini%20LNG%20Systems.pdf.

3.6.2 Pros and cons of the different technical options

The pros and cons of the different technologies are illustrated in Figure 9 (Total, 2008). When there is no local market or existing pipeline system, LNG remains the preferred monetisation option. Efforts are being made to improve its efficiency and profitability at smaller capacities (Mini LNG, Floating LNG). CNG represents a viable niche for small capacities and short transport distances provided regional markets exist. Gas conversion technologies produce added value products, especially in a high oil price scenario, but different challenges still need to be tackled:

- Fischer-Tropsch-Gas-to-Liquid (FT-GTL): high investment costs, efficiencies and CO_2 management.
- Methanol: relative price fluctuations, single large plant impact on world-scale production.

Figure 9 **SWOT analysis of the different monetising technologies**

	LNG	CNG	FT-GTL	Methanol	DME
Maturity	Standard technology		Few industrial units	Several industrial units	
Efficiency	~ 80-85% (ex:10,000 km + regas)	~ 90% (ex:1700km) f(distance)	~ 55-60%*	~ 65%*	~ 62%*
CO_2 emissions *(kt/Mboe inlet)*	~ 50 (ex:10,000 km + regas)	~ 30 (ex:1700km) f(distance)	100*	70*	77*
Markets	150 Mt/y *(Regasification)*	Regional	1100 Mt/y (Diesel)	40 Mt/y	Great potential
CAPEX	First train, added trains	Leasing/service contract	Multiple trains		
OPEX (incl. CO_2)		OPEX = Transport f(distance, capacity, gas composition)			
Transport	f(distance)				
Prices *(relative)*	*Gas market*	*Gas market*	Premium diesel	?	[LPG, +20% LPG]

Source: Total, 2008.

The further development of Total's Methanol-to-olefins technology could open up the olefins market for currently flared and vented gas and could change the perspective offered by methanol production.

3.6.3 Barriers for implementation

Barriers for implementation are not technical, but rather economical, organisational and policy related. They include for example Nexant (2006):
- hydrocarbon monetisation priorities for producers, focusing on bringing oil to the market;
- commercial viability:
    - production profile and volumes of gas flared;
    - infrastructure constraints;
    - absence of viable markets.
- contractual and regulatory framework.

Nexant also points at organisational barriers, such as a lack of medium to long-term policy strategy concerning recovery and monetisation of associated gas and NGLs[42] and lack of coordination among different stakeholders.

A study for the World Bank identified similar barriers for utilisation:
- lack of an efficient regulatory framework;
- poor access to local and international energy markets;
- financing constraints for projects that reduce gas flaring.

Under the Global Gas Flaring Reduction Partnership and programs of e.g. the EU and private initiatives such as the Climate Investment Funds, efforts are made to resolve these barriers. These however are evaluated to be only limitedly successful thus far (see GE Energy, 2010):

> *"While some financing tools exist from both public and private sources, there is a shortage of direct initiatives to develop countries' gas infrastructure backbone.*
> *Offsets programs like the Clean Development Mechanism (CDM) have demonstrated only limited success. Critical investments and pipeline, processing, and storage are required to make it economically feasible to gather the supply and foster gas use."*

42 NGLs = natural gas liquids, basically LPG and higher hydrocarbons.

Reduction potential

Figures for global reduction potential of flaring and venting emissions for the period up to 2020 are scarce. In E.ON Masdar (2011) a total reduction potential for global gas flaring of up to 150 million tonnes CO_2 out of a total emission of approximately 400 million tones of CO_2 by 2020 is mentioned. This figure is however not further substantiated.

Country specific analyses such as the 2010 Clean Technology Fund investment plan for Kazakhstan give more detailed information concerning reduction potential and the required investments and operational costs. However, analyzing the sources for the main flaring and venting countries will require quite some efforts.

3.7 Conclusions

Clearly, there is a whole range of sustainable options to meet the RED and FQD target, also within the broad definition of sustainability as given in Section 1.2 as a starting point.

Reducing energy use would be the fist option to implement, as this directly reduces CO_2 emissions and fossil fuel use and at the same time increases the efficiency with which the available renewable energy is used. This can be achieved by improving the fuel efficiency of vehicles, reducing transport volume and improving transport efficiency, by a shift to more efficient modes, etc. Many of these measures have significant potential, but require effective policy measures to be implemented. In the following, we assume that up to 22% energy reduction – compared to a business as usual development of emissions - might be feasible, noting that this requires significant policy interventions.

Increasing renewable electricity use in transport also has very significant potential in the longer term, but its maximum contribution in 2020 is relatively limited as the uptake of electric vehicles has only just started. Assuming a gradual but nevertheless rapid development of electric cars and vans, we estimate that road transport could contribute about 16 PJ of renewable electricity with the current RED methodology. These figures can then be multiplied by 2.5 in the RED methodology. Electric non-road transport is expected to contribute about 100 PJ of renewable electricity, again, with the current RED methodology.

Biogas has the potential to deliver about 300-500 PJ sustainable transport fuel in 2020, and can do so by only using uncontested feed stocks (i.e. true waste). The production and vehicle technology is mature, but the high upfront investments - to collect the waste, to produce the gas, to buy vehicles able to run on gas and to make the gas available through dedicated filling stations – are a barrier to its growth rate.

Used cooking oil (UCO) and animal fats are a sustainable feedstock for biodiesel production. Its EU potential is, however, limited, and estimated to be about 100 PJ. This could be reached in 2020 if market conditions are right, as investment are relatively limited.

Second generation biofuels are not expected to contribute much before 2020, unless both demand and investments significantly increase in the coming years. The technology is being developed, but still only in R&D stage. The amount of sustainable resources is uncertain, because of competing uses and environmental risks.

Hydrogen from renewable electricity might also be feasible in the longer term, but is also not expected to contribute in 2020.

The progress of each of these options depends strongly on policy actions from Member States and the EU, on investments from the various industries, on the willingness of consumers to purchase electric vehicles and on the market uptake of biomethane vehicles for dedicates uses (e.g. buses). It is important to realise that the potentials given here can only be achieved if effective policy measures are implemented in the coming years, as these developments need time.

4 How to meet the RED and FQD targets sustainably: exploring the options

4.1 Introduction

Based on the previous findings, a number of scenarios can be developed to further explore the question if and how the RED and FQD targets can be met without expanding the use of cultivated, land-based biofuels. The basic premises of these scenarios are:

- In accordance with the precautionary principle established in the EU Lisbon treaty, policy measures are introduced to freeze the consumption of land-based biofuels, or scale it down for the period up until 2020. An ILUC factor methodology is introduced to capture and display the real and full carbon footprint of those land-based biofuels still counting towards the targets.
- Sustainability requirements for land-based biofuels are strengthened from the social and agricultural perspectives, for example by introducing sustainability requirements in relation to land rights, food security, agricultural practices and water usage.
- Measures are taken to reduce fuel consumption, by further increasing vehicle efficiency, modal shift and reducing transport demand.
- The uptake of electric vehicles is promoted.
- Production of ILUC-free biofuels or low ILUC risk biofuels is increased in reasonable amounts, subject to overall sustainability limits, taking into account the risks identified in Section 3.4.

As a first step, **three basic biofuel scenarios** are developed. The key difference between these is the level of land-based (i.e. cultivated) biofuels that is used in 2020:

- **Assumption 1 - No land use:** land-based biofuels consumption is reduced to zero, only biofuels based on waste and residues are allowed.
- **Assumption 2 - 2008 land use:** land-based biofuels consumption is brought back to 2008 levels.
- **Assumption 3 - 2010 land use:** land-based biofuels consumption is frozen to current (2010) levels.

On top of these scenarios, a number of variants are then developed with which the gap between the biofuels volumes and the 10% RE in transport target and 6% GHG intensity in fuel quality target of the FQD could be filled.

This chapter is primarily intended to be an exploration of the requirements of the RED and FQD on an EU level, for the situation where demand for land-based biofuels is reduced over time, or maintained at current levels. In the following, scenarios are assessed on an EU-level. Realistic and more feasible scenarios are developed in the next chapter.

4.2 The assumptions: defining the base level of land-based biofuels in 2020

The first step is defining the base level of land-based biofuels for each of the three biofuels assumptions. The quantities of biofuels with Assumption 2 and 3 are derived from the Biofuel Barometer 2009 and 2010 (EuroObserv'Er, 2010 and 2011) [43].

- **Assumption 1:** land-based biofuel consumption is reduced to zero.
- **Assumption 2** takes the 2008 consumption of land-based biofuels as a starting point: 421.4 PJ.
- **Assumption 3** freezes the quantity of land-based biofuels to the biofuels volumes consumed in the EU in 2010, which was 582.1 PJ.

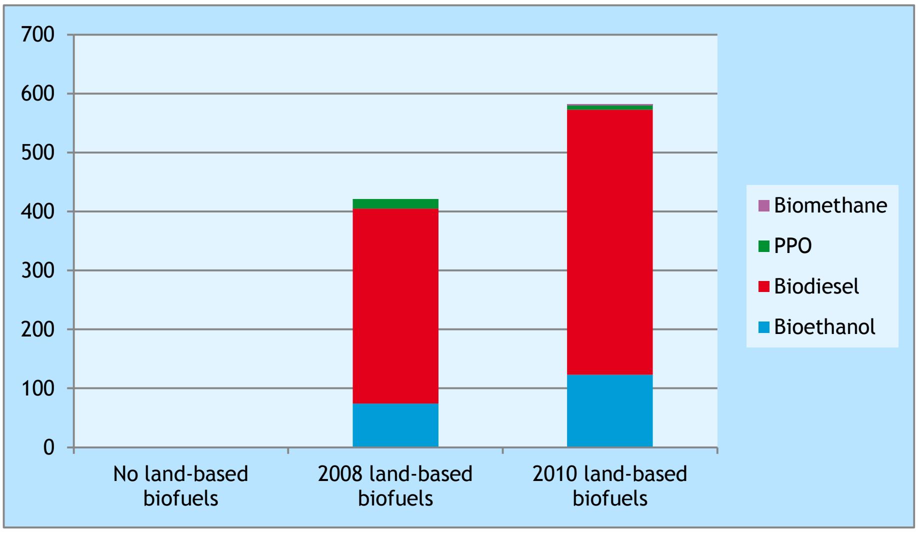
Figure 10 shows the share of the various land-based biofuels for the years 2008 and 2010. Mainly biodiesel and bioethanol have been consumed in those years. Between 2008 and 2010, the consumption of land-based biofuels increased by 38.1%.

Because the Biofuel Barometer does not make a distinction between single-counting and double-counting biofuels (i.e. biofuels produced from waste and residues), assumptions have been made on the share of double-counting biofuels in these years (2008 and 2010):

- Double-counting biodiesel is only significant in the Netherlands, where 20% of the biodiesel is double-counting in 2008, and 50% in 2010[44];
- 100% of the biomethane is assumed to be double counted for both years.

This is relevant to calculate the contribution of the base level biofuels consumption towards the RED target.

Figure 10 Base level of biofuel consumption of the different assumptions (in PJ)



43 While writing this report, the Biofuel Barometer 2012 has been published. This new publication contains somewhat lower numbers on biofuel consumption in 2010 than the previous barometer: 567 PJ (i.e. 13.55 Mtoe) instead of 581 PJ. Assuming the new numbers are correct, the base level of biofuels used for Assumption 3 is slightly overestimated in this report, and somewhat more biofuels from waste and residues, renewable electricity or energy efficiency improvements are needed to meet the 10% target than predicted here.

44 The Netherlands was one of the few Member States that implemented double counting in their biofuels policies, most other Member States have only introduced this in recent years.

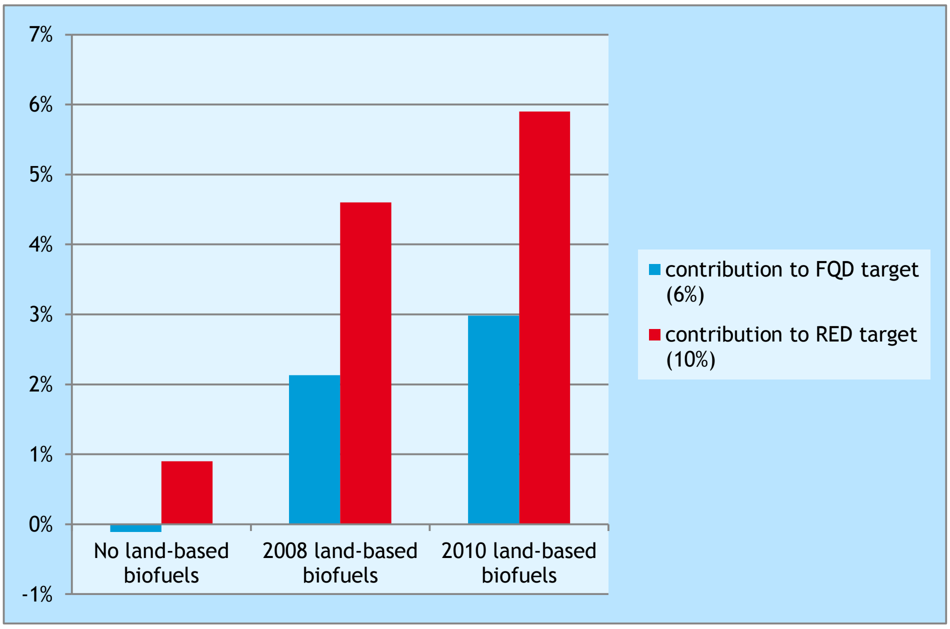
In all three scenarios, there is also a base-level contribution from renewable electricity use in railway transport.

This results in the following base level contribution to the RED target:
- Assumption 1 only assumes a contribution from renewable electricity in non-road transport (i.e. railway). This contribution is limited to 0.9% to the RED target, under current RED methodology.
- Under Assumption 2, the base level consists of the same contribution from electric railway plus the 2008 level of biofuels. This adds up to a 4.6% contribution towards the RED target.
- Assumption 3 results in a base level of 5.9% renewable energy, as more land-based biofuels are added. In these calculations, baseline data for transport energy demand were taken from the EU-wide transport model TREMOVE, version 3.3.2 alt (see www.tremove.org for more information).

The base level biofuels also contribute to the FQD target. In Scenario 1, there is no renewable energy to contribute to the FQD in 2020, as the electric railway transport is outside the scope of the FQD. Instead, the TREMOVE scenario that was used predicts a slight increase of the diesel share in the EU transport fuel mix, leading to a slightly higher GHG intensity of the fuels in 2020 than in the baseline (the GHG intensity of diesel is higher than that of petrol). In 2020, the contribution of the base level of biofuels towards the FQD target was found to be about 2.1% for Assumption 2 and 3.0% for Assumption 3.

The combined results are shown in Figure 11. The differences between these contributions and the 10% and 6% targets of the RED and FQD respectively are the gaps that we aim to fill sustainably in this report – with the strict sustainability definitions of Section 1.2.

Figure 11 Contribution of the different assumptions to the RED and FQD targets



4.3 Extremes of the playing field

Starting with these base level assumptions, we can now explore the extremes of the playing field. This is done by defining two variants, each focussing on a renewable energy source that has the potential to contribute sustainably towards both the RED and the FQD target.

These variants are defined along the following lines:
- **Variant A:** The remainder of the RED target is mainly achieved with biofuels based on waste and residues.
- **Variant B:** The remainder of the RED target is mainly achieved with renewable electricity use in road transport.

These two variants will be considered for each of the three basic assumptions. For each variant and assumption, we will determine how much biofuels or renewable electricity is needed to meet the RED target, assess what the effect would be of reducing transport energy use (Section 3.2) and determine the contribution of the renewable energy towards the FQD target.

4.3.1 Variant A: Filling the gap with biofuels from waste and residues

As described above, Variant A focusses on what it would mean to meet the 10% target by increasing the amount of sustainable biofuels from waste and residues. In this variant, the following options are explored in the calculations:

I Only biofuels from waste and residues (Article 21(2)) are used, otherwise business as usual.

II Only biofuels from waste and residues are used, in combination with a transport energy use reduction of 10%.

III Only biofuels from waste and residues are used, in combination with a transport energy use reduction of 20%.

Contribution to the RED target

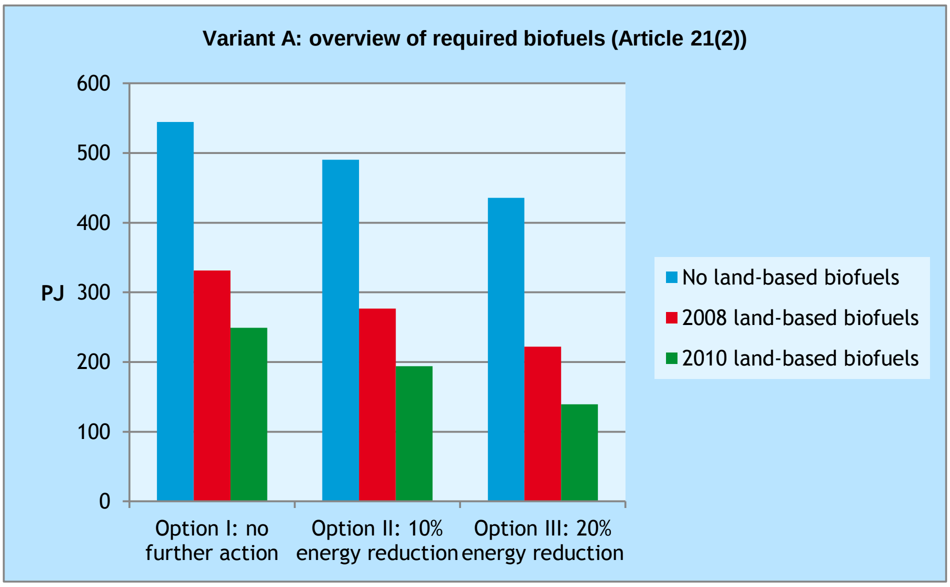
For each of the options within Variant A, the amount of biofuels from waste and residues needed to meet the 10% target was calculated. The results are shown in Figure 12. Biofuel volumes between about 140 and 550 PJ would be needed, depending on the assumptions and options.

To put these figures into the context of the findings of Section 3.4, it can be concluded that these volumes are within the range of the feasible and sustainable biofuels potential in 2020. It could be achieved with a significant increase in deployment of biodiesel from UCO and C1 animal fats and biogas from uncontested feedstocks (e.g. manure and household waste), possibly complemented by 2^{nd} generation biofuels.

Option I clearly requires more of these biofuels, the same holds for Assumption 1. Energy reduction helps to reduce the required amount of sustainable biofuels from waste, and increasing the level of land-based biofuels has a similar effect.

Reducing transport energy demand by 10 or 20% will reduce the amount of required biofuels accordingly: 10% reduction of energy demand means that with Assumption 1, the need for the sustainable biofuels also reduces with 10%. However, this reduction is higher than 10% under Assumptions 2 and 3: as the absolute level of land-based biofuels is the same in all three cases, they will have a larger contribution to the target if total transport energy demand is reduced.

Figure 12 Overview of required biofuels (Article 21(2)) for the different options within Variant A



Contribution to the FQD target

Figure 13 explores how the three options investigated here may affect the contribution of these renewables to the FQD target.

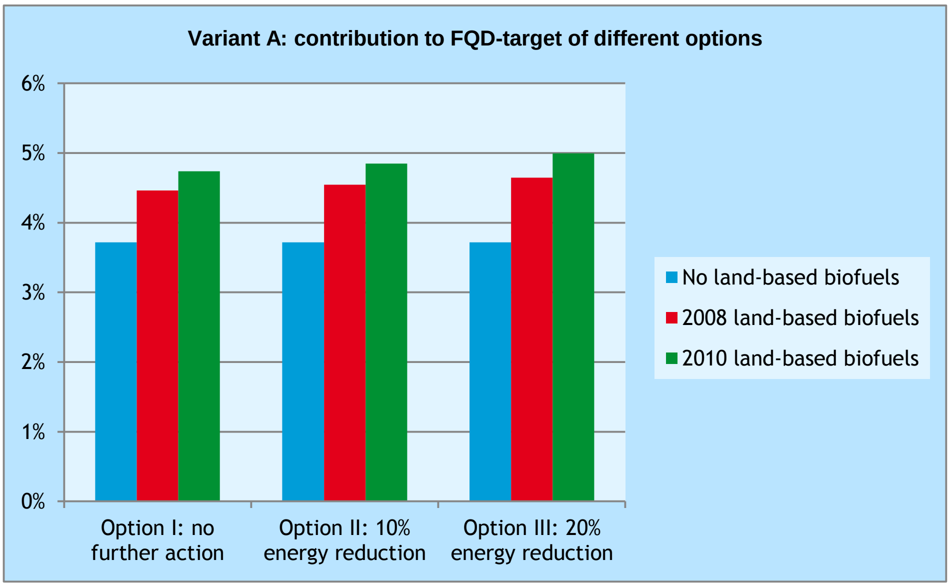
The main conclusion is that in most options, the renewable energy will contribute 3.7% to 5% of the (mandatory) FQD target of 6% reduction of the GHG intensity of transport fuels. This value is the lowest for Assumption 1, as the share of double-counting biofuels is highest in that case which reduces the actual biofuels volume in transport fuels - and double counting does not apply to the FQD. Note that reducing fuel demand also reduces the biofuels volume in 2020, but without this negative impact on the FQD contribution.

The lower the contribution of renewables towards the target, the more additional CO_2 mitigation measures need to be implemented by fuel suppliers. As discussed in the previous chapters, this can be done through:

- GHG mitigation in the fossil fuel life cycles, notably be reducing emissions of flaring and venting, as discussed in Section 3.6;
- choosing biofuels with higher GHG reduction values than assumed here;
- increasing the share of other low-carbon fuels or energy carriers such as electricity.

In view of the relatively high biofuels cost, and the relatively limited means that fuel suppliers have to implement the last option, the first mitigation option, reducing flaring and venting, would seem to be the most likely option to be implemented.

Figure 13 Variant A: contribution to FQD target of different options

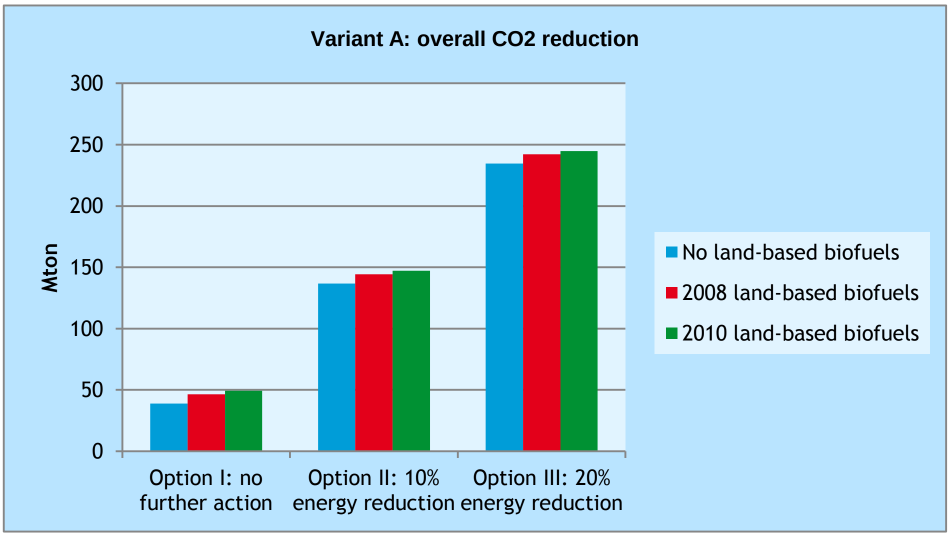


Overall CO_2 reduction

Both the renewable energy used and, in Options II and III, the energy demand reduction will reduce the overall CO_2 emissions of the transport sector. These are shown in Figure 14, for the various scenarios and options. Clearly, energy reduction is a very effective means to reduce emissions, as it directly results in an equivalent CO_2 emission reduction. A 10% reduction would amount to about 100 Mton CO_2 reduction, 20% represent about 200 Mton CO_2 reduction.

All renewable energy options only reduce CO_2 emissions partly, although a minimum reduction of 60% is assumed even for the land-based biofuels, in line with RED requirements and methodology. It will depend on the effectiveness of implementation of ILUC emission in the RED and FQD whether these are realistic figures or rather significant overestimations of real-life emission reduction. Furthermore, the double counting of biofuels (or even triple counting) reduces the actual share of renewables strongly, and thus the CO_2 emission reduction achieved with biofuels. A 10% energy demand reduction will thus reduce much more CO_2 emissions than a 10% RE share.

Figure 14 Variant A: CO_2 reduction compared to the reference assumption (Mton, life cycle emissions)



Feasibility

Comparing the volume of biofuels from waste and residues required in the various scenarios with that of the Member State plans for 2020 (109 PJ) it becomes clear that this variant would require very significant upscaling of this type of biofuels production and use.

When comparing these results with the potential availability of biofuels from waste in 2020 and beyond (Section 3.4), the volumes can be considered to be feasible in 2020, provided that policy strategies related to waste processing and bio-CNG/bio-LNG use in transport are changed quite drastically in the coming years. Combining this with significant efforts into reducing energy use in transport can significantly help to achieve the RED and FQD targets sustainably, and at the same time significantly reduce CO_2 emissions of the sector.

4.3.2 Variant B: Filling the gap with renewable electricity

For Variant B similar calculations are made as for Variant A, but instead of using biofuels from waste and residues to meet the RED target, renewable electricity in road transport is used in this variant.

The following options are explored here:

I Only renewable electricity in road transport is used to meet the RED target, otherwise business as usual.

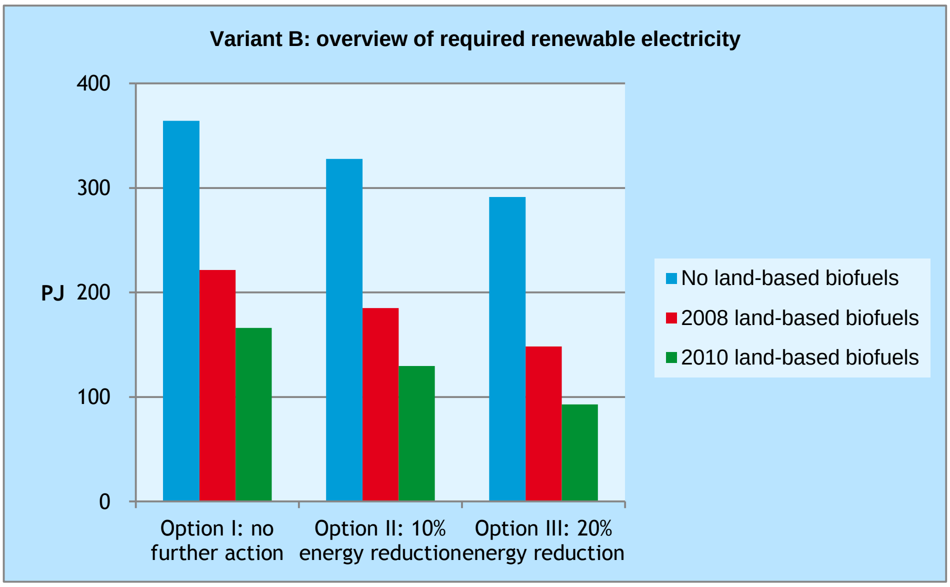
II The use of renewable electricity in road transport is combined with a transport energy use reduction of 10%.

III The use of renewable electricity in road transport is combined with a transport energy use reduction of 20%.

Contribution to the RED target

The results are shown in Figure 15. The business as usual case, Option I, would require 364 PJ of renewable electricity in road transport to meet the target under Assumption 1 (no biofuels at all). The more the energy demand is reduced, the least renewable electricity is needed, as this increases the contribution to the RED target per PJ of renewable electricity. Of course, adding a base level of biofuels also reduces the amount of renewable electricity needed to meet the target. To illustrate what these data mean in real life: 364 PJ would require about 130 million electric and plug-in hybrid vehicles in the EU, which would be more than 40% of all EU passenger cars, in 2020.

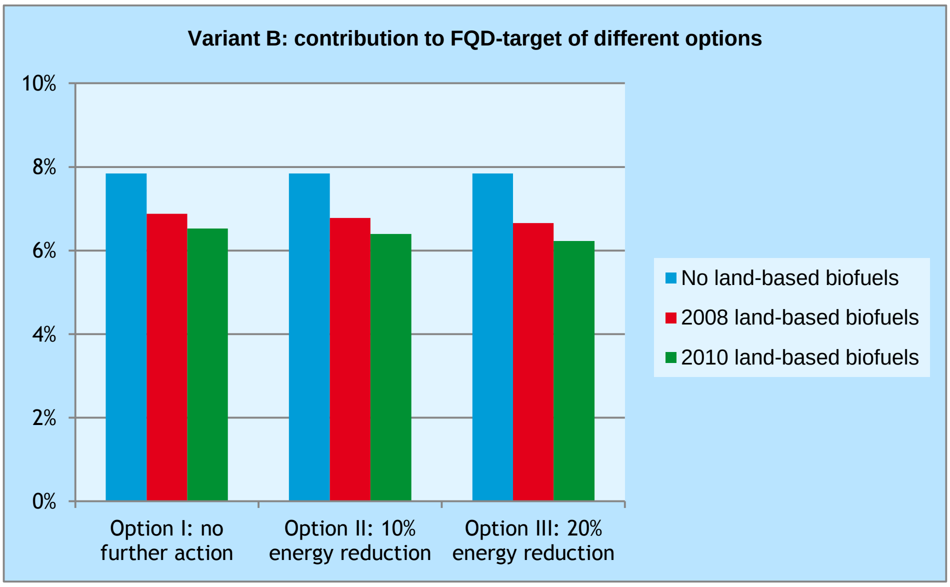
Figure 15 **Overview of required renewable electricity in road transport for the different options within Variant B**



Contribution to the FQD target

In Figure 16 the contribution of these options to the FQD target is depicted. Options I to III all score very well in this respect. All three options can easily meet the 6% target and may even reach almost 8% reduction of the average life cycle emissions of fuels. The reasons for these high outcomes are the higher efficiencies of electric vehicles in comparison to conventional vehicles, the multiplication factor of 0.4 that is included in the FQD calculations, and the relatively low average GHG intensity value of EU electricity in 2020.

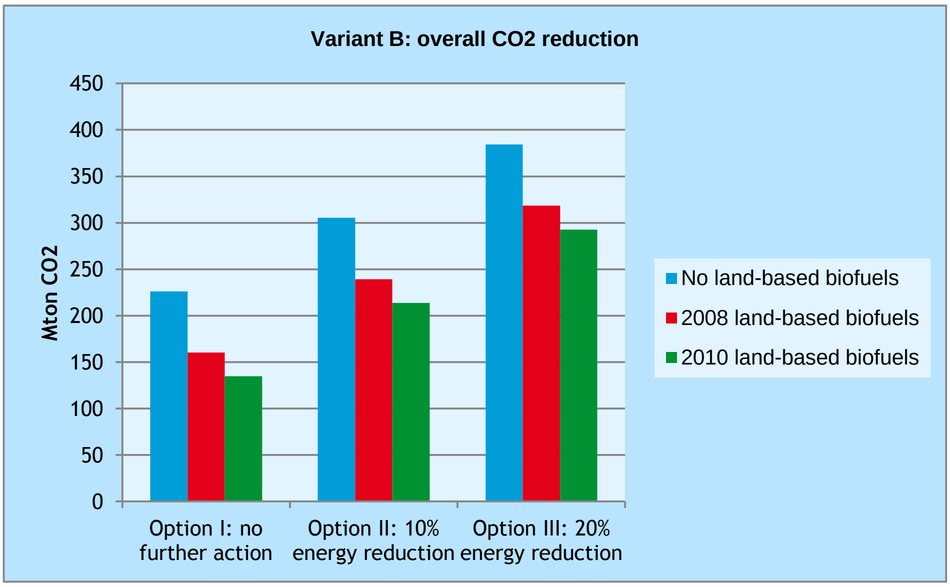
Figure 16 **Variant B: contribution to the FQD target of different options**



Overall CO_2 reduction

Shifting from conventional fuels to electricity can thus also result in quite significant overall CO_2 emission reductions, as can be seen in Figure 17. Combining this with other measures to reduce overall transport energy demand, as in Options II and III, will even be more effective. Of the emissions reductions in Option II, about 100 Mton is due to energy saving, in Option III this effect doubles to about 200 Mton.

Figure 17 Variant B: CO_2 reduction compared to the reference scenario (Mton, life cycle emissions)



Feasibility

The amount of renewable electricity in road transport needed to fill the gap between the base level renewable energy and the 10% RED target can now be compared with the estimates of potential electricity use derived in Section 3.3: 5 to 16 PJ renewable energy in 2020. Clearly, this is far below what is needed to meet the target, 93-364 PJ, depending on the biofuels base level and the energy demand reduction assumed for 2020.

Putting these figures into context: 364 PJ would require that more than 40% of all EU passenger cars would be fully electric or plug-in hybrid vehicles, in 2020. The lower end of the range, 93 PJ, can be achieved if about 10% of the EU-wide fleet would be electric or plug-in hybrid, still much higher than current estimates of EV market shares in 2020[45].

4.4 Conclusions of these calculations

The calculations above explore the requirements of the RED, if it was to be met with non-land use biofuels or renewable electricity only, for different energy demand developments.

[45] Note that 10% might be feasible in some countries that have effective and strong incentives in place, but considering the current levels of EV production, incentives and sales we do not consider this market share to be feasible on EU level.

RED
The three assumptions illustrate the effect of different quantities of base level biofuels. Clearly, the higher the base level of biofuels, the less alternative renewable energy sources are needed.

When comparing Variant A and B, it can be seen that less renewable electricity in road transport is needed compared to the required amount of biofuels or biogas to fulfil the RED target (in terms of PJ). This is due to the difference in multiplication factor: a factor of 2 is applied for biofuels from waste, 2.5 is used for renewable electricity. Nevertheless, in the short run, the feasibility of the variants with non-land biofuels or biogas is much higher than those based on renewable electricity in road transport. The share of electric vehicles is negligible today, whereas a 10-45% fleet share would be needed throughout the EU if the 2020 target is to be met with EVs.

Meeting the RED target with these two renewable energy options can be made much easier (and more feasible) if a number of accompanying measures are implemented that reduce fuel demand in the road transport sector. This effectively limits the required renewable PJ, whilst reducing overall CO_2 emissions significantly (see below). The more energy reduction is achieved, the less renewable energy is needed to meet the target.

In these scenarios, we have furthermore assumed that the RED methodology is modified so that renewable electricity used in non-road transport is treated the same as that used in road transport, and thus also multiplied with 2.5. This clearly helps to meet the target sustainably, as it adds another 1.3 to 1.5% towards the target. Under the current methodology, this would have to be filled with other types of renewable energy, increasing the need for sustainable biofuels from waste and renewable electricity, or for additional energy demand reduction.

FQD
Increasing the share of electric vehicles, Variant B, cannot only be seen as a very energy-efficient option to meet the RED target, it is also a very efficient option to meet the FQD target. The reasons for the high contribution of EVs towards the FQD target are threefold:
– the higher energy efficiency of these vehicles;
– the factor 0.4 which is included in the FQD calculation to compensate for the higher fuel efficiency of those vehicles;
– the relatively low average GHG intensity of electricity.

Due to these effects, electric vehicles achieve higher CO_2 intensity reductions than non-land-based biofuels.

If the RED target is met with non-land, sustainable biofuels or biogas, the contribution to the FQD target is also significant, albeit other measures such as reduction of flaring and venting emissions also need to be deployed.

Overall CO_2 emissions
Shifting to electric road transport has high CO_2 reduction potential, per PJ renewable energy: a reduction of about 250 Mton CO_2 emissions could be achieved if the RED target would be met with renewable electricity only. Meeting the target with sustainable biofuels from waste and residues only will result in almost 50 Mton CO_2 emission reduction.

Reducing energy demand of the sector has clearly very significant potential for overall CO_2 reduction in 2020. A 10% reduction will save about 100 Mton, a 20% reduction about 200 Mton CO_2 emissions.

5 Developing realistic and sustainable scenarios for 2020

5.1 Introduction

The calculations of the previous chapter gave insight into the extremes of the playing field: the potential demand for non-land-based biofuels and renewable electricity in transport in 2020 for the various scenarios, variants and options explored – all aimed at how to meet the RED target of 10% RE in transport sustainably and contributing to the 6% reduction target of GHG intensity in fuels defined in the FQD.

In the following, a number of integrated scenarios is developed, where the results of the previous two chapters are combined. A crucial question to be answered here is whether the RED and FQD targets for 2020 could be met without additional land use: are there sufficient alternatives to land-based biofuels, and can these be deployed in time with specifically targeted policies? As concluded earlier, quite drastic policy changes will be necessary at both EU and national government level to move from the current situation towards much more effective decarbonisation of the transport sector. How can the potentials of the various options be utilised, and what policies could be implemented to steer the markets towards these scenarios?

5.2 Feasible and sustainable scenarios for 2020

As was concluded in the previous chapters, the renewable energy sources with the highest potential contribution to the RED target in 2020 are the biofuels and biogas options from waste and residues. Renewable electricity in road transport has quite a number of advantages compared to the biofuels and biogas options (e.g. sustainability risks, improved energy efficiency, contribution to the FQD target and long-term potential), but a much lower potential for 2020.

Furthermore, renewable energy deployment should be combined with ambitious measures related to fuel efficiency improvements and other energy demand reduction measures, for two reasons:
1. Renewable transport energy will remain scarce and probably also costly in the future. Reducing energy demand will then make it easier to increase the renewable energy share in transport to a certain target.
2. Reducing energy demand directly reduces CO_2 emissions, and fossil fuel dependence (i.e. increase security of supply).

Based on these findings, we can now derive a number of scenarios that are both practically feasible and more sustainable than the implementation of the NREAPs.

The first scenario takes the feasible level of sustainable renewable energy in 2020 as a starting point, and assesses whether this is sufficient to meet the 10% RED target. If not, energy demand reduction is used to fill the gap. The second scenario takes a 15% energy demand reduction as a starting point, as well as the feasible potential for renewable electricity, and then fills the gap by increasing the use of sustainable biofuels from waste and residues.

Scenario 1: Fixed sustainable renewable energy supply

- **100 PJ** renewable electricity in non-road transport, in line with the expectations for 2020 as expressed in the national renewable energy action plans.
- **16 PJ** renewable electricity in road transport, which is roughly the amount of renewable electricity that 5 million PHEVs and BEVs would consume, at an average share of about 30% renewable electricity.
- **300 PJ** biofuels from waste and residues.
- Levels of hydrogen from renewable sources are assumed to remain negligible in 2020.
- A **multiplication factor of 2.5** is implemented for **non-road renewable electricity**, to bring this in line with the methodology used for electricity in road transport.

If this is insufficient to meet the 10% RED target, the **energy demand** is reduced to ensure that it does.

Scenario 2: Fixed energy demand reduction

- **Energy use in the transport sector is reduced by 15%**, by a range of measures that improve energy and transport efficiency, modal shift, etc.
- **100 PJ** renewable electricity in non-road transport.
- **16 PJ** renewable electricity in road transport, which is roughly the amount of renewable electricity that 5 million PHEVs and BEVs would consume, at an average share of about 30% renewable electricity.
- Levels of hydrogen from renewable sources are assumed to remain negligible in 2020.
- Implementing **a multiplication factor of 2.5** for **non-road renewable electricity** (to bring this in line with the methodology used for electricity in road transport).

The 10% RED target is then met by adding **sustainable biofuels** from waste and residues.

The potential contribution of the various renewable energy options and of energy demand reduction policies are not fixed numbers, but strongly depend on the choices that are made, the policies that are implemented and the timing of these policies. Both scenarios share the following assumptions regarding policy development:

- Apart from a base level of land-based biofuels listed in the assumptions above, the rest of the RED target is met via the more sustainable measures identified in Chapter 3. This is achieved through **much stricter sustainability criteria** in the RED and FQD regulations.
- Energy demand in transport is significantly reduced compared to business as usual developments, with **increased policy efforts to improving fuel and transport efficiency, reduce transport demand, etc.**
- The development and **market uptake of electric vehicles** (including plug-in hybrids) is strongly promoted, allowing the optimistic EV development scenarios to be realised.
- The use of **biomethane in transport** is strongly promoted throughout the EU. This biomethane is produced from waste and residues with no other applications (see the discussion in Section 3.4).
- **Other biofuels from waste and residues,** namely FAME and HVO, and new, 2nd generation conversion technologies are also promoted.
- GHG mitigation in the **fossil fuel life cycles** is significantly increased, notably by reducing emissions of flaring and venting, as discussed in Section 3.6, so that the FQD target is met as well.

- The RED methodology is adapted (see text box below) to such extent that **renewable electricity used in non-road is multiplied by 2.5** (in line with renewable electricity in road); transport by electric rail is, in almost all cases, more energy-efficient than transport by road (see, for example, CE (2008)). It therefore seems justified to extend the multiplication factor for electric road transport to that of non-road transport, which is put in place to account for the higher energy efficiency of electric vehicles.

As in the previous chapter, we assess these scenarios for the three different base levels of biofuels using the following assumptions:
- **Assumption 1**: land-based biofuel consumption is reduced to zero.
- **Assumption 2** takes the 2008 consumption of land-based biofuels as a starting point: 421 PJ.
- **Assumption 3** freezes the quantity of land-based biofuels to the biofuels volumes consumed in the EU in 2010, which was 582 PJ.

5.3 Scenario 1: Fixed sustainable renewable energy supply

The resulting mix of renewable energy options and supporting measures for Scenario 1 is shown in Figure 18. The graph shows the contribution of the various renewable energy options towards the target (in % of total road transport energy) for the three assumptions. In case of Assumption 1 (no land-based biofuels), an energy demand reduction is required to ensure that the target is met. In case of the other two assumptions, the renewable energy potential is more than sufficient and energy demand can remain at the reference level. Note that the striped columns indicate contributions due to the multiplication factors in the methodology, the plainly coloured columns represent actual renewable energy. In absolute terms, the contribution of biofuels and renewable electricity is the same under all three assumptions.

Figure 19 shows what this means in terms of actual volumes of renewable energy (in PJ), and the administrative contributions due to the multiplication factors used. A total of 1,145 PJ is needed to reach the target if energy demand develops in line with the reference scenario used, in this scenario this target is exceeded under Assumptions 2 and 3. Under Assumption 1 (no land-based biofuels), energy demand is reduced by 22%s so that the total of 890 PJ sustainable renewable energy is just sufficient to meet the target.

In all three assumptions, a significant share of the 10% target is met by administrative means, as result of double-counting of biofuels from waste and the multiplication factor of 2.5 for renewable electricity. The more land-based biofuels are assumed, the larger the share of physical PJ: under Assumption 3, about 2/3rd of the target is met by actual renewable energy, this share reduces to somewhat less than half in case of Assumption 1.

Figure 18 Scenario 1: Renewable energy mix to meet the 10% RED target

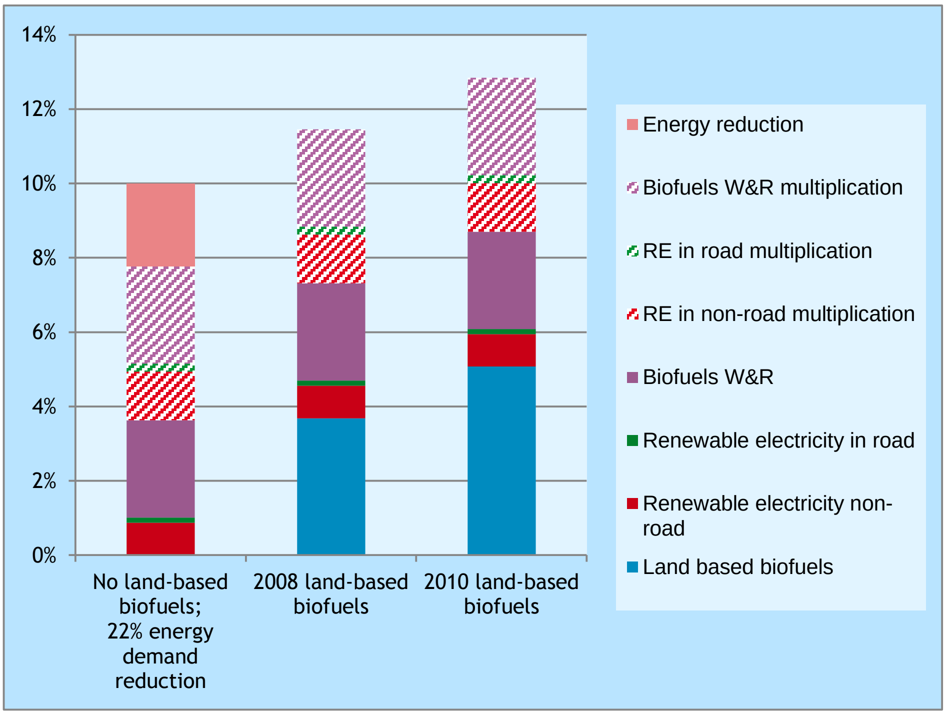
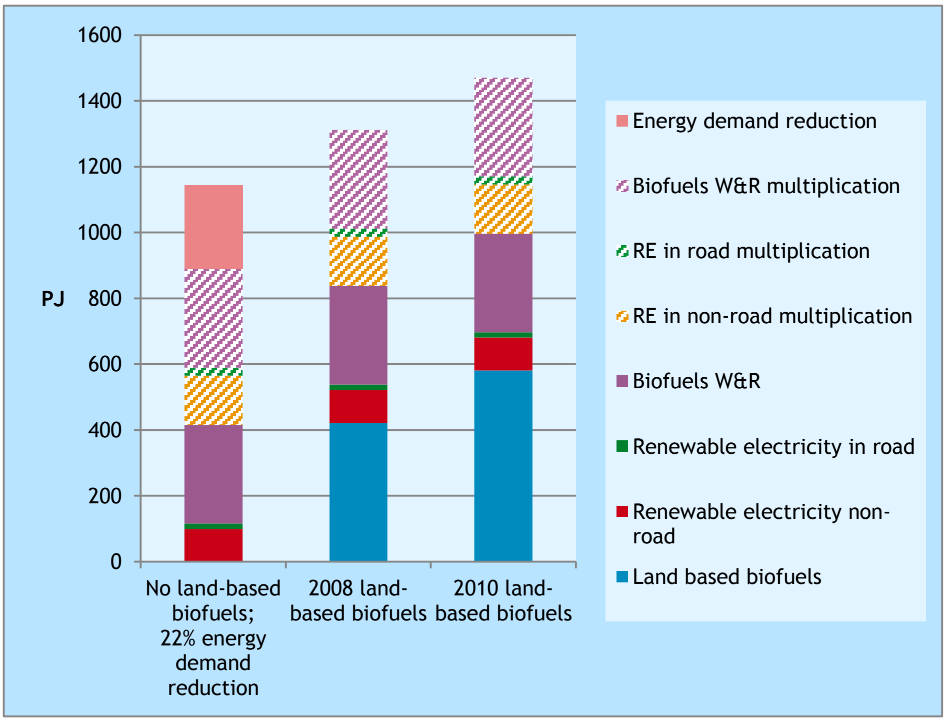
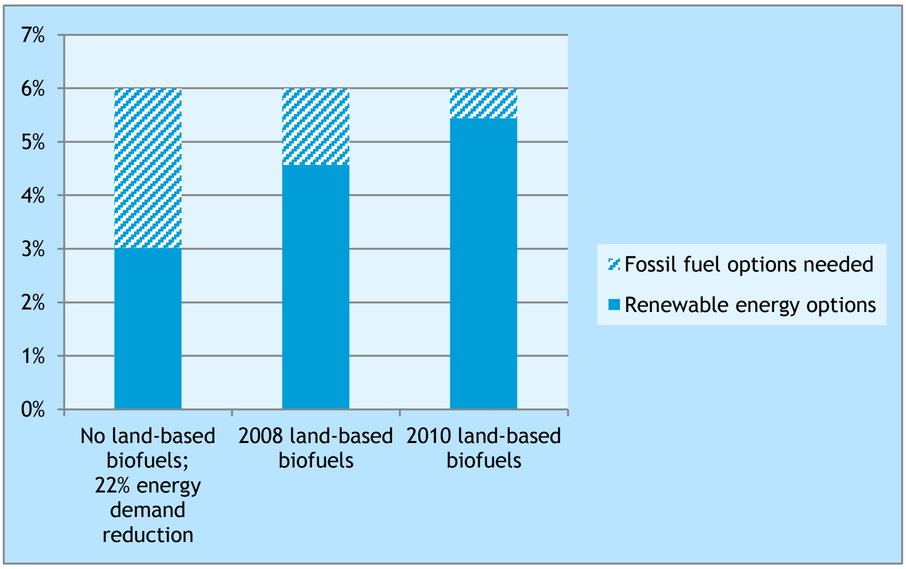


Figure 19 Scenario 1: Contribution of the various options, in PJ



The contribution of the renewable energy towards the FQD target is shown in Figure 20 for the three assumptions. Since the multiplication factors only apply to the RED and not to the FQD, only the real-life amounts of the biofuels and electricity contribute to the FQD. This results in a lower contribution of the renewable energy deployment to the FQD target in case of Assumption 1, compared to the other two assumptions[46]. Fuel suppliers will then have to invest more in alternative options to reduce the GHG intensity of their fuels. Reducing flaring and venting is likely to become an attractive mitigation option to fill the gap towards 6%, as discussed in Section 3.6.

Figure 20 **Scenario 1: Contribution of the renewable energy mix towards the FQD target**

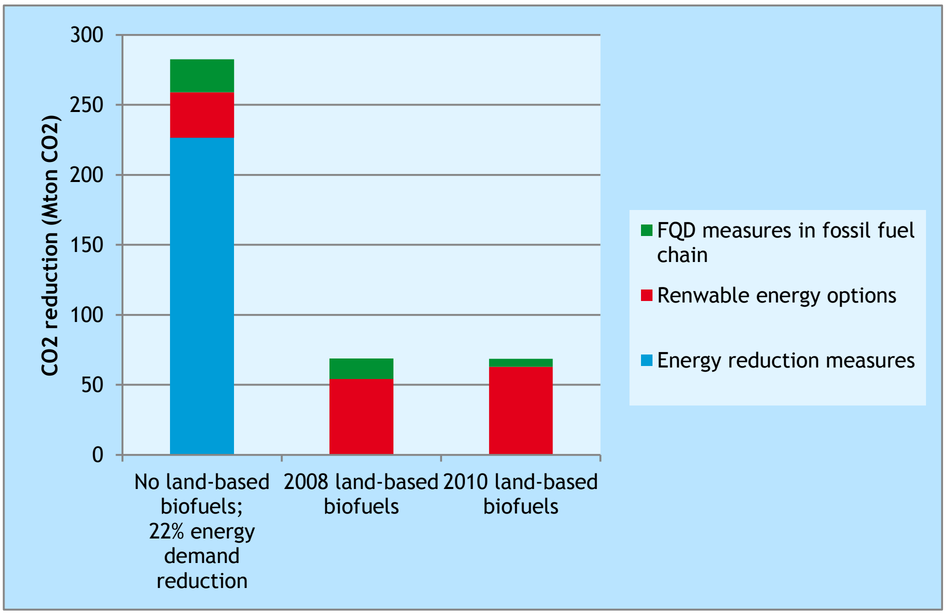


The total CO_2 reduction achieved by the energy demand reduction measures, the renewable energy options and the FQD measures in the fossil fuel chain is shown in Figure 21. As concluded earlier, reducing energy demand has a very direct and significant impact on CO_2 remissions, resulting in much higher CO_2 savings under Assumption 1, compared to that achieved by the other two assumptions – despite the lower volume of renewable energy that is deployed.

Note that in all calculations in this chapter, 60% savings are assumed for all biofuels. This is based on the assumption that all biofuels will meet the mandatory GHG reduction threshold, and ILUC factors are included in the calculation methodology in 2020. If biofuels with higher (average) savings would be used, their contribution to both the FQD and the overall CO_2 reduction would be higher, but the opposite also holds: if the actual life cycle savings are lower, CO_2 savings will also reduce.

[46] As was shown in the previous chapter, energy demand reduction has very limited effect on the contribution of the renewable energy measures to the FQD.

Figure 21 **Scenario 1: Total CO_2 reduction achieved (Mton)**



The comparison of the three variants of Scenario 1 shows that the most effective option from an environmental point of view is the one that reduces land-based biofuels to zero by 2020. It leads to the biggest CO_2 reduction. However, a significant effort is required to reduce energy demand and mitigate GHG emissions during fossil fuel production, to be able to meet the FQD target.

5.4 Scenario 2: Fixed energy demand reduction

Scenario 2 assumes that in 2020, an energy demand reduction of 15% is achieved, 100 PJ of renewable electricity is used in non-road transport and 16 PJ in road transport, and all renewable energy is multiplied by 2.5 in the RED. The 10% RED target is then met by varying the volume of sustainable biofuel/biogas from waste and residues.

The resulting renewable energy mix and its contribution towards the 10% RED target is shown in Figure 22. The sustainable biofuel/biogas volumes needed to meet the target depend on the assumption (i.e. on the base level of biofuels assumed), and vary as follows:
- Assumption 1: 342 PJ
- Assumption 2: 131 PJ
- Assumption 3: 52 PJ

These volumes are all feasible, as shown in in Section 3.4, where the 342 PJ can be considered to be quite ambitious and the 52 PJ can be achieved with relatively little effort, for example by utilising only half of the EU's potential of biodiesel from used cooking oil and animal fat.

Figure 22 Scenario 2: Renewable energy mix to meet the 10% RED target

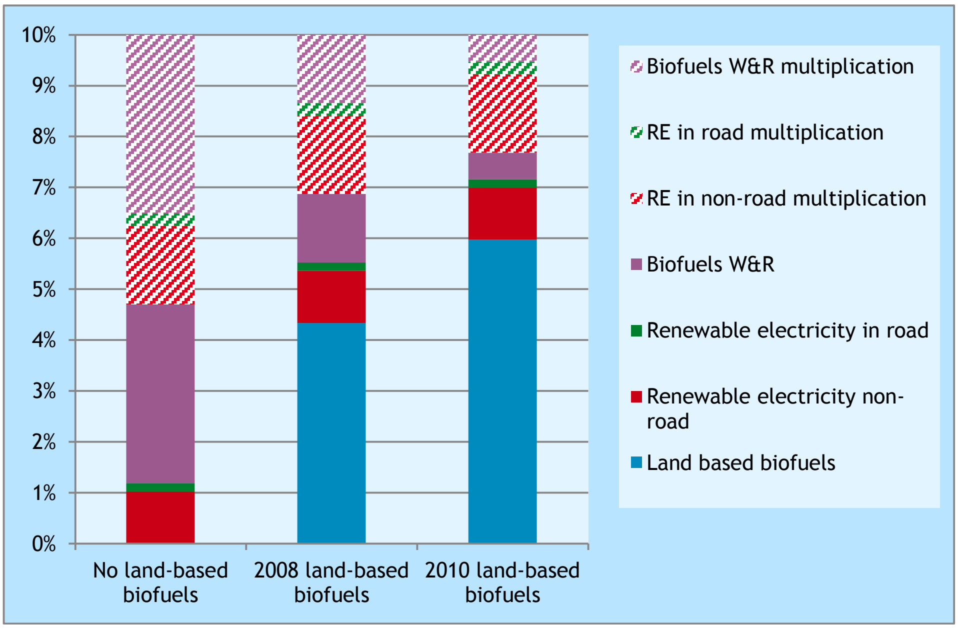
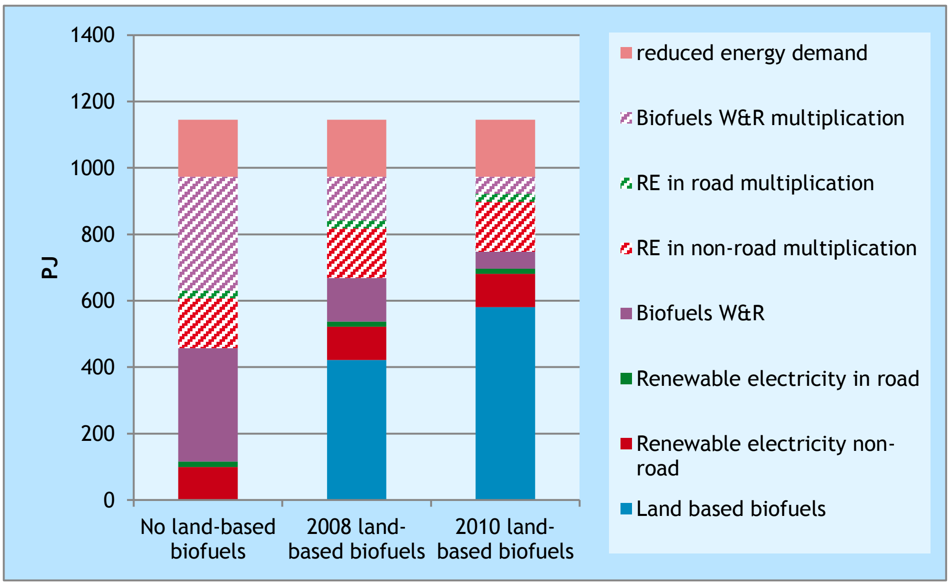


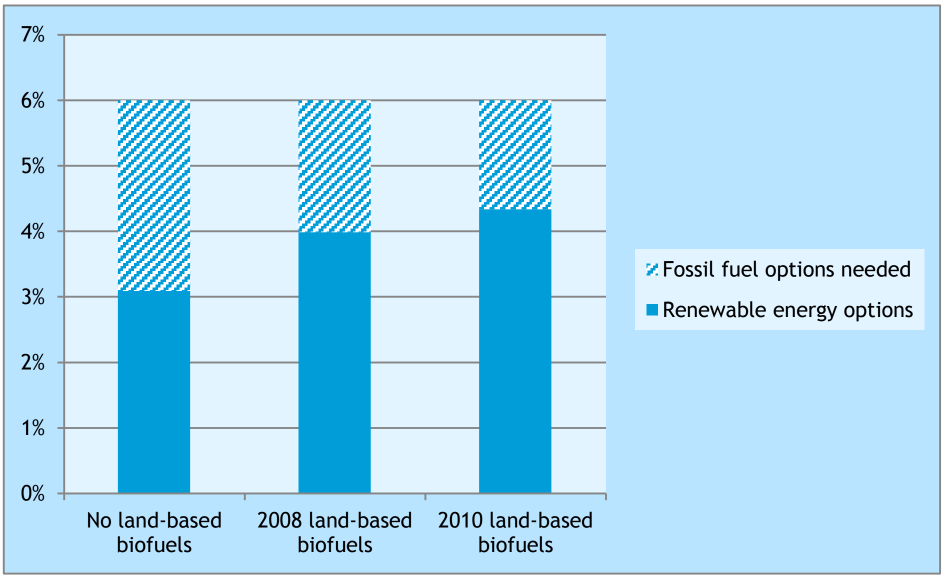
Figure 23 shows what this means in terms of actual volumes of renewable energy and energy reduction needed, on EU level.

Figure 23 Scenario 2: Contribution of the various options, in PJ



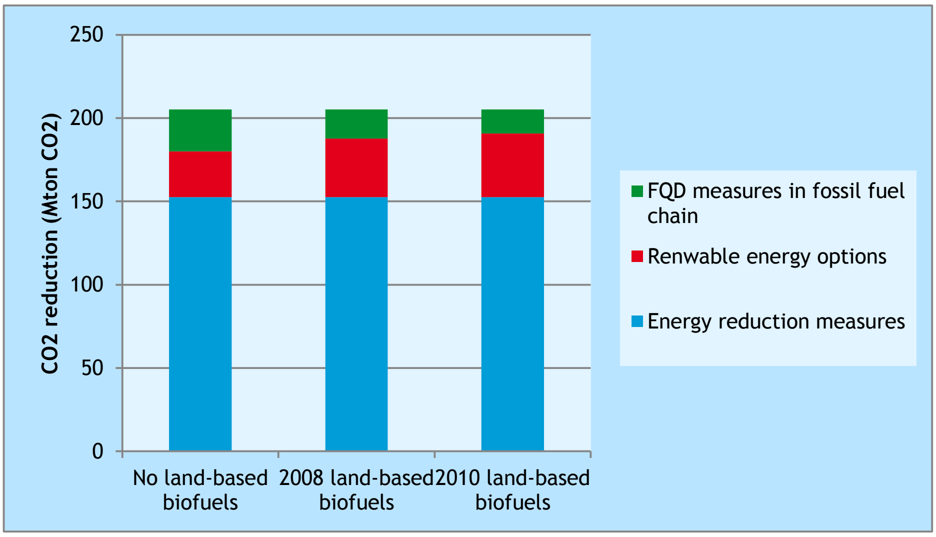
The contribution of the renewable energy to the FQD target in this scenario is shown in Figure 24. Compared to Scenario 1, this scenario results in a reduced contribution of the renewable energy options towards the FQD target, so that fuel suppliers will have to deploy more other CO_2 reduction measures to meet the target.

Figure 24 Scenario 2: Contribution of the renewable energy mix towards the FQD target



The overall CO_2 reduction achieved with these measures is shown in Figure 25. The energy demand reduction measures contribute significantly to the CO_2 savings, and reduce more than 150 Mton CO_2. The renewable energy and fossil fuel CO_2 reduction measures add another 50 Mton emission savings.

Figure 25 Scenario 2: Total CO_2 reduction achieved (Mton)



While the CO_2 reduction is somewhat less impressive than for Scenario 1 without land-based biofuels (Assumption 1), Scenario 2 without land-based biofuels might to be more achievable as a less ambitious level of energy demand reduction is assumed.

5.5 Biomethane in transport – the current situation

Increasing the consumption of sustainably produced biomethane in road transport is clearly a crucial part of these sustainable scenarios. This requires extensive expansion of the biomethane chain throughout the EU, and involves increasing biomethane production, increasing the share of gas-powered vehicles, development of an infrastructure to distribute the gas to the vehicles, etc. Biomethane and natural gas are used for transport in several Member States already and their market shares are increasing, but market shares are still limited. The following provides an overview of the current status in the EU. It is outside the scope of this study to go into further detail of how the market shares needed for the scenarios can be achieved, but it is recommended to assess this further so that effective policy measures can be developed.

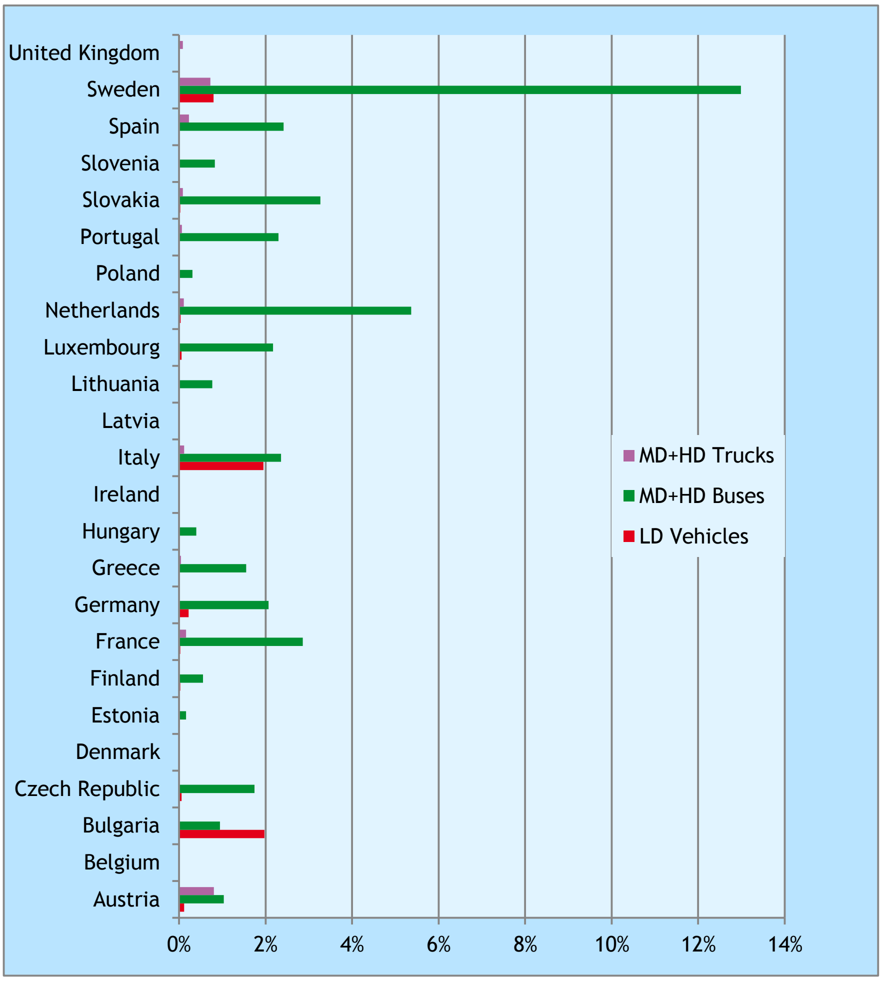
In the sustainable scenarios presented in the previous sections, the total market share of biofuels and biogas from waste and residues varies, between 0.5% and 3.5 % of road transport fuels. The maximum potential for sustainable biodiesel and bioethanol from waste and residues is about 1% of road transport fuels in 2020, the rest, up to 2.5%, would probably be biomethane. The share of gas-powered vehicles in the fleet then also needs to be at least in the same order of magnitude. For comparison, the current share of gas-powered vehicles (light duty, buses and trucks) is 0.38% (NGVA data), where most of these run on natural gas, not yet biomethane.

Various EU Member States are already promoting the use of either natural gas or biomethane in transport. In most countries, the focus has been on increasing the share of gas-powered vehicles in busses rather than in passenger cars or trucks. This approach has a number of benefits: it improves local air quality efficiently, and reduces the need to develop a large-scale infrastructure for the gas. The share of gas-powered passenger cars is still negligible in almost all EU Member States, except for Italy, Bulgaria and Sweden.

An overview of the market share of gas-powered vehicles in the national vehicle fleet is shown in Figure 26. Note that Germany, one of the case studies in this report, has the second largest fleet of gas-powered vehicles in the EU. The Netherlands score exceptionally well with a 5.4% share of the bus fleet[47]. These vehicles can drive on both natural gas and biomethane.

[47] On the website of the Natural and Bio Gas Vehicle Association, NGVA Europe, assessments can be found why gas-powered vehicles are a success in some Member States.

Figure 26 The market share of gas-powered vehicles in the national vehicle fleet in the EU



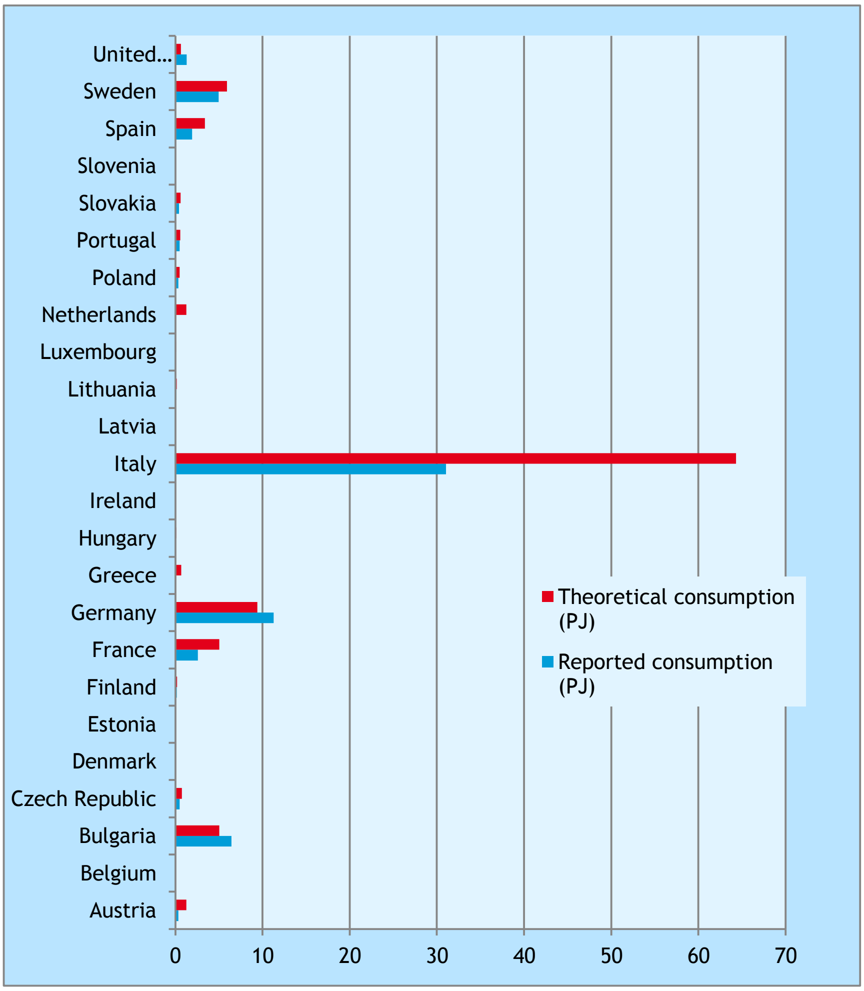
Source: NGVA Europe, data for 2011.

As gas-powered vehicles are a prerequisite for using these types of gas in transport, annual gas sales in transport are linked to the vehicle shares in the various countries. Gas sales data are shown in Figure 27 (based on NGVA Europe data). Two different data sets are shown as the gas consumption is relatively uncertain. Total annual EU sales were 60-100 PJ in 2011 (60 PJ according to reported data, 100 PJ theoretical consumption).

The vast majority of this consumption is natural gas. Sweden is the only exception: almost 60% of the gas sold in transport is biomethane. Germany has a share of 6%, Finland and France reports that 3% of the gas sales in transport is biomethane.

These data illustrate that the sustainable scenarios indeed require significant effort to promote the uptake of gas-powered vehicles, and to increase the biomethane uptake and infrastructure. It is outside the scope of this study to assess the best way to achieve this. It is therefore recommended to further explore the options how to effectively promote this route in the various Member States.

Figure 27 **Annual sales of gas (natural gas and biomethane combined) in transport, 2011 estimate**



Source: Based on data from NGVA Europe.

5.6 Conclusions

It can be concluded that a number of sustainable scenarios can be developed that meet the RED target and are practically feasible, but only if transport energy demand is reduced, and electric road transport, biofuels from true, sustainable waste and residues and biomethane use are all strongly promoted throughout the EU.

While maintaining a certain base level of land-based biofuels may help to reduce the efforts that need to be taken, it is clear that the environmental benefits are greatest in the scenarios whereby land-based biofuels are phased out by 2020.

In the scenarios shown here, the RED methodology was adapted so that the renewable electricity use in non-road transport is treated the same as that used in road transport. This measure would also contribute to the feasibility of the sustainable scenarios, reduce the need for land-based biofuels and provide an incentive to increase the use of (renewable) electricity in non-road transport modes.

How these sustainable scenarios can be realised is the topic of the following chapters.

6 Policy strategies and measures to arrive at these scenarios

6.1 Developing a new and improved policy strategy

Clearly, these sustainable scenarios are quite different from the current situation and the expectations of the Member States for 2020 as described in the NREAPs. Moving from the current renewable transport energy policies towards these much more sustainable strategies thus requires quite a drastic change of policy measures, on various levels.

The new policy strategies should consist of the following pillars:

- Remove all direct and indirect support for land based biofuels **and adopt a trajectory from current consumption levels towards near-zero use** in order to prevent further environmental and social damage. In the meantime:
  - Include ILUC emissions in the life cycle analysis of biofuels under the RED and FQD, and improve sustainability criteria for land-based biofuels and biogas (see Section 1.2) marketed in the EU.
  - Re-focus national renewable energy action plans on the untapped potential for energy efficiency in transport, reducing transport demand and encouraging a switch to less energy intensive transport modes. Increase policy incentives for fuel-efficient vehicles.
  - Implement other measures: reduce speed limits on motorways, implement road charging, increase fuel taxes, invest in modal shift towards more fuel-efficient modes, etc.
- Each Member State should set an indicative national **energy reduction** target for transport.
- Extend use of **multiplication factors** in the RED methodology for **renewable electricity to non-road transport** (railways).
- Implement national **incentives for the more sustainable, renewable energy options**, for example
  - Differentiate fuel taxes.
  - Increase the use of electric vehicles in road transport.
  - Increase the production of biogas/biomethane from consumer waste and manure.
  - Increase production of FAME and HVO from used cooking oil and waste animal fats, whilst safeguarding that the feedstocks are indeed waste streams with no other applications.
  - Increase the use of biomethane in dedicated transport fleets by providing incentives for gas-powered vehicles and the roll-out of a distribution network.
- Establish **clear definitions and sustainability criteria** for 'waste-streams', 'by-products' and 'residues' to limit use to sustainable levels, and to verify the origin of those streams to avoid indirect environmental impacts. Correct lifecycle carbon accounting of waste and residue streams is needed to ensure genuine emission reductions.
- Scale up **R&D for the roll-out of hydrogen** in transport.
- Incentivise the **reduction of GHG intensity of fossil fuels** via measures to reduce flaring and venting and other upstream mitigation options:
  - Implement an effective methodology for fossil fuels in the FQD: expand to include refinery efficiency and reductions from fossil fuel exploration.

- Ensure that the upstream emissions of unconventional fossil fuels with high GHG intensity like tar sands and shale oil are taken into account in the FQD methodology.

Some of the policies should be implemented on EU level whilst others are Member State (or even regional) policies.

The **RED** and **FQD** policies and targets are crucial means to achieve the long-term targets on transport decarbonisation, with significant impacts on the short and medium term as well. However, they will only be effective if they encourage changes in the sector that are both useful in the longer-term developments, and effective in the short to medium term. This will ensure that investments (e.g. in production capacity) and R&D are robust also in the longer term.

As it takes time to move from one policy strategy to another – see the discussion on opportunities and barriers in Section 2.5 – it is essential to start changing policy direction sooner rather than later. The scenario analysis in this report shows that the more the sustainable options contribute, the less land-based biofuels are necessary to meet the RED target, thus reducing the environmental risks related to these policies.

The policy strategy outlined above aims to optimise sustainable progress towards future transport decarbonisation, using the following criteria as a starting point:

- **Ready technology**: The technology has to be developed and applicable on a large scale already. Technology currently in the R&D stage is not likely to be able to contribute to 2020 transport in a significant way.
- **Contribution to EU targets:**
  - potential contribution to the RED;
  - potential contribution to the FQD target;
  - GHG emission reduction in 2020;
  - energy efficiency (WTW).
- **Long-term potential**: Potential to scale up to carbon-free transport and provide a significant contribution to longer-term GHG reduction goals in the sector and in the EU.
- **Least risk** of negative sustainability impact. How significant are risks of undesired and perhaps indirect knock-on effects (incl. indirect GHG emissions, impacts on biodiversity, water, air quality, noise, food prices, poor and vulnerable populations)?
- **Economic impacts:** Cost and benefit of the measure, both in terms of societal cost and benefit, and regarding impacts and benefits to specific stakeholders such as the renewable electricity producers, electric cars manufacturers, biofuels industry, consumers, etc.

This list covers the main issues related to practical and political feasibility, the short- and long-term goals and strategy and wider sustainability issues.

All the policy options have various pros and cons, and some are aimed at short term impacts where others are rather early steps in a development with potential after 2020. To clarify these issues and to enable an overall assessment where all the various aspects are taken into account, the key policy measures listed above are assessed using this list of assessment criteria. Results are shown in Table 3. The scores on these criteria could not all be quantified, as not all impacts have been assessed in detail in this study. Scoring was therefore based on a qualitative assessment, and expressed in a scale ranging from '++' to '--'.

Looking at these overall assessment results, it can be seen that some of these policy measures are aimed at incentivising the use of ready technology that may deliver significant contributions to the 2020 targets. Others, by contrast, still have to be developed further, but may have large potential for the future.

Almost all policy measures are likely to increase cost, compared to the current policy measures envisages in the NREAPs, but their cost effectiveness, in terms of € per ton CO_2 reduced, is likely to be much more attractive: the higher cost are typically outweighed by the (often significant) increase in actual CO_2 reduction achieved. Various studies have shown that biofuels from food crops are typically found to result in a cost effectiveness of several hundred and even thousands of Euro per ton CO_2 reduction even without ILUC taken into account. When ILUC effects are included, cost effectiveness will get worse, and in cases where in fact the GHG emissions increase, cost effectiveness can not even be determined (see, for example, CE (2012) for an overview of cost effectiveness of biofuels and other CO_2 mitigation measures in transport).

In the short to medium term, both the electric vehicle and the biomethane options require significant investments in vehicles and infrastructure. Their benefits can be found in relation to the other criteria, namely their contribution to the CO_2 mitigation, RED and FQD targets and limited sustainability risks. For example, electric vehicles score well on almost all criteria, except short-/medium-term cost[48]. Reducing energy use scores exceptionally well on almost all criteria, and is basically a no-regret option from an environmental point of view. It reduces GHG emissions and helps to meet the RED goals, both in the long and in the short term. Cost of this option depends on what measures are actually implemented to achieve this.

48 Costs may become competitive in the medium/longer term, depending on production volumes and R&D success.

Table 3 Assessment of policy measures

	Potential contribution to EU targets in 2020							
	Ready technology	RED	FQD	GHG emission reduction (WTW)	Energy efficiency (WTW)	Potential for further growth (>2020)	Limited risk of negative sustainability impacts	Economic impacts (cost) in the short/ medium term
Prevent use of land-based biofuels (improve sustainability criteria)	N/a	-	-	o	o	+	++	-
Reduce transport energy use	++	++	o	++	+/++	++	++	+/-
Incentives for electric vehicles	o/+	+	+	+	+	++	++	-
Increase production of biogas from consumer waste and manure	++	++			o	+	+	-
Increase production of FAME and HVO from UCO	+	+	+	+	o	o	o/+	-
Increase use of biomethane in transport (vehicles and filling stations)	+	++	++	++	o	+	+	-
R&D for hydrogen in transport	-	o	o	O	-	+	+	-
Incentive to reduce GHG intensity of fossil fuels	+	o	+	+	o	+	+	-

NB: Scores range from '--' to '++', where '++' is 'yes/very positive impact or potential', '--' is 'no/very negative impact' and 'o' means 'no or little impact or potential'. Economic impacts (cost) are compared to the renewable energy strategies outlined in the NREAPs.

6.2 Policy recommendations

This policy strategy can now be translated into the following list of concrete policy recommendations. Some of these relate to EU-level policy measures, others need action at Member State levels. Together, they can provide the basis for the change from the current situation towards the more sustainable transport energy policy described in the previous chapters.

EU level

- Remove all direct and indirect support for land based biofuels and adopt a trajectory from current consumption levels towards near-zero use in order to prevent further environmental and social damage.
  - In the immediate, include ILUC emissions in the life cycle analysis of biofuels under the RED and FQD, and improve sustainability criteria for land-based biofuels and biogas (see Section 1.2) marketed in the EU.

– Consider to extend the use of multiplication factor for renewable electricity in the RED methodology to non-road modes.
  - Re-focus national renewable energy action plans on the untapped potential for energy efficiency in transport, reducing transport demand and encouraging a switch to less energy intensive transport modes: Increase policy incentives for fuel-efficient vehicles.
  - Implement other measures: reduce speed limits on motorways, implement road charging, increase fuel taxes, invest in modal shift towards more fuel-efficient modes, etc.

– Clear definitions and sustainability criteria for 'waste-streams', 'by-products' and 'residues' should be established to limit use to sustainable levels, and to verify the origin of those streams to avoid indirect environmental impacts. Correct lifecycle carbon accounting of waste and residue streams is needed to ensure genuine emission reductions.

– Ensure effective implementation of fossil fuels' life cycle emissions in the FQD. Include reduction of flaring and venting, efficiency improvements in refineries, etc. to count towards the target.

– Support R&D of technologies for plug-in hybrid, battery electric and hydrogen vehicles and infrastructure.

– Harmonise fuel taxes in line with the EC proposal (i.e. based on energy content and CO_2 emissions), ensure the taxes are differentiated according to actual WTW CO_2 emissions.

– Tighten 2020 CO_2 reduction targets for cars and vans and set stringent targets beyond 2020 to stimulate market roll-out of alternative technologies.

– Improve type approval test for passenger cars and vans, to ensure the CO_2 target for 2020 is met also in real life.

– Implement fuel efficiency regulation for heavy duty vehicles.

– Develop an integrated strategy for biomass and bioenergy, based on an assessment of the availability of sustainable bio-feedstock, the potential demand from all different sectors and an evaluation of GHG reduction potential, etc.

– Request Member States to submit a revised national renewable energy action plan, taking the changes in the EU policy framework strategy into account.

Member State level

– Decide on a new strategy and action plan to meet the 10% target of the RED in a sustainable way. Revise the national renewable energy action plan accordingly.

– Shift transport policy focus from 1st generation biofuels towards improved energy efficiency, reducing energy demand for transport and GHG mitigation measures in the sector.
  - For example through stronger CO_2 differentiation of vehicle taxes, increased fuel taxes, investments in bicycle infrastructure and public transport, lowering of speed limits on motorways, investing in rail- or waterway transport to promote modal shift, implementation of road charging, etc.
  - Avoid rebound effects: a subsidy or tax reduction for fuel-efficient cars will increase car ownership and use, building of new infrastructure typically increases transport volumes unless compensating measures are taken (e.g. in fuel/car taxation or road pricing).

– Speed up market uptake of electric vehicles by ensuring that effective incentives are in place, and charging infrastructure is being developed at the same time.

– Scale up investments in, and support R&D of technologies for plug-in hybrid, battery electric and hydrogen vehicles and infrastructure.

- Encourage production and use of sustainable biofuels from waste and residues in reasonable amounts, subject to overall sustainability limits. Prevent further expansion of the use of land-based biofuels in the EU until the sustainability criteria set in Section 1.2 are satisfied.
- Develop an infrastructure and vehicle fleet for biomethane in transport.
  - This can be done by encouraging captive fleet operators/owners such as bus companies or taxis to shift to bio-CNG or bio-LNG vehicles, as well as through a more general, large-scale approach, where a national or regional bio-CNG infrastructure is developed and the share of gas-powered vehicles is increased at the same time. Distribution of the biogas may take place directly, or through injection into the natural gas grid. In the latter case, a system of green certificates or biotickets can be set up to provide a means to count the biogas towards the transport target (see for example the bioticket system in the Netherlands).
  - Ensure that biomethane is included in the renewable energy/biofuels policy (i.e. in quota or tax reduction measures).
- Implement (or further strengthen) incentives for the production of biomethane and other types of biofuels from waste and residues that have no other applications.
- Implement strict sustainability criteria for biomethane, including incorporation of ILUC emissions and methane emissions from leaks.

7 Country case studies

7.1 Introduction

The sustainable scenarios and policy conclusions of the previous chapter provide a clear picture of how the RED can be implemented sustainably in the coming years throughout the EU. This requires action by the EU, but also Member State policies play a crucial role in this development. These will be most effective if harmonised and aligned with the overall EU strategy, but different circumstances in the various Member States may present specific opportunities that can be used to speed up this transition.

In this chapter, the options to achieve the RED target without expanding the use of land-based biofuels are investigated in more detail for five EU Member States:
- Germany;
- Denmark;
- Finland;
- France;
- The Netherlands.

These countries have different ambitions and strategies, different electricity generation mixes and transport sector characteristics. It is thus interesting to explore the potential consequences of the alternative scenarios within this context.

Together, these countries represent almost 40% of the energy use in transport in the EU (excl. aviation) in 2020, as can be seen in Table 4. Especially France and Germany have very significant shares.

Table 4 Expected contribution of the five case study countries to the EU's transport energy consumption in 2020

	Share of total transport energy, excl. aviation, CNG, LPG, in 2020
Denmark	1.3%
Finland	1.5%
France	15%
Germany	17%
The Netherlands	3.9%

Source: TREMOVE Version 3.3.2 alt.

These five countries have different plans for meeting the 10% renewable energy in transport target, as they have outlined in the National Action Plans. Some key data are provided in Table 4 and Table 5, Table 6 provides a more detailed picture of the envisaged relative share of the various energy carriers in the various countries.

According to these action plans, biodiesel would have by far the largest contribution to the target in all these countries, followed by bioethanol and renewable electricity. Biodiesel shares are especially high in Germany, France Finland, whereas Denmark and the Netherlands have a relatively large contribution from ethanol (about 30%). The share of biofuels from waste and residues (biofuels that are double counted in the RED) is expected to be quite significant in some countries, but expectations vary between the countries.

Especially Denmark and Finland have the intention to consume a substantial amount of double-counting biodiesel, where Denmark plans to import all this biodiesel, and Finland will consume only biodiesel produced in the country itself. France did not specify the amounts of double-counting biofuels in its action plan.

Renewable electricity use is expected to mainly come from non-road (railway) transport. The contribution from road transport is expected to strongly increase in all five countries compared to the current situation (all start with 0% contribution in 2010), but remains limited compared to the other categories. Hydrogen from renewable energy sources is not expected to contribute to the target in any of these countries.

Table 5 **Expected contribution of various renewable energies in transport, for 2020, in selected countries (in PJ)**

	Denmark	Finland	France	Germany	The Netherlands
Bioethanol	3.9	5.4	27.2	35.9	11.8
Biodiesel	7.0	18.0	119.3	186.0	23.1
Hydrogen from renewables	0.0	0.0	0.0	0.0	0.0
Renewable electricity	1.2	1.7	16.8	27.9	3.0
Other biofuels (incl. biogas)	0.0	0.0	6.7	18.2	N/a
Total	12.2	25.1	170.1	258.9	37.9

Source: NREAPs.

Table 6 **Expected share of various renewable energies in transport, for 2020, in selected countries (in % of renewable energy in transport, multiplication factors are taken into account)**

		Denmark	Finland	France	Germany	The Netherlands
Bioethanol/ bio-ETBE	Total	32%	22%	16%	14%	31%
	Art. 21(2)	16%	7%	n/a	4%	4%
	Of which imported	32%	0%	1%	4%	27%
Biodiesel	Total	57%	72%	70%	72%	61%
	Art. 21(2)	29%	23%	n/a	2%	13%
	Of which imported	57%	0%	10%	46%	30%
Hydrogen from renewables		0%	0%	0%	0%	0%
Renewable electricity	Total	10%	7%	10%	11%	8%
	Road transport	4%	2%	3%	1%	3%
	Non-road transport	6%	3%	7%	10%	5%
Other biofuels	Total	0%	0%	4%	7%	N/a
	Art. 21(2)	0%	0%	1%	1%	N/a
Share of single-counting biofuels in total biofuels		*50%*	*68%*	*Up to 99% (data are lacking)*	*81%*	*93%*

Source: NREAPs.

The Member States also outline the policies they have implemented (or plan to implement) to meet these targets in the action plans. Three types of policy instruments are typically used, sometimes in combination:
- quota obligation;
- tax advantages (exemptions or reductions);
- subsidies.

These policy instruments can stimulate the use of renewable energy in general, but may also be focused on for example the use of Article 21(2) biofuels or the use of high blends biofuels[49]. Transport energy demand was not addressed in the action plans.

When comparing the Member State's plans outlined in the NREAPs with the sustainable energy scenarios and policy strategy derived in this report, it is clear that there are significant discrepancies. Denmark seems to be the closest, with a high share of biofuels from waste and residues and a relatively high share of renewable electricity in road transport included in its NREAP. The other countries, however, all rely mainly on land-based biofuels.

In the following, some of the main relevant policies and opportunities of each of the five case studies countries is given. The chapter concludes with concrete suggestions and recommendations on how these five countries can modify the current plans into much more sustainable action plans for sustainable and renewable transport energy. The basis for this analysis is the EU policy strategy derived in the previous chapters, combined with local characteristics, opportunities and developments. Note that the local information is not intended to be complete, but aims to provide an overview of the key relevant policies and issues in the various countries. These data were largely based on the input from the local NGOs that were involved in this project.

7.2 Denmark

As can be seen in Table 6, Denmark has relatively high ambitions regarding biofuels from waste and residues: 50% of both biodiesel and bioethanol was expected to fall into that category. Denmark did not report any plans regarding biomethane use, however. The more detailed plans in the Danish NREAP lead to the conclusion that the market for double-counting biofuels will only develop relatively late in time, as their shares in overall biofuels use increase from 0% in 2010 to 9% in 2015 and 50% in 2020.

Compared to the other countries assessed in this report, Denmark also has relatively high ambitions regarding the contribution of electric road transport. This will be partly due to the relatively high share of wind power in this country. Electric vehicles are actively promoted in this country as they can help absorb excess wind power.

7.2.1 Current policies relevant for renewable energy deployment and fuel efficiency

The Danish Act on Biofuel mandates importers or manufacturers of petrol or diesel to guarantee a biofuel share of 5.75% of a company's total annual fuel sales (measures by energy content). The target of 5.75% has to be reached in 2012. The new Danish energy agreement from March 2012 states that the biofuel mandate can be increased to 10% before 2020, but only after a research study (to be concluded by 2015) has investigated the alternative

[49] Noted that the NREAPs were written some time ago (in 2009/2010), and it may well be that some countries have changed their plans and policies in the meantime.

paths to fulfil the 10% RE obligation. In this context DKK 9million has been allocated to investigate the climate and energy policy aspects of using alternative solutions to meet the goal of 10% RE in transport.

Biofuels are exempt from the CO_2 tax levied on mineral petrol and diesel and electric vehicles are exempt from vehicle taxes and fuel consumption charges. This exemption has been extended up to and including 2015. After 2015, electric vehicles will be taxed favourably. The structure of vehicle taxation makes it more attractive to buy fuel-efficient vehicles. At the moment there are two annual car taxes. The first one is a tax differentiated by weight, which results in a reward for light vehicles. The tax related to ownership is differentiated to CO_2 emissions: a higher tax needs to be paid for inefficient vehicles.

From 2007-2010 2nd generation biofuels have been stimulated by the Energy Technology Development and Demonstration Programme (ETDDP). Further stimulation beyond 2010 depends on a new grant. Within the 'Green transport policy' transport agreement subsidies are available for energy-efficient transport solutions, including 2nd generation biofuels and electric vehicles. In addition, a research scheme for electric vehicles has been set up for the period 2008-2012. The government has also allocated budget for charging stations.

With respect to biomethane production, a new subsidy scheme agreed on in March 2012 provides subsidy to biogas regardless where it is used. The goal of the government is that 50% of manure will be converted to biogas by 2020. In Copenhagen a full-scale facility is being built which by help of enzymes will take the biodegradable waste from mixed municipal waste and provide a good feedstock for the production of biogas. The Danish gas grid uses a mass-balance system, which allows the trade in certificates.

7.2.2 Other relevant policy areas

Denmark has a relatively high share of wind in the total renewable electricity production (currently 20%) and political agreement has been reached on further increasing this share to 50% in 2020. A strategy for smart grids is expected this year to deal with possible overproduction related to renewable energy sources. EVs and electric heat pumps are recognised components expected to be necessary to absorb the excess electricity production at times of high production and low demand.

Regarding modal shift in transport, the amount of passenger kilometres is expected to increase further until 2050 and thus also in the coming years. An increase in passenger kilometres per car is mostly responsible for the total increase. According to Greenpeace, the large share (and increase) of the car in total modal split can be explained by too large tax advantages for small efficient cars together with a price increase of public transport. A congestion ring was planned around Copenhagen, but that has not yet been implemented.

The speed limit on motorways is relatively high with 130 km/h in selected sections, this could be reduced back to 110 to reduce emissions.

7.2.3 Specific opportunities in Denmark

Denmark is a Member State that can achieve benefits from electric transport that are significantly higher than in some of the other Member States due to its high shares of wind energy. This results in high CO_2 reduction and contribution to the renewable energy target per car, and the potential financial benefits due to positive impacts on grid stability and the ability to store excess amounts in times of electricity overproduction.

It has expressed relatively high ambitions regarding the use of biofuels from waste and residues, but concrete steps to achieve this seem to be lacking which makes it questionable whether these ambitions can be met in reality. New increased subsidies were agreed in March 2012 to support biomethane production from waste such as manure. This could be combined with incentives to use it in transport.

7.3 Finland

According to the Finnish NREAP, the biofuel mix in Finland will mostly consist of single-counting biodiesel, which is expected to be 49% of all renewable energy in transport in 2020. 32% of the biofuels is expected to be double counting, most of which will be biodiesel from waste and residues, the rest will be bioethanol from waste. Using biomethane in transport is apparently not actively promoted, as it is not included in the action plan.

The information in the NREAP, however, is not yet in line with the amount of already decided or planned biodiesel and bioethanol investments. For example, St1 is planning to produce 300 kt ethanol by 2020 which ought to be double counted. For comparison, total consumption of petrol is 1,7 Mt.

On top of this the UPM tall oil refinery (100,000 t) production will most likely be double counted, and Fortum will produce > 50.000 t by 2020.
It is very likely that at least one of the biomass BTL projects will actualise, meaning more than 100-200 kt. Neste Oil already has a capacity of 390 kt running and part of this should be double-counted according to the current share of feedstocks. Total diesel consumption in Finland is 2,2 Mt.

Also there is vast potential for commercialising biogas from waste if the GASUM/Botnia/Helsingin energia project actualises.

These investments are, however, still uncertain.

7.3.1 Current policies relevant for renewable energy deployment and fuel efficiency

The 'Act on the promotion of the use of biofuels in transport' obliges distributors of transport fuels to ensure a certain energy share of biofuels being distributed on the market each calendar year. The Finnish distribution obligation was 4% in 2010, this will increase up to 20% in 2020.

The carbon dioxide tax on fuels is reduced by 50% in case biofuels meet the sustainability criteria of the RED. Biofuels which are produced from waste and residues in accordance with Article 21(2) are exempt from the carbon dioxide tax. There is also an investment support scheme, aimed at supporting the development of one ore two large-scale pilot plants to produce innovative transport biofuels.

Biomethane is exempt from excise duty as that is only for liquid biofuels, which is harmonised in the EU. There is no energy- and carbon tax for biogas. The number of natural gas/biomethane vehicles has started to increase, but is still limited.

The annual vehicle tax is based on the level of CO_2 emissions of a vehicle[50], and fuel-efficient driving is included in the second phase of the driving exam. There is R&D support to develop electric vehicle technologies and services.

Electric cars are supported with low car registration tax, but then punished with the (annual) propulsion tax for other than petrol-driven vehicles. For example, for a 1.800 kg petrol-plug-in-hybrid-car, you need to pay 33 €/year propulsion tax, whereas a hybrid that can use only petrol is tax free. This tax rises to 99 €/year for full electric cars. This situation is improving somewhat as the taxation for electric cars is lowered and basic car taxation increased in 2012 and 2013. For a car that can use biogas one pays 204 €/year and all other renewable energy vehicles, like wind and hydrogen cars one pays 361 €/year tax.

Fuel energy tax is based on energy content and not on capacity/volume.

7.3.2 Other relevant policy areas

The amount of car passenger kilometres is increasing, and at the same time train passenger volumes have increased as a result of efforts to make travelling by train more attractive. The metro around Helsinki will be expanded, which will be ready around 2020. Other similar projects will be completed by 2030. Short-distance public transport is relatively expensive outside of Helsinki, because of the small volumes in Finland.

Due to its large hydropower resources, the share of renewable electricity is relatively high in Finland, 30.3% in 2010, where 14.5% of electricity was hydro and 11.4% from residues from forest industry. Industrial waste sludge is also used for power production, and contributes about 7% to total power production.

7.3.3 Specific opportunities in Finland

Speed limits on motorways are 100-120 km/hr in the summer, but 20 km/hr lower in winter. Applying the winter limits all year round would thus be a relatively easy measure to implement (although not from a political point of view).

A major process to merge towns and municipalities to better correspond to commuting patterns is on-going. So far, reducing driving or transport energy use is not a main driver of the process. Including this in the process could impact spatial planning developments (e.g. reduce urban sprawl) and public transport investments, with significant CO_2 and energy consequences in the future.

50 CO_2-based taxation has proved to be an effective way to reduce CO_2 emission of new cars. See graph in http://www.trafi.fi/palvelut/tilastot/tieliikenne/ensirekisteroinnit/CO2-paastot.

7.4 France

France does not provide estimates for double-counting bioethanol/bio-ETBE and biodiesel in the NREAP. However, it does report that 1% of all renewable energy in transport will consist of double-counting ‘other biofuels’. This is likely to be biomethane, as there are not many alternative options and France is already increasing the use of gas vehicles.

7.4.1 Current policies relevant for renewable energy deployment and fuel efficiency

The French biofuels plan includes a biofuel target of 7% in 2010. This target has been maintained for the period 2010-2012. For the period after 2012 the increase of the target will be moderate, most of the progression towards 2020 is planned to be made in the last years before 2020. From 2017, a contribution from biofuels made from cellulosic biomass is expected. In order to reach the targets set by the French government, four types of measures have been implemented.

- E10 has been introduced in the petrol sector since 1 April 2009;
- the high blends E85 and B30 have been authorised for the petrol and diesel sector;
- biodiesels in non-road transport can count towards the target.

Operators that bring fuels to the markets which contain a proportion of biofuels lower than the national targets have to pay a levy of the general tax on polluting activities (TGAP). Biodiesel and bioethanol benefit from a tax reduction of the Domestic consumption tax (TIC). Pure vegetable oils used in agriculture and fishing are fully exempt from paying this tax. These tax exemptions only apply to biofuels produced in approved production units.

A bonus malus system exists including a tax differentiation of the purchase tax of vehicles based on the CO_2 emissions of a car. Above 140 g CO_2/km car buyers have to pay a certain amount, while under 105 g CO_2/km car buyers receive a bonus. However, the revenues of the malus system are found not to cover the bonus expenditures.

In order to promote the renewal of the French vehicle fleet, subsidies for scrapping have been granted in 2010. In the same year the purchase of low-emission vehicles was promoted by providing an ecological bonus based on CO_2 emissions per kilometre (see the bonus malus system described above).

7.4.2 Other relevant policy areas

80–85% of freight transport consists of road transport. The share of rail transport decreases over time: the share was halved in the period 2000-2010 and still decreases, although the Grenelle (environmental legislation) states that 25% of all freight transport should be other than by road or by air. New maritime connections are created which can stimulate this modal shift. Looking at passenger transport, the modal share of cycling is only 3%, but has slightly increased over the last years. France has quite an extensive network of high-speed trains and toll roads.

The main sources of renewable electricity in France are hydropower, wind, biomass, biogas and photovoltaic. In 2010 the share of renewable electricity in total electricity generation was 14.5% – far below the national target of 21%. Hydropower is a main source, followed by wind and photovoltaic energy. 75% of total electricity production is nuclear.

Charging infrastructure for electric vehicles is promoted by the obligation to install a charging point in all new buildings with parking and will be obligatory in public buildings from 2015. Forecasts of the government predict 400,000 public charging points by 2020.

Biogas is mainly produced from sewage sludge, farm effluents, dump biogas and household waste. Its production is promoted via feed-in tariffs.

7.4.3 Specific opportunities in France

France is a country with a relatively high share of natural gas vehicles and infrastructure. This makes the transition to biogas easier. The extensive agricultural sector can provide the feedstock for the biomethane, but care has to be taken that it is indeed produced from waste and residues and not from land-based commodities.

The bonus malus system for vehicle taxes has resulted in a loss of government revenues compared to the previous system. Increasing the level of these taxes would compensate this, as well as reduce car ownership and use.

The speed limit on motorways is relatively high (130 km/h), this could be reduced to 120 km/h in order to align with other countries such as Belgium, Spain and the Netherlands.

Intensifying modal shift policies is necessary to meet the modal shift goals, and reduce goods transport by road. According to Greenpeace France, intermodal infrastructure is still lacking, and investments in conventional railways (i.e. additional to the high-speed network) should be increased significantly.

7.5 Germany

As shown in the introduction, Germany expects to have a relatively high share of biodiesel in 2020, most of which will be single-counting biodiesel (in line with the current situation). The use of renewable electricity in non-road transport will be far higher compared to the use of renewable electricity in road transport.

7.5.1 Current policies relevant for renewable energy deployment and fuel efficiency

Energy quota for the share of biofuels in conventional fuels have been introduced in Germany in 2007, and have been revised in 2009. The overall quota for 2009 was 6.25%, for the period 2010-2018 this quota increases to 8.0%. Sub-quotas exist for diesel and gasoline (3.6% for petrol and 4.4% for diesel).

Until the end of 2012, conventional biofuels that are not used to meet the quota obligation are granted a tax exemption. Until 2015, 2nd generation biofuels, biogas and bioethanol (E85) have lower taxes. 2nd generation biofuels used to meet the quota obligation are also allowed to receive tax benefits.

Vehicle taxes are not differentiated to CO_2 in Germany. The production of biomethane is not officially promoted by the government in the form of tax advantages (although a tax difference exist between gas and petrol) or subsidies.

An increasing number of private investors such as car producers focus on biomethane production. Several leading car producers are currently promoting natural gas in new cars. The higher purchase costs of these vehicles and the lack of filling stations in Germany (around 1,000 out of 14,000 in total) are the main barrier for biomethane as a transport fuel.

The German NPE (national platform for electric vehicles) promotes research and development projects on e-cars and e-mobility. The official objective is 1 million electric vehicles in 2020, but this is broadly deemed to be unrealistically high. The realisation of charging stations has been stopped, for economical reasons.

7.5.2 Other relevant policy areas

The modal split has been stable since a long time. Freight transport and passenger kilometres in passenger cars are still increasing. Germany has a road charging system for heavy duty vehicles on motorways (Maut), but there is doubt whether this has reduced transport kilometres. It also has a relatively dense network of high-speed and conventional railways. Environmental zoning is operational in a range of cities.

The current share of renewable electricity in Germany is around 20%. The national target for 2020 is 35% and will mostly come from wind. Use of renewable energy for electric transport will be covered in the National Development Plan Electric Mobility in the future.

7.5.3 Specific opportunities in Germany

Vehicle taxes can be differentiated to CO_2 emissions, thereby promoting the sales of fuel-efficient cars.

There are no speed limits on large parts of the German motorway network. Setting a limit of 120 km/h would be an effective means to reduce CO_2 emissions, and align the German situation with many other EU countries such as Belgium, Spain and the Netherlands.

According to GP Germany, the ‘Bundesverkehrswegeplan’, describing the plan for the development of transport routes at the federal level, is unable to promote modal shift, but promotes new roads for car traffic. Barriers should be removed in order to ensure a more frequent use of public transport, for example by reserving car lanes for public transport.

7.6 The Netherlands

Also in the Netherlands, the largest contribution to the RED target in 2020 is expected to come from biodiesel. 17% of all biofuels are expected to be produced from waste and residues (i.e. count double in the RED). No information on the use of ‘other biofuels’ is available. Compared to other Member States described in these case studies, the Netherlands estimate a relatively high contribution of renewable electricity in road transport compared to renewable electricity in non-road transport.

7.6.1 Current policies relevant for renewable energy deployment and fuel efficiency

According to Dutch legislation the share of biofuels in total fuel sales should be 4% in 2010, increasing annually to 5.5% in 2014, and then to 10% in 2020. Separate sub-targets are provided for petrol and diesel. Biofuels from waste and residues are allowed to count double towards the target. This has led to relative large shares of FAME produced from used cooking oil.

There are no tax reductions for biofuels, except for one: the excise duty tariff of E85 has been lowered to compensate for the lower energy content of ethanol compared to petrol. Only E85 produced in line with the RED sustainability criteria can benefit from this tax reduction.

At the vehicle purchase stage, the purchase tax is differentiated for CO_2 emissions. In addition, energy labels for vehicles also exist, where the classification is based on relative CO_2 emissions rather than absolute CO_2 emissions.

The programme Filling stations for alternative fuels (Tankstations Alternatieve Brandstoffen – TAB) has granted subsidies to establish a network of filling stations for alternative fuels such as E85, B30 and CNG/bio-CNG. Subsidies are also provided to stimulate the production of innovative biofuels.

In relation to electric vehicles, the Dutch government has imitated a 'Formule E-team' to coordinate actions in this field. The goal is 1 million electric vehicles in 2025. Electric vehicles do not have to pay vehicle registration nor circulation taxes. Pilot projects for electric vehicles ('proeftuinen') receive financial support.

7.6.2 Other relevant policy areas

The renewable electricity share in the Netherlands is relatively low, as its 2020 target for overall renewable energy use defined in the RED is 14%.

The Netherlands have a relatively high share of bicycle use, this is facilitated especially on city level. A few years ago, a railway connection between the port of Rotterdam and Germany was built to increase the share of goods transport via rail. However, road infrastructure is also continuously being expanded, enabling road transport volumes to increase as well.

Ecodriving is an integrated part of driving lessons and exams. There are plans to increase the speed limit on a large part of the Dutch motorways from 120 to 130 later this year.

7.6.3 Specific opportunities in the Netherlands

As the Netherlands have a large live stock sector, its potential for further development of biomethane production from manure is significant, but impacts of this sector on environment, health and animal welfare are significant as well.

Opportunities with less environmental risks are related to the relatively high population density and limited distances between cities, at least in the western and southern regions of the country. This makes it an attractive country for electric vehicles (incl. electric scooters and bicycles).

The popularity of cycling is already relatively high, but can be further increased, for example by increasing car parking cost, improving bicycle infrastructure and parking, etc.

An increase of fuel taxes might be an attractive option for the near future, because it can help with the national budget deficit. The recent political decision to remove the tax benefits granted for commuting will also help to reduce transport volume.

There are a number of decisions taken recently by the government that would have negative impacts on the developments discussed here: It was decided to increase the speed limit on a large part of the Dutch motorways from 120 km/h to 130 km/h, and it was decided to increase the biofuels quota. The status of these decision is currently not quite clear as the coalition has fallen recently.

7.7 Conclusions

7.7.1 Current Member State policies

The current Member State policies and strategies outlined in the National Renewable Action Plans need significant revisions in order to move towards a sustainable and renewable energy system in the transport sector. Especially the strong focus on land-based biodiesel needs to be revised. Of the five countries analysed here, Denmark seems to be in the best position, with a relatively strong focus on biofuels from waste and electric vehicles in combination with high shares of renewable electricity in their NREAP - although land-based biofuels are still expected to contribute to almost half of the RED target. Some countries have specific incentives for biofuels from waste and residues, either through double counting in a quota system or via fuel tax reductions, but actual shares of these types of fuel are still very low in most countries.

Policies that promote energy efficiency improvement of vehicles are becoming quite common, as most of the countries assessed here have implemented CO_2-differentiated vehicles taxes. None of these countries seem to have explicit goals for the reduction of transport demand or transport energy use.

Biomethane use in transport is still very limited in the EU, as is the number of gas-powered vehicles.

Looking at the NREAPs in more detail, we conclude the following:

- All five countries expect a large contribution from biodiesel, although there are differences in the expected share of biodiesel and bioethanol.
- There are significant differences in the expected share of double-counting biofuels, but all countries expect that those biofuels will only start to play a significant role from 2015 onwards. The action plans do not provide a clear picture of where these biofuels will come from or how the Member States will ensure that these expectations will be met.
- The use of renewable electricity in transport will mainly be due to electricity use in non-road transport. Electrification of road transport is expected to increase rapidly in the coming years, but will remain limited compared to the other energy sources. Germany expects the least contribution of EVs (0.1% of road transport energy), Denmark the highest (0.4%).
- Hydrogen will not play a significant role in 2020.

Use of renewable energy in transport is promoted in several ways.

- All five Member States have mandated percentage of biofuels to be blended with conventional fuels. The percentages vary as well as the period for which quota obligations have been defined already.
- In addition to the mandated use, tax exemptions and reductions are granted to biofuels in various Member States, however, without differentiation between land-based and waste-based biofuels. In most cases, these tax advantages were already in place before the implementation of biofuel quotas. The expectation is that most of these tax advantages will not be prolonged for single-counting biofuels.
- Subsidies are used to stimulate niche vehicles, high blends or biofuel production.
- Based on the information provided in the NREAPs, little can be said about the developments of biofuel policies between 2015-2020.

7.7.2 Towards sustainable renewable energy in transport in these Member States

As concluded above, all Member States will need to redesign and refocus their national policies in order to meet the 10% RED target sustainably. It is therefore recommended to redraft the transport part of the national renewable action plans in the coming year. This should be based on an integrated strategy which looks at all different aspects of the transport energy system, including transport energy demand, and takes a broad and comprehensive definition of sustainability as a basic premise.

It is recommended that the Member States consider the following list of actions and policy measures to be part of this new strategy.

Biofuel quota and fuel taxation

- Adapt the biofuel quota and fuel excise duty systems to discourage the use of land-based biofuels, and provide sufficient and effective incentives for biofuels from waste and residues without alternative uses.
- Do not increase the quota levels further before ILUC effects are included in the sustainability criteria effectively.
- Involve both the fuel suppliers and consumers in this shift towards sustainable fuels by ensuring adequate communication and transparency of information on both the sustainability of biofuels and the type of biofuels and vehicle types sold by the various suppliers.

Vehicle related taxation and subsidies

- Strengthen CO_2 differentiation of vehicles taxes to discourage sales of cars and vans with high fuel consumption. Prevent too strong financial incentives for fuel-efficient cars as this will increase car ownership and thus use.
- New cars have a lifetime of 16-20 years, which means that a new vehicle bought in 2012 will last until 2030. It is therefore very important to have incentives in place to ensure that vehicles being bought today suit the fuels of 2030. Those incentives should favour that current ICE personal cars are replaced with EV, and the share of gas-powered vehicles increases in those sectors where these technologies have the most benefits and opportunities.

Fuel taxation and road charging

- Increasing fuel taxes and implementing road charging can be a very effective means to improve fuel efficiency of the car fleet, promote efficient goods transport and manage transport demand.
- Road tolls are being discussed and investigated in a number of the countries studied (e.g. in the Netherlands, Finland and France) and often prove politically difficult to implement. However, it could be a crucial and economically sound way to limit transport volume growth and to prevent rebound effects of improving fuel and energy efficiency of vehicles. Also, measures reducing traffic congestion will reduce the economic cost of time lost in traffic.
- CO_2 differentiation of fuel taxes can provide a useful incentive for sustainable and renewable fuels, if the tax is based on realistic values for the well-to-wheel (life cycle) GHG emissions of the various fuels.

Electric vehicles

- Electrification of road transport has a very high CO_2 reduction and renewable energy potential and should be pursued. However, these impacts and opportunities vary between Member States. It thus makes sense to increase EV incentives in countries with high renewable energy shares and low GHG intensity of the power sector first, and focus on other alternative energy carriers in other countries.
- Limited population densities (e.g. in Finland) can also be a reason for countries to focus on other options first, as driving distances outside the main cities will be relatively far. Finland has the additional disadvantage of cold temperatures in winter. Cold temperatures reduce battery capacity and therefore driving range.
- National EV policies should mainly be aimed at reduce the cost of the vehicles to consumers and ensure that the number of charging points increases accordingly.

Biomethane

- Increasing the share of gas-powered vehicles in all EU Member States is a prerequisite for the sustainable RED scenarios developed in this study. The average share of these vehicles is currently only 0.38%, whereas the sustainable scenarios require a share of up to 2.5% of biomethane in total road transport energy use throughout the EU.
- Several EU Member States are actively promoting the use of natural gas in transport – including Germany, France and the Netherlands. Providing incentives to rather use biomethane than natural gas in these countries can be a relatively easy way to increase the contribution of biomethane towards the RED target and, at the same time, reduce the need for land-based biofuels.
- Developing this route can have significant additional benefits for Member States: it can have economical benefits as the biomethane is typically produced locally whereas biodiesel and bioethanol is often imported, and replacing diesel with gas-powered vehicles can improve local air quality.
- It is recommended to further assess the options on how to promote and further develop this energy source effectively: in which niche markets or vehicle categories can biomethane use best be increased, and what measures are necessary to achieve the potential growth rates of this route?

Other policies

- Promote reuse or processing of waste and residues into useful products such as biogas, prevent land fill.
- Green procurement can be an effective way to speed up the developments: national and local government car fleets ought to be first to be replaced by biomethane and electric vehicles. This has not yet been implemented effectively in all countries (e.g. not yet in Finland).
- Lowering speed limits is often a politically sensitive topic, but it can be an effective tool to improve fuel efficiency of road transport and reduce CO_2 and polluting emissions as well.
- Assess whether there are implicit car transport subsidies that form a barrier to decarbonisation greening of transport and remove these. Examples are fiscal benefits for commuting by car or for company car use for private use, implicitly embedding cost of parking spaces in the price of an apartment, etc. These could be replaced by subsidies for more environmentally friendly and energy-efficient transport such as cycling or public transport.

- Not only national policies can help speed up these developments, also regional or local policies can contribute effectively. For example, by providing local subsidies or other benefits such as free parking for gas-powered cars or electric vehicles, by requiring or encouraging city buses or taxis to run on biomethane, by investing in bicycle infrastructure and public transport and by various spatial planning policies. National governments can coordinate and support these actions.
- Innovative and new technology can (and should) be promoted by various kinds of incentives. Care should be taken, however, to prevent undesired rebound effects of these incentives. For example, reducing car taxes or providing free parking spaces can increase car ownership and use, reducing the CO_2 benefits that could be achieved.

It is outside the scope of this project to investigate the potential contribution of each policy measure and renewable energy option towards the RED and FQD target for each country case study. This requires a much more detailed assessment of, for example, sustainable biomass availability and of energy efficiency improvements.

However, in order to allow a more quantitative assessment of the various options to meet the RED, the extreme scenarios and variants of Chapter 4 were calculated for each of the five countries investigated in this chapter. This results in an overview of, for example, the volumes of land-free biomass and/or electricity use in road transport needed to meet the 10% RED goal, for the three different base levels of biofuels (the three assumptions also used in the previous chapters). These results are given in Annex B.

8 Conclusions and recommendations

The need for renewable energy and CO_2 reduction in transport

- There are three crucial pillars in the future transition to sustainable transport and in achieving the 60% GHG reduction target set for the sector for 2050: improved fuel efficiency, renewable energy deployment and reducing transport volume. These three options are communicating vessels: if one delivers less GHG reduction than expected, the others will have to achieve more.
- Scenario studies show that this long-term GHG reduction target can be met in a sustainable manner if all types of sustainable renewable energy options, fuel efficiency and energy demand reduction measures are deployed at much as possible, in parallel with limiting transport volumes. A re-orientation towards a much more low-carbon and renewable transport energy system is a prerequisite for meeting future climate targets.
- The RED is the driving force behind the recent market developments in renewable energy in transport, in conjunction with the FQD. The current policy framework in transport has, however, resulted in a growing market for unsustainable biofuels. The main problems occur due to insufficient sustainability criteria, the difficulty to effectively implement these criteria, monitor compliance on the ground and prevent the large-scale indirect land use change effects (ILUC) that are not yet incorporated in the official sustainability criteria.
- Alternatives to land-based biofuels exist, but their shares are still very low in most Member States. In the current market and policy framework, land-based biofuels have a cost advantage, and they are easy to use: they can be blended into conventional fuels and then be used in the existing vehicle fleet (up to a certain level). Some of the more sustainable alternatives need a new filling/charging infrastructure plus modified engines (e.g. biomethane) or a whole new drive train and battery technology. They can play a significant role in the future, in reasonable amounts, subject to overall sustainability limits, but they need political support and an adequate policy framework to be deployed.
- In view of the need to decarbonise the transport energy system in the coming three to four decades, it is important to be aware of the long lead times for the various technology developments, vehicle and infrastructure modifications, etc. that will be necessary. Changing the energy system in this sector is a very far-reaching exercise which needs strong policy incentives to ensure that the right steps are taken, that all actors move in the same direction and that effective boundary conditions are in place to prevent undesired impacts.

Can the RED and FQD targets be met without causing (additional) land use change?

- The scenario calculations in this report show that meeting the EU's targets without additional land use change is only feasible after drastic policy changes at EU level. Member States need to agree to these changes and refocus their policy strategy and take the necessary actions to move away from the land-use biofuels, towards energy efficiency and demand reduction, and other more sustainable alternatives.
- In the short to medium term, the uptake of renewable electricity in transport (in both electric road vehicles and railway transport) and, within

sustainable limits, the production of biofuels and biogas from waste and residues not currently used in other sectors, should be encouraged. In the longer term (end of 2020 and beyond), road vehicles run on hydrogen produced from renewable energy sources might also be an option, but costs are still high and the well-to-wheel energy efficiency is typically less favourable than with battery electric vehicles.
- In the time frame until 2020, the largest land-free renewable energy potential not yet deployed are biofuels produced from consumer waste and manure. A large share of these biomass streams can currently only be converted to biomethane. Using this potential therefore requires significant investments in bio-CNG and/or bio-LNG vehicles and infrastructure for dedicated fleets.
- The cost and benefits of these investments should be assessed further, probably best on a country-by-country basis (see below). A decision on further developing bio-CNG/LNG should also be part of a broader decarbonisation and bioenergy strategy, since climate policies will also lead to an increase of biomethane demand from other sectors.
- Improving energy efficiency and reducing transport energy demand are fundamental and equally important to the renewable energy efforts. These measures can contribute significantly to CO_2 reduction of the sector and reduce fossil fuels use at the same time.
- The RED can support these developments, but only if the sustainability criteria are significantly enhanced. Set a cap on the amount of land-based biofuels that can contribute to the target, taking into account the precautionary principle approach and the ecological limits of the planet and include ILUC emissions in the RED and FQD sustainability criteria for biofuels as soon as possible. This will be a clear signal to the industry and investors to increase investments more sustainable, innovative technologies.
- Experience with the current policy framework has shown that it is not easy to prevent undesired effects and unsustainable developments in this policy area. It is therefore recommended to closely monitor the effectiveness of any changes made to the sustainability criteria and incentives, and revise policies accordingly.

A number of sustainable scenarios were developed in this report to illustrate how the RED and FQD targets can be met without or with limited amounts of land-based biofuels. These scenarios require a drastic change of policy strategy at both EU and Member State levels, where key features of this revised strategy are:
- prevention of further growth of demand for land-based biofuels, limiting their use to levels much lower than anticipated in the National Action Plans;
- inclusion of ILUC impacts in sustainability criteria and GHG calculation methodologies of the RED and FQD;
- implementation of a range of policies that can achieve significant energy efficiency improvements and energy demand reductions;
- promote strong growth of renewable electricity use in road and non-road transport;
- ensure a strong increase of production and use of biofuels (incl. biogas) from waste and residues that are not used for other applications;
- promote a significant reduction of GHG emissions from oil and gas flaring.

Implications for the FQD

- The deployment of sustainable renewable energy can contribute significantly to the GHG intensity reduction target defined in the FQD as well.
- The scenarios developed in this report show that renewable energy options alone can reduce GHG intensity of transport fuels about 3% without any land-based biofuels, and up to 5.5% if the 2010 level of biofuels is kept as a base level. The FQD target is 6%, the remaining reduction will have to be achieved with other measures.
- GHG reduction options in the fossil fuel chain include reducing flaring and venting, shifting to fuels and energy sources with lower GHG intensity, etc. Especially the potential of flaring and venting reductions is large. The technology seems to be available, cost of these measures depend on the specific project.

CO_2 reduction

All measures recommended in this report achieve significant CO_2 savings. Especially the fuel efficiency improvements and energy demand measures are very effective in this respect, but the sustainable renewable energy options and reductions in flaring and venting will contribute as well.

The importance of reducing transport demand and transport energy consumption

- When designing an effective decarbonisation strategy for the transport sector, improving energy efficiency and reducing transport demand is at least equally important to increasing renewable energy demand and supply. Reducing energy demand means that less renewable energy is needed to achieve a certain reduction in the GHG intensity of transport fuels.
- Reducing energy demand will typically result in a lower GHG intensity of the fuels at a given level of renewable energy. Alternatively, it will require less renewable energy to achieve a certain GHG intensity.
- It will also directly reduce GHG emissions of the sector, as well as dependence on oil price and fossil fuel imports.
- Current biofuels are relatively costly GHG reduction measures, with cost effectiveness typically in the range of several hundred €/ton CO_2eq., and much higher for biofuels that do not significantly reduce GHG emissions. Implementing more cost-effective measures that improve energy efficiency or transport demand are therefore much more attractive from a cost effectiveness and climate policy point of view.

An important choice to be made: in which sector should the sustainable biomass be used?

- The amount of sustainable biomass is limited. It can be used to replace fossil fuels and thus reduce GHG emissions in transport. However, it can also be used in electricity and heat production, and in the chemicals industry. These sectors also need to significantly reduce their GHG emissions in the coming decades, and biomass is a convenient means to achieve this.
- The choice in which application the available sustainable biomass should be used depends on the assessment criterion that is used – each application has its pros and cons.
- Looking at this overall picture from a long-term perspective, it seems justified to use biomass in some industrial heat applications, part of the transport sector (e.g. aviation, maritime, heavy-duty long-distance transport) and in the chemical industry. These have few other options to lower the GHG intensity of their fuels.

- From a more short-term perspective, however, the land-free biomass can best be deployed in the power and heating sector. This saves more GHG emissions than using it in the transport sector.
- A balance has to be found between these short-term and long-term considerations. This requires building a strategy on the best use of the available biomass waste and residues, which takes into account all sectors, cost, potential alternatives, technological barriers, etc.

EU policy recommendations

It can be concluded that the RED and FQD targets can be met without or with limited levels of land-based biofuels, even though this requires quite some effort and policy changes. If properly focussed, these efforts can be a very crucial step towards future decarbonisation of the transport sector, and meeting the goals of the EU Roadmap for 2050 and the EU White Paper for Transport. The following EU-level actions are recommended:

- Remove all direct and indirect support for land based biofuels and adopt a trajectory from current consumption levels towards near-zero use in order to prevent further environmental and social damage.
- Include ILUC emissions in the life cycle analysis of biofuels under the RED and FQD, and significantly improve sustainability criteria for land-based biofuels and biogas (see Section 1.2) marketed in the EU.
- Consider extending the use of multiplication factor for renewable electricity in the RED methodology to non-road modes.
- Re-focus National Renewable Energy Action Plans on the untapped potential for energy efficiency in transport, reducing transport demand and encouraging a switch to less energy-intensive transport modes:
  - increase policy incentives for fuel-efficient vehicles;
  - implement measures such as reduce speed limits on motorways and road charging, increase fuel taxes, invest in modal shift towards more fuel-efficient modes, etc.
- Ensure that only biofuels from waste and residues that have no other use can be counted double.
- Establish clear definitions and sustainability criteria for ‘waste-streams’, ‘by-products’ and ‘residues’ to limit use to sustainable levels, and to verify the origin of those streams to avoid indirect environmental impacts. Correct lifecycle carbon accounting of waste and residue streams is needed to ensure genuine emission reductions.
- Request Member States to submit a revised national renewable energy action plan, taking the new insights and strategy into account.
- Ensure effective implementation of fossil fuels’ life cycle emissions in the FQD. Include reduction of flaring and venting, efficiency improvements in refineries etc. to count towards the target and prevent fossil fuels consumed in the EU from becoming worse in terms of their carbon footprint.
- Support R&D of technologies for battery electric and hydrogen vehicles and infrastructure.
- Harmonise fuel taxes and ensure taxes are differentiated according to actual WTW CO_2 emissions.
- Improve type approval testing for passenger cars and vans, to ensure the CO_2 target for 2020 is also met under real-world conditions.
- Implement fuel efficiency policies for heavy duty vehicles.
- Develop an integrated strategy for biomass and bioenergy based on an assessment of the availability of sustainable bio-feedstock, the potential demand from all different sectors and an evaluation of GHG reduction potential taking into account the ‘carbon payback time’, etc.

Member States and the RED target

The overall policy strategy described above should be a general guideline for Member States as well. However, each EU Member State has different characteristics that may justify a differentiated approach to meeting the RED target and the longer-term sustainable transport goals. It is thus recommended that each country revisits its strategy with the aim to refocus towards the more sustainable measures described above. The following can serve as a guideline:

- Decide on a new strategy and action plan to meet the 10% target of the RED in a sustainable way. Revise the national renewable energy action plan.
  - Shift transport policy focus from land-based biofuels towards improved energy efficiency and GHG mitigation measures in the sector. For example through stronger CO_2 differentiation of vehicle taxes, increased fuel taxes, investments in bicycle infrastructure and public transport, lowering of speed limits on motorways, investing in rail- or waterway transport to promote modal shift, implement road charging, etc.
  - Avoid rebound effects: a subsidy or tax reduction for fuel-efficient cars will increase car ownership and use, building of new infrastructure typically increases transport volumes unless compensating measures are taken.
- Speed up market uptake of electric vehicles by ensuring that effective incentives are in place, and charging infrastructure is being developed at the same time.
- Support R&D of technologies for battery electric and hydrogen vehicles and infrastructure.
- Encourage use of sustainable biofuels from waste and residues in reasonable amounts, subject to overall sustainability limits, and prevent land-based biofuels. Implement effective incentives in the national policies.
- Develop an infrastructure and vehicle fleet for biomethane in transport and green certificates with adequate verification.
- Implement (or further strengthen) incentives for the production of biomethane from waste and residues that have no other applications.
- Countries with a large share of renewable electricity and overall low GHG intensity of power production should specifically aim for a rapid development of electric road transport. In these countries, the contribution of EVs to the RED and FQD targets will be relatively high, as well as the GHG reduction that is achieved with these EVs.
- In countries or regions with a large animal husbandry sector, anaerobic digestion of manure should be developed further. All countries should aim to make most use of potential sources of waste and residues, by producing biomethane from municipal waste, FAME or HVO from C1 fats and used cooking oil, etc.

Member States can speed up and facilitate many of these developments with fiscal measures, subsidies or other incentives.

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Annex A The calculation model

A.1 Introduction

The main aim of the calculation model is to calculate the influence of different biofuel blending strategies on the achievement on the RED target as well as on the FQD target.

Input

The data used as input for the model can be categorised in a category country-specific data and data in line with the calculation methodology of the Renewable Energy Directive as well as the Fuel Quality Directive. Both categories will be explained shortly:

Country specific data

The predictions on the composition of the vehicle fleet by TREMOVE (Version 3.3.2 alt) for the year 2020 were used as a starting point for the model (see www.tremove.org for more information on the model and scenario assumptions). Predictions are provided in PJ for each individual Member State and for the total EU-27. The vehicle categories of TREMOVE were used to list the possible options to blend biofuels for each category. Both low blends in regular vehicles (bulk) and high blends in niche vehicles (niche) are included.

Besides data from TREMOVE other country-specific data were used as input for the model, namely:
- the average share of renewable electricity in 2020 (taken from ECN, 2011);
- the emission factor for electricity generation (taken from the FQD).

Calculation methodologies of the RED and FQD

The methodology for calculating the greenhouse gas emissions of biofuels and the contribution to the 10% target were already laid down in the Renewable Energy Directive.

The following data were obtained from the RED:
- multiplication factors for biofuels from waste and residues and for renewable electricity in road transport;
- energy content for biofuels as well as conventional fuels;
- GHG emissions factors per biofuel (the average was taken in case the Directive included emissions factors per feedstock).

Variables

The model makes it possible to vary a wide range of variables. The main variables in the model are:
- fuel efficiency rate (in %);
- multiplication factors;
- composition of low blends (in vol% per biofuel);
- composition of high blends (in vol% per biofuel);
- market share of niche vehicles (in %).

TREMOVE does not include estimations for the market share of niche vehicles, like full electric vehicles or vehicles running on E85. Therefore market shares of those vehicles are included as variables.

Outcome

Depending on the variables the model provides different outcomes. On the one hand the contribution to the RED and FQD target is an important part of the outcome in combination with the quantities of biofuels and renewable electricity needed to meet the targets. Quantities are provided per type of biofuel and a distinction is made between single- and double-counting biofuels. The amount of renewable energy in the transport sector is also provided for non-road as well as road transport. Per category the actual blended amount of biofuel/energy as well as the contribution to the target is presented. The sum of all those categories is presented as the total renewable energy (in PJ) together with the total amount of energy in the transport sector.

Annex B Country case studies: scenario results

B.1 Introduction

In the following, the scenario results are given for the five case studies: Denmark, Finland, France, the Netherlands and Germany.

For each case study, country-specific GHG emission factors were used for the electricity production in 2020. These were taken from EC, 2009d and shown in Table 7. The emission factor of France is relatively low, mainly because of its large share of nuclear energy. Germany has relatively high emissions because of its relatively large share of coal-powered plants.

Table 7 GHG emission factors of electricity production in the five case study countries, in 2020

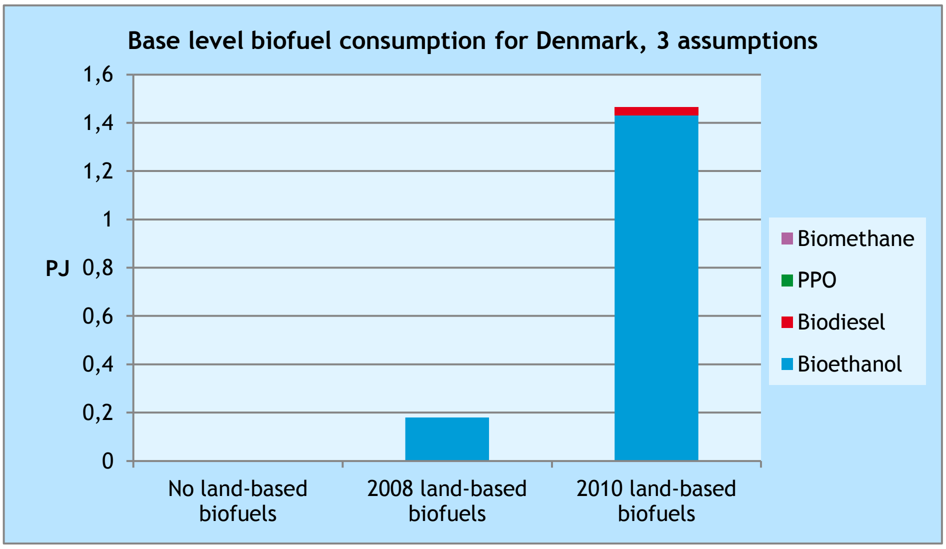
	Denmark	Finland	France	Germany	The Netherlands
g CO_2/MJ	52.8	41.7	13.9	100.0	72.2

Source: EC, 2009d.

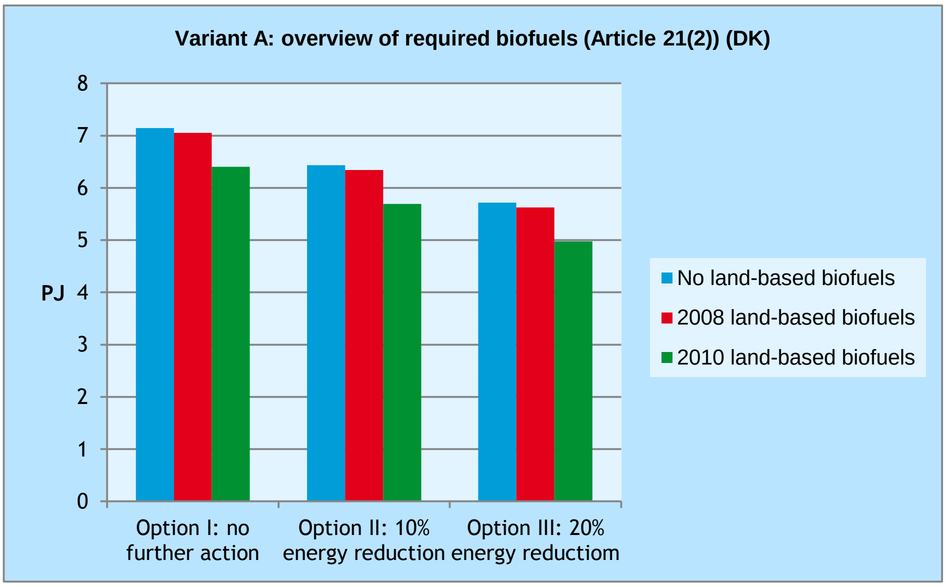
In addition, the country-specific base levels of biofuels were used to define the scenarios.

Successively, the following figures are given:
- The base level biofuels demand that was assumed in the three scenarios.
- Variant A: The volume of land-free biofuels needed to fill the gap between the base level and the 10% RED target in 2020, for the options outlined in Section 4.3:
  - I Only biofuels from waste and residues (Article 21(2)) are used.
  - II Only biofuels from waste and residues are used, in combination with a transport energy use reduction of 10%.
  - III Only biofuels from waste and residues are used, in combination with a transport energy use reduction of 20%.
- The contribution of renewable energy towards the FQD target, for these options.
- Variant B: The electricity demand in road transport that would be needed to fill the gap between the base level and the 10% RED target in 2020, for the options outlined in Section 4.3.
  - I Only renewable electricity in road transport is used to meet the RED target.
  - II The use of renewable electricity in road transport is combined with a transport energy use reduction of 10%.
  - III The use of renewable electricity in road transport is combined with a transport energy use reduction of 20%.
- The contribution of renewable energy towards the FQD target, for these options.

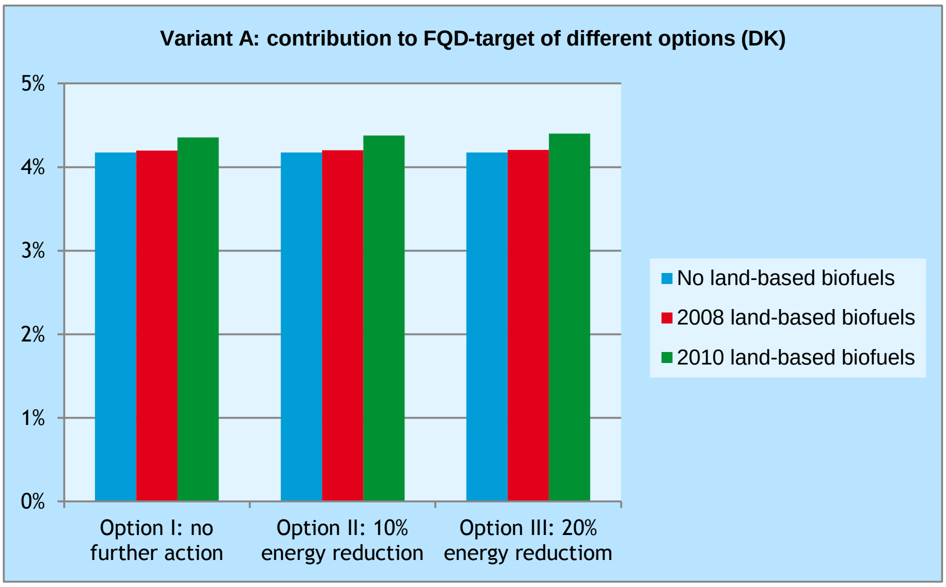
B.2 Denmark



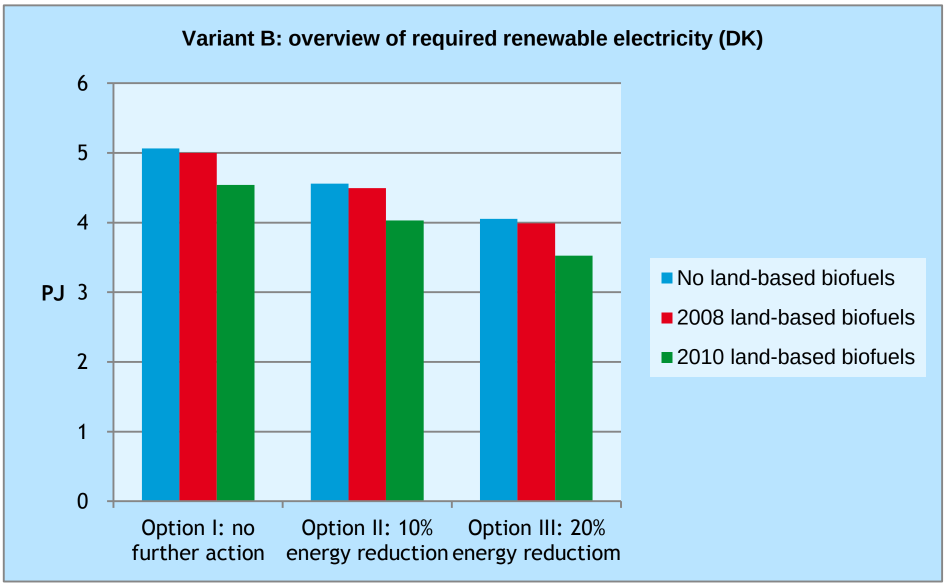
Base level biofuel consumption for Denmark, 3 assumptions
1,6
1,4
1,2
1
PJ 0,8
0,6
0,4
0,2
0
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels
Biomethane
PPO
Biodiesel
Bioethanol

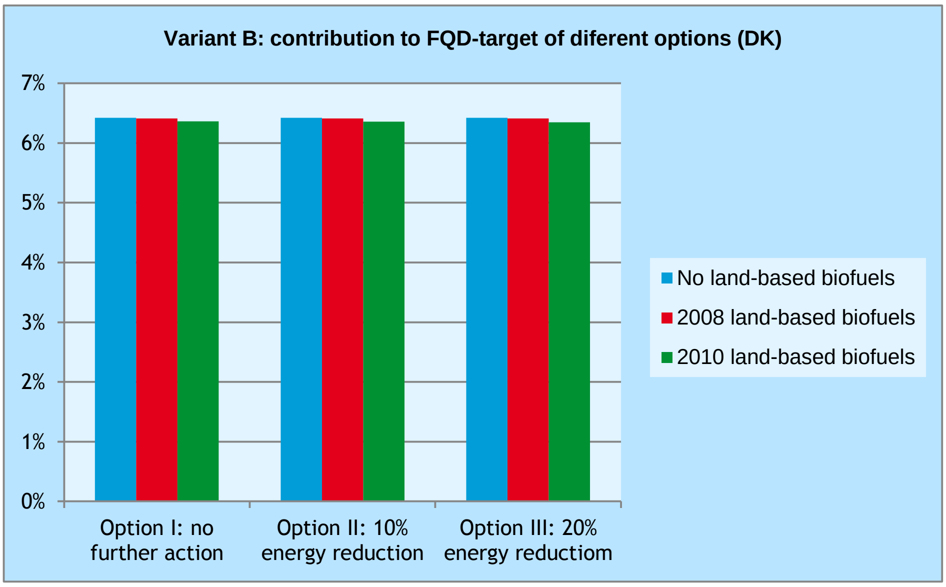


Variant A: overview of required biofuels (Article 21(2)) (DK)
8
7
6
5
PJ 4
3
2
1
0
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

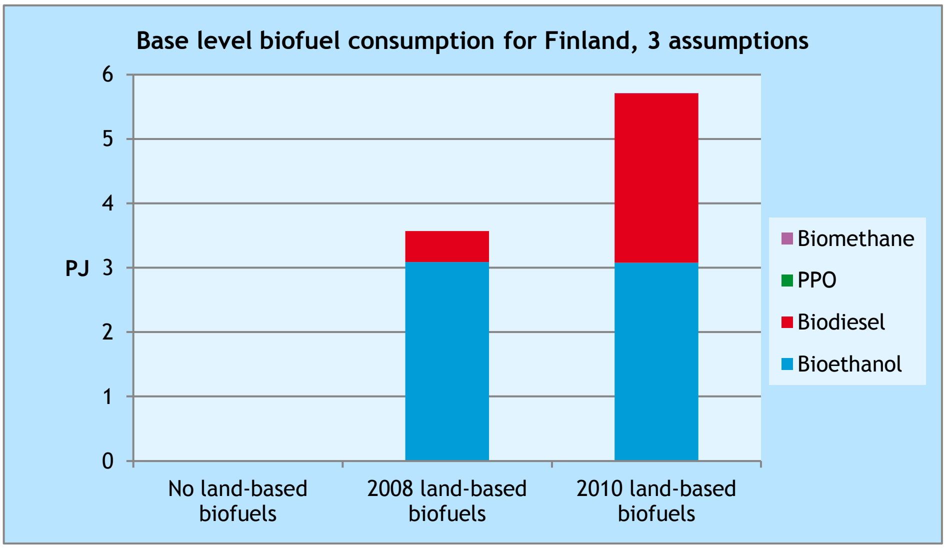


Variant A: contribution to FQD-target of different options (DK)
5%
4%
3%
2%
1%
0%
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reduction
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

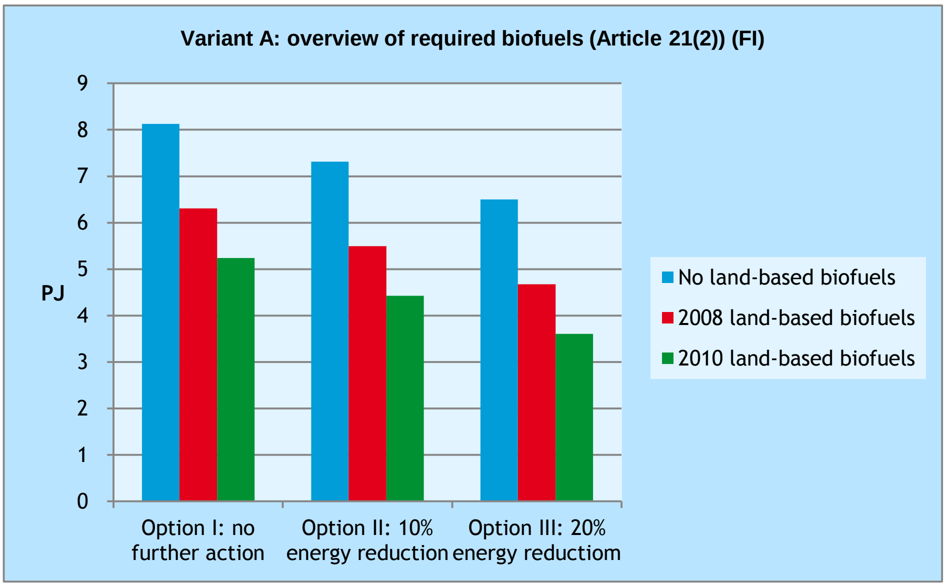

Variant B: overview of required renewable electricity (DK)
PJ
6
5
4
3
2
1
0
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels


Variant B: contribution to FQD-target of diferent options (DK)
7%
6%
5%
4%
3%
2%
1%
0%
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

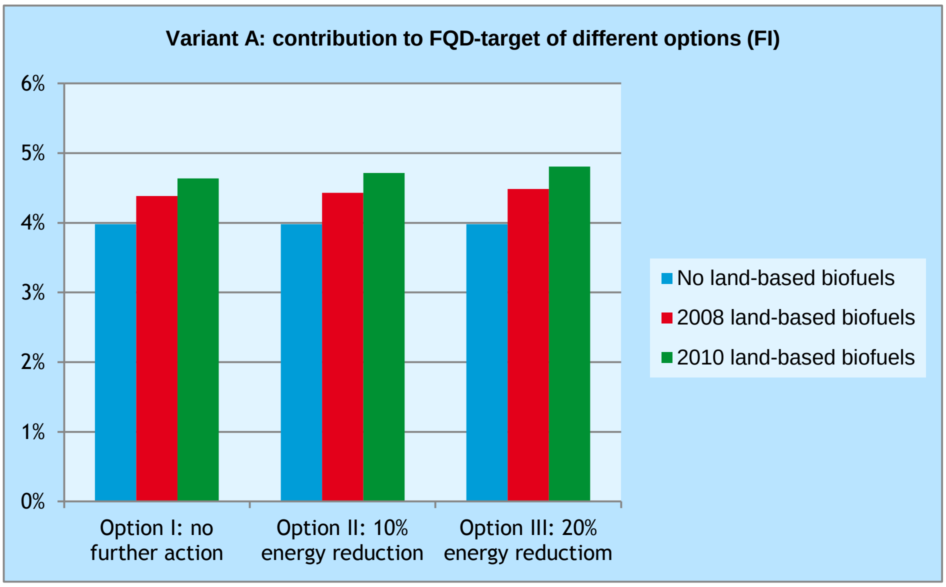
B.3 Finland



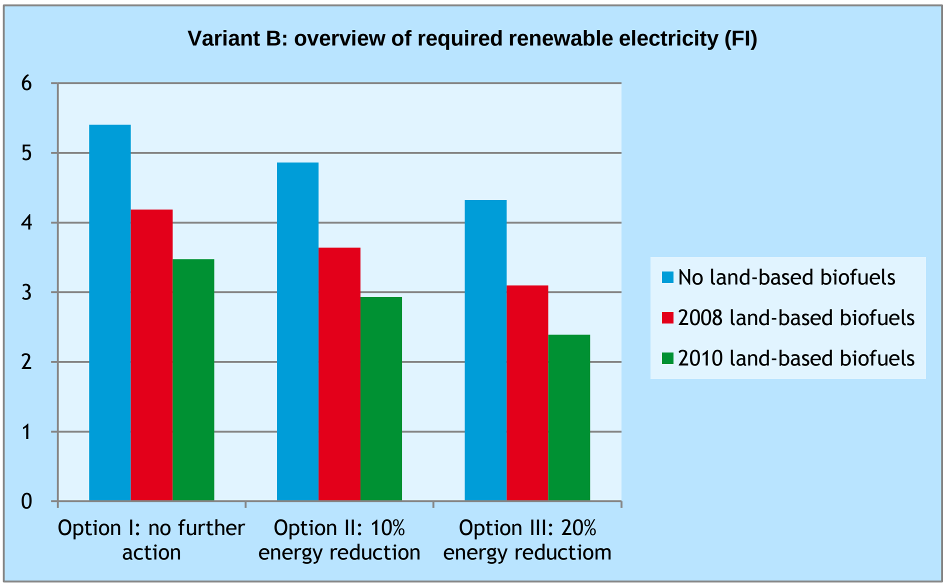
Base level biofuel consumption for Finland, 3 assumptions
PJ
6
5
4
3
2
1
0
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels
Biomethane
PPO
Biodiesel
Bioethanol

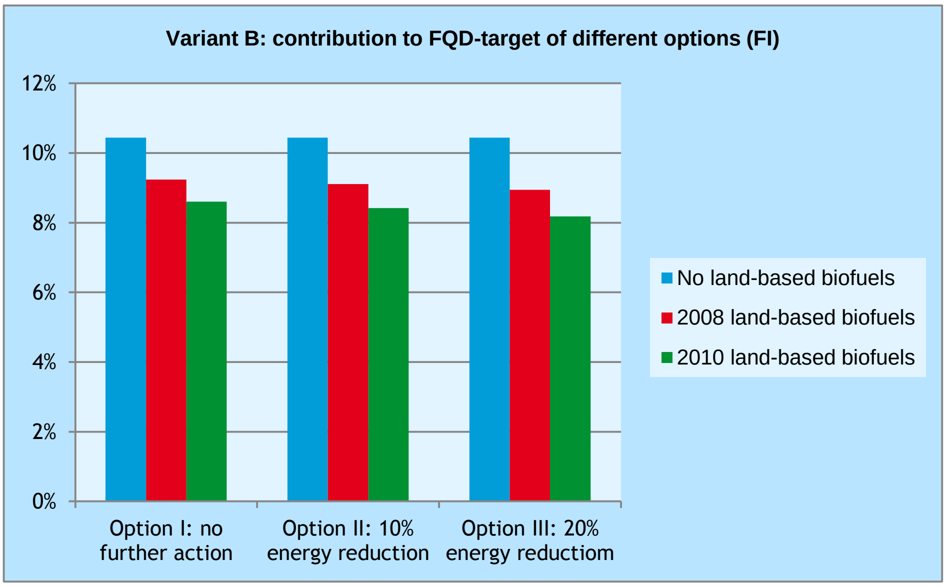


Variant A: overview of required biofuels (Article 21(2)) (FI)
PJ
9
8
7
6
5
4
3
2
1
0
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

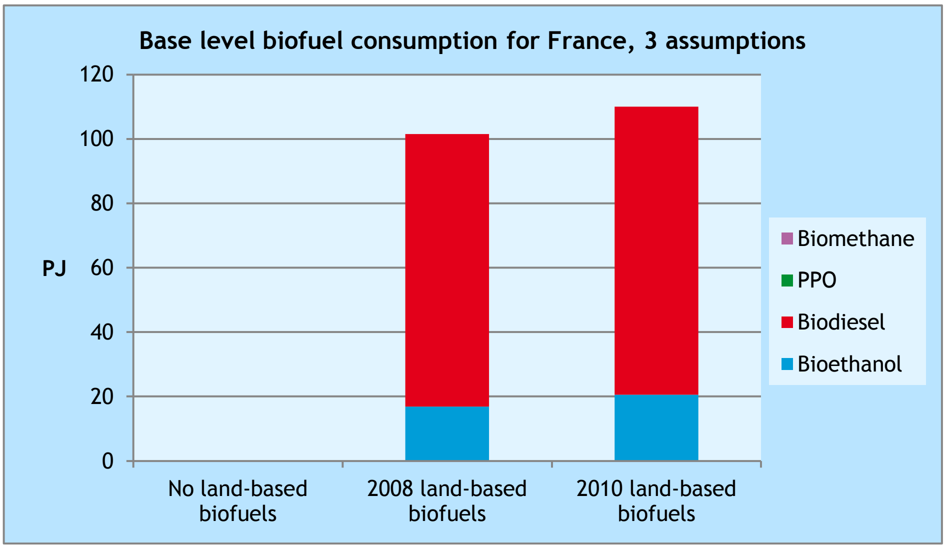


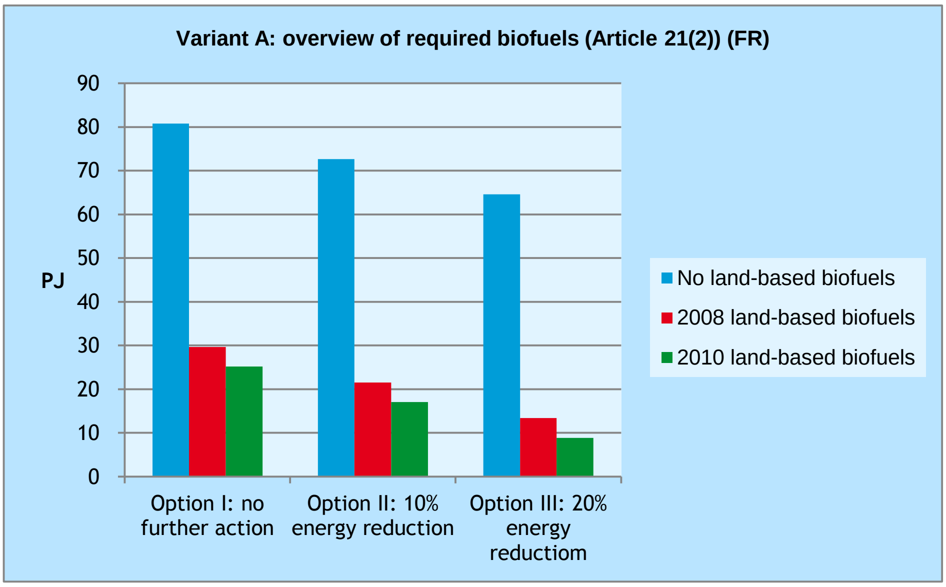
Variant A: contribution to FQD-target of different options (FI)
6%
5%
4%
3%
2%
1%
0%
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

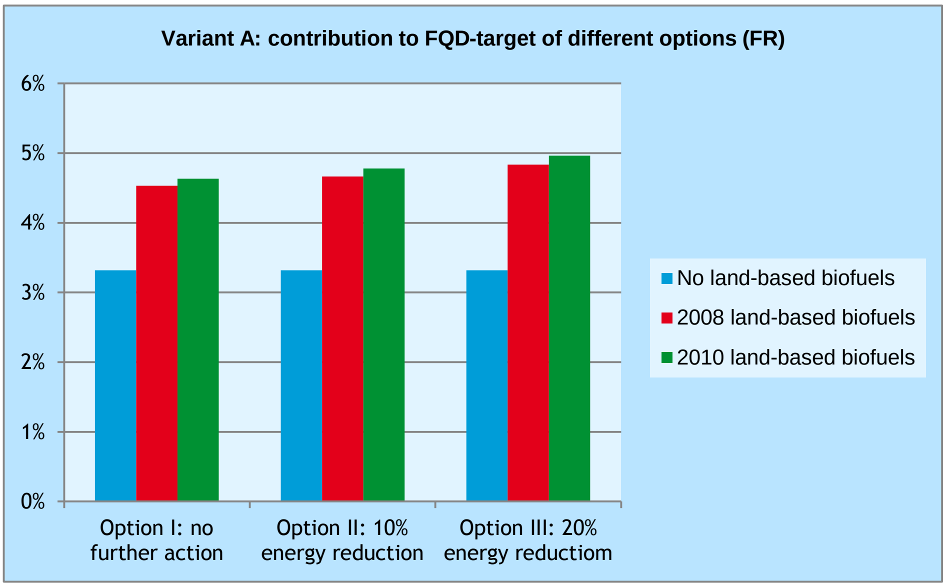

Variant B: overview of required renewable electricity (FI)
6
5
4
3
2
1
0
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

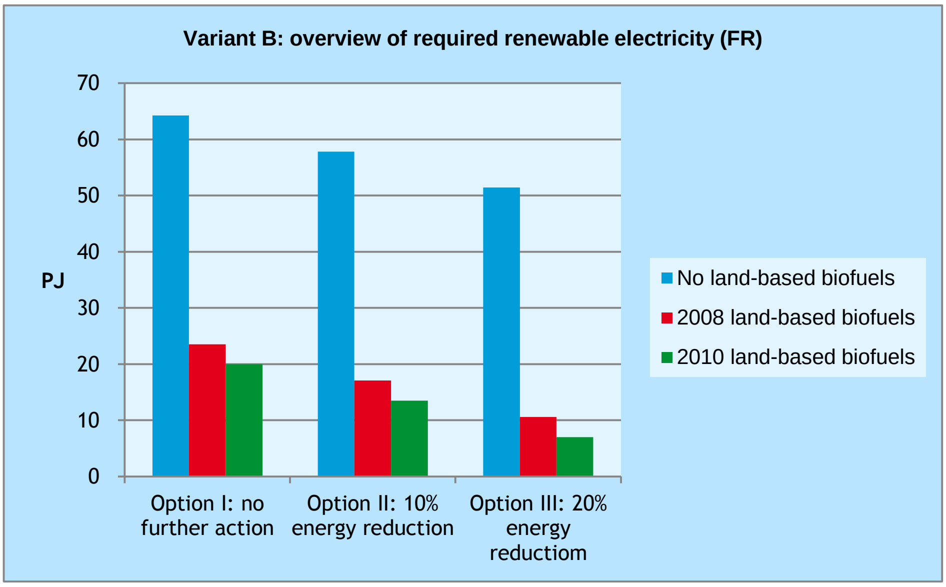

Variant B: contribution to FQD-target of different options (FI)
12%
10%
8%
6%
4%
2%
0%
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

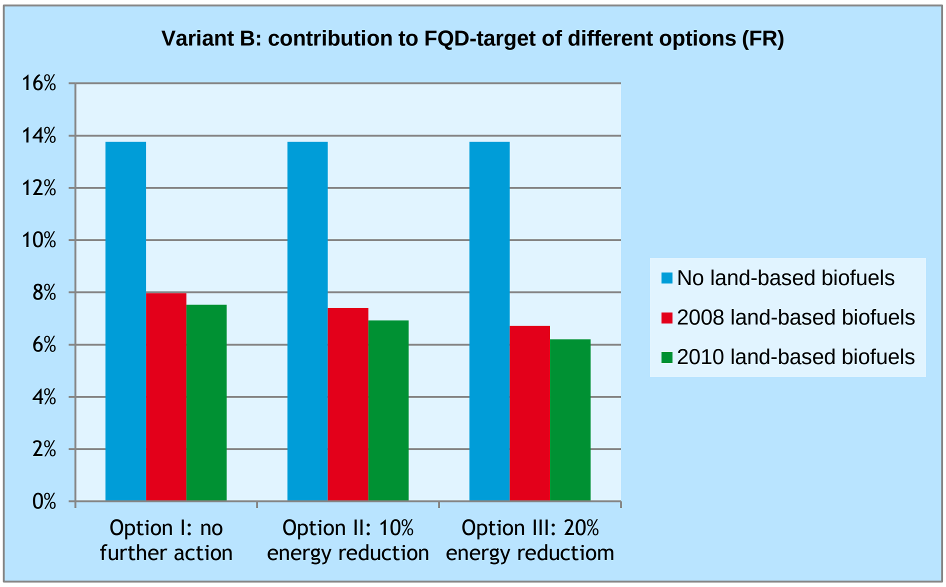
B.4 France


Base level biofuel consumption for France, 3 assumptions
120
100
80
PJ 60
40
20
0
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels
Biomethane
PPO
Biodiesel
Bioethanol

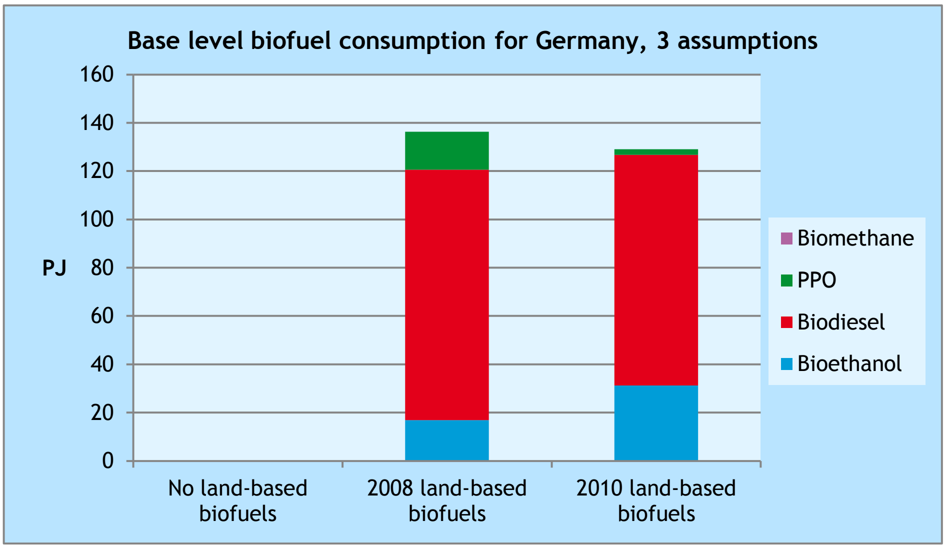

Variant A: overview of required biofuels (Article 21(2)) (FR)
90
80
70
60
50
PJ 40
30
20
10
0
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels


Variant A: contribution to FQD-target of different options (FR)
6%
5%
4%
3%
2%
1%
0%
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

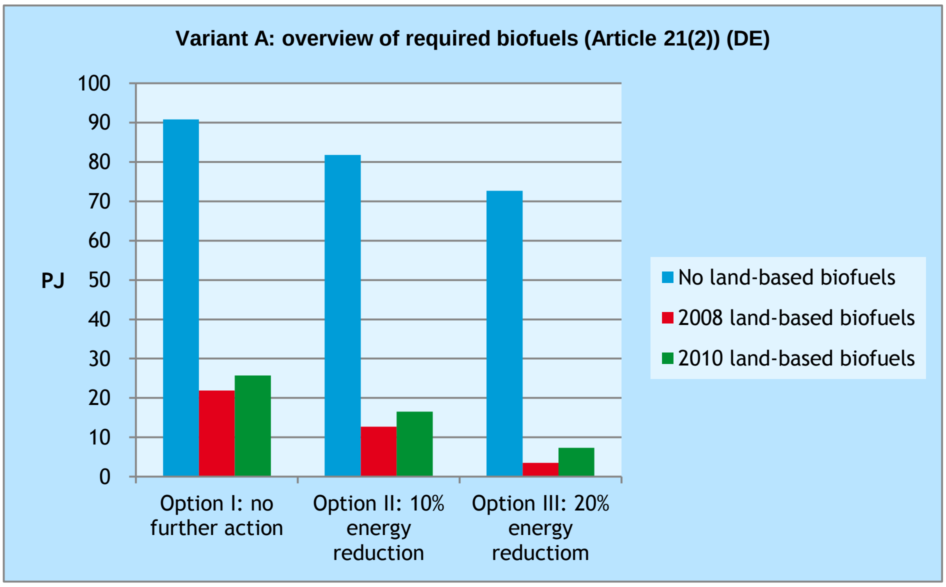

Variant B: overview of required renewable electricity (FR)
70
60
50
40
PJ
30
20
10
0
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels


Variant B: contribution to FQD-target of different options (FR)
16%
14%
12%
10%
8%
6%
4%
2%
0%
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

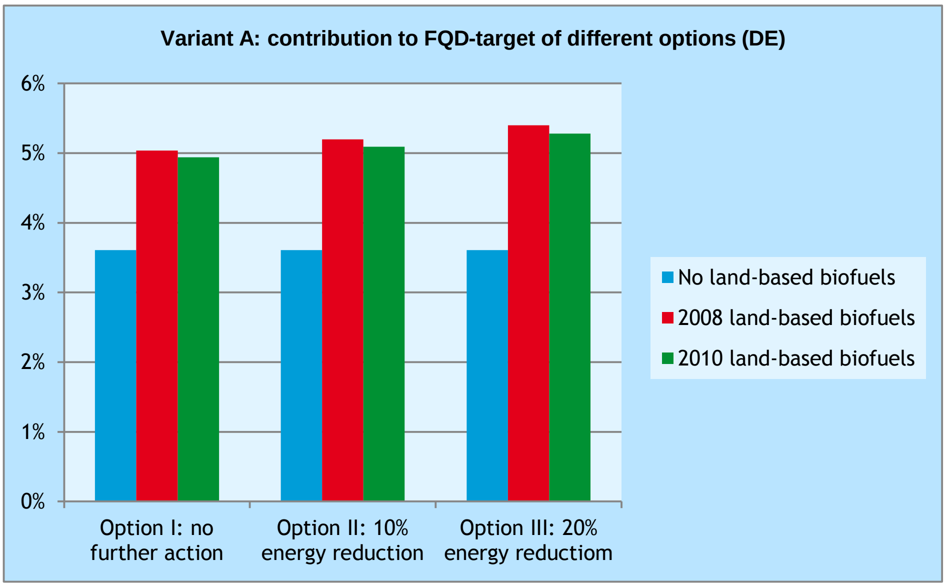
B.5 Germany



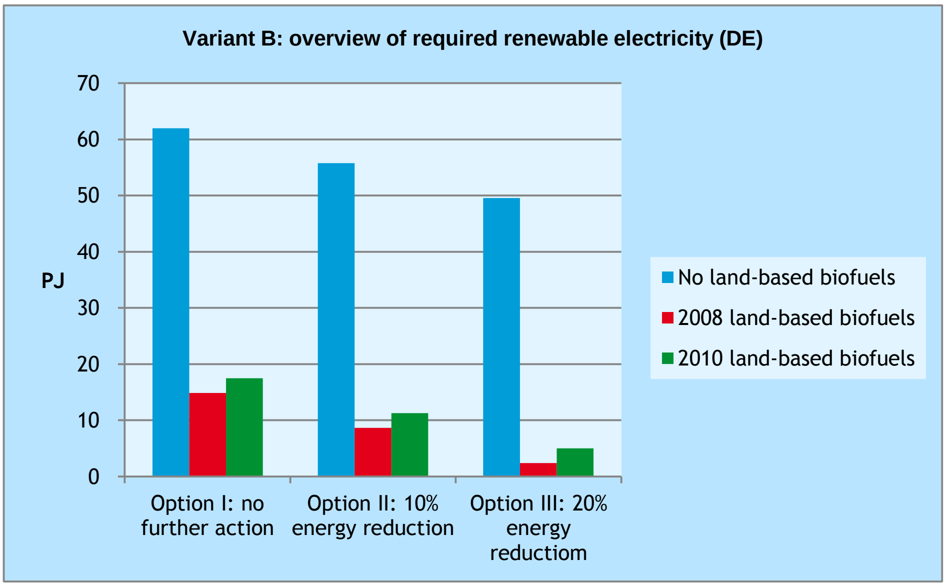
Base level biofuel consumption for Germany, 3 assumptions
PJ
0
20
40
60
80
100
120
140
160
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels
Biomethane
PPO
Biodiesel
Bioethanol

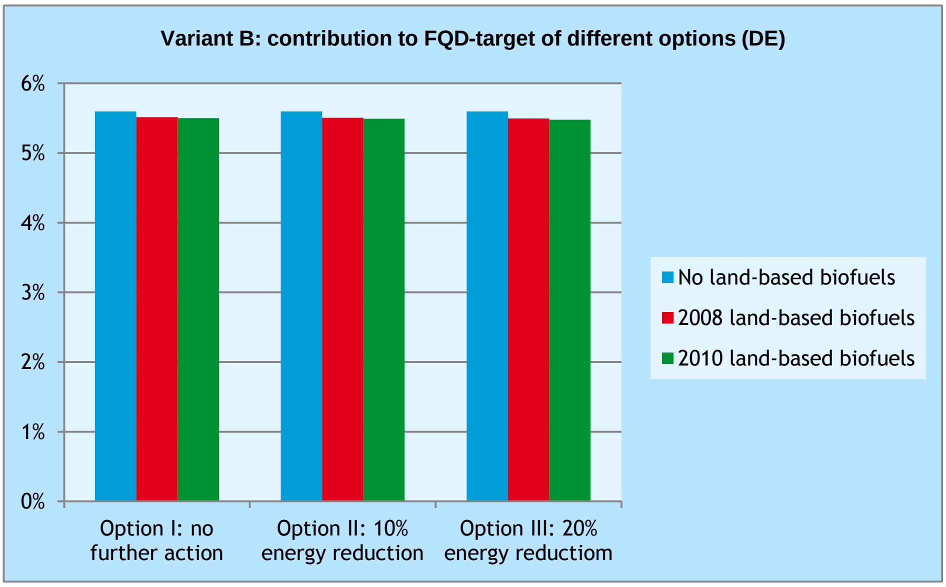


Variant A: overview of required biofuels (Article 21(2)) (DE)
PJ
0
10
20
30
40
50
60
70
80
90
100
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

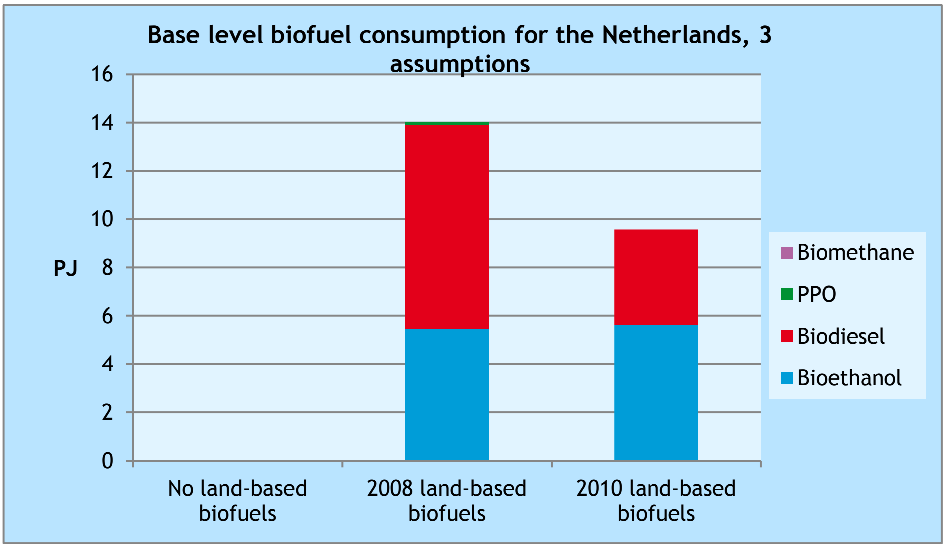


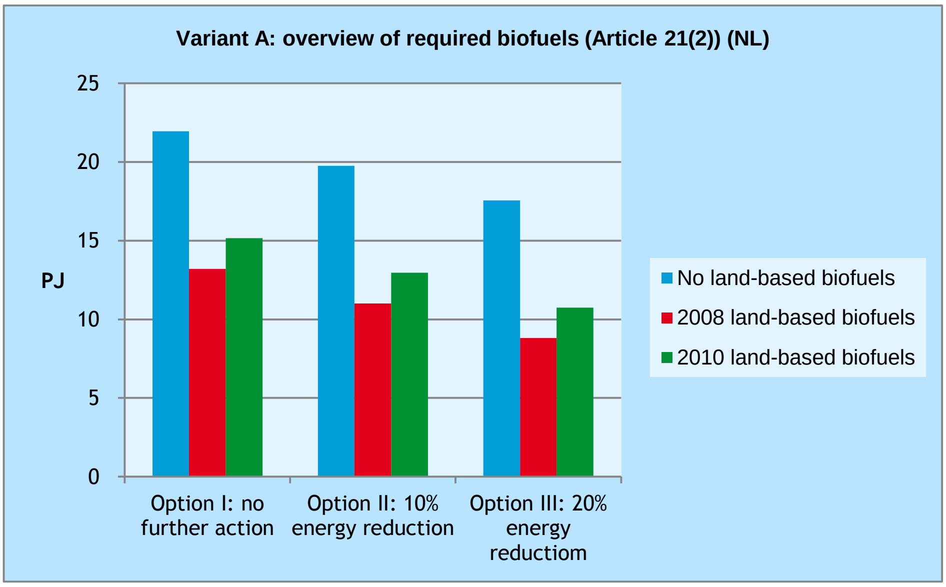
Variant A: contribution to FQD-target of different options (DE)
0%
1%
2%
3%
4%
5%
6%
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

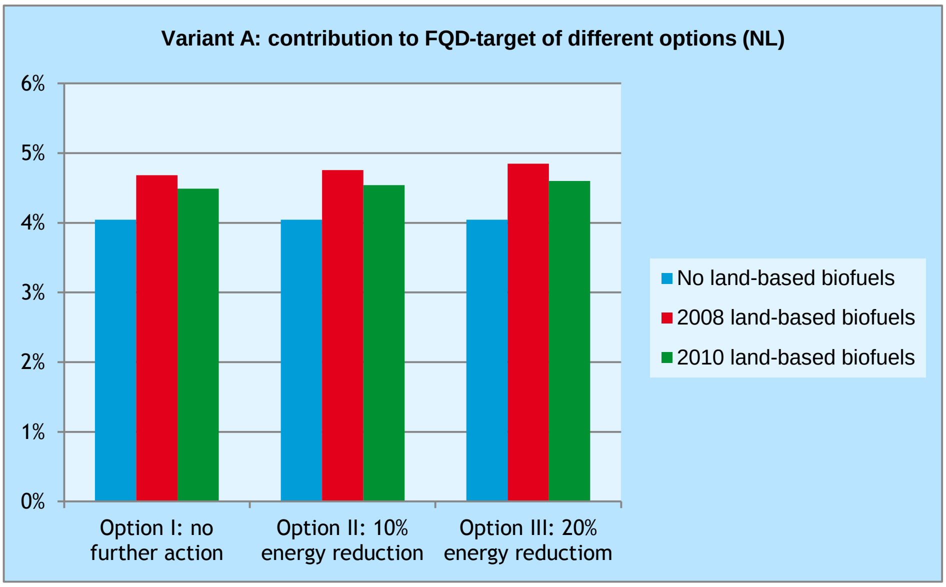

Variant B: overview of required renewable electricity (DE)
PJ
70
60
50
40
30
20
10
0
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

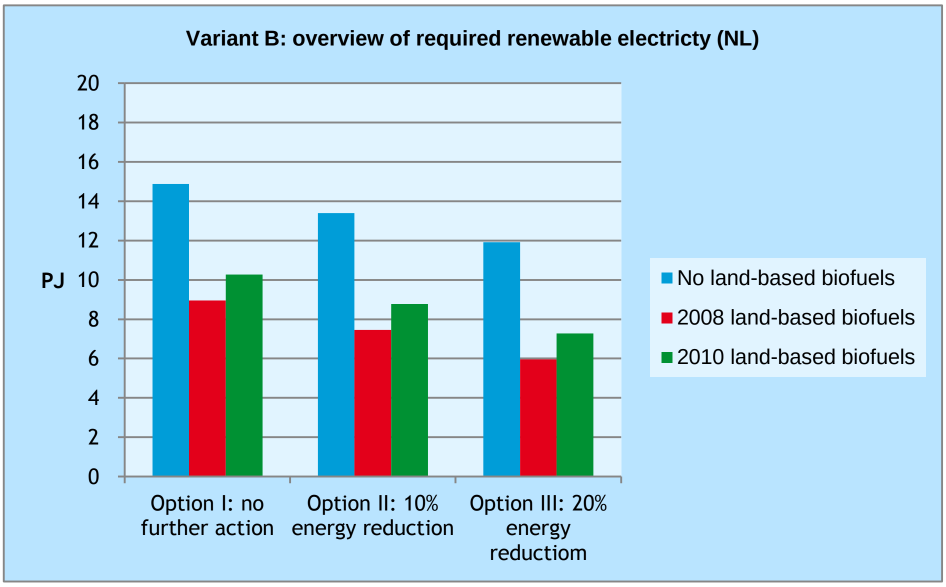

Variant B: contribution to FQD-target of different options (DE)
6%
5%
4%
3%
2%
1%
0%
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels

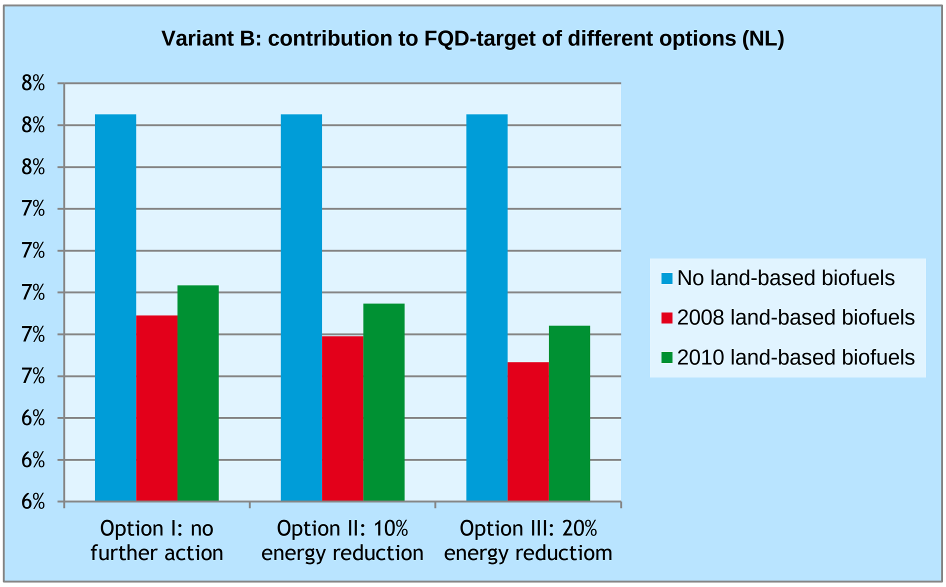
B.6 The Netherlands








Variant B: overview of required renewable electricty (NL)
20
18
16
14
12
PJ 10
8
6
4
2
0
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels


Variant B: contribution to FQD-target of different options (NL)
8%
8%
8%
7%
7%
7%
7%
7%
6%
6%
6%
Option I: no further action
Option II: 10% energy reduction
Option III: 20% energy reductiom
No land-based biofuels
2008 land-based biofuels
2010 land-based biofuels