

# 2030 Transport decarbonisation options



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**Date: 25 January 2019**

**Project number: 206260**

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## Executive Summary

### Overall conclusions

**Each EU Member State will finalize its Integrated National Climate and Energy Plan (NECP) to 2030** in the coming months, defining its ambitions for renewables in each sector of its economy to meet its obligations to achieve both 32% total renewables by 2030 and up to 40% decarbonisation of the non-ETS sector by 2030. These dual obligations will be challenging and potentially expensive, but they are needed by the EU as a whole to meet its Nationally Determined Contribution under the Paris Agreement.

**How Member States choose to meet their climate obligations to 2030** will vary, with some options carrying a large potential, but also high risks of failure or simply high costs. Realistic and affordable solutions should form the bulk of each Member State's policies.

**The transport sector is the only sector in the EU in which almost no climate progress has been made** to date and that also anticipates the highest growth rate in the coming decade. Because of the lack of progress in the transport sector, transport sector emissions that used to account for less than one sixth of total greenhouse gas emissions in the EU are now about to exceed one quarter.

**Within the transport sector, few scalable options for decarbonisation exist.** All options should be encouraged, but the only technologies that are realistically available for large scale decarbonisation to 2030 are electrification and biofuels. The relationship between these technologies is not either/or. Amongst others, IEA and IPCC state that both technologies need rapid expansion to achieve a 1.5-degree pathway.<sup>1,2</sup>

The current study confirms that **modest shares of renewable energy in transport will not be sufficient to reduce carbon emissions in the Study Region.** Modest means a business-as-usual development in line with the recast of the Renewable Energy Directive (RED II). Even with full compliance with the RED II, we project that transport sector emissions in the Study Region will increase by 38 Mtonne. The absolute consumption of fossil fuels will still increase, and these fossil fuels will have higher carbon intensities than those of today. Instead, **far reaching deployment of both electrification and biofuels (far beyond what RED II requires) are needed to achieve significant carbon savings in comparison to today.**

**The structure of RED II disincentivizes Member States who use less than 6% conventional biofuels in 2020, from maximizing the use of conventional biofuels in 2030.** Therefore, it makes climate and economic sense for Member States to ensure that they reach at least 6% conventional biofuels use in 2020. Member States that use

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<sup>1</sup> IPCC 2018 SR1.5 Chapter 4 Supplementary Material on Strengthening and implementing the global response.

<sup>2</sup> IEA 2018, Biofuels for transport, Tracking Clean Energy Progress

less than 6% conventional biofuels in 2020 may thus face far higher costs of compliance in 2030 than Member States that attain that threshold.

**Currently the average carbon abatement cost of electric driving in the Study Region exceeds €700/tonne CO<sub>2</sub> equivalent, while the cost of conventional biofuels (inclusive of ILUC) is less than €200/tonne.** Using the estimates for commodity prices that have been provided to the Member States for their NECP development, the carbon abatement cost of electric vehicles is expected to fall below **€200/tonne by 2030 and the cost of conventional biofuels to around €20/tonne.**

**These carbon abatement cost reductions require not only a continuation of current trends in biofuels, renewable electricity and electric vehicle technology, but also strong and effective governance within the Study Region.**

## Decarbonisation of transport in the Study Region

Decarbonization efforts now more than ever are at the forefront of international debate and ambitions. Since the inception of the Paris Agreement in 2015 and now with the release of the IPCC 1.5 degrees report, there is a sense of urgency in mitigating greenhouse gas emissions cost-efficiently, and in a timely manner. All sectors must act immediately and achieve deep decarbonisation. The transport sector, with a quarter of total EU-28 greenhouse gas emissions is no exception.<sup>3</sup> This report focuses on road transport, which represents about 90% of transport energy use and emissions.

There are roughly three options to reduce greenhouse gas emissions from road transport:

- Reducing transport demand, for instance through teleworking, modal shift, pricing and operational improvements. However, despite many actions in this area, transport is still projected to grow significantly.
- Vehicle efficiency improvements. Improved combustion engines and electrification are projected to significantly improve energy efficiency in transport. However, the replacement of the fleet with more efficient vehicles takes time and, consequently, by 2030 EU transport energy consumption will decrease only modestly.
- Use of alternative energy, including biofuels. Remaining transport energy should be provided from low carbon sustainable sources, such as sustainable biofuels and renewable electricity.

A combination of electric driving and sustainable biofuels can form an optimal pathway to meet EU climate targets.

This study explores what some Member States can do economically and politically with the three options listed above. This study specifically assesses the options for renewable energy in road transport in 9 Member States in Central & Eastern Europe: Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Austria (see Figure 1). For ease of reference, this large region will be referred to as the “Study Region”.<sup>4</sup>

The energy consumption in road transport in this region is set to increase by 16% following the rising demand for transport of people and goods.

Without additional policies, emissions from road transport would therefore increase by over 20% instead of decrease. This is discussed in Chapter 3.



Figure 1. Geographical scope of this study, collectively called “the “Study Region”.

<sup>3</sup> <https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-10>

<sup>4</sup> Study region scope was requested by client.

Multiple EU policies address transport sector carbon emissions:

- The Alternative Fuels Infrastructure Directive (2014/94/EU), which aims to promote alternative fuels infrastructure.
- The Renewable Energy (Sources) Directive 2009/28/EC, known as the RED, which requires 20% renewable energy overall in 2030 and 10% in the transport sector, but which expires in 2020. The RED will be replaced with the RED II, which has been agreed by the European Parliament and Council, but which is not yet enacted. The RED II requires 32% renewable energy overall in 2030, and between 2.6% and 10.5% in each Member State in the transport sector.<sup>5</sup>
- The Fuel Quality Directive (2009/30/EC), expiring in 2020, which requires fuel suppliers to reduce the average greenhouse gas intensity of their fuels by 6% in 2020.
- The Effort Sharing Decision (406/2009/EC), which attempts to reduce emissions in non-ETS sectors and expires in 2020 and is being replaced with the Effort Sharing Regulation, which is not yet promulgated, but which requires 30% reduction in these sectors (of which transport has the largest share of emissions) on an EU wide basis in 2030 compared to 2005, and between 0% and 40% in each Member State depending on GDP.<sup>6</sup>

Accordingly, in the period to 2020, the RED and the Fuel Quality Directive are of the most importance and are generally accepted as such by all stakeholders. But in the period from 2020-2030, with effectively no increase in transport sector renewables required by the RED II over 2020 required levels, the Effort Sharing Regulation could very well become a more important source of transport decarbonisation than the RED II.

The urgency of the climate problem and the limited ambition level of existing policy frameworks at the EU level call for acceleration of the deployment of renewable energy in transport at the Member State level. Especially the further development of biofuels is an interesting option for the Study Region, with multiple advantages:

- Spurring economic development and employment in rural regions.
- Investments in, and modernisation of, the agro-industrial sector.
- Increasing energy security and reducing dependency.
- Compliance with EU renewable energy and climate policies.
- Overcompliance could generate additional country income when allocations are sold to other Member States.

This study devotes particular attention to the renewable energy and carbon abatement potential of conventional biofuels. Advanced biofuels and biomethane (advanced and conventional) are omitted from this analysis only for the

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<sup>5</sup> As explained in more detail in Chapter 3, the target for crop-based biofuels in the RED II is between 0 and 7% depending on Member State preferences. The contribution of biofuels produced from Annex IX A type feedstock shall be 1.75% (counting double to arrive at 3.5% administratively). The contribution from other renewable energy should be 3.5% administratively. However, this can be achieved in a minimum case by 0.875% electricity in road transport (counting four times), or in a maximum case by 1.7% biofuels from Annex IX B type feedstock (counting twice to arrive at 3.4% administratively) plus 0.1% other renewable energy. The latter could be 0.066% electricity in rail counting 1.5 times. The minimum case adds up to 0% crop + 1.75% Annex IX A + 0.875% renewable electricity in road = 2.6%. The maximum case adds up to 7% crop + 1.75% Annex IX A + 1.7% Annex IX B + 0.066% electricity in rail = 10.5%.

<sup>6</sup> This means for instance that Bulgaria with the lowest GDP per capita has an ESR reduction target of 0%, whereas Luxemburg with the highest GDP per capita has a reduction target of 40%.

sake of simplicity.<sup>7</sup> The Study Region mainly produces biodiesel (2.0 Mtonne in 2016) from rapeseed and bioethanol (1.2 Mtonne) from corn.<sup>8</sup> There is a large potential to increase the production of both biofuels and biofuels feedstock in the Study Region, especially through increasing the yields and redeveloping abandoned agricultural land.

The lifecycle greenhouse gas emissions of Study Region biofuels have decreased over the past decade. Corn ethanol and rapeseed biodiesel now achieve over 65-70% emission reduction (under the old RED fossil fuel comparator of 83.8 g/MJ; these savings are higher under the RED II's higher fossil fuel comparator of 94.1 g/MJ), which is much better than what is commonly assumed. A further decrease of processing related emissions is expected towards 2030. Support policies can help to drive the carbon performance of biofuels by combining mandates with strict sustainability requirements or market benefits for higher greenhouse gas savings. Note that the Indirect Land Use Change emissions of the current biofuels volume are low because most of this volume was developed before 2010 with limited impacts, and the growth since 2010 has been slow. From 2020 onwards, additional corn and rapeseed can and must be produced without negative impacts from (direct or indirect) land use change. It is within the scope of governments to craft an appropriate framework for this, and within the scope of the agricultural sector of the Study Region to deliver this.

When the direct and indirect emissions of biofuels can be limited, their carbon savings can be maximised. This has two benefits: the cost of carbon abatement decreases and the overall emission reduction potential increases.

The average carbon abatement cost of electric driving in the Study Region currently exceeds €700/tonne CO<sub>2</sub> equivalent, while the carbon abatement cost of conventional biofuels (inclusive of ILUC) is less than €200/tonne. Using the estimates for commodity prices that have been provided to the Member States for their NECP development, the carbon abatement cost of electric vehicles is expected to fall below €200/tonne by 2030 and the cost of conventional biofuels to around €20/tonne. Note that for electric driving the results depend on the carbon intensity of the electricity.

A business-as-usual deployment of renewable energy in transport in line with RED II will avoid about 18 Mtonne of CO<sub>2</sub> equivalent emissions in 2030. However, the total emissions from road transport in the Study Region will still increase by 20% in comparison to today, because alternative energy deployment will be less than the increase in transport sector energy demand. Moreover, the additional fossil fuels will have a higher carbon intensity than the fossil fuels of today. A much higher deployment of all renewable energy options will be necessary to actively reduce transport emissions in comparison to today.

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<sup>7</sup> Note that the companies sponsoring this report have activities in conventional biofuels, but are also involved in investments in both advanced biofuels and biomethane. The sponsors are concerned that the contribution of these options will be constrained until 2030 for a variety of technical, investment and administrative reasons. With respect to advanced biofuels, they fear that it is not possible to reach desired scale or cost levels by 2030. With respect to biomethane, they foresee that the cost and scalability are quite favourable, but the role in transport will be limited by lack of vehicles and infrastructure for reasons analogous to the issues faced by electric vehicles. The sponsors are concerned that promises of emergent technologies are deceptive and often mis-applied in policy. Instead, they stress that policy should focus on maximizing the use of proven cost-effective transport decarbonization solutions while developing additional technologies in parallel. Only this combination can reduce the amount of fossil fuel in the transport sector. With oil currently accounting for 95% of transport sector energy, there is a clear need for more transport decarbonisation rather than debates about which options for transport decarbonisation are better. Thus, this report should be read correctly as promoting advanced biofuels at a level of ambition that is twice that of the RED II while also promoting electrification and conventional biofuels.

<sup>8</sup> Eurostat nrg\_107a on the Supply, transformation and consumption of renewable energies, primary production of biodiesels and biogasoline in 2016.

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# 1 Introduction

## 1.1 Greening EU Transport

A major milestone for international climate policy, the COP21 "Paris Agreement" of December 2015 set out a global target to limit the increase in global temperature to well below 2 °C above pre-industrial levels, with a strong ambition to limit the increase to 1.5 °C. With current emission rates, the global carbon budget for the 2 °C target will be used up in approximately 20 years.<sup>9</sup> The Paris agreement therefore urges immediate swift and sharp reductions of greenhouse gas emissions.

The EU 2030 climate and energy framework has set targets for cutting greenhouse gas emissions and increasing the share of renewable energy and energy efficiency to meet the aggregate nationally determined contribution of the European Union under the Paris Agreement (the "EU NDC"). By 2030, greenhouse gas emissions should be reduced by 40% compared to 1990, and at least 32% of energy should come from renewables.<sup>10</sup> Efforts in all sectors will be required to accomplish this, and many concurrent solutions will be needed.

Transport is a major emitter, responsible for a quarter of the EU's greenhouse gas emissions today, and this share is rapidly increasing (see Figure 2). Within this sector, road transport is by far the biggest emitter.

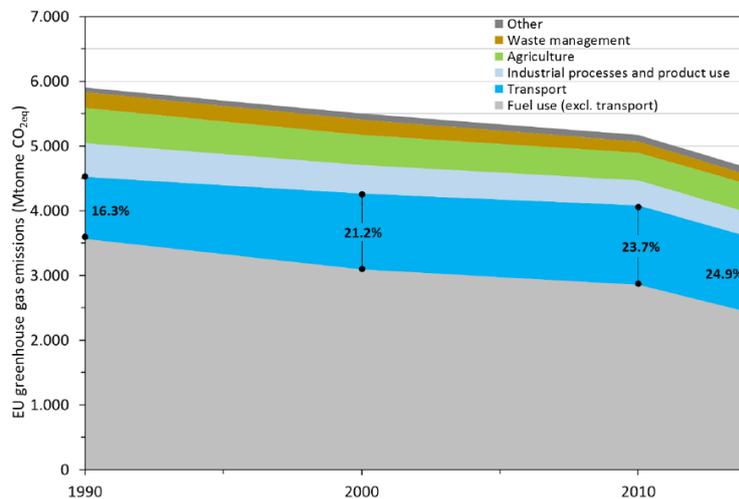


Figure 2. Greenhouse gas emissions by sector in the EU-28, with focus on share of transport.<sup>11</sup>

<sup>9</sup> The carbon budget is the estimated amount of carbon dioxide the world can emit while still having a likely chance of limiting global temperature rise to 2 °C above pre-industrial levels, see <http://www.globalcarbonproject.org/carbonbudget>.

<sup>10</sup> 2030 EU Climate & Energy Framework, see [https://ec.europa.eu/clima/policies/strategies/2030\\_en](https://ec.europa.eu/clima/policies/strategies/2030_en), as subsequently expanded through the fifth and final informal trilogue on the Renewable Energy Directive, 13-14 June 2018, which should soon be promulgated.

<sup>11</sup> Eurostat, Greenhouse gas emissions by source sector [env\_air\_gge], retrieved March 2017. Only end-use emissions. Transport includes international bunkering for aviation and navigation.

Decarbonizing the transport sector is a challenging task given the forecasted trajectories. On the one hand, the International Energy Agency projects that the demand for mobility in the EU will increase by around 60% in 2050.<sup>12</sup> On the other hand, the EU transport sector must reduce its greenhouse gas emissions by 30% in 2030 in order to meet the EU NDC rising to 60% in 2050, as shown in the figure below. This would necessitate a sharp break with the trend of increasing emissions to date.

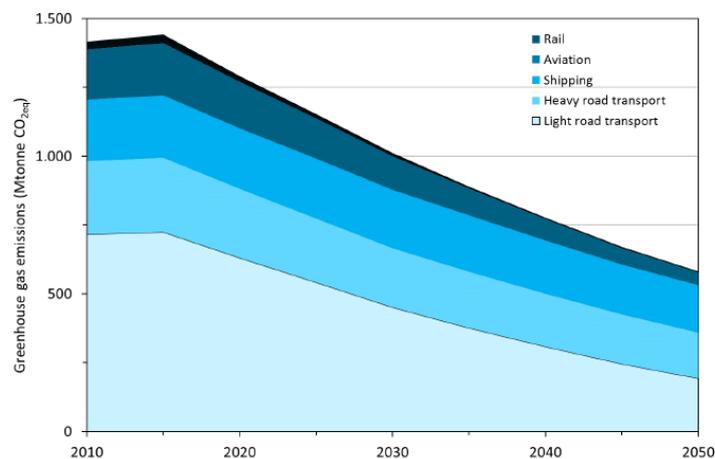


Figure 3. The emission reduction required in the EU transport sector under a 2°C climate scenario according to IEA’s Energy Technology Perspective 2016.<sup>12</sup>

However, the European Environmental Agency does not yet observe significant greenhouse gas emission reductions in EU transport. After a decrease between 2007 and 2013, emissions from this sector have been increasing continuously since 2014. The Agency projects that transport greenhouse gas emissions remain rather flat until 2030.<sup>13</sup>

There are three main options to reduce climate emissions from transport:

- Reduce transport energy demand** for transport, through teleworking, modal shift, pricing,<sup>14</sup> operational improvements or other demand-side measures. However, despite the adoption of teleworking and logistic solutions that temper the growth, there are too many other factors that in fact will still increase the demand. Modal shifts from individual private transport to collective public transport, from aviation to high-speed trains,

<sup>12</sup> The International Energy Agency assessed how carbon emission reductions can be distributed over all major sectors in the case of a 2 °C climate scenario. Known as Science Based Targets, this concept was developed by UN Global Compact, CDP, WRI and WWF, see sciencebasedtargets.org.

<sup>13</sup> European Environment Agency EEA, 2018, Trends and projections in Europe 2018 – Tracking progress towards Europe’s climate and energy targets, Copenhagen Denmark.

<sup>14</sup> An effort to reform the Energy Taxation Directive to include a transport carbon tax within fuel taxes in the EU was unsuccessful several years ago even though supported by 25 Member States. Also, the EU’s stated commitment in the Europe 2020 Strategy to abolish all fossil fuel subsidies by 2020 has not materialised, with diesel remaining the least taxed road fuel across most of the EU, while bioethanol is often the most highly taxed on an energy basis.

from road haulage to ship haulage would all help to reduce climate emissions per tonne-km or person-km. However, the impact is negligible when compared to the demand growth in each of the modalities.

- **Efficiency improvement** through electrification, hybrid drivetrains and improved internal combustion engines, is likely one of the most important developments in all modalities. Also, our projections later in this report demonstrate that efficiency improvements strongly slow-down the growth of energy demand, despite the sharp growth in transport demand.
- **Fuel switch** to energy carriers with lower carbon intensity, like renewable electricity or sustainable biofuels.

A part of transport decarbonisation is assumed to be covered by the transition of passenger cars to electric driving. Electric engines are about 3 times more efficient than internal combustion engines,<sup>15</sup> and an increasing share of electricity is of renewable origin. Electric vehicles could therefore strongly decrease the total demand for (liquid and gaseous) fuels. When battery costs fall and policy support increases, it is expected that 10 – 30% of all light duty vehicles sold around the world in the 2025 – 2030 timeframe will be electric.<sup>16</sup> Taking into consideration the legacy of internal combustion engine vehicles, about 7% of EU light duty vehicle fleet could be electric by 2030.<sup>17</sup> If historic data is any guide, the Study Region countries will see a lower share of electrification than Western-EU countries.

A number of traditional challenges still exist for electrification. In the foreseeable future, the weight, price, and performance of batteries make electrification challenging for most of the larger vehicles such as vans and trucks,<sup>18</sup> and unrealistic for shipping and aviation. Even with the projected acceleration of electric driving in light road transport, and certainly with the limitations to electric driving in the heavy road segment,<sup>19</sup> shipping and aviation, fuels as energy carriers in transport will be needed for several decades.

In this remaining demand for liquid and gaseous fuels, biofuels are needed to bridge part of the transport decarbonisation gap. Biofuels are already available in forms fungible with the current fuel distribution system and drivetrains. The application of biofuels thus does not require major vehicle or system changes. Biofuels are the single most prevalent renewable energy source in transport today.

The potential for biofuels can be very large. A considerable production capacity presently exists. European production increased from 2 Mtoe in 2005 to 14 Mtoe in 2016. About 5% of energy in EU road transport today comes from biofuels, which therefore currently contribute most to renewable energy in the EU transport sector.

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<sup>15</sup> In 2010, an electric vehicle was up to 4 times more efficient than a car with a conventional powertrain. Due to improvements in internal combustion engine technology, this will reduce to about 2.7 times by 2050. Upstream energy losses not accounted for. Ricardo AEA 2012, A review of the efficiency and cost assumptions for road transport vehicles to 2050.

<sup>16</sup> Navigant Research 2017, Market Data: EV Market Forecasts Global Forecasts for Light Duty Plug-In Hybrid and Battery EV Sales and Populations: 2017-2026 and ICCT 2015, Transition to a global zero-emission vehicle fleet: A collaborative agenda for governments (white paper).

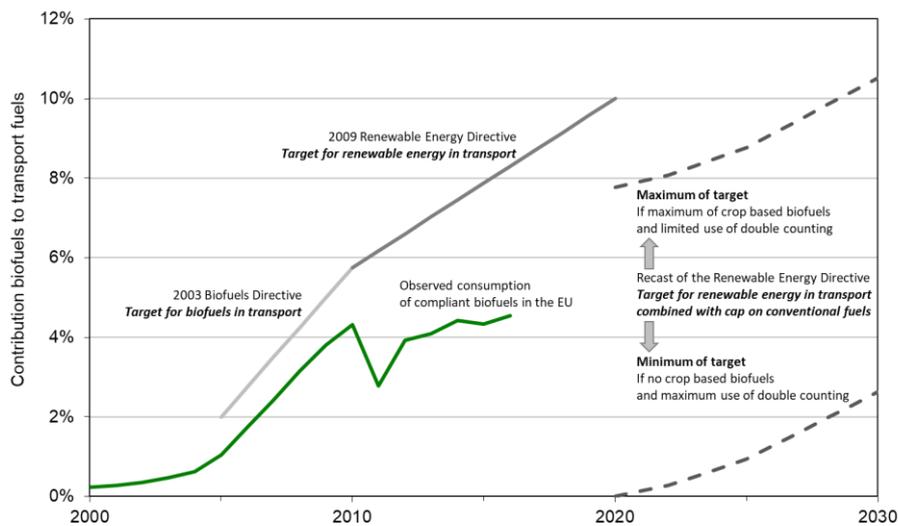
<sup>17</sup> European Commission 2016, EU Reference Scenario.

<sup>18</sup> Transport & Environment 2016, Electric vehicles in Europe.

<sup>19</sup> Volvo will start production in series of the Volvo FL Electric with 16t load and range 300km in 2019.

## 1.2 EU policies shape biofuel developments

In the European Union, Community level policies have shaped the development of biofuels. For instance, the 2003 Biofuels Directive foresaw a large role for biofuels, and set targets increasing from 2% in 2005 to 5.75% in 2010. Six years later, the 2009 Renewable Energy Directive (RED) introduced sustainability criteria for biofuels, highlighting concerns around Indirect Land Use Change (ILUC) emissions, and broadened the focus to alternatives besides biofuels. It set a 2020 target of 10% in total for all forms of renewable energy in the transport sector. While some Member States have gone much further in the stimulation of biofuels, others have not. On average, one can conclude that the EU policy has set the tone for fast initial growth of biofuels in the 2005-2010 period and reduced growth or even a standstill since 2010, as can be seen from the observed consumption of biofuels in Figure 4.



**Figure 4.** Targets set by key EU directives steering the EU biofuels development (including multiple counting and non-biofuel options), and the actual consumption of biofuels (single counted – green curve).<sup>20</sup> The target set by RED II varies from 7 to 14% in 2030 *administratively*. The dashed line indicates the minimum and maximum interpretation, depending on each Member State's preference. The 2011 dip in the actual contribution of biofuels (green curve) is caused by administrative issues.<sup>21</sup>

Reasons for stalling growth of biofuels deployment after 2010 relate for a large part to sustainability concerns, which has (1) led some Member States to limit policy support for crop based biofuels, and (2) led some Member States to

<sup>20</sup> Observed biofuel consumption from Eurostat SHARES. The minimum and maximum interpretation of the targets formulated in the RED II have been explained in Footnote 5.

<sup>21</sup> The Renewable Energy Directive 2009/28/EC stipulates that only biofuels and bioliquids that fulfil sustainability criteria should be included. In some Member States consumption of biofuels and bioliquids in the period 2011-2015 were not certified as compliant (sustainable) due to late implementation of Directive 2009/28/EC. Especially in 2011 there was a total absence of compliant biofuels reported by several EU Member States. Eurostat, 2017, Statistics explained - Energy from renewable sources.

introduce double counting mechanisms for biofuels with a more sustainable image, which allows them to achieve the overall target for renewable energy in transport with less physical biofuel use.

The future role of biofuels in decarbonizing EU transport will depend primarily on three pillars of new policy:

- **The transport sector provisions RED II oblige each EU Member State to achieve an *administrative* 7 to 14% share of renewable energy in transport by 2030**, to be determined through complex formulae and multiple counting such that the actual renewable energy obligation for each Member State in transport by 2030 is between 2.6% and 10.5%.<sup>5</sup> The RED II also includes a subtarget for certain biofuels and other forms of renewable energy as further explained in Table 1. Some stakeholders see this part of the RED II as the most important of the three pillars, since it applies specifically to transport, but that may not be the actual case.
- **RED II also sets an EU wide target of 32% renewables across the combined power, heating, cooling and transport sectors.** Contrary to the transport specific target, this overall target has to be achieved without any options of double counting. This could require a significant role for renewable energy in transport, because without a strong contribution from the transport sector – responsible for more than a quarter of the energy use and increasing – even more action would be required in other sectors.
- **The Effort Sharing Regulation (ESR) sets binding national emission reduction targets for the period between 2021 to 2030 for sectors that fall outside of the EU Emission Trading System ETS.** It covers transport, buildings, agriculture and waste. Like the RED II overall target, the ESR does not specify the exact emission reduction in each of these sectors. However, the overall ESR target is large (30% emission reduction) and transport represents an ever-increasing proportion of the EU's emissions. This implies again that transport cannot easily be ignored, since any shortcomings in one sector will have to be made up for in the other sectors.

In response to sustainability concerns around biofuels, the 2015 Indirect Land Use Change (ILUC) Directive limited the role of biofuels produced from food and feed crops to a maximum of 7% in 2020. The RED II keeps this cap at 7%, although it ultimately depends on each Member State's achievement in 2020. Table 1 gives an overview of targets and caps specified by the RED II.

Table 1. RED II targets and caps, as specified in Article 25.

<p><b>Overall target</b></p> <ul style="list-style-type: none"> <li>14% renewable energy in transport, can be achieved by a range of options.</li> </ul>
<p><b>Crop-based biofuels</b></p> <ul style="list-style-type: none"> <li>Capped at 1% above the 2020 fraction per Member State, or 7% (whichever is lower).</li> <li>If the 2020 fraction is below 1%, the crop cap may be set at 2% maximally.</li> <li>If a Member State caps crop-based biofuels at a level lower than 7%, then it can reduce the overall 14% target.</li> </ul>
<p><b>High ILUC risk biofuels</b></p> <ul style="list-style-type: none"> <li>Definition will be given by European Commission in delegated act.</li> <li>High ILUC risk biofuels will be phased out towards 2030.</li> <li>Unless they are certified as being low ILUC risk.</li> </ul>
<p><b>Biofuels from Annex IX A type feedstock</b></p> <ul style="list-style-type: none"> <li>0.2% required in 2022.</li> <li>1.0% required in 2025.</li> <li>3.5% required in 2030.</li> <li>Note that fuels may be double-counted to achieve this target, which de facto implies that the targets are only 0.1%, 0.5% and 1.75%.</li> </ul>
<p><b>Biofuels from Annex IX B type feedstock</b></p> <ul style="list-style-type: none"> <li>Capped at 1.7%, which may be double counted to arrive at a contribution of 3.4%.</li> </ul>
<p><b>Other forms of renewable energy in transport</b></p> <ul style="list-style-type: none"> <li>Renewable electricity. When used in road vehicles, renewable electricity counts 4 times. When used in rail, renewable electricity counts 1.5 times.</li> <li>Renewable liquid and gaseous transport fuels of non-biological origin. (can be produced from renewable electricity).</li> <li>No sub-targets are specified, but they contribute to achieve the overall 14% (or lower) target.</li> </ul>

As shown in the table overview, the crop cap and the options for multiple counting can lower the actual renewable shares in transport. Used cooking oil, cellulosic ethanol, cellulosic aviation fuels, electric vehicles, electric trains and many other types of renewables in transport are counted in the RED not based on their actual energy value but given a value 1.2x to 4x higher than their energy value. Moreover, the headline 14% target for renewable energy in transport can be cut to 7%. This means that any Member State could meet its 2030 RED II transport target by having less than 3% actual renewable energy in its transport sector.

The cap on crop-based biofuels is informed by concerns over Indirect Land Use Change.<sup>22</sup> However, Low-ILUC risk biofuels have the potential to sustainably increase the role of biofuels in greening the transport sector. Biofuels

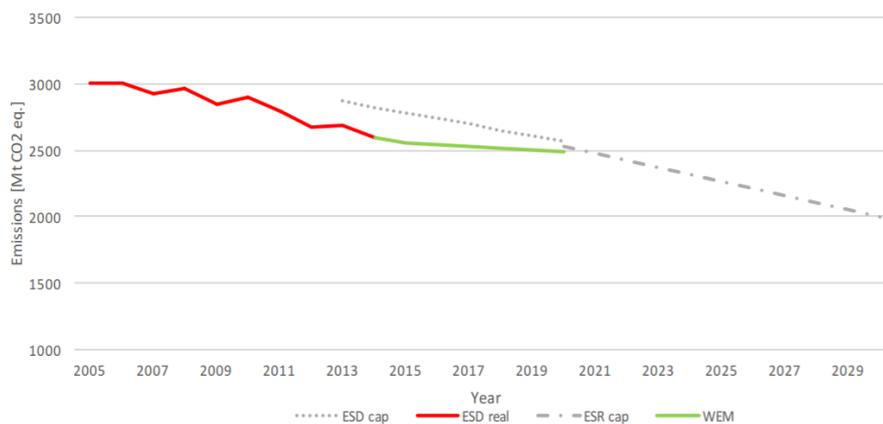
<sup>22</sup> Recital 62 BIS new, in version 18 of the final compromise text.

indeed can be sustainable and can carry low-ILUC risk, even when being crop-based, although some general observations apply:

- The ILUC impact from additional palm oil and soybean biodiesel is generally high.
- The ILUC impact from additional rapeseed biodiesel is moderate.
- The ILUC impact from ethanol based on sustainably cultivated sugar and starch crops, biofuels based on their sustainably collected residues, and of wood-based fuels is generally low.
- ILUC impacts result from the increase in demand and are initially high and decrease over time. GLOBIOM applies a 20-year amortisation period, after which the impacts become much lower. This means that the part of the biofuels that was already existing before 2010, will have a lower ILUC impact by 2030.
- Additional biofuel volumes can be produced with low ILUC risk if certain principles are observed.

In Chapter 2, the ILUC impact will be discussed in some more detail, and the ILUC impact from biofuels in a 2030 timeframe will be explored.

Under the Effort Sharing Regulation, lower GDP-performing Member States could take advantage of lower emissions targets placed on them and potentially sell Annual Emission Allocations (AEAs) to other Member States who need them. The implication being that certain Member States easily meet targets while higher-productive economies have a harder time reaching steeper emissions targets thus creating a demand incentive, and to some extent competitive advantage for these lower-performing Member States. Such cooperative compliance is expressly encouraged under the ESR.



**Figure 5. Real and projected development of emissions under ESD. ESD cap shows cap for the first phase of ESD (2013-20) while ESD real describes the actual development of emissions from non-ETS sectors since 2005 (baseline). WEM are projected emissions by Member States (projected With Existing Measures). ESR cap shows expected cap for 2021-30 not considering proposed flexibilities and assuming the average emissions 2016-18 to be the same as within the WEM projections.<sup>23</sup>**

<sup>23</sup> EDF 2016, Low-down on the new emissions caps for European countries, Environmental Defense Fund.

## Box 1. Effort Sharing Regulation in context.

General caps on emissions across the EU have been in place since 2005 to meet EU ETS targets. EU ETS includes most large industrial assets but does not include transport, agriculture, buildings, landfills or smaller assets. In an effort to create European-specific targets and cast a wider net, the EU established complementary measures to the EU ETS. The ESR serves as the second iteration of the Effort Sharing Decision (ESD), which had set caps otherwise known as annual emissions allocations (AEAs) on the sectors outside of the EU ETS. While the ESD covers the period between 2013-2020, caps were higher than actual emissions, leading to a surplus of AEAs. The ESR (which will regulate the 2021-2030 period) addresses this surplus issue and requires an aggregate reduction of 30% by 2030 compared to 2005, with each Member State allocated a specific target.

The non-ETS emissions budget for individual Member States are derived from linear trajectories in a range from 0%-40% compared to the country's level in 2005, with the magnitude determined by GDP. The linear reduction pathway is illustrated in Figure 5 on the previous page.

Member States have an opportunity to bank and borrow emission allocations. If a Member State were to keep its emissions below the annual allocation, these extra allocations can be banked into subsequent years until 2030. In the opposite case, if a Member State needs more allocations for a particular year, it may borrow up to 5% of its allocation from the following year.

Likewise, Member States are free to trade allowances with each other. Annual allocations for a given year can be transferred to another Member State who will be able to use them for compliance until 2030. It is possible to transfer up to 5% of allocations and transfer any surplus allocations after the compliance period has ended (post 2030).<sup>24</sup>

## 1.3 Renewable energy in road transport in the Study Region

This study assesses the role of renewable energy in road transport in the Study Region with a special focus on biofuels with regard to achieving the RED II and ESR targets in 2030. Several studies show that the Study Region has a significant biomass potential which is not yet used, and some studies suggest that biofuels production could have further socio-economic benefits for this region.<sup>25</sup> Increasing use of biofuels could therefore be an attractive option for these states to achieve over-performance with regard to EU climate and transport targets, provided that the additional biomass is produced with low-ILUC risk.

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<sup>24</sup> See EDF Europe Climate Fund, Low-down on the new emissions caps for European countries.

<sup>25</sup> MTA KRTK 2016, Sustainable Rural Renaissance: The Case of a Biorefinery, Centre for Economic and Regional Studies of the Hungarian Academy of Sciences, Pécs, Hungary.

## 2 Opportunities for biofuels

Table 2 gives an overview of the main types of biofuels that currently exist, or that are foreseen to play a major role in the coming decade in the Study Region. The main biofuels today are rapeseed biodiesel (RME) and corn based ethanol.

Stakeholders have frequently expressed concerns about the sustainability of crop-based biofuels. However, crop-based biofuels are not automatically good or bad. They contribute to decarbonisation when the greenhouse gas emissions from the production supply chain and emissions from indirect land use change are limited. The impact of crop-based biofuels on food commodity prices has been limited, certainly in comparison to other factors. Biofuels can actually help to attract investments in agriculture, drive innovations, and spur regional economies. Good performance of crop-based biofuels is possible when demand is accompanied by strict sustainability requirements.

**Table 2. Various types of biofuels.**

<b>Biofuels explained</b>	
Biofuels can be produced from different types of feedstock. Worldwide, many countries have introduced biofuels in their road transport sector. This mainly concerns crop-based biofuels that are produced today at industrial scale from, such as agricultural crops, as well as limited volumes of fuels made from wastes, residues, and cellulosic feedstocks (like wood or straw). The most common forms today are bioethanol produced from sugar or starch crops and biodiesel produced from oil crops. Application of biofuels in shipping and aviation is demonstrated but not yet widespread, mainly because international competition complicates the introduction of effective policy support measures.	
<b>FAME - Fatty Acid Methyl Esters</b>	Fatty acid esters derived by transesterification of vegetable oil. Within the EU and the Study Region, rapeseed oil is the common feedstock for this process, and fuel made from it is often called RME, instead of the broader term FAME.
<b>Bioethanol</b>	Alcohol produced from fermentation of sugar or starch crops
<b>Biodiesel</b>	FAME or HVO.
<b>HVO, Hydrotreated Vegetable Oil</b>	A form of biodiesel produced from vegetable oil and fats, via hydrogenation.
<b>Advanced biofuels</b>	A range of fuels produced primarily from cellulosic feedstocks, i.e. wood or straw.
<b>Biomethane</b>	Gas, commonly produced by decomposition (called anaerobic digestion) of organic matters such as plant materials, sewage waste, animal manure, organic waste, industrial waste, woody biomass etc.

## 2.1 Sustainability: Greenhouse gas emission reduction

Biofuels reduce greenhouse gas emissions. Biofuels exist on the market only because of mandatory obligations adopted due to a policy shift from fossil fuels to renewable low-carbon energy carriers. They directly displace fossil fuels within the existing internal combustion engine fleet.

EU policy including the RED, Fuel Quality Directive, ILUC Directive and RED II all require that biofuels achieve emission savings compared to the fossil fuels they replace.<sup>26</sup>

The emission reduction for biofuels after 2020 will be measured in comparison to a fossil fuel comparator of 94 gCO<sub>2eq</sub>/MJ, but there are strong arguments that the true decarbonisation impact of biofuels is understated. In a study for the European Commission, Exergia reported that the carbon intensity of fossil gasoline and diesel in the *current* EU market ranges from 84 to 110 gCO<sub>2eq</sub>/MJ and confirms that unconventional fossil fuels emit on average 114 CO<sub>2eq</sub>/MJ during their entire lifecycle.<sup>27</sup> Greenhouse gas emissions from unconventional fossil fuels that may eventually be avoided by biofuels, is around 115 gCO<sub>2eq</sub>/MJ.<sup>28</sup>

The annexes to RED II include an overview of the typical greenhouse gas values that can be used to demonstrate compliance with the thresholds mentioned above. Table 3 below shows the typical values for corn ethanol and rapeseed biodiesel as reported in the RED contrasted with actual greenhouse gas emission values as reported by biofuel producers in the Study Region.

**Table 3. Typical greenhouse gas emissions in RED II compared with actual and certified greenhouse gas emissions from biofuel producers in the Study Region (ILUC not included). Note that RED 'Default values' are even further away from the actual emissions.**

	RED II Typical value (gCO <sub>2eq</sub> /MJ)	Actual GHG emissions (gCO <sub>2eq</sub> /MJ) <sup>1)</sup>
<b>Corn ethanol</b>	42.5 <sup>2)</sup>	24 – 25 25.3 25.3 35.8
<b>Rapeseed biodiesel</b>	45.5	28.5 - 29.5 29.5 - 30.5 33.0 36.4

<sup>1)</sup> Obtained by author from selected biofuel producers in the Study Region, for a total of 8 production facilities. Certified by ISCC.

<sup>2)</sup> Typical value in RED II for corn ethanol produced in a facility that uses natural gas as process fuel in its CHP plant. This is considered the most sustainable set-up after facilities that would use forest residues in their CHP plant

<sup>26</sup> Note that biofuels not complying with the greenhouse gas emission reduction thresholds or other sustainability requirements, may still be sold in the EU market, but they will not contribute to RED II targets. There is basically no market in the EU today for these biofuels.

<sup>27</sup> Exergia, E<sup>3</sup>M lab and Cowi, 2015, Study on actual GHG Data for diesel, Petrol, kerosene and Natural gas, ENER/C2/2013-643 (Figure 9.5).

<sup>28</sup> Ecofys, 2014, Greenhouse gas impact of marginal fossil fuel use.

Actual values from producers in the Study Region are significantly below typical values as reported in the RED II. Typical values are below the 50% threshold, which is why, today, most biofuel facilities rely instead on actual values, which are certified and audited.

Various official sources also give insight into the real performance of biofuels in the EU market. In Germany, the legislation rewards biofuels with higher greenhouse gas savings, and more than 80% of all corn ethanol in the German market achieves > 65% emission reduction (even compared to the old, lower, fossil comparator). Likewise, over 95% of all rapeseed biodiesel in the German market achieves >65% emission reduction.<sup>29</sup> For point of reference, three of the four ethanol plants and one of the biodiesel plants covered in Table 3 meet these German averages. The Dutch Emission Authority (official administrator for biofuels in transport) reports an average of 28 g/MJ for corn ethanol, which implies an emission reduction of >70% (even compared to the RED's old lower, fossil comparator).<sup>30</sup> In the UK, an average of 30 g/MJ is reported for EU corn ethanol.<sup>31</sup> (In both countries, rapeseed biodiesel is hardly used in recent years, because double counting biodiesel based on used cooking oil displaced it.)

### **Further innovations to reduce emissions**

Emissions from cultivation of biofuel feedstocks can further decrease, by either decreasing the crop inputs per hectare, or by increasing the yields per hectare, or by cogeneration from biomass in the conversion stage. Default calculations using the Biograce tool<sup>32</sup> explain that the cultivation related emissions are largely due to the production and use of nitrogen fertiliser. More efficient use of fertiliser therefore offers significant options for decreasing emissions from cultivation.

There are several options to decrease N-fertiliser use and field N<sub>2</sub>O emissions. N<sub>2</sub>O is a strong greenhouse gas representing a significant part of total emissions, hence limiting these emissions is impactful. The most practical are the use of fertilizer with lower production emissions and the application of precision farming techniques that apply fertilizer surgically instead of the spraying and distribution technologies that dominated the last century. Both solutions are already gaining widespread acceptance.

With respect to processing emissions, the German decarbonisation quota is instructive.<sup>33</sup> If biofuels producers have incentives to increase their greenhouse gas savings, there are a large range of technologies and solutions available to do so that come down to simple cost-benefit calculations. The German market has provided a price premium for fuels with higher savings for the last three years, but no other market in the EU has. Accordingly, biofuels production facilities that sell in the German market, invested in the past three years in just such technologies, technologies like

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<sup>29</sup> In 2016, 82.09% of all corn ethanol sold in the German market achieved >65% emission reduction in comparison to the old fossil comparator of 83,8 g CO<sub>2</sub>eq/MJ. Even 95.37% of all rapeseed biodiesel sold in the German market achieved >65% emission reduction. BLE 2016, Evaluations und Erfahrungsbericht für das Jahr 2015, Biomassestrom-Nachhaltigkeitsverordnung & Biokraftstoff-Nachhaltigkeitsverordnung, Bundesanstalt für Landwirtschaft und Ernährung, Bonn Germany.

<sup>30</sup> NEa 2018, Reporting energy for transport in the Netherlands 2017 (in Dutch: Rapportage Energie voor Vervoer in Nederland), The Hague The Netherlands.

<sup>31</sup> DFT 2018, RTFO Biofuel statistics for the reporting year 2018-2019, update November 2018.

<sup>32</sup> Biograce is officially recognised by the EC for calculating GHG emissions from biofuels for the purpose of certification. <http://www.biograce.net/>

<sup>33</sup> Twelfth act amending the Federal Emission Protection Law

[https://www.bqbl.de/xaver/bqbl/start.xav?startbk=Bundesanzeiger\\_BGBI&start=//\\*\\*%255B@attr\\_id=%27bqbl114s1740.pdf%27%255D#\\_bqbl\\_%2F%2F\\*%5B%40attr\\_id%3D%27bqbl114s1740.pdf%27%5D\\_1540385785285](https://www.bqbl.de/xaver/bqbl/start.xav?startbk=Bundesanzeiger_BGBI&start=//**%255B@attr_id=%27bqbl114s1740.pdf%27%255D#_bqbl_%2F%2F*%5B%40attr_id%3D%27bqbl114s1740.pdf%27%5D_1540385785285)

methane recapture, heat exchangers, biomass CHP systems, and a range of other technologies.<sup>34</sup> According to owners of both biodiesel and ethanol production facilities, if they have reasons to make investments in new and better technologies, they can achieve the same kind of jump in greenhouse gas savings in the next few years that they have achieved in the past few years as the various options for increasing savings are far from exhausted.<sup>35</sup>

Biofuel greenhouse gas emissions in 2030 could be significantly lower than today's emission and could even become carbon-neutral with the use of carbon capture and storage or carbon capture and use, or through smart land use changes and agricultural practices that effectively accumulate soil carbon. These developments can be accelerated by policy and support measures that justify the necessary investments.

## 2.2 Sustainability: Indirect Land Use Change (ILUC)

Currently, the most complex topic related to the sustainability of biofuels is Indirect Land Use Change, or ILUC. This is, simply said, the rippling effect that an increasing demand for biofuels feedstock can have in global agriculture, and which could lead to land expansion and deforestation elsewhere, with the subsequent effect of carbon emissions. When additional biofuels increase demand for the crops grown on existing agricultural land, this additional demand could constrain supply, and thereby increase prices globally for those crops. The prospects of higher crop prices could trigger the clearing of high carbon stock land for additional agriculture. This effect is called ILUC. Other responses to the increasing demand are increasing productivity (which as of 2017 is estimated to account for 80% of the response<sup>36</sup>), bringing low carbon land into agricultural production, reducing consumption in other end-use sectors, or substituting a different commodity (which in turn, may or may not have ILUC impacts).

ILUC is not measurable as it takes place via complex economic interactions and is manifested only in small variations on the large dynamics of the global agriculture system. ILUC can only be analysed through detailed modelling. The European Commission commissioned the GLOBIOM consortium to assess the ILUC impact from several biofuels policy scenarios.<sup>37</sup> From this 2016 study, we see that the ILUC effect could depend amongst others on the type of biofuel crop and the regional land use context. The following conclusions are (only) valid for increasing volumes of biofuels, as calculated on the basis of a significant demand "shock":<sup>38</sup>

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<sup>34</sup> [http://www.biokraftstoffverband.de/tl\\_files/download/Daten\\_und\\_Fakten/14-12%20Erklaerung%20THG%20Quote%20fin%20\(2\).pdf](http://www.biokraftstoffverband.de/tl_files/download/Daten_und_Fakten/14-12%20Erklaerung%20THG%20Quote%20fin%20(2).pdf)

<sup>35</sup> Personal communication with representatives of EU biofuels industry.

<sup>36</sup> "The EU ethanol consumption had negligible impact on cereal prices given that the EU share in the global ethanol market did not exceed 7%, and the global cereal market is driven mainly by demand for feed. In the future, the strongest biofuel consumption growth is expected in developing countries, while the increased demand for food and feed for a growing and more affluent population is projected to be mostly met through productivity gains, with yield improvements expected to account for about 80% of the increase in crop output." [European Commission's 2017 Renewable Energy Progress Report; available at [https://ec.europa.eu/commission/sites/beta-political/files/report-renewable-energy\\_en.pdf](https://ec.europa.eu/commission/sites/beta-political/files/report-renewable-energy_en.pdf)].

<sup>37</sup> Ecofys, IIASA and E4Tech 2015, The land use change impact of biofuels consumed in the EU - Quantification of area and greenhouse gas impacts.

<sup>38</sup> For each crop-fuel combination, the ILUC impact was calculated on the basis of a 1% demand "shock", i.e. an increase of the contribution of this crop-fuel combination equivalent to 1% of EU transport sector energy. Note that the ILUC impact is not linear. Lower shocks would lead to lower ILUC values. More importantly, the ILUC value is only calculated for additional volumes after 2010 and are not valid for existing volumes. The consequences of these aspects are further explored in the text.

- Low ILUC factors are found for ethanol.
- Moderate ILUC factors are found for biofuels based on European rapeseed and sunflower oil,<sup>39</sup> but ILUC is paid back within a few years by the savings resulting from replacing fossil fuels.
- High ILUC factors are found for soybean and palm oil.
- Low to high ILUC factors are found for advanced biofuels, depending on feedstock land management.

This GLOBIOM study only considered increases in biofuels volume after 2010. The resulting ILUC factors cannot be applied to the whole biofuels volume, especially because historic biofuels volumes developed partially with and partially without ILUC. For instance, EU feedstock for biofuels before the original Renewable Energy Directive was largely developed on set-aside land that could not be used for other activities, and hence this feedstock was produced without ILUC impacts.

Looking beyond the targets and definitions of the RED II, it is clear that any far-reaching increases of biofuels deployment should be achieved while limiting ILUC risks, to optimize greenhouse gas emission reduction and to avoid biodiversity impacts.

ILUC can be avoided in several practical ways:

- Produce additional crops on unused low-carbon land, such as abandoned agricultural land or degraded land, where there is no recent history of land use change, so that it does not interfere with existing crop production.
- Yields can be increased above the baseline trends, through better practices, such as better fertilisation, better seeds, irrigation, better timed responses, better agro-chemicals and better machinery. All of these are facilitated by better information and equipment (smart, or precision agriculture).
- Additional crops can be produced on current agricultural land, for instance by double cropping.<sup>40</sup>

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<sup>39</sup> GLOBIOM reports that rapeseed biodiesel causes 65 g/MJ ILUC related greenhouse gas emissions, almost entirely because it indirectly increases the demand for palm oil. Other studies give significantly lower results: CARB reports 14.5 g/MJ, IFPRI reports 52 g/MJ.

<sup>40</sup> See Ecofys study Gas for Climate 2050 on sequential crops.

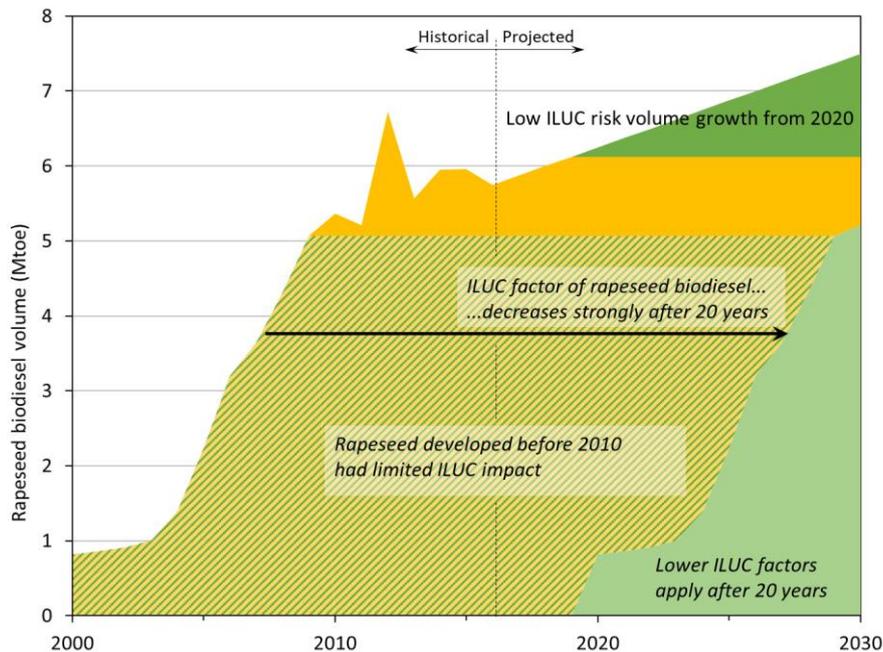


Figure 6. Example of how the ILUC factors apply to part of the biodiesel from EU rapeseed. The rapeseed developed before 2010 has a limited ILUC impact, as it was largely accommodated through yield increases (see Footnote 2 under Table 4), or on set-aside land, which did not incur ILUC impacts,<sup>41</sup> or otherwise delayed agricultural land abandonment in the EU, with a small ILUC impact.<sup>42</sup> After 2010, the volume of rapeseed biodiesel barely increased. The projected growth after 2018 is only for exemplary purpose. Growth after 2020 is assumed to be under low ILUC risk conditions, which would require strong governance.

Figure 6 demonstrates how the volume of biodiesel in the EU market relates to the GLOBIOM ILUC factors and how this changes over time. We assume that the growth beyond 2020 must be achieved with low ILUC impacts, as shown by the increasing green area at the top of the graph. This would imply that ILUC “containing” biofuels will gradually disappear, and that the biofuels volume can increase while ILUC impacts decrease. This would of course require strong governance and appropriate policy support measures (see Chapter 4). In our calculations, we assume that “low ILUC” implies a maximum allowable ILUC impact of 10 g/MJ for the additional volume.

<sup>41</sup> During the set-aside period, up to 1.5 million hectares was planted with rapeseed, yielding up to 5.5 Mtonne of rapeseed, or about 2.2 Mtonne of biodiesel.

<sup>42</sup> In the EU, agricultural land has been abandoned massively in the past 3 decades, mainly for farm-economic reasons that relate to overproduction and unattractive markets. Biofuel feedstock crops provide farmers with additional income which delays land abandonment. GLOBIOM projects that some abandoned land can develop into higher carbon forest. Through this lens, pre-RED rapeseed biodiesel has probably avoided some afforestation. This has an ILUC impact of about 7 g/MJ according to GLOBIOM.

**Table 4. ILUC factors for EU based corn ethanol and rapeseed biodiesel.**

	Ethanol from EU corn	Biodiesel from EU rapeseed
ILUC for the volume in the market before 2010 <sup>1)</sup>	0 g/MJ if feedstock was grown on set-aside land 0 g/MJ if the additional production was achieved via increasing yields <sup>2)</sup> 7 g/MJ if feedstock was grown on land that otherwise would have been abandoned <sup>3)</sup>	
ILUC for additional volumes in the market after 2010 <sup>4)</sup>	14 g/MJ	65 g/MJ
ILUC factor after 20-year amortisation <sup>5)</sup>	3 g/MJ	4 g/MJ
ILUC factor for low ILUC risk growth after 2020	Assumed to be 10 g/MJ maximally and primarily from avoided afforestation.	

- 1) GLOBIOM starts in 2010 and focuses on future growth. It does not consider the development of biofuels before 2010. It is therefore unknown what would be the "historic" ILUC. Biofuels feedstock that was produced on set-aside land did not lead to ILUC as it did not displace food crops. Moreover, biofuels feedstock produced on existing crop land avoided land abandonment (of the same land, or elsewhere in the system). Note that about 5 million hectares of agricultural land was abandoned in the EU in the 2000s, while the total EU land for rapeseed biodiesel is about 3 million hectares.
- 2) Rapeseed yields in the EU strongly increased from 2.75 tonne per hectare in 2002 to 3.61 tonne per hectare in 2015. Comparing the increase of RME over this period (about 5 Mtonne) with the increase of EU produced rapeseed (13 Mtonne), makes clear that RME was probably the only driver for the rapeseed cultivation increase. It can be concluded, that about 45% of the additional RME production was accommodated by yield increase, while the remainder was achieved on "additional" land [Oil World statistics summarized in Nazlin 2017, Competitiveness of the rapeseed industry in the European Union, Oil Palm Industry Economic Journal 17(1): 32-50].
- 3) The case of avoided land abandonment causes an ILUC impact of about 7 g/MJ. The reason is that land, if abandoned, could develop partially into forest, which would sequester carbon. In GLOBIOM, this is called foregone sequestration. "Excluding foregone sequestration has a large impact on ethanol feedstocks; the LUC value for wheat for example drops from 34 to 22 gCO<sub>2</sub> e/MJ biofuel consumed and for maize from 14 to 9 gCO<sub>2</sub> e/MJ. The EU 2020 biofuel mix scenario result drops from 97 gCO<sub>2</sub> e/MJ to 90 gCO<sub>2</sub> e/MJ without foregone sequestration". The average impact of foregone sequestration is thus 7 g/MJ.
- 4) GLOBIOM calculates ILUC factors based on a 1% demand "shock", or 2.9 Mtoe per crop-fuel combination. This is about twice the increase observed for rapeseed biodiesel between 2008 and 2016, and about equal to the increase suggested until 2020 in Figure 6 above. The increase observed for corn ethanol between 2008 and 2016 is about 17 PJ or 0.4 Mtoe. The ILUC impact is non-linear. Smaller than 1% increases would lead to lower ILUC impacts. However, the extend of this non-linearity is not known. We therefore still apply the GLOBIOM factors.
- 5) The emission categories considered in the GLOBIOM study behave as follows: (a) Loss of natural vegetation is instant (within few years, zero thereafter). (b) Soil organic carbon stabilises at a new equilibrium within 20 years, so zero before 20 years. (c) Peatland that is drained will oxidise, continues to do so for 50-100 years, although the emission rate decreases, but in the period of 20-40 years after the demand shock is assumed to be still 75% of that in the first 20 years. (d) Carbon in agricultural biomass is continuous if the biomass is removed after harvest; this depends on practice and crop. (e) Forest reversion is assumed to be forever, but the carbon uptake slows down in unmanaged forests. It is assumed that the carbon uptake in the 20-40 years period after the demand shock will have reduced to 40% of that in the first 20 years. Personal communication of Mr. Hamelinck with Mr. Valin, IIASA.

Table 4 summarises the ILUC factors for two crop-fuel combinations prominent in the EU market. When the crop-fuel development patterns are combined with the crop-fuel specific ILUC factors, one can calculate the average ILUC factor for the crop-fuel combination for a point in time. For biodiesel, the weighted average would be about 16 g/MJ today, and under the development pattern sketched in Figure 6, the ILUC impact in 2030 would be 13 g/MJ in 2030. For corn ethanol, the weighted average ILUC impact would be about 14 g/MJ and 9 g/MJ for 2018 and 2030 respectively.<sup>43</sup> These future low ILUC emissions are only achievable if there is a strong framework for proving low ILUC, and if there is sufficient demand for such low ILUC biofuels.

<sup>43</sup> We assume that 1/3 of the 2030 volume concerns corn ethanol that was developed before 2010 and by then has zero ILUC. The weighted average then becomes 9 g/MJ

Table 5. Greenhouse gas emissions and emission reduction in g/MJ. For 2018, the direct greenhouse gas emissions are based on the median of values observed with producers in the Study Region, see Table 3. Sector stakeholders are convinced that the 20 and 30 g/MJ direct emissions for corn ethanol and rapeseed biodiesel are achievable. ILUC factors are explained in the main text. Fossil fuel emissions are 95 g/MJ today, increasing to 115 g/MJ in 2030.

	Ethanol from EU corn		Biodiesel from EU rapeseed	
	2018	2030	2018	2030
Direct greenhouse gas emissions	25	20	33	30
Average ILUC emissions	14	9	20	18
<b>Total emissions for biofuels</b>	<b>39</b>	<b>29</b>	<b>53</b>	<b>48</b>
Comparator for fossil fuels	95	115	95	115
<b>Total emission reduction</b>	<b>56</b>	<b>86</b>	<b>42</b>	<b>67</b>

### 2.3 Sustainability: Impacts on food security

Concerns about the impact of biofuels on food security follow from a simple argument. An increasing use of basic agricultural commodities for biofuels production leads to supply constraints, which in turn increase food commodity prices.

Concerned stakeholders often refer to global spikes in food prices in 2007-2008 and 2010-2011. A correlation was observed between food price increases and biofuels volume growth in the period 2000-2008, as can also be seen in Figure 7. However, a correlation does not imply a causal relation, and a consideration of the data over a longer period demonstrates that the link between biofuels volumes and food prices is weak: while biofuels volumes continue to increase after 2008, the price of food actually drops, and when the development of biofuels slows down in 2010-2011, there is actually a new spike in food prices. In fact, food price developments and spikes are mainly related to oil prices and extreme weather events, in combination with systemic issues such as reduced reserves, speculation and hoarding. The demand for biofuels is by now seen as a smaller factor.<sup>44</sup>

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<sup>44</sup> A detailed assessment of the relation between biofuels and food prices, of existing literature on this topic, and of many arguments prevalent in the food-versus-fuel debate, is given in our report Biofuels and food security (Ecofys 2013).

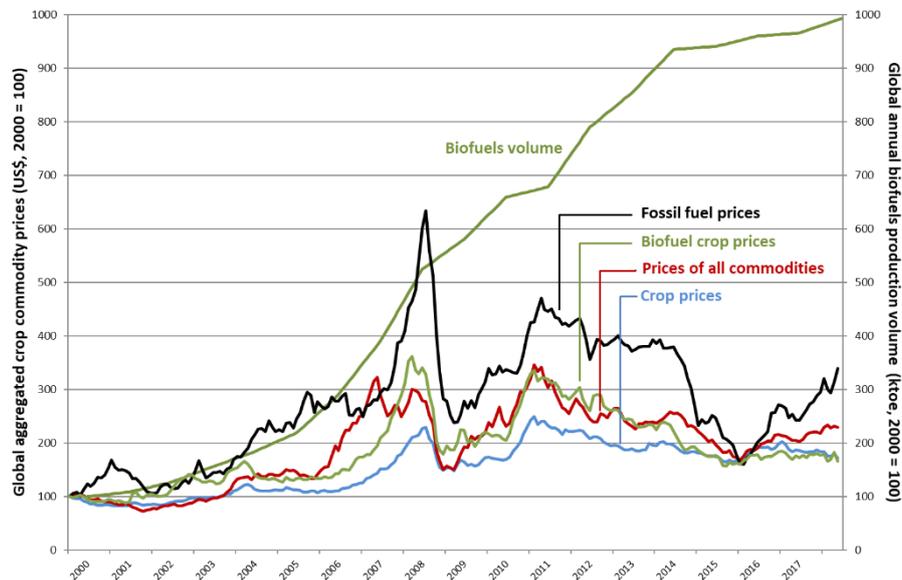


Figure 7. Global crop commodity prices and the aggregated price of all commodities, versus global biofuels production volume, both normalised.<sup>45</sup>

Experts from the International Food Policy Research Institute, World Bank and other renowned institutes concluded recently that bioenergy policies could have a strong positive effect on food security if designed in the right way. Also, it could help to attract investments in agriculture, mainly in developing countries. They stress that food and bioenergy do not necessarily compete for land, and that land is often not the most critical factor affecting food security.<sup>46</sup> The UN Food and Agriculture Organisation stresses that biofuels should actually be seen as a tool for responsible investment in agriculture and rural development.<sup>47</sup> Since 2010 FAO has developed the BEFS approach to optimise synergy between biofuels production and food security, and spur poverty reduction.<sup>48</sup>

## 2.4 Contribution to employment and rural development

Employment in the EU shifts away from the primary sector and from manufacturing to service and knowledge sectors. Agriculture and industry are important economic sectors for rural areas in the EU. Between 2000 and 2012, 4.8 million full equivalent jobs were lost in the EU agricultural sector. In this period, Romania alone lost more than 2 million full-time equivalent jobs in agriculture (56% of the jobs in the sector). Other countries, like Slovakia, Estonia,

<sup>45</sup> Based on commodity price data from World Bank, and biofuels production data from US Energy Information Administration and Eurostat. The graph is extensively explained in our report on Biofuels and food security (Ecofys 2013).

<sup>46</sup> Kline KL, Msangi S, Dale VH, Woods J, Souza GM, Osseweijer P, Clancy JS, Hilbert JA, Johnson FX, McDonnell PC and Mugera HK, 2017, Reconciling food security and bioenergy: priorities for action, GCB Bioenergy 9: 557–576.

<sup>47</sup> EURACTIV citing FAO senior officer Mr. Olivier Dubois: EURACTIV, 2017, FAO official: Food-based biofuels not necessarily bad.

<sup>48</sup> BEFS: Bioenergy & Food Security: <http://www.fao.org/energy/bioenergy/befs/en/>

Bulgaria and Latvia, also experienced decreases of over 45%.<sup>49</sup> The European Parliament expressed concerns that *“over the past few decades, the number of farmers in rural areas has drastically decreased, as have the incomes of farmers and other agricultural workers, and agricultural employment in those areas has continued to decline; whereas between 2005 and 2014 there was a reduction of almost one quarter (- 23,6 %) in agricultural labour input in the EU-28.”*<sup>50</sup> This development is important for rural areas, some of which are already faced with high unemployment rates, and out-migration of young and skilled people to urban areas. The EU framework on rural development policy aims to address a wide range of economic, environmental and social challenges typical for rural areas.<sup>51</sup>

Several of these rural challenges can be addressed by the production of biofuels feedstock, the industrial production of biofuels and the related logistics. For instance, a recent ex-post evaluation on a bioethanol plant in Hungary<sup>52</sup> concluded that the development and operation of this specific plant contributed to local rural renaissance through:

- **Creating** direct and indirect jobs, retaining skilled labour in region and preventing out-migration.
- **Contribution** to local tax.
- **Incentivizing** permanent and predictable demand for local suppliers, contributing to local economy.
- **Stimulating** investments in agricultural innovations.

The expansion of the biofuel industry in Europe since 2000 has contributed to generating new jobs and income, especially in rural areas. The vast majority of these jobs are not on farms (since modern arable farming requires very little labour per unit of production), but in the industrial and service sectors. Job creation will vary from context to context, but the general scale is evident from the citations below.

- According to REN21, in 2015, the EU liquid biofuel industry provided 105,000 direct and indirect jobs in the EU.<sup>53</sup>
- According to PwC, there were 19,990 total jobs in 2010 by the French biodiesel industry as a whole.

## 2.5 Animal feed co-products

Conventional, or first generation, biofuels are primarily made from grains and oilseeds, and therefore produce animal feed as co-products. A minority of ethanol in the EU is made from sugar beets; grains and oilseeds constitute perhaps 90% of all biofuel production in the EU. Whichever of these feedstocks is used, the result of processing is that roughly half of the final product by weight is biofuel and half is a high protein animal meal. Simplified, biofuels are just the extraction and isolation of starch from grains and fats from oilseeds, with everything else left behind.

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<sup>49</sup> EC 2013, EU Agricultural Economics Briefs – How many people work in agriculture in the European Union?

<sup>50</sup> European Parliament resolution of 27 October 2016 on how the CAP can improve job creation in rural areas (2015/2226).

<sup>51</sup> EC 2014, Rural development 2014-2020.

<sup>52</sup> Hungarian Academy of Sciences, Centre for Economic and Regional Studies, 2015, Sustainable rural renaissance: The case of a biorefinery, Pécs Hungary.

<sup>53</sup> REN21 2016, Renewables 2016: Global Status Report

This "everything else" is a highly valued animal feed rich in protein that in many cases costs more per tonne than the starting crop, meaning that biofuels extracts the lower value components of crops.<sup>54</sup>

Biofuel-derived protein feeds prevented increasing exports of soy products from the Americas over the past two decades. Such soy is associated with high levels of land use change, leading to high carbon emissions and biodiversity impacts, and it is genetically modified. Without the EU produced feeds, soy imports would likely be 50% higher than they are now, meaning that the conventional biofuels industry has become an important cornerstone of EU feed security and the main supplier of GMO-free high protein feeds.<sup>55</sup>

## 2.6 Costs

### ***Production costs of biofuels compared to those of fossil fuels***

The production costs of crop-based biofuels are for a large part determined by the costs of the agricultural feedstocks. The costs of the most common EU feedstock for biofuels (maize, wheat, rapeseed) are expected to increase by 8-18% towards 2030.<sup>56</sup> That said, the income from co-produced animal feed is also expected to rise slightly, which will limit the increase of the total production cost of these crop-based biofuels. Note that World Bank projects steeper increases for the prices of palm oil and soybean oil, of 40-60% towards 2030, but these play a much smaller role in EU biofuels today, while the fraction of palm oil may decrease significantly.<sup>57</sup> Altogether, a modest increase of feedstock costs for crop biofuels can be expected, but this may be entirely offset by gains in production efficiencies if current trends continue.

The production costs of "advanced biofuels" are expected to be considerably higher. This is not per se problematic for their deployment, since they will be supported via a subtarget.

The fossil crude oil price is projected to increase from about 70 USD/barrel today to 126 USD/barrel in 2030.<sup>58</sup> We assume this implies that the prices of diesel and gasoline will increase throughout the coming decade. The 70 USD

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<sup>54</sup> Quoted trade prices (MATIS, AHDB) demonstrate that corn ddgs has a higher value per tonne than corn.

<sup>55</sup> See Farm Europe 2016 report, <https://www.farm-europe.eu/travaux/poducing-fuel-and-feeds-a-matter-of-security-and-sustainability-for-europe/>

<sup>56</sup> The European Commission, in their Agricultural Outlook, estimates that EU wheat prices would increase from about 170 euro/tonne today to about 200 Euro/tonne in 2030, EU maize prices would increase from 160 Euro/tonne today to about 180 Euro/tonne in 2030. EU rapeseed prices would increase from about 400 euro/tonne today to about 430 euro/tonne in 2030. The estimations have a wide bandwidth of about 100 euro/tonne for the cereals and up to 180 euro/tonne for the oilseeds [EC 2017, EU Agricultural Outlook for the Agricultural Markets and Income 2017-2030]. World Bank projects that prices for wheat would increase from 210 USD/tonne today to 240 USD/tonne in 2030, maize from 163 USD/tonne today to 210 USD/tonne in 2030, soybean oil from 695 USD/tonne today to 1,000 USD/tonne in 2030, and palm oil from 570 today to 900 USD/tonne in 2030.

<sup>57</sup> The contribution of palm oil to EU biofuels may decrease towards 2030. The RED II states that the contribution of fuels "produced from food or feed crops for which a significant expansion of the production area into land with high carbon stock is observed, [...] shall decrease gradually to 0% by 31 December 2030 at the latest". While this does not explicitly identify palm oil, palm oil acreage often expanded into (high carbon) tropical rain forest and peatland. It is generally expected that this clause will limit the role of palm oil towards 2030.

<sup>58</sup> EU Fossil fuel import prices according to Figure 8 in EU Reference Scenario 2016.

today translates to wholesale prices of roughly 540 Euro/tonne for gasoline and 590 Euro/tonne for diesel.<sup>59</sup> The 126 USD/barrel in 2030 translates to about 799 and 873 euro/tonne for gasoline and diesel respectively.<sup>60</sup>

### **Carbon abatement costs of biofuels and other renewable energy for transport**

The cost of biofuels, as a carbon abatement measure, are different from the production costs. We should consider the *full and additional* costs of the fuels to society. *Additional* means that the costs should be compared to their fossil alternative. *Full* means that subsidies and taxes should be included, as well as margins and additional delivery costs. Ideally, also macro-economic impacts should be considered; but these are excluded from the study.<sup>61,62</sup>

The abatement cost analysis in the current study starts from wholesale prices, which are in fact more relevant for the costs to society than estimates of production costs.<sup>63</sup> Over the past decade, it has been frequently the case that the wholesale price of biofuels was consistently below estimates of their production costs, which suggests that these production cost estimates have not been entirely correct. This is an additional reason to rely on actual market prices.

**Table 6. Estimated wholesale prices for the most common biofuels and fossil fuels in the EU (before tax), in 2018 and 2030.<sup>1)</sup>**

	Wholesale prices in 2018 (Euro/tonne)	Wholesale prices in 2030 (Euro/tonne)
Fossil gasoline	540	799
Fossil diesel	590	873
Maize & wheat ethanol	609	609
Rapeseed biodiesel	764	764
Electricity (€/MWh) <sup>2)</sup>	131	148

1) Wholesale prices for gasoline, diesel, ethanol and biodiesel explained in text. Valid for the EU as a whole.

2) From EU Reference scenario, weighted average for Poland and Austria, representing the largest markets in the Study Region.

The impact from subsidies and taxes on the total cost is not straightforward. The excise on ethanol per litre is often the same as for gasoline per litre, which means a higher taxation per energy unit. In establishing the additional costs of ethanol over gasoline, one should correct for this additional government income. The level of excise (and VAT), and therefore this cost correction differs from country to country. The resulting delivery costs are shown in Figure 8, for the case of Poland.

<sup>59</sup> Average price of gasoline and diesel before taxation as reported by FuelsEurope for March 2018 [Breakdown of automotive diesel/gasoline prices across EU], compared to oil price at the same time.

<sup>60</sup> Today, the crude oil price is responsible for about 60% of the refined product price [FuelsEurope.com, Fuel price breakdown].

<sup>61</sup> Macro-economic impacts are seldom considered in abatement cost calculations.

<sup>62</sup> Furthermore, we have ignored agricultural subsidies. Current "single farm payments" are decoupled from the actual commodities being produced. In the absence of the biofuels, these would still be paid and therefore, these subsidies can be left out of the comparison.

<sup>63</sup> Wholesale prices are largely defined by production costs, but furthermore take into account market scarcities, which impact the margins and therefore impact the costs to the consumer/society.

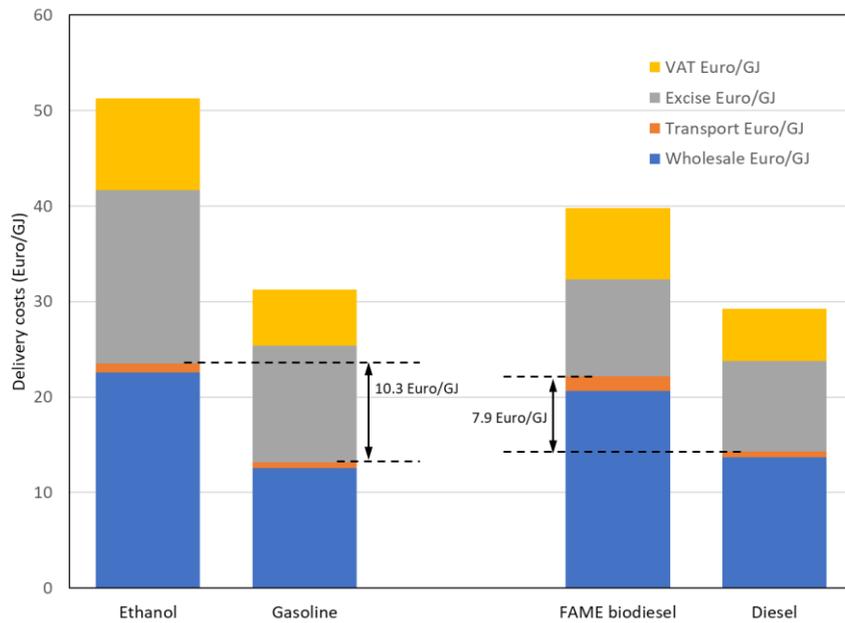
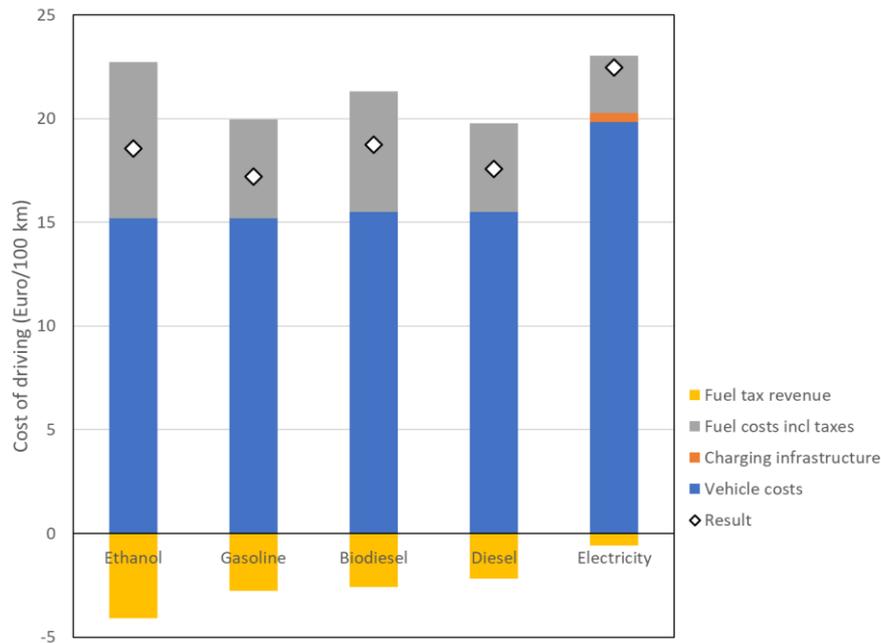


Figure 8. Resulting delivery prices for transport fuels in 2018, expressed per unit of energy (Euro/GJ). Excise duty and VAT are for Poland.

Note that consumers do not see the difference in delivery costs between fossil fuels and biofuels. In the case of blending obligations, fuel sellers can set the price of biofuels such that consumers will buy sufficient quantities of these fuels until the obligation is fulfilled.

For a comparison with electric driving – the other main option of renewable energy in transport – the costs of infrastructure and vehicles should also be considered.



**Figure 9. Total cost of driving for different fuel options and electric, per 100 km, in 2018. Comparison is based on a VW Golf (diesel, gasoline and e-Golf variations) and accounts for the listed sales price and fuel efficiencies, and 200,000 km depreciation. Charging infrastructure is assumed to cost 850 Euro/vehicle per year.<sup>64</sup> Costs of other support measures not included (for instance purchase grants and exemptions from road tax).**

Electric vehicles currently cost less from a consumer perspective than when considering their real price, since the sales of cars and the development of charging infrastructure are subsidised. Since the energy carrier is less taxed than liquid fuels, there is also a loss of tax revenue. Figure 9 shows the costs per 100 km, for the vehicles, additional fast charging infrastructure, the energy carriers and corrects for the tax revenues. Altogether, electric driving currently has the highest costs to society. With decreasing costs for electric vehicles, and less additional costs for fast charging infrastructure towards 2030, the costs of electric driving will decrease.

Carbon abatement costs result from combining the incremental costs for the energy carriers with the carbon savings they achieve (from Table 5).

<sup>64</sup> EC Communication "Towards the broadest use of alternative fuels - an Action Plan on Alternative Fuels Infrastructure" (COM/2017/0652 final) estimates that by 2020, the development of 440,000 publicly accessible charging points would require an investment of up to 3.9 Billion Euro, or about 8860 Euro/charging point. In addition to the publicly accessible recharging points, roughly 4 million private recharging points would be needed. On average, 1.1 charging point is needed per electric vehicle. We have assumed a payback time of about 10 years.

**Table 7. Carbon abatement costs in Euro/tonne CO<sub>2</sub>eq avoided. Costs of all energy options are explained in Figure 9. The greenhouse gas savings of corn ethanol and rapeseed biodiesel are explained in Table 5. For electric driving, only the carbon intensity of the electricity generation is considered, as a weighted average between electricity in Poland and Austria.**

	2018	2030
Corn ethanol	155	25
Rapeseed biodiesel	187	6
Electric driving	772	228

The carbon abatement costs of electric driving are relatively high for two reasons. The option is more expensive per km driven, as was discussed in Figure 9. At the same time, the carbon savings are limited because the carbon intensity of the grid electricity in the Study Region is considerable.<sup>65</sup> It should be noted that the result presents an average for the region. In Austria, with a higher than average share of renewable electricity, it can be expected that the carbon savings from electric driving will be higher and the abatement costs will be lower. On the other hand, in all the other countries in the Study Region, the share of renewable electricity is less. Coal fired power plants represent a large share of the electricity production and this leads to relatively high carbon emissions, which limits the carbon savings from electric driving, and increases the abatement costs.

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<sup>65</sup> The carbon intensity was taken as a weighted average between Austria and Poland which actually underestimates the carbon intensity in the Study Region.

## 3 Opportunity for biofuels in Central & Eastern Europe

### 3.1 Growing demand for energy in transport

Western Europe has been the focus of decarbonizing the transport sector. However, reaching EU targets for decarbonization is a concerted effort. The production and deployment of renewable biofuels for road transport in the Study Region can contribute to EU renewable and climate targets in 2030. This report arbitrarily focuses on 9 Central and Eastern European countries: Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Austria (see Figure 10). This region covers a large portion of the Eastern EU.

As illustrated in Figure 10, the demand for transport in the Study Region resides mainly with passenger cars and heavy trucks, and the demand for transport is also increasing the strongest for these modalities.

A few countries dominate the total transport demand within the Study Region. Poland has the largest share, representing 41% of the heavy-truck demand, and 33% of the passenger cars demand. Austria, Bulgaria and Czech Republic each have a share of 12-13% in the heavy truck demand, while Czech Republic, Austria and Romania each have a share of 11-13% in the passenger car segment. The other countries all have smaller shares.



Figure 10. The Study Region: Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Austria.

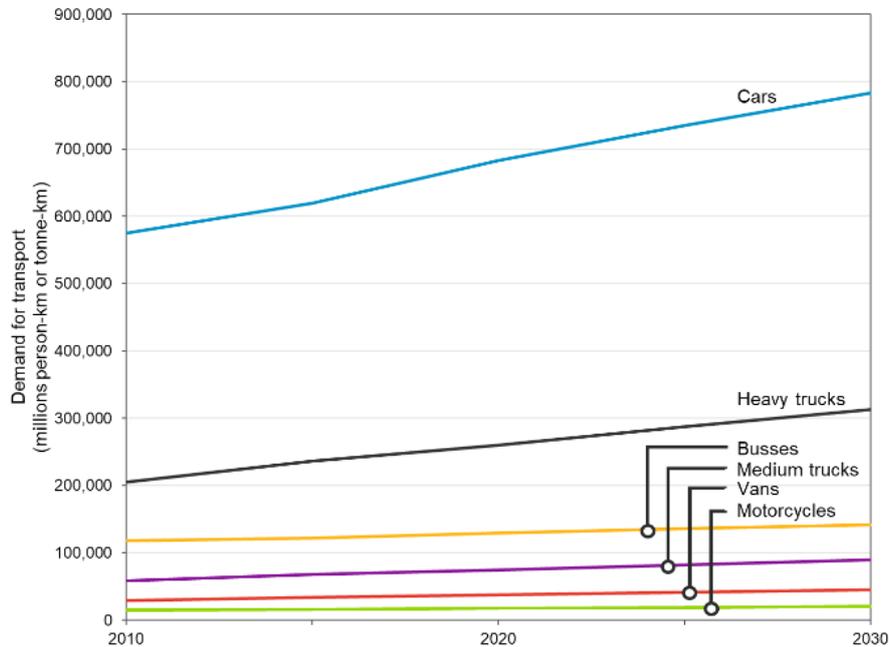


Figure 11. Development of demand per modality in the Study Region as projected by the EC in their business as usual scenario [EU Reference Scenario 2016].<sup>66</sup> Note this already assumes a certain level of modal shift.

Passenger cars (Figure 12, left) in the Study Region consist mainly of gasoline and diesel cars, with a small but significant share of LPG vehicles. Hybrid electric vehicles will gradually be introduced over the next decade. These vehicles are still fuelled with liquid fuels, but they drive more efficiently through hybrid electric technology.

The share of full electric vehicles will increase but remains small in comparison to the whole fleet. While we have assumed that the sales of these cars in the Study Region will increase to 4% in 2025 and 10% in 2030, their fraction in the total passenger car fleet remains below 4% in 2030 because the fleet is only slowly replaced.<sup>67</sup> These fractions represent 775 thousand full electric cars on the road in 2025, and 2.3 million in 2030.

<sup>66</sup> EU Reference Scenario 2016 projects per country the development of amongst others "Heavy goods and light commercial vehicles". The split into Heavy trucks, Medium Trucks and Vans is derived on basis of historic observations. Likewise, the category "Private cars and motorcycles" is split into Cars and Motorcycles.

<sup>67</sup> Replacement rate of all vehicle types is estimated for each country in the Study Region on basis of Ricardo's Sultan model version 6.1 from 2010. For passenger cars, the survival rate is 50% after 12 years. Note that vehicle lifetimes have increased over the past decades, which would imply that the introduction of alternative vehicles will be slower than what is discussed in the main text. In 2017, Ricardo reported a survival rate for passenger vehicles of 19 years [Ricardo 2016, Consideration of the impacts of Light-Duty Vehicles scrappage schemes, for European Commission, DG Climate Action].

Note that Austria and Poland have strong ambitions with electric driving. In 2016, the Austrian Environment Agency expressed that from 2020 onwards more electrically powered passenger cars should be sold.<sup>68</sup> However, the Platform on electro-mobility judges these Austrian targets for electromobility in 2020 as unrealistic, since fiscal (and other) incentives are not strong enough, and there is insufficient charging infrastructure to service the envisioned fleet.<sup>69</sup> Poland aspires to introduce 1 million electric vehicles by 2025,<sup>70</sup> although sales of electric vehicles in Poland have been limited to date.<sup>71</sup> Other countries have expressed strong ambitions with electric driving (Germany, Netherlands), but support schemes proved expensive, and ambition levels have been reduced.<sup>72</sup> Norway trimmed tax breaks for heavy electric cars.<sup>73</sup>

Bloomberg New Energy Finance forecasts that global sales of electric vehicles will increase to 11 million in 2025 and to 30 million in 2030.<sup>74</sup> This means that with our modest estimates, the Study Region would already represent 7-8% of the global electric car market in 2025-2030, which is at the high end, considering that Europe as a whole would represent 26% of the global electric vehicle market in 2030, with the Study Region representing 1/3 of the economy.

For heavy trucks (Figure 12, right), a modest introduction of hybrid electric vehicles has been assumed of 4% in 2030. Tesla and Scania are developing electric trucks.<sup>75</sup> Volvo will start production in series of the Volvo FL Electric with 16 tonne load and 300 km range in 2019. We expect the role of electric trucks to be smaller than the role of electric passenger vehicles, especially because price, vehicle weight, charging times and operational distances are all challenging with electric trucks.<sup>76</sup>

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<sup>68</sup> 2016 Report by the Austrian Environment Agency "Szenario erneuerbare Energie - 2030 und 2050" expresses that internal combustion engine vehicles should be phased out, but does not specify when [<http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0576.pdf>]. According to newspaper Salzburger Nachrichten, a representative from the Agency has stated that from 2020 onwards only electric vehicles may be sold in Austria [<https://www.sn.at/wirtschaft/oesterreich/umweltbundesamt-ab-2020-keine-diesel-und-benzinautos-mehr-1577830>].

<sup>69</sup> <http://www.platformelectromobility.eu/wp-content/uploads/2018/02/Emobility-Platform-AFID-analysis.pdf>

<sup>70</sup> <https://www.euractiv.com/section/energy/interview/polish-exec-electro-mobility-act-creates-whole-ecosystem-for-evs/>

<sup>71</sup> Poland is not in the top-15 of European markets for full electric and plug-in hybrid electric vehicles, according to EVolumes.com [<http://www.evolumes.com/country/total-euefta-plug-in-vehicle-volumes-2/>].

<sup>72</sup> Germany's previous ambition was to have 1 million electric cars on the road in 2020 but delayed this target to 2022. Netherland's current ambition is that full electric vehicles will represent 15% of passenger car new registrations by 2025.

<sup>73</sup> <https://uk.reuters.com/article/us-norway-budget-autos/norway-seeks-to-trim-lavish-electric-car-subsidies-idUKKBN1CH1PQ>

<sup>74</sup> Electric Vehicle Outlook [<https://about.bnef.com/electric-vehicle-outlook/#toc-download>]

<sup>75</sup> Tesla Semi is an all-electric truck serving as their primary platform ([https://www.tesla.com/en\\_GB/semi](https://www.tesla.com/en_GB/semi)) while Scania is part of Europe's first long haul electric truck trials (<https://www.scania.com/uk/en/truckeast/experience/news/2018/08/electric-truck-trials.html>).

<sup>76</sup> Navigant Research expects 1.8% sales of full electric and plug-in hybrid trucks by 2030 in "Eastern Europe", leading to a 0.5% share in the fleet.

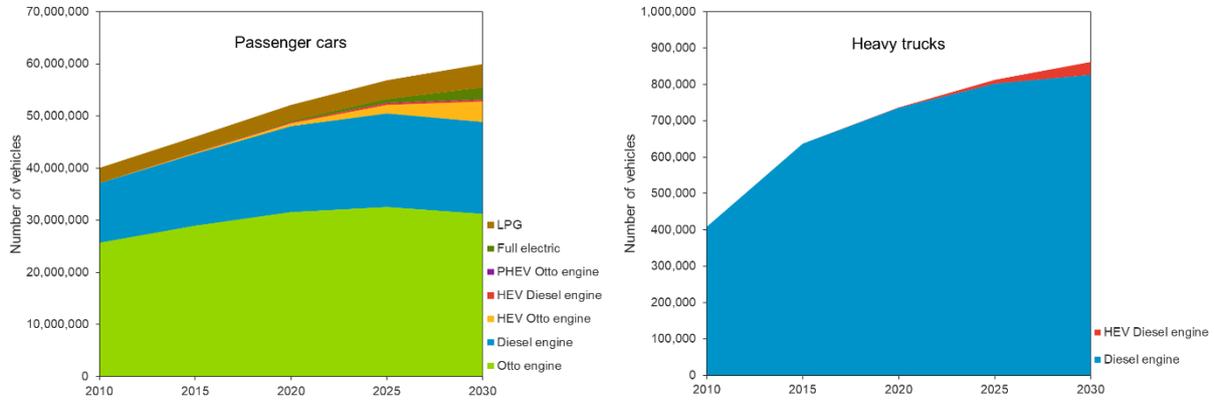


Figure 12. Development of the fleet of passenger cars (left) and of heavy trucks (right) in the Study Region. Retirement rate for old vehicles was based on Ricardo's Sultan Model, version .

Taking into account payload factors and efficiencies,<sup>77</sup> the demand for transport translates to a demand for energy as shown below in Figure 13. Overall, the energy consumption in road transport in the Study Region increases by 16% in 2030 compared to today. Efficiencies are calculated for the average cars in the fleet, with old and less efficient cars being gradually replaced with more efficient cars over time. Note that, a relatively large share of new passenger car registrations in the Study Region countries are second-hand cars imported from Western Europe,<sup>78</sup> which may imply that our calculations overestimate the efficiency of the fleet in the Study Region and, consequently, underestimate the final energy use.

<sup>77</sup> Vehicle payload factors are based on ICCT 2012. Vehicle efficiencies for passenger cars, motorcycles, vans and medium trucks are based on EIA Energy Outlook 2015, and for other modes on Ricardo's Sultan model.

<sup>78</sup> For instance, of the approximately 2 million cars introduced in Poland in 2015, over 600 thousand are imported and over half of the imported vehicles are >10 years old [Used Passenger Car Import to Poland, 2003 - 2015 data from the Polish Ministry of Finance, accessed via <http://www.pzpm.org.pl/en/Automotive-market/Used-Passenger-Car-Import-to-Poland/Used-Passenger-Car-Import-to-Poland-according-to-Ministry-of-Finance>].

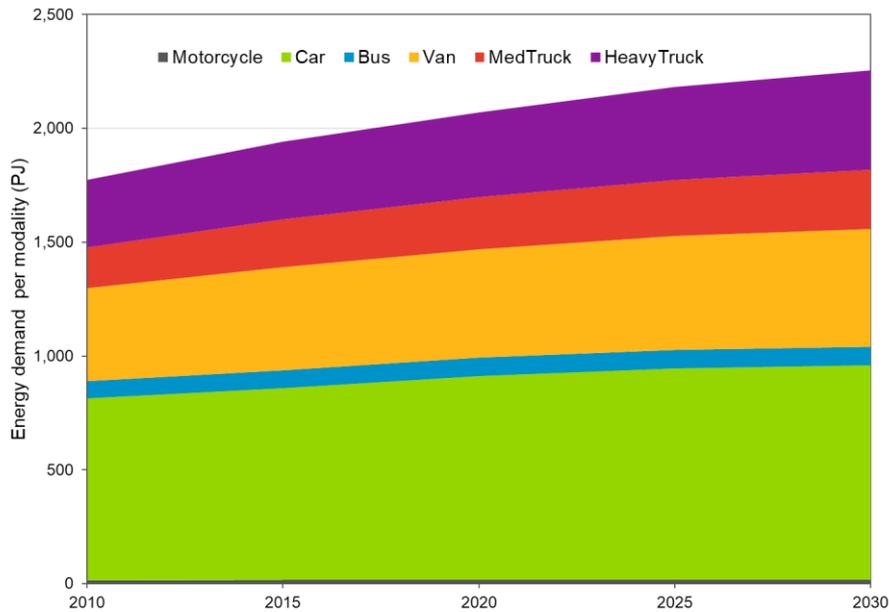


Figure 13. Final energy use in road transport in the Study Region.

In Chapter 1, we signalled that a sharp trend break in greenhouse gas emissions from transport is required (Figure 3). Logically, if the energy carriers are not decarbonised, the increasing energy use will lead to increasing emissions. The carbon intensity of the (small) share of electricity will slowly decrease. It is essential that also the liquid energy carriers decarbonise.

### 3.2 Increasing the role of biofuels in decarbonising transport

We assume that crop-based biofuels will represent 5 - 6% of transport sector energy in the Study Region in 2020. The further development of biofuels between 2020 and 2030 depends strongly on the policy framework.

In a business-as-usual scenario, we assume that the transport targets in RED II are the main policy driving deployment of biofuels, and that Member States will not implement targets beyond those. On the basis of the formulations of these targets, we therefore assume a 6% contribution of crop-based biofuels until 2030.<sup>79</sup> The

<sup>79</sup> The recast of the Renewable Energy Directive allows Member States states that “the contribution from biofuels [...] produced from food or feed crops, shall be no more than 1 percentage point higher than the contribution from those to the gross final consumption of energy from renewable energy sources in 2020 in that Member State, with a maximum of 7% of gross final consumption [...]”. This does not imply that higher fractions are not allowed in the market, only that higher

contribution of biofuels from the Annex IX A category (colloquially called “advanced biofuels”) is only 1.75% in 2030, because these fuels “may be double counted” to achieve the 3.5% target. The contribution of Annex IX B type biofuels likely reaches the maximum of 1.7% in 2030 (counts as 3.4%), since it is economically the most attractive option to fulfil the 7% sub target for non-crop-based biofuels.<sup>80</sup>

On the other hand, Member States may support the deployment of biofuels much stronger, which will have additional benefits for the country’s overall greenhouse gas emissions, and subsequently performance vis-à-vis overall RED II targets and Effort Sharing Regulation targets. The limits suggested by the RED II transport targets do not limit the contribution of the same biofuels to achieve other targets. Therefore, we also analyse a biofuels optimal scenario, with 14% crop-based biofuels in 2030, and 3.5% Annex IX A type biofuels (without double counting). Both scenarios are summarised in Table 8.

**Table 8. Specification of the two scenarios that have been compared**

	BAU (RED II policy) scenario		Biofuels optimal scenario	
	Legislation	Model assumptions	Description	Model assumptions
<b>Crop-based biofuels</b>	<ul style="list-style-type: none"> <li>Per Member State, the maximum is limited to 1% above the 2020 fraction</li> <li>Or to 7%, whichever is higher</li> </ul>	<ul style="list-style-type: none"> <li>Fraction in 2020 is 5% (extrapolation of the 2014-2016 fraction)</li> <li>Fraction in 2030 is 6%</li> </ul>	<ul style="list-style-type: none"> <li>Continuous growth towards high fraction if produced with low ILUC risks</li> </ul>	<ul style="list-style-type: none"> <li>6% in 2020</li> <li>10% in 2025</li> <li>14% in 2030</li> </ul>
<b>Biofuels from Annex IX A feedstocks</b>	<ul style="list-style-type: none"> <li>0.1% in 2022</li> <li>0.5% in 2025</li> <li>1.75% in 2030</li> </ul>	<ul style="list-style-type: none"> <li>0.1% in 2020</li> <li>0.5% in 2025</li> <li>1.75% in 2030</li> </ul>	<ul style="list-style-type: none"> <li>Twice RED II policy scenario</li> </ul>	<ul style="list-style-type: none"> <li>0.2% in 2020</li> <li>1% in 2025</li> <li>3.5% in 2030</li> </ul>
<b>Biofuels from Annex IX B feedstocks</b>	<ul style="list-style-type: none"> <li>Maximum contribution is 1.7%</li> <li>Note this only concerns diesel type fuels</li> </ul>	<ul style="list-style-type: none"> <li>In 2020 half of the cap, full cap reached in 2025</li> <li>0.85% in 2020</li> <li>1.7% in both 2025 and 2030</li> </ul>	<ul style="list-style-type: none"> <li>Same as in RED II policy scenario</li> </ul>	<ul style="list-style-type: none"> <li>0.85% in 2020</li> <li>1.7% in both 2025 and 2030</li> </ul>

Figure 14 presents the results. The historic performance until 2015 is the same in both graphs.

fractions do not count towards meeting the target formulated for renewable energy in transport, by the same directive. Higher fractions can still benefit the countries greenhouse gas total greenhouse gas savings.

<sup>80</sup> The Directive does not explicitly set this target. However, it follows implicitly from the formulation of the 14% overall target, of which maximum 7% can be achieved by crop-based biofuels.

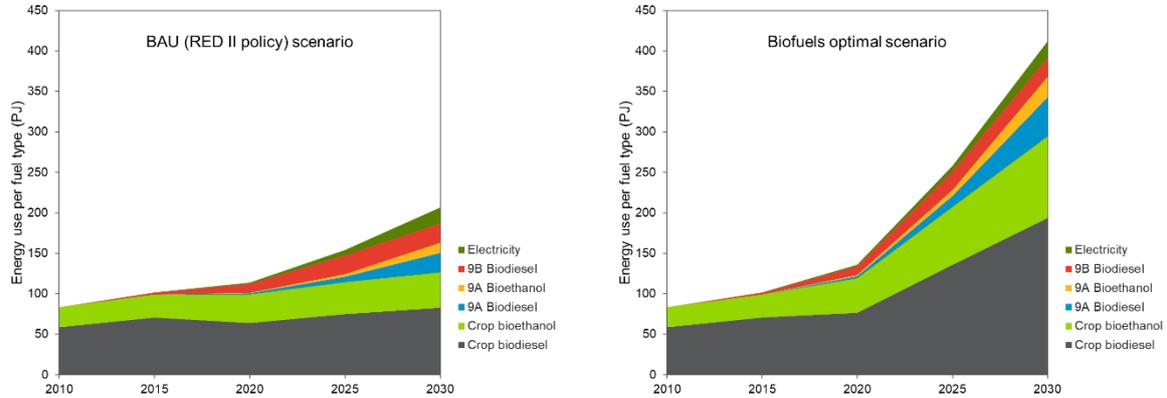


Figure 14. Results for the Business-as-usual scenario (left) and the biofuels optimal scenario (right). 9A/B: Biofuels from Annex IX A/B type feedstock. Note that only 37% of the indicated electricity contribution is renewable by 2030.

The resulting total volume of crop biofuels and electricity is shown in Table 9.

Table 9. Renewable energy in road transport in the Study Region under a Business-as-usual scenario, and in a more optimal biofuels scenario.

	2018	2030 BAU scenario	2030 Optimal biofuels scenario
Crop bioethanol (billion litres)	1.5	2.0	4.7
Crop biodiesel (billion liters)	2.0	2.5	5.8
Electricity (GWh)	351 (32% renewable)	5,600 (37% renewable)	

In the biofuels optimal scenarios, from 2021 onwards the fraction of ethanol will be above the current mainstream blend limit of 10% by volume. Similarly, the biodiesel fraction supersedes the 10% by volume blend limit for FAME/RME in mainstream diesel a few years later. For both ethanol and diesel many options exist to deploy biofuels above the blend limits (Figure 15). For instance, high impacts could be achieved by deploying E85 in 5% of the car fleet, deploying ED95 in buses, and biodiesel in blends from 30-100% in both light and heavy vehicles.<sup>81</sup> We assume that the fuel industry and governments will find solutions to allow and stimulate increasing volumes of alternative fuels.

<sup>81</sup> LowCVP 2009, Evaluating the opportunities for high blend liquid and gaseous biofuel penetration in the UK.

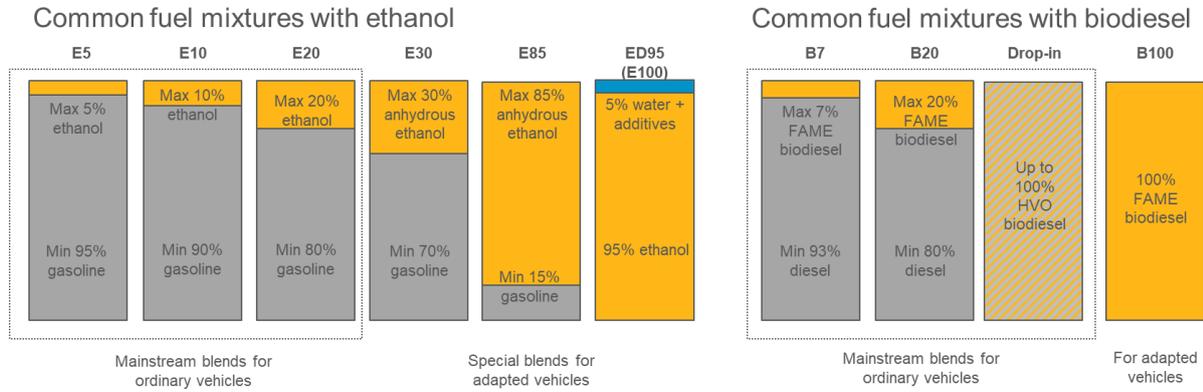


Figure 15. Common fuel mixtures with ethanol and biodiesel.

### 3.3 Greenhouse gas emission reductions under different scenarios

The model results for the fuel volumes are combined with the greenhouse gas performances as presented in Chapter 2. The savings achieved by the two biofuels options and by electric driving today and in the future are shown in Figure 16.

Note that the emission savings from electric driving are limited for two reasons. On the one hand, the role of electric driving remains small until 2030, because of the slow deployment of full electric vehicles. Note that hybrids still use liquid fuels. On the other hand, the carbon intensity of electricity in the Study Region is relatively high because coal fired power stations play a large role. Austria's high fraction of hydroelectric significantly brings down the average carbon intensity of electricity in the Study Region. Without Austria, the relative savings by electric driving would be even smaller.

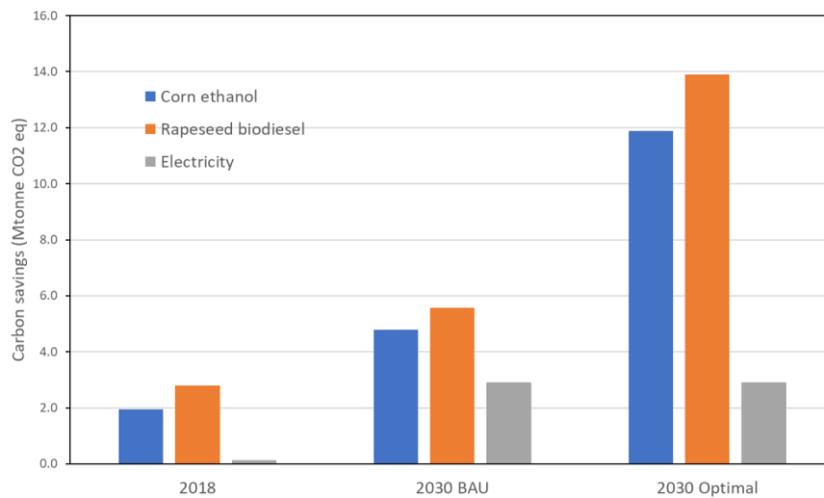


Figure 16. Carbon savings by deployment of three forms of alternative energy in the Study Region, today and in two future scenarios.

In the business-as-usual scenario, total carbon emissions in road transport increase by 20% in 2030 compared to 2018, whereas in the more optimal scenario they increase by much less: 12%.

The main reason that the total emissions still increase by 12% is that the demand for transport in the Study Region increases so fast that the combined effect of efficiency improvements and alternative energy is just sufficient to keep the demand for fossil energy at par with 2018. However, the greenhouse gas intensity of fossil fuels increases, as it will cost more energy to explore and refine crude oil in 2030 than today.

In fact, in our model only when the share of biofuels is increased to 35% do road transport emissions in the Study Region stabilise in comparison to 2018. This reinforces the conclusion that all options are needed in combination, to achieve relevant overall greenhouse gas emission savings. It also stresses that not even the most ambitious scenarios come close to pathways required by Science Based Targets (see again Figure 3). The challenge is far greater and requires a fresh look at the contribution of EU agriculture to the production of low ILUC biofuels.

**Table 10. Comparison of total carbon emissions and savings in the Study Region under different scenarios. The Business-as-usual (BAU) and Optimal biofuels scenarios have been discussed in the text. An Ambitious scenario is included in the table to demonstrate savings when the contribution of biofuels reaches 35%. It should be noted that the savings in all scenarios are only attainable when direct and indirect greenhouse gas emissions reduce to levels as presented in Table 5, which means that all the additional biofuels should be produced with low ILUC impacts.**

	2018	2030 BAU	2030 Optimal	2030 ambitious
Demand for transport payload-km		+ 18% more passenger kilometres + 25% more tonne-kilometers		
Energy in transport (EJ)	2.02 EJ	2.25 EJ or +12% more energy consumption		
Share of biofuels of all types	6%	10.5%	19.2%	35.2%
Emissions savings from crop-based biodiesel	2.8	5.6	13.9	29.6
Emission savings from crop-based ethanol	1.9	4.8	11.9	25.3
Emissions savings from all other biofuels	0.4	4.2	6.8	
Emission savings from electric driving	0.1	2.9		
Remaining emissions from fossil fuels	181	215	191	154
<b>Total emissions road transport</b>	<b>187 Mtonne</b>	<b>225 Mtonne (+20%)</b>	<b>210 Mtonne (+12%)</b>	<b>187 Mtonne (+0%)</b>

## 4 Conclusions

### 4.1 Results and implications

Crop-based biofuels can contribute to the decarbonisation of transport, at scale and with attractive carbon abatement costs. The Study Region has a large potential to produce additional feedstock, with benefits for the rural economy and agricultural development.

The additional feedstock can be produced with low ILUC impacts through increasing the yields in existing crop systems, and through re-developing abandoned agricultural land. Decarbonisation of transport is challenging in all EU Member States. The countries in the Study Region therefore have the opportunity to overperform and generate additional country income when allocations are sold to other Member States.

The lifecycle greenhouse gas emissions of crop-based biofuels have decreased over the past decade. Corn ethanol and rapeseed biodiesel now achieve over 65-70% emission reduction (even compared to the RED's old, lower, fossil comparator), which is much better than what is commonly assumed. A further decrease of especially the processing related emissions is expected towards 2030. Support policies can help to drive the carbon performance of biofuels by combining mandates with strict requirements or financial rewards for better performing biofuels. From 2020 onwards, additional corn and rapeseed can and must be produced without negative impacts from (direct or indirect) land use change.

When the direct and indirect emissions of biofuels can be limited, the carbon savings can be maximised. This has two benefits: the cost of carbon abatement decreases and the overall emission reduction potential increases.

The average carbon abatement cost of electric driving in the Study Region currently exceeds €700/tonne CO<sub>2</sub> equivalent, while the cost of conventional biofuels (inclusive of ILUC) is less than €200/tonne. Using the estimates for commodity prices that have been provided to the Member States for their NECP development, the carbon abatement cost of electric vehicles is expected to fall below €200/tonne by 2030 and the cost of conventional biofuels to around €20/tonne. Note that for electric driving the results depend on the carbon intensity of the electricity.

A business-as-usual deployment of renewable energy in transport in line with the recast of the Renewable Energy Directive will avoid about 18 Mtonne of CO<sub>2</sub> equivalent emissions in 2030. However, the total emissions from road transport in the Study Region will still increase by 20% in comparison to today, because the alternative energy deployment is still smaller than the increase in energy demand, and the still increasing volume of fossil fuels has a higher carbon intensity than the fossil fuels of today. A much higher deployment of all renewable energy options will be necessary to actively reduce transport emissions in comparison to today.

## 4.2 Policy recommendations

A larger deployment of biofuels than currently suggested by RED II is possible, but requires several support and safety measures:

- More ambitious targets for low carbon renewable energy in transport.
  - Increase the sales and use of crop-based biofuels before 2020.
  - Focus on phasing out of fossil fuels.
- Establish a higher market value for better performing biofuels, through:
  - Higher thresholds for direct and indirect greenhouse gas savings.
  - Allow low ILUC growth between 2020 and 2030.
  - Increase transparency on the origin and sustainability of biofuels.
  - Strict governance of sustainability impacts.
- Facilitation of higher blends of ethanol and biodiesel, through:
  - Offering higher blend levels at gas stations.
  - Stimulate logistical service providers and other fleet owners to apply high blends.

As requested by the client, specific recommendations are given below for each of the Visegrad countries, with the understanding that similar recommendations apply to other countries in the study region. All the countries would have to increase renewable energy in transport efforts in the light of Effort Sharing Regulation targets.

Recommendation	Czech Republic <sup>1)</sup>	Hungary <sup>2)</sup>	Poland <sup>3)</sup>	Slovak Republic <sup>4)</sup>
Maximise crop-based biofuels ≥ 6% in 2020	x	x	x	
Set/update targets for advanced biofuels	x	x	x	
Current biofuel targets are good basis for 2030				x
Review 2020-2030 electromobility targets			x	

1) Czech Republic has an overall target of 10% renewable energy in transport in 2020. With sub targets of 4.1 % biofuel by volume in petrol and 6.0 % by volume in diesel, it seems the contribution of crop-based biofuels (4.8% achieved in 2016) will remain below 6% in 2020. Targets for advanced or waste-based biofuels are unclear (0% achieved in 2016).

2) Hungary has an overall target of 10% renewable energy in transport in 2020, with a biofuels sub target of 4.9% rising to 6.4% in 2019 and 2020. This sub target includes double counting biofuels (before double counting 1.5% achieved in 2016), so that it can be expected that the share of crop-based biofuels (2.7% achieved in 2016) will remain well below 6% in 2020. There is no sub target on advanced or waste-based biofuels.

3) Poland has an overall target of 8.5% biofuels in transport in 2020, and some biofuels can be double counted, but there are no sub targets for advanced or waste-based biofuels. The biofuels target may be challenging, noting that just 2.8% was achieved in 2016, and there were 0% double counting biofuels in 2016. Poland expressed ambitious electromobility targets without appropriate support measures. The carbon savings from electromobility in Poland will be hindered by the share of coal-based electricity.

4) Slovak Republic has a biofuel obligation of 7.6% in 2020, including 0.5% of advanced biofuels. The current contribution of crop-based biofuels is already 6.0%. Therefore, it is expected that the contribution of crop-based biofuels in 2020 will be above 6% and the target for advanced biofuels is already appreciable.

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