Low carbon biofuels for the UK

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Executive summary

About 23% of the total 2013 greenhouse gas emissions in the UK originated from the transport sector, in which road transport had the majority share. Therefore, reducing greenhouse gas emissions from this sector is important for combating climate change. One of the options is to use sustainable and renewable transport fuels, such as biofuels produced from crops and waste streams. The UK today relies for a considerable part on Used Cooking Oil (UCO) based biodiesel (UCOME).

The Department for Transport is considering further increasing the role of these double counting biofuels, and to decrease the role of crop based biofuels by introducing lower crop caps than the 7% that has been agreed by the EU. This effectively limits the overall deployment of renewable energy in the UK transport sector.

A direct consequence of this policy would be that much less fossil fuels will be displaced by renewable energy sources. Of equal importance is the conclusion that lower crop caps do not lead to more climate savings, what seems to be the goal of DfT policy, but rather to less direct savings and to an increased risk for indirect (ILUC) emissions.

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1 Introduction

1.1 Biofuels for road transport in the UK

About 23% of the total 2013 greenhouse gas emissions in the UK originated from the transport sector, in which road transport had the majority share.[1] Therefore, reducing greenhouse gas emissions from this sector is important for combating climate change.

The key options to reduce greenhouse gas emissions from transport are to:

- Use sustainable and renewable transport fuels;
- Increase the fuel efficiency of vehicles;
- Decrease the demand for transport or shift between modes; and
- Improve logistical operations.

These actions are all necessary and should be developed in parallel. While they all deserve attention, this report focuses only on the first option and especially discusses the role low carbon biofuels can play in achieving renewable energy targets for the transport sector.[2]

The use of biofuels in the transport sector is supported in the EU by two policies i) the Renewable Energy Directive (RED), which mandates a nominal 10% renewable share in transport sector energy by 2020 and ii) the Fuel Quality Directive (FQD), which mandates a 6% reduction of fuel lifecycle greenhouse gas emissions by 2020 compared to 2010. The RED and FQD have been transposed to national legislation in most Member States. The FQD target of 6% greenhouse gas emission reduction has only been transposed in a handful of Member States, while only Germany has introduced measures that actually steer to achieve this. Only in 2015, the EU published calculation methods and reporting requirements related to the 6% target, with a transposition deadline in 2017.[3]

These directives do not specifically demand biofuels. However, in practice, biofuels, especially biodiesel and bioethanol, have been the most widely applied forms of renewable energy in transport.

Both directives, as well as the amendments thereto contained in the so-called ILUC Directive[4] aim to stimulate the use of feedstocks that have been assumed to have a better greenhouse gas performance. This is achieved by means of (i) capping the share of biofuels produced from feed crops to a maximum of 7% of the final consumption of energy in transport in 2020, and (ii) double counting biofuels produced from waste, residues and lignocellulose feedstock, towards the achievement of the 10% target.

The UK today relies for a considerable part on Used Cooking Oil (UCO) based biodiesel (UCOME), which counts twice towards the 10% target and which is excluded from the 7% cap. Most UCO produced in

[1] 2014 UK greenhouse gas emissions, provisional figures, Department of Energy and Climate Change, 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/416810/2014_stats_release.pdf

[2] Note that the second option (fuel efficiency) is also relevant to biofuels, as they generally have a higher octane or cetane rating, which can give a somewhat higher fuel efficiency, although this depends also on engine type and operating conditions.

[3] Directive 2015/652/EU, presenting the methodology for the implementation of Article 7a of the FQD, known as the "7a implementation Directive" (http://eur-lex.europa.eu/eli/dir/2015/652/oj/eng/pdfa1a).

[4] Directive 2015/1513/EU (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015L1513).

the European Union is a de jure waste; it can neither be used as animal feed, nor can it be exported to other countries to be used as an animal feed.

For 2020, the UK Department for Transport (DfT) is considering lowering the cap on crop based biofuels to 5%, 3% or even 1.5% and increasing the role of biodiesel based on UCO and tallow. This approach is motivated in particular by concerns about so-called indirect land use change effects (ILUC). In recent years, an increasing part of this UCO feedstock comes from outside of the EU, and it is expected that this fraction will further increase towards 2020. However, UCO from outside of the EU may not be waste, as it often has a legal use as animal feed. Biodiesel produced from such UCO would not have a great carbon mitigation potential, when its former use is replaced by other materials.

The proposed low ambitions for biofuels in the UK imply that the role of fossil fuels will remain large and as a result climate emissions will hardly decrease, or may even increase. To understand this better, this study discusses two main questions:

- Can the UK meet the legally binding 10% target for renewable energy in the transport sector, in a sustainable way, if it further limits the contribution of crop based biofuels?
- What would be the impacts of the lower caps on conventional biofuels on the total greenhouse gas emission savings from the UK transport sector, taking into account the estimated ILUC emissions of all biofuels?

To answer these questions, the report first discusses the recent developments of biofuels in the UK market, with a focus on the role of waste based biofuels in general and UCOME in particular. Next, the report discusses the waste status and estimated ILUC emissions of UCO from non-EU origin. Finally, Ecofys has modelled the renewable energy composition (including biofuels and electricity) in UK road transport on the basis of the most discussed DfT policy options to forecast how the UK will meet the RED 10% renewable energy and the FQD 6% GHG emission reduction targets in 2020.

2 Background to the UK focus on UCO

2.1 Carbon accounting

As climate mitigation is one of the main reasons for supporting biofuels, their ability to reduce greenhouse gas emissions is an important argument. Greenhouse gas emissions resulting from the application of biofuels fall basically in two categories.

- Direct emissions, mainly resulting from energy and material use along the supply chain; and
- Indirect emissions, such as the adverse impact of changes in landscape carbon stocks triggered by the additional land use or the positive impact of fuel efficiency increase in combustion engines.

The RED presents a thorough methodology for the calculation of *direct* emissions, including a list of typical and default values for common supply chains. The RED and FQD demand that biofuels achieve at least 35% emission reduction now, increasing to at least 50% by 2018, and 60% for new installations (after 5 October 2015). This has spurred some agricultural developments, and it is observed that the greenhouse gas performance of many supply chains has already significantly improved.

The RED methodology also specifies how to calculate the greenhouse gas emissions from a direct land use change, which should be taken into account if the feedstock is produced on land that had a different status in January 2008. However, this rarely takes place in practice, since most feedstock comes from long-existing crop land.

Also indirect land use change could occur. When biofuel feedstocks come from land that was already in agricultural use, which is often the case, then the additional demand may trigger efforts to increase yields, the reactivation of abandoned land, a slow-down in land abandonment, and displacements and substitutions in the global agricultural system that could result in bringing new crop land into use somewhere in the world. In countries where land use regulations are inadequate, this can ultimately involve an expansion of the agricultural frontier into previously non-cropland such as grasslands, forests or peat lands, inducing a lasting loss of carbon stock. This phenomenon is called ILUC (indirect land use change) and ILUC emissions can reduce the greenhouse gas emission savings from biofuels.

So, ILUC can be triggered by the marginal increase of biofuels. It is therefore important to understand which biofuels types and feedstocks increase in the policy period to understand the likely ILUC impact of a biofuels policy. Biofuels ILUC emissions have been estimated by several studies. Recently, Ecofys, IIASA and E4tech have published the Globiom study, which assessed the ILUC impact for a wide range of biofuel supply chains.[5]

In order to reduce the (carbon) risks arising from indirect land use change, the European Parliament and Council[4] have limited the share of biofuels produced from food and feed crops to maximally 7% of the final consumption of energy in transport in 2020, while the remaining 0.6-1.5% (since all of the

[5] Ecofys, IIASA and E4tech, 2015, The land use change impact of biofuels consumed in the EU Quantification of area and greenhouse gas impacts.

remaining options are either 2x, 2.5x or 5x counted) would come from waste-based and advanced biofuels and electricity in road or rail transport.

2.2 Double counting mechanism

The Renewable Energy Directive and amendments made by the ILUC Directive allow Member States to count biofuels produced from certain wastes, residues, non-food cellulosic material, and lignocellulosic material twice towards their 10% renewable energy in transport target for 2020.

The double counting of biofuels is meant to encourage the use of advanced biofuels and waste based biodiesel over single counted (often crop based) biofuels. This means that, theoretically, the 10% target could be met by the supply of 5% biofuels from waste.

Together with the Netherlands, the UK was amongst the first countries to apply the double counting mechanism in its biofuels market.

An obvious complexity is the definition of waste. The Dutch government points out that "*Only raw materials that cannot be used for something of a higher value rather than for generating electricity or heat, composting or using the ligno-cellulosic part as animal fodder, are eligible for double counting. Should a particular raw material have an alternative application, then a market analysis must be used to prove that there is an excess of this material available, before it may become eligible for double counting.*" This is operationalised by a Verification Protocol[6]. In the UK this safeguard does not exist.

2.3 The UK focus on waste based biofuels

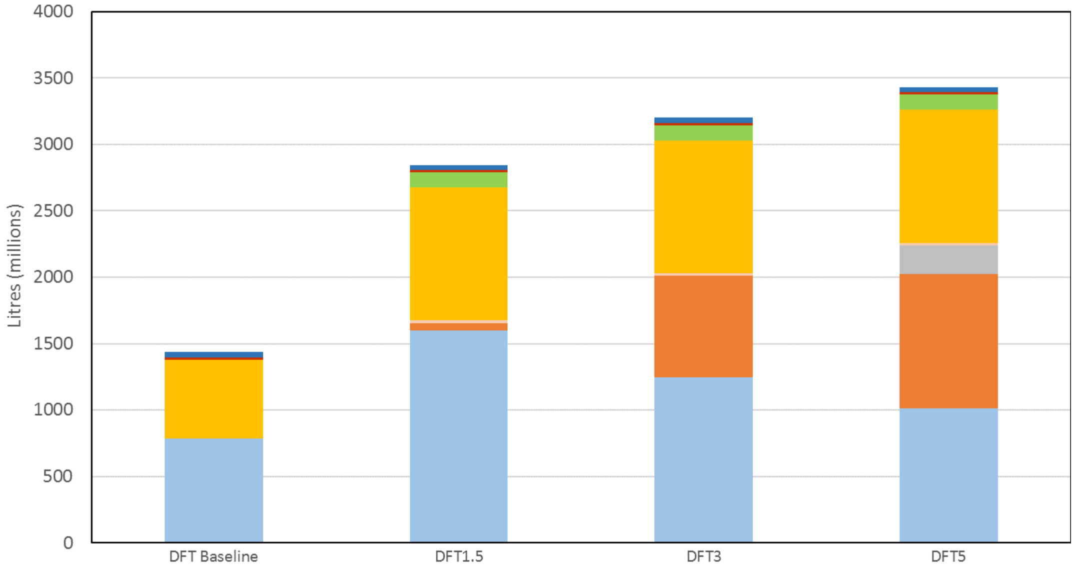
The UK Transport Energy Task Force, established by DfT and the Low Carbon Vehicle Partnership (LowCVP), remarks that the level of the cap at 7% (discussed above) is *"highly contentious"*[7] and evaluates scenarios of biofuel supply with *"a crop share below 5%, and no scenarios exceed 7%"*. Since March 2015, DfT has built on the work by the Task Force to examine more detailed policy options.

In the summer of 2015, DfT presented several possible options[8], based on 5%, 3% and 1.5% crop caps, as shown in Figure 1. These policy options suggest that DfT indeed is considering lowering the cap to below 5%. Importantly, the presented options suggest that DfT intends to rely for a considerable part on waste based biofuels – with increasing volumes of waste based biodiesel in the lower cap scenarios. These waste based biofuels are double counted towards the RED target, which implies that even when the administrative 10% target is met nominally, the actual amount of the UK renewable energy in transport will remain well under 8%, and thus less fossil fuels are being replaced.

[6] http://english.rvo.nl/subsidies-programmes/gave/dutch-biofuels-policy/double-counting-biofuels and http://english.rvo.nl/sites/default/files/2013/12/Rapport_Verificatie_dubbeltelling_betere_biobrandstoffen_Achtergrondrapport_bij_verificatie protocol_en_proefverificaties_GAVE-09-03.pdf.

[7] Transport Energy Task Force, Options for transport energy policy to 2030, Final report (March 2015), Low Carbon Vehicle Partnership, London UK, 2015.

[8] Trajectories, crop caps and E10 analysis, presentation by Thomas Robertson, DfT, London UK, 2015.



	DFT Baseline	DFT1.5	DFT3	DFT5
Biomethanol	38	38	38	38
Biomethane	18	18	18	18
Advanced ethanol	0	116	116	116
Low blend crop ethanol	597	1000	1000	1000
Advanced biodiesel	0	19	19	19
High blend crop biodiesel	0	0	0	215
Low blend crop biodiesel	0	57	763	1013
Low blend waste biodiesel	783	1598	1246	1013

Figure 1. DfT representation of the 2020 E10 success policy option.

The UK today relies for a considerable part on double counting Used Cooking Oil (UCO) based biodiesel, known as UCOME. DfT defines UCO as oils and fats from vegetable or animal origin that have been used by restaurants, catering facilities and kitchens to cook food for human consumption.[9]

Until 2003, UCO was a standard animal feed in EU markets, especially in the UK, where a system of UCO collection and distribution was built out. In other words, until recently, UCO was not considered a waste. However, as a reaction to mad cow disease, UCO was banned as an animal feed in the EU. While animal feed was the primary market for UCO, oleochemical use constituted (and continues to constitute) another non-waste market for UCO in the EU. Accordingly, since the oleochemical industry's use of UCO remains small, UCO produced within the EU is effectively a waste by law.

As can be derived from Figure 2 below, the fraction of UCOME in total biofuel sales between 2010 and 2015 has been 30% to 34%. Thanks to double counting, this means that 45% to 46% of UK compliance with the RED is driven by UCOME. For economic operators that have an obligation to sell biofuels in the transport market, double counting biofuels has proven to be an economically attractive option.

[9] RTFO Guidance – Wastes and residues, valid from 15 April 2013 - v6.0: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/175680/list-of-wastes-and-residues-yr6-v6.0.pdf

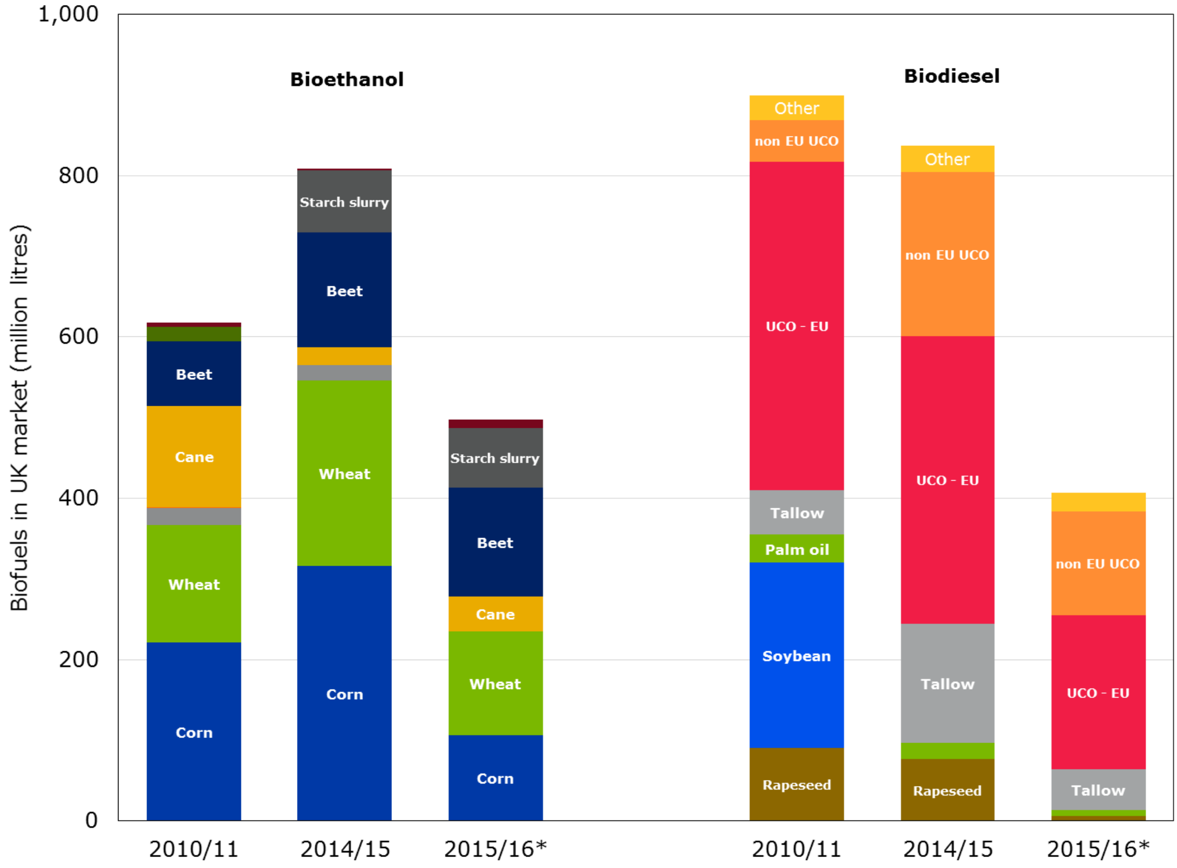


Figure 2. Biofuels sold on the UK market in reporting years 2010/11 and 2014/15, with breakdown to feedstocks. *data for 2015/16 are not final and covers only 14 April 2015 – 15 December 2015 (from DfT website).

Figure 2 also shows that an increasing share of this UCO is from non-EU origin and this category is showing the most rapid increase in market share. This is problematic because for UCO from third countries it is often not clear whether it can be judged as a waste material. In 2014/15 of the non-EU UCO, about 40% originated from the USA, and 10% both from Saudi Arabia and from South Korea.[10]

In the US, the original and alternative use of UCO (apart from biodiesel) is primarily in animal feed[11] and the supply is limited.[12] Previous Ecofys research noted that it was not possible to estimate the potential of UCO in the US that had no other use, or to estimate the amount that could be labelled as Low ILUC.[13] That study also found that it was impossible to gain a clear view on the US UCO market.

In situations where UCO has an alternative use, it may not be classified as a waste and, consequently, its use as biodiesel feedstock may lead to indirect carbon emissions. In the EU, UCO was also used as

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[10] Renewable Transport Fuel Obligation statistics: period 8 2015/16, report 3.
[11] Murphy D.J. (ed), 2009, Plant Lipids: Biology, Utilisation and Manipulation, section 4.2.3, John Wiley & Sons, New York USA.
[12] US Energy Information Agency (EIA), 2004, Biodiesel Performance, Costs, and Use, http://www.eia.gov/oiaf/analysispaper/biodiesel/
[13] Ecofys 2013, Low ILUC potential of wastes and residues for biofuels - Straw, forestry residues, UCO, corn cobs, Utrecht the Netherlands.

an animal feed until that use was made illegal, and so the analysis for EU-derived UCO is fairly straightforward. However, it is observed that other countries do not treat UCO the same way as the EU, and so it is unsound to categorize UCO as a waste if it is imported from outside the EU. This is further explored in the next chapter.

Finally, note that there is also an increasing contribution of tallow biodiesel. Tallow is a fatty solid substance rendered from animal fats. In Europe tallow is a waste and is used for biodiesel production. The majority of tallow used for biodiesel production in the UK in 2014/15 originated from Europe (>99%).

3 Used Cooking Oil

In the previous chapter it was observed that non-crop based biofuels, mainly produced from UCO and tallow play a considerable role in the current UK biofuel consumption, and that also the DfT predicts a large role for this type of fuels in the various policy options they consider for 2020. While the most widely used source for biodiesel production in the UK has been reported to be used cooking oil (UCO) from within Europe, the fraction of imported UCO from especially the USA has most strongly increased over the past years.[14] In the current chapter we assess in how far much the UCO based biodiesel (UCOME) could be classified as waste-based and what are the consequences for carbon accounting.

3.1 UCO potential for the UK biofuels market

Used cooking oil is an all-purpose word to indicate oils and fats that have been used for cooking or frying in the food processing industry, restaurants, snack bars and in households. UCO can be collected and recycled to be used for other purposes, although different rules apply in different countries. UCO can originate from both vegetable and animal fats and oils. It has to be noted that UCO from vegetable oil could nevertheless include small quantities of animal fats, depending on the products that have been fried.

As a feedstock for biodiesel production, UCO is first purified to remove impurities and water. Depending on the free fatty acid content, these free fatty acids are either first neutralised (and accepted as lost product) or esterified, after which a common *trans*esterification of the of the remaining fatty acids takes place. The biodiesel product of the UCO is so-called UCOME (used cooking oil methyl esters). The process for UCO into UCOME is identical to the processing of virgin plant oils into biodiesel. The technology is relatively simple and cheap, and it is a conventional biofuel technology.[15]

The potential supply of UCO and tallow feedstock in the UK is necessarily limited but unknown. We estimate the potential by establishing a lower boundary of current actual supply, and an upper boundary from the theoretical untapped EU supply, translated to UK scale.

The current reported supply of UCO and tallow in the UK is about 177 ktoe. This consists of 49.7 ktoe (62 million litres) of biodiesel based on tallow and 127 ktoe (159 million litres) based on UCO.[16] Compare this to a total UK road fuel use of about 36.9 Mtoe in 2020. This implies that UK sourced UCO and tallow currently supply about 0.5% of renewable energy in transport (single counted, i.e. real energy fraction).This observed value is used as a lower bound for scenario calculations in Chapter 4.

[14] https://www.gov.uk/government/collections/biofuels-statistics, also discussed in Chapter 1.
[15] European Commission SWD(2012) 343 final.
[16] RTFO statistics Biofuel statistics: Year 7 (2014 to 2015), report 6 (final).

UCO and tallow could also be sourced from the larger EU. Ecofys previously estimated that the potential scale of sustainable EU-derived UCO from businesses is about 874,800 tonnes.[17] If the (largely) untapped potential of household UCO is taken into account, the potential for sustainable UCO might increase to 3 million tonnes. If the tallow market is assumed to be 1/3 the size of the UCO market, that would mean a total potential UCO and tallow supply for the EU of no more than 4 million tonnes. Compared to the EU road fuel use of about 279 Mtoe this implies that UCO and tallow can maximally provide 1.5% of the EU road transport fuel (again, without the double counting). This pro rata potential value is used as upper bound for scenario calculations in Chapter 4. Higher fractions would lead to displacement, i.e. to import of non-EU UCO to other Member States.

3.2 Waste classification of UCO

Used cooking oil is generally considered in the EU to be a waste, and therefore UCOME is (1) double counted, and (2) considered to be free of ILUC risk.

The EU Waste Framework Directive, defines 'waste' as 'any substance or object which the holder discards or intends or is required to discard'.

Following this definition, almost all UCO of EU origin can be categorised as a waste:

1. The vast majority of UCO cannot be used in the production of animal feed anywhere in the EU (or exported as animal feed) after the BSE scandal in the early 2000s. As a reaction to mad cow disease, UCO was banned as an animal feed, and this became an EU-wide ban through the EU Animal by-product Regulation (1774/2002). EU law also prohibits the export from the EU of materials for animal feed that are not legal animal feed within the EU. For the same reasons, tallow is a waste. Only a few high quality sources of vegetable oil UCO, such as from food manufacturing processes where the inputs are pure and uniform and the processes are well controlled, are permitted to be used for animal feed;[18]
2. Other alternative uses, especially in the oleochemical industry, are limited.[19] There is some use of UCO in oleochemicals[20], but it is very small and decreasing since the 2013 amended Animal by-products Regulation (1069/2009) widens the options to use of animal fats for oleochemical applications. Animal fats are a more attractive feedstock for oleochemistry, compared to UCO, due to lower risk of contamination, more constant quality and more regular carbon chains.

As was shown in Section 2.3, an increasing share of the UCO used for biodiesel production in the UK is supplied by imports (mainly) from the US. Data from the online resource for bioenergy and bioproducts, SunGrant BioWeb[21], shows that in 2005 about 35% of the total (605.7 ktonne) collected UCO (called yellow grease in the US) in the US was used domestically for livestock feed and the rest was used for

[17] Ecofys 2013, Low ILUC potential of wastes and residues for biofuels.
[18] http://www.food.gov.uk/multimedia/faq/wasteoilfaq/#.UoI2ZuKxPl8
[19] Low ILUC potential of wastes and residues for biofuels, Ecofys, 2013.
[20] http://www.bioenergytrade.org/downloads/t40-low-iluc-UCO-august-2014.pdf
[21] http://bioweb.sungrant.org/Technical/Biomass+Resources/Agricultural+Resources/Processing+and+Food+Wastes/Waste+Grease+and+Fats/Default.htm

other industry applications including oleochemistry and biodiesel production. This implies that UCO from the US should not be classified automatically as being a waste-feedstock.

It is not easy to establish the waste status of US sourced UCO on the basis of the supply chain, since for existing UCO sources, it cannot be known whether the UCO consignment would have had an alternative use or not in absence of biodiesel (similar to how the ILUC concept works on biofuel crops).

Only new and so-far untapped UCO sources can be considered to be waste-feedstocks.

However, in this regard the Waste Framework Directive is also instructive in that it creates a hierarchy for treatment of waste with the very highest priority being prevention. In other words, policies that encourage the creation of waste are incompatible with the Waste Framework Directive. The UK emphasis on UCOME may conflict with the Waste Framework Directive in two aspects.

First, as UCO becomes a valuable commodity in its own right, it can encourage inefficient use of cooking oils, for example by encouraging restaurant owners to use more cooking oil. Of course, an extension of this concern is also that otherwise pure vegetable oil can be adulterated to make it saleable as UCO, a concern of heightened risk given some of the jurisdictions from which the UK has begun importing large quantities of UCO.

Second, any US or Chinese or South Korean used cooking oil is free to be sold as animal feed, including to export markets. When exported from these markets, the UCO is exported not as a waste but as a known commodity. However, once any UCO enters the EU, it becomes a waste forever, and cannot be re-exported as animal feed.

3.3 ILUC emissions

The ILUC value of UCOME in the recently published Globiom study is considered to be zero only because UCO is assumed to originate from the EU. The Globiom study supports the assumption that EU-derived UCO is a climate friendly biofuel feedstock, and the present study only reinforces that assumption.

However, in situations where UCO is not a waste feedstock, it induces indirect land used change (ILUC) with corresponding emissions. In the absence of detailed calculations of the ILUC emission factor for US UCO, we assume that the factor will equal that of the feedstock that is marginally displaced. This assumption is basic and defensible, while a more detailed calculation would be desired to better understand and quantify the UCO ILUC factor.

The use of UCO from the US, which is the largest contributor of non-waste UCO to the UK market, in UK biodiesel, reduces simultaneously the use of that same UCO in the production of animal feed. The reason for the use of UCO in animal feed is to provide fat calories to livestock. The most likely replacement for that fat is to replace the UCO by a virgin plant oil. In the US, this is likely soybean oil. The exact replacement ratio and the type of oil that is marginally displaced, are uncertain. It is possible that the fat replacement is partially assisted by other feedstock types and that other plant oils play a role. Therefore, soybean oil (with an ILUC value of 150g CO2eq/MJ) is considered as a reasonable upper-boundary to understand the ILUC risk from US sourced UCO. It is advised that proper modelling establishes a better value, but we consider it to be unlikely that this ILUC value will be lower than that of EU rapeseed oil (with an ILUC value of 65g CO_{2eq}/MJ).

Table 1 gives an overview of the direct and indirect emission values that we have used for the current study. ILUC emissions for other biodiesel and for bioethanol are further discussed in (page 17).

Table 1. Direct and ILUC emissions of different renewable fuels for road transport used in this study.

Renewable energy type	Direct emissions [1)] (gCO_2/MJ)	ILUC emissions ($gCO2/MJ$) [2)] of biofuels *in 2016,* introduced to the UK market …	
		…before 2008	*…after 2008*
Biodiesel	32	0	65
ILUC free UCOME	12	-	0
UCOME with ILUC	10	-	65 - 150
Bioethanol	26	0	18
Advanced biofuel	10	-	0
Electric in road	77.2	-	-
Electric in rail	77.2	-	-

1) Direct emissions are based on the most recently available DfT actual values, or, where none is reported for that fuel, RED typical values. For biodiesel, the 2010 observed value for French rapeseed biodiesel is used. Emissions for electricity are based on a greenhouse gas intensity of 500 g/kWh (see explanation in Section 4.2), and the end-use efficiency of electric vehicles is assumed to be 45% better than that of internal combustion engine vehicles.

2) Indirect emissions presented in accordance with Globiom data, as discussed in Box 1 (page 17). Note that the biofuels volume currently in the UK market includes a fraction that was already introduced before 2008. At that time biofuel crops in the EU were generally produced on set-aside land, which can be considered to be free of ILUC. This implies that part of the biofuels in the current UK market can be considered to be free of ILUC.

4 Scenarios for 2020

As explained in Section 1.4, in 2015 the DfT suggested several policy options for capping crop-based biofuels. The consequences of these options are assessed, both for the deployment of renewable energy in UK transport, in the frame of the RED 10% target, and for the total emission savings from avoiding fossil fuels, in the frame of the FQD 6% target.

4.1 Scenario definitions

The DFT policy options are defined as below and are modelled in this study to assess the chances for the UK to reach the fuel targets in 2020:

- DFT1.5: UK allows biofuel from crops a market share of only 1.5% of transport sector energy;
- DFT3: UK allows biofuel from crops a market share of only 3% of transport sector energy;
- DFT5: UK allows biofuel from crops a market share of only 5% of transport sector energy.

For comparison, the EU proposed 7% cap is also modelled ("CAP7").

The DfT has envisioned that within the three options the 10% RED target should be met by a combination of different types of renewable energies (refer to Figure 1), including renewable electricity, biomethanol, biomethane, bioethanol, biodiesel (from waste, mainly UCO, or from crops) and advanced biofuels (biofuels such as bioethanol, biodiesel and drop-in diesel produced using advanced conversion technologies).

The DfT anticipates that crop-based biofuels will contribute less than 5% (on energy basis) to the UK renewable energy demands for 2020, primarily out of a stated desire to avoid ILUC emissions. This means that at lower caps, more fuels from wastes would be required to meet the RED 10% target. In comparison, the CAP7 allows use of maximum 7% of the crop-based biofuels.

In Table 2 these policy options are reconstructed in energy fractions.

Table 2 Reconstruction of DfT policy options for E10 success.

	DFT1.5	DFT3	DFT5
Advanced biofuels	0.2%	0.2%	0.2%
Crop based biodiesel	0.1%	1.6%	2.6%
Crop based bioethanol	1.4%	1.4%	1.4%
UCO and tallow biodiesel	3.5%	2.7%	2.2%
Total	5.2%	5.9%	6.4%

4.2 Results: fractions of renewable energies

To understand the contribution of the main forms of renewable transport energy in the UK transport sector under the different scenarios, Ecofys made assumptions for the renewable energies with minor contributions as the following:

- Biomethanol is not included in the scenario calculations since its currently envisioned fraction in 2020 is very small (see Figure 1);
- The combined contribution of *renewable* electricity in UK road and rail energy use was about 0.6% in 2014 when using the new multipliers (respectively, 5x and 2.5x).[22] This electricity would lead to zero greenhouse gas emissions if it was renewable electricity, from marginal new renewable generation capacity, but that is clearly not the case. Therefore the emissions are taken the same as from average UK non-renewable electricity, i.e. 500 g/kWh;[23]
- Since electrification will take time[24] and the UK electrical energy mix remains mostly carbon intensive, the contribution of renewable electricity will probably remain small into 2020. Based on the LowCVP report,[7] we assume that the contribution of renewable electricity in rails will be 0.2% (single-counted) of the total UK renewables in transport. The contribution of renewable electricity in the UK roads is also assumed to be 0.2% (single-counted) of total UK renewables in transport;
- The availability of advanced biofuels in the UK is also foreseen to be limited in 2020.[19] Advanced biofuels are in the early stages of technical developments and lack large-scale investment, mainly due to policy uncertainties. In the case of *truly* advanced biofuels (so excluding UCOME from the definition), a reachable target of "0.5%" is predicted by LowCVP[7] for UK road transport energy. We conclude this assumes a multiple counting factor, as the energy fraction of advanced biofuels shown in the LowCVP report is only 0.2%;
- Considering the assumed limited availabilities of electricity and advanced biofuels, it is obvious that only a small fraction of the required total 10% UK renewable transport sector energy in 2020 will be met by electrification and advanced biofuels. Therefore, in order to meet the 10% target, the remaining fraction above the cap is likely to be met by UCO and tallow, and, considering trends, waste starch ethanol.

Waste-based biodiesel (mainly UCO) can either have low or high ILUC emissions. As explained in Chapter 2, UCO sourced from within the EU is considered to be ILUC free.

The availability of UCO in the UK or from the EU (pro rata) is uncertain as explained in Section 3.1. Therefore, a lower and upper boundary is considered: the contribution of ILUC free UCOME is between 0.5% and 1.1%. Combined with tallow, it is between 0.7% and 1.5%.

The required level of crop-based bioethanol and biodiesel for the transport sector in the future will depend on the engines running on diesel and gasoline, since biodiesel and bioethanol are compatible for blending with, respectively, diesel and gasoline. Accordingly, several assumptions can be made to calculate the required level of biodiesel and bioethanol for the future: i) it can be assumed that in 2020

[22] Eurostat SHARES 2014 reports for 2014: 1.4 ktoe renewable electricity in road transport and 84.6 ktoe renewable electricity in other transport. Including the 5x and 2.5x multipliers this gives 218.4 ktoe. The RES-T denominator was 39,466 ktoe (or slightly more taking account of the new multipliers).

[23] Defra 2016, Government emission conversion factors for greenhouse gas company reporting.

[24] Transport Energy Task Force, Options for transport energy policy to 2030, Final report (March 2015).

an equal amount of crop-based bioethanol and biodiesel will be required or ii) maximum contribution from either of biofuels will be required or iii) a split of biodiesel/bioethanol similar to that of diesel/gasoline split ratio will be required. The diesel/gasoline ratio required for the UK 2020 road transport energy has been projected to be 73/27 on an energy basis. Therefore, in this study, Ecofys used the third assumption (split ratio similar to diesel/gasoline) as a realistic assumption.

The scenario options were assessed based on the above mentioned assumptions and the data presented in Table 1 and 2. The results will be shown in the following paragraphs.

The disaggregated energy fractions of the renewable energies' contribution to the UK 2020 transport sector are shown in Figure 3, based on multiple-counting and single-counting factors and taking into account the low level of *truly* ILUC free waste-based biodiesel. The results are also compared with the situation when the CAP7 is considered to meet the UK 2020 transport fuel targets.

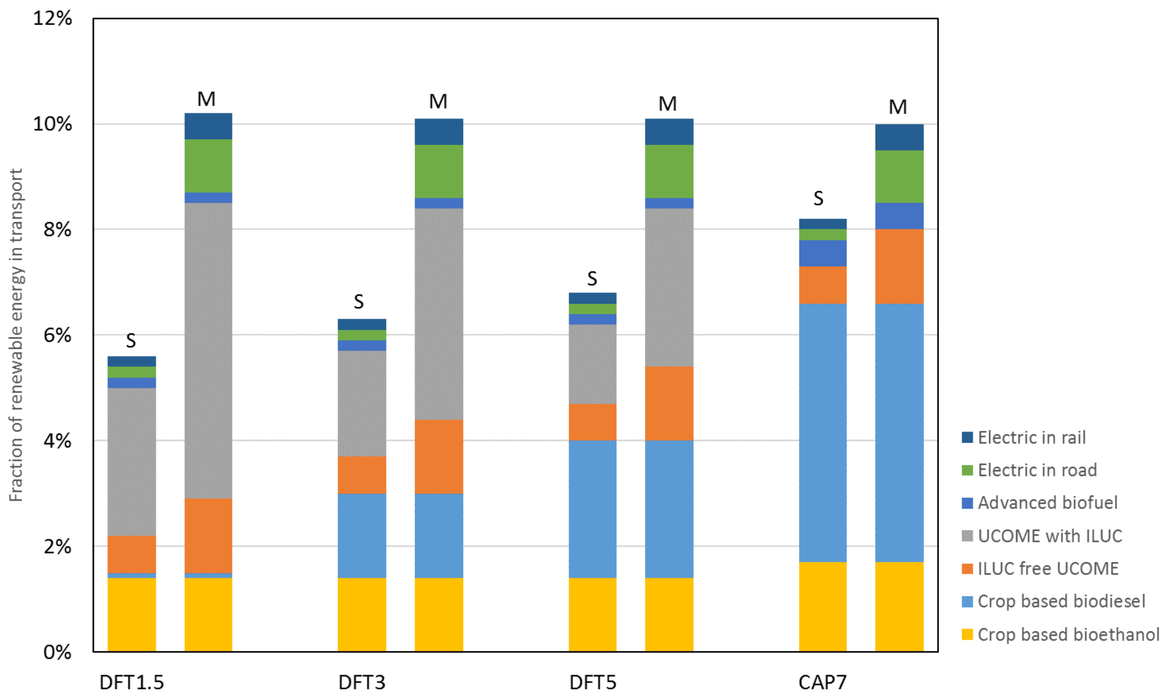

Figure 3: single (S) and multiple (M) counted energy fraction of renewable fuels in the UK transportation section in respect to total volume of transportation fuels in 2020 for different scenarios; renewable fuel count factors were taken into account for these calculations; calculations were done taking into account low end of ILUC free waste based biodiesel (0.7%).

The main findings are the following:

- When the incentive multiple counting factors are considered, the 10% target set out in the RED is achievable under all scenarios;
- However, the real fractions of renewable energy in transport are always lower than 10%. Under the EU 7% crop cap scenario, the total fraction of renewable fuels in transport is just above 8%. It is considerably lower under the policy options that are considered by DfT, down to less than 6% if the 1.5% crop cap is implemented. This implies that effectively much less fossil fuels are removed from the market;
- For crop caps below 1.5%, bioethanol would be the dominant crop-based biofuel and crop-based biodiesel would virtually disappear from the UK market. It should be noted here that this has already happened: crop based biodiesel is now effectively gone from the UK market, with imported UCO taking its place;
- While lowering crop caps, a larger fraction of the energy target is met by UCOME.

Similar trends were also observed when a high level (1.5%) of ILUC free UCO and tallow based biodiesel is considered. The total fuel volumes in the DFT scenarios are the same for all fuels, except that the distribution between biofuel feedstock countries of origin shifts. High or low level of ILUC free waste-based biodiesel will only impact the greenhouse gas emission savings, which will be shown in the next section.

4.3 Greenhouse gas emission savings

Figure 4 and Figure 5 compare, respectively, direct and ILUC emissions of each 2020 transport scenario and their emission reduction potentials from the UK transport sector in 2020.

Figure 4 shows that the lower the cap, the more likely the UK fails to meet the FQD target of 6% greenhouse gas emission reduction. With lower crop caps the contribution from all biofuels decreases and less fossil fuels are being displaced.

Emission savings are calculated from the difference of fossil emissions avoided and total renewable energy emissions. The greenhouse gas savings in relation to the FQD target (right axis) are calculated by comparing emission savings to a baseline fossil fuels consumption of 36.9 Mtoe as predicted for the UK 2020 transport sector (145,196 ktonne CO2eq).

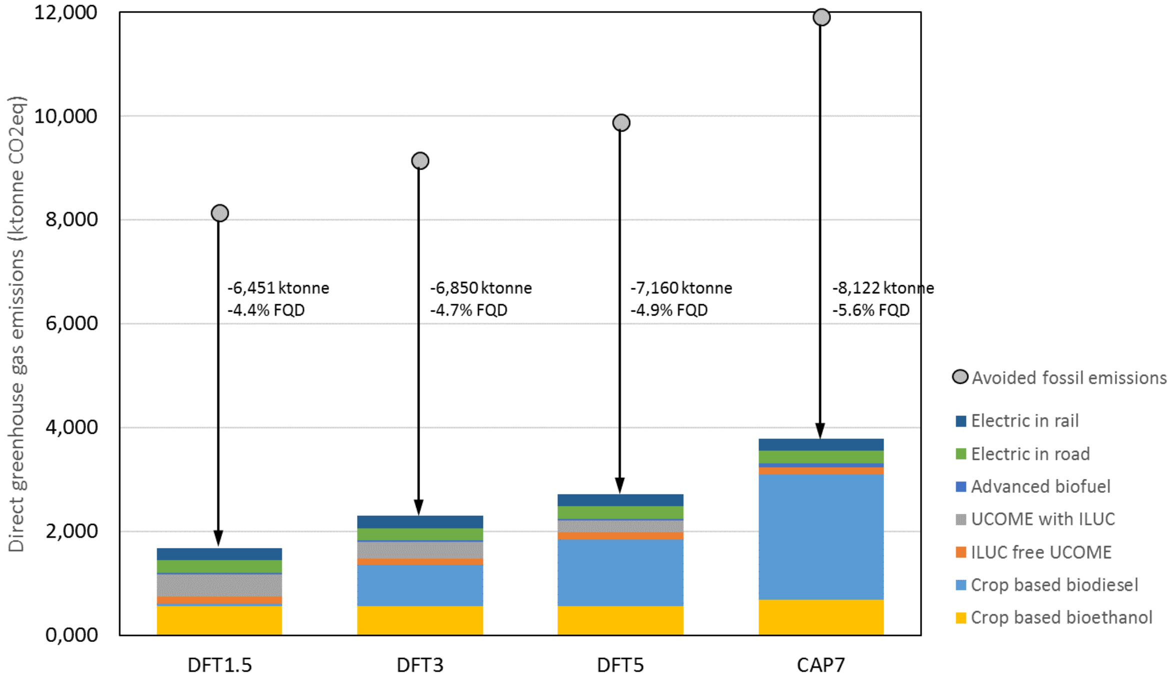

Figure 4: Direct GHG emissions of different renewable fuel per scenarios for UK 2020 transport energy compared to the avoided emissions from displaced fossil fuels; calculations were done taking into account low end of ILUC free waste based biodiesel (0.7%).

Taking into account the ILUC emissions, the situation becomes worse. Box 1 explains the ILUC values that have been used for crop based biodiesel and crop based bioethanol, taking into account the marginal changes in feedstocks for these crops over the past decade.

Box 1. ILUC value for biodiesel and bioethanol.

The ILUC value for biodiesel and bioethanol differs per type of feedstock.

This study uses ILUC factors that have been estimated by the Globiom study, based on 1% marginal increases ("demand shocks") of certain crop-fuel combinations, during the 2010-2030 study period.

The results are non-linear. A more than 1% increase would result in a higher factor, and a less than 1% increase in a lower factor.

More importantly, the results are only applicable for biofuels-feedstock combinations of which the volume is indeed increased during the study period. Much of the European feedstock for biofuels during 2000-2007 was actually produced under set-aside conditions. It did not displace feedstock for other uses and was, at that time, free of ILUC risk. We find it is reasonable to assume that feedstock that does not induce ILUC, should keep this status for a significant time.

Finally, ILUC has a temporary nature, and mostly relates to carbon emissions that take immediately or shortly after the demand shock has taken place. On the other hand, the replacement of fossil fuels with biofuels results in a continuous and lasting direct emission reduction. Over time, the ILUC emissions are paid back by direct savings. ILUC can therefore be seen as a carbon investment, which pays back.

Biodiesel

By far the preferred crop feedstock for biodiesel in Northwest Europe is rapeseed, as shown in the RTFO carbon and sustainability data for recent years (79% of all crop based biodiesel). However, there is also a significant fraction of palm oil (21% in 2014/15). The Globiom study calculated that a 1% marginal increase of rapeseed biodiesel between 2010 and 2030 would lead to an ILUC factor of 65 gCO2eq/MJ, and of palm oil biodiesel to 231 g/MJ.

The average ILUC emissions from rapeseed biodiesel in the UK market are actually much lower because the rapeseed biodiesel volume that first entered the UK market before 2008, was produced from EU set-aside land and at that moment free of ILUC. This volume of rapeseed biodiesel remains free of ILUC forever.

Since the monitoring of biodiesel in the UK market started in 2008/09 (RTFO reporting year 1), the volume of biodiesel in the UK market, from all crops (rapeseed, palm oil, soybeans, sunflower), has actually decreased. This implies that all rapeseed and sunflower biodiesel currently still in the UK market, was added free of ILUC. This is obviously not the case for palm oil and soybean biodiesel, which were never produced free of ILUC.

For this study, however, we chose to rely on the EU feedstock composition, and changes in this composition, to calculate average ILUC values, mainly because UK data on feedstocks and their origins is of insufficient quality for 2008 and earlier. Moreover, the Globiom study reported ILUC values for EU wide feedstock demand shocks, and it is unknown what would be the result for UK specific shocks.

Box 1. ILUC value for biodiesel and bioethanol - continued.

On a European scale, the production and consumption of biodiesel since 2008 first increased and later decreased. With the current market outlook, we expect limited or no growth of the EU crop based biodiesel market in the coming years. Therefore, we can base the average ILUC value (between now and 2020) on knowledge of the 2008 and current volumes and feedstock compositions, resulting in the following composition of the current biodiesel in the EU market:[25]

	Fraction free of ILUC	Fraction with ILUC
Rapeseed	51%	17%
Sunflower oil	2%	2%
Palm oil		17%
Soybean oil		11%

The average ILUC value for all crop based biodiesel in the EU market then becomes 68 g/MJ. Note that this value is still high because of the contribution of especially palm oil and soybean oil. If palm oil and soybean oil would no longer be used in EU biodiesel, the average ILUC value for current crop based biodiesel would decrease to 31 g/MJ.

Bioethanol

Feedstock crops for ethanol are corn, wheat, sugar beet and sugar cane. However, since 2008, mainly the ethanol volumes from corn has increased, with small increases of beet and wheat, while ethanol produced from other feedstocks decreased. With further the same arguments as discussed for biodiesel above, the following composition results for the current ethanol in the EU market:[26]

	Fraction free of ILUC	Fraction with ILUC
Corn	14%	27%
Wheat	21%	7%
Other cereals	6%	0%
Sugar beet	20%	5%

The average ILUC value for all crop based bioethanol in the EU market then becomes 7 g/MJ.

[25] Based on biodiesel production data until 2014 from Eurostat (Supply, transformation and consumption of renewable energies - annual data), and for 2015-2016 from FO Licht (World ethanol & biofuels report). Feedstock composition for 2008 from Ecofys 2011, Biofuels baseline 2008, and for 2014 from USDA FAS 2016 EU Biofuels report.

[26] Based on bioethanol production data and feedstock composition from ePure, for 2009 (as proxy for 2008) and 2014.

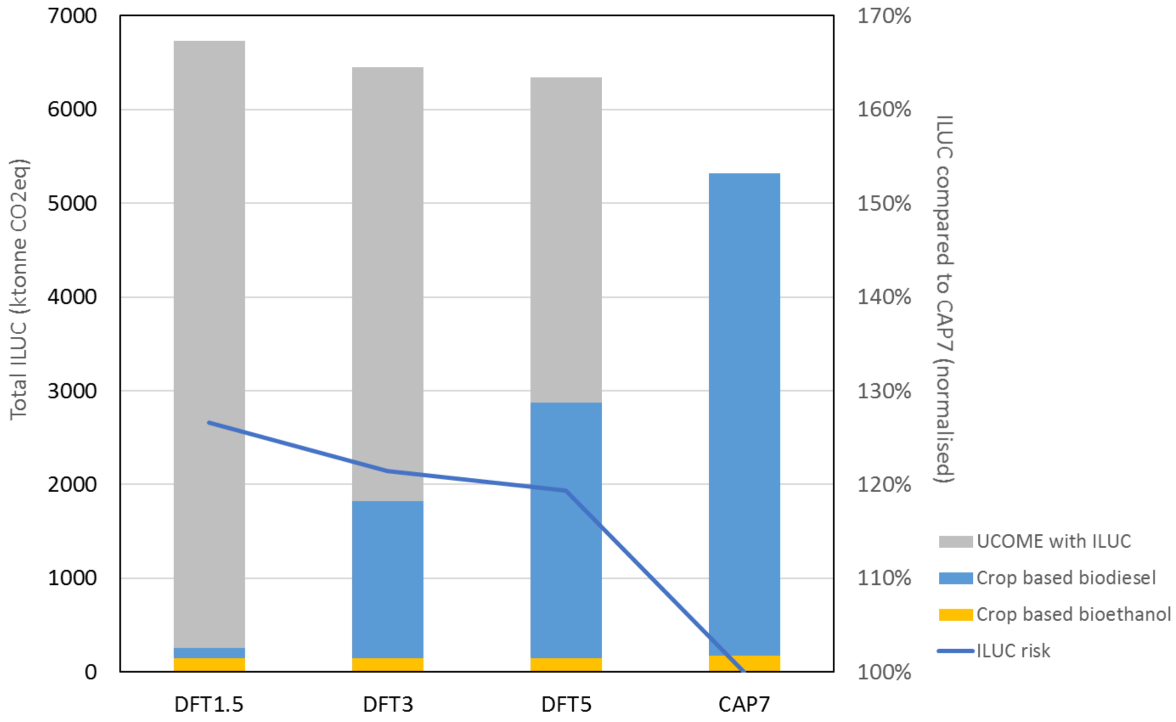

Figure 5: ILUC emissions of different renewable fuel per scenarios for UK 2020 transport energy; calculations were done taking into account the lower end of availability of ILUC free waste-based biodiesel (0.7%, see Section 3.1); ILUC risk on the right axis are normalized to the ILUC value of CAP7 scenario and shown as percentage difference. For ILUC containing waste based biodiesel an ILUC factor of 150 gCO2/MJ is used (see Section 3.3). The graph is based on corrected values, taking into account that a large part of current crop based biofuels were actually introduced under zero ILUC set-aside conditions (pre-2008). See Box 1 for more information.

As can be seen from Figure 5, ILUC emissions have significant impacts on the CO_2 emissions of biofuels. At lower crop caps, the risk for higher ILUC emissions increases. Compared to CAP7 the ILUC risk under DFT1.5 will even increase by 27%. This happens because the lower crop caps trigger more use of UCOME. To meet the increasing demand of UCOME, its source (UCO) has to be imported from third countries, which increases the ILUC risk of UCOME. This is remarkable because DfT has proposed lower caps specifically because of concerns over ILUC.

If we do not take into account the zero ILUC impact of biofuels that were added under the set-aside regime, then the ILUC factor for crop based bioethanol becomes 21 g/MJ and for crop based biodiesel becomes 102 g/MJ. In this case the DFT1.5 scenario has 14% less ILUC emissions than the CAP7 scenario.

The relatively high ILUC factor for biodiesel results from 17% palm oil and 11% soybean oil assumed in the feedstock mix. If palm oil and soybean oil would be banned as feedstock, because of their high ILUC impacts, then the average ILUC factor for crop biodiesel becomes about equal to the factor for rapeseed biodiesel, i.e. 65 g/MJ, and even 31 g/MJ when considering the zero ILUC from set-aside before 2008 (see Box 1). In this case, the DFT1.5 scenario has 29% more ILUC emissions than the CAP7 scenario, and even *2.7 times* more ILUC emissions when considering the zero ILUC from set-aside before 2008.

The Globiom study reports two types of ILUC values. The values applied so far (above) include a notion of foregone sequestration, i.e. the assumption that with less demand for biofuels, more natural vegetation would regrow on abandoned agricultural land, and production of biofuels would thus forego such carbon sequestration. If natural vegetation does not regrow on abandoned agricultural land (in both the biofuels scenarios and the counterfactual), then the ILUC factors slightly decrease.

If we assume that abandoned agricultural land does not (automatically) revert to natural vegetation, and include the notion that EU biofuel crops before 2008 were produced under set-aside regime, then the DFT1.5 scenario has 32% more emissions than the CAP7 scenario. If we further exclude the palm oil and soybean oil from crop biodiesel feedstock, then the DFT1.5 scenario would even emit 3.5 times more ILUC emissions.

We conclude that the EU proposed CAP7 scenario is generally better for the climate, and has lower ILUC, than any of the alternative options proposed by DfT. Biodiesel ILUC performance is much better served by a ban on palm oil and soybean oil, than by a focus on UCO beyond what is available as waste feedstock in the EU.

Alternatively, a consistent support of advanced biofuels, or a shift from the biodiesel orientation to ethanol (e.g. through E10 and E20) would produce much higher climate savings.

5 Conclusions and recommendations

The UK biofuels market is currently relying on double counting biofuels, such as biodiesel produced from Used Cooking Oil (UCO), which effectively limits the overall deployment of renewable energy in the UK transport sector. The Department for Transport is considering further increasing the role of these double counting biofuels, and to decrease the role of crop based biofuels by introducing lower crop caps than the 7% that has been agreed by the EU.

A direct consequence of this policy would be that much less fossil fuels will be displaced by renewable energy sources, limiting the contribution of the transport sector to greenhouse gas mitigation.

Previous Ecofys research, for DfT, concluded that UCO can be ILUC free and that large volumes of ILUC free UCO can potentially be made available worldwide.

The vast majority of UCO from the UK or the EU is classified as waste, so that policymakers can consider it all to be ILUC free if anti-fraud safeguards are put in place. Use of this UCO for biodiesel is beneficial for the climate, and it is advised to exploit the potential of domestic sourcing. However, while the supply of UCO from the UK/EU is significant, it is currently limited, and the increase in collection (e.g. from households) of this UCO is probably both economically constrained and unattractive considering the ease of imports.

The previous studies also noted that of the estimated UCO potential outside of the EU, less than 30% would be ILUC free. This implies that the ILUC free nature would have to be proven per consignment and that one cannot automatically assume that UCO from outside of the EU is free of ILUC impacts.

The ILUC impacts of US UCO (currently the largest source of non-EU UCO) could be considerable as the current use for animal feed is possibly replaced by soybean oil, which has a high ILUC factor. If the UK were to import UCO from Asian countries where use of palm oil is prevalent, then the ILUC factor of that UCO could be even higher.

Therefore, there is a considerable risk that the UK's over-reliance on UCO as feedstock for sustainable biofuels actually increases the ILUC risks that it seeks to avoid.

A truly ambitious DfT set of options for 2020 would incentivize home level collection of UCO over imports of UCO, would acknowledge the existence and availability of low ILUC risk conventional biofuel feedstock (for both biodiesel and ethanol production) as anticipated by the ILUC Directive, would ban palm oil and soybean oil as feedstocks for biodiesel, would address unwanted indirect effects in third countries through direct actions, and would steer for deploying higher fractions of ethanol such as E10 and E20.

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