**Note on fossil carbon content in biofuels**

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# Introduction

According to the 2006 IPCC GLs (volume 2, chapter 3, section ‘CO2 emissions from biofuels’ in page 3.17): “it is important to assess the biofuel origin so as to identify and separate fossil from biogenic feedstocks”. In other words, **a part of the carbon of biofuels (and the associated CO2 emissions) may have a fossil origin**. The IPCC GLs provide some examples about biofuels’ fossil part:

“biodiesel made from coal methanol with animal feedstocks has a non-zero fossil fuel fraction and is therefore not fully carbon neutral. Ethanol from the fermentation of agricultural products will generally be purely biogenic (carbon neutral), except in some cases, such as fossil-fuel derived methanol. Products which have undergone further chemical transformation may contain substantial amounts of fossil carbon ranging from about 5-10 percent in the fossil methanol used for biodiesel production upwards to 46 percent in ethyl-tertiary-butyl-ether (ETBE) from fossil isobutene (ADEME/DIREM, 2002). Some processes may generate biogenic by-products such as glycol or glycerine, which may then be used elsewhere”.

However, the exact fossil C part per biofuel type is not explicitly provided in the GLs.

The **objective** of this note is to establish an accorded point of view among EU MS to agree on a common understanding and define possible ways how to estimate the associated CO2 emissions to the fossil carbon content in Biofuels. The aim of the note is to cover all possible biofuel types that are used to replace diesel and gasoline.

# Calculating the fossil fuel content of biofuels that replace fossil diesel (biodiesel)

The following biofuels are used to replace fossil diesel:

1. Hydrotreated vegetable oil (HVO)
2. Fatty acid methyl esters (FAME)

## Hydrotreated vegetable oil (HVO)

HVO is produced through the hydro-treatment of the triglyceride-containing feedstocks (vegetable oil or animal fat). **All carbon can be considered of biogenic origin (no fossil part)**. For the production of HVO, vegetable oil reacts only with hydrogen, without the use of other chemicals that contain fossil carbon. Most likely, hydrogen is produced from fossil sources (e.g. by steam reforming of natural gas). The associated CO2 emissions from hydrogen production should have been reported under CRF category 2.B.10.

## Fatty acid methyl esters (FAME)

Vegetable oils or animal fats are reacted with methanol in the presence of catalysts to form glycerol and a Fatty Acid Methyl Ester (FAME). The FAME is the desired component of biodiesel and the glycerol is separated as a by-product.

The use of **fossil-derived methanol** in the production of biodiesel means that the fossil fuel and biomass aspects within the biodiesel are chemically bonded. Figure 1 below shows the chemical reaction that occurs in the typical biodiesel-FAME manufacturing process.

As we can see from the chemical reaction, FAME (ROOCH3) contains the carbon of the Fatty acids of triglyceride (R- part), and one C from the methyl group (CH3-) of methanol.

**The fossil carbon of FAME originates from the methyl group of methanol**, i.e. 1 mole C per mole of FAME (ROOCH3).



***Figure 1. The chemical reaction for FAME production[[1]](#footnote-1)***

The **fossil part of FAME** ranges from **5.3 to 5.5%** and depends on the type of vegetable oil or animal fat used for FAME production. The appendix A contains the calculations. The carbon content of FAME biodiesel (both biogenic and fossil origin) ranges from 74 to 77% and also depends on the type of vegetable oil or animal fat used for FAME production. The appendix B contains the calculations.

## Step-by-step approach to estimate fossil CO2 emissions from biodiesel

In order to estimate the fossil CO2 emissions from biodiesel, the following step by step approach is proposed:

**Step 1:** Obtain data about kt of biodiesel used within the country (Source: national energy balance / IEA / UNECE questionnaires). By using country specific information, identify which part of the reported quantities is FAME and which HVO. The HVO is not associated to fossil CO2 emissions. If country-specific information is not available about FAME / HVO split, consider that all biodiesel is FAME.

**Step 2:** Estimate the total carbon content (CC) of FAME (both bio and fossil origin). If country specific information is available about the composition of FAME used within the country, use it to estimate the weighted average CC of FAME by applying values of carbon content per FAME type from Appendix B or other well documented source. If country-specific information is not available about the composition of FAME, use 76.5% kgC/kgFAME as default value (it is estimated by considering that FAME composition is 50% rapeseed / 30% sunflower / 20% palm oil).

**Step 3:** Estimate the fossil part of carbon content of FAME. If country specific information is available about the composition of FAME used within the country, use it to estimate the weighted average share of fossil part of FAME by applying fossil carbon percentages from Appendix A or other well documented source. If countrs-specific information is not available about the composition of FAME, use 5.4% as default value of carbon content fossil part (it is estimated by considering that FAME composition is 50% rapeseed / 30% sunflower / 20% palm oil).

**Step 4:** Calculate both fossil and biogenic CO2 emissions associated to FAME by applying the following equations:

**Fossil origin CO2 (kt) = (kt FAME / step 1) \* (carbon content of FAME / step 2) \* (fossil part of C of FAME / step 3) \* 44/12**

**Bio origin CO2 (kt) from FAME = (kt FAME / step 1) \* (carbon content of FAME / step 2) \* [100% - (fossil part of C of FAME / step 3)] \* 44/12**

**Bio origin CO2 (kt) from HVO = (kt HVO / step 1) \* (carbon content of HVO[[2]](#footnote-2)) \*44/12**

## Important note for biodiesel

According to the 2006 IPCC GLs, the default CC and NCV for biodiesel are 19.3 kg/TJ and 27 TJ/kt, respectively. By combining these numbers, we can calculate that the CC of biodiesel in mass units is 52.1% (kg/kg). This number deviates by more than 30% from the carbon contents that are calculated in Appendix B. For accuracy reasons, the use of the defaults CC and NCV for biodiesel from 2006 IPCC GLs should be avoided.

The NCV of biodiesel can be obtained as follows: the NCV of HVO is similar to petro-diesel, while the NCV of FAME can be obtained from Appendix C.

# Calculating the fossil fuel content of biofuels that replace fossil gasoline (biogasoline[[3]](#footnote-3))

The following biofuels are used to replace or as additives to fossil-gasoline:

1. Bioalcohols (i.e. biomethanol, bioethanol and biobutanol)
2. Bioethers (i.e. bio MTBE, bio ETBE, bio-TAEE)

Bioalcohols (i.e. biomethanol, bioethanol and biobutanol) are produced by fermentation of biomass. It is considered that their carbon is 100% of bio origin.

Bioethers (i.e. bio MTBE, bio ETBE, bio-TAEE) are synthesized by mixing bioalcohols and isobutylene (methylbutene for TAEE) and reacting them with heat over a catalyst. They are commonly used as an oxygenate gasoline additive in the production of gasoline from crude oil. Given that isobutylene is currently derived from fossil sources from either refining or from natural gas, we conclude that bioethers have a fossil part. In the following table, the CC and the fossil part of it are presented.

***Table 1: Carbon content and fossil fraction of carbon content of biogasoline***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **C atoms** | **Molecular weight** | **Carbon content (fossil + bio) % kg/kg** | **Fossil part of carbon content** |
| Bio MTBE | 5 | 88.2 | 68.0% | 80.0% |
| Bio ETBE | 6 | 102.2 | 70.5% | 66.7% |
| Bio TAEE | 7 | 116.2 | 72.3% | 71.4% |
| Bio methanol | 1 | 32.04 | 37.5% | 0% |
| Bio ethanol | 2 | 46.07 | 52.1% | 0% |
| isobutylene | 4 | 56.106 |  |  |
| methyl butene | 5 | 70.135 |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| **chemical reactions** | | | | |
| bio methanol + isobutylene --> MTBE | | | | |
| bio ethanol + isobutylene --> ETBE | | | | |
| bio ethanol + methyl butene --> TAEE | | | | |

Both bio-ethers and bio-alcohols are used as biogasoline in EU. In general bio-ETBE is preferred to be used in some countries in conventional vehicles and fuel distribution systems, because it requires minimal investment in distribution system infrastructure. According to information from MS received during the preparation of this note, biogasoline in UK is 91-100% bioethanol, and in Sweden is 100% bioethanol.

AD of biogasoline in kt (mass units) can be obtained from IEA-UNECE-Eurostat energy balance questionnaires. Regulation (EC) No 1099/2008 on energy statistics defines reporting obligations and includes reporting of biogasoline and its component bioethanol. Currently 40 countries report to Eurostat (28 EU Member states, all candidate and all potential candidate countries, Iceland, Norway, Moldova, Ukraine and Georgia). There is a need for additional country-specific information in order to disaggregate biogasoline to the respective types of bioalcohols and bioesters (biomethanol, bioethanol, biobutanol, bio MTBE, bio ETBE, bio-TAEE).

The following equations can be used for the calculation of fossil and biogenic CO2 associated to biogasooline consumption:

**Fossil origin CO2 (kt) = (kt biogasoline) \* carbon content (kg/kg) \* fossil fraction of CC (%) \* 44/12**

**Bio origin CO2 (kt) = (kt biogasoline) \* carbon content (kg/kg) \* (100% - fossil fraction of CC (%)) \* 44/12**

For example, if we consider that the whole quantity of biogasoline from energy balance is bio-ETBE then CO2 emissions can be calculated as follows:

Fossil origin CO2 (kt) = (kt biogasoline) \* 70.5% \* 66.7% \* 44/12

Bio origin CO2 (kt) = (kt biogasoline) \* 70.5% \* (100%-66.7%) \* 44/12

**Important note:** According to the 2006 IPCC GLs, the default CC and NCV for biogasoline are 19.3 kg/TJ and 27 TJ/kt, respectively. By combining these numbers, we can calculate that the CC of biogasoline (default from 2006 IPCC GL) is 52.1% (kg/kg), which is the bioethanol CC (see Table 1). Therefore, when other type of biogasoline is used than bioethanol, the default CC and NCV values are not accurate and should be avoided.

# CRF Tables

CO2 emissions associated to the fossil part of biofuels should not be reported under “Biomass” in CRF Table1.A(a)s3, because by this way the emissions will not be included in the national total. It is suggested to be reported under “other fossil fuels”. The CRF Reporter software provides the option to specify the type of fossil fuel (e.g. it can be named “fossil part of biodiesel or biogasoline”.

The related activity data (AD) associated to the fossil part of biofuels should be also reported under “other fossil fuels”. They can be estmated by multiplying the amount of biofuel by the fossil part of the carbon content (%).

# Note on reporting and collection of energy statistics

The scope of official European statistics on energy is defined in Regulation (EC) No 1099/2008 on energy statistics. Currently the reporting methodology is based on the following principle:

All liquid fuels produced from renewable feedstocks (such as vegetable oil and animal fat), regardless of origin of the methanol used in the chemical reaction, should be reported as production of liquid biofuels in the renewable questionnaire. This can be generalised for other fuels than methanol and other more complex transformation processes.

The results of this consultation will be used as an input to future discussions in the Energy Statistics Working Group on changing the reporting methodology, both in annual energy statistics (energy balances; Regulation (EC) No 1099/2008) and in the SHARES tool (calculation of the share of energy from renewable sources according to Directive 2009/28/EC).

# Appendix A

**Calculations of fossil carbon part of biodiesel per vegetable oil or animal fat**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Vegetable oil or animal fat** | **Fatty acid type** | **% (kg/kg) in oil[[4]](#footnote-4)** | **C atoms in FA (based on formula)** | **C atoms in R part (fatty part) of FAME** | **C atoms in CH3 -** | **C atoms in FAME** | **C fossil part (origin from methanol)** |
|  |  |  |  |  |  |  |  |
| **Sunflower** | Palmitic | 5.0% | 16 | 0.8 |  |  |  |
| Stearic | 6.0% | 18 | 1.1 |  |  |  |
| Oleic | 30.0% | 18 | 5.4 |  |  |  |
| Linoleic | 59.0% | 18 | 10.6 |  |  |  |
|  |  |  |  | 17.9 | 1 | 18.9 | 5.3% |
|  |  |  |  |  |  |  |  |
| **Rapeseed (canola)** | oleic | 61.0% | 18 | 11.0 |  |  |  |
| Linoleic | 21.0% | 18 | 3.8 |  |  |  |
| alpha linoleic | 11.0% | 18 | 2.0 |  |  |  |
| Palmitic | 4.0% | 16 | 0.6 |  |  |  |
| Stearic | 2.0% | 18 | 0.4 |  |  |  |
|  |  |  |  | 17.9 | 1 | 18.9 | 5.3% |
|  |  |  |  |  |  |  |  |
| **Palm oil** | oleic | 36.6% | 18 | 6.6 |  |  |  |
| Linoleic | 9.1% | 18 | 1.6 |  |  |  |
| Palmitic | 43.5% | 16 | 7.0 |  |  |  |
| Stearic | 4.3% | 18 | 0.8 |  |  |  |
| myristic | 1.0% | 14 | 0.14 |  |  |  |
|  |  |  |  | 17.0 | 1 | 18.0 | 5.5% |
|  |  |  |  |  |  |  |  |
| **Cottonseed** | Palmitic | 23.0% | 16 | 3.7 |  |  |  |
| Palmitoleic | 1.0% | 16 | 0.2 |  |  |  |
| stearic | 2.5% | 18 | 0.5 |  |  |  |
| oleic | 17.0% | 18 | 3.1 |  |  |  |
| trans oleic | 0.1% | 18 | 0.0 |  |  |  |
| linoleic | 56.0% | 18 | 10.1 |  |  |  |
| trans linoleic | 0.1% | 18 | 0.0 |  |  |  |
| linolenic | 0.3% | 18 | 0.1 |  |  |  |
|  |  |  |  | 17.5 | 1 | 18.5 | 5.4% |
|  |  |  |  |  |  |  |  |
| **Tallow** | palmitic | 26.0% | 16 | 4.2 |  |  |  |
| stearic | 14.0% | 18 | 2.5 |  |  |  |
| myristic | 3.0% | 14 | 0.4 |  |  |  |
| oleic | 47.0% | 18 | 8.5 |  |  |  |
| linoleic | 3.0% | 18 | 0.5 |  |  |  |
| palmitoleic | 3.0% | 16 | 0.5 |  |  |  |
| Linolenic | 1.0% | 18 | 0.2 |  |  |  |
|  |  |  |  | 17.3 | 1 | 18.3 | 5.5% |
|  |  |  |  |  |  |  |  |
| **Lard** | palmitic | 26.5% | 16 | 4.2 |  |  |  |
| stearic | 13.0% | 18 | 2.3 |  |  |  |
| myristic | 1.0% | 14 | 0.1 |  |  |  |
| oleic | 45.5% | 18 | 8.2 |  |  |  |
| linoleic | 8.0% | 18 | 1.4 |  |  |  |
| palmitoleic | 3.0% | 16 | 0.5 |  |  |  |
|  |  |  |  | 17.4 | 1 | 18.4 | 5.4% |

# Appendix B

**Calculations of carbon content of biodiesel per vegetable oil or animal fat**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Number of atoms** | | |  |  |  |
| **Vegetable oil or animal fat** | **Fatty acid type** | **% (kg/kg) in oil[[5]](#footnote-5)** | **C** | **H** | **O** | **MW of CH3** | **Molecular Weight (MW)** | **Carbon content (bio and fossil) % kg/kg** |
| **Sunflower oil** | Palmitic | 5.0% | 16 | 32 | 2 | 15 | 13.5 |  |
| Stearic | 6.0% | 18 | 36 | 2 | 15 | 17.9 |  |
| Oleic | 30.0% | 18 | 34 | 2 | 15 | 88.8 |  |
| Linoleic | 59.0% | 18 | 32 | 2 | 15 | 173.5 |  |
|  |  |  |  |  |  |  | 293.6 | 77.2% |
|  |  |  |  |  |  |  |  |  |
| **Rapeseed (canola)** | oleic | 61.0% | 18 | 34 | 2 | 15 | 180.6 |  |
| Linoleic | 21.0% | 18 | 32 | 2 | 15 | 61.7 |  |
| alpha linoleic | 11.0% | 18 | 30 | 2 | 15 | 32.1 |  |
| Palmitic | 4.0% | 16 | 32 | 2 | 15 | 10.8 |  |
| Stearic | 2.0% | 18 | 36 | 2 | 15 | 6.0 |  |
|  |  |  |  |  |  |  | 294.1 | 76.5% |
|  |  |  |  |  |  |  |  |  |
| **Palm oil** | oleic acid | 36.6% | 18 | 34 | 2 | 15 | 108.3 |  |
| Linoleic | 9.1% | 18 | 32 | 2 | 15 | 26.8 |  |
| Palmitic | 43.5% | 16 | 32 | 2 | 15 | 117.5 |  |
| Stearic | 4.3% | 18 | 36 | 2 | 15 | 12.8 |  |
| myristic | 1.0% | 14 | 28 | 2 | 15 | 2.4 |  |
|  |  |  |  |  |  |  | 283.4 | 71.8% |
|  |  |  |  |  |  |  |  |  |
| **Cottonseed** | Palmitic | 23.0% | 16 | 32 | 2 | 15 | 62.1 |  |
| Palmitoleic | 1.0% | 16 | 30 | 2 | 15 | 2.7 |  |
| stearic | 2.5% | 18 | 36 | 2 | 15 | 7.5 |  |
| oleic | 17.0% | 18 | 34 | 2 | 15 | 50.3 |  |
| trans oleic | 0.1% | 18 | 34 | 2 | 15 | 0.3 |  |
| linoleic | 56.0% | 18 | 32 | 2 | 15 | 164.6 |  |
| trans linoleic | 0.1% | 18 | 32 | 2 | 15 | 0.3 |  |
| linolenic | 0.3% | 18 | 30 | 2 | 15 | 0.9 |  |
|  |  |  |  |  |  |  | 288.7 | 77.0% |
|  |  |  |  |  |  |  |  |  |
| **Tallow** | palmitic | 26.0% | 16 | 32 | 2 | 15 | 70.2 |  |
| stearic | 14.0% | 18 | 36 | 2 | 15 | 41.7 |  |
| myristic | 3.0% | 14 | 28 | 2 | 15 | 7.3 |  |
| oleic | 47.0% | 18 | 34 | 2 | 15 | 139.1 |  |
| linoleic | 3.0% | 18 | 32 | 2 | 15 | 8.8 |  |
| palmitoleic | 3.0% | 16 | 30 | 2 | 15 | 8.0 |  |
| Linolenic | 1.0% | 18 | 30 | 2 | 15 | 2.9 |  |
|  |  |  |  |  |  |  | 286.7 | 73.6% |
|  |  |  |  |  |  |  |  |  |
| **Lard** | palmitic | 26.5% | 16 | 32 | 2 | 15 | 71.6 |  |
| stearic | 13.0% | 18 | 36 | 2 | 15 | 38.7 |  |
| myristic | 1.0% | 14 | 28 | 2 | 15 | 2.4 |  |
| oleic | 45.5% | 18 | 34 | 2 | 15 | 134.7 |  |
| linoleic | 8.0% | 18 | 32 | 2 | 15 | 23.5 |  |
| palmitoleic | 3.0% | 16 | 30 | 2 | 15 | 8.0 |  |
|  |  |  |  |  |  |  | 287.6 | 74.4% |

# Appendix C

**Calculations of NCV of biodiesel per vegetable oil or animal fat**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Vegetable oil or animal fat** | **Fatty acid type** | **% (kg/kg) in oil[[6]](#footnote-6)** | **GCV [[7]](#footnote-7)**  **(TJ/kt)** | **NCV**  **(TJ/kt)** |
|  |  |  |  |  |
| **Sunflower** | Palmitic | 5.0% | 39.8 |  |
|  | Stearic | 6.0% | 40.4 |  |
|  | Oleic | 30.0% | 40.3 |  |
|  | Linoleic | 59.0% | 40.1 |  |
|  |  |  | 40.2 | 36.1 |
|  |  |  |  |  |
| **Rapeseed (canola)** | oleic | 61.0% | 40.3 |  |
|  | Linoleic | 21.0% | 40.1 |  |
|  | alpha linoleic | 11.0% | 40.1 |  |
|  | Palmitic | 4.0% | 39.8 |  |
|  | Stearic | 2.0% | 40.4 |  |
|  |  |  | 40.2 | 36.2 |
|  |  |  |  |  |
| **Palm oil** | oleic | 36.6% | 40.3 |  |
|  | Linoleic | 9.1% | 40.1 |  |
|  | Palmitic | 43.5% | 39.8 |  |
|  | Stearic | 4.3% | 40.4 |  |
|  | myristic | 1.0% | 39 |  |
|  |  |  | 40.0 | 36.0 |
|  |  |  |  |  |
| **Cottonseed** | Palmitic | 23.0% | 39.8 |  |
|  | Palmitoleic | 1.0% | 39.6 |  |
|  | stearic | 2.5% | 40.4 |  |
|  | oleic | 17.0% | 40.3 |  |
|  | trans oleic | 0.1% | 40.3 |  |
|  | linoleic | 56.0% | 40.1 |  |
|  | trans linoleic | 0.1% | 40.1 |  |
|  | linolenic | 0.3% | 40 |  |
|  |  |  | 40.1 | 36.1 |
|  |  |  |  |  |
| **Tallow** | palmitic | 26.0% | 39.8 |  |
|  | stearic | 14.0% | 40.4 |  |
|  | myristic | 3.0% | 39 |  |
|  | oleic | 47.0% | 40.3 |  |
|  | linoleic | 3.0% | 40.1 |  |
|  | palmitoleic | 3.0% | 39.6 |  |
|  | Linolenic | 1.0% | 40 |  |
|  |  |  | 40.1 | 36.1 |
|  |  |  |  |  |
| **Lard** | palmitic | 26.5% | 39.8 |  |
|  | stearic | 13.0% | 40.4 |  |
|  | myristic | 1.0% | 39 |  |
|  | oleic | 45.5% | 40.3 |  |
|  | linoleic | 8.0% | 40.1 |  |
|  | palmitoleic | 3.0% | 39.6 |  |
|  |  |  | 40.1 | 36.1 |

1. Source: OFGEM, Renewables Obligation: Biodiesel and fossil-derived bioliquids guidance [↑](#footnote-ref-1)
2. If the carbon content of HVO is not available, use the carbon content of petro-diesel and not of FAME, because HVO has similar chemical composition with petro-diesel and not FAME. [↑](#footnote-ref-2)
3. Biogasoline is used here for the denomination of biofuels replacing fossil gasoline [↑](#footnote-ref-3)
4. Source: wikipedia [↑](#footnote-ref-4)
5. Source: wikipedia [↑](#footnote-ref-5)
6. Source: wikipedia [↑](#footnote-ref-6)
7. Source: OFGEM, Renewables Obligation: Biodiesel and fossil-derived bioliquids guidance [↑](#footnote-ref-7)