Typical greenhouse gas emissions in the cultivation phase of raw materials for the production of biofuels

REPORT FROM PORTUGAL

(Drawn up pursuant to Article 19(2) of Directive 2009/28/EC)

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Contents

Summary

This report identifies the areas in Portugal which are classified as NUTS II where it is expected that greenhouse gas emissions during the cultivation phase of raw materials for the production of biofuels will be lower than those set out in Directive 2009/28/EC. The areas which meet this objective are PT16 (Centre) and PT 18 (Alentejo) for the cultivation of sunflower and PT 16 (Alentejo) *[sic]* for the cultivation of maize.

1. Objective

Article 19(2) of Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources lays down that the Member States must submit to the European Commission a report which includes a list of those areas on their territory which are classified as NUTS II, or a more disaggregated NUTS level, where the typical greenhouse gas emissions from the agricultural phase of the production of biofuels can be expected to be lower than or equal to the emissions reported under the heading 'Cultivation' in part C of Annex V and in part D of the same Annex. The report to be submitted must also include a description of the method used to draw up the NUTS II list referred to above and must take account of the soil characteristics, climate and expected raw material yields.

This report meets the requirement of Article 19(2) for Portugal.

2. Framework

The European Directive on the promotion of the use of energy from renewable sources, Directive 2009/28/EC, established the objective that, by 2020, 20% of all the gross final consumption of energy in the Community should come from renewable sources, bearing in mind that for the transport sector, this quota should be 10%. In order to meet this overall objective, individual objectives are laid down for the Member States and, for Portugal, the quota to be reached by 2020 is 31%.

At the same time, and in addition to the targets for replacing sources of energy in the transport sector, sustainability criteria are laid down in Article 17 of Directive 2009/28/EC for biofuels and bioliquids, which are essential for these to meet the requirements of the Directive and, consequently, for them to be counted for the national objectives and be eligible for financial support for their consumption. Accordingly, and regardless of whether the cultivation of raw materials takes place within or outside the European Community, the biofuels and bioliquids must provide a reduction of greenhouse gases of at least 35%, and it is not necessary to prove this reduction until 1 April 2013 for plants which were in operation on 23 January 2008. The reduction required to meet with the sustainability criteria will be increased to 50% in 2017 and to 60% from 1 January 2018 in the case of new plants in which production started on or after 1 January 2017.

Despite the reduction targets, the sustainability criteria provide that the cultivation of raw materials for the production of biofuels and bioliquids shall not jeopardise the high biodiversity of certain areas of the country.

The definition of the areas allocated to the cultivation of raw materials for the production of

biofuels and bioliquids, in addition to the reductions of greenhouse gases attributed to the cultivation of these raw materials in Directive 2009/28/EC, is therefore becoming a decisive factor for the sustainability of the latter.

2.1. Institutions involved

The institutions involved in collecting information and drawing up this report were the Laboratório Nacional de Energia e Geologia, I.P. (National Laboratory for Energy and Geology, LNEG) under the jurisdiction of the Ministry of Economic Affairs, Innovation and Development and the Policy and Planning Cabinet (GPP) under the jurisdiction of the Ministry of Agriculture, Regional Development and Fisheries.

2.2. Agricultural crops considered

The value chains, which are the subject of analysis in this report, are those related to the different endogenous agricultural raw materials which in Portugal are, or can be, associated with the production of biodiesel and bioethanol. **Table 1** shows these raw materials and the respective biofuels.

Table 1 – Raw materials and respective biofuels

Raw material	Biofuel
Rape seed	Rape seed biodiesel
Sunflower	Sunflower biodiesel
Wheat	Wheat ethanol
Maize	Maize ethanol

The data required for calculating the greenhouse gas emissions relating to the cultivation of the raw materials which are being studied were collected based on the NUTS II

classification (Figure 1). These data include information on the area cultivated, the productivity, the fertilisers and pesticides applied, the seeds and fuel consumed by agricultural machinery, as well as information relating to soil characteristics. The soil N_2O emissions were estimated using the IPCC methodology.

Fig. 1 – Map of Portugal with the subdivisions in accordance with the NUTS II classification.

Adapted from [1].

Table 2 shows the NUTS II classification for the country and the respective agricultural crops studied.

In the case of maize, this is largely produced on irrigated land throughout mainland Portugal, with the North (PT11), Centre (PT16) and Alentejo (PT18) regions being those which produce the most. Wheat is produced on dry land, with the Alentejo region (PT18)

representing about 80% of the production area of this cereal at national level.

Table 2 – Agricultural crops per NUTS II region

NUTS Code	Level 2	Agricultural crops considered			
		Rape seed	Sunflower	Wheat	Maize
PT11	North	-	-	x	x
PT15	Algarve	-	-	x	x
PT16	Centre	x	x	x	x
PT17	Lisbon	-	-	-	-
PT18	Alentejo	x	x	x	x
PT20	Madeira	-	-	x	-
PT30	Azores	-	-	-	x

With regard to oil plants, the main crop is sunflower, with about 96% of production being in the Alentejo region (PT18), whilst rape seed is a crop which is still not widely grown in Portugal.

3. Methodology

3.1 Data collection

The data contained in **Tables 3 to 7** relating to the cultivation of raw materials, broken down by NUTS II area, relate to the year 2009. The data relating to mainland Portugal were collected by the GPP of the Ministry of Agriculture, Regional Development and Fisheries

based on the following sources of information:

Agricultural productivity and crop area

The agricultural productivity and crop area for maize and wheat were provided by the National Statistics Institute (INE) in the "Crop production table" referring to 2009 [2]. In the specific case of the cultivation of maize, the data relating to the areas and production drawn up by the INE for the various regions are regional averages which include the production of green maize (which has low productivity, see **Table 7**), related to livestock production (particularly dairy), and not only the production of 'grain' maize which can be used in the production of bioethanol. For this reason, the productivity and inputs presented in **Table 7** for the NUTS II regions of Centre and Alentejo only refer to the production of 'grain' maize (productivity figures of 13 000 and 12 000 kg/ha respectively), which is relevant for the production of biofuels. In the case of the NUTS II Centre region, the production of grain maize is concentrated in the NUTS III regions of Médio Tejo and Oeste, and therefore had the same productivity as the NUTS II Centre region, since the production conditions are the same. For the cultivation of sunflower, the data on the areas and productivity figures and used were based on information provided by farmers to the Agriculture and Fisheries Financing Institute (IFAP) also in 2009. With regard to rape seed, as it is not a significant crop in Portugal, it was only possible to obtain information provided by farmers with regard to the crop area by NUTS II area, and IFAP was the source of information, given that statistics are not compiled on this crop.

In the case of the Autonomous Regions of Madeira and the Azores, the information made available came from EUROSTAT [3].

Fuel (diesel), fertilisers, pesticides and seeds

The data relating to fuel, fertilisers, pesticides and seeds were obtained from the Regional Directorates for Agriculture and Fisheries, based on surveys done amongst both Farmers' Associations and farmers themselves. The exception is the data relating to the cultivation of maize in the Alentejo region (PT18) which were based on information provided by the National Association of Sorghum and Maize Growers (ANPROMIS).

Soil characteristics

With regard to the agricultural soil characteristics, the pH values were obtained from the 'Map of acidity and alkalinity of soil in Portugal' drawn up by the National Agronomics Centre [4]. The data relating to the type of soil were obtained from Cardoso et al., 1973 [5], Lithological Map of Portugal [6] and from additional information from the Directorate-General for Agriculture and Regional Development.

3.2. Crop data

The data relating to the cultivation of raw materials, broken down by NUTS II area, are presented in **Tables 3 to 7**. These data enable greenhouse gas emissions to be calculated based on information relating to each of the parameters considered in the cultivation phase, which depend on the type of crop, the type of soil and the climate. With regard to NUTS Lisbon (PT17), as this relates to a metropolitan area, the amount of agricultural production is negligible, and crop data are therefore not given for this region.

In the tables containing crop data, the disaggregated figures for the productivity of the various raw materials relate to seeds/dry grains and humidity values are not shown. The marketing of seeds/grains is done after drying, and is done only when necessary.

In the case of sunflower, the information available allows us to distinguish the crop data according to whether the crop is grown on irrigated or non-irrigated land. Thus, for this crop, two different tables are shown. It should be highlighted that fertiliser figures are not shown when the crop is grown on non-irrigated land, since, in this situation, the limiting factor is water. It is not technically correct to fertilise this land since it can lead to a big increase in vegetation, thereby negatively affecting the productivity of the crop.

Table 3 – Crop data for rape seed by NUTS II region

Parameter	Unit	North	Algarve	Centre	Lisbon	Alentejo	Madeira	Azores
		PT11	PT15	PT16(1)	PT17	PT18(1)	PT20	PT30
Area cultivated	ha/year	0	0	322	0	201	0	0
Productivity	Kg/ha/year	-	-	2425	-	2425	-	-
Diesel used	l/ha/year	-	-	83	-	83	-	-
Fertiliser N	Kg/ha/year	-	-	133	-	133	-	-
Fertiliser P_2O_5	Kg/ha/year	-	-	63	-	63	-	-
Fertiliser K_2O	Kg/ha/year	-	-	63	-	63	-	-
Fertiliser CaO	Kg/ha/year	-	-	-	-	-	-	-
Pesticides	Kg/ha/year	-	-	2	-	2	-	-
Seeds	Kg/ha/year	-	-	10	-	10	-	-
Soil characteristics	pH	-	-	5.6 to 7.3	-	5.6 to 7.3	-	-
	Coarse, medium, fine	-	-	not available	-	Not available	-	-

(1) Except for the area cultivated, the data shown correspond to average figures, calculated based on overall figures for Portugal.

Table 4 – Crop data for sunflower grown on non-irrigated land by NUTS II region

Parameter	Unit	North	Algarve	Centre	Lisbon	Alentejo	Madeira	Azores
		PT11	PT15	PT16	PT17	PT18	PT20	PT30
Area cultivated	ha/year	0	0	152	0	18617	0	0
Productivity	Kg/ha/year	-	-	650	-	650	-	-
Diesel used	l/ha/year	-	-	100	-	100	-	-
Fertiliser N	Kg/ha/year	-	-	0	-	0	-	-
Fertiliser P_2O_5	Kg/ha/year	-	-	0	-	0	-	-
Fertiliser K_2O	Kg/ha/year	-	-	0	-	0	-	-
Fertiliser CaO	Kg/ha/year	-	-	-	-	-	-	-
Pesticides	Kg/ha/year	-	-	0.57	-	0.57	-	-
Seeds	Kg/ha/year	-	-	3	-	3	-	-
Soil	pH	-	-	5.6 to 7.3	-	5.6 to 7.3	-	-
	Coarse, medium, fine	-	-	Coarse, medium, fine	-	Fine (clay)	-	-

Table 5 – Crop data for sunflower grown on irrigated land by NUTS II region

Parameter	Unit	North	Algarve	Centre	Lisbon	Alentejo	Madeira	Azores
		PT11	PT15	PT16	PT17	PT18	PT20	PT30
Area cultivated	ha/year	0	0	861	0	4367	0	0
Productivity	Kg/ha/year	-	-	3000	-	3000	-	-
Diesel used	l/ha/year	-	-	157	-	157	-	-
Fertiliser N	Kg/ha/year	-	-	21	-	21	-	-
Fertiliser P_2O_5	Kg/ha/year	-	-	63	-	63	-	-
Fertiliser K_2O	Kg/ha/year	-	-	63	-	63	-	-
Fertiliser CaO	Kg/ha/year	-	-	-	-	-	-	-
Pesticides	Kg/ha/year	-	-	1.50	-	1.50	-	-
Seeds	Kg/ha/year	-	-	7	-	7	-	-
Soil	pH	-	-	5.6 to 7.3	-	5.6 to 7.3	-	-
	Coarse, medium, fine	-	-	Coarse, medium, fine	-	Coarse, medium, fine	-	-

Table 6 – Crop data for wheat by NUTS II region

Parameter	Unit	North	Algarve	Centre	Lisbon	Alentejo	Madeira	Azores
		PT11(1)	PTI5'11	PT16	PT17	PT18	PT2O'1'	PT30
Area cultivated	ha/year	6616	605	3973	0	48519	100	0
Productivity	Kg/ha/year	891	974	3000	-	3000	1000	-
Diesel used	l/ha/year	159	159	176	-	158	159	-
Fertiliser N	Kg/ha/year	102	102	110	-	101	102	-
Fertiliser P_2O_5	Kg/ha/year	94	94	75	-	96	94	-
Fertiliser K_2O	Kg/ha/year	2	2	27	-	0	2	-
Fertiliser CaO	Kg/ha/year	-	-	-	-	-	-	-
Pesticides	Kg/ha/year	0.30	0.30	0.13	-	0.32	0.30	-
Seeds	Kg/ha/year	171	171	180	-	170	171	-
Soil	pH	not available	not available	5.6 to 6.5	-	5.6 to 7.3	not available	-
	Coarse, medium, fine	not available	not available	Coarse, medium, fine	-	Fine (clay)	not available	-

(1) Except for the area cultivated and productivity, the data shown correspond to weighted average figures, calculated based on actual figures for NUTS PT16 and PT18, and so must be considered as estimates.

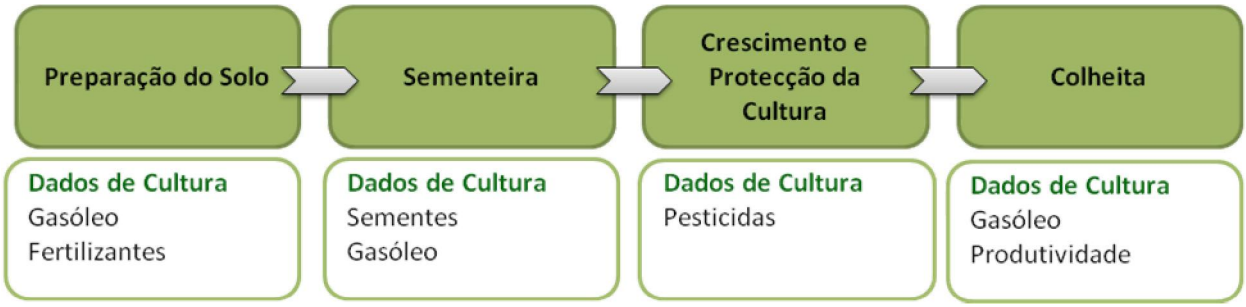
Table 7 – Crop data for maize by NUTS II region

Parameter	Unit							
		PT11(i)	PTI5'11'	PT16	PT17	PT18	PT20	PT30'1'
Area cultivated	ha/year	34879	560	39268	0	21760	0	600
Productivity	Kg/ha/year	3110	7401	13000	-	12000	-	2170
Diesel used	l/ha/year	223	223	198	-	261	-	223
Fertiliser N	Kg/ha/year	222	222	204	-	250	-	222
Fertiliser P_2O_5	Kg/ha/year	97	97	98	-	95	-	97
Fertiliser K_2O	Kg/ha/year	107	107	98	-	120	-	107
Fertiliser CaO	Kg/ha/year	20	20	0	-	50	-	20
Pesticides	Kg/ha/year	2.34	2.34	2.52	-	2.02	-	2.52
Seeds	Kg/ha/year	29	29	28	-	30	-	29
Soil	pH	not available	not available	5.6 to 6.5	-	6 to 8	-	not available
	Coarse, medium, fine	not available	not available	Coarse, medium, fine	-	Coarse, medium, fine	-	not available

(1) Except for the area cultivated and productivity, the data shown correspond to weighted average figures, calculated based on actual figures for NUTS PT16 and PT18, and so must be considered as estimates.

3.3. Calculation of greenhouse gas emissions

The greenhouse gas emissions resulting from the cultivation of the different energy crops which are grown in Portugal were calculated using a lifecycle analysis which was based on the methodology described in Annex V to Directive 2009/28/EC and by the Joint Research Centre [7]. These calculations take account of the crop data referred to above and broken down in **Tables 3 to 7**, which correspond to the agricultural inputs of the different growing phases: preparation of the ground, sowing, growth and protection of crops and harvesting.



Translation:

Preparation of ground	Sowing	Growth and protection of crops	Harvesting
Crop data Diesel Fertilisers	Crop data Seeds Diesel	Pesticides	Diesel Productivity

Figure 2 – Lifecycle phases in the cultivation of raw materials for biofuels.

The quantification of greenhouse gas emissions corresponding to these agricultural inputs was calculated using emission factors corresponding to the lifecycle of each input. Thus for each of the inputs, the following have been taken into account:

Emission factors for fertilisers and pesticides

The production processes of raw materials to make fertilisers and/or pesticides are included, as well as the energy associated with their production process and with transporting them to the land where they are applied.

Emission factors for seeds

These include the energy associated with the physical (cleaning, drying) and chemical processing, and with storage with a view to sowing.

Emission factors for diesel

These include the extraction of crude oil, the processes of refining and transporting it from the refinery and to the end consumer, as well as the energy associated with using it in the cultivation phase. The consumption of diesel is influenced by the type of soil and also by the characteristics of the machinery used on each farm.

The emission factors used in the calculations are data referenced in the transparency platform of the European Community and published in [8] by the partners in the European project BIOGRACE as being the emission factors used in creating the typical and default values in Annex V to Directive 2009/28/EC. In [8] there is an exhaustive list of all the factors required for calculating the emissions resulting from the complete production lifecycle of biofuels. **Table 8** lists the factors used in this study.

Table 8 – Emission factors for the various agricultural inputs (adapted from [8])

Parameter	**Emissio of CO_2 gCO_2/kg**	**Emissio of CH_4 gCH_4/kg**	**Emissio of N_2O gN_2O/kg**	**gCO_2-eq/kg**
Fertilisers				
Fertiliser N	2827.0	8.68	9.6418	5880.6
Fertiliser P_2O_5	964.9	1.33	0.0515	1010.7
Fertiliser K_2O	536.3	1.57	0.0123	576.1
Fertiliser CaO	119.1	0.22	0.0183	129.5
Pesticides	9886.5	25.53	1.6814	10971.3
Seeds				
Rape seed	412.1	0.91	1.0028	729.9
Sunflower	412.1	0.91	1.0028	729.9
Wheat	151.1	0.28	0.4003	275.9
Maize	0	0	0	0
Diesel **(gCO_2/MJ)**	87.64	0	0	87.64

The greenhouse gases considered for calculating emissions during cultivation were CO_2, N_2O and CH_4. The emission values are presented in CO_2 equivalents. According to Directive 2009/28/EC, this equivalence is 296 for N_2O and 23 for CH_4. The values shown in **Table 9** were used for calculating the lower calorific values (LCV) of each seed/grain.

Table 9 – Lower calorific values (adapted from [8])

Seed	LCV MJ/kg
Rape seed	26.4
Sunflower	26.4
Wheat	17.2
Maize	18.5
Diesel	36.086 MJ/L [9]

Table 10 shows the yield from the processing phases and relevant energy allocations used in order to calculate greenhouse gas emissions in CO_2 eq./ $MJ_{biofuel}$.

Table 10 – Yield from processing phases and allocations relating to each biofuel (adapted from [7])

Biofuel	Yield from the processing phase ($MJ_{Seed}/MJ_{Biofuel}$)	Energy allocation (%)
Rape seed biodiesel	1.63	58.7
Sunflower biodiesel	1.52	63.0
Wheat ethanol	1.89	59.5
Maize ethanol	1.94	54.6

3.4. Soil N_2O emissions

In order to calculate soil N_2O emissions, the methodology proposed by the IPCC (Intergovernmental Panel on Climate Change) Level 1 was used, which counts all nitrogenous inputs added to the soil by means of fertilisers and crop waste. In this methodology, indirect emissions resulting from the volatilisation and leaching of nitrogenous species are also taken into account. The various factors used in the calculations are listed in **Table 11**. Crop waste was taken into account to

calculate soil N_2O emissions using the IPCC methodology set out in Table 11.2 'Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application, pages 11.17 and 11.18.'

Table 11 – Emission factors used to calculate N_2O emissions

Emission	**Unit**	**Factor**
Direct emissions		
Nitrogenous inputs	kg N_2O-N/(kgN)	0.01
Treatment of organic soil	kg N_2O-N /ha	8
Indirect emissions		
Volatilisation	kg N_2O-N/ (kg NH_3-N + NOX-N)	0.01
Leaching	kg N_2O-N/(kg N)	0.0075

For this calculation, information is required on the soil characteristics, in addition to the data on agricultural productivity and nitrogenous fertilisers.

Soil in Portugal is classified as: arenosols, vertisols, leptosols, fluvisols, regosols, cambisols, solonchaks, luvisols, planosols and podzols; since they are not classified as organic soils [10], the parameter resulting from the treatment of organic soils was not taken into account in the calculation of soil N_2O emissions.

4. Results

The results obtained in the calculations of greenhouse gas emissions for energy crops in the Portuguese NUTS II areas are broken down in **Table 12**.

The results of emissions which are below and above the default values given in part D (cultivation) of Annex V to Directive 2009/28/EC are shown highlighted in green and red respectively.

Table 12 – Results of typical emissions calculated for each crop in the different NUTS II areas in Portugal

	RAPE SEED gCO2eq/MJ biodiesel	SUNFLOWER gCO2eq/MJ biodiesel	WHEAT gCO2eq/MJ ethanol	MAIZE gCO2eq/MJ ethanol
PT 11 North	-	-	145	69
PT 15 Algarve	-	-	133	31
PT 16 Centre	33	13[i] 23[ii]	50	18
PT 18 Alentejo	33	14[i] 23[ii]	46	22
PT 20 Madeira	-	-	129	-
PT 30 Azores	-	-	-	98
Directive 2009/28/EC	29	18	23	20

i – irrigated; ii – dry

5. Conclusions

This report enables information to be obtained about greenhouse gas emissions resulting from the national agricultural practice of cultivating raw materials for the production of biofuels. With regard to soil N_2O emissions, it should be noted that the use of the IPCC Level 1 methodology leads to values for Portugal which are higher than those reported by the Joint Research Centre in its report [7].

The results obtained show that in the case of the cultivation of wheat, the emissions for the cultivation phase are higher than the reference values in Directive 2009/28/EC for all NUTS II areas in Portugal. Actual emission values must therefore always be used for this crop. For the cultivation of maize, the values calculated for the NUTS 16 area (Centre) are lower than those indicated in the Directive, and the same has been noted for the cultivation of sunflower on

irrigated land, whether in NUTS PT 16 (Centre) or NUTS PT 18 (Alentejo).

In conclusion, the areas of the country classified as NUTS II for which the default values shown in the heading 'Cultivation' in part D of Annex V to Directive 2009/28/EC can be used in the calculation of greenhouse gas emissions are only NUTS PT 16 and PT 18 for the cultivation of sunflower and NUTS PT 16 for the cultivation of maize; in the other areas, as the planting of agricultural crops for energy purposes is not prevented by the Directive, the overall calculations for the reduction of greenhouse gas emissions must be made based on the actual cultivation values in order to assess their sustainability.

With regard to the cultivation of rape seed in Portugal and maize in Alentejo, these show values which are very close to those in Directive 2009/28/EC and an increase in productivity, by means of improving agricultural practices, could enable a decrease in greenhouse gas emissions to values lower than those laid down in Directive 2009/28/EC.

The assessment produced in this National Report can be reviewed at any time by means of changing the methodology and/or values presented in Annex V to the Directive, improving national agricultural practice or introducing new energy crops in Portugal.

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