MINISTRY OF INDUSTRY, TOURISM AND TRADE

Subdirectorate-General for International Energy Relations

STATE SECRETARY FOR ENERGY

IDAE - Institute for Diversification and Saving of Energy

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REPORT

REPORT FROM SPAIN PURSUANT TO ARTICLE 19(2) OF DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL OF 23 APRIL 2009 ON THE PROMOTION OF THE USE OF ENERGY FROM RENEWABLE SOURCES AND AMENDING AND SUBSEQUENTLY REPEALING DIRECTIVES 2001/77/EC AND 2003/30/EC

1. BACKGROUND

Article 19(2) of Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC states that:

"2. By 31 March 2010, Member States shall submit to the Commission a report including a list of those areas on their territory classified as level 2 in the nomenclature of territorial units for statistics (NUTS) or as a more disaggregated NUTS level in accordance with Regulation (EC) No 1059/2003 of the European Parliament and of the Council of 26 May 2003 on the establishment of a common classification of territorial units for statistics (NUTS) where the typical greenhouse gas emissions from cultivation of agricultural raw materials can be expected to be lower than or equal to the emissions reported under the heading ‘Disaggregated default values for cultivation’ in part D of Annex V to this Directive, accompanied by a description of the method and data used to establish that list. That method shall take into account soil characteristics, climate and expected raw material yields."

This report has been drawn up to comply with the above provisions in the case of Spain.

2. METHODOLOGY

This report presents the greenhouse gas balance for the stages of cultivation inherent in the production of biofuels in Spain from the most suitable raw materials, taking the national agronomic conditions into account.

For the purposes of assessing greenhouse gas emissions from biofuels, one MJ of biofuel produced serves as the basic reference (functional) unit. The following biofuel production processes were considered:

- Production of bioethanol from wheat, barley and sugar sorghum,
- Production of biodiesel from sunflower, rapeseed and cardoon (cardoon) oil.

The methodology for drawing up greenhouse gas balances for the biofuels produced in Spain was as described in Directive 2009/28/EC on the promotion of the use of energy from renewable sources (OJ L 140, 5.6.2009), based on life-cycle analysis (LCA) methods. This methodology establishes a set of working assumptions which is, in certain respects, the subject of controversy within the scientific community dealing with LCA, as regards (for the agricultural stages of production)

- The greenhouse gas emissions to be considered and the factors that characterise them.
- The effects on land-use changes that need to be considered, and the amortisation period to be taken into account in the case of such changes.

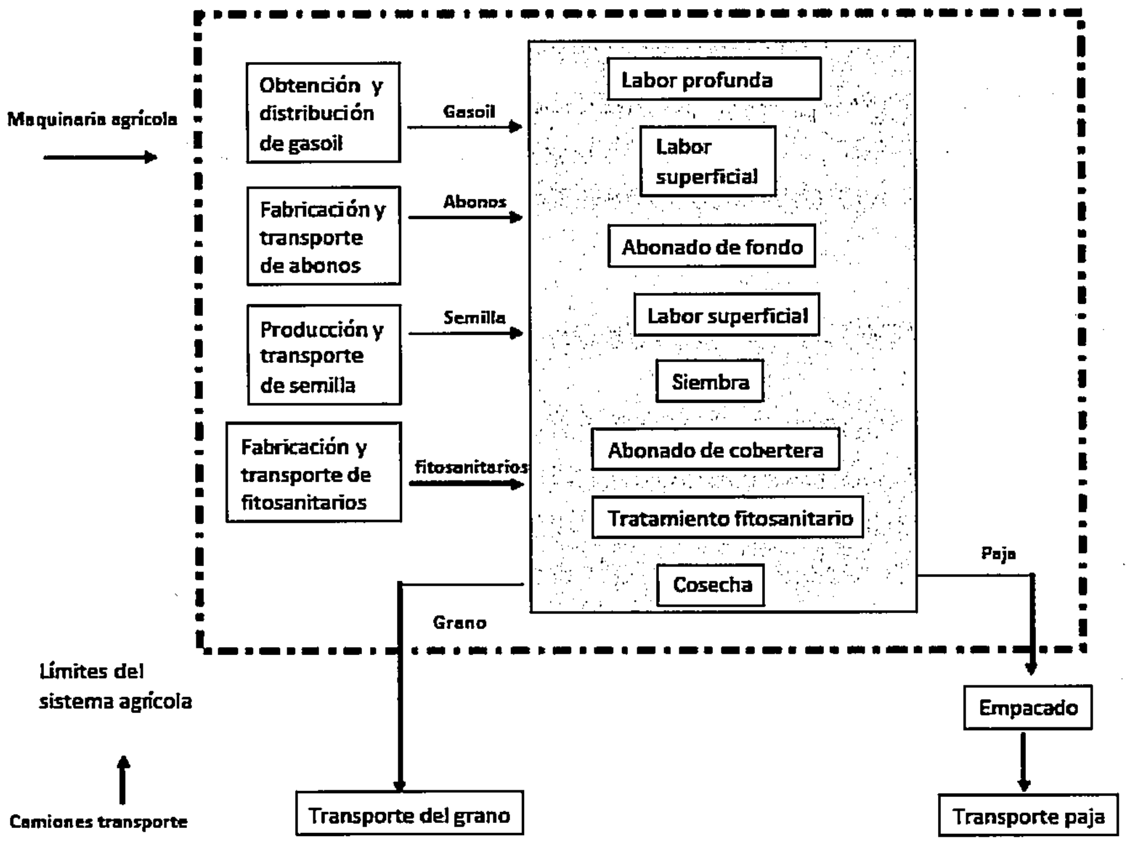
In all these respects, the working assumptions established in the Directive will be adhered to, so that the results obtained in this study are perfectly compatible with the methodology described in the Directive.

The Directive establishes typical and default values for specific biofuel production chains, based on a study by the JRC, Eucar and Concawe (JEC, 2007), and the methodology followed in that study has therefore been used as the reference methodology for drawing up the greenhouse gas balance in this report.

Lastly, it should be noted that the greenhouse gas balance has been drawn up using the SIMAPRO 7 software tool, and that the data used has been obtained from various sources, albeit related as far as possible to actual situations occurring in Spain.

3. INVENTORY OF AGRICULTURAL PRODUCTION SYSTEMS

The activities included in the agricultural production systems analysed are outlined in the following diagram.



Key:

Limites del sistema agrícola	Limits of the agricultural system
Camiones transporte	Transport by lorry
Maquinaria agricola	Agricultural machinery
Obtención y distribución de gasoil (diesel)	Production and distribution of gasoil
Fabricación y transporte de abonos	Manufacture and transport of fertilisers
Producción y transporte de semilla	Production and transport of seed
Fabricación y transporte de fitosanttarios	Manufacture and transport of plant protection products
Gasoil	Gas oil (diesel)
Abonos	Fertilisers
Semilla	Seed
Fitosanitarios	Plant protection products
Labor profunda	Deep ploughing
Labor superficial	Surface tilling
Abonado de fondo	Basal dressing
Labor superficial	Surface tilling
Siembra	Sowing
Abonado de cobertera	Top dressing
Tratamiento fitosanitario	Phytosanitary treatment
Cosecha	Harvesting

Grano	Grain
Paja	Straw
Transporte del grano	Transport of grain
Empacado	Baling
Transporte paja	Transport of straw

STAGES AND PROCESSES CONSIDERED

(a) Production of seed for sowing: includes the energy consumed during pre-cleaning, cleaning, drying, chemical treatment and storage. The growing processes are considered to be similar to conventional growing methods.

(b) Fertiliser production: from obtaining the raw materials to producing the final product, as well as transporting them to the land where the crops are grown.

(c) Production of plant protection products: includes the production processes from obtaining the raw materials to producing the final product, as well as transporting them to the land where the crops are grown.

(d) Diesel production: includes the extraction of crude oil, refining processes and transport from the refinery to the final user.

(e) Water consumption for irrigation: the loads associated with obtaining the energy needed to pump irrigation water are taken into account.

(f) Stages and processes not taken into consideration in this study: the packaging of agrochemicals used as fertilisers and the associated life cycles were disregarded, owing to the wide variety of types of containers used and given that their contribution relative to the different categories of impact is minimal in the system under consideration. Likewise, the baling and transport of straw, except in the case of sorghum and artichoke grown exclusively as biomass, was disregarded. In such cases, all of the harvested biomass is gathered and transported. Activities connected with the manufacture of implements, the building of farm infrastructure and all infrastructure at plants where the various agricultural inputs are produced were also disregarded.

INPUT DATA FOR STAGES IN AGRICULTURAL PRODUCTION

This data was provided by the ETSIA Agro-Energy Group (at the Technical University of Madrid). The aforementioned group assessed the resources associated with farming operations performed in the context of producing the crops studied in this report: wheat (*Triticum aestivum L*), barley (*Hordeum vulgare*), sugar sorghum (*Sorghum bicolor L*), rape (*Brassica napus L*), sunflower (*Helianthus annuus*) and cardoon (*Cynara cardunculus L*). The resources (energy and materials) taken into condieration in this study may be grouped as follows:

(a) Surface
(b) Crop production
(c) Fertilisers
(d) Plant protection products
(e) Water and power for irrigation
(f) Agricultural machinery
(g) Fuel

The assessment was carried out at district level, taking into account the agronomic characteristics of each agricultural district, the results then being aggregated at provincial or regional level, as appropriate. The resources deployed to work the land are assessed separately for each crop and according to a specific system for each section, as detailed below.

(a) Area

The energy and materials used in the context of the farming operations to produce the crops studied here are assessed for those districts which include areas under the crops in question. To this end, the municipal database of agricultural areas, as provided by the Ministry of the Environment and Rural and Marine Affairs (MARM), has been used in a GIS environment and the area data has been aggregated by crop at district level.

For wheat, barley, rape and sunflower, this indicates the area of non-irrigated land and irrigated land within each municipality on which the crop was grown in 2004, the most recent year for which the MARM has data covering the whole of Spain.

In the case of cardoon and sugar sorghum, the area considered is that in which these plants could grow. To do this, a set of agro-climatic criteria are established that are representative of the agro-ecology of the crop concerned. Based on tabulated data from the SIGA relating to the climate in Spanish municipalities, and using other pedo-climatic layers compatible with a GIS environment, average values are calculated for the relevant agro-climatic variables for each district.

In the case of cardoon, the agro-climatic variables taken into consideration when analysing its potential distribution are: annual precipitation, rainfall readings in spring - i.e. from March to June (AEMET), minimum April temperatures (SIGA) and soil depth (SGDBE -JRC).

The potential distribution of sugar sorghum as a crop is confined to Andalusia, owing to its tropical origin. In those districts where the established agro-climatic conditions are met, the area available for cardoon and sorghum is deemed to be 50% of the fallow land and other unused agricultural areas, plus 10% of the area intended for growing arable crops. The area considered is non-irrigated land in the case of cardoon and irrigated land in the case of sugar sorghum

(b) Crop production

Cereals

In the case of cereals, the yield is estimated using a database of average provincial cereal yields for the whole of Spain over a ten-year period (1996-2006), obtained from the Annual Agri-Food Statistics (AEA) produced by the Ministry of the Environment and Rural and Marine Affairs (MARM). To obtain district-level yield data, the production regionalisation index (IRP) devised as part of CAP programmes indicating crop productivity at regional level, was applied. This index is compiled on the basis of the information available in the Agricultural Geographical Information System (SIGA).

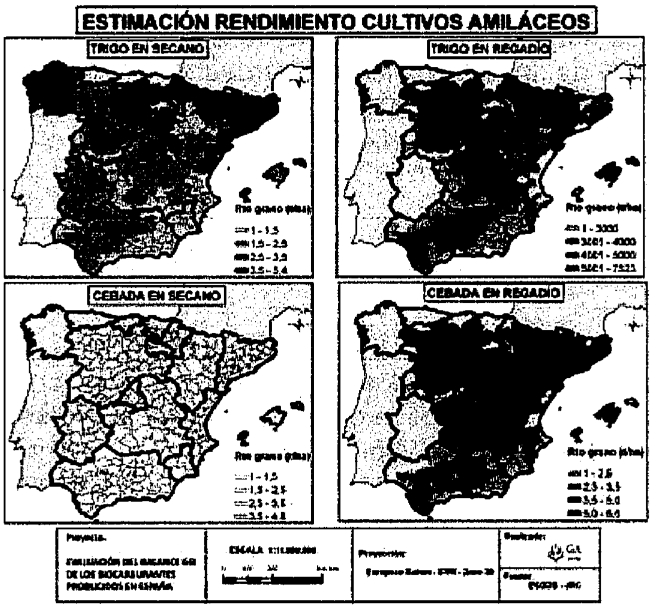
The cereal yield is therefore estimated on the basis of the average IRP at district level, multiplied by a specific coefficient (IPC) for each province, which produces an estimate of potential cereal grain production for each IRP unit (weighted provincial average). To obtain the quantity of residual farm biomass arising from grain production, i.e. cereal straw, a specific total biomass to grain ratio (Rb/g) is applied for each crop.

The IPC takes account of the relationship between the average provincial cereal (grain) yield and the province's average weighted IRP. This index was calculated from a weighted average of district IRPs, on the basis of the areas under cereals in each of the agricultural districts. In this way, the index is calculated solely for farming areas under cereal crops. The value of the IPC equates to a province's theoretical average cereal grain yield for each IRP unit. The formula used to estimate the cereal grain yield in each district is therefore as follows:

Cereal grain yield (t DM/ha) = IRP * IPC

This is used to obtain district-level yield data for wheat and barley grown on non-irrigated and on irrigated land.

ESTIMATED YIELD OF STARCH CROPS



Key:

TRIGO EN SECANO	WHEAT ON NON-IRRIGATED LAND
TRIGO EN REGADÍO	WHEAT ON IRRIGATED LAND
CEBADA EN SECANO	BARLEY ON NON-IRRIGATED LAND
CEBADA EN REGADÍO	WHEAT ON IRRIGATED LAND

Rape and sunflower

In the case of sunflower, the procedure used was the same as in the case of cereals, albeit using provincial productivity data for both crops, adjusted to take account of the respective areas under each crop.

In the case of rape, use was made of the database compiled from the crop area and crop yield survey (ESYRCE) which the Ministry of the Environment and the Rural and Marine Affairs forwards every year to Eurostat. The IRP indices are applied to the provincial yields to obtain district-level data. The reason for using this information source is that rape cultivation has seen a resurgence in Spain in recent years, so that the statistics in the AEAs (up to 2006) are not very representative of the current figures for this crop. By contrast, the data compiled in the crop area and crop yield surveys in 2004-08 are more representative than the AEA data covering the 1996-2006 period.

Cardoon

The cardoon yield was calculated on the basis of a production-function approach to estimating or predicting the crop yield on the basis of a set of agro-climatic variables that have a major bearing on crop productivity. Basically, the district-level yield is estimated on the basis of annual precipitation and the Turc index of agricultural potential, which itself takes into account variables such as sunlight, water balances, minimum temperatures, etc.

The formula used to estimate the biomass yield for cardoon in each district is therefore as follows:

$$y' = 14.69 * Ln[(T+2P/3)] + 16\,381$$

y' = theoretical yield (t/ha DM)
T = standardised Turc index
P = standardised annual precipitation

Using this equation, and having the Turc data and annual precipitation data for every municipality in Spain, we are able to estimate potential cardoon production. This equation is applied only to areas where there is non-irrigated farmland and the soil is of a specific depth, so as not to give yield values for cardoon in areas where it would not be viable.

<u>Sugar sorghum</u>

The sugar sorghum crop yield is estimated using a database of yield data for a series of trials on 11 varieties of sorghum conducted in the provinces of Málaga, Córdoba and Seville, obtained from the National Institute for Agricultural and Food Research and Technology (INIA), dating from 1981 (Table 1).

Table 1: Green matter and dry matter yield (t/ha) of the different varieties of sorghum

VARIETY	Green matter production (t/ha)			Dry matter production (t/ha)		
	Seville	Málaga	Córdoba	Seville	Málaga	Córdoba
Brandes	65.2	61.3	57.1	19.5	18.3	17.1
Dale	76.2	68.1	63.5	22.8	20.4	19.0
Honey	59.8	62.9	61.9	17.9	18.8	18.5
Keller	84.3	78.0	54.8	25.2	23.3	16.4
Rio	83.6	63.3	103.1	25.0	18.9	30.9
Roma	59.1	42.1	26.9	17.7	12.6	8.1
Theis	80.1	48.0	69.0	24.0	14.4	20.6
Tracy	67.3	79.2	64.3	20.1	23.7	19.2
Wiley	78.9	47.4	42.1	23.6	14.2	12.6
Wray	95.8	70.2	56.3	28.7	21.0	16.8
Ramada	40.5	20.6	11.1	12.1	6.2	3.3

The sugar sorghum yield is estimated by linking the maximum yields with the total number of hours of sunshine from April to October in the year in question (Fig. 11).

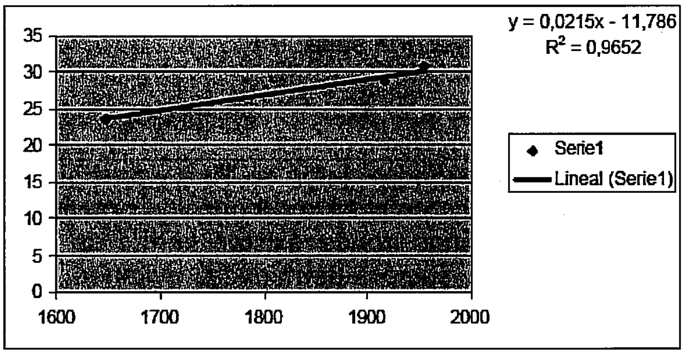


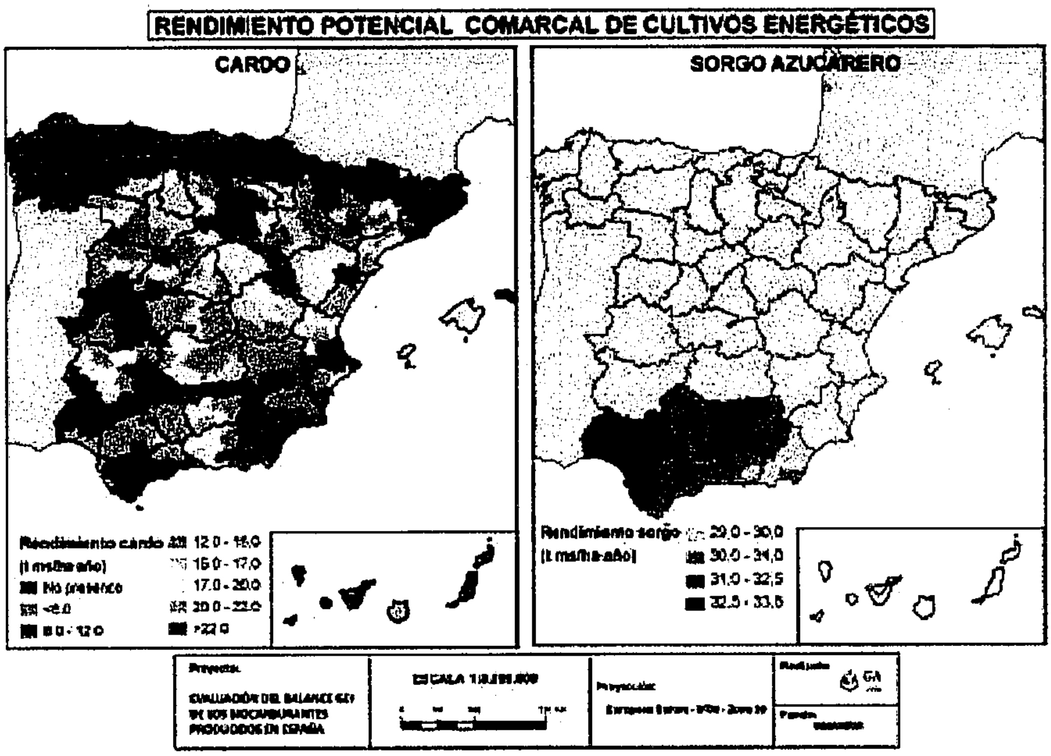
Figure 11. Graph linking the total number of hours of sunshine from April to October (h) and the maximum sorghum dry matter production (t/ha) for each province

The formula used to estimate the biomass yield for sorghum in each district is therefore as follows:

Sorghum biomass yield (t DM/ha) = 0.0215 * total number of hours of sunshine from April to October – 11.786

The energy crop yield resulting from the application of the respective production functions is shown below.

POTENTIAL DISTRICT-LEVEL YIELD OF ENERGY CROPS



Key:

CARDO = CARDOON
SORGO AZUCARERO = SUGAR SORGHUM

(c) Fertilisers

Fertiliser use is estimated on the basis of the yield of each crop in the agricultural districts of Spain, as the necessary input of nutrients into the soil is determined by the quantity of elements removed from it when the crops are harvested. On the basis of the nitrogenous fertiliser database used by the MARM to calculate the nitrogen balance for Spanish faming practices, which is compiled at autonomous community level and indicates organic and mineral nitrogen doses per area, an estimate is made, for each autonomous community, of the nitrogenous fertiliser dose per tonne of produce by linking it with crop yields at autonomous community level, weighted by the area of the provinces concerned.

The nitrogenous fertiliser dose per tonne at autonomous-community level is then applied to the district-level yield so as to obtain nitrogenous fertiliser data for the various traditional crops in each agricultural district. Depending on the various types of fertiliser used in the production of the crops studied, data for doses of other fertilisers are then calculated. The average yields for each district and crop and the relationship between nutrient removal and fertiliser requirements in the case of a particular crop are therefore used to identify the amounts of fertilisers needed in each district for the various crops.

Fertiliser requirements base as a function of crop type and production

Crop	Production (kg/ha)	Total quantity NPK	
Wheat*	1 000	Kg N/ha	35
		Kg P_20_5/ha	25
		Kg K_20/ha	25
Barley*	2 500	Kg N/ha	75
		Kg P_20_5/ha	75
		Kg K_2O/ha	75
Rape** (non-irrigated land)		Kg N/ha	44.8
		Kg P_20_5/ha	11.7
		Kg K_20/ha	19.5
		Kg KNO_3/ha	17.11
	1 000	Kg $(NH_4)_2S0_4$	172.4
Rape** (irrigated land)		Kg N/ha	48.4
		Kg P_20_5/ha	12.6
		Kg K_20/ha	21.1
		Kg KNO_3/ ha	18.5
		Kg $(NH_4)_2S0_4$	186.2
Sunflower* (irrigated land)	1 000	Kg N/ha	60
		Kg P_2O_5/ha	23
		Kg K_20/ha	120
Cardoon***	20 000	Kg N/ha	554
		Kg P_20_5/ha	257
		Kg K_20/ha	848
Sorghum****	7 000	Kg N/ha	200
		Kg P_2O_5/ha	100
		Kg K_20/ha	150

* Source: Guerreo, A., 2003; Urbano, P., 1999, Box, M., 2005. MARM, 1999
** Source: ITACyl, 2009
*** Source: Fernández, 2009
**** Source: Agro-Energy Group (Grupo de Agroenergética)

The use of fertilisers in the case of sunflower merits particular mention in this section. Although the various agronomics manuals recommend applying fertiliser to sunflower in line with the nutrients removed from the soil, the specific situation of the farming sector in Spain, where yields of this crop are very low, especially on non-irrigated land, and the price of fertilisers is so high and fluctuating, means that Spanish farmers in general do not apply fertilisers to this crop. Also, the plant's taproot means that it is good at utilising fertilisers that were applied to the preceding crop and had penetrated deep into the soil.

This is manifest in the rotation of crops, where sunflower is usually preceded by a cereal crop. These farming practices associated with sunflower-growing are reflected in the Survey of the use of means of production on farms (*Encuesta sobre utilización de medios de producción de la explotación Agraria)* carried out by the MARM in 1999.

Fertiliser inputs on the area under sunflower on non-irrigated land were therefore zero, whereas – on irrigated land – the methods used are the same as for other crops, because increased yields go hand in hand with an increase in the amount of nutrients removed from the soil that has to be replaced

In the case of rape, fertiliser requirements as a function of crop production are indicated in a certificate on the agronomic characteristics and management of rape crops issued by the Agricultural Technology Institute of Castile-Leon (ITACyL). The move away from growing rape in the 1980s led to a sharp decline in the area under this crop and a change in agronomic practices not geared to big harvests, so that the aforementioned institute is developing new cultivation manuals and trial growing areas to improve yields of new varieties. It is therefore deemed more appropriate to take account of the fertiliser requirements mentioned in this information source than those relating to an era when rape was a marginal crop. The recommended crop dose is thus 300 kg/ha of NPK 8-15-15 and 450 kg/ha of ammonium sulphate (21% N) for rape grown on non-irrigated land and 450 kg/ha of NPK 8-15-15 and 450 kg/ha of ammonium sulphate for rape grown on irrigated land.

(d) Plant protection products

The use of pesticides, fungicides and herbicides in the production of the crops in question is analysed at provincial or autonomous-community level, depending on the extent to which pest-related information found in bibliographic references differs.

On the basis of the list of plant protection products included in the Ecoinvent database subsequently used to produce the life-cycle analysis (LCA), the most suitable ones for treating the identified pests are selected. The selection is also performed on the basis of a survey of crop-growing practices in each province or autonomous community. As there is insufficient information on pests and diseases at autonomous-community level, plant health checks are carried out as a function of the pests and diseases most commonly encountered in Spain. Data on products and the relevant doses were obtained from the ' AgroVademecum '.

To ensure a general treatment of all the crops dealt with in this study, the following plant protection products were taken into consideration: Carbofuran, deltamethrin, carbendazim, maneb, linuron, pendimethalin, trifluralin, propyzamide and metazachlor.

Different examples are then listed of how these plant protection products work, either in combination or separately, grouped as to whether they are pesticides, fungicides or herbicides.

• Pesticide treatment: deltamethrin: aphids and caterpillars on rape and sunflower crops.

• Fungicide treatment: carbendazim 8% + maneb 64%: septoriosis, rust, root rot (*Ophiobolus graminis*) and powdery mildew (*Erysiphe graminis*) in wheat and barley.

• Herbicide treatment:

- linuron 12% + trifluralin 24%: annual weeds in wheat and barley,

- pendimethalin: annual weeds in sunflower,
- propyzamide: annual weeds in rape,
- metazachlor: perennial and annual grasses in rape.

(e) Water and power for irrigation

The quantity of water used in different irrigated areas throughout Spain is calculated as a function of the positive difference between grain yields on non-irrigated and irrigated land. After obtaining district-based yield data for the various crops, both on non-irrigated land and on irrigated land, the quantity of water used for crops grown on non-irrigated land is estimated (taking into account the weighted average precipitation as derived from AEMET (State Meteorological Agency) raster layers. This is divided by the grain yields for the crops grown on non-irrigated land to obtain a Q factor expressed in cubic metres per kilogram of dry matter (m^3/kg DM), i.e. water-use efficiency. The difference between the average grain yields of the crops grown, respectively, on non-irrigated land and irrigated land at district level is then calculated, and this is multiplied by the Q factor referred to above to reveal the quantity of irrigation water needed at district level for crops grown on irrigated land. The water requirements for the different crops as a function of productivity are presented below.

Crop	Water-use efficiency (m3/kg DM)	Average (m^3/kg DM)
Wheat	1-1.2	1.1
Barley	1-1.2	1.1
Sunflower	0.4-1.1	0.75
Rape	0.35-1.15	0.75
Sorghum	0.16-0.27	0.215

In order to determine the power needed for irrigation, the origin of the water referred to above is investigated, this potentially being of three types: surface water, ground water or treated water. This information is available for the provincial and autonomous-community levels from the farm databases maintained by the National Statistical Institute (INE, 2009). Thus, electricity consumption associated with irrigation varies according to the type of irrigation and the water consumption of the crops, as a function of the origin of the water used. In the case of sprinkler irrigation, for instance, the associated electricity consumption is estimated to be 0.265 kWh/m^3 if groundwater is used where the water table is at a depth of 60 m, whereas it is 0.1 kWh/m^3 if surface water is used.

(f) Agricultural machinery

On the basis of the specific agricultural operations involved in producing each of the crops, the machinery needed for each task is identified. This section considers the 'typical agricultural machinery' for each crop in such a way that the machinery does not vary from one agricultural district to another, except in terms of its capacity (yield, as measured in h/ha), that will be affected by the agronomic characteristics of each district.

The tasks taken into account as part of agricultural operations differ from annual to multi-annual crops.

- Annual crops (cereals, sunflower, rape): ploughing, levelling, tilling, applying fertiliser, sowing, applying plant protection products and harvesting;

- Multi-annual crops (cardoon, sugar sorghum):

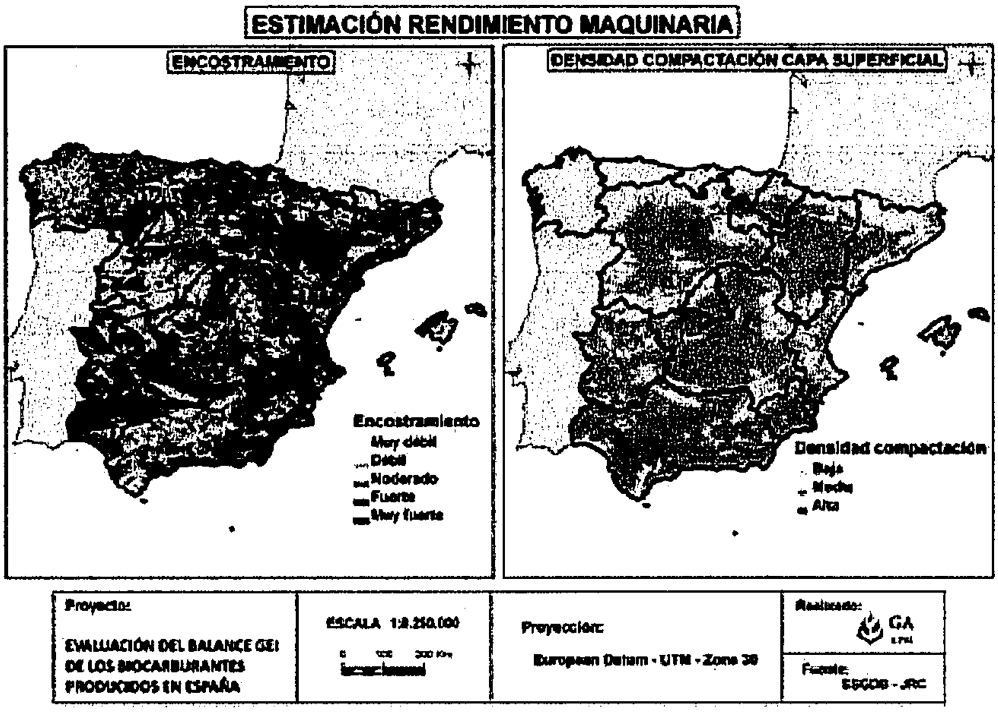
  - Planting year: lifting, tilling, applying fertiliser, sowing, applying herbicide, tilling and applying plant protection products,

  - Production year: applying fertiliser, tilling, levelling, applying insecticide and harvesting.

Task performance data ha been derived from the calculation of the costs of using farm implements and machinery on the MARM's knowledge base for rural and fishing communities (*plataforma de conocimiento para el medio rural y pesquero*) The basic unit is a single tractor engaged in the tasks in question, fitted with implements.

The JRC's European Soil Database (SGDBE) is used to estimate the performance of machinery at district level. This database maps soil typology units for the whole of the European continent at a scale of 1:1 000 000. For each soil unit, it evaluates a set of parameters, some of which are representative of soil hardness, such as surface textural class, crusting class, packing density, etc. It is available in a format that is compatible for use with GIS, so that it is possible to calculate the percentage of each agricultural district's area that is covered by the various soil units.

Pedological variables affecting the performance of agricultural machinery



<u>Key</u>:

ESTIMACION RENDIMIENTO MAQUINARIA = ESTIMATED PERFORMANCE OF MACHINERY
ENCOSTRAMIENTO = SOIL CRUSTING (very slight to very marked)
DENSIDAD COMPACTACION CAPA SUPERFICIAL = TOPSOIL PACKING DENSITY (low to high)

At the same time, the selected SGDBE parameters are related to machinery performance so as to obtain performance data (h/ha) for each task and agricultural district. For operations that are greatly affected by soil characteristics, crusting and packing density values are used to obtain a range of values for the various agricultural districts.

[*Translator's note: please refer to original for the figures in the following tables*]

(a) Operations highly influenced by soil characteristics

IMPLEMENTS (Reference conditions and fuel consumption with a 120 CV tractor)	Consumption l/h	Consumption l/ha	Capacity (h/ha)	Weight (kg)
Shareplough				
Chisel plough				
Subsoiler				
Disc harrow				
Flexible-arm cultivator				
Rotary cultivator				
TDF-activated harrow				

(b) Operations little influenced by soil characteristics

MACHINE (Reference conditions and fuel consumption with a 120 CV tractor, for Group 2 machinery)	Effective capacity (h/ha)	Consumption l/h	Consumptio n l/ha	Weight (kg)
Centrifugal fertiliser spreader				
Suspended fertiliser spreader				
Towed fertiliser spreader				
Seed drill				
Seed drill SD				
Single-seed drill				
Potato planter				
Manure spreader				
Liquid manure tank				
Mounted sprayer				
Towed sprayer				

(c) Harvesting operations

MACHINE (Reference conditions and fuel consumption with a 120 CV tractor, for Group 3 machinery)	Effective capacity (h/ha)	Consumption l/h	Consumptio n l/ha	Production (t/ha)	Weight (kg)
Mower-conditioner (discs and drums)					
Side-delivery rake					
Conventional baler					
Rotobaler					
Macro baler					
Self-loading trailer					
Cutter-loader					
Tuber harvester					
Self-propelled forage cutter-loader					
Grain harvester (wheat, barley)					
Grain harvester (sunflower)					
Grain harvester (maize)					

(g) Fuel

Based on the methodology used by the MARM in the knowledge base for rural and fishing communities for calculating the costs of using agricultural implements and machinery, hourly fuel consumption data (l/h) is selected for each type of machinery. This is combined with machinery performance data (h/ha) to obtain, at district level, data on fuel consumption per agricultural task and unit of area (l/ha).

4 EMISSION FACTORS AND ENERGY CONSUMPTION

The emission factors used in this study are summarised in the tables in the Annex. Most of them were derived from the Ecoinvent 2.1 database (http://www.pre.nl/ecoinvent). In some cases, data from scientific literature on this subject was used and, in some instances, factor data provided by biofuel producers derived from calculations performed by their suppliers.

ESTIMATION OF NITROUS OXIDE EMISSIONS IN THIS REPORT

For the purposes of compiling this report, publications on measures underway in Spain to tackle nitrous oxide emissions were reviewed, and it was concluded that there was no database that was complete enough for it to be used to provide an estimate of the emissions with the required level of spatial disaggregation.

The results of the simulations performed by the JRC at Ispra using the DNDC-CAPRI models and the Stehfest and Bouwman model (Leip, 2009 y 2010) were subsequently evaluated. On the basis of an analysis of the results of the above-mentioned models, it was concluded that there was a major discrepancy between them and our study in terms of the baseline data regarding the levels of fertiliser use for the various crops. Those models use international databases (IFA, 2009, JRC/PBL, 2009) which provide a single value for all regions of Spain. For example, the value for fertiliser use for a particular crop is the same for all regions of the country, something which is far-removed from reality and from the scenarios explored in this study.

Likewise, the level of fertiliser use for sunflower and rape is exactly the same in those models, when in actual fact sunflower is a crop for which fertilisers are scarcely used in Spain and the level of fertiliser use is significantly higher in the case of rape. As a result of all these discrepancies, the nitrous oxide fluxes simulated for the regions of Spain in those models are not applicable in this study. Accordingly, it has been decided to use IPCC Tier 1 methodology in this study.

5 PROCESSING YIELDS AND ALLOCATION FACTORS

In order to estimate emissions per MJ of biofuel produced, a number of processing yields and a number of allocation factors relating to the biofuel produced were taken into consideration, and these are summarised below.

These factors were calculated on the basis of data for the processing industry in Spain.

[*Translator's note: top line illegible*]		
Wheat ethanol	1.79	60%
Barley ethanol	2.07	55%
Sorghum ethanol	2.99	100%
Sunflower biodiesel	1.73	63%
Rapeseed biodiesel	1.85	60%

Cardoon biodiesel (using seed)	1.52	63%
Cardoon biodiesel (bio-refinery - paste)	8.66	45%
Cardoon biodiesel (bio-refinery - energy)	8.66	21%

6. RESULTS AND EVALUATIONS

The following table shows, for each autonomous community, the results for greenhouse gas emissions during the cultivation of the raw materials considered in this study. The regions whose emissions exceed the default value for the cultivation stage are shown in red; those whose greenhouse gas emissions are below the default value are shown in green; and the regions in which the raw material concerned is not grown are shown in grey. Crops for which no default value exists are shown in white.

Greenhouse gas emissions during the agricultural stages of production, expressed in g CO^2eq per MJ of biofuel produced

Código NUTS2	CCAA	Trigo	Cebada	Girasol	Colza	Cardo	Cardo bior. pasta	Cardo bior energía	Sorgo Andalucia
ES61	"Andalucia"	[illegible]	[illegible]	8	26	66	40	19	53
ES24	"Aragon"	[illegible]	[illegible]	16	29	66	40	19	
ES12	"Asturias"	[illegible]							
ES53	"Baleares"	[illegible]	[illegible]	9		66	40	19	
	"Canarias"	[illegible]	[illegible]			66	40	18	
ES13	"Cantabria"	[illegible]	[illegible]	7					
ES41	"Castilla-Leon"	[illegible]	[illegible]	12	26	67	40	19	
ES42	"Castilla-La Mancha"	[illegible]	[illegible]	15	26	67	40	19	
ES51	"Cataluna"	27	24	14	26	66	40	19	
ES63 y ES64	Ceuta y Melilla								
ES30	"Comunidad de Madrid"	[illegible]	[illegible]	14		52	40	19	
ES52	"Comunidad Valenciana"	[illegible]	[illegible]	[illegible]	[illegible]	66	40	19	
ES43	"Extremadura"	[illegible]	[illegible]	[illegible]	27	66	40	19	
ES11	"Galicia"	[illegible]							
ES23	"LA Rioja"	[illegible]	[illegible]	8		66	40	19	
ES62	"Murcia"	[illegible]	[illegible]	[illegible]		67	41	19	
ES22	"Navarra"	[illegible]	[illegible]	16	26	66	40	19	
ES21	"Pais Vasco"	[illegible]	[illegible]	6	26	66	40	18	

Key:

Código NUTS2	= NUTS2 code
CCAA	= autonomous communities
Trigo	=wheat
Cebada	= barley
Girasol	= sunflower
Colza	= rape
Cardo	= cardoon
Cardo bior. pasta	= cardoon bio-refinery paste
Cardo bior. energía	= cardoon bio-refinery energy
Sorgo Andalucía	= sorghum (Andalusia)

CONCLUDING REMARKS

This study is based on the report entitled '*Evaluación del balance de gases de efecto invernadero y balance energético de los biocarburantes producidos en España*' (Evaluation of the greenhouse gas balance and energy balance of biofuels produced in Spain) drawn up by the Centre for Energy, Environmental and Technological Research (CIEMAT) for the IDAE in the context of the drafting of the renewable energy action plan (PANER) to which Article 4 of Directive 2009/28/EC refers and which requires a revision and updating of the work that CIEMAT did in this field in 2005 and 2006 (*Análisis de Ciclo de Vida de Combustibles alternativos para el Transporte*; Lechón et al, 2005 y 2006).

Amongst the main conclusions that may be drawn on the basis of the report referred to in the previous paragraph, and which concern the provisions of Directive 2009/28/EC, is that co-products are not sufficiently taken into consideration in the methodology used for greenhouse gas calculations, as set out in Annex V to the Directive, which severely penalises the production of ethanol from cereals by not taking into account the fact that agricultural by-products such as straw cannot ever be considered to be residues in the conditions that apply in Spain, as they always have a use and hence economic value. There is therefore a pressing need to review the way in which this type of by-product is taken into consideration in the methodology used for greenhouse gas calculations, as provided for in Article 19(7) of Directive 2009/28/EC.

ANNEX: EMISSION FACTORS

Calorific values

	IHV (MJ/kg DM)
Wheat	17.00
Barley	17.00
Sunflower	26.40
Rape	26.40
Cardoon seed	23.30
Cardoon biomass	15.88
Sorghum biomass	17.26
Sunflower, rapeseed and cardoon oil	36.00
Sunflower, rapeseed and cardoon biodiesel	37.20
Glycerol	16.00
Sunflower, rapeseed and cardoon meal	15.00
Diesel	43.10
Ethanol	26.80
Wheat DDGS	17.97
Barley DDGS	16.92

Fertiliser emission factors

		Energía	GEI			
		Energía fosil	CO_2	N_2O	CH_4	Total
Fertilizante	Proceso	MJ/kg	kg CO_2 equiv/kg	kg CO_2 equiv/kg	kg CO_2 equiv/kg	kg CO_2 equiv/kg
N		49,17	3,02	2,85	0,19	6,07
P_2O_5		15,47	0,99	0,0026	0,03	1,02
K_2O		9,73	0,55	0,0004	0,04	0,58

Source: JEC, 2007

Key:

Energía	= energy
GEI	= GHG
Energía fosil	= fossil-fuel energy
Fertilizante	= fertiliser
Proceso	= process

Plant protection product emission factors

		Energía	GEI			
		Energía fosil	CO2	N2O	CH4	Total
Fitosanitario	Proceso	MJ/kg	kg CO2 equiv/kg	kg CO2 equiv/kg	kg CO2 equiv/kg	kg CO2 equiv/kg
CARBARIL	[thio]carbamate-compounds, at regional storehouse/RER U	**185,39**	6,53	0,05	0,38	**6,96**
MALATION 50% [EC] P/V	Organophosphorus-compounds, at regional storehouse/RER U	**179,31**	7,27	0,06	0,38	**7,70**
DIMETOATO	Organophosphorus-compounds, at regional storehouse/RER U	**179,31**	7,27	0,06	0,38	**7,70**
CARBOFURANO 5 % [GR] P/P	Carbofuran, at regional storehouse/RER U	**358,64**	13,33	0,10	0,58	**14,01**
DELTAMETRIN 0,5% [UL] P/V	Pyretroid-compounds, at regional storehouse/RER U	**437,41**	20,83	0,15	0,74	**21,72**
CLORMEFOS 5% [GR] P/P	Organophosphorus-compounds, at regional storehouse/RER U	**179,31**	7,27	0,06	0,38	**7,70**
CARBENDAZIMA [8%] + MANEB [64%]	[thio]carbamate-compounds, at regional storehouse/RER U	**185,39**	6,53	0,05	0,38	**6,96**
LINURÓN [48%]	Linuron, at regional storehouse/RER U	**237,87**	6,85	0,05	0,45	**7,34**
PENDIMETALINA [33%] [EC] P/V	Dinitroaniline-compounds, at regional storehouse/RER U	**114,30**	4,35	0,03	0,19	**4,58**
TRIFLURALINA [48%] [EC] P/V	Dinitroaniline-compounds, at regional storehouse/RER U	**114,30**	4,35	0,03	0,19	**4,58**
PROPIZAMIDA [40%] [SC] P/V	Acetamide-anillide-compounds, at regional storehouse/RER U	**209,90**	7,74	0,06	0,33	**8,13**
METAZACLORO [50%] [SL] P/V	Acetamide-anillide-compounds, at regional storehouse/RER U	**209,90**	7,74	0,06	0,33	**8,13**

Source: Ecoinvent 2.1. http://www.eco¡nventch/

Key:

Energía	= energy
GEI	= GHG
Energía fosil	= fossil-fuel energy
Fitosanitario	= plant protection product
Proceso	= process

Emission factors of diesel (gas oil) used in agriculture

		Energía	GEI			
Combustible	Proceso	Energía fosil	CO2	N2O	CH4	Total
		MJ/kg	kg CO2 equiv/kg	kg CO2 equiv/kg	kg CO2 equiv/kg	kg CO2 equiv/kg
Diesel	Diesel, at regional storage RER	53,74	3,580	0,038	0,046	3,66

Source: Ecoinvent 2.1. http://www.ecoinventch/

Key:
Energía = energy
GEI = GHG
Energía fosil = fossil-fuel energy
Combustible = fuel
Proceso = process

Emission factors of electricity used in irrigation

		Energía	GEI			
		Energía fosil	CO2	N2O	CH4	Total
	Proceso	MJ/kWh	g CO2equiv/kWh	g CO2equiv /kWh	g CO2equiv/kWh	g CO2equiv/kWh
electricity mix	electricity, low voltage, production, ES	10,99	566,25	5,15	26,41	597,81
		MJf/MJ	g/MJ	g/MJ	g/MJ	g/MJ
		3,05	157,29	1,43	7,34	166,06

Key:
Energía = energy
GEI = GHG
Energía fosil = fossil-fuel energy
Proceso = process