Umweltbundesamt

Austrian Environment Agency

TYPICAL GREENHOUSE GAS EMISSIONS FROM CULTIVATION OF AGRICULTURAL RAW MATERIALS FOR USE AS BIOFUEL AND BIOLIQUID

Data from the Republic of Austria
in accordance with Article 19(2) of Directive 2009/28/EC

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SUMMARY

This report fulfils the reporting obligation under Article 19(2) of Directive 2009/28/EC. It covers the calculation of the typical greenhouse gas emissions from cultivation of agricultural raw materials for use as biofuel and bioliquid at NUTS II (federal province) level.

Table 1 shows the calculated greenhouse gas emissions from cultivation of the various crop types that are used as raw material for the production of biofuel and bioliquid. The right-hand side of the table shows the individual provinces – 'X' shows that the crop studied is cultivated in this region. In the middle the maximum and minimum emission results are shown in each case, as well as the default values laid down in the Directive.

In all NUTS II regions the emission values for cultivation of the different crop types fall markedly short of the default values presented in the Annexes to Directive 2009/28/EC. Accordingly, in all NUTS II regions for which cultivation of the relevant crop type was specified in the report it will henceforward be permissible, for calculating the greenhouse gas emissions in accordance with Article 19 of Directive 2009/28/EC for all crop types for which default values for cultivation are given in Directive 2009/28/EC, to use the default values for cultivation of agricultural raw materials in accordance with Annex V Part D of Directive 2009/28/EC or, as the case may require, the default values for biofuel and bioliquid in accordance with Annex V Part A of Directive 2009/28/EC.

Table 1: GHG emissions in Austria

					Cultivation in the federal provinces (NUTS Code)								
Crop types	Biofuel and bioliquid	Standard GHG emission [gCO2eq/M]	Min. GHG emission [gCO2eq/M]	Max. GHG emission [gCO2eq/M]	B	K	NÖ	OÖ	S	St	T	V	W
					AT11	AT21	AT12	AT31	AT32	AT22	AT33	AT34	AT13
Sugar beet	*Sugar beet ethanol*	*12*	*7.46*	*7.70*	**X**	**X**	**X**	**X**		**X**			**X**
Wheat	*(Common) wheat ethanol*	*23*	*18.78*	*20.82*	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Grain maize	*Grain maize ethanol*	*20*	*9.86*	*12.54*	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Rape	*Rape seed biodiesel*	*29*	*19.36*	*2338*	**X**	**X**	**X**	**X**	**X**	**X**			**X**
	Pure vegetable oil from rapeseed	*30*	*20.62*	*24.06*	**X**	**X**	**X**	**X**	**X**	**X**			**X**
Sunflower	*Sunflower biodiesel*	*18*	*10.76*	*13.83*	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**
Soya bean	*Soybean biodiesel*	*19*	*9.71*	*12.05*	**X**	**X**	**X**	**X**	**X**	**X**			**X**

1. INTRODUCTION

The Environment Agency was commissioned by the Federal Ministry of Agriculture, Forestry, the Environment and Water Management to draw up this report into the calculation of typical greenhouse gas emissions from cultivation of agricultural raw materials for use as biofuel or bioliquid. The basic data for this were supplied by the Ministry.

1.1. Legislative background

On 23 April 2009 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) – the 'Renewable Energy Directive' was promulgated in Official Journal L 140.

The aim of the Renewable Energy Directive is to be able by 2020 to cover from renewable sources at least 20% of the Community's gross final consumption of energy. There is an overall national target for each Member State, and by 2020 Austria must increase its percentage share of renewable energy to at least 34% of gross final consumption.

Besides the main target relating to renewable energy sources, the Directive sets a secondary objective for the transport sector: each Member State has to ensure that the share of energy from renewable sources in all forms of transport in 2020 is at least 10% of the final consumption of energy in transport in that Member State. In 2008 as much as 5.5% (calculated on the basis of energy content) of the fuel used in transport in Austria was already replaced by biofuel [Umweltbundesamt 2009].

In addition to the substitution targets, for the first time sustainability requirements are also set for biofuel and bioliquid production.

The sustainability requirements are intended to ensure that certain areas with a high biodiversity (environmentally sensitive areas), for instance primary forest or moors, are not used, or only under certain circumstances, for biomass cultivation for the production of raw materials for biofuel and bioliquid. Also, compared with fossil energy sources the greenhouse gas emission saving from the use of biofuels and bioliquids must be at least 35%, and at least 50% by 2017 (even as much as 60% in the case of new plants from 2017 onwards). In the case of biofuels and bioliquids produced by installations that were in operation on 23 January 2008, proof of the reduction of 35% does not have to be given until 2013. Biogenic fuels may be used for achieving the national target of 10% only if they satisfy the requirements.

Emissions from biofuels and therefore emission reductions too are calculated using life cycle assessment (LCA), or 'ecobalance', models which have to be geared to the requirements of Annex V to the Directive.

The wide range of soil quality, climatic conditions and farming methods in Europe give rise to considerable differences in crop yields and the farming equipment required – which make it difficult to specify default values. Article 19(2) of the Directive also says:
"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 ensures that only those areas where the greenhouse gas emissions are below the default values specified in the Directive are used for biomass production.

1.2. Results sought

The purpose of commissioning the report was to calculate the greenhouse gas emissions from the cultivation of various crop plants from basic agricultural data such as yields or fertiliser use by means of an LCA model. The calculations were done for crop plants mentioned in the Directive that are relevant for Austria, and are shown separately for each province (NUTS II level).

The results were compared with the default values given in the Annexes to Directive 2009/28/EC.

Once the calculated data have been reported to the Commission, it will be possible to use the default values for the cultivation of agricultural raw materials for biogenic fuel production in the Annexes to the Directive, as well as the default values for the corresponding biofuels and bioliquids[1], for all those Austrian NUTS II regions where the actual emissions from the cultivation of the agricultural raw materials are at least as high as the default values given in the Directive.

[1] Provided there have been no direct changes in land use in accordance with the Directive. Any such changes would have to be taken into account.

2. METHODOLOGY

Below we describe the framework conditions for the calculation, such as the areas studied, the LCA model and the systematic limits set for it.

2.1. NUTS II regions

The following table shows the NUTS II regions in Austria. The crop plants cultivated in each province are shown in the right-hand column.

Table 2: Austrian NUTS II regions and the crop plants studied there

NUTS CODE	LEVEL II	Crop plants studied					
		Sugar beet	(Common) wheat	Grain maize	Rape	Sunflower	Soya bean
AT11	Burgenland (Bgld)	X	X	X	X	X	X
AT12	Lower Austria (NÖ)	X	X	X	X	X	X
AT13	Vienna	X	X	X	X	X	X
AT21	Carinthia (Ktn)	X	X	X	X	X	X
AT22	Styria (Stmk)	X	X	X	X	X	X
AT31	Upper Austria (OÖ)	X	X	X	X	X	X
AT32	Salzburg (Sbg)		X	X	X	X	X
AT33	Tyrol		X	X			
AT34	Vorarlberg (Vbg)		X	X		X	

The emission results are calculated by means of the LCA model GEMIS using data provided by the Federal Ministry of Agriculture, Forestry, the Environment and Water Management (BMLFUW).

2.2. Life-cycle assessment (LCA)

Life-cycle assessment (LCA), or 'ecobalance', is an instrument for assessing the environmental impact of a given product. An LCA consists of a systematic analysis of the environmental impacts of products throughout their life cycle, i.e. 'from cradle to grave'. It covers, in principle, all environmental impacts during production, use and disposal of the product, as well as all the associated upstream and downstream processes.

Figure 1: LCA flow diagram [glossary]

Vorleistungen	*Preliminary services*
– Anlagenerrichtung	– Plant construction
– Energieumwandlung	– Energy conversion
– Energiebereitstellung	– Energy supply
– Wartung	– Maintenance
– Entsorgung	– Waste disposal
Input	*Input*
– Energieeinsatz	– Energy input
– Materialeinsatz	– Materials input
Prozesskette	*Process chain*
– Abbau und Förderung von Rohstoffen	– Extraction of raw materials
– Transport	– Transport
– Materialveredelung	– Refining
– Herstellung	– Production
– Dienstleistung	– Service provision
Output	*Output*
– Emissionen	– Emissions
– Abfälle	– Waste

The environmental impacts comprise all environmentally relevant removals from the environment (e.g. raw materials) and emissions into the environment (e.g. waste, carbon dioxide emissions). Depending on the products or services studied, 'system boundaries' are defined which determine the processes included in the analysis.

Figure 2: Process chain for biofuels and bioliquids [glossary]

Anbau *(eec = Emissionen bei der Gewinnung oder beim Anbau der Rohstoffe)*	*Cultivation* *(eec = emissions from the extraction or cultivation of raw materials)*
Saatgut-Produktion	Seed production
Rapsanbau	Rape cultivation
Kalzium	Calcium
Phosphorsäure	Phosphoric acid
Kalium	Potassium
Stickstoff	Nitrogen
Biozid	Biocide
Dünger & Pflanzenschutz	Fertilisers & pesticides
Energieeinsatz Maschinen am Feld	Energy input for machines in the field
Transportweg 1	Transport run 1
Verarbeitung *(ep = Emissionen bei der Verarbeitung)*	*Processing* *(ep = emissions from processing)*
Energetische Allokation:	Energy allocation:
54.69% in RME	54.69% in rapeseed methyl ester (RME)
42.47% in Presskuchen	42.47% in press cake
2.84% in Glyzerin	2.84% in glycerol
Rapsölgewinnung/Pressen	Rapeseed oil production/pressing
Umesterung/Raffination	Transesterification/refining
Chemische Stoffe	Chemical substances
Energieeinsatz	Energy input
Transportweg 2	Transport run 2

Transport + Vertrieb (etd = Emissionen bei Transport und Vertrieb)
Speicherung/Verteilung
Energieeinsatz

Transport + distribution (etd = emissions from transport and distribution)
Storage/distribution
Energy input

The links in the system chain, i.e. all processes lying within the system boundaries, are defined as follows in Directive 2009/28/EC:

"Total emissions from the use of the fuel take into account:

- *emissions from the extraction or cultivation of raw materials;*
- *annualised emissions from carbon stock changes caused by land-use change;*
- *emissions from processing;*
- *emissions from transport and distribution;*
- *emissions from the fuel in use;*
- *emission saving from soil carbon accumulation via improved agricultural management;*
- *emission saving from carbon capture and geological storage;*
- *emission saving from carbon capture and replacement; and*
- *emission saving from excess electricity from cogeneration.*

Emissions from the manufacture of machinery and equipment shall not be taken into account."[2]

2.2.1. GEMIS

Building on German research work, the Austrian Environment Agency has developed the GEMIS model (***G**esamt **E**missions-**M**odell **I**ntegrierter **S**ysteme*) for preparing ecobalances for Austria, which makes it possible to carry out such system analyses in simplified form. GEMIS is a computer-assisted tool with which the environmental impacts of different systems can be calculated and compared easily, accurately and above all comprehensively.

Based on Austria-specific data, GEMIS takes into account all relevant processes from primary energy and raw materials extraction to useful energy and material supply, including therefore, for example, the auxiliary energy and material needed for the manufacture of power plants and transport systems, and therefore offers the possibility of taking into account upstream process emissions in addition to the local emissions.

[2] Since these manufacturing emissions are included among the processes in the LCA model used (GEMIS), contrary to the Directive they have been taken into account in the results presented. Due to the long lifetime of plant and machinery, however, the emissions associated with biomass cultivation are negligibly small and adapting the processes would have been at a disproportionately higher cost.

GEMIS covers all stages from primary energy and raw materials extraction to useful energy and material supply and also includes the auxiliary energy and material input for manufacturing power plants and transport systems.

For all of these processes, the database contains data relating to:

- efficiency, performance, capacity utilisation, lifetime;
- direct air pollutant emissions (SO_2, NO_x, halogens, dust, CO);
- greenhouse gas emissions (CO_2, CH_4, N_2O and all CFCs and HFCs);
- solid residues (ash, desulphurisation products, sewage sludge, production waste, overburden);
- liquid residues (e.g. inorganic salts);
- land requirement;
- cumulated energy consumption.

GEMIS 4.5 – Austria

Compared with the basic GEMIS model, GEMIS-Austria contains an upgrade of the database, in particular with Austria-specific data sets allowing the computer model to be used for issues in Austria. GEMIS-Austria can also analyse costs – the relevant codes for the fuels and energy and transport processes (investment and operating costs) are contained in the database.

2.3. Processes and system boundaries taken into account

The system boundary necessary in the report is confined to the cultivation of the raw materials, including harvesting. The following processes are analysed:

- **Seed** – production cost for preparing the seed.
- **Fertiliser and pesticide production** (calcium, potassium, phosphorus, nitrogen, biocide, etc.) – this also includes all processes necessary for producing the raw materials for fertiliser manufacture, as well as the necessary energy requirement and the transport runs.
- **Energy input for machines in the field** – this comprises fuel inputs for agricultural machines used for working the fields (including spreading fertilisers and pesticides). The manufacture of the machines is also taken into account (including production of the necessary materials, etc.).
- **Soil** – this includes the laughing gas emissions caused by the application of nitrogen fertiliser. Direct land-use changes are not taken into account because in

Austria it can be assumed that only land already being farmed will be used for fuel production.[3]

Through the fact that emissions from the manufacture of agricultural machinery are taken into account in GEMIS-Austria, the analysis under consideration differs from the system boundaries definition specified in the Directive. The emission results are therefore somewhat higher, though the deviation does not exceed 1% of the total amount of greenhouse gas emissions.

2.4. Energy allocation

Since biofuel and bioliquid production also gives rise to co-products in the processing plants, the emissions hitherto treated as combined emissions in the LCAs, and therefore all those occurring during substrate production as well, are divided up. Glycerol and press cake are produced in the case of biodiesel, while in bioethanol production protein feed (DDGS) is made. Current codes for the breakdown of the environmental impact are geared to the energy content, the economic value, or the mass of the different products.

According to the Directive (Annex V(C), 17), the energy allocation method is to be used for calculating the greenhouse gas emissions:
"Where a fuel production process produces, in combination, the fuel for which emissions are being calculated and one or more other products (co-products), greenhouse gas emissions shall be divided between the fuel or its intermediate product and the co-products in proportion to their energy content (determined by lower heating value in the case of co-products other than electricity)."

Since the Directive contains no data on the energy density of the products (main products and co-products) and therefore no fixed allocation code is defined in it – this depends very much on the specific installations involved in each case – the values corresponding to the Austrian installation structure were used for the analysis. The data come from the GEMIS-Austria database. The respective allocation codes are given with the results.

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[3] There are not yet any EU-level specifications for indirect land-use changes.

3. DATA BASIS

This Chapter introduces the input data drawn from the various categories for the analysis.

3.1. Agricultural data

For the purposes of this report, typical greenhouse gas emissions from cultivation of agricultural raw materials for the production of biofuels and bioliquids at NUTS 2 level (Austria's federal provinces) were listed. The calculations were made for all crop types shown in the Directive which are used for the manufacture of biofuels or bioliquids in Austria:

- <u>Cereals</u>: grain maize and common wheat
- <u>Oil seed</u>: rape, sunflower, soya bean
- <u>Other</u>: sugar beet

The agronomic data used in the analysis and their sources are described below:

- <u>Total of energy inputs in litres or kWh for the mechanical processing of the relevant crop plants per crop year and hectare</u>

The crop-related energy input in the field was calculated by the Austrian Council for Agricultural Engineering and Rural Development (ÖKL). The energy expenditure calculations were based on the necessary work stages for cultivation, care and harvesting, as well as the yields per hectare of the different crop plants.

- <u>Yields per hectare in dt (decitonnes) per crop plant species at NUTS 2 level</u>

The calculations of greenhouse gas emissions in this report used yield data for the crops concerned for the years 2004 to 2009 at federal province level. Average yields in dt per ha were based on data from Statistics Austria, especially the harvest surveys of Agrarmarkt Austria Marketing GesmbH.

- <u>Fertiliser and pesticide input in kg/ha</u>

Data for fertiliser and pesticide input for the crops studied were taken from the current Gross Margin Catalogue (BMLFUW 2008: *Deckungsbeiträge und Daten für die Betriebsplanung 2008* – Gross Margins and Data for Farm Production Planning 2008).

The Gross Margin Catalogue as such is a planning instrument which lists indicative/empirical values for input use according to the yield level.

With regard to fertiliser and pesticide input for the different crops the Gross Margin Catalogue distinguishes between dry and wet areas.

Departing from the approach described above, in the case of grain maize and sugar beet the N values were taken from the 6th edition of the Guidelines for the Appropriate Use of Fertilisers because these recommendations give a picture of fertiliser use for these crops that relates even more closely to practice.

- Subdivision of cultivation regions (provinces) into dry and wet areas

Austria is situated in the temperate climatic zone and through its central position in Europe it is also exposed to oceanic and continental climatic influences. The southern parts of Austria are also influenced by the Mediterranean climate (fig. 4). As a result of this variety of climatic influences, annual precipitation is unevenly distributed over the country (see figs. 4 and 6). Generally speaking, precipitation decreases from west to east and from north to south. Whereas annual precipitation is as much as 2500 mm in western Austria, in the eastern part of the country it is often only around 600 mm. For this reason, the subdivision into wet and dry areas adopted for the Gross Margin Catalogue was used.

- Dry areas: Vienna, Lower Austria, Burgenland
- Wet areas: Vorarlberg, Tyrol, Salzburg, Carinthia, Styria, Upper Austria

- Quantity of seed kg/ha

The assumptions for average quantities of seed sown per hectare by farmers are based on Austrian Agency for Health and Food Safety (AGES) surveys. The figures for seed quantities used were based on the calculations of the Austrian Seed Association (Saatgut Österreich).

3.2. Laughing gas emissions

For calculating the emissions of laughing gas from cultivation of biomass, the calculation method according to [IPPC 2006] was used. The IPPC method distinguishes between direct and indirect emissions from farmland. Direct N_2O emissions from farmland include those from livestock manure, while indirect emissions are produced elsewhere by N movement/loss (e.g. by N leaching, N volatilisation).

The national emission factors necessary for the calculation were taken from the Austrian Air Pollutant Inventory [Umweltbundesamt 2008]. This results in the following correlations between the amount of nitrogen fertiliser applied and the laughing gas emissions caused by it:

Direct N_2O emissions:

0.0125 kg N_2O-N/kg N

Indirect N_2O emissions from deposition:

0.003 kg N_2O-N/kg N

Indirect N_2O emissions from leaching:

0.0075 kg N_2O-N/kg N

The conversion of nitrogen to laughing gas is calculated by means of the factor 44/28, which takes into account the molecular weight.

3.3. Energy input for machines

The operations required for working in the fields and the energy (fuel) consumption of the agricultural machinery needed for them depend very much on the type of crop in each case (see Table 3). For the energy input calculations, average field sizes, conventional production systems and average yield levels were assumed (see Table 4). The energy expended on the manufacture of mineral fertilisers and pesticides was not taken into account in these calculations.[4]

[4] It is discussed in another section.

Table 3: Number of operations needed for each type of crop; source: Austrian Council for Agricultural Engineering and Rural Development (ÖKL).

	Operations	**Grain maize**	**Spelt wheat**	**Common wheat**	**Rape**	**Sunflower**	**Soya bean**	**Sugar beet**
Cultivation	*Ploughing, scarifying, harrowing*	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	Sowing	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Care	*Fertiliser application*	**2**	**2**	**2**	**2**	**1**	**1**	**2**
	Pesticide application	**1**	**2**	**2**	**3**	**1**	**2**	**3**
Harvesting	Harvesting + transport	**2**	**2**	**2**	**2**	**2**	**2**	**1**
	(Working in of) crop residues	**1**	**2**	**2**	**2**	**2**	**1**	**1**

Besides the working operations, the specific energy concerned is also relevant to the intensity of energy input for machines. Table 4 shows the fuel input for each operation in litres of diesel per unit area (hectares).

Table 4: Fuel input per operation; total fuel input per hectare; source: Austrian Council for Agricultural Engineering and Rural Development (ÖKL) 2010.

	Operations	**Grain maize**	**Spelt wheat**	**Common wheat**	**Rape**	**Sunflower**	**Soya bean**	**Sugar beet**
Cultivation	Ploughing, scarifying, harrowing	7.0	7.0	7.0	7.0	7.0	7.0	29.0
	Sowing	3.4	4.8	4.8	4.8	4.3	3.4	4.3
Care	Fertilising – mineral	0.9	1.8	1.9	1.9	0.9	0.9	2.2
	Fertilising – slurry	6.6	0.0	0.0	0.0	0.0	0.0	0.0
	Pesticide application	1.0	2.0	2.0	3.0	1.0	2.0	3.0
Harvesting	Harvesting + transport	23.0	17.4	20.9	20.9	15.9	23.0	49.0
	(Working in of) crop residues	8.5	18.3	18.3	18.3	18.3	8.5	8.5
Fuel	Total (l/ha)	**50.4**	**51.3**	**54.9**	**55.9**	**47.4**	**44.8**	**96.0**

The energy content of the fuel was set at 9.8 kWh per litre in accordance with the Austrian Fuel Regulation [Fuel Regulation 2004 – *Kraftstoffverordnung 2004*].

3.4. Yields

An important influence is exerted on the emissions from cultivation of agricultural raw materials by the yield level of the plants used in biofuel and bioliquid manufacture. In order to ensure that the yield values are representative, the yields per hectare of the crop plants were averaged out over six years (2004-9) at province level. To make sure that the results were as accurate as possible, the highest (yellow) and the lowest (blue) yield figure in each case were taken out of the average value calculations. But in every case at least three values were used for calculating the average harvest yields.

Table 5: Crop plant yields by province 2004 to 2009; source: (Statistik Austria 2009), (Agrarmarkt Austria 2009) [glossary – for figures see original]

Bundesländer	Federal provinces
Bgld.	Burgenland
Kärnten	Carinthia
NÖ	Lower Austria
OÖ	Upper Austria
Sbg.	Salzburg
Stmk.	Styria
Tirol	Tyrol
Vbg.	Vorarlberg
Wien	Vienna
Ø-Ertrag in dt/ha (Trockengewicht)	Average yield in dt/ha (dry weight)
Ø-Ertrag über 6 Jahre 2004-2009	Average yield over 6 years 2004-9
Weichweizen	Common wheat
Körnermais	Grain maize
Ölsonnenblume	Oil sunflower
Sojabohne	Soya bean
Zuckerrübe	Sugar beet
Raps	Rape

3.5. Fertiliser and pesticide input

In order to calculate the fertiliser and pesticide input for the agricultural raw materials, the average yields of these were rounded up or down to the nearest yield values for the treated crops in the Gross Margin Catalogue (see section 3.4). Using these values the relevant value for the respective input (fertiliser or pesticide) was then read off from the Gross Margin Catalogue.

In the case of grain maize and sugar beet, however, for calculating the fertiliser input the N values in the 6th edition of the Guidelines for the Appropriate Use of Fertilisers were used because they give a truer picture of N input for these crops.

For biofuel production several processing types of the various crops (e.g. milling wheat, feed wheat) are often used. In that case an average of the different processing types of each crop is taken for determining the fertiliser and pesticide input for the respective crop.

Table 6: Average fertiliser and pesticide input in kg/ha or l/ha respectively; source: (BMLFUW 2008) [glossary – for figures see original]

Bundesländer	Federal provinces
Bgld.	Burgenland
Kärnten	Carinthia
NÖ	Lower Austria
OÖ	Upper Austria
Sbg.	Salzburg
Stmk.	Styria
Tirol	Tyrol
Vbg.	Vorarlberg
Wien	Vienna
Düngemitteleinsatz [kg/ha])	Fertiliser input [kg/ha])
Pflanzenschutzmitteleinsatz [kg/ha od. l/ha])	Pesticide input [kg/ha or /ha])
Bor	Boron
Mesurol Schnecken	Mesurol Snail and Slug Bait
Korit fl.	Korit fl.
Herbizide	Herbicides
Fungizide	Fungicides
Insektizide	Insecticides
Gesamt	Total
Weichweizen	Common wheat
Raps	Rape
Ölsonnenblume	Oil sunflower
Sojabohne	Soya bean
Zuckerrübe	Sugar beet
Körnermais	Grain maize

In Table 6, soya bean is seen to have a negative value under nitrogen fertiliser owing to nitrogen fixation. For the calculation this value was set at zero, so no N credits are taken into account.

3.6. Seed

Table 7: Seed quantity used in Austria, year of cultivation 2007/2008; source: *BMLFUW 2009*

[kg/ha]	Common wheat	Maize	Winter rape	Oil sunflowers	Soya beans
Quantity of seed, estimated	180	22	5	7	120

The relevant variable for the calculations is the quantity of seed in kg/ha. The quantity in each case is correlated with the associated emission factors in GEMIS, this giving a picture of the emissions during the preparation of the seed (see Table 7).

3.7. Climate and soil data

Yields in each case and necessary fertiliser applications for the substrates studied in this report are influenced to a large extent by soil quality, precipitation and climatic conditions. The following figures illustrate the conditions prevailing in the NUTS II regions (provinces) studied.

Figure 3: The federal provinces (NUTS II regions) in Austria – for key to abbreviations see Table 2

Figure 4: Climate map of Austria; source: [BMLFUW 2003]

<u>Glossary:</u>

Abnahme der Niederschläge	Decrease in precipitation
ATLANTISCH	ATLANTIC
POLAR bzw. SUBPOLAR	POLAR/SUBPOLAR
KONTINENTAL	CONTINENTAL
SUBMEDITERRAN	SUBMEDITERRANEAN
(zweites Ns-Maximum im Spätherbst)	(second precipitation peak in late autumn)
I	Alpine climate (mountain climate/elevation levels)
IIa	Central European transitional climate (lowland, hill country)
IIb	Central European transitional climate (high plateau climate)
III	Pannonian climate
IV	Illyrian climate

2-10	Climate stations
x x x	Northern barrier layers
....	Main Alpine ridge

Figure 5: Digital map of soil groups in Austria – 'cleaned' version of the Soil Map of Europe 1:1 000 000 (1998); source: [Nestroy 1998]

Figure 6: Mean annual precipitation (model calculation with uncorrected data); source: [BMLFUW 2003]

4. EMISSIONS

The calculated (actual) emission results given in this chapter for biomass cultivation in Austria must not exceed the typical greenhouse gas emissions listed in fig. 7 (see section 1.1).

Biofuel and bioliquid production pathway	Typical greenhouse gas emissions (gCO_{2eq}/MJ)	Default greenhouse gas emissions (gCO_{2eq}/MJ)
sugar beet ethanol	12	12
wheat ethanol	23	23
corn (maize) ethanol, Community produced	20	20
sugar cane ethanol	14	14
the part from renewable sources of ETBE	Equal to that of the ethanol production pathway used	
the part from renewable sources of TAEE	Equal to that of the ethanol production pathway used	
rape seed biodiesel	29	29
sunflower biodiesel	18	18
soybean biodiesel	19	19
palm oil biodiesel	14	14
waste vegetable or animal (*) oil biodiesel	0	0
hydrotreated vegetable oil from rape seed	30	30
hydrotreated vegetable oil from sunflower	18	18
hydrotreated vegetable oil from palm oil	15	15
pure vegetable oil from rape seed	30	30
biogas from municipal organic waste as compressed natural gas	0	0
biogas from wet manure as compressed natural gas	0	0
biogas from dry manure as compressed natural gas	0	0

Figure 7: Disaggregated default values for cultivation: 'e_{ec}' as defined in part C of the Annex to Directive 2009/28/EC

4.1. Biodiesel

In accordance with the energy allocation method, taking into account the Austrian data basis 54.69%[5] of the emissions are allocated to biodiesel (FAME) and 45.31% to the coproducts (the separation is made in the installation at the point where the fuel is produced). This value is independent of the raw materials going into the production process (rapeseed oil, sunflower oil, etc.).

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5 Allocation code corresponds to Austrian plant structure; source GEMIS Austria

4.1.1. Rape – RME

Table 8: Greenhouse gas emissions from rape RME

NUTS code	Crop: rape	Seed (in g CO_2-equivalent emissions/MJ_{RME})	Fertiliser & pesticide (in g CO_2-equivalent emissions/MJ_{FAME})	Energy input (in g CO_2-equivalent emissions/MJ_{RME})	Release from soil (N_2O) (in g CO_2-equivalent emissions/MJ_{RME})	Total (in g CO_2-equivalent emissions/MJ_{RME})
AT12	Lower Austria	0.001	9.57	1.20	8.83	19.60
AT13	Vienna	0.001	9.69	1.38	8.53	19.60
AT11	Burgenland	0.001	9.51	1.26	8.59	19.36
AT31	Upper Austria	0.001	10.14	1.05	9.06	20.25
AT22	Styria	0.001	10.36	1.15	9.20	20.71
AT21	Carinthia	0.002	11.98	1.59	9.81	23.38
AT32	Salzburg	0.002	10.97	1.46	8.98	21.41
AT33	Tyrol	–	–	–	–	–
AT34	Vorarlberg	–	–	–	–	–

The results extend from 19.36 to 23.38 g CO_2/MJ_{RME} and are therefore markedly below the default value of 29 g CO_2/MJ_{RME}. Rape is not grown in the provinces of Tyrol and Vorarlberg (no data).

4.1.2. Sunflowers – RME

Table 9: Greenhouse gas emissions from sunflowers RME

NUTS code	Crop: sunflowers	Seed (in g CO_2-equivalent emissions/MJ_{FAME})	Fertiliser & pesticide (in g CO_2-equivalent emissions/MJ_{FAME})	Energy input (in g CO_2-equivalent emissions/MJ_{FAME})	Release from soil (N_2O) (in g CO_2-equivalent emissions/MJ_{FAME})	Total (in g CO_2-equivalent emissions/MJ_{FAME})
AT12	Lower Austria	0.003	6.79	1.39	2.58	10.76
AT13	Vienna	0.003	7.29	1.34	3.04	11.67
AT11	Burgenland	0.003	7.61	1.48	3.05	12.14
AT31	Upper Austria	0.004	8.25	1.69	3.13	13.07
AT22	Styria	0.004	8.10	1.66	3.04	12.80
AT21	Carinthia	0.004	8.29	1.61	3.32	13.22
AT32	Salzburg	0.005	8.72	1.79	3.31	13.83
AT33	Tyrol	–	–	–	–	–
AT34	Vorarlberg	0.005	8.45	1.85	2.91	13.22

The results extend from 10.76 to 13.83 g CO_2/MJ_{RME} and are therefore markedly below the default value of 18 g CO_2/MJ_{RME}. Sunflowers are not grown in the Tyrol (no data).

4.1.3. Soya beans – RME

Table 10: Greenhouse gas emissions from soya beans RME

NUTS code	Crop: soya beans	Seed (in g CO_2-equivalent emissions/MJ_{FAME})	Fertiliser & pesticide (in g CO_2-equivalent emissions/MJ_{FAME})	Energy input (in g CO_2-equivalent emissions/MJ_{FAME})	Release from soil (N_2O) (in g CO_2-equivalent emissions/MJ_{FAME})	Total (in g CO_2-equivalent emissions/MJ_{FAME})
AT12	Lower Austria	0.08	8.80	1.64	0	10.52
AT13	Vienna	0.14	9.70	2.21	0	12.05
AT11	Burgenland	0.07	8.36	1.56	0	9.99
AT31	Upper Austria	0.05	8.40	1.33	0	9.78
AT22	Styria	0.06	8.70	1.38	0	10.14
AT21	Carinthia	0.05	8.34	1.32	0	9.71
AT32	Salzburg	0.07	8.30	1.55	0	9.92
AT33	Tyrol	–	–	–	–	–
AT34	Vorarlberg	–	–	–	–	–

The results extend from 9.71 to 12.05 g CO_2/MJ_{RME} and are therefore markedly below the default value of 19 g CO_2/MJ_{RME}. Rape [sic] is not grown in the provinces of Tyrol and Vorarlberg (no data).

4.2. Vegetable oil – RME

In accordance with the energy allocation method, taking into account the Austrian data basis 56.29%[6] of the emissions are allocated to vegetable oil (VO) and 43.71% to the co-products (divided up in the installation at the point where the fuel is produced).

[6] Allocation code corresponds to Austrian plant structure; source GEMIS Austria

4.2.1. Rape – vegetable oil

Table 11: Greenhouse gas emissions from rape (vegetable oil)

NUTS code	Crop: rape	Seed (in g CO_2-equivalent emissions/MJ_{VO})	Fertiliser & pesticide (in g CO_2-equivalent emissions/MJ_{VO})	Energy input (in g CO_2-equivalent emissions/MJ_{VO})	Release from soil (N_2O) (in g CO_2-equivalent emissions/MJ_{VO})	Total (in g CO_2-equivalent emissions/MJ_{VO})
AT12	Lower Austria	0.001	10.50	1.23	9.09	20.82
AT13	Vienna	0.001	10.72	1.42	8.78	20.92
AT11	Burgenland	0.001	10.48	1.30	8.84	20.62
AT31	Upper Austria	0.001	10.33	1.08	9.33	20.74
AT22	Styria	0.001	10.66	1.18	9.47	21.31
AT21	Carinthia	0.002	12.33	1.64	10.09	24.06
AT32	Salzburg	0.002	11.29	1.50	9.24	22.03
AT33	Tyrol	–	–	–	–	–
AT34	Vorarlberg	–	–	–	–	–

The calculations show emission levels between 20.62 and 24.6 g CO_2/MJ_{VO} and therefore markedly below the default value of 30 g CO_2/MJ_{VO}. Rape is not grown in the provinces of Tyrol and Vorarlberg (no data).

4.3. Bioethanol & ETBE

In accordance with the energy allocation method, taking into account the Austrian data basis 67.00%[7] of the emissions are allocated to bioethanol (or ETBE) and 33.00% to the coproducts (divided up in the installation at the point where the fuel is produced). This value is independent of the raw materials going into the production process (sugar beet, wheat, etc.). In the emissions from cultivation no distinction is made with regard to the limit values according to Directive 2009/28/EC between bioethanol and the bio-ETBE made from it (see fig. 7).

[7] Allocation code corresponds to Austrian plant structure; source GEMIS Austria

4.3.1. *Grain maize – bioethanol*

Table 12: Greenhouse gas emissions from grain maize

NUTS code	Crop: grain maize	Seed (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Fertiliser & pesticide (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Energy input (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Release from soil (N_2O) (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Total (in g CO_2-equivalent emissions/$MJ_{ethanol}$)
AT12	Lower Austria	0.0001	5.08	0.54	4.55	10.17
AT13	Vienna	0.0001	6.32	0.66	5.56	12.54
AT11	Burgenland	0.0001	5.57	0.60	5.07	11.24
AT31	Upper Austria	0.0001	5.08	0.51	4.27	9.86
AT22	Styria	0.0001	5.19	0.46	4.66	10.31
AT21	Carinthia	0.0001	5.44	0.48	4.89	10.81
AT32	Salzburg	0.0001	5.83	0.60	5.05	11.48
AT33	Tyrol	0.0001	5.96	0.61	5.17	11.74
AT34	Vorarlberg	0.0001	5.73	0.58	4.92	11.23

The results extend from 9.86 to 12.54 g CO_2/MJ_{ETHO} and are therefore markedly below the default value of 20 g CO_2/MJ_{ETHO}.

4.3.2. *Common wheat – bioethanol*

Table 13: Greenhouse gas emissions from common wheat

NUTS code	Crop: common wheat	Seed (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Fertiliser & pesticide (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Energy input (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Release from soil (N_2O) (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Total (in g CO_2-equivalent emissions/$MJ_{ethanol}$)
AT12	Lower Austria	0.003	9.71	1.34	8.34	19.39
AT13	Vienna	0.003	10.52	1.55	8.75	20.82
AT11	Burgenland	0.003	10.47	1.55	8.71	20.73
AT31	Upper Austria	0.001	9.23	1.05	8.50	18.78
AT22	Styria	0.002	10.05	1.27	8.70	20.02
AT21	Carinthia	0.003	9.87	1.46	8.23	19.56
AT32	Salzburg	0.002	10.06	1.36	8.45	19.87
AT33	Tyrol	0.003	10.42	1.54	8.69	20.65
AT34	Vorarlberg	0.002	10.35	1.31	8.97	20.63

The results extend from 18.78 to 20.82 g CO_2/MJ_{ETHO} and are therefore below the default value of 23 g CO_2/MJ_{ETHO}.

4.3.3. Sugar beet – bioethanol

Table 14: Greenhouse gas emissions from sugar beet

NUTS code	Crop: sugar beet	Seed (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Fertiliser & pesticide (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Energy input (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Release from soil (N_2O) (in g CO_2-equivalent emissions/$MJ_{ethanol}$)	Total (in g CO_2-equivalent emissions/$MJ_{ethanol}$)
AT12	Lower Austria	0.0001	3.92	0.70	2.88	7.50
AT13	Vienna	0.0001	4.04	0.69	2.84	7.57
AT11	Burgenland	0.0002	4.05	0.67	2.98	7.70
AT31	Upper Austria	0.0001	3.98	0.68	2.80	7.46
AT22	Styria	0.0001	4.17	0.80	2.72	7.69
AT21	Carinthia	0.0001	4.00	0.72	2.94	7.66
AT32	Salzburg	–	–	–	–	–
AT33	Tyrol	–	–	–	–	–
AT34	Vorarlberg	–	–	–	–	–

The results extend from 7.46 to 7.70 g CO_2/MJ_{ETHO} and are therefore markedly below the default value of 12 g CO_2/MJ_{ETHO}. Sugar beet is not grown in the provinces of Salzburg, Tyrol and Vorarlberg (no data).

5. BIBLIOGRAPHY

[BIBLIOGRAPHY]