Report pursuant to Article 19 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 and to Article 7d of Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions.

The Report presents the results of a study carried out by the Agricultural Institute of Slovenia on greenhouse gas emissions in the cultivation of raw materials for biofuels, and specifically the production of rapeseed, corn, wheat and sunflower.

The aim of the study was to ascertain whether it could be expected that typical greenhouse gas emissions from the cultivation of agricultural raw materials in Slovenia would be lower than or equal to the emissions reported under the heading ‘Disaggregated default values for cultivation’ in Part D of Annex V to Directive 2009/28/EC and Part D of Annex IV to Directive 2009/30/EC.

Calculations were performed for Slovenia as a whole; calculations of greenhouse gas emissions were also made at NUTS Level 2 for Eastern and Western Slovenia. The results of the study are shown in the table below.

Table: Greenhouse gas emissions from the cultivation of wheat, corn, rapeseed and sunflower

	Wheat (g CO_2 eq/$MJ_{ethanol+pellets}$)	Corn (g CO_2 eq/$MJ_{ethanol+pellets}$)	Rapeseed (g CO_2 eq/$MJ_{biodiesel+cake}$)	Sunflower (g CO_2 eq/$MJ_{biodiesel+cake}$)
Slovenia	19.8	13.8	24.2	23.4
Eastern Slovenia	19.9	14.0	22.3	no data
Western Slovenia	22.7	13.9	27.0	no data

The data in the table shows that we can expect that, in Slovenia, in the eastern and western parts of the country, typical greenhouse gas emissions from the cultivation of corn, wheat and rapeseed will be lower than the emissions reported under the heading ‘Disaggregated default values for cultivation’ in Part D of Annex V to Directive 2009/28/EC and Part D of Annex IV to Directive 2009/30/EC.

This means that Eastern and Western Slovenia may be included in the list of areas where typical emissions from the cultivation of wheat, corn and rapeseed can be expected to be lower than or equal to the emissions laid down in Article 19 of Directive 2009/28/EC and Article 7d of Directive 2009/30/EC.

In the cultivation of sunflower, the calculated greenhouse gas emissions do exceed the ‘Disaggregated default values for cultivation’ given in the Annex to Directive 2009/28/EC and the Annex to Directive 2009/30/EC. Consequently, only actual values for cultivation may be used in Slovenia for the cultivation of sunflower; however, due regard must be paid to the fact that sunflower has been cultivated in Slovenia on a mere 243 ha (average for the last three years), with the average crop totalling 1.62 tonnes/ha. Should interest in cultivating sunflower for energy purposes increase in the future, one can expect an increase in the size of the crop, necessitating a new assessment of greenhouse gas emissions from sunflower cultivation.

The methodology used to calculate greenhouse gas emissions from the cultivation of corn, wheat, rapeseed and sunflower and the data deployed are described in detail in the enclosed expert paper.

Enclosed: Report for Expert Paper – Greenhouse Gas Emissions from the Cultivation of Rapeseed, Sunflower, Corn and Wheat for Bio-Gene Fuels, Agricultural Institute of Slovenia

Kmetijski inštitut Slovenije
Agricultural Institute of Slovenia

1001 Ljubljana,
Hacquetova 17,
SLOVENIA
Tel: +386 1 / 280-52-62, p.p. 2553
Fax: +386 1 /280-52-55
e-mail: KIS@KIS.SI

Agricultural Institute of Slovenia

Agricultural Engineering Department

REPORT FOR EXPERT PAPER

Greenhouse Gas Emissions from the Cultivation of Rapeseed, Sunflower, Corn and Wheat for Bio-Gene Fuels

Client: Ministry of Agriculture, Forestry and Food

Compiled by: Dr Viktor Jej•i• ---illegible---

1. CO_2 EMISSIONS FROM THE CULTIVATION OF RAPESEED

Emissions from cultivation have been divided into:

a) CO_2 emissions from mineral diesel fuel used to drive agricultural machinery involved in the production of rapeseed (soil treatment, sowing, fertilising, plant protection, harvesting, seed transport and straw collection, and transport);
b) emissions arising from the loss of N_2O into the atmosphere and groundwater from fertilisers;
c) emissions from the production of mineral fertilisers.

1.1 CO_2 emissions from mineral diesel fuel used to drive agricultural machinery

CO_2 emissions from the combustion of mineral diesel fuel in agricultural machinery engines, tractors/tractor units (tractor + various attached machines for soil treatment, sowing, protection, transport and straw collection) and combine harvesters. For calculation purposes, the average fuel consumption values for different mechanised phases of the production process have been given. The CO_2 emissions stated could be additionally lowered with the use of biofuels (biodiesel or vegetable oil) to drive agricultural machinery.

Figures on mineral diesel fuel consumption are from own measurements for basic treatment and transport (AIS – Agricultural Engineering Department), while other figures have been taken from Witney and from Kri•ka et al. For the purpose of determining CO_2 emissions from mineral diesel fuel in the use of agricultural machinery, it has been estimated that 150 litres of mineral diesel fuel are consumed per hectare for the cultivation of rapeseed (in the Netherlands, Croezen et al). According to German figures, it is 88 l/ha (KTBL Handbook) and according to Grau et al, it is 70 l/ha (direct sowing technology). In our calculation, separate work operations are envisaged for Slovenian conditions for the cultivation of rapeseed. In the case of direct sowing and supplementary treatment in a single pass, overall fuel consumption for cultivation would be reduced further. In Slovenia, biodiesel is mixed into mineral diesel fuel up to 5% so that consumption of pure mineral diesel fuel is lower by up to 5% in the given calculations (this is not specifically taken into account in the tables).

Table 1: Consumption of mineral diesel fuel and energy used for cultivation (basic and supplementary soil treatment and other work operations on an area of 1 ha) and the quantities of CO_2 thereby produced from mineral diesel fuel

	Fuel consumption (l/ha)	Density of mineral diesel fuel (kg/l)	Mass of mineral diesel fuel (kg)	Calorific value (MJ/kg)	Energy used (MJ)	Quantity of CO_2 (kg)
Basic and supplementary treatment						
Ploughing*	15		12.45		522.9	43.8
Harrowing**	13		10.79		453.18	38.0
Other work operations						
Sowing**	4		3.32		139.44	11.7
Fertilising**	9	0.83	7.47	42	313.74	26.3
Protection**	3		2.49		104.58	8.8
Harvesting***	21.8		18.09		759.9	63.7
Transport of grains*	9		7.47		313.74	26.3
Straw collection*	6		4.98		209.16	17.5
Transport of straw*	9		7.47		313.74	26.3
TOTAL	89.8		74.5		3130.4	262.3

CO_2 emissions	4.5g CO_2 /MJ of vegetable oil or biodiesel + cake

*consumption according to AIS (Agricultural Engineering Department), **according to Witney, ***according to Kri•ka et al

Total consumption of mineral diesel fuel for this process, when the collection and transport of straw are not taken into account, amounts to 74.8 l/ha (89.8 l/ha if they are taken into account). For the purpose of the calculations, the energy value of mineral diesel fuel has been taken as being 42 MJ/kg and its density as 0.83 kg/l. For the entire quantity of mineral diesel fuel consumed in the cultivation process, we have assumed emissions of 83.8 g CO_2 eq/MJ (EU Directive on the promotion of the use of energy from renewable sources, 23 March 2009).

We have calculated emissions from cultivation using the following procedure:

a) We determined the mass of mineral diesel fuel from fuel consumption and the density of mineral diesel fuel (89.8 l/ha * 0.83 kg/l = 74.5 kg).
b) We know the calorific value of mineral diesel fuel. We are able to calculate how much energy we have consumed (74.5 kg * 42 MJ/kg = 3,130.4 MJ)
c) 1 MJ of mineral diesel fuel produces 83.8 g of CO_2. From this we calculated the quantity of CO_2 (3,130.4 MJ * 83.8 g CO_2/MJ/1000 = 262.3 kg CO_2)
d) The average rapeseed crop per ha in Slovenia is 2.46 t grains (Statistical Office of the Republic of Slovenia, SORS), 2004–2008 average. From this we obtain 40% grain and 60% cake. In quantitative terms, this amounts to 984 kg of oil and 1,476 kg of cake. The calorific value of the oil is 37 MJ/kg and of the cake 15 MJ/kg. We are able to calculate the energy value of the oil: 37 MJ/kg * 984 kg = 36,408 MJ. Energy value of cake: 15 MJ/kg * 1,476 kg = 22,140 MJ (see Table 4).
e) CO_2 emissions from cultivation: 262.3 kg CO_2/(36,408 MJ + 22,140 MJ) * 1,000 = 4.5 g CO_2/MJ

1.2 N_2O emissions

Emissions of nitrogen (N) from chemical fertilisers have been converted to CO_2 emissions in order to make it easier to compare all CO_2 emissions in the cultivation of rapeseed. For the quantity of nitrogen used, data from the 'Consumption of mineral fertiliser, by culture, Slovenia, 2008' (SORS) has been used. Quantities for individual cultures have been determined on the basis of sample statistical research involving 11,084 family farms and all agricultural concerns engaged in plant cultivation (SORS). The quantity of nitrogen is lower than the theoretical values provided by the norms contained in various handbooks; these values range between 140 and 180 kg/ha. An estimate of the average consumption of the main plant nutrients per hectare of agricultural land in use (KZU) in Slovenia in 2008 amounts to 49 kg/ha for nitrogen. The quantity of N_2O released in fertilisation using mineral fertilisers has been divided into: direct emissions into the atmosphere, indirect emissions resulting from emissions of NH_3 and NO_x, and indirect emissions resulting from the leaching of nitrogen into groundwater. The quantity has been determined using the IPCC 2006 methodology.

Table 2: Quantity of CO_2 released in the fertilisation of rapeseed using mineral fertilisers.

	Quantity	Direct emissions	Emissions into the atmosphere	Leaching into the soil and groundwater	Root residues	CO_2 equivalent	
FERTILISER	kg/ha	kg					kg CO_2
N	96.3*	1.5	0.15	0.34	0.75	1 kg N_2O = 296 kg CO_2	811
Production of mineral fertilisers							

P_2O_5	44.5*	0.71 kg CO_2 eq/kg**	31.6 kg CO_2	
K_2O	67.4*	0.46 kg CO_2 eq/kg**	31.0 kg CO_2	
N	96.3*	2.9 kg CO_2 eq/kg**	279.3 kg CO_2	
CO_2 emissions	19.7 g CO_2/MJ of rapeseed vegetable oil or biodiesel + cake			

*SORS
**according to Ahlgren et al

CO_2 emissions are also generated by the production of mineral fertilisers. According to Swedish findings (Ahlgren et al), these emissions amount to 2.9 kg CO_2 eq/kg of nitrogen fertiliser. In 2003 the emission values for the production of mineral fertilisers in Europe, chiefly for nitrogen, amounted to 6.8 kg CO_2 eq/kg of mineral nitrogen fertiliser (Ahlgren et al). This average is most likely lower today and the value can be taken into account in the worst-case scenarios. Our study assumes that in the production of mineral nitrogen fertilisers, we produce emissions of 2.9 kg CO_2 eq/kg of mineral fertiliser from nitrogen, 0.719 kg CO_2 eq/kg of mineral fertiliser from phosphorus (P_2O_5) and 0.46 kg CO_2 eq/kg of mineral fertiliser from potassium (K_2O).

Direct emissions of N_2O from managed soils

$$N_2O_{direkt}\_N = \sum_i (F_{SN} + F_{ON})_i \cdot EF_{1i} + (F_{CR} + F_{SOM}) \cdot EF_1 + N_2O\_N_{OS} + N_2O\_N_{PRP}$$

$$N_2O_{direkt\,N} = 96{,}3 \cdot 0{,}01 + izračuno\ posebej \cdot 0{,}01 = 0{,}963\ kg\ N_2O_N/leto$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0{,}963 * \frac{44}{28} = 1.5\ kg\ N_2O$$

izra•unano posebej = calculated separately
leto = year

CO_2 emissions: 1.5 kg N_2O * 296 = 444 kg CO_2

We have calculated emissions from root residues separately.

Emissions from the atmospheric discharge of nitrogen (N) evaporating from managed soils (emissions into the atmosphere):

N_2O from discharge into the atmosphere and from nitrogen evaporating from managed soils:

$$N_2O_{(ATD)} - N = [(F_{SN} \cdot Frac_{GASF}) + ((F_{ON} + F_{PRP}) \cdot Frac_{GASM})] \cdot EF_4$$

$N_2O_{(ATD)}$ — N – annual quantity of N_2O-N produced from the discharge of volatile nitrogen into the atmosphere from the cultivation of soil [kg N_2O-N/year]

F_{SN} – annual quantity of mineral nitrogen fertiliser spread on agricultural land [kg N/year]

$Frac_{GASF}$ – fraction of the mineral nitrogen fertiliser which evaporates as NH_3 and NO_x, and kg N which evaporates [kg N]

F_{ON} – annual quantity of organic fertiliser (animal slurry, compost, residual sludge and other organic nitrogen additives) [kg N/year]

F_{PRP} – nitrogen from the annual quantity of urine and manure produced during pasturing [kg N/year]

$Frac_{GASM}$ – fraction of the spread organic nitrogen fertiliser (F_{on}), urine and manure (F_{prp}) which evaporates as NH_3 and NO_x, and kg N which evaporates [kg N]

EF_4 – emission factor for N_2O emissions from the discharge of nitrogen into the atmosphere from the soil (fields, managed soils) and water areas [kg N-N_2O (kg NH_3-N + NO_x-N evaporation)-[1]]

$$N_2O_{(ATD)} - N = [(96.3 \cdot 0.1) + ((0 \ oz. ni\ podatka + 0) \cdot 0.2)] \cdot 0.01 = 0.0963 \ kg\ N - N_2O/\text{leto}$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0.0963 * \frac{44}{28} = 0.15\ kg\ N_2O$$

oz. ni podatka = or no data
leto = year

CO_2 emissions: 0.15 kg N_2O * 296 = 44.4 kg CO_2

N_2O emissions from leaching:

$$N_2O_{(L)} - N = [(F_{SN} + F_{ON} + F_{PRP} + F_{CR} - F_{SOM}) \cdot Frac_{LEACH-(H)}] \cdot EF_5$$

$N_2O_{(L)}$ — N – annual quantity of N_2O-N produced from the leaching and outflow of nitrogen in areas where leaching occurs [kg N_2O-N/year]

F_{SN} – annual quantity of mineral nitrogen fertiliser spread on agricultural land where leaching occurs [kg N/year]

F_{ON} – annual quantity of organic fertiliser (animal slurry, compost, residual sludge) and other organic nitrogen additives spread on managed soils where leaching occurs [kg N/year]

F_{PRP} – nitrogen from the annual quantity of urine and manure which is produced during pasturing and which leaches [kg N/year]

F_{CR} – nitrogen in crop residues (above and below ground), including nitrogen-specific crops and from the renewal of feed/pastures, which enters the earth in areas where leaching occurs [kg N/year]

$Frac_{LEACH-(N)}$ – fraction of all nitrogens added/mineralised in managed soils in areas where leaching occurs [kg N]

F_{SOM} – annual quantity of mineralised nitrogen in soil which is linked to the loss of soil carbon from organic substances as a result of changes to land where leaching occurs [kg N/year]

EF_5 – emission factor for N_2O emissions from the leaching and outflow of N from [kg N-N_2O]

$$N_2O_{(L)} - N = [(96.3 + 0 + 0 + izračunano\ posebej + 0) \cdot 0.3] \cdot 0.0075 = 0.216675\ \text{kg}\ N_2O - N/\text{leto}$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0.216675 * \frac{44}{28} = 0.34\ kg\ N_2O$$

izra•unano posebej = calculated separately
leto = year

CO_2 emissions: 0.34 kg N_2O * 296 = 100.64 kg CO_2 We have calculated emissions from root residues separately.

Emissions from root residues

According to some figures, rapeseed takes 70 kg of nitrogen per tonne of crop (Trinsoutrot et al). The decomposition of plant residues is a complex phenomenon and is bounded by numerous factors, including: availability of carbon and nitrogen, the physical and chemical properties of plant residues, and the contact between the soil and the plant residues (Trinsoutrot et al). According to Trinsoutrot et al, nitrogen content in rapeseed root residues in cases where there has been no fertilisation is 0.5 kg N/ha. In fertilisation using 270 kg of mineral nitrogen, the nitrogen content in root residues is 1.2 kg N/ha. If we carry this value over to a quantity of mineral nitrogen fertiliser of 96.3 kg N/ha (as used in Slovenia, SORS figures for 2007 and 2008), the nitrogen content from rapeseed root residues is 0.75 kg N/ha.

CO_2 emissions from root residues: 0.75 kg N_2O * 296 = 222 kg CO_2, which amounts to 3.8 g CO_2/MJ

Total emissions from N_2O:

TOTAL EMISSIONS FROM N_2O: 0.34 + 0.15 + 1.5 + 0.75 = 2.74 kg N_2O, -> CO_2 emissions: 2.74 * 296 = 811 kg CO_2
CO_2/MJ EMISSIONS: (811 + 279.3 + 31.6 + 31) kg CO_2/58,548 MJ = 19.7 g CO_2/MJ

In the calculations, we have used the following emission factors for calculating nitrogen oxide emissions (IPCC 2006):

- emission factor from indirect emissions: 0.01
- emission factor from evaporation: 0.01
- emission factor from leaching of nitrogen into groundwater: 0.0075

1.3 Total emissions from cultivation and fertilisers

To determine g CO_2 eq/MJ of fuel, total emissions (g CO_2/ha) from cultivation and fertilisation have been taken; for the energy value of fuel, the quantity of vegetable oil (kg/ha) produced from the average rapeseed crop per ha has been taken. The period taken for the crop in Slovenia is 2004 to 2008 (SORS). The value determined for the quantity of oil produced by 1 t of rapeseed grains is 40% (60% for cake) (Riva et al).

Table 3: Energy value of rapeseed biodiesel and oil and rapeseed cake in relation to the average annual rapeseed crop per ha in Slovenia

Average crop (t/ha)*	Quantity (kg)	Calorific value (MJ/kg)	Calorific value (MJ/ha)
2.46	984.0 (oil**)	37	36,408
2.46	1,476 (cake**)	15	22,140
Total calorific value			58,548

*SORS, **1 t of rapeseed grains produces 400 kg of oil and 600 kg of cake (Riva et al)

The value assumed for cultivation and fertilisers amounts, for rapeseed biodiesel, to 29 g CO_2/MJ of fuel, and for pure vegetable oil

from rapeseed, 30 g CO_2/MJ of fuel (figures taken from the EU Directive on the promotion of the use of energy from renewable sources, 23 March 2009). The calorific value of rapeseed cake is 15 MJ/kg.

The total from Tables 1 and 2 gives us 24.2 g CO_2/MJ of vegetable oil or biodiesel + cake.

Taking emissions from the production of mineral fertilisers and emissions from cultivation and the collection and transport of straw into account, CO_2 emissions amount to 24.2 g CO_2/MJ of vegetable oil or biodiesel from rapeseed and cake.

2. CO_2 EMISSIONS FROM THE CULTIVATION OF WHEAT

Emissions from cultivation have been divided into:

a) CO_2 emissions from mineral diesel fuel used for driving agricultural machinery involved in the production of wheat (soil treatment, sowing, fertilising, plant protection, harvesting, seed transport and straw collection, and transport);
b) emissions arising from the loss of N_2O into the atmosphere and groundwater from fertilisers;
c) emissions from the production of mineral fertilisers.

2.1 CO_2 emissions from mineral diesel fuel used to drive agricultural machinery

CO_2 emissions from the combustion of mineral diesel fuel in agricultural machinery engines, tractors/tractor units (tractor + various attached machines for soil treatment, sowing, protection, transport and straw collection) and combine harvesters. For calculation purposes, the average fuel consumption values for different mechanised phases of the production process have been given. The CO_2 emissions stated could be additionally lowered with the use of biofuels (biodiesel or vegetable oil) to drive agricultural machinery.

Figures for fuel consumption: basic treatment, fertilisation, protection, straw collection and transport (AIS – Agricultural Engineering Department). Other figures have been taken from Witney and from Kri•ka et al. In the case of direct sowing and supplementary treatment in a single pass, overall fuel consumption for cultivation would be reduced further.

Total consumption of mineral diesel fuel for this process, when the collection and transport of straw are not taken into account, amounts to 74.8 l/ha (89.8 l/ha if they are taken into account). For the purpose of the calculations, the energy value of mineral diesel fuel has been taken as being 42 MJ/kg and its density as 0.83 kg/l. For the entire quantity of mineral diesel fuel consumed in the cultivation process, we have assumed emissions of 83.8 g CO_2 eq/MJ (EU Directive on the promotion of the use of energy from renewable sources, 23 March 2009).

Emissions from cultivation:

Table 4: Consumption of mineral diesel fuel and energy used for cultivation (basic and supplementary soil treatment and other work operations on an area of 1 ha) and the quantities of CO_2 thereby produced from mineral diesel fuel

	Fuel consumption (l/ha)	Density of mineral diesel fuel (kg/l)	Mass of mineral diesel fuel (kg)	Calorific value (MJ/kg)	Energy used (MJ)	Quantity of CO_2 (kg)
Basic and supplementary treatment		0.83		42		
Ploughing*	15		12.45		522.9	43.8
Harrowing**	13		10.79		453.18	38.0
Other work operations						
Sowing**	4		3.32		139.44	11.7
Fertilising*	8		6.64		278.88	23.2

Protection*	2		1.66		69.72	5.8
Harvesting**	21.8		18.09		759.9	63.7
Transport of grains*	9		7.47		313.74	26.3
Straw collection*	6		4.98		209.16	17.5
Transport of straw*	9		7.47		313.74	26.3
TOTAL	89.8		74.5		3,130.4	256.3
CO_2 emissions		3.6 g CO_2/MJ of wheat ethanol and pellets				

*consumption according to AIS (Agricultural Engineering Department), **according to Witney, ***according to Kri•ka et al

2.2 N_2O emissions

Emissions of nitrogen from chemical fertilisers have been converted to CO_2 emissions in order to make it easier to compare all CO_2 emissions in the cultivation of wheat. For the quantity of nitrogen used, data from the 'Consumption of mineral fertiliser, by culture, Slovenia, 2008' (SORS) has been used. Quantities for individual cultures have been determined on the basis of sample statistical research involving 11,084 family farms and all agricultural concerns engaged in plant cultivation (SORS). The quantity of nitrogen is lower than the theoretical values provided by the norms contained in various handbooks; these values range between 140 and 180 kg/ha. An estimate of the average consumption of the main plant nutrients per hectare of agricultural land in use (KZU) in Slovenia in 2008 amounts to 49 kg/ha for nitrogen. The quantity of N_2O released in fertilisation using mineral fertilisers has been divided into: direct emissions into the atmosphere, indirect emissions resulting from emissions of NH_3 and NO_x, and indirect emissions resulting from the leaching of nitrogen into groundwater. The quantity has been determined using the IPCC 2006 methodology.

CO_2 emissions are also generated by the production of mineral fertilisers. According to Swedish studies (Ahlgren et al), these emissions amount to 2.9 kg CO_2 eq/kg of nitrogen fertiliser. In 2003 the average emission values for the production of mineral fertilisers in Europe, chiefly for nitrogen (N), amounted to 6.8 kg CO_2 eq/kg of mineral nitrogen fertiliser (Ahlgren et al). This average is most likely lower today and the value can be taken into account in the worst-case scenarios. Our study assumes that in the production of mineral nitrogen fertilisers, we produce emissions of 2.9 kg CO_2 eq/kg of mineral fertiliser from nitrogen.

Table 5: Quantity of CO_2 released in the fertilisation of wheat using mineral fertilisers

	Quantity	Direct emissions	Emissions into the atmosphere	Leaching into the soil and groundwater	CO_2 equivalent	
FERTILISER	kg/ha	kg				kg CO_2
N	91.7*	2.2	0.1441	0.51	1 kg N_2O = 296 kg CO_2	844.7
Production of mineral fertilisers						
P_2O_5	45.0*	0.71 kg CO_2 eq/kg**	20.4 kg CO_2			
K_2O	58.3*	0.46 kg CO_2 eq/kg **	26.8 kg CO_2			
N	991.7*	2.9 kg CO_2 eq/kg**	265.9 kg CO_2			
CO_2 emissions	16.2 g CO_2/MJ of wheat ethanol and pellets					

*SORS 2008, **according to Ahlgren et al

Direct emissions of N_2O from managed soils

$$N_2O_{direkt}\_N = \sum_i (F_{SN} + F_{ON})_i \cdot EF_{1i} + (F_{CR} + F_{SOM}) \cdot EF_1 + N_2O\_N_{OS} + N_2O\_N_{PRP}$$

$$N_2O_{direkt_N} = 91,7 \cdot 0,01 + 52,7 \cdot 0,01 = 1,444 kg\ N_2O_N / leto$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 1,444 \cdot \frac{44}{28} = 2,2\ kg\ N_2O$$

leto = year

CO_2 emissions: 2.2 kg N_2O * 296 = 651.2 kg CO_2

Emissions from the atmospheric discharge of nitrogen (N) evaporating from managed soils (emissions into the atmosphere):

$$N_2O_{(ATD)} - N = [(91,7 \cdot 0,1) + ((0 + 0) \cdot 0,2)] \cdot 0,01 = 0,0917\ kg\ N - N_2O/\text{leto}$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0,0917 * \frac{44}{28} = 0,1441\ kg\ N_2O$$

leto = year

CO_2 emissions: 0.1441 kg N_2O * 296 = 42.6 kg CO_2

N_2O emissions from leaching:

$$N_2O_{(L)} - N = [(F_{SN} + F_{ON} + F_{PRP} + F_{CR} - F_{SOM}) \cdot Frac_{LEACH-(H)}] \cdot EF_5$$

$$N_2O_{(L)} - N = [(91,7 + 0 + 0 + 52,7 + 0) \cdot 0,3] \cdot 0,0075 = 0,325\ \text{kg}\ N_2O - \text{N/leto}$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0,325 \cdot \frac{44}{28} = 0,51\ kg\ N_2O$$

leto = year

CO_2 emissions: 0.5 kg N_2O * 296 = 150.9 kg CO_2

Total emissions from N_2O:

TOTAL EMISSIONS FROM N_2O: 2.05 + 0.1441 + 0.46 = 2.6541 kg N_2O, -> CO_2 emissions: 2.6541* 296 = 785.7 kg

CO_2

CO_2/MJ EMISSIONS: (844.7 + 265.9 + 20.4 + 26.8) kg CO_2/71,360.6 MJ = 16.2 g CO_2/MJ

Calculation of annual quantity of nitrogen from roots and below-ground harvest residues (F_{CR})

$$F_{CR} = \sum_T \{AG_{DM(T)} \cdot (Area_{(T)} - Area\ burnt_{(T)} \cdot CF\ ) \cdot Frac_{Renew\,(T)} \cdot [N_{AG(T)} \cdot (1 - Frac_{Remove(T)}) + R_{BG-BIO(T)} \cdot N_{BG(T)}]\}$$

$$Crop_{(T)} = 4420\ kg/ha \cdot 0{,}89\ kg\ SS/kg = 3933{,}8\ kg\ SS/ha$$

$$AG_{DM\,(T)} = Crop_{(T)} \cdot slope_{(T)} + intercept_{(T)} = 3{,}9338\ t\frac{SS}{ha} \cdot 1{,}51 + 0{,}52 = 6{,}46\ t\ SS/ha$$

$$R_{BG(T)} = \frac{AG_{DM(T)} + Crop_{(T)}}{Crop_{(T)}} \cdot R_{BG-BIO} = \frac{6460\ kg\ SS + 3933{,}8\ kg\ SS}{3933{,}8\ kg\ SS} \cdot 0{,}24 = 0{,}63$$

$$F_{RC} = 6460\ (1-0) \cdot 1 \cdot [0{,}006 \cdot (1-0) + 0{,}24 \cdot 0{,}009] = 52{,}7\ kg\ N/leto$$

leto = year

2.3 Total emissions from cultivation and fertilisers

To determine g CO_2 eq/MJ of fuel, total emissions (g CO_2/ha) from cultivation and fertilisation have been taken; for the energy value of fuel, the quantity of bioethanol (kg/ha) produced from the average wheat crop (grains) per ha has been taken. The period taken for the crop in Slovenia is 2004 to 2008 (SORS). The value of 340 kg has been determined for the quantity of bioethanol produced from 1 t of wheat grains (Hamelinck et al). The yield of DDG (Distillers' Dried Grain), the pelleted and dried remains of distillation, is 350 kg/t (according to $(S\&T)^2$ Consultants Inc.). The quantity of pellets we obtain as a co-product in the production of wheat ethanol is, in our case, 1,547 kg. The calorific value of the pellets is 19.9 MJ/kg (Nyachoti et al).

Table 6: Energy value of bioethanol in relation to the average annual wheat crop per ha in Slovenia

Average wheat crop (t)*	Product	Quantity of ethanol (kg)	Calorific value of bioethanol (MJ/kg)	Energy value (MJ/ha)
4,42	Ethanol	1,502.8	27	40,576
	Pellets	1,547	19.9**	30,785
	Total			71,361

*SORS
**Nyachoti et al

The value assumed for cultivation and fertilisers amounts, for wheat ethanol, to 23 g CO_2/MJ (figure taken from the EU Directive on the promotion of the use of energy from renewable sources, 23 March 2009).

CO_2 emissions from wheat for cultivation and from fertilisers: 19.8 g CO_2/MJ of wheat ethanol and pellets

3. CO_2 EMISSIONS FROM THE CULTIVATION OF SUNFLOWER

Emissions from cultivation have been divided into:

a) CO_2 emissions from mineral diesel fuel used for driving agricultural machinery involved in the production of sunflower (soil treatment, sowing, fertilising, plant protection, harvesting, seed transport and straw collection, and transport);
b) emissions arising from the loss of N_2O into the atmosphere and groundwater from fertilisers;
c) emissions from the production of mineral fertilisers.

3.1 CO_2 emissions from mineral diesel fuel used to drive agricultural machinery

CO_2 emissions from the combustion of mineral diesel fuel in agricultural machinery engines, tractors/tractor units (tractor + various attached machines for soil treatment, sowing, protection, transport and straw collection) and combine harvesters. For calculation purposes, the average fuel consumption values for different mechanised phases of the production process have been given. The CO_2 emissions stated could be additionally lowered with the use of biofuels (biodiesel or vegetable oil) to drive agricultural machinery.

Figures on mineral diesel fuel consumption are from own measurements for basic treatment (AIS – Agricultural Engineering Department), while other figures have been taken from Witney or from other literature (Kri•ka et al). For the purpose of determining CO_2 emissions from mineral diesel fuel in the use of agricultural machinery, the same figures have been taken for the cultivation of sunflower as for fuel consumption in the cultivation of rapeseed; this is because their cultivation procedures are identical. In our calculation, separate work operations are envisaged for Slovenian conditions for the cultivation of sunflower. In the case of direct sowing and supplementary treatment in a single pass, overall fuel consumption for cultivation would be reduced further.

Total consumption of mineral diesel fuel for this process, when the collection and transport of straw are not taken into account, amounts to 64 l/ha. For the purpose of the calculations, the energy value of mineral diesel fuel has been taken as being 42 MJ/kg and its density as 0.83 kg/l. For the entire quantity of mineral diesel fuel consumed in the cultivation process, we have assumed emissions of 83.8 g CO_2 eq/MJ (EU Directive on the promotion of the use of energy from renewable sources, 23 March 2009).

Table 7: Consumption of mineral diesel fuel and energy used for cultivation (basic and supplementary soil treatment and other work operations on an area of 1 ha) and the quantities of CO_2 thereby produced from mineral diesel fuel

	Fuel consumption (l/ha)	Density of mineral diesel fuel (kg/l)	Mass of mineral diesel fuel (kg)	Calorific value (MJ/kg)	Energy used (MJ)	Quantity of CO_2 (kg)
Basic and supplementary treatment						
Ploughing*	15		12.45		522.9	43.8
Harrowing**	13		10.79		453.18	38
Other work operations						
Sowing**	4	0,83	3.32	42	139.44	11.7
Fertilising**	9		7.47		313.74	26.3
Protection**	3		2.49		104.58	8.8
Harvesting***	21.8		18.09		759.95	63.7
Transport of grains*	9		7.47		313.74	26.3
TOTAL	74.8		62.1		2,607.5	218.5
CO_2 emissions		5.5 g CO_2/MJ of sunflower biodiesel or vegetable oil and cakes				

*consumption according to AIS (Agricultural Engineering Department), **according to Witney, ***according to Kri•ka et al

3.2 N_2O emissions

Emissions of nitrogen from chemical fertilisers have been converted to CO_2 emissions in order to make it easier to compare all CO_2 emissions in the cultivation of sunflower. For the quantity of nitrogen used, data from the ‘Consumption of mineral fertiliser, by culture, Slovenia, 2008’ (SORS) has been used. Quantities for individual cultures have been determined on the basis of sample statistical research involving 11,084 family farms and all agricultural concerns engaged in plant cultivation (SORS). The quantity of nitrogen is lower than the theoretical values provided by the norms contained in various handbooks; these values range between 140 and 180 kg/ha. An estimate of the average consumption of the main plant nutrients per hectare of agricultural land in use (KZU) in Slovenia in 2008 amounts to 49 kg/ha for nitrogen. The quantity of N_2O released in fertilisation using mineral fertilisers has been divided into: direct emissions into the atmosphere, indirect emissions resulting from emissions of NH_3 and NO_x, and indirect emissions resulting from the leaching of nitrogen into groundwater. The quantity has been determined using the IPCC 2006 methodology.

Table 8: Quantity of CO_2 released in the fertilisation of sunflower using mineral fertilisers

	Quantity	Direct emissions	Emissions into the atmosphere	Leaching into the soil and groundwater	CO_2 equivalent	
FERTILISER	kg/ha	kg				kg CO_2
N	73.1*	1.1487	0.11487	0.26	1 kg N_2O = 296 kg CO_2	451
Production			of mineral fertilisers			
P_2O_5	38.9*	0.71 kg CO_2 eq/kg**	27.6 kg CO_2			
K_2O	55.2*	0.46 kg CO_2 eq/kg**	25.4 kg CO_2			
N	73.1*	2.9 kg CO_2 eq/kg**	212 kg CO_2			
CO_2 emissions	17.9 g CO_2/MJ of vegetable oil or biodiesel from sunflower + cake					

*SORS
**according to Ahlgren et al

Direct emissions of N_2O from managed soils

$$N_2O_{direkt_N} = 73{,}1 \cdot 0{,}01 + ni\ podatka \cdot 0{,}01 = 0{,}731\ kg\ N_2O_N/leto$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0{,}731 * \frac{44}{28} = 1{,}1487\ kg\ N_2O$$

ni podatka = no data
leto = year

CO_2 emissions: 1.1487 kg N_2O * 296 = 340 kg CO_2

Emissions from the atmospheric discharge of nitrogen (N) evaporating from managed soils (emissions into the atmosphere):

$$N_2O_{(ATD)} - N = [(73{,}1 \cdot 0{,}1) + ((0+0) \cdot 0{,}2)] \cdot 0{,}01 = 0{,}0731\ kg\ N - N_2O/\text{leto}$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0.0731 * \frac{44}{28} = 0{,}11487\ kg\ N_2O$$

leto = year

CO_2 emissions: 0.11487 kg N_2O * 296 = 34 kg CO_2

N_2O emissions from leaching:

$$N_2O_{(L)} - N = \left[(F_{SN} + F_{ON} + F_{PRP} + F_{CR} - F_{SOM}) \cdot Frac_{LEACH-(H)}\right] \cdot EF_5$$

$$N_2O_{(L)} - N = [(73{,}1 + 0 + 0 + \textit{ni podatka} + 0) \cdot 0{,}3] \cdot 0.0075 = 0{,}164475 \text{ kg } N_2O - N/leto$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0{,}164475 * \frac{44}{28} = 0{,}26 \ kg \ N_2O$$

ni podatka = no data
leto = year

CO_2 emissions: 0.26 kg N_2O * 296 = 77 kg CO_2

Total emissions from N_2O:

TOTAL EMISSIONS FROM N_2O: 0.26 + 0.11487 + 1.1487 = 1.52357 kg N_2O, -> CO_2 emissions: 1.52357 * 296 = 451 kg CO_2

CO_2/MJ EMISSIONS: (451 + 212 + 27.6 + 25.4) kg CO_2/40,011 MJ = 17.9 g CO_2/MJ

3.3 Total emissions from cultivation and fertilisers

To determine g CO_2 eq/MJ of fuel, total emissions (g CO_2/ha) from cultivation and fertilisation have been taken; for the energy value of fuel, the quantity of bioethanol (kg/ha) produced from the average wheat crop (grains) per ha has been taken. The period taken for the crop in Slovenia is 2004 to 2008 (SORS). The value determined for the quantity of vegetable oil produced by 1 t of sunflower grains is 40% (60% for cake) (Riva et al).

Table 9: Energy value of vegetable oil from sunflower in relation to the average annual sunflower crop per ha in Slovenia

Average sunflower crop (t)*	Quantity of vegetable oil or cake (kg)	Calorific value of vegetable oil (MJ/kg)	Energy value (MJ/ha)
1.62	648 (oil**)	37	23,976
1.62	1,069 (cake**)	15	16,035
Total energy value (MJ/ha)			40,011

*SORS
**1 t of sunflower grains produces 400 kg of oil and 600 kg of cake (Riva et al)

The value assumed for cultivation and fertilisers amounts, for hydrotreated vegetable oil from sunflower, to 18 g CO_2/MJ; the same value applies to sunflower biodiesel (figures taken from the EU Directive on the promotion of the use of energy from renewable sources, 23 March 2009).

CO_2 emissions from sunflower for cultivation and from fertilisers: 23.4 g CO_2/MJ of vegetable oil or biodiesel and cakes from sunflower

The values of CO_2/MJ emissions from sunflower exceed the limit values even before root residues and below-ground harvest residues have been taken into account. For this reason we have not calculated them.

4. CO_2 EMISSIONS FROM THE CULTIVATION OF CORN

Emissions from cultivation have been divided into:

a) CO_2 emissions from mineral diesel fuel used for driving agricultural machinery involved in the production of corn (soil treatment, sowing, fertilising, plant protection, harvesting, seed transport and straw collection, and transport);
b) emissions arising from the loss of N_2O into the atmosphere and groundwater from fertilisers;
c) emissions from the production of mineral fertilisers.

4.1 CO_2 emissions from mineral diesel fuel used to drive agricultural machinery

CO_2 emissions from the combustion of mineral diesel fuel in agricultural machinery engines, tractors/tractor units (tractor + various attached machines for soil treatment, sowing, protection, transport and straw collection) and combine harvesters. For calculation purposes, the average fuel consumption values for different mechanised phases of the production process have been given. The CO_2 emissions stated could be additionally lowered with the use of biofuels (biodiesel or vegetable oil) to drive agricultural machinery.

Figures on mineral diesel fuel consumption are from own measurements for basic treatment (AIS – Agricultural Engineering Department), while other figures have been taken from Witney or from other literature (Kri•ka et al). For the purpose of determining CO_2 emissions from mineral diesel fuel in the use of agricultural machinery, the same figures have been taken for the cultivation of corn as for fuel consumption in the cultivation of rapeseed; this is because their cultivation procedures are identical. In our calculation, separate work operations are envisaged for Slovenian conditions for the cultivation of corn. In the case of direct sowing and supplementary treatment in a single pass, overall fuel consumption for cultivation would be reduced further.

Table 10: Consumption of mineral diesel fuel and energy used for cultivation (basic and supplementary soil treatment and other work operations on an area of 1 ha) and the quantities of CO_2 thereby produced from mineral diesel fuel

	Fuel consumption (l/ha)	Density of mineral diesel fuel (kg/l)	Mass of mineral diesel fuel (kg)	Calorific value (MJ/kg)	Energy used (MJ)	Quantity of CO_2 (kg)
Basic and supplementary treatment		0,83		42		
Ploughing*	15		12.45		522.9	43.8
Harrowing**	13		10.79		453.18	38
Other work operations						
Sowing**	4		3.32		139.44	11.7
Fertilising**	9		7.47		313.74	26.3
Protection**	3		2.49		104.58	8.8
Harvesting***	21.8		18.09		759.95	63.7
Transport of grains*	9		7.47		313.74	26.3
TOTAL	74.8		62.1		2,607.5	218.5
CO_2 emissions		2.0 g CO_2/MJ of corn ethanol				

*consumption according to AIS (Agricultural Engineering Department), **according to Witney, ***according to Kri•ka et al

Total consumption of mineral diesel fuel for this process, when the collection and transport of straw are not envisaged, amounts to 74.8 l/ha. For the purpose of the calculations, the energy value of mineral diesel fuel has been taken as being 42 MJ/kg and its density as 0.83 kg/l. For the entire quantity of mineral diesel fuel consumed in the cultivation process, we have assumed emissions of

83.8 g CO_2 eq/MJ (EU Directive on the promotion of the use of energy from renewable sources, 23 March 2009).

4.2 N_2O emissions

Emissions of nitrogen from chemical fertilisers have been converted to CO_2 emissions in order to make it easier to compare all CO_2 emissions in the cultivation of corn. For the quantity of nitrogen used, data from the 'Consumption of mineral fertiliser, by culture, Slovenia, 2008' (SORS) has been used. Quantities for individual cultures have been determined on the basis of sample statistical research involving 11,084 family farms and all agricultural concerns engaged in plant cultivation (SORS). The quantity of nitrogen is lower than the theoretical values provided by the norms contained in various handbooks; these values range between 140 and 180 kg/ha. An estimate of the average consumption of the main plant nutrients per hectare of agricultural land in use (KZU) in Slovenia in 2008 amounts to 49 kg/ha for nitrogen. The quantity of N_2O released in fertilisation using mineral fertilisers has been divided into: direct emissions into the atmosphere, indirect emissions resulting from emissions of NH_3 and NO_x, and indirect emissions resulting from the leaching of nitrogen into groundwater. The quantity has been determined using the IPCC 2006 methodology.

Table 11: Quantity of CO_2 released in the fertilisation of corn using mineral fertilisers

	Quantity	Direct emissions	Emissions into the atmosphere	Leaching into the soil and groundwater	CO_2 equivalent	
FERTILISER	kg/ha	kg				kg CO_2
N	103.7*	2,5	0.16	0.56	1 kg N_2O = 296 kg CO_2	954
Production of mineral fertilisers						
P_2O_5	50.5*	0.71 kg CO_2 eq/kg**		35.8 kg CO_2		
K_2O	64.2*	0.46 kg CO_2 eq/kg**		29.5 kg CO_2		
N	103.7*	2.9 kg CO_2 eq/kg**		300.7 kg CO_2		
CO_2 emissions	11.9 g CO_2/MJ of corn ethanol and pellets					

*SORS 2008

**according to Ahlgren et al

Direct emissions of N_2O from managed soils

$$N_2O_{direkt_N} = 103{,}7 \cdot 0{,}01 + 55{,}6 \cdot 0{,}01 = 1{,}59\ kg\ N_2O_N/leto$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 1{,}59 * \frac{44}{28} = 2{,}5\ kg\ N_2O$$

leto = year

Translator's note: As it appears in the original: CO_2 emissions: 2,2,5 kg N_2O * 296 = 740 kg CO_2

Emissions from the atmospheric discharge of nitrogen (N) evaporating from managed soils (emissions into the atmosphere):

$$N_2O_{(ATD)} - N = [(103{,}7 \cdot 0{,}1) + ((0 + 0) \cdot 0{,}2)] \cdot 0{,}01 = 0{,}1037\ kg\ N - N_2O/\text{leto}$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0{,}1037 * \frac{44}{28} = 0{,}162957\ kg\ N_2O$$

leto = year

CO_2 emissions: 0.162957 kg N_2O * 296 = 48.2 kg CO_2

N_2O emissions from leaching:

$$N_2O_{(L)} - N = [(F_{SN} + F_{ON} + F_{PRP} + F_{CR} - F_{SOM}) \cdot Frac_{LEACH-(H)}] \cdot EF_5$$

$$N_2O_{(L)} - N = [(103{,}7 + 0 + 0 + 55{,}6 + 0) \cdot 0{,}3] \cdot 0{,}0075 = 0{,}358\ \text{kg}\ N_2O - N/\text{leto}$$

$$N_2O = N_2O\_N \cdot \frac{44}{28} = 0{,}358 * \frac{44}{28} = 0{,}56 kg\ N_2O$$

leto = year
CO_2 emissions: 0.56 kg N_2O * 296 = 165.29 kg CO_2

Total emissions from N_2O:

TOTAL EMISSIONS FROM N_2O: 0.56 + 0.162957 + 2.5 = 3.22 kg N_2O, -> CO_2 emissions: 3.22 * 296 = 954 kg CO_2
CO_2/MJ EMISSIONS: (954 + 300.7 + 35.8 + 29.5) kg CO_2/111,018 MJ = 11.9 g CO_2/MJ

Calculation of annual quantity of nitrogen from roots and below-ground harvest residues (F_{CR})

$$F_{CR} = \sum_T \{AG_{DM(T)} \cdot (Area_{(T)} - Area\ burnt_{(T)} \cdot CF\ ) \cdot Frac_{Renew\ (T)} \cdot [N_{AG(T)} \cdot (1 - Frac_{Remove}(T)) + R_{BG-BIO(T)} \cdot N_{BG(T)}]\}$$

$$Crop_{(T)} = 7560\ kg/ha \cdot 0{,}87\ kg\ SS/kg = 6577{,}2\ kg\ SS/ha$$

$$AG_{DM\ (T)} = Crop_{(T)} \cdot slope_{(T)} + intercept_{(T)} = 6{,}5772\ t\frac{SS}{ha} \cdot 1{,}03 + 0{,}61 = 7{,}38\ t\ SS/ha$$

$$R_{BG(T)} = \frac{AG_{DM(T)} + Crop_{(T)}}{Crop_{(T)}} \cdot R_{BG-BIO} = \frac{7380\ kg\ SS + 6577{,}2\ kg\ SS}{6577{,}2\ kg\ SS} \cdot 0{,}22 = 0{,}46$$

$$F_{CR} = 7380\ (1 - 0) \cdot 1 \cdot [0{,}006 \cdot (1 - 0) + 0{,}22 \cdot 0{,}007] = 55{,}6\ kg\ N/leto$$

leto = year

4.3 Total emissions from cultivation and fertilisers

To determine g CO_2eq/MJ of fuel, total emissions (g CO_2/ha) from cultivation and fertilisation have been taken; for the energy value of fuel, the quantity of bioethanol (kg/ha) produced from the average corn crop (grains) per ha has been taken. The period taken for the crop in Slovenia is 2004 to 2008 (SORS). The value of 794 kg has been determined for the quantity of bioethanol produced from 2.4 t of corn grains (Saiki et al). The yield of DDG (Distillers' Dried Grain), the pelleted and dried remains of distillation, is 295 kg/t (according to $(S\&T)^2$ Consultants Inc.). The quantity of pellets we obtain as a co-product in the production of corn ethanol is, in our case, 2,230.2 kg. The calorific value of the pellets is 19.5 MJ/kg (Bern, Rottinghaus).

Table 12: Calorific value of bioethanol in relation to the average annual crop of corn grains per ha in Slovenia

Average corn crop (t)*	Product	Quantity of ethanol (kg)	Calorific value of bioethanol (MJ/kg)	Energy value (MJ/ha)
7.56	Ethanol	2,501.1	27	67,529
	Pellets	2,230.2	19.5**	43,489
	Total			111,018

*SORS
**(S&T)^2 Consultants Inc.

The value assumed for cultivation and fertilisers amounts, for corn ethanol produced in the Community, to 20 g CO_2/MJ of fuel (figure taken from the EU Directive on the promotion of the use of energy from renewable sources, 23 March 2009).

Total CO_2 emissions for the cultivation of corn and from fertilisers: 13.8 g CO_2/MJ of corn ethanol and pellets

5. CO_2 EMISSIONS FROM CULTIVATION (NATIONAL LEVEL)

Table 13: CO_2 emissions in Eastern and Western Slovenia

		Rapeseed	Wheat	Sunflower	Corn
	CO_2 emissions (kg/ha)	1,193.2	1,419.8	934.5	1,533.1
Eastern Slovenia	CO_2 emissions (t)	5,677	43,742	no data	61,180
Western Slovenia		169	4,143	no data	3,673

Table 14: Crop areas in Eastern and Western Slovenia for 2007 and 2008 (SORS)

Area (ha)			
SLOVENIA	Eastern Slovenia*	Western Slovenia*	
33,727	30,809	2,918	Wheat and spelt
42,302	39,906	2,396	Grain corn
4,900	4,758	142	Rapeseed and turnip rape

*SORS (average for 2007 and 2008)

6. CO_2 EMISSIONS IN EASTERN AND WESTERN SLOVENIA

Table 15: Crop (t/ha) of wheat, grain corn and rapeseed for Eastern and Western Slovenia, 2007 and 2008 – average (SORS)

	Eastern Slovenia	Western Slovenia
	Crop – per ha (t/ha) – average (2007 to 2008)	
Wheat	4.4	3.8
Grain corn	7.45	7.5
Rapeseed and turnip rape	2.65	2.2

6.1 CO_2 emissions from rapeseed in Eastern and Western Slovenia

In Eastern Slovenia, the average rapeseed crop for 2007–2008 is 2.65 t/ha; in Western Slovenia it is 2.2 t/ha.

Table 16: Calorific value of biodiesel, rapeseed oil and rapeseed cake in relation to the average rapeseed crop in Eastern Slovenia

Average rapeseed crop in Eastern Slovenia (t/ha)	Quantity (kg)	Calorific value (MJ/kg)	Calorific value (MJ/ha)
2,65	1,060.0 (oil)	37	39,220
	1,590 (cake)	15	23,850
Total calorific value			63,070

Table 17: Calorific value of biodiesel, rapeseed oil and rapeseed cake in relation to the average rapeseed crop in Western Slovenia

Average crop in Western Slovenia (t/ha)	Quantity (kg)	Calorific value (MJ/kg)	Calorific value (MJ/ha)
2,2	880 (oil)	37	32,560
	1,320 (cake)	15	19,800
Total calorific value			52,360

Table 18: CO_2 emissions/MJ for Eastern and Western Slovenia for rapeseed

Rapeseed	UNIT	Eastern Slovenia	Western Slovenia
Emissions from cultivation	g CO_2/MJ of oil and cake	4.1	5.0
Emissions from fertilisation and fertilisers		18.2	22.0
Total emissions		22.3	27.0

6.2 CO_2 emissions from wheat in Eastern and Western Slovenia

Table 19: Calorific value of wheat ethanol and pellets in relation to the average wheat crop in Eastern Slovenia, 2007 and 2008

Average wheat crop (t)*	Product	Quantity of ethanol (kg)	Calorific value of bioethanol (MJ/kg)	Energy value (MJ/ha)
4.4	Ethanol	1,496	27	40,392
	Pellets	1,540	19.9**	30,646
	Total			71,038

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Table 20: Calorific value of wheat ethanol and pellets in relation to the average wheat crop in Western Slovenia, 2007 and 2008

Average wheat crop (t)*	Product	Quantity of ethanol (kg)	Calorific value of bioethanol (MJ/kg)	Energy value (MJ/ha)
3,8	Ethanol	1,292	27	34,884
	Pellets	1,330	19.9**	26,467
	Total			61,351

**Nyachoti et al

Table 21: CO_2 emissions/MJ for Eastern and Western Slovenia for wheat

Wheat	UNIT	Eastern Slovenia	Western Slovenia
Emissions from cultivation	g CO_2/MJ of ethanol and pellets	3.6	4.1
Emissions from fertilisation and fertilisers		16.3	18.6
Total emissions		19.9	22.7

6.3 CO_2 emissions from corn in Eastern and Western Slovenia

Table 22: Calorific value of corn ethanol and pellets in relation to the average corn crop in Eastern Slovenia, 2007 and 2008

Average corn crop in Eastern Slovenia (t)	Product	Quantity of ethanol (kg)	Calorific value of bioethanol (MJ/kg)	Energy value (MJ/ha)
7,45	Ethanol	2,465	27	66,555
	Pellets	2,198	19.5**	42,861
	Total			109,416

**(S&T)[2] Consultants Inc.

Table 23: Calorific value of corn ethanol and pellets in relation to the average corn crop in Western Slovenia, 2007 and 2008

Average corn crop in Western Slovenia (t)	Product	Quantity of ethanol (kg)	Calorific value of bioethanol (MJ/kg)	Energy value (MJ/ha)
7,5	Ethanol	2,481.25	27	66,994
	Pellets	2,212.5	19.5**	43,144
	Total			110,138

**(S&T)[2] Consultants Inc.

Table 24: CO_2 emissions/MJ for Eastern and Western Slovenia for grain corn

Corn	UNIT	Eastern Slovenia	Western Slovenia
Emissions from cultivation	g CO_2/MJ of ethanol and pellets	2.0	2.0
Emissions from fertilisation and fertilisers		12.0	11.9
Total emissions		14.0	13.9

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Head of the Agricultural Engineering Department

Viktor Jej•i•