Report of the Republic of Lithuania in accordance with the requirements of Article 19(2) of the 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

Article 19(2) of Directive 2009/28/EC provides:

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.

1. **List of territories**

According to 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) ((OJ 2003 L 154, p. 1) (as amended by Regulation (EC) No 1888/2005 of the European Parliament and of the Council of 26 October 2005 amending Regulation (EC) No 1059/2003 on the establishment of a common classification of territorial units for statistics (NUTS) by reason of the accession of the Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia and Slovakia to the European Union (OJ 2005 L 309, p. 1)), Lithuanian territory is subdivided into NUTS level 1, NUTS level 2 and NUTS level 3 territorial units. As the entire territory of the country is classified as NUTS level 1 and NUTS level 2, typical greenhouse gas emissions from cultivation of agricultural raw materials for the production of biofuels and bioliquids have been assessed in the more disaggregated NUTS level 3 territorial units.

NUTS 1	Code	NUTS 2	Code	NUTS 3	Code
LITHUANIA	LT0				
		Lithuania	LT00		
				Alytus county	LT001
				Kaunas county	LT002
				Klaip•da county	LT003
				Marijampol• county	LT004
				Panev•žys county	LT005
				Šiauliai county	LT006
				Taurag• county	LT007
				Telšiai county	LT008
				Utena county	LT009
				Vilnius county	LT00A

2. Calculation

2.1 Lithuania’s climate conditions and soil characteristics

In cultivation of agricultural raw materials for the production of biofuels their yields and fertility are greatly influenced by local climate conditions and soil fertility. Lithuania is situated in the cool temperate climate zone with moderately warm summers and moderately cold winters. Average temperature in July amounts to about 17°C and in winter – about -5°C; temperature range is about 20°C. Average ambient temperature recorded by the Lithuanian Hydrometeorological Service in 2009 is specified in Table 1, whereas its deviations from the average multiannual temperature are specified in Table 2[1].

Table 1. Average ambient temperature (°C) in 2009

County	**Months**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Alytus	-3.8	-3.0	0.9	8.1	12.5	14.7	18.3	16.2	13.2	5.2	3.7	-2.9
Kaunas	-3.4	-3.4	0.9	8.9	12.7	15.1	18.4	16.9	13.8	5.3	3.9	-2.5
Klaip•da	-0.3	-1.9	1.5	8.3	11.3	14.3	18.7	18.2	15.4	6.9	5.0	-0.9
Marijampol•	-2.6	-2.9	1.3	9.2	12.6	15.1	18.6	16.9	14.2	5.7	4.4	-2.2
Panev•žys	-2.8	-3.7	0.5	8.5	12.7	15.2	18.2	16.4	13.7	5.1	3.9	-2.5
Šiauliai	-2.4	-3.6	0.0	8.5	12.5	15.1	18.2	16.7	14.0	4.7	3.6	-3.0
Taurag•	-3.2	-3.9	-0.1	8.0	11.3	14.2	17.2	15.8	13.0	4.5	3.3	-3.1
Telšiai	-2.3	-3.5	0.3	8.7	12.0	14.8	18.0	16.6	14.0	5.0	3.8	-2.6
Utena	-3.1	-3.7	0.3	7.9	12.3	14.8	18.0	15.9	13.5	5.1	4.0	-2.7
Vilnius	-3.8	-3.6	0.5	8.7	12.4	14.8	18.0	16.4	13.6	4.8	3.3	-3.1

Table 2. Deviation of ambient temperature from average multiannual temperature (°C) in 2009

County	**Months**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Alytus	2.0	1.6	1.5	2.1	0.2	0.4	1.4	0.0	1.5	-1.6	1.9	-0.1
Kaunas	1.9	0.9	1.3	3.1	0.3	0.3	1.5	0.5	1.9	-1.8	2.1	-0.2
Klaip•da	2.5	0.7	1.2	3.3	0.6	0.5	2.1	1.5	2.1	-2.1	1.1	-0.8
Marijampol•	1.8	0.9	1.1	3.0	0.2	0.4	1.7	0.5	1.8	-2.1	1.9	-0.3
Panev•žys	2.5	1.1	1.0	2.9	0.3	0.6	1.2	0.3	2.0	-1.8	2.1	0.3
Šiauliai	2.7	1.1	0.9	3.3	0.7	0.4	1.5	0.6	2.3	-2.3	1.8	-0.4
Taurag•	2.1	0.9	1.1	3.3	0.1	0.2	1.2	0.3	1.8	-2.2	1.8	-0.3
Telšiai	2.5	0.9	1.2	3.8	0.8	0.6	1.6	0.9	2.6	-2.0	2.1	-0.3
Utena	2.9	1.5	1.5	2.4	0.1	0.5	1.2	0.0	2.2	-1.5	2.6	0.6
Vilnius	2.2	1.2	1.1	3.0	0.0	0.5	1.1	0.1	1.9	-1.8	2.1	-0.2

The given figures show that temperature differences in different counties and temperature deviations from average multiannual temperature are quite modest.

In assessing climate conditions, the amount of precipitations is as important. The amount of precipitations specified in Table 3 has been recorded in each county in 2009 on a monthly basis. These figures show that there was only a small difference between the amounts of precipitations in each county during the same month.

Table 3. Amount of precipitations in counties in 2009 (mm)

County	**Months**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Alytus	42	35	44	10	49	53	131	49	28	93	70	67
Kaunas	72	42	47	9	43	52	84	87	29	101	75	48
Klaip•da	52	38	59	3	32	53	73	77	62	112	81	60
Marijampol•	36	52	41	7	39	60	97	63	44	101	52	40
Panev•žys	36	35	52	12	26	65	136	61	41	86	63	68
Šiauliai	32	26	44	8	21	51	79	41	51	95	50	46
Taurag•	46	28	41	4	29	56	94	74	97	139	89	50
Telšiai	61	29	60	5	34	63	180	56	63	119	82	64
Utena	39	38	35	17	30	61	76	71	78	91	67	60
Vilnius	46	28	40	6	46	51	107	68	60	109	72	70

Lithuanian soils are classified on the basis of fertility scoring of utilised agricultural area. The Lithuanian map prepared by the SE State Land Management Institute, demonstrating average fertility scoring of the utilised agricultural area in the counties, is shown in Figure 1[2]. The given figures show that fertility scoring of utilised agricultural area in the counties varies between 32.7 and 44.8. The utilised agricultural area of most counties (except that of Utena) has average fertility rate (in general, such fertility scoring is between 34 and 45). There is no utilised agricultural area in Lithuania with very high fertility scoring, and fertility scoring of Utena county utilised agricultural area is slightly lower than the average.

Figure 1. Utilised agricultural area fertility scoring in Lithuanian counties

The requirement for nitrogen fertilisers for cultivation of agricultural plants depends on the residual mineral nitrogen content in soil. The map showing mineral nitrogen content in spring of 2009, prepared by the Agrochemical Research Center of the Lithuanian Institute of Agriculture, is shown in Figure 2. It shows that mineral nitrogen content in soil is low; however, its distribution according to the regions of the country is very uneven. The largest amounts of mineral nitrogen in the soil layer from 0 to 60 cm are found in Middle Lithuania – 62.9 kg/ha in average, and the lowest amounts are found in Western and Eastern Lithuania, 42.5 kg/ha and 44.1 kg/ha respectively. Nitrogen fertiliser rates are differentiated according to mineral nitrogen content in soil.

Figure 2. Mineral nitrogen content in the Lithuanian soil in spring 2009

2.2 Types of biofuel

The following two types of biofuel are produced in Lithuania:

- rape oil methyl esters (RME) for diesel engines, and
- bioethanol for Otto engines.

Of types of biofuel in 2009 biodiesel (RME) formed the larger part, whereas bioethanol amounted to about 18% of all biofuels produced in the country during the same year. A total of 104 thousand tonnes of biodiesel and 24 thousand tonnes of bioethanol were produced in the country in 2009.

Table 4. Biofuel production and gross consumption in Lithuania in 2004-2009 (calculated on the basis of the data published by the Lithuanian Department of Statistics)

Year	**Produced, thousand**			**Consumed, thousand**			**Part of biofuel in the fuel consumed, %**
	biodiesel	**bioethanol**	**total**	**biodiesel**	**bioethanol**	**total**	
2004	2.2	1.7	3.9	0.8	0.1	0.9	0.082
2005	7	6.6	13.6	3.2	0.9	4.1	0.35
2006	10.3	14.3	24.6	15.8	8.4	24.2	1.9
2007	24.8	15	39.8	47.6	18.3	65.9	4.33
2008	64	17	81	51.8	24.2	76	4.91
2009	104	24	128	42.7	22.4	65.1	5.14

Several companies produce biofuels (biodiesel and bioethanol) in Lithuania. Major biodiesel producers are Mestilla UAB and Rapsoila UAB. Production capacity of these companies is shown in Table 5.

Table 5. Lithuanian biofuel producers and their production capacity

Company name	Production capacity, thousand
Biodiesel	
Mestilla UAB (Klaip•da)	100
Rapsoila UAB (Mažeikiai region)	30
Arvi cukrus UAB (Marijampol•)	12
SV Obeliai KB (Obeliai)	8
Total:	**150**
Bioethanol	
Biofuture UAB (Šilut•)	40
Kurana UAB (Pasvalys)	20
Total:	**60**
Total of biofuels:	**210**

2.3 Raw materials for the production of biofuels

The following raw materials are used for the production of biofuels in Lithuania: summer and winter rape seeds for the production of biodiesel (RME), and mostly winter triticale and wheat seed for the production of bioethanol.

Average yields, fertility and cultivation areas of raw materials for the production of biofuels (Table 6) in different counties in 2009 have been taken from the data provided by the Lithuanian Department of Statistics[3].

Dynamics of the amount of raw materials used for the production of biofuels, including dynamics of their cultivation areas, is shown in Tables 7 and 8.

Table 6. Gross fertility, yields and crop areas of raw materials for the production of biofuel

County	Fertility, tonnes/ha	Yields, tonnes	Crop area, ha
Winter wheat			
Alytus	3.83	34 179	8 918
Kaunas	4.68	360 467	77 095
Klaip•da	3.20	19 967	6 234
Marijampol•	4.92	332 760	67 624
Panev•žys	4.24	321 633	75 770
Šiauliai	4.55	515 511	113 177
Taurag•	4.01	61 376	15 322
Telšiai	3.29	45 361	13 775
Utena	3.14	28 514	9 091
Vilnius	2.90	29 654	10 212
Winter triticale			

Alytus	2.51	13 203	5 270
Kaunas	3.32	63 403	19 080
Klaip•da	3.25	38 069	11 712
Marijampol•	3.95	50 837	12 855
Panev•žys	3.20	55 948	17 474
Šiauliai	3.47	70 461	20 312
Taurag•	2.80	32 941	11 751
Telšiai	2.68	33 711	12 598
Utena	2.84	12 150	4 274
Vilnius	2.56	23 906	9 323
Rape			
Alytus	2.02	5 681	2 816
Kaunas	2.30	74 833	32 484
Klaip•da	1.39	9 734	6 956
Marijampol•	2.18	58 936	27 087
Panev•žys	2.12	76 068	35 880
Šiauliai	2.35	152 820	64 929
Taurag•	2.04	14 229	6 990
Telšiai	1.52	7 599	4 993
Utena	1.56	5 504	3 518
Vilnius	1.65	10 362	6 268

Table 7. Dynamics of crop areas of raw materials for the production of biofuels in Lithuania

Raw material	**Intended for cultivation of raw materials for the production of biofuels, thousand ha**			**Total cultivated in 2009, thousand ha**
	2007	**2008**	**2009**	
Rape seed	40	100	160	192
Wheat and triticale grain	17	20	30	136

Table 8. Dynamics of the amount of raw materials for the production of biofuels in Lithuania

Raw material	**Consumed, thousand**			**Total threshed in 2009, thousand, tonnes**
	2007	**2008**	**2009**	
Rape seed	75	200	370	416
Wheat and triticale grain	52	60	70	426

2.4. Method for calculating greenhouse gas emissions from cultivation of agricultural raw materials for the production of biofuels

The actual greenhouse gas emissions in agriculture have been calculated on the basis of energy output related to mechanised agricultural works, materialised energy in seeds, fertilisers and plant protection products, fuel output from drying and transportation of seed and grain. The assessment also included nitrous oxide emissions related to nitrification/denitrification, nitrogen volatilization and leakage processes in soil.

The following general formula has been applied for the calculation of greenhouse gas emissions from cultivation of agricultural raw materials for the production of biofuels:

$$e_{ec} = \frac{(E_{\check{Z}\bar{U}} + E_S + E_{Tr} + E_T + E_{AAP} + E_D + E_N) \times I}{D \times \check{S}} \times K \quad (1)$$

where:

e_{ec} - greenhouse gas emissions from cultivation of raw materials for the production of biofuels, $gCO2_{eq}/MJ$;

$E_{\check{Z}}$. – greenhouse gas emissions from fuel output for mechanised agricultural works (soil preparation, sowing, cultivation of crops, yield harvesting), $kgCO_{2eq}/ha$

E_S – greenhouse gas emissions from using seed for sowing, $kgCO_{2eq}/ha$

E_{TR} – greenhouse gas emissions from fuel output upon transportation of yields, $kgCO_{2eq}/ha$

E_T – greenhouse gas emissions from using fertilisers and liming preparations, $kgCO_{2eq}/ha$

E_{AAP} – greenhouse gas emissions from using plant protection products, $kgCO_{2eq}/ha$

E_D – greenhouse gas emissions from fuel output for drying rape seed, wheat and triticale seed, $kgCO_{2eq}/ha$

E_N – greenhouse gas emissions from direct and indirect release of N_2O, $kgCO_{2eq}/ha$

D – fertility of agricultural raw materials used for the production of biofuels, t/ha

I – biofuel output, t (biofuels)/t (raw materials);

Š – biofuel heat value, MJ/kg (bioethanol – 27 MJ/kg; rape oil methyl ester – 37 MJ/kg (Directive 2009/28/EC).

This formula (1) takes into account biofuel output from one hectare of utilised agricultural area and heat value of resulting biofuels (MJ/kg), therefore, the final result is the amount of gCO_{2eq} for 1 MJ of biofuel energy.

2.5Basic data

Greenhouse gas emissions from fuel output for mechanised agricultural works $E_{Ž•}$ ($kgCO_{2eq}$/ha) have been calculated on the basis of agricultural machinery fuel output for 1 ha for sowing, crop cultivation and harvesting works of raw material cultivated for the production of biofuels.

Data for the calculation of fuel output are taken from the recommendations drawn up by the Lithuanian Institute of Agrarian Economics[4]. The following data were used: agricultural machinery output rates and fuel output for 1 ha of crops for certain agricultural works, depending on the power of the machinery in use. Since there is no reliable data on the distribution by county of agricultural machinery stocksin terms of their power, average data for the country as a whole have been used. The number of mechanised operations required for agricultural crop cultivation has been taken from the recommendations found in scientific literature for cultivation of rape seed, wheat and triticale [5-7]. Fuel output (1/ha) has been calculated for each agricultural operation and particular machinery in use based on the following formula:

$$\mathbf{DS_{Ž•} = S \times \boldsymbol{n}} \qquad (2)$$

where:

$DS_{Ž•}$ – fuel output for a particular operation and for using particular agricultural machinery, 1/ha;

S – fuel output resulting for a particular operation and for using particular agricultural machinery, 1/ha;

n – soil slope angle rate.

Gross fuel output for mechanised agricultural works is obtained by aggregating the amount of fuel consumed for different agricultural operations ($DS_{BŽ•}$ = • $DS_{Ž•}$), 1/ha.

The following formula was applied for the calculation of greenhouse gas emissions from fuel output for mechanised agricultural works ($E_{Ž•}$, $kgCO_{2eq}$/ha):

$$\mathbf{E_{Ž•} = (DS_{BŽ•} \times \bullet \times 3.757) \times \boldsymbol{10^{-3}}}$$

where:

$DS_{BŽ•}$ – gross fuel output for mechanised agricultural works ($DS_{BŽ•}$ = • $DS_{Ž•}$), 1/ha.

• - fuel density, kg/m^3

3.757 - rate of turning mineral diesel to CO_{2eq} ($kgCO_{2eq}$/kg of diesel) (JEC, 2007) [8].

Greenhouse gas emissions from sowing works (E_S, CO_{2eq}/ha), calculated on the basis of the amount of rape seed, wheat and triticale required for sowing 1 ha and emission factors found in literature [8].

Greenhouse gas emissions from fuel output for agricultural machinery upon transportation of crops (E_{Tr}, kgCO_{2eq}/ha) have been calculated on the basis of fuel output. For fuel output (1/ha), average distance from seed or grain storage places to driers (km), fuel output of vehicles in use (l/km), vehicle capacity (t) and seed or grain fertility (t/ha) have been taken into consideration.

Formula applied for calculation:

$$DS_{Tr} = \frac{R \times L \times D}{T} \quad (4)$$

where:

DS_{Tr} – fuel output for agricultural machinery upon yield transportation, 1/ha

R – vehicle and agricultural machinery mileage, km

L – vehicle fuel output, 1/km

D – crop fertility, t/ha

T – vehicle capacity, t

The following formula was applied for calculating greenhouse gas emissions from fuel output for agricultural machinery upon yield transportation (E_{Tr}, kgCO_{2eq}/ha):

$$\mathbf{E_{Tr} = (DS_{TR} \times \bullet \times 3.757) \times 10^{-3}} \quad (5)$$

where:

• - fuel density, kg/m^3

3.757 - rate of turning mineral diesel to CO_2 (kgCO_{2eq}/kg of diesel) (JEC, 2007) [8].

Greenhouse gas emissions from the use of fertilisers and liming preparations (E_T, kgCO_{2eq}/ha) have been calculated on the basis of recommendations for the cultivation of agricultural plants, related to fertiliser and liming preparation rates for crops, climate, precipitation and residual nitrogen content indicators and soil fertility scoring. In the recommendations for plant cultivation the amount of nutrients required for fertilising plants is given as N kg/ha, P_2O_5 kg/ha and K_2O kg/ha, and liming preparations as CaO kg/ha.

Formula for calculating greenhouse gas emissions from the use of fertilisers and liming preparations E_T (kgCO_{2eq}/ha):

$$\mathbf{E_T = (m_N \times k_N) + (m_{P2O5} \times k_{P2O5}) + (m_{K2O} \times k_{K2O}) + (m_{CaO} \times k_{CaO})}, \quad (6)$$

where:

m_N - nitrogen output from fertilisation of 1 ha of crops, kg/ha

m_{P2O5} – P_2O_5 output from fertilisation of 1 ha of crops, kg/ha

m_{K2O} – K_2O output from fertilisation of 1 ha of crops, kg/ha

m_{CaO} – CaO output from fertilisation of 1 ha of crops, kg/ha

k_N, k_{P2O5}, k_{K2O}, k_{CaO} - rates of turning materials to CO_{2eq} (emission factors)

Table 9. Rates of turning the amount of fertilisers and liming preparations to CO_{2eq}

Product	Unit	Value	Source
Fertilisers:			
Nitrogen (N)	$kgCO_{2eq}$/kg N	6.065	JEC, 2007
Phosphorus (P_2O_5)	$kgCO_{2eq}$/kg P_2O_5	1.018	
Potassium (K_2O)	$kgCO_{2eq}$/kg K_2O	0.584	
Calcium (CaO)	$kgCO_{2eq}$/kg CaO	0.124	

Greenhouse gas emissions from the use of plant protection products (E_{AAP},$kgCO_{2eq}$/ha) have been calculated on the basis of the amount of plant protection products used for cultivation of raw materials for the production of biofuels. The required amount of herbicides, insecticides and fungicides per one hectare of crops has been taken from the recommendations for the cultivation of agricultural plants, and their dry matter content has been calculated on the basis of product descriptions in the Kemira catalogue [7].

Greenhouse gas emissions from the use of plant protection products E_{AAP}($kgCO_{2eq}$/ha) have been calculated on the basis of the following formula:

$$\mathbf{E_{AAP} = \bullet\ m_{AAP} \times 17.258} \qquad (7)$$

where:

- m_{AAP} – the sum of the masses of all plant protection products used, kg/ha;

17.258 - rate of turning plant protection product mass to $kgCO_{2eq}$/ha ($kgCO_{2eq}/kg_{AAP}$) [8].

Greenhouse gas emissions from biofuel output for drying raw material for biofuel production (E_D, $kgCO_{2eq}$/ha) have been calculated on the basis of fuel output for agricultural products grown for drying 1 ha. Fuel output has been calculated on the basis of performance of currently most popular dryers with heat exchangers, average moisture of harvested wheat and triticale grain and rape seed and conditional moisture, forming the basis for buying-in of rape seed and wheat and triticale grain for processing.

Fuel output for drying (l/ha) has been calculated on the basis of the following formula:

$$\mathbf{DS_D = (T_2 - T_1) \times N_D \times D}, \tag{8}$$

where:

DS_D - fuel output for drying 1 ha of cultivated plants, l/ha

N_D - dryer performance, 1/ºC × T

D - agricultural plant fertility, t/ha

Greenhouse gas emissions from fuel output for drying agricultural products E_D ($kgCO_{2eq}$/ha) have been calculated on the basis of the following formula:

$$\mathbf{E_D = (DS_D \times \bullet \times 3.757) \times \mathit{10}^{-3}}, \tag{9}$$

where:

• - fuel density, kg/m^3

3.757 - rate of turning mineral diesel to CO_{2eq}, $kgCO_{2eq}$/kg of diesel [8].

Greenhouse gas emissions from direct and indirect release of N_2O, E_N ($kgCO_{2eq}$/ha) have been calculated on the basis of Tier 1 methodology supplied by IPCC (2006)[9].

Upon calculating direct nitrous oxide emissions mineral nitrogen entering the soil together with fertilisers was taken into consideration. Nitrogen remaining in plant residues in above and below soil has also been added. It was calculated on the basis of plant biomass and seed or grain biomass ratio, percentage of residues in above and below soil and nitrogen content in plant residues.

Table 10. Data for the calculation of N_2O emissions

Indicator	Rape (winter and summer)	Wheat and triticale (winter)
Ratio of cultivated plant biomass and seed or grain biomass (DM.)	1.7:1	1.5:1
Plant residues in above soil, %	10	40

Average nitrogen content in plant residues in above soil, % (DM)	0.8	0.5
Plant residues in below soil, %	22	21
Average nitrogen content in plant residues in below soil, % (DM)	0.9	0.5

Amount of direct N_2O-N emissions (kg N_2O-N/kgN) has been calculated on the basis of the following formula:

$$\mathbf{N_2O_T\text{-}N \quad (F_{MT} + F_{AL}) \times E_{F1}}, \tag{10}$$

where:

- F_{MT} - nitrogen content in fertilisers used for fertilising plants, kg N/ha;
- F_{AL} - nitrogen content in plant residues, kg N/ha
- E_{F1} - emission factor for turning the amount of N utilised to direct N_2O-N emissions, kgN_2O-N/kgN utilised (Table 11).

The following formula may be applied for calculating N_{AL} per hectare of plants (IPCC Guidelines for National Greenhouse Gas Inventories, 2006)

$$\mathbf{F_{AL} = D \times (R_{P\check{Z}} \times N_{P\check{Z}} + R_{A\check{Z}} \times N_{A\check{Z}})}, \tag{11}$$

where:

- F_{AL} – nitrogen content in plant residues, kg N/ha;
- D – dry mass of cultivated plants, kg/ha;
- $R_{P\check{Z}}$ – plant residue in below soil and gross plant mass ratio, kg(DM)/kg(DM)
- $N_{P\check{Z}}$ - nitrogen content in plant residues in below soil, kgN/kg (DM)
- $R_{A\check{Z}}$ –plant residue in above soil and common plant mass ratio, kg(DM)/kg(DM)
- $N_{A\check{Z}}$ – nitrogen content in plant residues in below soil, kgN/kg (DM)

The following formula has been applied for turning N_2O_T-N to N_2O (kg/ha):

$$\mathbf{N_2O = N_2O_T\text{-}N \times 44/28}, \tag{12}$$

Indirect N_2O_N-N emissions (kg N_2O-N/kgN) have been calculated on the basis of the following formula:

$$\mathbf{N_2O_N\text{-}N = F_{MT} \times FRAC_{GASF} \times E_{F4}} \quad (13)$$

where:

F_{MT} – nitrogen content in fertilisers used for fertilising plants, kg N/ha

$FRAC_{GASF}$ – share of N released from soil in the result of volatilization, kg (NH_3-N+NO_x-N) N utilised;

E_{F4} – emission factor for calculation of indirect N_2O emissions, kg N_2O-N/ kg(NH_3-N+NO_x-N) (Table 11).

The following formula has been applied for turning N_2O_N-N to N_2O (kg/ha):

$$\mathbf{N_2O_N = N_2O_N\text{-}N \times 44/28,} \quad (14)$$

Table 11. Direct and indirect N_2O emission calculation factors

Factor	Unit	Value	Source
E_{F1} (direct) N_2O)	kg N_2O-N/kgN utilised	0.01 (0.003–0.03)	IPCC, 2006
E_{F4} (indirect N_2O resulting from volatilization and re-deposition	kg N_2O-N/kg(NH_3-N+NO_x-N)	0.01 (0.002–0.05)	IPCC, 2006
E_{F5} (indirect in the result of leaching/runoff)	kg N_2O–N/kg N leaked	0.0075 (0.0005–0.025)	IPCC, 2006
$FRAC_{GASF}$ (N fraction, evaporating in the form of NH_3 and NO_x)	kg (NH_3-N+NO_x-N)/kgN utilised	0.1 (0.03–0,3)	IPCC, 2006
$FRAC_{LEACH}$ (N fraction lost due to leakage)	kg N lost/kg N utilised	0.3 (0.1–0.8)	IPCC, 2006

The obtained N_2O emission values have been turned to gCO_{2eq} values by applying the rate specified in Table 12.

Table 12. Impact values of different gases on greenhouse effect after turning to gCO_{2eq}

Gases	Value after turning to gCO_{2eq} (Directive 2009/28/EC)
1 gCO_2	1 gCO_{2eq}
1 gCH_4	25 gCO_{2eq}
1 gN_2O	296 gCO_{2eq}

After aggregating the $kgCO_{2eq}$ emissions obtained at different stages for 1 ha of agricultural area in use for raw material for the production of biofuel it was turned to the amount of gCO_{2eq} for 1 MJ of produced biofuel. The following data was used for this purpose:

- rape seed or wheat and triticale grain output for biofuel mass unit. It depends on the efficiency of biofuel production technologies applied, and this efficiency differs, therefore, average data specified in the report published by the European Commission, Joint Research Centre, Institute for Environment and Sustainability[10] was used;
- biofuel raw material fertility in the county, t/ha (Table 6) (data of the Lithuanian Department of Statistics);
- biofuel heat value, MJ/t (specified in Directive 2009/28/EC)
- energy ratio *K* of energy accumulated in biofuels and that from products of common production (including by-products). It has been included in the general equation for the calculation of greenhouse gas emissions (1) and is calculated by assessing the share of the mass of products resulting from biofuel production and heat value. RME, rape pomace and glycerol are taken into consideration for biodiesel and spirit dregs for bioethanol. K shall be calculated on the basis of the following formula:

$$K = \frac{C_P}{C_P + C_{\check{S}P}} \qquad (15)$$

where:

C_P – energy content in biofuels, MJ/ha;

$C_{\check{S}P}$ – energy content in by-products, MJ/ha;

Energy value of rape oil methyl-ester and bioethanol is specified in Annex III to the Directive 2009/28/EC.

2.6 Greenhouse gas emissions from agricultural raw materials for the production of biofuels

The calculated greenhouse gas emission values are given in Table 13.

Table 13. Typical greenhouse gas emission values $\mathbf{e_{ec}}$ from cultivation of agricultural raw materials for the production of biofuels in Lithuania in NUTS Level 3 territorial units.

NUTS Level 3 territorial unit	Wheat and triticale grain, gCO_{2eq}/MJ of ethanol	Rape seed, gCO_{2eq}/MJ RME

LT001 Alytus county	22.81	26.70
LT002 Kaunas county	20.02	24.56
LT003 Klaip•da county	22.12	28.17
LT004 Marijampol• county	20.27	24.56
LT005 Pan•vežys county	22.41	26.70
LT006 Šiauliai county	21.12	25.58
LT007 Taurag• county	21.53	26.61
LT008 Telšiai county	22.75	28.20
LT009 Utena county	21.72	28.88
LT00A Vilnius county	21.77	28.75
In entire Lithuania (**NUTS Level 1)**	**21.7**	**26.8**
Default greenhouse gas emission value (Directive 2009/28/EC)	**23**	**29**

After calculating greenhouse gas emissions from cultivation of agricultural raw materials for the production of biofuels in different counties, the resulting values were compared to the default values (gCO_{2eq}/MJ) given in part D of Annex V to the Directive 2009/28/EC for biodiesel obtained from rape seed and for bioethanol obtained from wheat and triticale grain. It was established that the typical amount of greenhouse gas emissions from cultivation of agricultural raw materials in all NUTS Level 3 territorial units is lower than the emissions reported on the basis of part D of Annex V to the Directive 2009/28/EC.

The difference between the default greenhouse gas emission value from cultivation of raw materials for the production of biofuels and the average of typical calculated values is specified in Table 14 in terms of percentage.

Table 14. Difference between default greenhouse gas emission value (e_{ec}) resulting from cultivation of agricultural raw materials, as provided in Directive 2009/28/EC, and average calculated typical values in percentage terms.

Raw material	Biofuel	Default disaggregated cultivation values e_{ec},	Difference (average),

		gCO_{2eq}/MJ	%
Wheat and triticale grains	Bioethanol	23	5.6
Rape seed	Rape oil methyl-esters (RME)	29	7.6

2.7 Gross actual amount of greenhouse gas emissions from cultivation of agricultural raw materials for the production of biofuels and from biofuel production

Given that it is impossible to calculate the amount of agricultural produce used for the production of biofuels in each county, the gross actual amount of greenhouse gas emissions from cultivation of raw materials for the production of biofuels in Lithuania was calculated on the basis of average greenhouse gas emissions in Lithuania (Table 13).

The gross actual amount of greenhouse gas emissions from cultivation of raw materials for the production of biofuels in Lithuania in 2009 was calculated on the basis of the following formula:

$$\mathbf{E_{F\check{Z}.} = [B \times \check{S}] \times e_{ec},} \qquad (16)$$

where:

$E_{F\check{Z}.}$ - actual amount of greenhouse gas emissions from cultivation of raw materials for the production of biofuels in Lithuania during 2009, gCO_{2eq}/MJ

B - amount of biofuels produced during 2009, t (Table 4)

S - biofuel heat value, MJ/t

e_{ec} - average typical greenhouse gas emission value, gCO_{2eq}/MJ

Actual calculated greenhouse gas emissions from cultivation of rape and wheat and triticale for the production of biofuels are given in Table 14.

Having regard to the fact that the purpose of this study was not to assess energy and material output related to biofuel production processes in industry, and Directive 2009/28/EC states that the common amount of greenhouse gas emissions resulting from production and use of biofuels may be calculated “by using a value calculated as the sum of the factors of the formula referred to in point 1 of part C of Annex V, where disaggregated default values in part D or E of Annex V may be used for some factors, and actual values, calculated in accordance with the methodology laid down in part C of Annex V, for all other factors”, the gross actual amount of greenhouse gas emissions from cultivation of raw materials for the production of biofuels and from production of biofuels in the Republic of Lithuania in 2009 was calculated by using the actual calculated amount from cultivation of agricultural raw materials for the production of biofuels and the disaggregated default values for processing provided in Directive 2009/28/EC.

Greenhouse gas emissions from biofuel production have been calculated on the basis of the following formula:

$$\mathbf{E_{PR} \bullet [B \times \check{S}] \times e_P\text{-}e_C}, \tag{17}$$

E_{PR} – actual amount of greenhouse gas emissions from cultivation of raw materials for the production of biofuels in Lithuania during 2009, gCO_{2eq}/MJ;

B - amount of biofuels produced during 2009, t (Table 4);

S - biofuel heat value, MJ/t;

e_P-e_C – disaggregated default processing value, gCO_{2eq}/MJ (Directive 2009/28/EC).

Summarized figures are given in Table 15.

Table 15. Greenhouse gas emissions in Lithuania from cultivation of rape and wheat and triticale for the production of biofuels and from biofuel production in 2009

Raw mate rial	**Actual greenhouse gas emissions from cultivation of raw materials for the production of biofuels $GgCO_{2eq}$**	**Greenhouse gas emissions from biofuel production, $GgCO_{2eq}$**	**Gross greenhouse gas emissions from cultivation of raw materials and from biofuel production, $GgCO_{2eq}$**
Rape seed	103	84.7	187.7
Winter wheat and triticale grain	14	29.2	43.2

The given figures show that greenhouse gas emissions from biodiesel production are almost 4 times higher in Lithuania, compared to those from the production of bioethanol. Undoubtedly, this relates to higher biodiesel production volume due to higher diesel consumption rates in vehicles and more greenhouse gas emissions in agriculture from cultivation of rape seed for the production of biodiesel.