Annex 2

Slovak Report on winter wheat regarding Article 19(2) of Directive 2009/28/EC on the promotion of the use of energy from renewable sources

1 NUTS CLASSIFICATION OF THE SLOVAK REPUBLIC

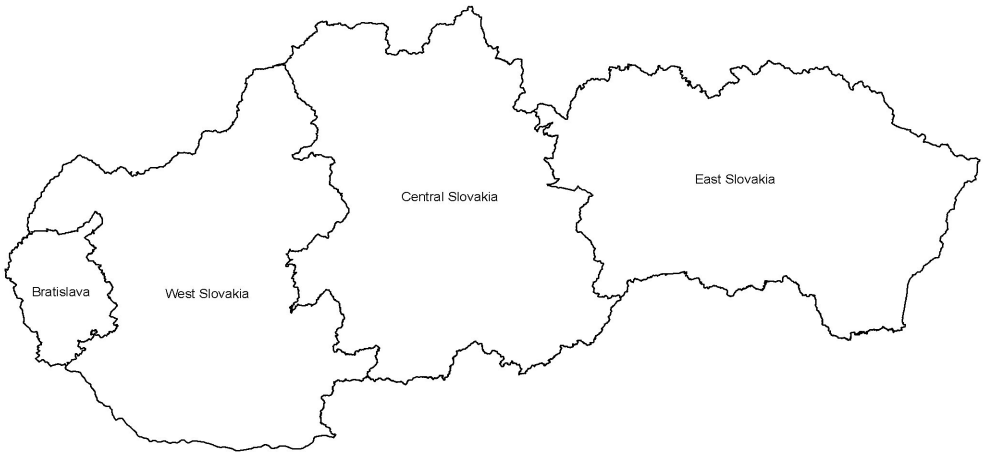
In the Slovak Republic there are defined the following NUTS regions:
NUTS 1 - Slovak republic
NUTS 2 - aggregated regions (4)
NUTS 3 - regions (8)
NUTS 4 - districts (79)
NUTS 5 - municipalities (2 922)

NUTS 2 regions are represented by 4 combined regions: Bratislava, West Slovakia, Central Slovakia and East Slovakia. Spatial distribution of NUTS2 regions are provided in Fig. 1. Individual NUTS2 regions consist of following NUTS3 regions:
- Bratislava - Bratislava;
- West Slovakia – embracing the territory of Trnava, Trenčín and Nitra;
- Central Slovakia - embracing the territory of Žilina and Banská Bystrica;
- East Slovakia - embracing the territory of Prešov and Košice.

Table 1 Slovak NUTS area classification

NUTS 1	NUTS 2 name	NUTS 2 codes	NUTS 3 name	NUTS3 codes
Slovak Republic SK0	Bratislava	SK01	Bratislava region	SK01
	West Slovakia	SK02	Trnava region	SK021
			Trenčín region	SK022
			Nitra region	SK023
	Central Slovakia	SK03	Žilina region	SK031
			Banská Bystrica region	SK032
	East Slovakia	SK04	Prešov region	SK041
			Košice region	SK042

Fig. 1 Allocation of NUTS 2 regions within Slovakia Territory



2 SOIL TYPES WITHIN AGRICULTURAL LAND

According to WRB 2006 within agricultural land are classified the following soil types groups:
1. Chernozems and Phaeozems
2. Luvisols
3. Eutric Cambisols
4. Dystric Cambisols
5. Albic Luvisols and Stagnosols and Planosols
6. Arenosols
7. Gleyic Chernozems and Gleyic Phaeozems
8. Fluvisols
9. Gleysols
10. Calcaric Cambisols and Rendzic Phaeozems
11. Podzols
12. Solonetz and Solonchacks
13. Leptosols
14. Anthrosols and Technosols

Table 2 Distribution of soil types groups within aggregated regions (%)

NUTS2 SK	SK01	SK02	SK03	SK04
Cernozems and Phaeozems	24,9	35,6	0,3	1,3
Luvisols	12,4	21,7	10,9	3,6
Eutric Cambisols	4,0	8,6	36,3	33,4
Dystric Cambisols	4,2	0,5	8,9	4,7
Albic Luvisols and Stagnosols and Planosols	0,1	3,9	13,3	13,7
Arenosols	12,7	1,5	0,0	0,7
Gleyic Chernozems and Gleyic Phaeozems	18,9	7,7	1,5	2,1
Fluvisols	16,4	13,9	10,0	18,8
Gleysols	3,1	0,7	1,5	4,3
Calcaric Cambisols and Rendzic Phaeozems	1,0	3,7	5,8	3,3
Podzols	0,0	0,0	0,4	0,0
Solonetz and Solonchacks	0,0	0,1	0,0	0,1
Leptosols	0,1	1,9	10,9	14,0
Anthrosols and Technosols	2,2	0,2	0,0	0,0

3 CALCULATION OF EMISSIONS FROM CULTIVATION

$$e_{ec} = e_{FERT} + e_{PPP} + e_{SEEDS} + e_{N2O} + e_{FUEL}$$

e_{FERT} – emissions from production of fertilisers
e_{PPP} – emissions from application of plant protection products
e_{SEEDS} – emissions from seeds
e_{N2O} – direct and indirect emissions N2O according to IPCC 2006 Guidelines
e_{FUEL} – emissions from fossil fuel consumption
e_{DRY} – emissions from energy consumption for grain drying

Each item was calculated to kgCO2eq/ha.
In the end of the calculation there are the values converted to gCO2eq/MJ fuel.
Calculation of particular items see below.

Input data

- Average yields
  Average crop yields of the winter wheat at NUTS 2 level for years 2005 – 2009 (see Tab 5) were calculated as weighted averages of yields available at NUTS 3 level. Statistic data that were basis for the calculation were provided by the Central Control and Testing Institute for Agriculture, Bratislava.

- Emission factors - see table 3

Table 3 Emission factors

	Emission factor $kgCO_2eq/kg$	Source
N fertilisers	6,065	JEC 2007
P_2O_5 fertilisers	1,018	
K_2O fertilisers	0,584	
Plant protection products	10,97	BioGrace
Winter wheat seeds	0,2759	BioGrace
Diesel	3,757	JEC 2007
Natural gas	0,055	SPP*

*SPP-Slovak Gas Industry

- Biofuel yield – see table 4

Table 4 Biofuel yield from winter wheat for production of bioethanol and allocation ratio for their production

Crop	Products	Average biofuel yield	Allocation ratio for biofuel based on energy content
Winter wheat	Bioethanol	3,3 kg winter wheat to 1 kg bioethanol	64 %

3.1 EMISSIONS FROM THE PRODUCTION OF FERTILIZERS E_{FERT}

Emissions form production of fertilisers was calculated by following equation:
e_{FERT} (kgCO2eq/ha) = amount of fertiliser (kg/ha) x emission factor (kg CO_2eq/kg nutrient)

Nutrient off-take by average yield (see Table 5) is calculated for average crop yields in period 2005-2009. Application of fertilizers (N, P_2O_5, K_2O) on yield unit is calculated as average value in period 2005-2009 (data from The Central Control and Testing Institute for Agriculture, Bratislava and Ministry of Agriculture SR).

Table 5 Average nutrient off-take by yield of selected crops (kg/ha)

NUTS2	Yields	Average application rate of fertilisers kg/ha			
	kg/ha	N	P_2O_5	K_2O	Total
Winter wheat					
SK01	4084	95,43	18,51	19,51	133,45
SK02	4340	98,85	18,86	15,94	133,65
SK03	3590	81,23	12,53	10,23	103,99
SK04	3380	79,26	11,30	7,98	98,54

Emission factors from fertilizers are as follows:

N fertilisers 6065 g CO_{2eq}/kg N,
P_2O_5 fertilisers 1018 g CO_{2eq}/kg P2O5,
K_2O fertilisers 584 g CO_2 eq/kg K_2O (JEC, 2007)

Table 6 Emissions from fertiliser production

NUTS2	Emissions ($CO_{2\ eq}$/kg per ha of nutrient)			Total
	N	P_2O_5	K_2O	$kgCO_{2eq}$/ha
Winter wheat				
SK01	578,78	18,84	11,39	609,02
SK02	599,53	19,20	9,31	628,03
SK03	492,66	12,76	5,97	511,39
SK04	480,71	11,50	4,66	496,88

3.2 EMISSIONS FROM PLANT PROTECTION PRODUCTS E_{PPP}

Emissions from plant protection products were calculated by following equation:

e_{PPP} ($kgCO_{2eq}$/ha) = amount of PPP (kg/ha) x emission factor ($kgCO_{2eq}$/kg)

The input of plant protection products (PPP) per area unit was calculated as an average value in 2005/2006-2008/2009 for the whole Slovak Republic (data from The Central Control and Testing Institute for Agriculture, Bratislava).

Table 7 Emissions from plant protection products

NUTS2	Plant protection products		
	Input kg/ha	Emission factor $kgCO_{2eq}$/kg nutrient (BioGrace)	Emissions gCO_{2eq}/ha
Winter wheat			
SK01-SK04	1,09	10,97	11,96

3.3 EMISSIONS FROM SEEDS E_{SEEDS}

Emissions from seeds were calculated by following equation:

e_{SEEDS} ($kgCO_{2eq}$/ha) = amount seeds (kg/ha) x emission factor ($kgCO_{2eq}$/kg seeds).

Seed rates for the selected crops: winter wheat 130 kg/ha

Emission factor from seeds is not watched in Slovakia. For the calculation we used the factors from BioGrace model:

winter wheat == 0,2759 $kgCO_{2eq}$/kg seeds (BioGrace)

Table 8 Emissions from seeds

NUTS2	Seed rate kg/ha	Emission factor $kgCO_{2eq}$/kg seeds	Emissions $kgCO_{2eq}$/ha
Winter wheat			
SK01	130	0,2759	35,867
SK02	130	0,2759	35,867
SK03	130	0,2759	35,867
SK04	130	0,2759	35,867

3.4 EMISSIONS N_2O

N_2O emissions were calculated according to the formula (IPCC 2006 Guideline):

$$N_2O\ emisions = eN_2O_{DIRECT} + e\ N_2O_{INDIRECT}$$

Table 9 Factors used for the calculation of direct and indirect N_2O emissions

Factor	Unit	Value	Source
EF_1 (direct) N_2O	kg N2O-N/kgN utilised	0.01 (0.003–0.03)	IPCC, 2006
EF_4 (indirect N_2O resulting from volatilization and redeposition)	kg N2O-N/kg(NH3-N+NOx-N)	0.01 (0.002–0.05)	IPCC, 2006
EF_5 (indirect in the result of leaching/runoff)	kg N2O–N/kg N leaked	0.0075 (0.0005–0.025)	IPCC, 2006
FRACGASF (N fraction, evaporating in the form of NH_3 and NO_x)	kg (NH3-N+NOx-N)/kgN utilised	0.1 (0.03–0,3)	IPCC, 2006
FRACLEACH (N fraction lost due to leakage)	kg N lost/kg N utilised	0.3 (0.1–0.8)	IPCC, 2006

The conversion from N_2O-N emissions to N_2O emissions were calculated according to the formula (IPCC 2006 Guideline):

$$N_2O = N_2O\text{-}N \times 44/28$$

Following values of different GHG were used to their conversion to gCO_{2eq} (Directive 2009/28/ES, Annex V, C.)

Table 10

Gas	Value after conversion to gCO_{2eq}
1 gCO_2	1 gCO_{2eq}
1 gCH_4	25 gCO_{2eq}
1 gN_2O	296 $gCO2_{eq}$

DIRECT EMISSIONS $N2O_{DIRECT}$

Direct N2O emissions were calculated according to the formula (IPCC 2006 Guideline):

$$N_2O_{DIRECT}\ (kgCO2eq/ha) = (F_{SN} + F_{CR})\ x\ EF_1\ x\ 44/28$$

F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}

F_{CR} = amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs, kg N yr^{-1}

N_2O loses from applied N-fertilizers are assumed to be 1% of applied rate (IPPC, 2006).

Table 11 Direct N_2O emissions from applied N-fertilizers and from crop residues (yield by-product (*above ground*) + root residues (*below ground*))

NUTS 2	Average yield (kg/ha)	Fertilizer N consumption (kg/ha)	N_2O-N loses from fertilizers (kg/ha)	N_2O-N loses from crop residues (above + below ground) (kg/ha)	N_2O loses total (kg/ha)	N_2O emissions kg $CO_{2eq/ha}$
Winter wheat						
SK01	4084	95,43	0,95	0,23	1,85	548,87
SK02	4340	98,85	0,98	0,24	1,92	567,47
SK03	3590	81,23	0,84	0,20	1,63	483,75
SK04	3380	79,26	0,79	0,19	1,54	455,84

According to IPCC (2006) Vol 4, Chapter 11, table 11.2 the ratio of below - ground residues to above – ground biomass is assumed 0,23.
According to IPCC (2006) Vol 4, Chapter 11, table 11.2 the N content of winter wheat root residues is assumed to be 0,9% .
35 % of straw (by- product) is ploughed
Yield of by-product is calculated by ratio between main and by-product of yield. Straw/grain ratio for winter wheat is 1:1. The assumed value of N content in by-product of winter wheat is 5,5 kg N per tonne. Both these value were undertaken from the study BUJNOVSKÝ,R.: Efektívne hnojenie pôdy a poľných plodín (Effective fertilization of the soil and arable crops). Bratislava : ÚVTIP – NOI, 2002, 44 s. ISBN 80-89088-05-8.)

INDIRECT EMISSIONS $N_2O_{INDIRECT}$

These emissions from managed soils arising from agricultural inputs of N embrace synthetic N fertilizers and crop residues. Indirect N2O emissions are calculated by following formulas (according to IPPC 2006):

$$N_2O_{INDIRECT}\ (kgCO_2eq/ha) = N_2O_{(ATD)}\text{-}N + N_2O_{(L)}\text{-}N$$

$N_2O_{(ATD)}$-N = annual amount of N_2O–N produced from atmospheric deposition of N volatilised from managed soils, kg N_2O–N yr^{-1}
$N_2O_{(L)}$-N = annual amount of N_2O–N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kg N_2O–N yr^{-1}

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

F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}
$Fracf_{GASF}$ = fraction of synthetic fertiliser N that volatilises as NH_3 and NO_X, kg N volatilised (kg of N applied)$^{-1}$
F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr^{-1}

F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1}
$Frac_{GASM}$ = fraction of applied organic N fertiliser materials (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) that volatilises as NH_3 and NO_X, kg N volatilised (kg of N applied or deposited)$^{-1}$
EF_4 = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, [kg N–N_2O (kg NH_3–N + NO_X–N volatilised)$^{-1}$]

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

F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}
F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils in regions where leaching/runoff occurs, kg N yr^{-1}
F_{PRP} = annual amount of urine and dung N deposited by grazing animals in regions where leaching/runoff occurs, kg N yr^{-1}
F_{CR} = amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs, kg N yr^{-1}
F_{SOM} = annual amount of N mineralised in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions where leaching/runoff occurs, kg N yr^{-1}
$Frac_{LEACH\text{-}(H)}$ = fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)$^{-1}$
EF_5 = emission factor for N_2O emissions from N leaching and runoff, kg N_2O–N (kg N leached and runoff)$^{-1}$

In the calculation we did not count in the factors F_{ON} (they are not used in cultivation of these crops), F_{PRP} (these crops are cultivated on arable land), F_{SOM} (these crops are not cultivated on such types of soil in Slovakia).

Usually, in the case of wither wheat, in areas where wheat is cultivated, nitrogen leaching does not occur and so this loss of nitrogen is not taken into account.

Table 12 Indirect emissions if no leaching occurs

NUTS 2	Average yield (kg/ha)	N fertilizer consumption (kg/ha)	volatilization and redeposition (mineral fertilizer N) N_2O-N(kg/ha)	Total indirect Emissions kg CO_{2eq}/ha
SK01	4084	95,43	0,10	46,51
SK02	4340	98,85	0,10	45,98
SK03	3590	81,23	0,08	37,78
SK04	3380	79,26	0,08	36,87

3.6 FUEL FOR CULTIVATION E_{FUEL}

e_{FUEL}= fuel (L/ha) x density(kg/m3) x emission factor

Average consumption of diesel during the cultivation were in the range 60-65 L/ha (Agricultural Technical and testing Institute in Rovinka) what are the values commonly used in Slovakia. To calculate the emissions in $kgCO_{2eq}$/ha there was used the emission factor 3,757 $kgCO_2$/kg (JEC2007).

4 FINAL RESULTS

Typical emissions = $e_{ec} = e_{FERT} + e_{PPP} + e_{SEEDS} + e_{N2O} + e_{FUEL}$

According to Direction 2009/28/EC the GHG emissions have to be in gCO2eq/MJ fuel (ethanol/FAME).

The values calculated in kgCO2eq/ha were converted to the values in gCO2eq/MJ according to the following equation:

$$gCO2eq/MJ = \frac{Emission\ (gCO_2eq/ha)\ x\ allocation\ f.}{Crop\ yield\ (kg/ha)\ x\ fuel\ energy\ (MJ/kg)}$$

Calculations of energy balance for maize were based on the estimates that 1 L pure ethanol is produced from 3,4 -3,3 kg winter wheat (Slovnaft VÚRUP, corp.). Energy content of ethanol is 21 MJ/L (Directive 2009/28/EC, Annex III). Density is 832 $kg.m^{-3}$ .Then the fuel energy content per unit mass was calculated to 7,98 MJ/kg.
Em. Coff. kg CO_2/kg =3,757 (JEC 2007).
Allocation factor for biofuel based on energy content- 0,64

Table 13 Calculation of typical emissions from winter wheat cultivation (g CO_{2eq}/MJ) for bioethanol

NUTS 2 name	Code	Fertilisers	Plant protection products	Seeds	N2O direct	N2O indirect	Fossil fuel for cultivation	Typical emissions	Directive
Bratislava region	SK01	11,21	0,82	0,66	10,10	0,86	0,22	**23,88**	23
Western Slovakia	SK02	10,88	0,82	0,62	9,83	0,80	0,21	**23,16**	
Central Slovakia	SK03	10,71	0,82	0,75	10,13	0,79	0,25	**23,46**	
Eastern Slovakia	SK04	11,05	0,82	0,80	10,14	0,82	0,27	**23,90**	
Slovakia	SK0	10,96	0,82	0,71	10,05	0,81	0,24	**23,60**	

Table 14 Calculation of typical emissions from winter wheat cultivation (g CO_{2eq}/MJ) for bioethanol

NUTS 3 name	Code	Fertilisers	Plant protection products	Seeds	N2O direct	N2O indirect	Fossil fuel for cultivation	Typical emissions	Directive
Bratislava region	SK010	11,21	0,82	0,66	10,10	0,86	0,22	**23,88**	23
Trnava region	SK021	9,73	0,82	0,60	9,03	0,71	0,2	**21,09**	
Trenčín region	SK022	11,58	0,82	0,69	10,51	0,85	0,23	**24,69**	
Nitra region	SK023	11,39	0,82	0,58	10,28	0,83	0,19	**24,10**	
Žilina region	SK031	10,05	0,82	0,72	9,32	0,74	0,24	**21,88**	
Banská Bystrica region	SK032	11,41	0,82	0,79	10,47	0,85	0,26	**24,61**	
Prešov region	SK041	10,91	0,82	0,85	10,02	0,81	0,28	**23,70**	
Košice region	SK042	11,16	0,82	0,75	10,27	0,83	0,25	**24,08**	