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

1. Preface

Article 19(2) of Directive 2009/28/EC reads as follows:

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.

2. List of regions

Out of the 13 total NUTS2 Regions in Greece, in 7 of them, where energy crops are cultivated, the typical greenhouse gas emissions from the cultivation of agricultural raw materials are below the emissions given under the heading 'Disaggregated default values for cultivation' in Annex V Part D of Directive 2009/28/EC.

These Regions are as follows:

1. Thessaly
2. Epirus
3. West Macedonia
4. East Macedonia & Thrace
5. Central Macedonia
6. Continental Greece & Euboea
7. Western Greece

3. Calculation

3.1 Relevant biomass raw materials

Currently in Greece only biodiesel is produced using raw materials from locally produced energy crops.

As a result, the following energy crops grown in Greece are relevant for the report under Article 19(2) of Directive 2009/28/EC:

- Sunflower
- Oilseed rape
- Soybean

3.2 Approach

The procedures followed throughout, were in accordance with the ones described for same purposes by BioGrace *(http://www.biograce.net/content/ghgcalculationtools/overview)*.

The greenhouse gas emissions were calculated by including emissions from the cultivation and harvesting of energy crops, as well as greenhouse gas emissions from the material and energy inputs used for production and for cultivation by means of accurately measured data.

The main product is the product of a stage of the production chain from which the biofuel or the liquid biomass is produced in the subsequent stages of the production chain.

All data for the input parameters were made in mass units on the basis of the area unit (e.g. diesel [kg]/hectare).

The allocation factor (AF) is the proportion of emissions allocated to the main product. Using the allocation factor, emissions 'de-allocated' from crop to by-products of later stages of the process were re-allocated to crop. To convert the reference MJ of refined oil to the reference kg of the crop, the conversion factor CF is required. The conversion factor for e_{ec} indicates the quantity of each crop (in kg) required for 1 MJ of refined oil.

The functional unit used in calculations was 1 MJ of biodiesel.

4. Data Basis

The following data were required to calculate the regional greenhouse gas emissions during cultivation:

- Diesel [l/(ha*yr)] - Total quantity of diesel used (e.g. for tractors) per hectare and year

- Lower heating value (MJ/kg) of diesel *(Biograce)*

- Emission factor for diesel [g of CO_2/MJ of diesel] *(Biograce)*
- Seed [kg/ha] – Total quantity of sown seed
- *Emission factor for seed production [g of CO_2/kg of seed]*
- Fertilizer [kg/(ha*yr)] - Total quantity of N, P_2O_5 and K_2O fertilizer used per hectare and year
- Emission factor for fertilizer production [g of CO_2/kg of N fertilizer] *(Biograce)*
- Pesticide [kg/(ha*yr)] – Total quantity of pesticides applied per hectare per year (herbicides or insecticides)
- Emission factor for pesticide production [g of CO_2/kg of pesticide] *(Biograce)*
- N_2O Emissions. Nitrous oxide emissions from the use of fertilizer were estimated using the following equation that includes both direct and indirect emissions:

  N_2O [t] = 0.0125 × N applied [t] + 0.01 (NH_3 + NO) emitted [t]
- Crop yield [kg of crop yield/(ha*yr)] – Annual yield in kg per hectare and year.
- Biodiesel production [kg of biodiesel/(ha*yr)]
- Lower heating value (MJ/kg) of biodiesel *(Biograce)*
- Allocation factors (AF) were taken from the BioGrace GHG emissions calculator.
- Drying costs were not taken into account due to low post harvest moisture content for both sunflower and oilseed rape in Greece.
- Emission factors for the production and use of diesel and fertilizer:

Factor	***Unit***	***Value***	***Source***
Diesel	g of CO_2eq/MJ	87.64	*Biograce (2010)*
Seed	g of CO_2eq/kg	729.9	
Nitrogen	g of CO_2eq/kg of N	5,880.6	
Phosphorous	g of CO_2eq/kg of P_2O_5	1,010.7	
Potassium	g of CO_2eq/kg of K_2O	576.1	
Pesticides	g of CO_2eq/kg	10,971.3	
LHV_{diesel}	MJ/kg	43.1	
$LHV_{biodiesel}$	MJ/kg	37.2	
Sunflower cultivation AF	%	62.9	
Oilseed rape cultivation AF	%	58.6	
Soybean cultivation AF	%	32.9	

5. Results

Typical values calculated for greenhouse gas emissions from the cultivation of energy crops by NUTS2 region in Greece are presented in the following table:

	Energy crop	***Sunflower***	***Oilseed rape***	***Soybean***
	Year of data	*2008**	*2009-2010***	*2010****
No	***NUTS2 region***	***gr of CO_2eq/MJ of FAME***		
1	Thessaly	17.55	-	17.36
2	Epirus	17.55	-	17.36
3	West Macedonia	17.39	-	17.36
4	East Macedonia & Thrace	16.92	28.19	17.36
5	Central Macedonia	16.19	27.64	17.36
6	Continental Greece & Euboea	17.91		17.36
7	Western Greece	17.25[+]	-	17.36
	Disaggregated default values e_{ec}	**18**	**29**	**19**

[+] *Actual data from relevant operators (no statistical data officially available).*

* *Data derived from the Hellenic Statistical Authority.*

** *Average actual data from relevant operators (no statistical data officially available).*

*** *Average actual data from relevant operators in 2010 (no statistical data officially available), as well as historical data from pilot cultivation in the 80's.*

6. Conclusion

The calculation of greenhouse gas emissions from cultivation of energy crop is always based on the mass in kg of the raw material (sunflower, rape seed, soybean). However, the default values of Directive 2009/28/EC were calculated on the basis of the energy content of biodiesel, which is only obtained after further conversion processes. The conversion from a mass-based value to an energy-based value depends essentially on the further stages of these processes and the resulting by-products (the values primarily presented in 'kg of CO_2 eq/kg of agricultural product' converted in a further stage into 'g of CO_2eq/MJ of biodiesel). To that end, where available, the conversion rates and allocation factors were derived from the BioGrace tables.

The regional values for the greenhouse gas emissions were then compared with these control values. It turned out that, **in all cases, the regional values for the greenhouse gas *emissions are below the control value*.**

GHG Emissions Calculation Tool

Sunflower

Greece

Estimation of GHG Emissions Reduction

Steps

1) Estimation of the consumed fossil fuel per hectare during the whole cultivation period (l/ha).
2) Conversion of the fossil fuel consumed into energy (MJ/ha), and subsequent conversion to emissions, using the fossil fuel emission factor (g CO_2/ ha).
3) Estimation of the emissions, occurring during the production of inputs ,by using the applied quantities and and the respective emission factors (g CO_2/ ha). At the same step, N_2O emission calculation takes place using an equation that takes into account both direct and indirect emissions.
4) Summation of the estimated emissions.
5) Estimation of the biofuel produced per hectare.
6) Estimation of typical GHG emissions (g CO_2/ $MJ_{of\ biofuel}$)
7) Emissions occuring after harvest and until the filling station stage (derived from the BioGrace example) are summed up so as to calculate the final typical GHG emissions.
8) Finally the GHG emissions reduction (%) is estimated (compared to the replaced fossil fuel).

GHG EMISSIONS ESTIMATION FOR THESSALY REGION

Feedstock production emissions for Sunflower

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	40
ripping	-
cultivating	15
rolling	-
sowing	8
fertilizing	-
spraying	2
hoeing	15
Harvesting	20
Sum	100
Sum (kg/ha)	83,20

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
3585,92	314270,03

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	5	3649,5
N	45	264627
P_2O_5	20	20214
K_2O	20	11522
pesticide	0,4	4388,52
Sum		304401,02

N_2O emissions (g CO_2e/ ha)	170096,4

Total Emissions (g CO_2e/ ha) **788767,45**

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
2000	760	760	28272

Typical cultivation emissions (g CO_2/ MJ_{Farm})	Typical cultivation emissions (Allocation) (g CO_2/ MJ_{Farm})
27,90	17,55

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro Inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	729,9
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	296

Values (Biograce GHG emission calculation tool

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0,82	0,82	0,82
Filling station	0,44	0,44	0,44
Sum	26,16	26,63	43,2

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8
	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9

GHG EMISSIONS ESTIMATION FOR EPIRUS REGION

Feedstock production emissions for Sunflower

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	40
ripping	-
cultivating	15
rolling	-
sowing	8
fertilizing	-
spraying	2
hoeing	15
Harvesting	20
Sum	100
Sum (kg/ha)	83,20

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
3585,92	314270,03

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	5	3649,5
N	45	264627
P_2O_5	20	20214
K_2O	20	11522
pesticide	0,4	4388,52
Sum		304401,02

N_2O emissions (g CO_2e/ ha)	170096,4

Total Emissions (g CO_2e/ ha) **788767,45**

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
2000	760	760	28272

Typical cultivation emissions (g CO2/ MJ_{Fame})	Typical cultivation emissions (Allocation) (g CO2/ MJ_{Fame})
27,90	17,55

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro Inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	729,9
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	296

Values (Biograce GHG emission calculation tool

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0,82	0,82	0,82
Filling station	0,44	0,44	0,44
Sum	26,16	26,63	43,2

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8

	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9

GHG EMISSIONS ESTIMATION FOR WEST MACEDONIA REGION

Feedstock production emissions for Sunflower

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	40
ripping	-
cultivating	15
rolling	-
sowing	8
fertilizing	-
spraying	2
hoeing	15
Harvesting	20
Sum	100
Sum (kg/ha)	83,20

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
3585,92	314270,03

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	5	3649,5
N	20	117612
P_2O_5	20	20214
K_2O	20	11522
pesticide	0,4	4388,52
Sum		157386,02

N_2O emissions (g CO_2e/ ha)	75598,4

Total Emissions (g CO_2e/ ha)	547254,45

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
1400	532	532	19790,4

Typical cultivation emissions (g CO2/ MJ_{biod})	Typical cultivation emissions (Allocation) (g CO2/ MJ_{biod})
27,65	17,39

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	729,9
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	296

Values (Biograce GHG emission calculation tool

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0,82	0,82	0,82
Filling station	0,44	0,44	0,44
Sum	26,16	26,63	43,2

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8

	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9

GHG EMISSIONS ESTIMATION FOR EAST MACEDONIA & THRACE REGION

Feedstock production emissions for Sunflower

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	40
ripping	-
cultivating	15
rolling	-
sowing	8
fertilizing	-
spraying	2
hoeing	15
Harvesting	20
Sum	100
Sum (kg/ha)	83,20

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
3585,92	314270,03

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	5	3649,5
N	35	205821
P_2O_5	20	20214
K_2O	20	11522
pesticide	0,4	4388,52
Sum		245595,02

N_2O emissions (g CO_2e/ ha)	132297,2

Total Emissions (g CO_2e/ ha) **692162,25**

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
1820	691,6	691,6	25727,52

Typical cultivation emissions (g CO2/ MJ_{fame})	Typical cultivation emissions (Allocation) (g CO2/ MJ_{fame})
26,90	**16,92**

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	729,9
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	296

Values (Biograze GHG emission calculation tool

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0,82	0,82	0,82
Filling station	0,44	0,44	0,44
Sum	26,16	26,63	43,2

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8

	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9

GHG EMISSIONS ESTIMATION FOR CENTRAL MACEDONIA REGION

Feedstock production emissions for Sunflower

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	40
ripping	-
cultivating	15
rolling	-
sowing	8
fertilizing	-
spraying	2
hoeing	15
Harvesting	20
Sum	100
Sum (kg/ha)	83,20

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
3585,92	314270,03

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	5	3649,5
N	50	294030
P_2O_5	20	20214
K_2O	20	11522
pesticide	0,4	4388,52
Sum		333804,02

N_2O emissions (g CO_2e/ ha)	188996

Total Emissions (g CO_2e/ ha) **837070,05**

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
2300	874	874	32512,8

Typical cultivation emissions (g CO2/ MJ_{Fame})	Typical cultivation emissions (Allocation) (g CO2/ MJ_{Fame})
25,75	16,19

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	729,9
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	296

Values (Biograce GHG emission calculation tool

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0,82	0,82	0,82
Filling station	0,44	0,44	0,44
Sum	26,16	26,63	43,2

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8

	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9

GHG EMISSIONS ESTIMATION FOR CONTINENTAL GREECE & EUBOEA REGION

Feedstock production emissions for Sunflower

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	40
ripping	-
cultivating	15
rolling	-
sowing	8
fertilizing	-
spraying	2
hoeing	15
Harvesting	20
Sum	100
Sum (kg/ha)	83,20

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
3585,92	314270,03

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	5	3649,5
N	30	176418
P_2O_5	20	20214
K_2O	20	11522
pesticide	0,4	4388,52
Sum		216192,02

N_2O emissions (g CO_2e/ ha)	113397,6

Total Emissions (g CO_2e/ ha)	643859,65

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
1600	608	608	22617,6

Typical cultivation emissions (g CO2/ MJ_{biod})	Typical cultivation emissions (Allocation) (g CO2/ MJ_{biod})
28,47	17,91

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	729,9
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	296

Values (Biograce GHG emission calculation tool

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0,82	0,82	0,82
Filling station	0,44	0,44	0,44
Sum	26,16	26,63	43,2

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8

	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9

GHG EMISSIONS ESTIMATION FOR WESTERN GREECE REGION

Feedstock production emissions for Sunflower

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	40
ripping	-
cultivating	15
rolling	-
sowing	8
fertilizing	-
spraying	2
hoeing	15
Harvesting	20
Sum	100
Sum (kg/ha)	83,20

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
3585,92	314270,03

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	5	3649,5
N	50	294030
P_2O_5	30	30321
K_2O	30	17283
pesticide	0,4	4388,52
Sum		349672,02

N_2O emissions (g CO_2e/ ha)	188996

Total Emissions (g CO_2e/ ha) 852938,05

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
2200	836	836	31099,2

Typical cultivation emissions (g CO_2/ MJ_{sunf})	Typical cultivation emissions (Allocation) (g CO_2/ MJ_{sunf})
27,43	17,25

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	729,9
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	296

Values (Biograce GHG emission calculation tool

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0.82	0.82	0,82
Filling station	0.44	0.44	0,44
Sum	26,16	26,63	43,2

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8

	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9

GHG Emissions Calculation Tool
Oilseed rape
Greece

Estimation of GHG Emissions Reduction

Steps

1) Estimation of the consumed fossil fuel per hectare during the whole cultivation period (l/ha).
2) Conversion of the fossil fuel consumed into energy (MJ/ha), and subsequent conversion to emissions, using the fossil fuel emission factor (g CO_2/ ha).
3) Estimation of the emissions, occurring during the production of inputs ,by using the applied quantities and and the respective emission factors (g CO_2/ ha). At the same step, N_2O emission calculation takes place using an equation that takes into account both direct and indirect emissions.
4) Summation of the estimated emissions.
5) Estimation of the biofuel produced per hectare.
6) Estimation of typical GHG emissions (g CO_2/ $MJ_{of\ biofuel}$)
7) Emissions occuring after harvest and until the filling station stage (derived from the BioGrace example) are summed up so as to calculate the final typical GHG emissions.
8) Finally the GHG emissions reduction (%) is estimated (compared to the replaced fossil fuel).

GHG EMISSIONS ESTIMATION FOR EAST MACEDONIA - THRACE

Feedstock production emissions for Oilseed rape

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	40
ripping	30
cultivating	-
rolling	15
sowing	8
fertilizing	-
spraying	2
hoeing	-
Harvesting	20
Sum	115
Sum (kg/ha)	95,68

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
4123,81	361410,53

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	5	3649,5
N	100	588060
P_2O_5	20	20214
K_2O	20	11522
pesticide	0,4	4388,52
Sum		627834,02

N_2O emissions (g CO_2e/ ha)	377992

Total Emissions (g CO_2e/ ha) **1367236,55**

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
2000	764	764	28420,8

Typical cultivation emissions (g CO2/ MJ_{Fame})	Typical cultivation emissions (Allocation) (g CO2/ MJ_{Fame})
48,11	28,19

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	729,9
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	296

Values (Biograce GHG emission calculation tool

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0,82	0,82	0,82
Filling station	0,44	0,44	0,44
Sum	26,16	26,63	43,2

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8

	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9

GHG EMISSIONS ESTIMATION FOR CENTRAL MACEDONIA REGION

Feedstock production emissions for Oilseed rape

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	-
ripping	-
cultivating	15
rolling	15
sowing	8
fertilizing	-
spraying x 2	4
hoeing	15
Harvesting	20
Sum	77
Sum (kg/ha)	64,06

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
2761,16	241987,92

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	5	3649,5
N	120	705672
P_2O_5	20	20214
K_2O	20	11522
pesticide	0,4	4388,52
Sum		745446,02

N_2O emissions (g CO_2e/ ha)	453590,4

Total Emissions (g CO_2e/ ha)	**1441024,34**

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
2150	821,3	821,3	30552,36

Typical cultivation emissions (g $CO2/ MJ_{crop}$)	Typical cultivation emissions (Allocation) (g $CO2/ MJ_{crop}$)
47,17	27,64

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	729,9
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	296

Values (Biograce GHG emission calculation tool)

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0,82	0,82	0,82
Filling station	0,44	0,44	0,44
Sum	26,16	26,63	43,2

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8

	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9

GHG Emissions Calculation Tool
Soybean (non irrigated)
Greece

Estimation of GHG Emissions Reduction

Steps

1) Estimation of the consumed fossil fuel per hectare during the whole cultivation period (l/ha).
2) Conversion of the fossil fuel consumed into energy (MJ/ha), and subsequent conversion to emissions, using the fossil fuel emission factor (g CO_2/ ha).
3) Estimation of the emissions, occurring during the production of inputs ,by using the applied quantities and and the respective emission factors (g CO_2/ ha). At the same step, N_2O emission calculation takes place using an equation that takes into account both direct and indirect emissions.
4) Summation of the estimated emissions.
5) Estimation of the biofuel produced per hectare.
6) Estimation of typical GHG emissions (g CO_2/ $MJ_{of\ biofuel}$)
7) Emissions occuring after harvest and until the filling station stage (derived from the BioGrace example) are summed up so as to calculate the final typical GHG emissions.
8) Finally the GHG emissions reduction (%) is estimated (compared to the replaced fossil fuel).

GHG EMISSIONS ESTIMATION FOR ALL APPLICABLE REGIONS

Feedstock production emissions for Soybean (non irrigated)

Diesel Consumption

Operation	Consumption (l/ ha)
ploughing	40
ripping	30
cultivating	15
rolling	15
sowing	8
fertilizing	2
spraying	2
hoeing	15
Harvesting	20
Sum	147
Sum (kg/ha)	122,30

Fuel energy consumed (MJ/ ha)	Emissions (g CO_2/ ha)
5271,30	461976,94

Input Production emissions

	Quantity (kg/ ha)	Emissions per ha
seed	70	385000
N	0	0
P_2O_5	20	20214
K_2O	20	11522
pesticide	0,4	4388,52
Sum		421124,52

N_2O emissions (g CO_2e/ ha)	0

Total Emissions (g CO_2e/ ha)	883101,46

Typical Emissions

seed yield (kg/ ha)	oil yield (kg/ ha)	biodiesel yield (kg/ ha)	biodiesel energy (MJ/ ha)
1800	450	450	16740

Typical cultivation emissions (g CO2/ MJ_{crop})	Typical cultivation emissions (Allocation) (g CO2/ MJ_{crop})
52,75	17,36

Default Values

	Density (kg/ m^3)	LHV (MJ/ ha)	Emission Coefficient (g Co_2eq/ MJ)
Diesel Default Values	832	43,1	87,64
Biodiesel Default Values	890	37,2	-

Agro inputs	Emission Coefficient (gr CO_2eq/ kg)
Sunflower seed	729,9
Oilseed rape seed	*729,9*
Soybean seed	-
Pesticides	10971,3
N	5880,6
P_2O_5	1010,7
K_2O	576,1

Global Warming Potential (GWP's)	g CO_2eq/g
CO_2	1
N_2O	256

Values (Biograce GHG emission calculation tool

	g CO_2/ MJ		
	Sunflower	Oilseed rape	Soybean
Seed transport (50km)	0,28	0,3	0,3
Oil extraction	6,05	6,5	23,07
Oil refining	1,06	1,06	1,06
Esterification	17,51	17,51	17,51
FAME transport (300km)	0,82	0,82	0,82
Filling station	0,44	0,44	0,44
Sum	*26,16*	*26,63*	*43,2*

Crop	Total Allocation Factor (%)
Sunflower	25
Oilseed rape	31,5
Soybean	57,8
	Cultivation Allocation Factor (%)
Sunflower	62,9
Oilseed rape	58,6
Soybean	32,9