Ministry of Environment and Physical Planning
The Government of the Republic of Macedonia

Climate change mitigation potential and measures in the sector agriculture

Third National Communication to UNFCCC

Skopje, 2013

This document presents the climate change mitigation potential in the agriculture sector, and further proposes mitigation mesasures and estimates their feasibility, CO_2 reduction and possible co-bennefits. This document provides important guidance for policy-makers in developing adaptation strategies and further strengthens the dialogue, information exchange and cooperation among all the relevant stakeholders including governmental, non-governmental, academic, and private sectors.

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1. Introduction

The agriculture sector, including the value added in the processing industry, contributes 16% to country's GDP and provides employment to 36% of the workforce. The most recent national census recorded 192,675 family farms in a country of 2.1 million inhabitants. Consequently, given the fact that about 45% of country's population live in rural areas where off farm employment opportunities are rather limited (active workforce unemployment rate in Macedonia is as high as 32%), a more realistic conclusion would be that the agriculture sector is of critical importance for the wellbeing of about half of country's population. Macedonian agricultural sector is characterized with a dual structure i.e. corporate farms that farm larger pieces of land acquired through the privatization of the former state owned farms, and small family farms that farm about 80% of country's agricultural land with an average landholding of 2.8 hectares divided into 6 non-contiguous plots(source?). Based on the available resources and capital intensity the family farming sector can be broken down into three groups: (a) market producers; (b) semi-subsistence farms; and (c) subsistence farms. Land use for agriculture in the form of cropland and pastures is substantial in Macedonia and occupies approximately less than 50% of the surface area of the country (1121 thousand ha, State Statistical Office, 2010),

By area, wheat is clearly the major annual crop grown, with smaller areas used for barley, maize and a range of vegetable crops. Grapes are the main perennial crop in Macedonia and occupy close to 25000 ha. Although the area occupied by fruit and nut trees is relatively small, potential exists to expand this area in the future.

The agriculture sector plays an important role in FYR Macedonia's economy through its contributions to GDP (agriculture accounts for 12% of GDP), employment, trade and the rural economy, with the country's nearly half the population living in rural areas. About 49% of the total land area is agricultural land, split evenly between arable land and pastures. Of the cultivated land, about 80% is used by approximately 180,000 private family farms(source?).

Each year, on a global level agriculture emits 10 to 12 percent of the total estimated GHG emissions, or nearby 5.1 to 6.1 Gt CO2 equivalents per year(source?).

In Republic of Macedonia the sector Agriculture accounts for an average of 13% of the total GHG emissions of the country, and therefore is country's second biggest contributor to GHG emissions (source: National Inventory Report 2003 -2009, Third National Communication to the UNFCCC, Republic of Macedonia). The country is considered to be agricultural country with a long tradition of crop production, and this gives many possibilities for GHG mitigation practices and techniques.

The agricultural sector has high mitigation potential with strong adaptation and sustainable development co-benefits. In this paper the mitigation potential of the agricultural sector will be assessed end evaluated, and the most promising and feasible measures for GHG mitigations will be addressed and prioritized.

Table 1.1. Measures and activities for mitigating GHG emissions from agriculture (Source: *UNEP Risø Centre on Energy, Climate and Sustainable Development*)

Mitigation measure	**Activity**	**Technology examples discussed**	**Mitigation effects**		
			CO_2	**CH_4**	**N_2O**
Cropland	**Agronomy**	Agricultural biotechnology	√	√	
		Cover crop technology	√		
	Nutrient management	Fertiliser management technologies	√		√
		Using mycorrhiza	√		
	Tillage/residue management	Zero-tillage, Conservation tillage	√		?
		Biochar	√		

	Water management	Sprinkler and drip irrigation, Fog and rainwater harvesting	?		√
	Rice management	Fertiliser and manure management		√	
		Mid-season water drainage		√	√
		Alternate wetting and drying		√	
		Potassium fertiliser application		√	
		Nitrification inhibitors		√	
		Agriculture biotechnology		√	
		Methane mitigation using reduced tillage		√	
		Chemical fertiliser amendment		√	
		Direct seeding technology		√	
		Amendment in ethanogenic activity using electron acceptors		√	
	Agro-forestry	Agro-forestry	√		√
Livestock management	**Improved feeding practices**	Feed optimisation		√	
		Extension of ammoniated straw and sillage		√	
	Specific agents and dietary additives	GM rumen bacteria to produce lower methane		√	
	Longer term structural and management changes and animal breeding	Animal species and performance		√	
Manure/ bio-solid management	**Improved storage and handling**	Covering manure storage facilities		√	?
	Anaerobic decay of agriculture waste (anaerobic digestion)	Crop residue management		√	?
		Biogas digester with methane recovery	√	√	√
Bioenergy	**Energy crops, solid, liquid, biogas, residues**	Agriculture for bio-fuel production	√	√	√
		Micro-algae (also to make bio-diesel)	√		
Integrated and other technologies	**Organic agriculture**	Organic agriculture	√	√	√

In this assessment few mitigation options of agricultural practices and techniques applicable in FYR Macedonia are proposed in order to achieve specific reductions in GHG emissions:

- Organic Farming
- Etheric Fermentation
- Manure Management
- Crop residues management

- Production of biogas from farming
- Sprinkler and drip irrigation
- Conservation of tillage and fertilizers

The technical mitigation potential of agriculture is extremely large, especially relative to emissions from the sector.
In terms of abatement costs, the sector is particularly attractive, with many abatement options being cost neutral or net-profit-positive (increases in agricultural production, already economically justify the adoption of some mitigation activities), with low capital investment required.

2. Agricultural management practices

2.1. Irrigation

Irrigation is important to achieving high yields in arid and semi-arid regions, but on the other hand irrigation is very carbon intensive meaning that lot of energy is spent for pumping water. The required energy for water pumping depends on many factors including total dynamic head (based on water lift, pipe friction, system pressure), the water flow rate and the pumping system efficiency furthermore, inefficient irrigation that leaves the soil overly wet leads to higher emissions of N_2O which is an green-house gas with higher global warming potential than the CO_2. On the other hand irrigation leads to higher biomass production that leads to higher carbon sequestration. Carbon sequestration is the process of capture and long-term storage of atmospheric CO_2 and may refer specifically to naturally capturing CO_2 from the atmosphere through biological, chemical or physical processes in the plants. CO_2 emissions can be reduced with effective irrigation by increasing yields and crop residues which can enhance carbon sequestration. Increasing yields and efficiency generally reduces emissions as well, since more food results from the same or less effort.
For the purposes of the Third National Communication to UNFCCC an investigation was made of the impact of irrigation to three crops with main economic importance: maize, wheat and sunflower. The research was done for the South Eastern Region and further extrapolated for the whole territory of the country. The modeling of the crop yield production was done in the BioMa framework developed by the Joint Research Center in Ispra by utilization of the CropSyst model. The gathered results are presented in the document "Vulnerability assessment and Adaptation on Climate Change in Agriculture, Third Nationa Communication to UNFCCC". In order to access the mitigation potential from the irrigation practices and increased biomass production the results from the above mentioned document will be used.
In order to calculate the yield production different scenarios were proposed which describe different irrigation patterns. For the purpose of our investigations the time horizons that are studied are 2025 and 2050, and the comparison is done against a baseline year – 2000, considered as a representative of current conditions. In the scenarios are included different irrigation types: sprinkler, drip irrigation, furrow and border irrigation. For each irrigation scenario is described a water volume and irrigation pattern with number of irrigations. The irrigation pattern can be fixed e.g. every 20 days or can be dependent from other circumstances e.g. drought period.
The scenarios are described in the tables below:

Table 2.1 Agro management scenario for wheat, (Source: "Vulnerability assessment and Adaptation on Climate Change in Agriculture, Third Nationa Communication to UNFCCC")

	SC 0	SC 1	SC 2	SC 3	SC 4	SC 5
PLANTING						
Planting depth [m]	0.03	0.04	0.04	0.04	0.04	0.04
Day of the year	296	297	297	319	328	328
HARVESTING						
Yield loss fraction [%]	0.0	0.1	0.1	0.1	0.1	0.1
Day of the year	253	254	254	230	216	216

IRRIGATION						
Start-Day of the year		202	220	165	150	130
End-Day of the year		224	220	191	191	190
Irrigation type	NO IRRIGATION	SPRINKLER	SPRINKLER	SPRINKLER	SPRINKLER	SPRINKLER
Irrigation volume [mm]		60	80	60	60	60
Max. No of irrigations		2	1	2	2	ON 20d

Table 2.2. Agro management scenario for maize, (Source: "Vulnerability assessment and Adaptation on Climate Change in Agriculture, Third Nationa Communication to UNFCCC".)

	SC 0	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6	SC 7	SC 8	SC 9
PLANTING										
Planting depth [m]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Day of the year	110	110	110	110	110	110	110	110	110	110
HARVESTING										
Yield loss fraction [%]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Day of the year	263	263	263	263	263	263	263	263	263	263
IRRIGATION										
Start-Day of the year		157	177	171	157	157	177	171	160	160
End-Day of the year		216	216	206	227	216	216	206	225	225
Irrigation type	NO IRRIGATION	SPRINKLER	SPRINKLER	SPRINKLER	DRIP IRRIGATION	FURROW	FURROW	FURROW	SPRINKLER	BORDER IRRIGATION
Irrigation volume [mm]		60	60	80	30	60	60	80	30	30
Max. No of irrigations		5	4	2	13	5	4	2	ON 14d	ON 14d

Table 2.3. Agro management scenario for sunflower, (Source: "Vulnerability assessment and Adaptation on Climate Change in Agriculture, Third Nationa Communication to UNFCCC".)

	SC 0	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6	SC 7	SC 8	SC 8
PLANTING										
Planting depth [m]	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Day of the year	116	117	117	117	117	117	117	117	117	117
HARVESTING										
Yield loss fraction [%]	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Day of the year	254	254	254	254	254	254	254	254	254	254

IRRIGATION										
Start-Day of the year		159	163	173	159	159	163	173	173	160
End-Day of the year		217	208	206	234	217	208	206	206	220
Irrigation type	NO IRRIGATION	SPRINKLER	SPRINKLER	SPRINKLER	DRIP IRRIGATION	FURROW	FURROW	FURROW	FURROW	SPRINKLER
Irrigation volume [mm]		50	50	70	15	50	50	70	70	50
Max. No of irrigations		4	3	2	12	4	3	2	2	ON 20d

Except the agro management scenarios that were proposed the Cropsyst needs to be fed with data describing the future weather events, soil and crop. An initial default soil data was collected form the JRC in Ispra. Since coverage of soil profiles is not uniform throughout Europe for the purposes of this project the soil parameter files were customized in order to comply to the South Eastern region specifics. The model can be run on a single soil profile at a time. Because of this limitation different soil profiles were developed and the simulations were executed on different sets of parameters. Around 20 soil profiles were developed, keeping in mind that the alluvial soils are more convenient for maize and sunflower cultivation and colluvial soilsare more appropriate for wheat and barley cultivation the produced files will be uses correspondingly. It must be pointed out that the simulations limited to soil water are sensitive to basic soilparameters derived from texture, and soil depth, as they determine the hydraulic characteristics. The CropSyst model uses a specific set of parameters corresponding to the crop type. The Crop parameters are numerical representation of the phenology (thermal time requirements to reach specific growth stages, modulated by photoperiod and vernalization requirements if needed), Morphology (Maximum LAI, root depth, specific leaf area and other parameters defining canopy and root characteristics), Growth (transpiration-use efficiency normalized by VPD, light-use efficiency, stress response parameters, etc.), Residue (decomposition and shading parameters for crop residues), Harvest Index etc. For the purposes of this simulation three crop files were developed that represent the crops in the in Macedonia. The gathered results for each scenario are displayed in the Table 2.5. for two years in the future and yield growth rate in comparison to the base scenario (Scenario 0) are displayed in Table 2.6.

Table 2.4. Crop yield production depending on different agro management techniques, [kg/ha]

MAIZE [kg/ha]										
Year	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y	SC 9 Y
2000	5,335.80	7,227.82	7,010.98	6,721.87	7,141.10	7,083.26	6,938.71	6,649.59	7,227.82	6,442.25
2025	3,407.21	6,434.38	6,241.35	4,519.05	5,976.25	6,134.99	5,449.43	4,470.46	5,381.56	4,168.01
2050	2,858.93	4,121.02	3,997.38	3,711.30	4,061.47	4,038.60	3,937.90	3,671.40	3,983.99	3,431.40

WHEAT [kg/ha]						
Year	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y
2000	3,378.78	3,716.66	3,547.72	4,348.04	4,495.79	4,495.79
2025	2,699.46	2,969.41	2,834.44	3,116.24	3,973.97	3,701.27

2050	2,555.83	2,811.42	2,683.63	3,437.04	3,973.97	4,456.81

SUNFLOWER	[kg/ha]								
Year	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y
2000	1,703.68	2,416.67	2,370.64	2,340.72	2,407.47	2,391.36	2,340.72	2,336.12	2,329.21
2025	1,161.39	2,111.95	2,071.72	1,841.65	1,990.81	1,998.36	1,770.95	1,760.69	2,035.52
2050	966.93	1,170.68	1,148.38	1,133.89	1,166.22	1,158.42	1,133.89	1,131.66	1,128.31

Table 2.5. Yield growth rate depending on different agro management techniques, [kg/ha]

MAIZE										
Year	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y	SC 9 Y
2000	0.00%	35.46%	31.40%	25.98%	33.83%	32.75%	30.04%	24.62%	35.46%	20.74%
2025	0.00%	88.85%	83.18%	32.63%	75.40%	80.06%	59.94%	31.21%	57.95%	22.33%
2050	0.00%	44.15%	39.82%	29.81%	42.06%	41.26%	37.74%	28.42%	39.35%	20.02%

WHEAT						
Year	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y
2000	0.00%	10.00%	5.00%	28.69%	33.06%	33.06%
2025	0.00%	10.00%	5.00%	15.44%	47.21%	37.11%
2050	0.00%	10.00%	5.00%	34.48%	55.49%	74.38%

SUNFLOWER									
Year	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y
2000	0.00%	41.85%	39.15%	37.39%	41.31%	40.36%	37.39%	37.12%	36.72%
2025	0.00%	81.85%	78.38%	58.57%	71.42%	72.07%	52.49%	51.60%	75.27%
2050	0.00%	21.07%	18.77%	17.27%	20.61%	19.80%	17.27%	17.04%	16.69%

The above presented results are referring to a single region in Macedonia that will further be extrapolated to the entire country. The final task is to calculate which of the irrigation practices is most feasible in terms of CO_2 mitigation but, also positively influences the crop yield production and it is a cost effective solution for the farmers. The literature review estimates C emission at the average rate of 1448.3 kg CO_2-eq /ha for furrow irrigation, 446 kg CO_2 -eq/ha for sprinkler irrigation and 792 kg CO_2-eq /ha for drip irrigation (ITRC, 1994).

A mitigation strategy would include improvement of the water utilization effectiveness flood and furrow irrigation which is assessed to be the most wasteful use of water in favor of sprinkler irrigation or using drip and sub-irrigation. Another important aspect that will be assessed is the number of irrigations and amount water used. The results from this investigation are displayed in the Table 6, 7 and 8 in kg CO_2-eq/kg yield. It is visually distinguished which scenarios are less carbon intensive per kilogram yield with greener color.

Table 2.6. Carbon intensity per kilogram maize yield, [kg CO_2 -eq/kg yield]

MAIZE	[kg CO_2 -eq/kg yield]								
Year	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y
Irrigation type		Sprinkler	Sprinkler	Sprinkler	Drip Irr.	Furrow	Furrow	Furrow	Sprinkler

[mm] water per irr.		60	60	80	30	60	60	80	30
irr. number		5	4	2	13	5	4	2	ON 14d
2000	/	0.06	0.05	0.04	0.14	0.20	0.17	0.12	0.03
2025	/	0.13	0.06	0.04	0.23	0.24	0.19	0.14	0.05
2050	/	0.16	0.09	0.06	0.28	0.36	0.29	0.20	0.06

Table 2.7. Carbon intensity per kilogram wheat yield, [kg CO_2 -eq/kg yield]

WHEAT	[kg CO_2 -eq/kg yield]					
Year	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y
Irrigation type		Sprinkler	Sprinkler	Sprinkler	Sprinkler	Sprinkler
[mm] water per irr.		60	80	60	60	60
irr. number		2	1	2	2	ON 20d
2000	/	0.12	0.08	0.10	0.10	0.15
2025	/	0.15	0.10	0.14	0.11	0.18
2050	/	0.16	0.11	0.13	0.11	0.15

Table 2.8. Carbon intensity per kilogram sunflower yield, [kg CO_2 -eq/kg yield]

SUNFLOWER	[kg CO_2 -eq/kg yield]								
Year	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y
Irrigation type		Sprinkler	Sprinkler	Sprinkler	Drip Irr.	Furrow	Furrow	Furrow	Sprinkler
[mm] water per irr.		60	60	80	30	60	60	80	30
irr. number		5	4	2	13	5	4	2	ON 20d
2000	/	0.26	0.15	0.10	0.44	0.60	0.48	0.33	0.15
2025	/	0.38	0.17	0.11	0.56	0.73	0.58	0.44	0.20
2050	/	0.46	0.30	0.21	0.91	1.24	1.00	0.68	0.32

The results above shows what irrigation practices are most suitable in order to mitigate the GHGs emissions but comparing how much is the carbon intensity of the practice comparing to the yield production growth rate. It is shown that even that higher number of irrigations with less water is more energy demanding but the yield production growth rate is higher which implies less emission per kilogram yield. Also can be seen that efficient irrigation (only in the days of droughtaccodin the plant needs) is a better solution than a (fixed irrigation schedule) static days of irrigation (e.g. every second week) although the results vary depending on the weather condition and the crop. In terms of type of irrigation is clear that the furrow irrigation is least efficient and leads to higher GHGs emission.
Further it has to be investigated how much the implementation of the irrigation system will cost the farmers. An economic feasibility analysis was performed for investing in the irrigation system and also for the water collecting and irrigation system together. The results are given in Table 9 and Table 10.

Table 2.9 Economic feasibility to invest in irrigation system (Source: Economic feasibility analysis of the proposed Climate Change modeling scenarios in the agriculture sector)

MAIZE

Scenario	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y
PP		3	3	9	33				4
NPV	-8943	4259	3979	711	-3250	-9704	-10789	-12828	2874
IRR		38.30%	36.32%	10.40%	-0.23%				24.59%

WHEAT

Scenario	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y
PP				23	8	12
NPV	-2629	-1969	-2203	-685	1524	1539
IRR				2.76%	13.08%	11.49%

SUNFLOWER

Scenario	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y
PP		5	5	8					6
NPV	-4580	600	654	-88	-5886	-13279	-13769	-13758	466
IRR		15.01%	15.01%	3.25%					13.29%

When relating the two analysis can be concluded that SC1, SC2, SC3 for maize, SC4 for wheat and SC2, SC3 for sunflower are the most cost effective mitigation practices if the farmer invests only in the irrigation system.

Table 2.10 Economic feasibility to invest in water collecting and irrigation system (Source: Economic feasibility analysis of the proposed Climate Change modeling scenarios in the agriculture sector)

MAIZE

Scenario	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y
PP		8	8	24					8
NPV	-8943	1237	1509	-1022	-7117	-12743	-13281	-14587	1331
IRR		8.92%	10.23%	3.19%					10.32%

WHEAT

Scenario	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y
PP					15	18
NPV	-2629	-3367	-3234	-2067	158	-378
IRR					6.42%	5.30%

SUNFLOWER

Scenario	SC 0 Y	SC 1 Y	SC 2 Y	SC 3 Y	SC 4 Y	SC 5 Y	SC 6 Y	SC 7 Y	SC 8 Y
PP									
NPV	-4580	-1518	-1004	-1654	-7819	-15414	-15435	-15332	-1192
IRR		-0.21%	0.66%						-0.52%

On the other hand if the farmer additionally invests in the water collection system then the SC1, SC2 for maize, SC4 for wheat and no scenario for sunflower are the most cost effective mitigation practices.

2.2. Management of fertilizers

Efficient use of nitrogenous fertilisers can reduce N_2O emissions from agricultural fields. In addition, by reducing the quantity of synthetic fertilisers required, improved management can also reduce CO_2 emissions associated with their manufacture. Organic agriculture reduces emission of N_2O due to the ban on the use of mineral nitrogen and the reduction in livestock units per hectare. A diversified crop rotation with green manure in organic farming improves soil structure and diminishes emissions of N_2O, although the nitrogen provided by the green manure does contribute to N_2O emissions. Soils in organic farming are more aerated and have significantly lower mobile nitrogen concentrations, which reduces emissions of N_2O. Since organic crop systems are limited by the availability of N, they aim to balance their N inputs and outputs and their N use efficiency.

Substituting the use of mineral fertiliser through compost use offers the opportunity of reducing GHG emissions caused by the manufacturing and transportation of fertilisers. In order to estimate the potential for reducing GHG emissions, the typical nutrient contents of compost has to be established, as well as the level of GHG emissions that are associated with the manufacturing and transportation of various fertiliser.

Table 2.11 Nutrient content in fertilizers and GHG emissions from fertilizers

Nutrient element	***Nutrient content***	***Crop uptake***	***Fertilizer nutrients replaced***	***Fertilizer GHG emissions (kg CO2eq/t)***	***Avioded GHG emissions (kgCO2-eq per t)***
N	15	40%	6	3500	21
P	3	100%	3	350	1.1
K	8	100%	8	300	2.4
Total					24.5

The use of 10 tonnes of mature organics compost on hectare as agricultural soil conditioner is expected to replace the use of synthetic fertiliser which saves **178 kg CO2-eq o**f GHG emissions (Source: The benefits of using compost for mitigating climate change, Department of Environment, Climate Change and Waterof Australia, February 2011). For app. 1,100,000 ha of agriculture land in the country, net reductions are 1.54 Gg of CO_2-eq. per year.
Thus, their emissions are lower than those of conventional farming systems per unit of land area.

Table 2.12 Comparation between the GHG emissions from synthetic and organic fertilizers[1]

Fertilizer type	N_2O	CO_2-eq	CO_2-eq reductions	Cummulative CO_2-eq reductions until 2030 (measures implemented starting from year 2014)
Organic F	0.05	15.5	1.54	26.18
Synthetic F	0.08	24.8	/	/

Fertilisers can comprise up to 30 % of farm expenditure, so it is important to use the right quantity and product. The higher the crop's potential, the greater is its nutrient requirement. Seasonal forecasts can be useful when determining a flexible nitrogen fertiliser strategy. Having a better understanding of the timing and amounts of rainfall and their impact on potential yield will allow growers to take advantage of different growing season conditions.

[1] Source: Technologies for efficient manure utilization and nutrient management Agren Inc., ICF Consulting

Under wet conditions, emission of N_2O from NO^{3-}containing fertilisers is often higher than from fertilisers containing only NH^{4+} (Clayton et al., 1997). Therefore, for wet conditions, a fertilisation strategy in which fertiliser containing only NH^{4+} instead of the commonly used NO^{3-} fertiliser are applied, may be an appropriate option to *mitigate N_2O emission from intensively managed arable land or grasslands*.
A reduction (e.g. by limits) of the application of synthetic fertiliser in arable and grassland systems can reduce the total amount of nitrogen in the systems (AEA Technology Environment, 1998; Hendriks et al., 1998). This implies a more efficient use of manure that is otherwise disposed of as waste products (Hendriks et al., 1998).
Emissions of N_2O as well as emissions of NH_3 will decrease because of a reduction in the use of synthetic fertilisers. AEA Technology Environment (1998) reported that a limit on synthetic fertiliser application on cereals and grassland of 22-50 kg per ha would result in a clear reduction of synthetic fertiliser use and associated N_2O emissions. Table below shows reduction potential from reduced N-fertilizers input and substitution of synthetic fertilizers with animal manure on wheat and barley crops in our country (Options to reduce nitrous oxide emissions, EC 1998) if measures are implemented from the year 2014 until 2030.

Table 2.13 Reduction potential from reduced N-fertilizers input and substitution of synthetic fertilizers with animal manure on wheat and barley crops

Type of Measure	Crop	Land [ha]	Reduction potential	N_2O-N reduction [t]	N_2O reduction [t]	N_2O reduction [Gg]	Cummulative N_2O under BAU [Gg]	Cummulative N_2O reduction [Gg]
Reduced use of N-fertilizers	Wheat	67,105	50kg/ha	3,355	41.94	13	406.78	185.79
	Barley	23,881	30kg/ha	716	8.96	2.78		47.26
Use of animal manure	Wheat and Barley	90,986	22kg/ha	2,001	25.02	7.76		131.92

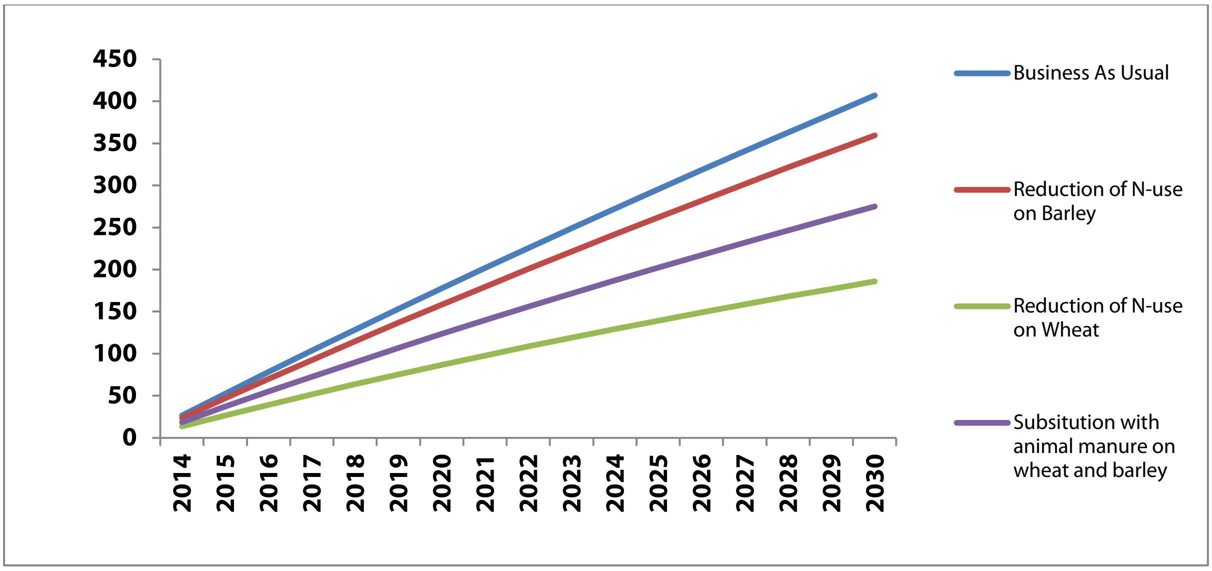

Figure 2.1. Comparing diferent scenarios for reduction or substitution of synthetic fertilizers and cumulative GHG emissions (source??)

According to recent research studies on composts in Europe (J. Barth, ECN, Quality and markets for compost and digestion residues in Europe, p.7) price is 12.5 EUR per tonne of compost. Raw livestock waste is collected from the farm and transported 50 km to a processing plant. Given a hypothetical distance of 100 km for a return journey, costs of *transporting the manure* would be 12 EU/kg N (slurry), 22 EU/kg N (manures) and 1.8 EU/kg N (poultry litter). The waste is stored, dried, and then transported 100 km to the point of application and back on the farm. The estimated cost of *processing* the manure was based on a Dutch study of the costs of treating pig slurry (van de Kamp & Smart, 1993). The researchers estimated that treating pig slurry costs 17 EU/t. *Storage costs* were based on an estimated cost of slurry storage at 2.71 EU/t/yr (ETSU, 1996). Storage capacity was assumed to be 25% of the total volume of raw manure handled.

Table 2.14 Typical manure management costs

Processing of manure costs (EUR)	***Storage of manure costs (EUR)***	***Transport of manure costs (EUR)***	***Total costs (EUR)***
126,207	20,119	163,326	309,625

Synthetic fertilizers cost (Diammonium phosphate, Super-phosphate, Ammonium nitrate, Potassium chloride) in 2011 were on average 305 EUR per tonne (World Bank database on fertlizers, 2011).
Substiution of 7,423 tonnes synthetic fertilizers (SSO, 2009) with animal manure should reduce the costs from 2,264,296 EUR/year to 402,451 EUR/year (not considering costs for NPK enrichment of soils, since animal manure has a very low percentage of these elements in contrast to synthetic fertilizers). Table below presents comparison between organic and synthetic fertilizers nutrient content.

Table 2.15 Nutrient cotent in organic and synthetic fertilizers 2

Organic fertilizers (treated animal manure)	**% N**	**% P**
Cattle	2.0	1.5
Sheep	1.9	1.4
Poultry	4.5	2.7
Synhtetic fertilizer type	**% N**	**% P**
Ammonium Nitrate	33.5	/
Diammonium phosphate	20	50

Following Table presents expected total manure from different animal farms and nutrient content.

Table 2.16 Estimation of animal manure from different livestock animals and expected amounts of N:P:K in tonnes/year (activity data from SSO, 2009)3.

Livestock	***Average weight (kg)***	***Manure per animal (t/yr)***	***Total Manure (t/yr)***	***N per animal (t/year)***	***Total N in manure (t/yr)***	***P per animal (t/year)***	***Total P in manure (t/yr)***	***K per animal (t/year)***	***Total K in manure (t/yr)***
Dairy	635	21.9	2,405,890	0.03	3,186	0.03	3,186	0.08	8,679
Non-dairy	567	13.7	740,882	0.02	1,190	0.03	1,676	0.05	2,650
Sows	170	4.1	114,767	0.006	168	0.0045	126	0.013	364
Broilers	0.9	0.026	909	0.0002	5	0.0002	5	0.0001	4
Layers	1.81	0.038	77,562	0.0002	408	0.0002	408	0.0001	204
Totals:			3,340,010		4,957		4,957		5,402

In case of six representative farms (5 pig and 1 poultry) in the country, total expected organic fertilizers and profit from sales are presented below:

[2] Source: Massey R, 2007. Value of manure as a fertilizer, http://chemicalland21.com/industrialchem/inorganic/NPK.htm
[3] Source: http://learningstore.uwex.edu/How-Much-Fertilizer-Do-Your-Animals-Produce-P105.aspx

Table 2.17 Animal manure and potential profit from sale of oganic fertilizers on the market

Farm	Animals	Manure per animal (t/yr)	Total manure (t/yr)
Agria	28,403	4.1	116,452
ZZ Edinstvo	27,140	4.1	111,274
Mak Meso	26,300	4.1	107,830
Vinefarm	18,500	4.1	75,850
Zito Malesh	15,750	4.1	64,575
Veze Shari	240,000	0.026	6,240
		Total animal manure	482,221
Total organic fertilizer after composting (43.75%)			210,972
		Sales profit	2,637,148

In case all animal manure in the country??? is utilized trough composting (1.46 million tonnes) and sold on the market at average price 12.5 EUR/tonne compost, there is a potential profit of 18,250,000 EUR/annualy.

2.3. Carbon sequestration nema primer za nasata zemja, dali da ostane ova??

The link to climate change mitigation is based on its carbon neutrality and potential for additional carbon sequestration. The sustainable use of biomass for energy production, that is the use of biomass at a rate at which it can be reproduced on the same land,is per se carbon neutral. Carbon neutrality implies that the carbon, which is released to the atmosphere through the combustion process, is sequestered equally in the re-growing biomass. Most biomass production schemes will, however, sequester additional carbon in a so-called buffer stock, which allows for continuous biomass production and its storage.

The sequestration of carbon, which is the underlying process of biomass production through land use, land use change and forestry activities, is by itself an eligible mitigation option for GHG emissions under the Kyoto Protocol. Developing countries have the opportunity to contribute to energy and carbon sequestration related mitigation activities under the Clean Development Mechanism (CDM) of the Kyoto Protocol.

Improved land management including organic farming, which through manure applications and incorporation of legumes into the rotation could sequester Soil Organic Carbon??(SOC). Management practices that lead to an increase in organic inputs (biomass and manure) enhance microbial functions and promote SOC sequestration (Jarecki and Lal, 2003). Organic production frequently utilizes practices recommended for increasing SOC sequestration such as surface mulching, continuous cropping, cover cropping, legumes in rotation, and manure application. Like organic production other low-input or sustainable management systems incorporating some of the above practices as well (Johnson J et al. USDA Agricultural Research Service, 2007. Agricultural opportunities to mitigate greenhouse gas emissions).

Reports from Denmark and Belgium also suggest that organic production systems have the potential to sequester as much as 0.5 Mg C ha^{-1} yr^{-1} depending on the specific management practices utilized (Dendoncker et al., 2004; Foereid and Høgh-Jensen, 2004; Freibauer et al., 2004). Freibauer et al. (2004) estimated global C sequestration potential of 0.1 to 0.8 Mg C ha^{-1} yr^{-1} by conversion to organic management. Similar global estimates (0.3 to 0.6 Mg C ha^{-1} yr^{-1}) were made by Pretty and Ball (2001). A study by Smith et al. (2005) indicated that organic farming is a promising management system for enhancing C storage on cropland. Further discussion on sequestration can be found in next chapter.

2.4. Tillage

Tillage systems influence physical, chemical, and biological properties of soil and have a major impact on soil productivity and sustainability. Conventional tillage practices may adversely affect long-term soil productivity due to erosion and loss of organic matter in soils. Sustainable soil management can be practiced through conservation tillage (including no-tillage), high crop residue return, and crop rotation[4]. Studies conducted under a wide range of climatic conditions, soil types, and crop rotation systems showed that soils under no-tillage and reduced tillage have significantly higher soil organic matter contents compared with conventionally tilled soils. Conservation tillage is defined as a tillage system in which at least 30% of crop residues are left in the field and is an important conservation practice to reduce soil erosion [3]. The advantages of conservation tillage practices over conventional tillage include (1) reducing cultivation cost; (2) allowing crop residues to act as an insulator and reducing soil temperature fluctuation; (3) building up soil organic matter; (4) conserving soil moisture[5]. The application of improved agricultural techniques (e.g. organic agriculture, conservation tillage, agroforestry) reduces or stops soil erosion and converts carbon losses into gains.

Consequently, considerable amounts of CO_2 are removed from the atmosphere.

Organic agriculture already provides effective methods to reach both of these goals, even though there is still need for further improvement, especially with regards reduced tillage techniques. Soil conservation techniques such as reduced tillage, no tillage, contour farming, strip cropping and terracing.

Reduced tillage techniques, increasingly and successfully applied to organic systems (Berner, *et al.*, 2008; Teasdale, *et al.,* 2007), enhance carbon sequestration rates considerably. Contrary to conventional no-till systems, organic reduced tillage systems do not increase herbicide and synthetic nitrogen input. Typical carbon sequestration snd greenhouse gas emissions per hectare from three different tillage techniques are: Conventional tillage: Emissions 1140 kg CO2-eq ha-1 yr-1;C-sequestation 0. Reduced tillage techniques: the emissions are 570 kg CO2-eq ha-1 yr-1; C-sequestration rates on arable land could be easily increased to 570 kg CO2-eq ha-1 yr-1. No till: Emissions 140 kg CO2-eq ha-1 yr-1; C-sequestation 1100 kg CO2-eq ha-1 yr-1. [6]

When combining organic farming with *reduced tillage* techniques, the C-sequestration rates on arable land could be easily increased to 570 kg CO_2-eq ha^{-1} yr^{-1}.

A good source of information on the differences in the cost of production [converted from 2012 USD/acre in 2012 EUR/ha] by three different tillage practices can be found in the Pennsylvania Five Acre Corn Club annual summaries (1994)[7]:

Table 2.18 Differences in the cost of production, GHG emissions and sequestation by three different tillage scenarios

Item	Scenario 1: Conventional tillage (EUR/ha)	Scenario 2: Reduced tillage (EUR/ha)	Scenario 3: No-till (EUR/ha)
Selected variable costs			
Seed	43.16	42.72	45.22
Fertilizer	81.92	85.20	74.16
Lime	18.10	15.51	17.17
Herbicides	33.64	34.85	49.41
Insecticides	9.21	12.78	8.73

[4] P. R. Hobbs, K. Sayre, and R. Gupta, "The role of conservation agriculture in sustainable agriculture," Philosophical Transactions of the Royal Society B, vol. 363, no. 1491, pp. 543–555, 2008.

[5] T. O. West and W. M. Post, "Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis," Soil Science Society of America Journal, vol. 66, no. 6, pp. 1930–1946, 2002.

[6] Source: Niggli, U., FlieЯbach, A., Hepperly, P. and Scialabba. Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems., FAO, April 2009

[7] Available at: http://extension.psu.edu/plants/crops/soil-management/conservation-tillage/economics-of-conservation-tillage

Item	Scenario 1: Conventional tillage (EUR/ha)	Scenario 2: Reduced tillage (EUR/ha)	Scenario 3: No-till (EUR/ha)
Machinery operating	39.27	39.83	25.21
Custom hire	12.32	13.50	24.64
Total variable costs	**285.53**	**301.27**	**293.42**
Fixed costs			
Machinery ownership	81.49	75.38	44.26
Total costs	**367.02**	**376.65**	**337.67**
Total GHG emissions [t/ha]	1.14	0.5	0.14
Total GHG emissions [Gg/yr]	315.78	157.89	38.78
Total C-sequested [Gg CO_{2-eq}/yr]	0	138.5	304.7

The major difference in profitability between the three systems comes not from average yield differences or variable costs, but from the difference in machinery fixed cost. Machinery ownership costs conventional and reduced tillage farmers 70 to 85% more than no-till farmers. Having a slightly higher yield and lower total costs made *no-till* the most profitable system.

For 227,000 ha total sow arable land in the country (SSO, 2011), a greenhouse gas reduction of 90.54% can be achieved trough changing conventional tillage to no-tillage, resulting in 304.7 of total C-sequested (in CO_{2}-eq Gg) or a 138.5 C-sequested in case of reduced tillage techniques.

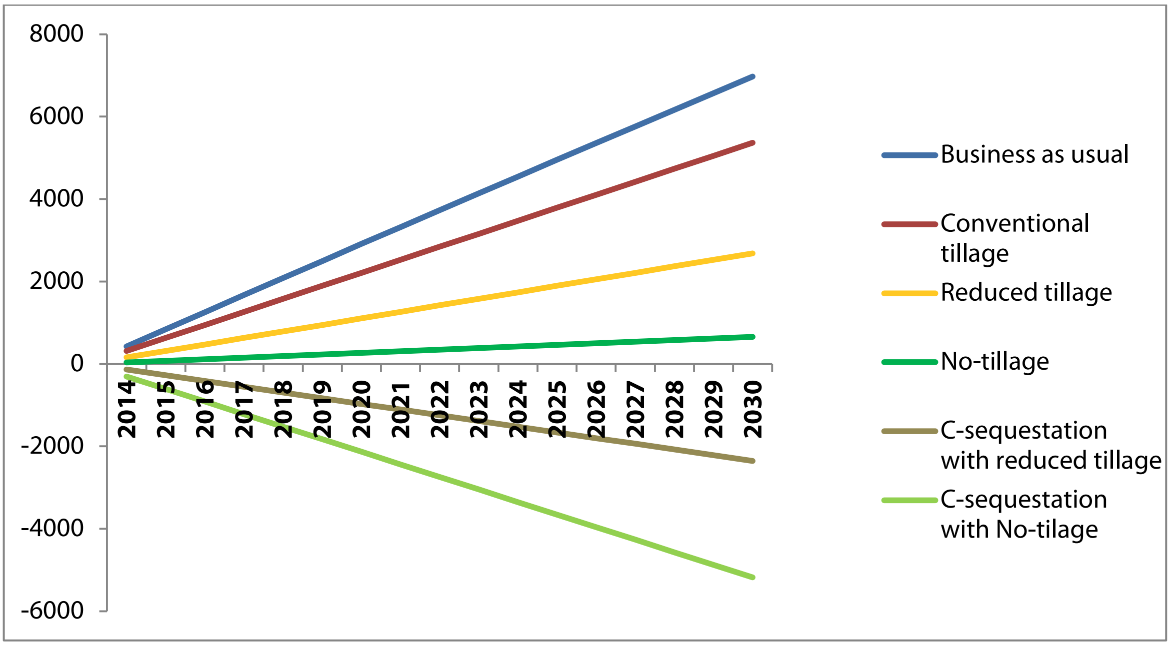

Figure 2.2. Comparison of greenhouse gas emissions from three different tillage scenarios and Business as usual.

Under Business-as-usual scenario, the projected total cumulative greenhouse gas emissions until year 2030 are 6,970.46 CO_2-eq [Gg]. With Scenario 1: Conventional tillage (measure implemented in 2014) emissions are 5,368.26 Gg. Under Scenario 2: introduction of reduced tillage 2,684.13 Gg shall be emited and 2,354.50 Gg CO_2-eq. sequested, while with Scenario 3: no-tillage (measure implemented in 2014) cumulative greenhouse gas emissions are 659.26 Gg with sequestration of 5179.90 Gg CO_2-eq.

3. Organic agriculture

Organic agriculture is an agricultural practice that utilizes techniques such as crop rotation, green manure, compost and biological pest control. Organic farming uses fertilizers and pesticides but excludes the use of synthetic fertilizers, pesticides, hormones, livestock antibiotics, food additives, genetically modified organisms, human sewage sludge and nanomaterials. With application of organic agriculture it is directly contributed to greenhouse gas emissions reduction comparing to conventional agricultural practices as it emits less N_2O from nitrogen application (due to lower nitrogen input), less N_2O and CH_4 from biomass waste burning because the burning is avoided and requires almost no usage of chemical fertilizers. The mitigation effects are complemented with additional adaptation benefits like increased soil quality that makes the agriculture more resilient to droughts or extreme weather events that further adds benefits of the measures.

Organic agriculture is based on scientific knowledge combined with traditional agricultural practices based on natural occurring biological processes.

The key characteristics of organic farming include (George McRobie, Demonstrating Sustainable Agricultuer, 1990):

1. Protecting the long term fertility of soils by maintaining organic matter levels, encouraging soil biological activity, and careful mechanical intervention;
2. Providing crop nutrients indirectly using relatively insoluble nutrient sources which are made available to the plant by the action of soil micro-organisms;
3. Nitrogen self-sufficiency through the use of legumes and biological nitrogen fixation, as well as effective recycling of organic materials including crop residues and livestock manures;
4. Weed, disease and pest control relying primarily on crop rotations, natural predators, diversity, organic manuring, resistant varieties and limited (preferably minimal) thermal, biological and chemical intervention;
5. The extensive management of livestock, paying full regard to their evolutionary adaptations, behavioural needs and animal welfare issues with respect to nutrition, housing, health, breeding and rearing;
6. Careful attention to the impact of the farming system on the wider environment and the conservation of wildlife and natural habitats.

3.1. Status of the organic agriculture in Macedonia

Organic agriculture is in an early development stage in Macedonia with first taken actions in the late 90ties when the largest pharmaceutical company in Macedonia has introduced several varieties of organic teas to the market produced from wild collection, following by first activities in the field of organic agriculture in Macedonia initiated by 4-5 farmers from the region of Ohrid, Kumanovo and Strumica. From the total production of agricultural goods in Macedonia organic products have share of 0.9%. According to the Macedonian law on organic agriculture has the expert control of organic producers, processors and traders to be conducted by registered inspection bodies. These bodies must have headquarters in Macedonia, employ at least three staff persons and be accredited.

Table 3.1. Total agricultural land used for crop production in Macedonia, [ha] (Source: State Statistical Office of Macedonia)

	Arable land [ha]	Agricultural land[ha]	Fields and gardens [ha]
2012	510,000	1,268,000	414,000
2011	511,000	1,120,000	415,000
2010	509,000	1,121,000	415,000

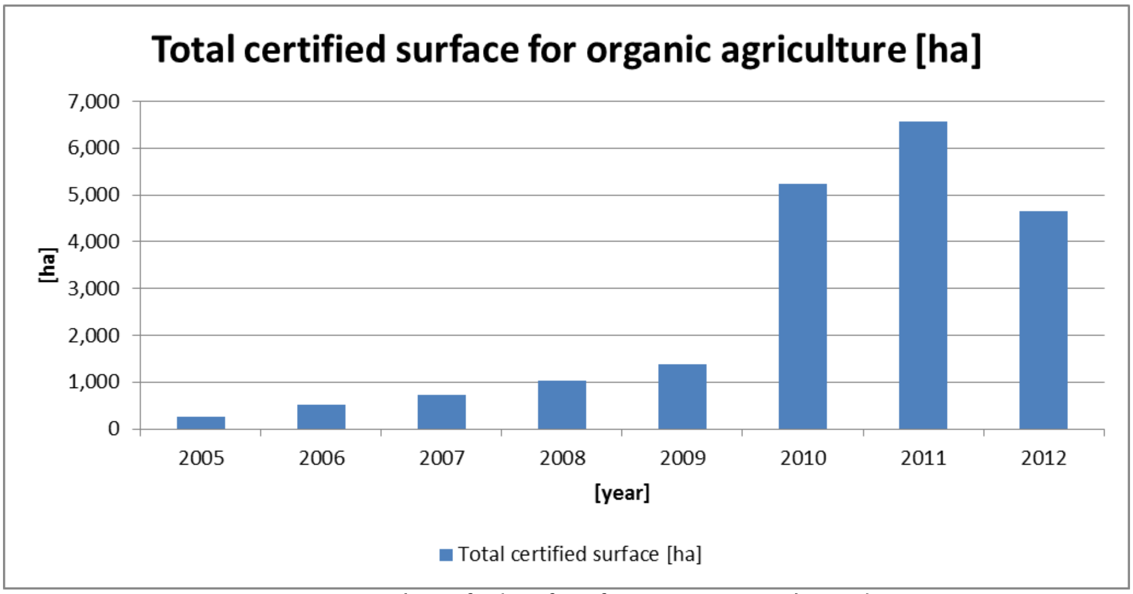

Figure 3.1. Total certified surface for organic agriculture, [ha]

Table 3.2. Total certified surface for organic agriculture, [ha] (Source: Ministry of Agriculture, Forestry and Water Economy)

Year	Total certified surface [ha]	Number of operators
2005	266.00	50
2006	509.42	102
2007	714.47	150
2008	1,029.00	226
2009	1,373.83	321
2010	5,228.00	562
2011	6,580.92	780
2012	4,663.08	576

Products from certified organic producers are rare to find on the Macedonia market but are well recognized and valued by the customers. Usually products that are produced with an organic agricultural practice are connected to a specific region and traditional practices that have good reputation in such production (e.g. cheese and potatoes from Berovo, honey from Mariovo, tomatoes from Strumica, cherries from Ohrid). The agricultural experience that has been nurtured with these traditional practices in most of the rural regions in Macedonia sets a good foundation for further development of the organic agriculture.

In Macedonia several actions are taken in order to regulate and promote the organic agriculture. At the end of 2000 the first draft of the Organic Production Law was prepared with consultation of European experts for organic production. In 2001the Government has adopted the draft Law for Organic Production and passed to the Parliamentary procedure. The Law on Organic Agricultural Production was adopted by the Parliament in April 2004 (the Official Gazette No. 16/2004) which required furthermore the adoption of 12 by-laws. The first by-laws have been adopted in December 2004 to establish an Advisory Coordination Commission on OA. The task of the Commission is to support MAFWE in the development and implementation of the organic agriculture policy and related activities. Training was organized for inspection of organic products according to EU Regulation 2092/91. The second by-law, the Organic Agriculture Support and Development Programme, was adopted in March 2005 and implemented in the same year. The Programme allocated funds to support 50 certified organic farmers based on land in conversion, inspection and certification costs and laboratory analyses. In the 2001 also can be noticed the initiation and establishment of the first organic production associations. In the period of 2002-2005 year a regional cooperation in the organic agriculture was promoted through organizing several workshops under the topic "Promotion of the Organic Agriculture in the Balkans". Three by-laws regulating the production standards in organic agriculture (plant production, animal production and processing) were adopted in June 2006 (the Official Gazette No. 60/2006). (National strategy with action plan for organic agriculture of the republic of Macedonia 2008-2011).

In August 2007 was published the National strategy with action plan for organic agriculture of the Republic of Macedonia for the period 2008-2011 that elaborated on the situation analyses regarding the organic agriculture in Macedonia in order to develop actions plans that lead to visible and measurable results.

Table 3.3. Organic crop production, [ha] (Source: Ministry of Agriculture, Forestry and Water Economy)

Organic crop production												
	2009			2010			2011			2012		
Crop	in conversion [ha]	Organic [ha]	total [ha]	in conversion [ha]	Organic [ha]	total [ha]	in conversion [ha]	Organic [ha]	total [ha]	in conversion [ha]	Organic [ha]	total [ha]
Cereals	501.52	166.35	667.87	2,723.70	276.1	2,999.80	3,292.38	378.03	3,670.41	1,345.12	899.24	2,244.36
Fodder Crops	101.04	82.05	183.09	848.9	145.7	994.6	724.48	260.76	985.24	435.87	552.13	988
Industrial crops	12.31	31.32	43.63	32.1	0	32.1	32.73	4.89	37.62	17.34	15.19	32.53
Oilseeds	63.78	0	63.78	40.7	6.7	47.4	149.9	9.26	159.16	86.33	73.42	159.75
Orchards	137.48	73.55	211.03	165.9	168.3	334.2	764.25	206.87	971.12	424.12	78.78	502.9
Vineyards	46.25	13.92	60.17	223.6	20.7	244.3	11.07	29.67	40.74	80.27	46.5	126.77
Vegetables	84.22	58.64	142.86	164.2	35.7	199.9	192.67	70.54	263.21	111.52	46.16	157.68
Fallow			0	306.4	66.3	372.7	406.18	47.24	453.42	316.45	134.64	451.09

Table 3.4. . Organic livestock, [ha] (Source: Ministry of Agriculture, Forestry and Water Economy)

Organic livestock												
	2009			2010			2011			2012		
Livestock	in conversio n [number]	organic [number]	total [number]	in conversion [number]	organic [number]	total [number]	in conversion [number]	organic [number]	total [number]	in conversion [number]	organic [number]	total [number]
Cattle	180	197	377	2,522	37	2,559	3,810	1,411	5,221	712	1,981	2,693
Sheep	21,844	208	22,052	92,523	6,275	98,798	63,670	50,234	113,904	28,160	45,551	73,711
Goats	791	248	1,039	2,470	578	3,048	2,084	3,049	5,133	412	2,605	3,017
Pigs	5	0	5			0			0			0

3.2. Mitigation effect by implementation of organic agriculture

Table 3.5. Literature review of greenhouse gas emissions per kilogram organic versus conventional agricultural product

Product	GHG Emissions per KG product (CO_2-Eq/Kg)			Reference
	Conventional agriculture	Organic agriculture	Ratio	
Oranges	0.11	0.08	0.8	Knudsen et al. (2011)
Leeks	0.094	0.044	0.5	de Backer et al. (2009)
Patatoes	0.24	0.2	0.9	Williams et al. (2006)
Carrot	0.12	0.21	1.7	Halberg et al. (2006)
Tomatoes	3.45	4.96	1.4	Halberg et al. (2006)
Wheat	0.37	0.14	0.4	Hirschfeld et al. (2008)
Oilseed rape	1.51	0.954	0.6	LCAfood (2003)
Barley	0.62	0.32	0.5	LCAfood (2003)
Oat	0.57	0.39	0.7	LCAfood (2003)
Rye	0.72	0.62	0.9	LCAfood (2003)

Product	GHG Emissions per KG product (CO_2-Eq/Kg)			Reference
Meat and dairy	Conventional agriculture	Organic agriculture	Ratio	
Beef	13	11.1	0.9	Casey & Holden (2006)
Pork	2.72	1.7	0.6	Hirschfeld et al. (2008)
Poulutry	4.6	6.9	1.5	Williams et al. (2006)
Sheep	17	10.2	0.6	Williams et al. (2006)
Eggs	5.5	7.2	1.3	Williams et al. (2006)
Milk	0.7	0.63	0.9	Hirschfeld et al. (2008)

Taking into account the general trend of the past organic production given in Table 3.3. it is assumed that the organic production will increase in similar manner until 2030. These extrapolated values of the land used for organic production was multiplied to an average production rate ([t/ha]) per crop that will give an average crop production in tonnes presented in Table 3.6.

Table 3.6. Crop production in Macedonia [t], (Source: State Statistical Office of Macedonia)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Wheat	299,356	246,208	266,961	225,300	356,825	333,880	293,326	218,076	291,719	271,117	243,137	256,103	214,963
Maize	125,383	117,070	140,694	136,492	141,875	148,234	147,494	118,378	127,125	154,237	129,045	126,096	115,928
Tobacco	22,175	23,217	22,911	23,986	21,630	27,691	25,036	22,056	17,087	24,122	30,280	26,537	27,333
Potato	160,444	172,473	179,682	170,625	193,523	186,653	188,146	179,729	187,754	204,717	200,125	192,675	168,859
Onion	36,336	30,594	34,589	30,478	34,334	38,465	33,853	33,524	34,934	41,863	47,432	44,540	43,732
Tomato	134,654	126,313	109,506	129,739	114,490	116,633	142,387	117,981	121,637	145,395	168,010	165,642	145,818
Pepper	116,597	111,611	108,073	111,494	127,852	127,472	140,905	140,558	141,729	154,771	168,150	153,842	166,247
Cherry	3,346	2,412	3,175	2,782	4,017	4,358	4,646	4,966	5,631	5,587	5,701	6,019	5,539
Sour cherries	3,293	3,032	3,213	3,690	7,324	5,532	6,037	7,034	8,832	8,684	5,207	6,514	8,127
Apricots	4,168	2,271	2,546	1,436	4,476	2,964	3,561	3,531	3,706	2,950	2,996	3,747	4,503
Apple	84,275	38,433	63,470	61,936	82,414	86,217	95,826	152,089	174,315	106,356	121,383	124,552	127,171
Pear	8,949	6,487	7,817	5,980	7,058	8,892	9,728	8,235	8,260	8,313	7,586	7,460	6,937
Plum	23,421	13,252	24,203	15,313	25,815	25,254	29,745	27,773	32,826	35,610	38,431	35,448	35,444
Peach	9,512	4,598	6,315	7,264	12,045	11,041	10,532	10,461	11,252	10,266	10,211	9,039	8,987
Nuts	3,862	1,758	1,957	1,984	3,672	4,511	5,527	4,786	4,863	4,981	5,769	5,480	4,952
Grape	264,256	229,805	118,935	243,821	254,613	265,717	254,308	209,701	236,834	253,456	253,372	235,104	240,461

To get the organic production mitigation potential the values in Table 3.6. are multiplied with the mitigation potential calculated with the LCA (Life-Cycle Assessment) expressed in CO2- Eq per Kg produced crop given in Table 3.5. These values were grouped in several crop types: Cereal, Fodder Crops, Industrial Crops etc. The calculated results of possible CO2-eq reduction in the period 2015-2030 is given in the Table 3.7.

Table 3.7. CO2 - eq [kt] Mitigated per year with organic crop production

CO2 - eq [kt] Mitigated per year with organic crop production																
	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Cereals	-8.22	-9.43	-10.69	-12.01	-13.38	-14.81	-16.29	-17.82	-19.40	-21.02	-22.70	-24.42	-26.18	-27.99	-29.84	-31.74
Fodder Crops	-4.12	-4.72	-5.36	-6.02	-6.71	-7.42	-8.16	-8.93	-9.72	-10.53	-11.37	-12.24	-13.12	-14.03	-14.95	-15.90
Industrial crops	-0.03	-0.03	-0.03	-0.04	-0.04	-0.05	-0.05	-0.06	-0.06	-0.07	-0.07	-0.08	-0.08	-0.09	-0.09	-0.10
Oilseeds	-0.13	-0.14	-0.16	-0.18	-0.20	-0.23	-0.25	-0.27	-0.30	-0.32	-0.35	-0.37	-0.40	-0.43	-0.46	-0.49
Orchards	-6.60	-7.56	-8.58	-9.64	-10.74	-11.88	-13.07	-14.30	-15.56	-16.87	-18.21	-19.59	-21.01	-22.46	-23.95	-25.47
Vineyards	-0.44	-0.51	-0.58	-0.65	-0.72	-0.80	-0.88	-0.96	-1.04	-1.13	-1.22	-1.31	-1.41	-1.51	-1.61	-1.71
Vegetables	3.02	3.46	3.92	4.41	4.91	5.44	5.98	6.54	7.12	7.72	8.33	8.96	9.61	10.28	10.96	11.65
Fallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The following step that remains is to calculate the economic benefit or loss from organic farming implementation. For this purpose six different scenarios are developed that incorporate assumptions about the amount of investment, possible subventions by the country and behavior of the market. The economic analysis is performed for different type of crops per one hectare of land.

Scenario 1: The farmer does not have sufficient knowledge about organic farming and therefore needs to invest in education. The used technology for the farming will be basic so, no significant investment in technology will be made which on the other hand will result in higher labor demanding farming. The organic certification will be performed by a Macedonian accredited company and inspections will be performed twice a year. In this scenario the country does not offer subventions for any type of organic farming. The customers are not knowledgeable and do not recognize the organic products on the market therefore the products are less competitive.
Scenario 2: The farmer does not have sufficient knowledge about organic farming and therefore needs to invest in education. The farmer will invest in automated technology that will make the framing less labor intense comparing to Scenario 1. The organic certification will be performed by a Macedonian accredited company and inspections will be performed twice a year. In this scenario the country does not offer subventions for any type of organic farming. The customers are not knowledgeable and do not recognize the organic products on the market therefore the products are less competitive.
Scenario 3: The farmer does not have sufficient knowledge about organic farming and therefore needs to invest in education. The used technology for the farming will be basic so, no significant investment in technology will be made which on the other hand will result in higher labor demanding farming. The organic certification will be performed by a Macedonian accredited company and inspections will be performed twice a year. In this scenario the country provides subventions for organic farming. The customers are not knowledgeable and do not recognize the organic products on the market therefore the products are less competitive.
Scenario 4: The farmer does not have sufficient knowledge about organic farming and therefore needs to invest in education. The farmer will invest in automated technology that will make the framing less labor intense comparing to Scenario 1. The organic certification will be performed by a Macedonian accredited company and inspections will be performed twice a year. In this scenario the country provides subventions for organic farming. The customers are not knowledgeable and do not recognize the organic products on the market therefore the products are less competitive.
Scenario 5: The farmer does not have sufficient knowledge about organic farming and therefore needs to invest in education. The used technology for the farming will be basic so, no significant investment in technology will be made which on the other hand will result in higher labor demanding farming. The organic certification will be performed by a Macedonian accredited company and inspections will be performed twice a year. In this scenario the country provides subventions for organic farming. It starts to develop market where organic products are recognized by the customers and therefore competitive with their unique characteristics.
Scenario 6: The farmer does not have sufficient knowledge about organic farming and therefore needs to invest in education. The farmer will invest in automated technology that will make the framing less labor intense comparing to Scenario 1. The organic certification will be performed by a Macedonian accredited company and inspections will be performed twice a year. In this scenario the country provides subventions for organic farming. It starts to develop market where organic products are recognized by the customers and therefore competitive with their unique characteristics.
Taking into account these six scenarios the economic analysis was made by calculation of the NPV (net present value) in USD that compares the present value of money today to the present value of money in the future, taking inflation and returns into account. The investigated period was 15 year and the rate used to discount future cash flows to the present value was 10%. In order to measure and compare the profitability of investments across the different scenarios was calculated the IRR (internal rate of return) and the payback period in years that represent how when the farmer will make a full return of the investment. The input data for the average crop prices on the market and prices for the investment were gathered from the State Statistical Office and Ministry of Agriculture, Forestry and Water Economy. The prices for organic production certification were used from the pricelist of the Macedonian accredited company "PROCERT". The results are represented in Table 7.

Table 3.8. Economic analysis by calculating NPV [USD], IRR and PP [years] for 1 ha land.

		SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Cereals	**NPV**	1,562	2,054	8,835	12,963	9,861	13,989

	IRR	0.11	0.11	0.20	0.20	0.21	0.21
	PP	7.31	6.32	4.99	4.89	4.07	4.86
Fodder Crops	NPV	-10,746	-3,870	-5,035	-1,324	-4,801	-1,091
	IRR		-0.01	-0.10	0.05	-0.08	0.06
	PP				10.88		10.20
Industrial crops	NPV	-11,217	-4,341	-5,506	-1,796	-5,283	-1,572
	IRR		-0.03	-0.14	0.02	-0.11	0.04
	PP				12.66		11.67
Oilseeds	NPV	20,669	20,034	28,305	31,670	29,795	33,159
	IRR	0.24	0.20	0.38	0.32	0.39	0.33
	PP	4.32	4.99	3.05	3.39	3.05	3.39
Orchards	NPV	68,049	77,276	77,139	91,094	80,489	94,444
	IRR	0.33	0.30	0.45	0.42	0.46	0.43
	PP	3.89	4.04	3.34	3.35	3.34	3.35
Vineyards	NPV	-1,655	4,905	7,436	18,723	8,773	20,059
	IRR	0.09	0.12	0.17	0.22	0.18	0.22
	PP	8.33	6.99	5.62	4.72	5.51	4.69
Vegetables	NPV	86,102	95,330	95,193	109,148	99,000	112,955
	IRR	0.38	0.34	0.51	0.47	0.52	0.47
	PP	3.58	3.76	3.12	3.16	3.12	3.16

By comparing the results form Table 6 and Table 7 it can be concluded what scenario is the most suitable for implementation of organic farming with regards to highest CO_2 mitigation potential. As expected for all type of crops the most convenient scenario is the one where the country will give subventions to the farmers and the organic products will be recognized in the market. On a long run the investment I automated technology will pay off but it will result with higher CO2 emissions. As it can be seen by the results not all of the crops result in decrement of CO_2-eq emissions. For example the organic production of some vegetables (e.g. tomato) is estimated to emit higher amount of $CO_{2\ \text{than}}$ the conventional agriculture practices. On the other hand the organic production of cereals and fruits is estimated to have the highest mitigation potential.

4. Production of biofuels from crop residues

Agricultural burning is the practice of using fire to reduce or dispose of the crop residues from an agricultural activity. Crop residues burning may seem like a simple method of managing crop residue, but it is actually expensive and damaging. Burning causes environmental concerns about carbon dioxide emissions and pollution from burning crop residues, respiratory and health issues, possible soil erosion, adverse effects on soil fertility, organic matter depletion and soil structure damage, reduced numbers of macro and micro-organisms etc. The crop residues burning also has some positive implications such as termination of the weed seeds, removals of residues and thereby more effective incorporation of pre-emergent herbicides, improves disease and pest management and eliminates short-term nitrogen tie-up.Many practices have been advocated to mitigate emissions from crop residues burning. Often a practice will affect more than one gas, by more than one mechanism, sometimes in opposite ways, so that the net benefit depends on the combined effects on all gases. In addition, the temporal pattern of influence may vary among practices or among gases for a given practice; some emissions are reduced indefinitely, other reductions are temporary.

4.1. General Benefits from production of briquettes from the crop residues

The most effective manner for managing of the crop residues is the usage of mechanical equipment for residue removal and packaging. This is the most common practice since the burning of agricultural residues in many developed countries is sickly prohibited. The straw remaining can be used as energy source, livestock food, insulation material, etc. Crops and residues from agricultural lands can be used as a source of fuel, either directly or after conversion to fuels such as ethanol or diesel (Cannell 2003; Schneider & McCarl 2003). Crop residues left in the field after grain harvest have a large potential as a bioenergy feedstock. Crop residues of interest for bioenergy include; corn stover, corn cobs, wheat straw, soybean straw, and rice hulls. These bioenergy feedstocks still release CO2 upon combustion, but now the C is of recent atmospheric origin (via photosynthesis), rather than from fossil C. The net benefit of these bioenergy feedstocks to the atmosphere is equal to the fossil-derived emissions displaced less any emissions from their production, transport and processing.
The IPCC default methodology assumes that an average of 25% of the quantity of dry residue is burned. The rest of the residues are supposed to be used as a livestock food and many other manners mainly connected to the livestock accommodation and additional agricultural practices. The emissions from crop residues burning are expressed in CO2, CH4 and N2O emissions and the amount of the GHG emissions from this activity is not neglect able, especially due to open air and uncontrolled combustion.

4.2. National Circumstances

The economy of Republic of Macedonia is highly dependent of the Agricultural sector and this sector is the second biggest source of GHG emissions in the country.
The burning of the crop residues is a well-known practice of handling of the agricultural waste, and this practice is very often source of serious air pollution and land degradation, and many times source of uncontrolled fires in the agricultural areas.
With the recent policy changes the open fire burning of the agricultural residues in Republic of Macedonia is strictly prohibited, and now the farmers are looking for a solution for the collection, transport and the disposal of the crop residues, which has a significant financial cost.

4.3. Environmental assessment

The mitigation potential of the crop residues management can provide cross sectorial GHG emission reduction. The avoidance of the crop residues burning reduces the emissions from the sector Agriculture and the usage of this agricultural by products in the Energy sector as a substrate for biofuels or biomass fuels reduces the usage of the fossil fuels and decreases the emissions from this sector as well.
The emissions from the subsector agricultural burning of crop residues are included in the country inventory starting from 2003. The time period 2003 - 2009 is used as a basis for modeling of the emissions from the subsector till 2030. The forecasted emissions from tis subsector in units of CO2, CH4 and N2O emissions are presented in the table 4.1.
The open fire burning of agricultural residues generates1.82 t of CO2 eq. emissions for each tone of burned dry material.

Table 4.1. – Total amount of dry material and emissions from the burning of crop residues 2003 – 2009, and modeled amount of dry material and BAU emissions 2010 - 2030

Year	Total biomass burned [kt]	CO2 emissions [kt]	CH4 emissions [kt]	N2O emissions [kt]	Total emissions in CO2 eq. [kt]
2003	88,47	152,57	0,22	0,01	159,95

2004	133,9	231,66	0,34	0,01	242,24
2005	125,8	217,65	0,32	0,01	227,57
2006	116,18	200,9	0,29	0,01	210,21
2007	90,99	156,46	0,37	0,01	166,94
2008	119,45	206,11	0,37	0,01	217,01
2009	116,2	199,8	0,34	0,01	210,22
2010	117,69	202,83	0,37	0,01	213,85
2011	118,33	203,89	0,38	0,01	215,07
2012	118,91	204,85	0,39	0,01	216,17
2013	119,43	205,71	0,39	0,01	217,16
2014	119,9	206,5	0,4	0,01	218,07
2015	120,34	207,23	0,4	0,01	218,9
2016	120,74	207,9	0,41	0,01	219,67
2017	121,12	208,52	0,41	0,01	220,39
2018	121,47	209,11	0,41	0,01	221,06
2019	121,8	209,66	0,42	0,01	221,7
2020	122,11	210,18	0,42	0,01	222,29
2021	122,41	210,67	0,43	0,01	222,85
2022	122,69	211,13	0,43	0,01	223,39
2023	122,95	211,57	0,43	0,01	223,9
2024	123,21	212	0,43	0,01	224,38
2025	123,45	212,4	0,44	0,01	224,84
2026	123,68	212,78	0,44	0,01	225,29
2027	123,9	213,15	0,44	0,01	225,71
2028	124,12	213,51	0,44	0,01	226,12
2029	124,32	213,85	0,45	0,01	226,51
2030	124,52	214,18	0,45	0,01	226,89

Potential dry matter 2202,16 kt **Potential emission removal 3791,96 kt**

The amount of the emissions from burning of agricultural residues for the period 2014 – 2030 can be avoided trough the re-use of the agricultural residues as an energy source.
The predicted cumulative crop residues production till 2030 is estimated to be 2202.16 kt of dry matter, and consequently the potential reduction of the CO2 eq. emissions from implementation of this measure is foreseen to be 3791.96kt CO2 eq.
The usage of the biomass as an energy source has very high environmental and economic benefits, although according to the IPCC methodology the CO2 emissions from the biomass combustion are not calculated in the total GHG emissions. The feed stocks used for manufacture are a side product from other activity and are very cheap, and consequently this can bring to high investment returnable rate and high economic benefits.

4.4. Cost benefit assessment

Today one of the most effective and most economical ways to produce heat is using the briquettes and pellets. Briquettes as such can be made from scrap wood waste, residues from vineyards and other types of agricultural residues. The technology for production of briquettes is now available for affordable prices. One of the cheapest and the simplest methods for production of briquettes is usage of the crop residues as a feedstock.

Crop residues which are mainly consisted of straw have great advantages for production of briquettes such as:

- Normally no need for drying
- High bulk density of 500-600 kg/m^3
- Heat value of app 17 MJ/kg [1]
- Straw briquettes are CO^2 neutral
- Lower cost (0.02 EUR / kg), which is 3.5 times lower than the cost of the wood [2]
- Briquettes from straw left significantly less ash compared to wood and have a higher calorific value.
- Special burners for burning of the straw briquette are not required. They can be used in most boilers and fireplaces as a direct replacement for wood or coal.

The number of companies and people which are producing briquettes in Macedonia is in continuous progress, mainly because the high cost of electricity and the low investment cost in such equipment.

When assessing the cost and the benefits from the production of waste biomasses raw material for briquettes we need to consider all stages of the product manufacture, from the energy consumption in harvesting (mowing) of the residues, the cost of the labor and the mechanization, the manufacturing equipment cost, the electricity consumption of the manufacturing equipment and the overall resulting energy value of the biomass produced.

Energy consumption for transportation of biomass depends on the mass transported and the distance to the plant for production of briquettes and pellets.

The process of transformation of the agricultural residues in briquettes can be done using two different techniques:

- Direct processing with usage of bonding (adhesive) which doesn't require high pressurization of the products, but it requires 4-8% of adhesive.
- High pressure bonding without usage of adhesive. The working pressure of this equipment is 1000 – 1500 bar and this equipment is more expensive that the previous one. Consequently this type of equipment consumes more energy than the first group.

The market offers many different types of the briquettes production plants and for this cost benefit assessment we would use the most advanced production plant BP 6000 high pressure production plant. The technical specification of the briquette production plant is presented in the table 4.2.

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[1] Thermal Pre-treatment of Biomass for Large-scale Applications, IEA Bioenergy 2011

[2] State Statistical Office Annual Publications, R. Macedonia

Table 4.2. – Technical specification of the high capacity plant of production of briquettes

Technical Specifications for BP 6000 HD with BBCS	
Briquette dimension	Ø90 mm
Main motor	55 kW with softstart
Capacity range	1200 - 1800 kg/hour *)
Pressure lubrication	Bronze bushings for excentric
Weight	app. 5800 kg
Dim. (BxHxL)	1700x1550x3050 mm

Price	245,000.00 EUR [3]
*The capacity is depending on raw material and briquette size	

The additional auxiliary equipment needed for production of briquettes, as well as the investment for production facility with capacity 1200 – 1800 kg/h is as follows:

- Wood Chopper PP H 4000D, capacity 1800kg/h, 22.5 KW, price 5,800.00 EUR
- Rotary Dryer HZG10, capacity 1500 – 3000 kg/h, 7.5KW, price 40,000.00 EUR
- Packing machine AV31 ITALY, capacity 50 packs/h, price 45,000.00EUR
- Location and construction works for a facility, size 250m2, price 100,000.00 EUR.

For this investment assessment the equipment which is considered to be most reliable and with the highest quality is taken.

[3] Ceprosard Production of pallets and briquettes, Dr. Slave Armenski, Dr. Done Tashevski, Dr. Ljubica Karakasheva

Table 4.2. – Cost benefit assessment of introduction of plant for production of briquettes, 2014 - 2030

Year	Capacity (kg/h)	Investment in production plant (EUR)	Max annual production per 8h/day [kt/year]	Annual Investment in feedstock and transport cost [EUR]	Annual amoount of electricity needed for self supply of the plant (kWh)	Annual amoount of electricity spent for self supply of the plant (EUR)	Annual production income	Annual Net profit from the marketing of the briquettes
2014	1,500.00	440,300.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2015	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2016	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2017	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2018	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2019	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2020	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2021	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2022	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2023	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2024	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2025	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2026	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2027	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2028	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2029	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
2030	1,500.00	34,030.00	3.12	78,000.00	197,600.00	21,736.00	202,800.00	103,064.00
		984,780.00						**1,752,088.00**

The table above shows that even the investment in the newest and the most expensive technology for production of briquettes from crop residues gives significant finance results and provides sustainable financial benefits. The payback period for the initial investment is estimated to be approximately 4.3 years.
The cumulative investment is the period 2014 – 2030 is foreseen to be 984.780.00 EUR, and the cumulative net profit for the same period is calculated at 1,752,088.00 EUR, which means that this mitigation measure is predicted to generate profit of 767.308,00 EUR in the period till 2030 (17 years).

The average feedstock price, the electricity price and the product price are taken as a fixed values, because of the linear dependency between the parameters, for example if the price of the electricity is raised the price of the final products (briquettes) will be raised as well.

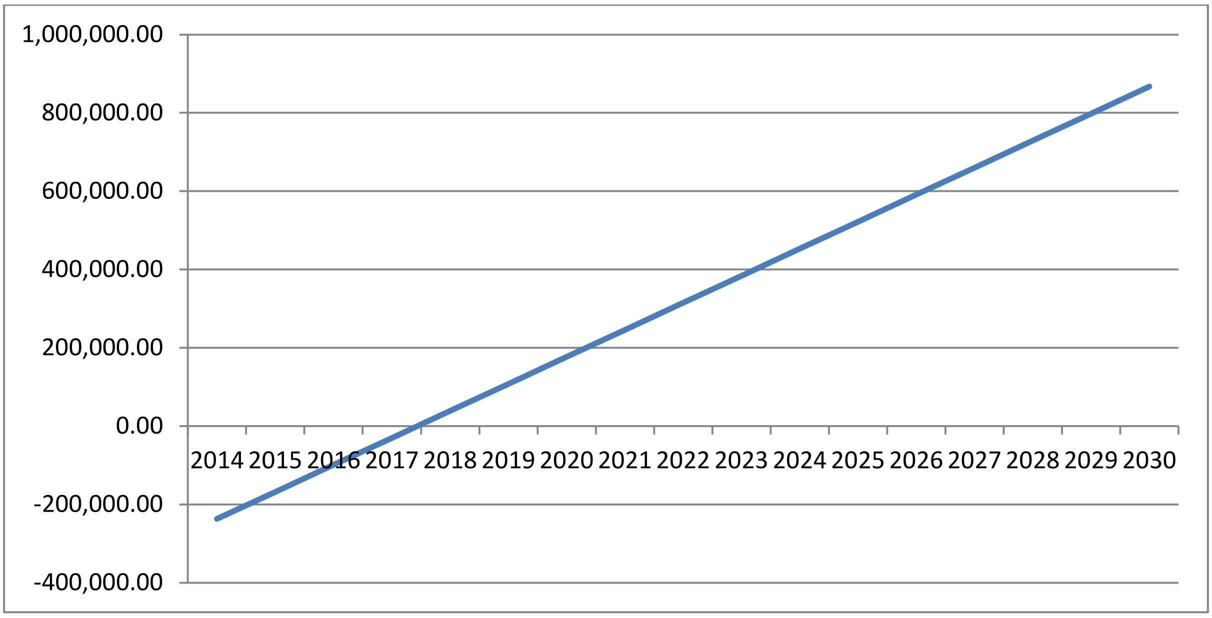

Figure 4.1. - End year financial balances 2014 – 2030

The calculated cost benefit assessment of the agricultural residues concerns only 3.12kt of the dry matter, which is 2.8 % of the amount of dry matter produced in 2009. If this measure is implemented to the total amount of the dry matter burned it can provide great financial and environmental benefits.

5. Enteric fermentation

5.1. Mechanism of enteric fermentation

Ruminant animals have a unique digestive system, which enables them to eat plant materials, but also produces methane, a potent greenhouse gas that contributes to global climate change. Methane is released into the atmosphere from animal effluences. Enteric fermentation is a natural part of the digestive process for many ruminant animals where anaerobic microbes, called methanogens, decompose and ferment food present in the digestive tract producing compounds that are then absorbed by the host animal. Measures to mitigate enteric fermentation would not only reduce emissions, they may also raise animal productivity by increasing digestive efficiency. Larger ruminants like bison, moose and cattle produce greater amounts of methane than smaller ruminants because of their greater feed intake.

In humans and other non-ruminant mammals, digestion is achieved by the action of enzymes in the gastric juices of the stomach. Food has a relatively short residence time in the gut and so there is little fermentation and associated methane production. In ruminant animals however, such as cows and sheep, plant polymers in the feed cannot be digested by host enzymes alone.

Food enters the rumen where it is fermented to volatile fatty acids (VFA), carbon dioxide and methane. The VFAs pass through the rumen wall into the circulatory system and are oxidized in the liver, supplying a major part of the energy needs of the host; they may also be directly utilised by the host as building blocks for synthesis of cell material. Fermentation is also coupled to microbial growth and the microbial cell protein synthesized forms the major source of protein for the animal. The gaseous waste products of the fermentation, carbon monoxide and methane, are mainly removed from the rumen by eructation (Dougherty et al, 1965). A small proportion of methane is absorbed in the blood and is eliminated through the lungs.

The efficiency of fermentation in the rumen, and hence methane emissions, depends on the diversity, size and activity of the microbial population in the rumen, which are largely determined by diet. An extensive grazing ruminant will feed on forage, the term given to fibrous material, usually involving the whole plant. A more intensively reared ruminant may feed on forage for part of the time and concentrates for the remainder. (Concentrates are feedstuffs that are mainly derived from the seeds of plants or by-products of the seeds after processing.) In the wild and extensive grazing situation, rumen efficiency will vary with seasonal and climatic differences as they affect the availability, composition and variety of vegetation available. In domesticated ruminants, where conditions are less variable, changes in diet composition, physical form and amount offered are largely responsible for changes in the microbial population (Thorley et al, 1968; Mackie et al, 1978). Bacteria are the principal micro-organisms that ferment carbohydrates in the rumen (Hungate, 1966). The type of bacteria required depends on the animal's diet. For animal fed on forage and concentrates, both cellulolytic and amyl lytic bacteria must be present to maximize rumen efficiency. The composition of micro-organisms in the rumen is also important in determining the composition of products from the fermentation process. Finally, the presence of protozoa, another type of micro-organism, in the rumen may also be important.

5.2. Methane emissions from livestock

Methane emissions from livestock depend on the average daily feed intake and the percentage of this feed energy which is converted to methane. Average daily feed intake for any particular livestock type can vary considerably and is related to, amongst other things, the weight of the animal (and the energy required to maintain it), its rate of weight gain, and for dairy cows, the rate of milk production. Methane conversion efficiency depends, as discussed above, on rumen efficiency and the quality (digestibility and energy value) of the feed. Non-dairy cattle produce about half as much methane per head as dairy cows, but are responsible for just over half of enteric emissions.

5.3. Options to increase rumen efficiency

Establishing conditions under which rumen fermentation will be optimized requires an understanding of the nutrient requirements of the mixed microbial population. Growth of rumen microbes will be influenced by chemical, physiological and nutritional components.

The major chemical and physiological modifiers of rumen fermentation are rumen pH and turnover rate and both of these are affected by diet and other nutritionally related characteristics such as level of intake, feeding strategies, forage length and quality and forage vs. concentrate ratios. Although significant advances in knowledge of effects of various combinations of these factors on microbial growth have been made in recent years, there is still insufficient information available to identify and control the interactions in the rumen that will result in optimum rumen fermentation. Feeding ruminants on diets containing high levels of readily fermented non-structural carbohydrate has been shown to minimize methane production by reducing the protozoal population and lowering rumen pH. However, this can give rise to an overall depressed ruminal fermentation, which may lower the conversion of feed energy into animal product and may be detrimental to the animal's health. Using diets with extreme nutrient compositions is

therefore not considered likely to be a successful or sustainable method to control methane emissions from ruminants.
A number of possible options have been identified for increasing rumen efficiency without threatening animal health:

- Hexose partitioning
- Propionate precursors
- Direct fed microbials (acetogens or methane oxidisers)
- Genetic engineering
- An immunogenic approach

A. Hexose partitioning

During rumen fermentation, feedstuffs are converted into short-chain volatile fatty acids (VFAs), ammonia, methane, carbon dioxide, cell material and heat. Animal performance is dependent on the balance of these products and this balance is ultimately controlled by the types and activities of micro-organisms in the rumen. The VFAs are used by the animal as an energy source while the microbes serve as an important source of amino acids for protein synthesis. Ammonia, methane and heat by contrast represent a loss of either nitrogen or energy unavailable to the animal.

By varying diet, it may be possible to manipulate the amount of the feed carbohydrate going directly into microbial growth as opposed to fermentation (hexose partitioning). Theoretical studies have shown that increasing the quantity of microbial cells leaving the rumen per unit of carbohydrate consumed may have a large effect on the overall methane production (up to a 35% reduction; Beever, 1993). Further experimental research is required to investigate, in vitro, carbohydrate sources that provide improved hexose partitioning and to use this information to design diets with enhanced hexose partitioning for testing in vivo to determine the impact on methane emissions. Theoretically this technology should also enhance protein utilisation and hence reduce ammonia emissions. The cost of implementing the option is likely to be minimal as the overall effect would be increased productivity which would offset any additional feed costs associated with the option. However, no reliable cost or performance data are available at present.

B. Propionate precursors

Within the rumen, hydrogen produced by the fermentation process may react to produce either methane or propionate. By increasing the presence of propionate precursors such as the organic acids, malate or fumarate, more of the hydrogen is used to produce propionate, and methane production is reduced. Propionate precursors can be introduced as a feed additive for livestock receiving concentrates. The propionate precursor, malate, also occurs naturally in grasses, and it is possible that plant breeding techniques could be used to produce forage plants with high enough concentrations of malate. Considerable research is needed, but if these techniques were successful then this mitigation option could then also be used with extensively grazed animals. It is estimated that if successful, the option could reduce methane emissions by up to 25% and that there could be other benefits to the livestock industry such as improved feed degradation which would be likely to reduce feed costs. Another possible benefit would be a reduced incidence of acidosis (a digestive disorder) in high producing dairy cows and intensively reared cattle, which could lead to considerable cost savings. As propionate precursors naturally occur in the rumen, they are likely to be more readily acceptable than antibiotic or chemical additives.

C. Direct fed microbials

Certain microbes in the rumen are known to promote reactions that minimise methane production and it may be possible to introduce such microbes directly as feed supplements. Such microbes include acetogens and methane oxidisers. Acetogens are bacteria that produce acetic acid by the reduction of carbon dioxide with hydrogen, thus reducing the hydrogen available for reaction to produce methane (methanogenisis) (Demeyer and de Graeve, 1991). Although this reaction is theoretically possible in the rumen, populations of acetogens in the rumen of adult ruminants are low and a methane producing reaction tends to dominate. Research groups are currently investigating these reactions with the aim of devising practical solutions for the survival of acetogenic bacteria in the rumen and hence the displacement of methanogenic bacteria. This would not only decrease methane production, but would also increase the efficiency of ruminant production. The costs associated with isolating, growing and preparing this type of micro-organism are not clear, but some of these costs would inevitably be offset by improved rumen efficiency. Methane oxidisers could also be introduced as direct-fed microbial preparations. The oxidation reaction would compete with the production of methane, which is a strictly anaerobic process. Methane oxidisers from gut and non-gut sources could be screened for their activity in rumen fluid in vitro and then selected methane oxidisers could be introduced into the rumen on a daily basis in a manner analogous with current feed supplements. If successful, this option has the potential to reduce methane production in the rumen by a minimum of 8% (ADAS, 1998). As for acetogens, the option would be available to all ruminants receiving supplements on a controlled and regular basis but the costs associated with isolating, growing and the preparation of the micro-organism are not clear.

D. Genetic Engineering

Recombinant deoxyribonucleic acid (DNA) technology could potentially be used to modify the fermentation characteristics of rumen micro-organisms (Armstrong and Gilbert, 1985). Examples of application include an enhanced cellulolytic activity in the rumen biomass for forage fed animals to increase their supply of VFAs and amino acids, and a reduction in methanogenesis accompanied by an alternative hydrogen sink through increasing propionate production. This method however, is likely to be unacceptable to most EU Member States as there is considerable opposition to the increased release of genetically engineered organisms into the environment.

E. Immunogenic approach

A team of researchers at CSIRO in Australia have made an application for a world wide patent for a method of improving the productivity of a ruminant animal by administering to the animal an immunogenic preparation effective to invoke an immune response to at least one rumen protozoan. The removal of one species of protozoan from the rumen will invoke the improvements in productivity associated with defaunation. It is also believed that by modifying the activity of the rumen protozoan, there will be an indirect effect on the activity of methanogens, due to their commensal relationship with rumen protozoa. Data from this work are not yet published but it is anticipated that methane production could be reduced by as much as 70%. The long term prospects of this approach are not yet available but areas to be considered are the longevity of the immunisation and whether other species of protozoa and methanogens will increase their populations to compensate for those species where immunisation has taken place. If this option develops successfully, it could be applied to the whole ruminant population. The costs associated with the approach could be high initially due to the monopoly associated with patents. The increased protein utilisation associated with defaunation would mean reduced emissions of ammonia and increased animal productivity.

5.4. Mitigation measures Enteric Fermentation

Success in reduce methane emissions from ruminants by increasing animal productivity depends on keeping overall production levels constant. That is, a reduction in total emissions of methane would only result if total output levels (e.g. total milk or beef produced) remained constant and the advantages gained from increased productivity were realised by reducing livestock numbers.

The most direct approach to reduce enteric emissions is to increase rumen efficiency and reduce the amount of methane produced for a given amount of feed intake.
Possible options for increasing ruminant productivity are discussed below:

Probiotics

Probiotics are microbial feed additives containing live cells and a growth medium. They are already widely available in the EU, and are used to improve animal productivity. From an analysis of published results from more than 1000 cows, Wallace and Newbold (1993) calculated that probiotics stimulated milk yield by 7.8%, and from 16 trials using growing cattle, they showed an average increase in liveweight gain of 7.5%. Further research is required to confirm whether there is any additional effect on methane production per se. Even without a direct effect on methane production, there would be a reduction in methane production per unit of production (e.g. per litre of milk).

Ionophores

Ionophores are chemical feed additives which increase productivity (weight gain per unit of feed intake) by adjusting several fermentation pathways. On average, an 8% increase in feed conversion efficiency has been observed (Chalupa, 1988). Reductions in methane production (of up to 25%) have been observed (Van Nevel and Demeyer, 1992), but the persistence of this reduction is unproven. Ionophores are fed to beef animals only in the EU. Their use in dairy cows is not permitted because a withdrawal period is required before human consumption. The use of chemicals and antibiotics to increase animal productivity is increasingly becoming unpopular to the consumers of animal products. It is therefore considered that the use of ionophores to reduce methane production is not a viable option.

Bovine somatotropin

Bovine somatotropin (BST) is a genetically engineered metabolic modifier approved for use in some countries to enhance milk production from dairy cows. Again, this is not a popular consumer choice for enhancing animal productivity and its use now banned by all EU Member States. Again this is therefore not considered a viable option.

Forage type and supplementation

Supplementing forages whether of low or high quality, with energy and protein supplements is a well-documented method of increasing microbial growth efficiency and digestibility, and thus increasing milk and meat productivity. The direct effect on methanogenesis is variable and unclear.
Research has shown that increasing the level of non-structural carbohydrate in the diet (by 25%) would reduce methane production by as much as 20%, but this may result in detrimental health effects e.g. acidosis, fertility problems (Moss, 1994). Also with the implementation of quotas for milk production in the EU, many producers are optimising milk production from home-grown forages in order to reduce feed costs. Supplementing poor quality forages and chemically upgrading them may be a good option for increasing productivity and in turn reducing methane emissions per unit product. Feeding of ruminants to optimise rumen and animal efficiency is a developing area and the efficient deployment of appropriate nutritional information to all livestock producers would benefit the environment in terms of both methane and nitrogen emissions.

High genetic merit dairy cows

Improving the genetic merit of dairy cows has escalated in the last decade with the import of Holstein genetic material from US and Canada for use on the EU native dairy breeds. As a result, average national yields have increased. For example, the UK dairy herd has increased its average yield by 8.8% from 1995 to 1997 (ADAS, 1998). One of the major improvements is the ability of the cow to partition nutrients into milk preferentially to maintenance and/or growth. This has undoubtedly resulted in increased efficiency. The genetic merit of livestock within the EU is rapidly improving and this will undoubtedly bring with it increased efficiency, and potential reductions in methane emissions of 20 to 30%. However, the management of these high genetic merit cows will also become more complex and overall implementation of this approach may be stalled by animal welfare implications. High genetic merit cows can have increased problems with fertility, lameness, mastitis and metabolic disorders, and all these issues will have to be addressed if genetic progress is to be successfully continued.

5.5. Costs and cost-effectiveness of measures

With respect to enteric fermentation, enough cost and performance data is available to calculate the cost-effectiveness of two options:

A. propionate precursors;

B. probiotics.

-The average methane emission for dairy cows is 100 kg/head/year and for non-dairy cattle is 48 kg/head/year (IPCC, 1996).
-Propionate precursors cost EUR 1,628/ton and probiotics cost EUR 1,554/ton in 1997 (ADAS, 1998). Capital costs are zero.
-Both additives are given to animals as daily supplements. These supplements are generally only given to larger herds (see below). Supplements are given to dairy cows year-round but non-dairy cattle can only be fed with supplements when they are housed inside in the winter. It is estimated that suckler cows can take supplements for 30-40% of the year and beef cattle for 40-50% of the year. For these calculations the two categories are taken together as non-dairy cattle and it is assumed that supplements are taken for 40% of the year.
-80g/day of propionate precursor is required per head of cattle to give a reduction in methane emissions of 25% (ADAS, 1998). Assuming the propionate precursor is used throughout the year, the total cost of additive per head per year is therefore:
Cost/head/yr = 1,628 EUR/kg x 0.08 kg/day x 365 day/yr1000= EUR 47.5/head/yr (Source: Options to Reduce Methane Emissions, EC Report, 1998). This gives an emissions reduction of 25% of the total annual emissions = 25 kg CH4/head/yr for dairy cows. For non-dairy cattle, costs are 40% of EUR 47.5, and reduction is 4.8 kg CH4/head/yr (Source: Options to Reduce Methane Emissions, EC Report, 1998).
-For probiotics, 50g/day/head is required to give an emissions reduction of 7.5% (ADAS, 1998). Using the same calculation as above, the cost of probiotics is EUR 28.4/head/year and the emissions reduction is 7.5 kg/head/yr for dairy cows and EUR 11.36 and 1.44 kg/head/yr for non-dairy cattle (Source: Options to Reduce Methane Emissions, EC Report, 1998).

Table 5.19. Greenhouse gas emissions under Business as usual (BAU) scenario in R. Macedonia

BAU Enteric Fermentation (without Measures)			
T1 Enteric Fermentation sto e T1?	*2014*	*2020*	*2030*
Dairy	12.17	12.01	11.80
Non-dairy	5.86	5.81	5.74
Buffalo	0.05	0.05	0.05
Total CH4	**18.08**	**17.87**	**17.59**
Total CO2eq	**379.68**	**375.20**	**369.38**
T2 Enteric Fermentation sto e T2	2014	2020	2030
Dairy	11.88	10.98	9.48
Non-dairy	6.40	6.35	6.27
Buffalo???? A small ruminants?	0.06	0.06	0.06
Total CH4 [Gg]	**18.34**	**17.39**	**15.81**
Total CO2eq [Gg]	**385.17**	**365.24**	**332.01**

Table below summarises the cost-effectiveness of measures to reduce emissions of CH4 from enteric fermentation. It indicates that the use of propionate precursors for dairy cows is the most

cost effective option. The same option for non-dairy cattle is less effective because non-dairy cattle emit less than half the methane of dairy cows. Probiotics are less cost-effective because they are expected to give a smaller percentage reduction in methane emissions than propionate precursors. It is important to note that the emissions reductions offered by these options are still very uncertain and further research is required to confirm the data. In addition the estimates below do not take into account any savings from the increased productivity which may result from the use of the additives and the costs given below may thus be an overestimate..
For both measures a slow penetration rate has been taken into account, i.e if the measures are implemented from year 2014 on a 6.6% of catle population (dairy and non-dairy animals), in year 2015 on 8.3% population, 2018 – 10%, 2022-12.5%, 2026-20% and by year 2030 on 50% of cattle population in the country.

Table 8.0.20 Cost effectiveness and GHG reduction from mitigation measures for enteric fermentation

Animal type	**Costs EUR per unit/year**		**CH4 reduction [Gg]**		**CH4 reduction per unit [kg/head/yr]**	
	EUR per head/yr	EU per head/yr				
	Probiotics	Propionate precursors	Probiotics	Propionate precursors	Probiotics	Propionate precursors
T1 Scenario						
Dairy	28.4	47.5	1.13	3.76	7.5	25
Non-dairy	11.36	19.02	0.15	0.50	1.44	4.8
Buffalo	11.36	19.02	0.00	0.00	1.44	4.8
			1.28	**4.26**		
T2 Scenario						
Dairy	28.4	47.5	1.02	3.41	7.5	25
Non-dairy	11.36	19.02	0.15	0.51	1.44	4.8
Buffalo	11.36	19.02	0.00	0.01	1.44	4.8
			1.18	**3.93**		

Table 8.0.21 Greenhouse gas emissions, cumulative reduction of emissions and associated costs with mitigation measures under two different time-series prediction until year 2030 (with measures implemented from 2014).

Business as usual	Total GHG emissions [Gg]					
Trend line T1	6,360.28					
Trend line T2	6,096.03					
Penetraion rate of the measure (year and % of cattle population)	**2014 – 6.6%**	**2015 - 8.3%**	**2018 – 10%**	**2022-12.5%**	**2026-20%**	**2030-50%**
Measure	Total GHG emissions [Gg]		Total Costs [EUR]		GHG reduction [%]	
Trend line T1 proprionate precusors	1497.66		22,567,210		**23.55**	
Trend line T2 proprionate precusors	1278.33		19,262,481		20.97	
Trend line T1 probiotics	449.30		13,489,682		**7.06**	
Trend line T2 probiotics	383.50		11,513,737		6.29	

6. Manure Management

Animal manures contain organic compounds such as carbohydrates and proteins. These relatively complex compounds are broken down naturally by bacteria. In the presence of oxygen, the action of aerobic bacteria results in the carbon being converted to carbon dioxide and, in the absence of oxygen, anaerobic bacteria transform the carbon to methane. When livestock are in fields and their manure ends up being spread thinly on the ground, aerobic decomposition usually predominates. However with modern intensive livestock practices, where animals are often housed or kept in confined spaces for at least part of the year, manure concentrations will be higher and manure will often be stored in tanks or lagoons where anaerobic conditions generally predominate and methane will be evolved. There is therefore a need to adopt measures which avoid the evolution of methane or convert evolved methane to carbon dioxide.

Improving management systems for handling waste of animal origin (AWMSs) can significantly reduce GHG emissions associated with manure treatment. This practice is based on the drying of cattle waste, since dry cattle manure produces seven times less methane than the equivalent wet weight.

Nitrous oxide emissions from manures

Animal manures contain nitrogen in the form of various complex compounds.

Nitrogen emissions are released from different types of animal waste management systems (AWMS) on livestock farms: anaerobic lagoons, liquid systems, solid storage or other systems closed facilities, etc.)

Only cattle farms have nitrous oxide emissions from an anaerobic lagoon systems, liquid systems are practiced also on cattle farms (73.7%) and smaller amounts on pig (20%) and poultry farms (6.3%). Emissions from solid storage are coming from dairy (41.7%) and non-dairy cattle farms (58.3%). On pasture and paddock systems, 64.5% of emissions are coming from sheep breeding, while at other systems 52% of emissions from sheep breeding, 28% from pig farm systems and 14% from poultry farms.

Table 6.1. Animal waste management systems in R.Macedonia and nitrous oxide emissions percentage

Animal Waste Management System	Percentage of N_2O emissions (%)
Anaerobic lagoons	0.26
Liquid systems	2.63
Daily spread	0
Solid storage & drylot	82.57
Pasture range and paddock	NA
Other	14.54

If manures are applied to land, then this nitrogen enters the nitrogen cycle, as various bacteria in the soil break down these nitrogen containing compounds. Under the right conditions this can lead to the evolution of nitrous oxide which has an even higher global warming potential than methane. Therefore, any measures to reduce methane releases to atmosphere resulting from animal manures, should attempt to avoid creating conditions which increase nitrous oxide releases. Nitrous oxide emissions are influenced by nitrogen availability, soil moisture content and temperature. Of these, nitrogen availability is the most important (Colbourn 1993) and the most readily controlled. It is therefore important that, where manures are applied to land, the nitrogen load is matched to the crop demand. This will help to avoid excess soil nitrogen and hence the potential for nitrous oxide releases.

Methane emissions from manures
Methane emissions from manure depend on:

- the quantity of manure produced, which depends on number of animals, feed intake and digestibility
- the methane producing potential of the manure which varies by animal type and the quality of the feed consumed
- the way the manure is managed (e.g. whether it is stored as a liquid or spread as a solid) and the climate as the warmer the climate the more biological activity takes place and the greater the potential for methane evolution. Also, where precipitation causes high soil moisture contents, air is excluded from soil pores and the soils become anaerobic again increasing the potential for methane release (for wastes which have been spread).

Over half of the methane emissions come from cattle manure (56.83%) and most of the remainder from pig manure (36.17%).

Table 6.2. Precenage of methane emissions from different animal farms in our country

Livestock type	***% of CH_4 emissions***
Dairy Cattle	30.75
Non-dairy Cattle	26.08
Buffalo	0.29
Sheep	3.52
Goats	0.48
Horses	1.51
Swine	36.17
Poultry	1.19

6.1. Measures to mitigate emissions from Manure Management

The agricultural waste encompasses waste arising from agricultural processes. App. 5 million tonnes of animal waste (faeces, excreta, bedding, dead animals)) is generated annually in Macedonia. Out of the total animal waste app. 5,600 t/year is carcases and app. 6,000 t/year animal by-products from slaughterhouses (some portion of the latter is further processed and as such it goes not end up neither in sewers nor at the existing landfills). Some 370,000 tonnes of plant residues is never disposed (or burned) because it is used for stock-breeding.

Table 6.3. Q*uantities of generated agricultural waste*[8]

TYPE OF WASTE	**ESTIMATED QUANTITY [t/year]**
Waste from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	
Animal by-products	5,060,000

The animal waste contains also infectious carcasses, which is considered hazardous and not suitable to be recovered due to the waste being infected with bacteria, viruses and sprout. The amount of animal waste with a recovery potential is estimated at 3.6 – 4.0 million tonnes per annum. Emissions of methane from animal manures depends on several factors:

- Animal numbers;
- Feed intake and digestibility;

[8] Source: *National Waste Management Plan (2009 – 2015), MoEPP*

- Climatic conditions;
- Type of management (animal waste system).

Following Table shows some mitigation measures and example of technologies and mitigation effects for Manure management (reduction potential of GHG):

Table 6.4. Mitigation measures for manure management and estimated effects

Mitigation measure	Activity	Technology examples	Mitigation effects		
			CO_2	CH_4	N_2O
Manure Management	Improved storage and handling	Covering manure storage facilities		x	?
	Anaerobic decay of waste (AD)	Crop residue management; Biogas digester with recovery of methane		x	?

Increased animal productivity will reduce the maintenance overhead associated with each unit of product; hence emissions from manure per unit product will be reduced. Total emissions will only be reduced if the level of output remains constant. As output (meat and milk) is influenced by market demand and the Common Agricultural Policy, reducing animal numbers cannot be considered a realistic mitigation option. Any methane reduction strategy should therefore seek to avoid uncontrolled releases from anaerobic degradation, either by ensuring aerobic digestion or recovering methane evolved from anaerobic degradation. Consequently, practical measures to reduce methane releases resulting from animal manures fall into two categories:

A. Measures to ensure aerobic decomposition (ex. composting, open pit) and avoid methane evolution;

B. Measures to convert evolved methane to carbon dioxide.

A. Aerobic decomposition

In our country, some 40% of dairy cattle manure is treated as liquid slurry releasing 10 to 35% of the manure's methane potential, depending on annual average temperature, and for beef cattle 50% of manure is treated in this way. 73% of pig manure is treated by pit storage for more than 1 month, again releasing 10 to 35% of the manure's methane potential, depending on annual average temperature. These relatively large emissions are due to anaerobic storage conditions. Farming practices which ensure that manure degrades aerobically can therefore reduce methane emissions from current levels.

Livestock management

When manures are spread thinly across the land then decomposition will be largely aerobic, and livestock kept in pastures or rangeland result in manure being naturally widely spread. Within the EU, the main market driver is currently for cheap food products and this has led to intensive farming methods, which normally involve animals being housed rather than pasture based systems. There is some potential for a market led switch to greater use of pasture as a result of public concern for animal welfare and an increasing demand for organically produced foodstuffs. However, for the purposes of this study it is considered that any switches to more extensive farming systems will be small for the foreseeable future and therefore are not considered further as a methane reduction option.

Land application management

Intensive livestock management regimes lead to animals being housed for at least part of the year. Under these circumstances high concentrations of manure arise, often on farms with little land,

and manure storage is required. Stored manure will degrade anaerobically and the sooner the manure is spread onto the land the less anaerobic decomposition will have taken place and the less methane evolved. When spreading to land, anaerobic degradation can be minimised by avoiding anaerobic soil condition and by spreading thinly and evenly. Spreading has the potential to release emissions of both nitrous oxide and ammonia, and their minimisation should also be considered. As already mentioned manure applications should be matched to crop nitrogen needs to avoid excess soil nitrogen and hence nitrous oxides release. Up to 90% of ammonia loss to atmosphere occurs within 12 hours of spreading (Burton et al.1997) hence it is important to incorporate the manure into the soil as effectively as possible to minimise this loss (this equally applies to spreading of manures treated by anaerobic digestion).

Aerobic treatments can be applied to liquid manures through aeration and to solid manures by composting. Aeration involves dissolving sufficient oxygen in the liquid manure to allow bacteria to oxidise the organic carbon. Systems for aeration involve mechanical methods for passing air through the liquid, usually driven by electric motors. When considering methane reduction using this technique, emissions of greenhouse gases from electricity generation should be deducted from any saving. Other factors to consider are that aeration may leave up to 70% of the total organic load (Burton et al 1997) which may subsequently degrade anaerobically if the liquid manure is stored and that losses of 4 to 11% of the total nitrogen as nitrous oxide have been reported from the aeration of liquid pig manure (Burton et al 1993). Therefore there is considerable uncertainty as to the effectiveness of this treatment option. *Solid manures can be aerobically treated by composting*. This may require de-watering of liquid manures or addition of other dry organic materials to increase porosity and penetration of air.

Also organic material may have to be added to increase the carbon/nitrogen ratio to levels suitable for *composting*.

Composting is the natural biological breakdown of organic material into a more stable organic substance. During the process of aerobic composting (presence of oxygen), microorganisms consume organic matter (carbon) and release heat and carbon dioxide (CO2). Aerobic composting methods decompose material faster and more efficiently than anaerobic composting methods (absence of oxygen), such as stock piling manure. Persistent odours and the risk of water contamination by surface runoff are reduced when agriculture wastes are composted compared to conventional land management (stock piling manure). Further, composting is a waste management system that creates a recycled product, which is carbon rich and free of most pathogens and weed seeds.

Passively-aerated composting eliminates the need for turning by supplying air to the composting materials through perforated pipes or layers of porous material embedded in each windrow. Open-ended perforated pipes are placed at the base of a compost pile. Compost material is then loaded on top of the pipes, and airflow is achieved through convection. The pipes are pulled out once composting is completed. Actively-aerated composting uses a fan to supply air to the compost material through the pipes. Theoretically, no turning of the materials is required, however occasional turning breaks up air channels, redistributes moisture, and exposes fresh material to microbial attack. The advantage of aerated composting systems is it takes much less time to compost than passive systems. Composting represents a recycled, low input form of slow release fertilizer. Compost application to soil reduces the amount of inorganic fertilizer required. Therefore, the net GHG emission is reduced because the energy-intensive fertilizer production and associated GHG emission is reduced. In addition, compost amended soil is more resistant to wind and water erosion because soil structure is improved and soil moisture-holding capacity is increased. Adding compost to soil alleviates soil compaction by improving root penetration, water absorption and drainage. Recent studies (Analysis of biodegradable waste treatment in order to reduce quantity of disposed waste, , Bojana Tot et al, *32nd annual meeting of the international association for impact assessment ,* 2012) show that for 80,000 of biodegradable waste one can expect 35,000 tonnes of compost meaning that 3,34 million tonnes animal waste can 1,46 million tonnes of compost / annually.

B. Conversion of methane to carbon dioxide

Anaerobic digestion

Anaerobic digestion (AD) is the bacterial fermentation of organic material under controlled conditions in a closed vessel. The process produces biogas which is typically made up of 65% methane and 35% carbon dioxide with traces of nitrogen, sulphur compounds, volatile organic compounds and ammonia. This biogas has a typical calorific value of 17 to 25 MJ/m3 and can be combusted directly in modified gas boilers, used to run an internal combustion engine or simply flared. Applying this process to animal manures ensures that most of the carbon is ultimately converted to carbon dioxide before being released to atmosphere. Typically, between 40% and 60% of the organic matter present is converted to biogas. The remainder consists of a relatively odour free residue with an appearance similar to peat, which has some value as a soil conditioner and also, with some systems, a liquid residue which has potential as a fertiliser.
According to IPCC AD releases 5% of the manure's total methane potential. This release is largely due to further decomposition of the digested material on removal from the digester. These emissions can be minimised through covered storage with gas collection or by reducing storage times. Leakage of biogas is another potential source of methane emissions but this should be minimised by good system design and maintenance. AD plants vary from small 'low-tech' on-farm systems to highly engineered centralised plant. In the latter case commercial drivers ensure that plants recover all practicable methane for energy generation and fugitive methane emissions will be minimised. For example covered digestate storage with gas collection is becoming the industry norm for centralised AD plants. These types of plant are likely to operate with less than 5% methane releases, but this figure will be used here as a conservative assumption.
It should be noted that an additional benefit of utilising biogas from AD plants to produce heat and electricity is that this will offset greenhouse gas emissions resulting from fossil fuel energy sources and this should be accounted for when considering the contribution of AD to wider greenhouse gas reduction. There are some constraints on the applicability of this measure. Any plant needs sufficient feedstock from the surrounding area without incurring excessive transport costs (both financial and environmental). For on-farm plants this is not an issue and there is no real limit to how small a digester can be. In practice, for commercial plant rather than self-built units, about $50m^3$ is the smallest plant being installed. Such a plant would be suitable for about 50 cattle or 500 pigs.

Covered Lagoons

In some cases liquid manures are stored in open pits or lagoons. These lagoons often have an impervious liner to prevent leaching into soils and ground water. Slurry lagoons also undergo anaerobic digestion and hence emit methane. In an uncovered lagoons about 90% of the manure's methane potential can be released to atmosphere. Covered lagoons, which collect and use the methane evolved, can be considered as simple, low cost AD plants and have a similar potential for methane reduction. Methane releases from covered lagoons may be higher than for AD plant due to difficulties in sealing over the large areas concerned. The potential use of covered lagoons will be lower than for AD due to land constraints where intensive farming is carried out. This will be especially the case for pig and poultry farming.

Cost of Measures

Three options to reduce CH4 emissions for which some cost data is available, have been identified:

- Aerobic treatment - Composting;
- Aerobic treatment - Daily spread of manure;
- Anaerobic treatment- Covered lagoon;

There is a fourth option anaerobic digestion, but it is considered in Chapter 6.3.

Daily spread of manure

According to IPCC *daily spreading* of manure results in the release of 0.1 to 0.5% of the manure's methane potential and switching to daily spreading of manure could therefore reduce methane emissions from these sources significantly.

However, there are limitations to the applicability of daily spreading:

- during times of high rainfall there will be a risk of run-off causing water pollution;
- application of nutrients in the manure cannot always be matched to crop requirements hence the risk of nitrous oxide release and eutrophication is increased;
- large numbers of vehicle movements may result in damage to soil structure;
- access to the land may be restricted at certain times of the year;
- increased labour requirement.

The cost–effectiveness of this measure has been estimated using data collected from the Farm Management Pocketbook (1996) and costs from Adjustment Plan in IPPC Environmental Permits from largest farms in te country.

- Investment costs: EUR 10,000 to purchase land by concession and 70,000 EUR for equipment.
- The annual operational costs are EUR 10 per pig per year, EUR 50 per head of non-dairy per year and EUR 100 per dairy cow per year. In case of Agria farm which has 28,403 pigs this means EUR 284,030 operational annual costs.
- The option has a lifetime of 1 year and requires 0 years to install.

For temperate climates, methane reductions are 0.0186 tonnes per pig, 0.0380 tonnes per head of beef, and 0.1014 tonnes per dairy cow.

Aerobic treatment of manure-Composting

Based on the data from Agria farm, a small scale compost facility should cost EUR 20,000 and additional costs of 70,000 EUR for equipment for manure spreading of liquid and solid manure (Operational Plan of the IPPC A-environmental permit). Farmers have costs for transport of ready compost on land, so it's feasible to have available land in the 20km radius. Based on these time estimates, the researchers calculated annual operating costs for each composting method, including fuel, labor maintenance and costs of straw to mix with the manure (at 3,000 EUR). The option has a lifetime of 20 years and requires 0 years to install.

During composting, about 50% of carbon contained in the raw materials is lost as CO_2 and 50% is retained, mostly in recalcitrant organic compounds. The rate and extent of mineralisation of compost products after application to soil depends on the quantity, type, maturity and particle size distribution of the applied product, as well as on soil properties, environmental conditions, and agricultural management practices. The labile organic compounds contained in compost are degraded relatively quickly, and the recalcitrant fractions remain in the soil.

Compost use can supply at least some of the mineral nitrogen that would otherwise have to be provided through mineral fertilisers, as well as most, if not all, of the crop's phosphorous, potassium and trace element requirements.

Anaerobic Digestion: small-scale plant producing electricity and heat

A dairy cow will typically produce 53 litre excreta, use up to 2.9 kg of bedding and generate 18 litre of parlour washings per day (COGAP figures). Based on these figures, a large herd of 500 dairy cows would produce about 37 m3 manure and slurry including parlour washings per day. Assuming that this is put through an AD plant with a typical 20-day retention time, the total

quantity of waste (manure) being digested at any time will be 740 m^3. As this is under the 1000 m^3 limit, it will be eligible for a paragraph 12 exemption for the digestion process.
1 m^3 cattle manure typically produces up to 20 m^3 of biogas, and the calorific value of this gas will typically be 5.83 kWh/m.
Dairy cows produce 17.3 tonnes of manure per head per year, beef cattle produce 8.7 tonnes of manure per head per year, and pigs produce 1.7 tonnes of manure per head per year. The maximum potential methane emission per animal is as above. Anaerobic digestion results in the release of only 5 per cent of the maximum potential methane. In cool climates the use of this plant therefore results in annual savings in methane emissions of 14 tonnes, 6 tonnes, and 8 tonnes, for treating pig, beef or dairy manure, respectively. Further discussion on costs for AD can be found in Chapter 6.3.

Covered lagoons

An indicative calculation has been made based on data from IPPC A-environmental permit from the biggest pig farm in our country (1,517 sows and 26,526 wearing pigs).
In the Operational Plan of the permit, Agria Farm near city of Veles estimated 40,000 EUR investment costs to cover two lagoons with volume 13,200m^3.
-The option has a lifetime of 10 years, and requires 1 year to install.
The same investment is projected in the second largest pig farm ZZ Edinstvo Chelopek near Tetovo (IPPC Environmental Permit-Annex, p.162).
The annual operating costs are EUR 2.30 per pig per year or EUR 11.50 per head of beef per year, and EUR 23.00 per dairy cow per year. The use of a covered lagoon results in annual savings of methane emissions of *0.0162 tonnes per pig, 0.033 tonnes per head of non-dairy animal and 0.0882 tonnes per dairy cow* (EC,1998. Options To Reduce Methane Emissions). A-Environmental permit of the bigest poultry farm in our country VEZE SHARI, village Trebosh in Zhelino Municipality (240,000 broilers) states that 140,000 EUR investment is needed for sanation and modernization of their pit (Annex to IPPC Environmental permit, p.140).

To summarize, for the largest 5 pig farms and one poulry farm in our country, the total investment and operational costs are presented below (excluding AD discussed in Chapter 6.3):

Table 6.5. Investment and annual operating costs for 6 largest farms in R. Macedonia.

			Investment costs [EUR]			***Operating costs [EUR]per year***		
Type	***Farm name***	***Animals***	Daily spread	Covered Lagoon	Composting	Daily spread	Covered Lagoon	Composting
Pig farms	Agria	28,403	90,000	40,000	90,000	284,030	65,327	3,000
	ZZ Edinstvo	27,140	85,000	40,000	85,000	271,400	62,422	3,000
	Mak meso	26,300	80,000	40,000	80,000	263,000	60,490	3,000
	Vinefarm	18,500	75,000	40,000	75,000	185,000	42,550	3,000
	Zito Malesh	15,750	70,000	40,000	70,000	157,500	36.225	3,000
Poultry farms	Veze Shari	240,000	0	140,000	150,000	0	120,000	13,000
			400.000	340,000	550,000	1,160,930	387,014	28,000
Total costs [EUR]			**1,290,000**			**1,575,944**		

Overall, the most cost-effective measure to reduce methane emissions from the agricultural sector is *anaerobic digestion, where the biogas produced is used to generate electricity and or heat*. The small scale plants are more cost effective, due mainly to a simpler design leading to lower capital costs. Composting facilities can be a feasible choice, but do not give large reductions of GHG and are associated with land availability for application of compost, equipment maintenance and transport costs.

Since these mitigation measures fall under IPPC environmental legislation (A-Integrated permits), they must be in completed in **2019**, according to latest amendment of the Law on environment (Official gazette of R.M, no.53/05)and IPPC Decree (Official gazette of R.M, no.89/05).

Table 6.6. Possible reduction of methane emissions from Manure Management (in Gg CO_2-eq.)

	Animal type	Reductions CH4eq. per animal	*2019*	*2020*	*2030*
Anaerobic treatment	pigs	0.00002	0.003	0.003	0.003
	non-dairy	0.00003	0.003	0.003	0.003
	dairy	0.0001	0.01	0.01	0.01
			0.02	**0.02**	**0.02**
	covered lagoon		**0.42**	**0.41**	**0.41**
Aerobic treatment	pigs	0.0000186	0.004	0.004	0.004
	non-dairy	0.000038	0.004	0.004	0.004
	dairy	0.0001014	0.02	0.02	0.01
			0.02	**0.02**	**0.02**
	Daily spread		**0.48**	**0.48**	**0.47**
	pigs	0.00024	0.05	0.05	0.05
	non-dairy	0.0004	0.04	0.04	0.04
	dairy	0.0004	0.06	0.06	0.06
			0.15	**0.15**	**0.15**
	Compost		**3.15**	**3.13**	**3.11**

A cost-benefit analysis with penetration of measures in 2019 and associated costs is presented below.

Table 6.7. Comparing GHG reduction and cumulative costs until 2030 from different mitigation measures with Business as usual scenario

Measure	*BAU emissions CO_2-eq [Gg] 2030*	*Reduced emissions CO_2-eq [Gg] in 2030*	*% reduction*	*Cumulative costs [million EUR]*	*Potential profit [million EUR]*
Covered lagoon	529,41	524,46	0,93	28.08	44.8
Daily spread		523,72	1,08		
Composting		491,95	7,08		

Further discussion on benefits and profit from selling animal manure as organic fertilizer is presented in Chapter 5.2.

7. Production of biogas from farming

Biogas is produced when the organic material decays in environment with limited oxygen presence in the presence of microorganisms. The process of decay is called anaerobic digestion

and naturally takes place in many environments with limited oxygen present: for example, in ponds and swamps, in rice fields, and also in the stomachs of ruminants.
This natural process can be used in biogas plants where organic material is placed. Substantial part of the plant is a closed chamber or sealed container (or often called reactor - digester) which place the digestion reaction. Final product of the breakdown is a fuel called biogas and organic residue in cupboards containing minerals and is suitable to be used for fertilization as liquid or solid bio fertilizers.
The biogas is mainly composed of methane (chemical formula: CH_4). The biogas, depending on conditions at the time of creation, contains 45% to 85% methane and 15% to 45% carbon dioxide (chemical formula: CO_2). The biogas also contains small amounts of hydrogen sulfur, ammonia and nitrogen, and often it may contain water vapor (H_2O). The amount of biogas is usually expressed in cubic meters (m^3), an amount of biogas 0°C and atmospheric pressure (1 bar).
Biogas can be purified from other compounds and the remaining methane can be used as fuel, be injected in natural gas pipeline or system, and used as a heat source or production of electricity.

7.1. General Benefits from Implementation of Systems for Biogas production

In the developed countries this is well known technique to handle the agriculture waste, whether it is for silage, manure or waste from meat and dairy. The simplest usage of the biogas produced is to operate the appliances that use natural gas, or in the produced natural gas is purified and compressed it can be used for vehicle powering of production of electricity or heat. The smaller farms can meet their energy needs, and those larger to sell the produced natural gas, heat or electricity.
Additional co-benefit from installation of bio digesters is the production of high quality compost, which is at the same time placed on the exact location from which can be easily transported or packed.
The process of the processing of the manure and the sludge finalizes the bio-circle on a sustainable way, provides economic benefits and provide sustainable development and clean energy. The multiple environmental benefits in terms of GHGs reduction are the following: reduction of the CH_4 from the etheric fermentation and manure management, reduction of the CO_2 emissions from fossil fuels used as energy or a heat source, reduction of CH_4 and nitrogen absorption in the soil and in the waters etc.
With only two cows and using their manure a farmer can make considerable savings in power consumption in the family. By installing plastic bio digesters for processing the manure the produce biogas can be used to operate stoves, water heaters and many other appliances.
In the same this measure can lead to increased number of livestock farms, while simultaneously increasing the percentage of utilization of manure and silage. This is especially important because the European countries, which have long tradition of biogas plants (40 percent usage of silage and 60 percent of the manure).

7.2. National Circumstances

The R. Macedonia has a huge potential for production of biogas from the manure and sludge management because of the numerous farming associations in the country. Unfortunately this potential is not used at all, because of the lack of the financial incentives for these types of mitigation measures, as well as lack of the awareness from the farmers and potential investors.
The tradition and the general practice for manure management in Macedonia are to place the manure in heaps, and use it as an organic fertilizer when needed. This traditional agricultural practice has a major environmental impact, because of the huge amount of raw methane released in the atmosphere and remaining methane which penetrates deep into the soil and pollutes groundwater. Very serious environmental problem is also experienced from the deposition of the waste from the dairy and meat industry in the dumps or rivers, which latter contaminates the entire biotope.
The livestock populations adequate for production of biogas are cattle and pigs.
The pig farms potential for installation of biogas plants will be assessed in details in this study, because of the available data for the exact number of pigs raised in big farming associations. The

data used for accessing of the mitigation potential from manure management of the swine farms are taken from the IPPC applications of the biggest five farming associations.
Because of the low country GDP, this type of investments in clean energy are not still implemented in the country, but the IPARD program can be a great incentive and provide subsidies for the purchase of such equipment from which the state will have multiple benefits.

7.3. Environmental assessment of the application of systems for manure management and biogas production on big swine farms

The referent activity data taken for the calculation of the emissions from manure management is total swine population for the period 1990 – 2012. For this period a calculation of the total emissions of the manure management of the swine population was made. In order to estimate the predicted swine population and consequently the emissions from the manure management two different population trends with the statistically modeled values of swine populations have been made, and consequently the business as usual emissions from the swine population were estimated.

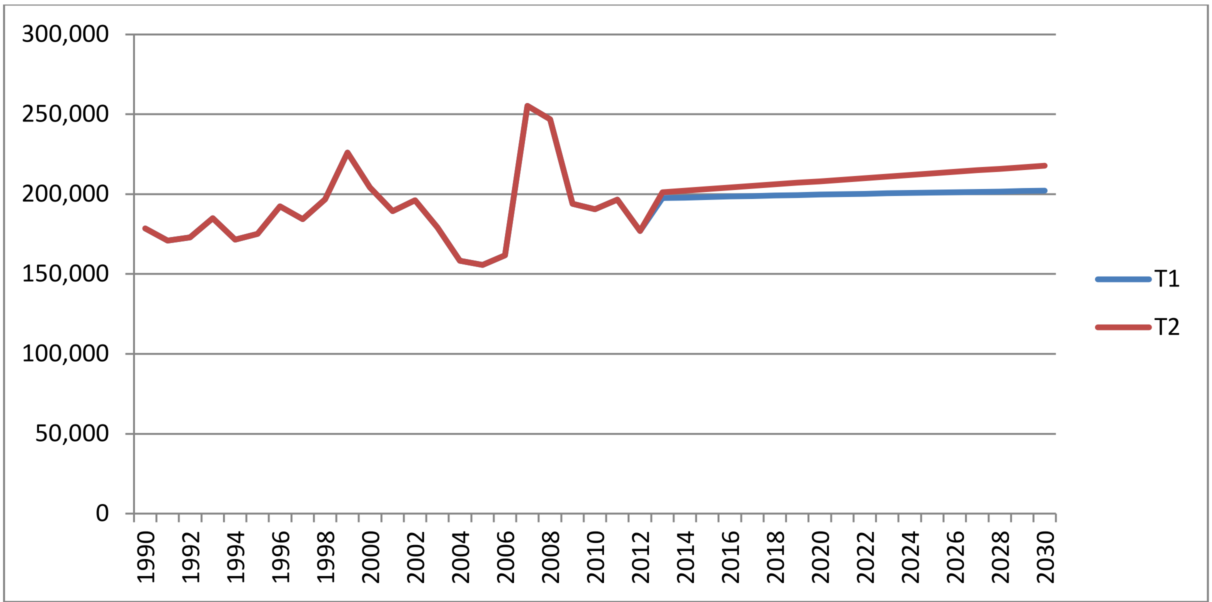

Figure 7.1. - Total number of swine 1990 - 2012, and modeled values Trend 1 and Trend 2

The forecasted trends of the swine population are made using the extrapolation of the data based on previous time series. The Trend 1 shows lower increase of the swine population than the Trend 2.
For the assessment of the country potential for production of biogas real data from the five biggest swine farms (included in their IPPC applications) have been taken. The total maximum allowed capacity of these five swine farms is a value of 104,250.00 animals, and this maximum capacity is used as a base number for the estimation of the potential reduction, and lately as a basis for increase of the capacity of the systems for biogas production. This base number of swine population taken as adequate for production of biogas in this assessment is also in concordance with the EU and developed countries average production of biogas from the farming associations (50 – 60% of the total livestock population).
Additionally the penetration rate of the measure implementation of systems for manure management and biogas production is modeled on two different ways. The first penetration rate model shows 20% annual penetration rate of this measure, which means that the measure for manure management and biogas production will be completely introduced on the five major swine farms after 5 years starting from year 2014, and for the period 2019 – 2030 a continuous increase of the systems for manure management and biogas production of 1% yearly is modeled.

The second penetration rate model shows more rapid introduction of the systems for biogas production on big swine farming associations, with a penetration rate of 25% yearly, which means will be completely implemented after 4 years starting from year 2014, and for the period 2019 – 2030 a continuous increase of the systems for manure management and biogas production of 1% yearly is modeled.

The different trends and the penetration rates considered in the evaluation of the environmental impact of the measure produced four different scenarios presented in the tables below.

The Scenario 1 is consisted of Trend 1 lower population growth rate and 5 years penetration rate of the measure, which is also low penetration rate. The estimated emission reduction from implementation of this measure is 53.26% till 2020, and 58.13% till 2030.

The Scenario 2 is consisted of Trend 1 lower population growth rate and 4 years penetration rate of the measure, which is considered as high penetration rate. The estimated emission reduction from implementation of this measure is 53.79% till 2020, and 58.71% till 2030.

The Scenario 3 is consisted of Trend 2 higher population growth rate and 5 years penetration rate of the measure, which is considered as low penetration rate. The estimated emission reduction from implementation of this measure is 51.12% till 2020, and 53.93% till 2030.

The Scenario 4 is consisted of Trend 2 higher population growth rate and 4 years penetration rate of the measure, which is considered as high penetration rate. The estimated emission reduction from implementation of this measure is 51.63% till 2020, and 54.47% till 2030.

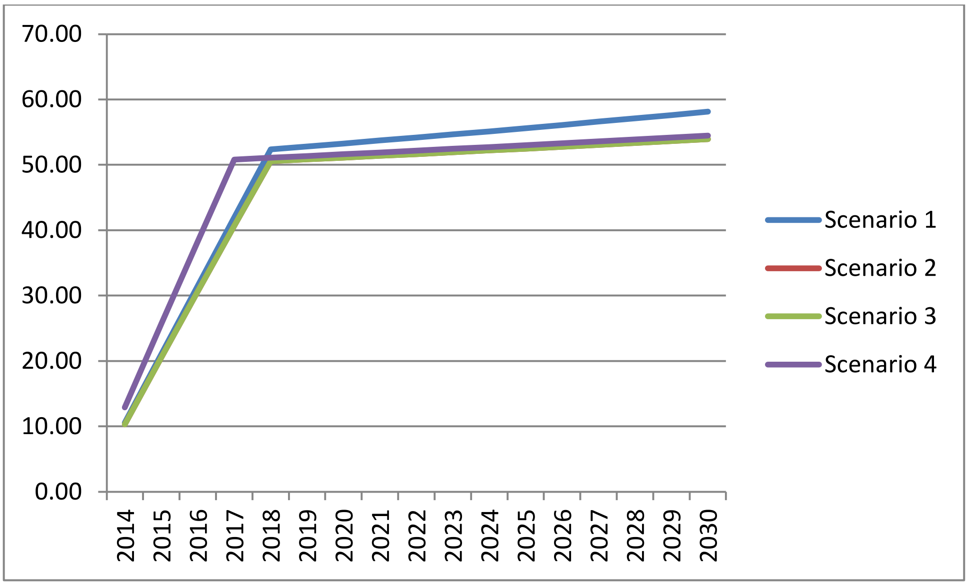

Figure 7.2. – Comparation of the scenarios in terms of emissions reductions 2014 – 2030 [%]

Table 7.1. – Scenario 1 Emissions considering the introduction using the population Trendline 1 and 5 years implementation of the systems for biogas production wih on the major swine farming associations

Year	Number of Animals	CH4 emissions Factor for Manure Management (kg/head/yr)	CH4 emissions from Manure Management BAU (t/yr)	Number of animals registed on big farming associations suatable for biogas production	CH4 emissions reductions from Manure Management Systems for Biogas production (t/yr)	CH4 emissions from Manure Management Systems for Biogas production (t/yr)	Total emission reduction %
2009	193,840.00	4.00	775.36	n/a	n/a	n/a	n/a
2010	190,552.00	4.00	762.21	n/a	n/a	n/a	n/a
2011	190,552.00	4.00	762.21	n/a	n/a	n/a	n/a
2012	176,920.00	4.00	707.68	n/a	n/a	n/a	n/a
2013	197,481.55	4.00	789.93	n/a	n/a	n/a	n/a
2014	197,831.49	4.00	791.33	20,850.00	83.40	707.93	10.54
2015	198,167.71	4.00	792.67	41,700.00	166.80	625.87	21.04
2016	198,491.23	4.00	793.96	62,550.00	250.20	543.76	31.51
2017	198,802.99	4.00	795.21	83,400.00	333.60	461.61	41.95
2018	199,103.81	4.00	796.42	104,250.00	417.00	379.42	52.36
2019	199,394.42	4.00	797.58	105,292.50	421.17	376.41	52.81
2020	199,675.51	4.00	798.70	106,345.43	425.38	373.32	53.26
2021	199,947.67	4.00	799.79	107,408.88	429.64	370.16	53.72
2022	200,211.46	4.00	800.85	108,482.97	433.93	366.91	54.18
2023	200,467.37	4.00	801.87	109,567.80	438.27	363.60	54.66
2024	200,715.87	4.00	802.86	110,663.48	442.65	360.21	55.13

2025	200,957.36	4.00	803.83	111,770.11	447.08	356.75	55.62
2026	201,192.23	4.00	804.77	112,887.81	451.55	353.22	56.11
2027	201,420.84	4.00	805.68	114,016.69	456.07	349.62	56.61
2028	201,643.52	4.00	806.57	115,156.86	460.63	345.95	57.11
2029	201,860.55	4.00	807.44	116,308.43	465.23	342.21	57.62
2030	202,072.23	4.00	808.29	117,471.51	469.89	338.40	58.13

Table 7.2. - Scenario Emissions considering the introduction using the population Trendline 1 and 4 years implementation of the systems for biogas production wih on the major swine farming associations

Year	**Number of Animals**	**CH4 emissions Factor for Manure Management (kg/head/yr)**	**CH4 emissions from Manure Management BAU (t/yr)**	**Number of animals registed on big farming associations suatable for biogas production**	**CH4 emissions reductions from Manure Management Systems for Biogas production (t/yr)**	**CH4 emissions from Manure Management Systems for Biogas production (t/yr)**	**Total emission reduction %**
2009	193,840.00	4.00	775.36	n/a	n/a	n/a	n/a
2010	190,552.00	4.00	762.21	n/a	n/a	n/a	n/a
2011	190,552.00	4.00	762.21	n/a	n/a	n/a	n/a
2012	176,920.00	4.00	707.68	n/a	n/a	n/a	n/a
2013	197,481.55	4.00	789.93	n/a	n/a	n/a	n/a
2014	197,831.49	4.00	791.33	26,062.50	104.25	687.08	13.17
2015	198,167.71	4.00	792.67	52,125.00	208.50	584.17	26.30
2016	198,491.23	4.00	793.96	78,187.50	312.75	481.21	39.39
2017	198,802.99	4.00	795.21	104,250.00	417.00	378.21	52.44

2018	199,103.81	4.00	796.42	105,292.50	421.17	375.25	52.88
2019	199,394.42	4.00	797.58	106,345.43	425.38	372.20	53.33
2020	199,675.51	4.00	798.70	107,408.88	429.64	369.07	53.79
2021	199,947.67	4.00	799.79	108,482.97	433.93	365.86	54.26
2022	200,211.46	4.00	800.85	109,567.80	438.27	362.57	54.73
2023	200,467.37	4.00	801.87	110,663.48	442.65	359.22	55.20
2024	200,715.87	4.00	802.86	111,770.11	447.08	355.78	55.69
2025	200,957.36	4.00	803.83	112,887.81	451.55	352.28	56.18
2026	201,192.23	4.00	804.77	114,016.69	456.07	348.70	56.67
2027	201,420.84	4.00	805.68	115,156.86	460.63	345.06	57.17
2028	201,643.52	4.00	806.57	116,308.43	465.23	341.34	57.68
2029	201,860.55	4.00	807.44	117,471.51	469.89	337.56	58.19
2030	202,072.23	4.00	808.29	118,646.22	474.58	333.70	58.71

Table 7.3. - Scenario 3 Emissions considering the introduction using the population Trendline 2 and 5 years implementation of the systems for biogas production wih on the major swine farming associations

Year	**Number of Animals**	**CH4 emissions Factor for Manure Management (kg/head/yr)**	**CH4 emissions from Manure Management BAU (t/yr)**	**Number of animals registed on big farming associations suatable for biogas production**	**CH4 emissions reductions from Manure Management Systems for Biogas production (t/yr)**	**CH4 emissions from Manure Management Systems for Biogas production (t/yr)**	**Total emission reduction %**
2009	193,840.00	4.00	775.36	n/a	n/a	n/a	n/a
2010	190,552.00	4.00	762.21	n/a	n/a	n/a	n/a

2011	196,570.00	4.00	786.28	n/a	n/a	n/a	n/a
2012	176,920.00	4.00	707.68	n/a	n/a	n/a	n/a
2013	201,204.60	4.00	804.82	n/a	n/a	n/a	n/a
2014	202,182.25	4.00	808.73	20,850.00	83.40	725.33	10.31
2015	203,159.90	4.00	812.64	41,700.00	166.80	645.84	20.53
2016	204,137.55	4.00	816.55	62,550.00	250.20	566.35	30.64
2017	205,115.20	4.00	820.46	83,400.00	333.60	486.86	40.66
2018	206,092.85	4.00	824.37	104,250.00	417.00	407.37	50.58
2019	207,070.50	4.00	828.28	105,292.50	421.17	407.11	50.85
2020	208,048.15	4.00	832.19	106,345.43	425.38	406.81	51.12
2021	209,025.80	4.00	836.10	107,408.88	429.64	406.47	51.39
2022	210,003.45	4.00	840.01	108,482.97	433.93	406.08	51.66
2023	210,981.10	4.00	843.92	109,567.80	438.27	405.65	51.93
2024	211,958.75	4.00	847.84	110,663.48	442.65	405.18	52.21
2025	212,936.40	4.00	851.75	111,770.11	447.08	404.67	52.49
2026	213,914.05	4.00	855.66	112,887.81	451.55	404.10	52.77
2027	214,891.70	4.00	859.57	114,016.69	456.07	403.50	53.06
2028	215,869.35	4.00	863.48	115,156.86	460.63	402.85	53.35
2029	216,847.00	4.00	867.39	116,308.43	465.23	402.15	53.64
2030	217,824.65	4.00	871.30	117,471.51	469.89	401.41	53.93

Table 7.4. - Scenario 4 Emissions considering the introduction using the population Trendline 2 and 4 years implementation of the systems for biogas production wih on the major swine farming associations

Year	Number of Animals	CH4 emissions Factor for Manure Management (kg/head/yr)	CH4 emissions from Manure Management BAU (t/yr)	Number of animals registed on big farming associations suatable for biogas production	CH4 emissions reductions from Manure Management Systems for Biogas production (t/yr)	CH4 emissions from Manure Management Systems for Biogas production (t/yr)	Total emission reduction %
2009	193,840.00	4.00	775.36	n/a	n/a	n/a	n/a
2010	190,552.00	4.00	762.21	n/a	n/a	n/a	n/a
2011	196,570.00	4.00	786.28	n/a	n/a	n/a	n/a
2012	176,920.00	4.00	707.68	n/a	n/a	n/a	n/a
2013	201,204.60	4.00	804.82	n/a	n/a	n/a	n/a
2014	202,182.25	4.00	808.73	26,062.50	104.25	704.48	12.89
2015	203,159.90	4.00	812.64	52,125.00	208.50	604.14	25.66
2016	204,137.55	4.00	816.55	78,187.50	312.75	503.80	38.30
2017	205,115.20	4.00	820.46	104,250.00	417.00	403.46	50.83
2018	206,092.85	4.00	824.37	105,292.50	421.17	403.20	51.09
2019	207,070.50	4.00	828.28	106,345.43	425.38	402.90	51.36
2020	208,048.15	4.00	832.19	107,408.88	429.64	402.56	51.63
2021	209,025.80	4.00	836.10	108,482.97	433.93	402.17	51.90
2022	210,003.45	4.00	840.01	109,567.80	438.27	401.74	52.17
2023	210,981.10	4.00	843.92	110,663.48	442.65	401.27	52.45
2024	211,958.75	4.00	847.84	111,770.11	447.08	400.75	52.73

2025	212,936.40	4.00	851.75	112,887.81	451.55	400.19	53.01
2026	213,914.05	4.00	855.66	114,016.69	456.07	399.59	53.30
2027	214,891.70	4.00	859.57	115,156.86	460.63	398.94	53.59
2028	215,869.35	4.00	863.48	116,308.43	465.23	398.24	53.88
2029	216,847.00	4.00	867.39	117,471.51	469.89	397.50	54.17
2030	217,824.65	4.00	871.30	118,646.22	474.58	396.71	54.47

7.4. Cost benefit assessment of the systems for biogas productions

Dairy cows produce 17.3 tons of manure per head per year, beef cattle produce 8.7 tons of manure per head per year, and pigs produce 1.7 tons of manure per head per year (Source Options To Reduce Methane Emissions - Final Report: November 1998).
According to the number farm parameters taken for this assessment (farm 1 population 30000, farm 2 population 23000, farm 3 popolation1875, farm 4 population15750 and farm 5 population16750), the assessed swine farms in R. Macedonia have the capacity of daily input of dry material from 80 to 100 tons per day, or the total investment of a national level is estimated on 4,175,440.00 EUR.

Table 7.5. – Cost for diiferent capacity systems for biogas production on farms [5]

Capacity for daily input of dry material	Feasibility study	Constrution works	Survailance and revision of the construction works	Mechanical and electrical equiplent	Cost for materials	Total Invstment Cost (EUR)	Number of farms in this category
80	24,000.00	75,000.00	17,000.00	385,000.00	300,000.00	801,080.00	3
100	24,000.00	90,000.00	17,000.00	430,000.00	325,000.00	886,100.00	2

Table 7.6. - Technical Characteristic of the systems for production of biogas on farms [6]

Capacity for daily input of dry material	Enery Consumption by the system	Heat Consumptionby the system	Production of solid biofertilizer	Production of liquid biofertilizer
80	25	96	40	32
100	30	115	51	43

Biogas can be used in similar ways to natural gas in gas stoves, lamps or as fuel for engines. It consists of 50-75% methane, 25-45% carbon dioxide, 2-8% water vapour and traces of O2 N2, NH3 H2 H2S. The natural gas contains contains 80 to 90% methane. The energy content of the gas depends mainly on its methane content. High methane content is therefore desirable. A certain carbon dioxide and water vapour content is unavoidable, but sulphur content must be minimised - particularly for use in engines.
The pre-treated organic feedstock when placed in sealed tanks naturally occurring micro-organisms break down the organic materials resulting in the release of gas. The amount of biogas produced on farms can be injected in the pipeline system, if available, or can be converted in heat or electricity. Because R. Macedonia doesn't have a pipeline network on the entire territory this option will be not accessed, and also the option of conversion in heat will be also eliminated. The most feasible solution is the methane produced to be used to generate renewable electricity. Normally a biogas engine can gain an electrical conversion efficiency of up to 35% with the remainder being available as heat. In most cases, biogas is used as fuel for combustion engines, which convert it to mechanical energy, powering an electric generator to produce electricity.

[5] [6] Ceprosard – Guidelines for biogas production on lifestock farms, Mile Dimitrovski, Dame Dimitrovski, Dejan Spaskov

Appropriate electric generators are available in virtually all countries and in all sizes. The technology is well known and maintenance is simple. In most cases, even universally available 3-phase electric motors can be converted into generators.
Technologically far more challenging is the first stage of the generator set: the combustion engine using the biogas as fuel. In theory, biogas can be used as fuel in nearly all types of combustion engines, such as gas engines (Otto motor), diesel engines, gas turbines and Stirling motors etc.
In most commercially run biogas power plants today, internal combustion motors have become the standard technology either as gas or diesel motors.

The average calorific value of biogas is about 21-23.5 MJ/m^3, so that 1 m^3 of biogas corre-sponds to 0.5-0.6 l diesel fuel or about 6 kWh (FNR, 2009).
However, when we convert biogas to electricity, in a biogas powered electric generator, we get about 2 kWh of useable electricity, the rest turns into heat which can also be used for heating applications.
In most EU member states electricity utilities now buy electricity generated from renewable sources produced by individuals and companies. Prices paid for 'self-produced' electricity is called a *feed-in tariff.*
The R. Macedonia feed-in tariff is 0.0729 EUR for all renewable source produced electricity, and this price is used for all years in the scenario, as a predicted minimum income from the investment. The price for feed-in tariffs in R. Macedonia is lower than the European average, and according to the European Energy Agency with the global increase of the energy consumption will lead to higher electricity tariffs.

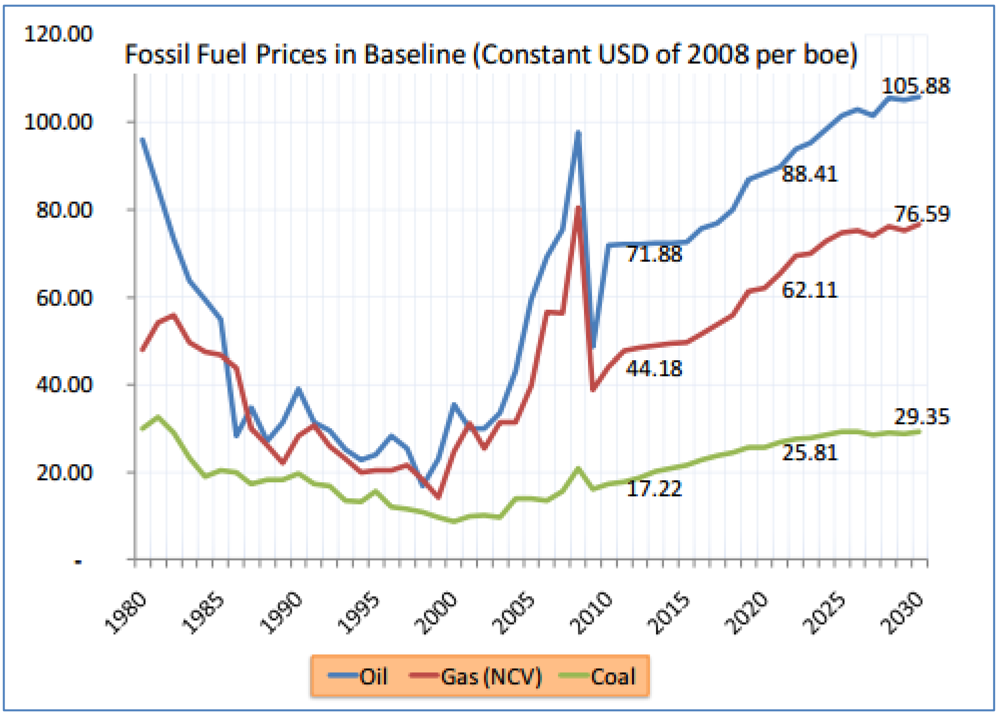

Figure 7.3. Predicted Fossil Fuel Prices up to 2030 in Baseline Scenario

For the economical assessment of the measure introduction of biogas power plants on swine farming associations two different scenarios which are in line with the environmental scenarios penetration rates were been developed.
The first scenario has a penetration rate of the measure of 5 years, and additional expansion of the farms for biogas and electricity production of 1additional percent per year. The beginning investment period is the ear 2014, the measure will be fully implemented by the beginning of 2019, and till 2030 additional expansion of 12.68% of the capacity is estimated.
The second scenario has a more rapid penetration rate of 4 years and additional expansion of the farms for biogas and electricity production of 1additional percent per year. The beginning

investment period is the year 2014, the measure will be fully implemented by the beginning of 2018, and till 2030 additional expansion of 13.81% of the capacity is estimated.
The tables bellow consider the annual investment cost, annual electricity consumption by the system itself, and resulting electricity available for marketing expressed in EUR as the annual financial income from the implementation of this measure is given.

Table 7.7. - Cost benefit assessment of implementation of the biogas production plants on big farming associations, penetration rate 5 years

Year	Scenario 1 Number of swine	Annual input of dry material (tonnes)	Annual Investment cost (EUR)	Amout of biogas poduced(m3)	Annual conversion to electricity (kWh)	Annual amoount of electricity needed for self supply of the biogas plant (kWh)	Ammount of electricity avaiable for maketing (kW/h)	Annual Financial Income from electricity trading feed-in tarifs (EUR)
2014	20,850.00	35,445.00	835,088.00	1,240,575.00	2,481,150.00	1,144,056.00	1,337,094.00	97,474.15
2015	41,700.00	70,890.00	835,088.00	2,481,150.00	4,962,300.00	2,288,112.00	2,674,188.00	194,948.31
2016	62,550.00	106,335.00	835,088.00	3,721,725.00	7,443,450.00	3,432,168.00	4,011,282.00	292,422.46
2017	83,400.00	141,780.00	835,088.00	4,962,300.00	9,924,600.00	4,576,224.00	5,348,376.00	389,896.61
2018	104,250.00	177,225.00	835,088.00	6,202,875.00	12,405,750.00	5,720,280.00	6,685,470.00	487,370.76
2019	105,292.50	178,997.25	41,754.40	6,264,903.75	12,529,807.50	5,777,482.80	6,752,324.70	492,244.47
2020	106,345.43	180,787.22	42,171.94	6,327,552.79	12,655,105.58	5,835,257.63	6,819,847.95	497,166.92
2021	107,408.88	182,595.09	42,593.66	6,390,828.32	12,781,656.63	5,893,610.20	6,888,046.43	502,138.58
2022	108,482.97	184,421.05	43,019.60	6,454,736.60	12,909,473.20	5,952,546.31	6,956,926.89	507,159.97
2023	109,567.80	186,265.26	43,449.80	6,519,283.96	13,038,567.93	6,012,071.77	7,026,496.16	512,231.57
2024	110,663.48	188,127.91	43,884.29	6,584,476.80	13,168,953.61	6,072,192.49	7,096,761.12	517,353.89
2025	111,770.11	190,009.19	44,323.14	6,650,321.57	13,300,643.14	6,132,914.41	7,167,728.73	522,527.42
2026	112,887.81	191,909.28	44,766.37	6,716,824.79	13,433,649.58	6,194,243.56	7,239,406.02	527,752.70
2027	114,016.69	193,828.37	45,214.03	6,783,993.04	13,567,986.07	6,256,185.99	7,311,800.08	533,030.23
2028	115,156.86	195,766.66	45,666.17	6,851,832.97	13,703,665.93	6,318,747.85	7,384,918.08	538,360.53
2029	116,308.43	197,724.32	46,122.83	6,920,351.30	13,840,702.59	6,381,935.33	7,458,767.26	543,744.13
2030	117,471.51	199,701.57	46,584.06	6,989,554.81	13,979,109.62	6,445,754.68	7,533,354.93	549,181.57
Total			**4,704,990.30**				**105,692,788.35**	**7,705,004.27**

Table 7.8. - Cost benefit assessment of implementation of the biogas production plants on big farming associations, penetration rate 4 years

Year	Scenario 2 Number of swine	Annual input of dry material (tonnes)	Annual Investment cost (EUR)	Amout of biogas poduced(m3)	Conversion to electricity (kWh)	Annual amoount of electricity needed for self supply of the biogas plant (kWh)	Ammount of electricity avaiable for maketing (kW/h)	Annual Financial Income from electricity trading feed-in tarifs (EUR)
2014	26,062.50	44,306.25	1,043,860.00	1,550,718.75	3,101,437.50	1,430,070.00	1,671,367.50	121,842.69
2015	52,125.00	88,612.50	1,043,860.00	3,101,437.50	6,202,875.00	2,860,140.00	3,342,735.00	243,685.38
2016	78,187.50	132,918.75	1,043,860.00	4,652,156.25	9,304,312.50	4,290,210.00	5,014,102.50	365,528.07
2017	104,250.00	177,225.00	1,043,860.00	6,202,875.00	12,405,750.00	5,720,280.00	6,685,470.00	487,370.76
2018	105,292.50	178,997.25	41,754.40	6,264,903.75	12,529,807.50	5,777,482.80	6,752,324.70	492,244.47
2019	106,345.43	180,787.22	42,171.94	6,327,552.79	12,655,105.58	5,835,257.63	6,819,847.95	497,166.92
2020	107,408.88	182,595.09	42,593.66	6,390,828.32	12,781,656.63	5,893,610.20	6,888,046.43	502,138.58
2021	108,482.97	184,421.05	43,019.60	6,454,736.60	12,909,473.20	5,952,546.31	6,956,926.89	507,159.97
2022	109,567.80	186,265.26	43,449.80	6,519,283.96	13,038,567.93	6,012,071.77	7,026,496.16	512,231.57
2023	110,663.48	188,127.91	43,884.29	6,584,476.80	13,168,953.61	6,072,192.49	7,096,761.12	517,353.89
2024	111,770.11	190,009.19	44,323.14	6,650,321.57	13,300,643.14	6,132,914.41	7,167,728.73	522,527.42
2025	112,887.81	191,909.28	44,766.37	6,716,824.79	13,433,649.58	6,194,243.56	7,239,406.02	527,752.70
2026	114,016.69	193,828.37	45,214.03	6,783,993.04	13,567,986.07	6,256,185.99	7,311,800.08	533,030.23
2027	115,156.86	195,766.66	45,666.17	6,851,832.97	13,703,665.93	6,318,747.85	7,384,918.08	538,360.53
2028	116,308.43	197,724.32	46,122.83	6,920,351.30	13,840,702.59	6,381,935.33	7,458,767.26	543,744.13
2029	117,471.51	199,701.57	46,584.06	6,989,554.81	13,979,109.62	6,445,754.68	7,533,354.93	549,181.57
2030	118,646.22	201,698.58	47,049.90	7,059,450.36	14,118,900.71	6,510,212.23	7,608,688.48	554,673.39
Total			**4,752,040.21**				**109,958,741.84**	**8,015,992.28**

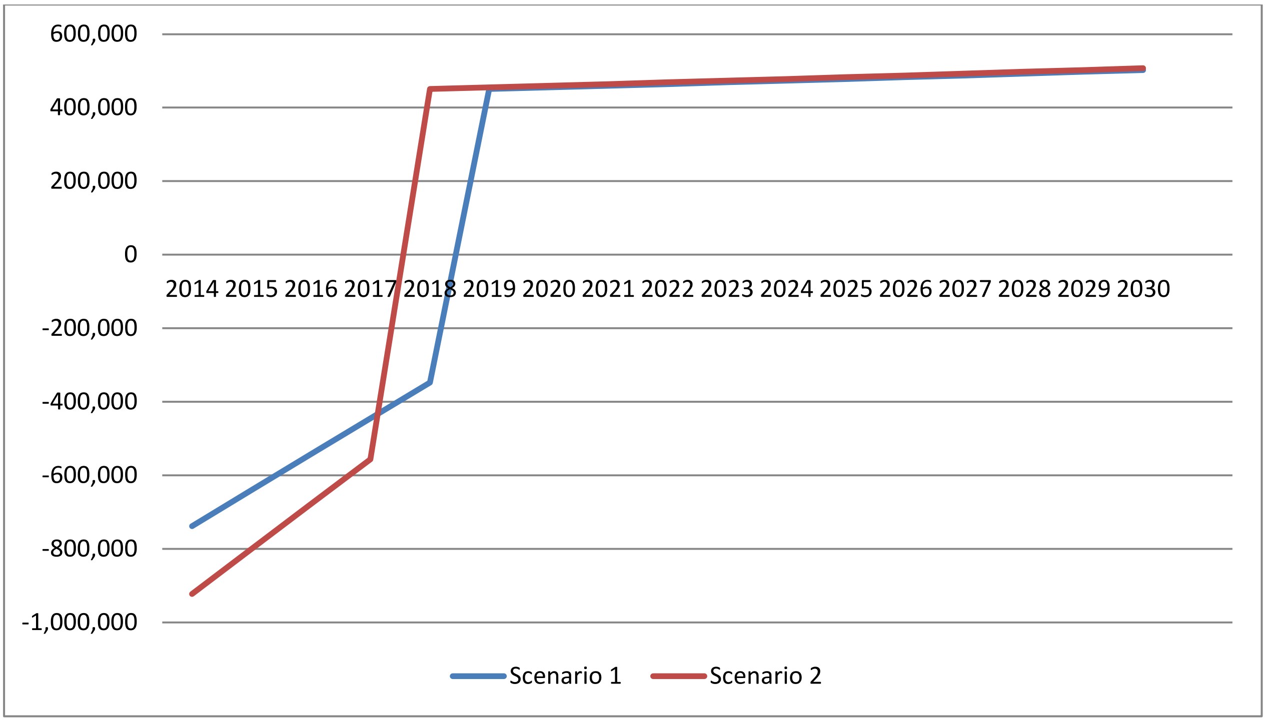

Figure 7.4. - End year financial balances 2014 – 2030

The results from the Scenario 1 show that the pay-back period of the full price of the instantiation of the system is approximately 11 years, and for Scenario 2 the full price of the instantiation of the system has a pay-back period of 10 years for the whole investment. The improved results from the Scenario 2 are owned to the enhanced capacity of 15% compared to Scenario 1 to the year 4, which means better financial benefit from higher investment, and one year shortened pay-back period.

In terms of end period financial balance (cululative income till 2030) Scenarion 1 is predicted to generate gross profit of 3,000,013.97 EUR, while Scnario 2 is predicted to generate 3,263,952.07 EUR, which means that Scenario 2 will generate 263,938.00 EUR more goss profit than the Scenario 1.

In terms of environmental benefits and GHG emissions reduction cumulatively till 2030 the predicted emission reductions from Scenario 1 are estimated on 6.59 kt of CH_4 of 138.39 kt CO_2 eq, while Scenario 2 is estimated to generate reductions of 6.86 kt of CH_4, which means that Scenario 2 provides 4.04% grater methane emission reduction that the Scenario 2.

From the assessment of the implementation of the measure it can be concluded that the installation of biogas systems for manure management on big swine farms is from one site investment in clean energy source, can have a significant financial benefits and is important for environmental conservation and technological breakthrough.

Additional benefit of implementation of systems for manure management and biogas production is the side production of high amount and high quality bio-fertilizers, which with regular agricultural practices are very difficult and time-consuming to obtain. This side product is gathered on an automatized and centralized way and can be easily transported or packed for marketing.

If same assessment was done for the manure management of the farms wit dairy and non-dairy cattle the resulting biogas produced will be even higher because of the fact that dairy cows produce 17.3 tons of manure per head per year, beef cattle produce 8.7 tons of manure per head per year, while pigs produce 1.7 tons of manure per head per year.

8. Summary

Overall effects of mitigation measures must be taken in combination of measures, since one option is dependant of applicability of another measure.

The emissions from the irrigation practices mainly derive from the energy use to pump and lift the water in the irrigation system and the land application of the water. It is very important to have an efficient irrigation system since inefficient irrigation leaves the soil overly wet and leads to higher emissions of N_2O that has 310 times higher global warming potential than CO_2. The inefficiency of the system can also result with higher usage of electricity and water which overcomes the capacity of the plant. In this report were modeled different irrigation scenario and was performed financial analysis accordingly. It has been shown that flood and furrow irrigation should be abandoned as practices in favor to sprinkler irrigation and drip irrigation as proven to be more effective techniques. It can also be concluded that higher frequency of irrigations with lower amount of water is more efficient that to use the same amount of water in one irrigation.

Conservation techiques (reduced or no-tillage) on intensively managed arable land and manure management are also a feasible option for mitigation, both with total costs up to year 2030 over 22 million EUR giving a total GHG reduction potential 6,311.20 CO_2-eq [Gg] or 90.5% of N_2O emissions (in case of no-tillage) or7.06% emissions (in case of management of manures with composting only for dairy, non-dairy and swine populations). Management of fertilizers and substitution of synthetic with organic fertilizers can be very good mitigation option costing 6.8 milion up to year 2030, but only if applied to all arable land, in case of increasing market demand for organic fertilizers and stabile market prices.

In terms of expected income, the most profitable options are no-tillage techiques and production of electricilty on livestock farms (swine), both in combination with sufficient animal manure produced and implemented solid manure management practices. Conservation techniques have potential for highest greenhouse gas reductions, followed by production of electricity (biogas) and substitution of fertilizers.

Organic agriculture directly contributes to CO_2-eq mitigation since is less intense than the conventional agricultural practices as it emits less N_2O from nitrogen application (due to lower nitrogen input), less N_2O and CH_4 from biomass waste burning because the burning is avoided and requires almost no usage of chemical fertilizers. However from the analysis it can be seen that applying organic agriculture to all types of crops does not necessary means CO_2 reduction for example it is shown that for production of organic tomatoes results in higher CO2 –eq emissions. On the other hand the mitigation effect of organic farming is usually side benefit so; the farmers are mostly concerned of the financial benefit in contrary to the cost. The financial analysis shows that the organic farming for all of the crops will be most profitable if part of the investment is covered by subventions and the organic products are recognized by their labeling on the market.

Enteric fermentation is feasible miigation option only if the Government gives an adequate subsidies in the upcoming period for replacement of feed intake of animals and this measure can only be applied for cattle populations in the country (dairy and non-dairy). Penetration rate starts from year 2014 on 10.000 animals and by the year 2030 measure should be implemented on half of the population. Total estimated costs for this measure is 22.5 milion EUR with a total GHG reduction potential of 1,497.66 CO_2-eq [Gg].

The assessment of the mitigation measure usage of the crop residues for production od briquettes showed that this mesure provides high environmental and economical benefits, and the investment in big size production plant pays back the investition for 4.3 years.

From the assessment of the mitigation measure installation of biogas systems for manure management is concluded that the high penetration rate of this measure gives improved economical and environmental results and the investment period is foreseen to be 4 years.

An indicative summary of was done by evaluating all proposed measures according to five criteria: economic effectiveness, environmental effectiveness, feasibility, measurability and co-benefits. The rating is graded in the range from 1 to 5, 1 been the worst and 5 being the best. The economic effectiveness is evaluated in the terms of cumulative cost for implementation of the measures. The environmental effectiveness id evaluated in terms of CO_2-eq reduction per measure. The feasibility criteria demonstrate if the proposed measure is possible to be implemented in the near future in Macedonia. Measurability criteria describes if the proposed measure impact can be easily measured in terms of CO_2-eq reduction. The co-benefits are associated with other advantages of the measures like: job creation, adaptation, additional income, positive health effect etc. The results are presented in Table 8.2.

Table 8.1. Indicative summary of the proposed mitigation measures

	Economic effectivness	Environmental effectivness	Feasibility	Mesurability	Co-benefits
Agricultural management practices					
Irrigation	**4**	**3**	**5**	**2**	**5**
Management of fertilizers					
Carbon sequestration					
Tillage					
Organic agriculture	**4**	**3**	**5**	**2**	**5**
Production of biofuels from crop residues	**5**	**3**	**3**	**3**	**3**
Enteric fermentation					
Manure Management					
Production of biogas from farming	**5**	**5**	**3**	**4**	**2**