European Climate Change Programme

(COM(2000)88)

Working Group 7 – Agriculture

Final Report

Mitigation potential of Greenhouse Gases in the Agricultural Sector

EUROPEAN COMMISSION

AGRICULTURE DIRECTORATE-GENERAL

Content

List of Annexes

Glossary

AD:	Anaerobic digestion
AvRa:	Average ranking
C:	Carbon
CAP:	Common Agricultural Policy
CH_4:	Methane
CHP:	Combined Heat and Power
CO_2:	Carbon dioxide
COP:	Conference Of the Parties -
DG:	Directorate-General
ECCP:	European Climate Change Programme
ENV:	Environment
eq.:	Equivalent
ESE:	Environmental side effects
EU:	European Union
ExpRa:	Expert ranking
F (T):	Technical feasibility
GHG:	Greenhouse gases
ha:	hectare
M:	Million
MS:	Member States
Mt:	Million tonnes
N_2O:	Nitrous dioxide
RDP:	Rural Development Policy
t:	Tonne
WG:	Working Group

1. Introduction

On 8 March 2000, the Commission adopted the Communication on "EU policies and measures to reduce greenhouse gas emissions: Towards a European Climate Change Programme (ECCP)", COM(00)88.[1]

The ECCP activity is carried out over a period of one year and started in June 2000 with different Working Groups (Flexible Mechanism, Energy Supply, Energy Consumption, Transport, Industry, Research), which already completed their work in June 2001. In December 2000 the number of working groups was extended to areas such as agriculture and sinks[2]. After several meetings the Working Group Agriculture completed its work by the end of 2001.

The work of the WG Agriculture should provide the technical background analysis that helps the Commission to propose in due course, if appropriate, concrete policy proposals to the Council and the European Parliament. Proposals for policy measures in the agricultural sector should also consider possible synergy effects with other policies to increase the reduction potential of Greenhouse Gases (GHG).

In the European Union, the main sources of emissions of greenhouse gases from agriculture are N_2O emissions from agricultural soils, N_2O and CO_2 emissions from cultivated organic soils e.g. peat, CH_4 emissions from enteric fermentation and CH_4 and N_2O emissions from manure management.

Methane emissions from agriculture were 41% of all CH_4 emissions while nitrous oxide emissions from agriculture reached 51% of all N_2O emissions in 1990. Including the CO_2 emissions, 11% of all greenhouse gas emissions of the EU in 1990 can be attributed to the agricultural sector.

On the other hand, the results of the Climate Conferences in Bonn (the **6**th **C**onference **O**f the **P**arties - **COP 6 bis**) in July 2001 and in Marrakesh (COP 7) in November 2001 give a higher importance to the agricultural sector due to the carbon sequestration potential of agricultural soils. Because of the carbon absorption potential the agricultural sector could contribute significantly to fulfilling the reduction objective of the EU, which is -8% between 2008 and 2012 from a 1990 base.

According to this situation, the Working Group Agriculture (WG 7) has tackled the following issues:

- Mitigation potential of nitrous oxide emissions from agricultural soils
- Sequestration potential of agricultural soils
- Mitigation potential of carbon dioxide by providing renewable raw materials for the energy/industrial sector
- Mitigation potential of methane emissions from enteric fermentation and
- Mitigation potential of methane and nitrous oxide emissions from manure management

---

[1] COM(2000)88 final.

[2] The sinks group is a subgroup of the Working Group Research.

2. Methodology

The analysis of relevant greenhouse gas emissions (GHG) from the agricultural sector and its reduction potential is based on a review of literature and data, already existing studies and finally on the expert knowledge of the members of the Working Group Agriculture.

The Working Group discussed around 60 potential measures, aimed at reducing GHG emissions, and evaluated them regarding specific costs, effects on farm income and labour, the emission reduction potential, environmental side effects (ESE) and technical feasibility F (T). These 6 "indicators" were ranked between 1 (very negative/low) and 5 (very positive/high). The values for the emission reduction potential, ESE and F (T) were double counted for the average ranking (AvRa.) because of their relatively higher importance. In case the average ranking did not reflect the opinion of the experts, an extra column is foreseen for a final expert ranking (ExpRa.) (see annexes I and II).

Measures valued better than 3 may be suitable for possible policy actions. Those judged between 4 and 5 are recommended or even highly recommended for possible policy actions. To the contrary all measures, ranked between 1 and 3 do not seem to be appropriate for policy actions with the scientific knowledge we have at this stage.

In some cases the specific costs of the measures are negative. That means that in general, and related to the reduction of 1 tonne of CO_2 equivalent, the costs associated with the implementation of such a measure would be smaller than the benefits. In a second step the experts assessed the economic effects at the farm level/(income).

All measures with a ranking better than 4 are listed in annex I, those that lie between 1 and 4 are provided in annex II

All measures listed in annexes I and II under "A" are related to the reduction of nitrous oxide emissions from agricultural soils, under "B" are related to the sequestration potential of agricultural soils and the mitigation potential of carbon dioxide by providing renewable raw materials for the energy/industrial sector.

Measures listed under "C" reflect the possibilities to mitigate methane emissions from enteric fermentation and "D" measures provide an overview of options to mitigate methane and nitrous oxide emissions from manure management.

3. Agricultural Soils

3.1 Reduction of N_2O emissions

Fertilisation of crops significantly contributes to the emission of greenhouse gases, especially through the emission of nitrous oxide (N_2O) from soils. This is a result of incomplete transformation of ammonia to nitrate (nitrification) and/or the incomplete transformation of nitrate to nitrogen gas (denitrification). In general, incomplete denitrification is considered to be the most important of the two processes. Reduction options for N_2O are generally based on the reduction of nitrogen inputs to soils through enhanced efficiency of fertiliser use and a better integration in and accounting of N in manure applied to soil. The measures examined in the sWG aim to reduce nitrogen surpluses at the field, farm and regional level. The biological potential for greenhouse gas reduction could reach up to 50 Mt CO_2-eq. per year due to different measures, most of them described in annexes I and II. Out of this 50 Mt CO_2-eq. per year, 10 Mt CO_2-eq. seem to be feasible from the economic point of view at negative or low cost within the first commitment period.

A number of measures at the farm level can be activated to "tighten the N-flow of the farm" and thereby lead to reduced losses of reactive N into air and water. To achieve success in this area, it is very important to increase the knowledge about GHGs, especially N_2O, among farmers and extension services, so that people that take daily decisions on fertilising and feeding, really understand how vital an efficient N-cycle in the food chain is for reductions of GHG emissions from agriculture. Therefore extension/knowledge projects, such as the Swedish "Catch the nutrients" initiative could help reduce emissions, whereby it is difficult to quantify the effects.

From 22 evaluated measures 6 have been ranked better than 4. Those are recommended or even highly recommended for possible policy action. The highest reduction potential is associated with measure A6, continuation of set-aside (6,2 Mt CO_2), followed by A1, enhanced spreader maintenance (fertilizer and manure) (2 Mt CO_2). Further measures with a ranking better than 4 are fertiliser and manuere-free zones (A2), optimising distribution geometry (field level) (A3), precision farming in fertilizer application (A4) and optimising N application by allowing for manure N and residual N (A5).

On nitrous oxide emissions from agricultural soils, there is a very close link of examined measures with measures being implemented as part of EU water policy, e.g. action programmes in the context of the nitrates directive but also codes of good agricultural practice in the context of rural development plans. The different measures, surrounding the more efficient use of different kinds of N-fertiliser could lead to a reduction of 10 M tonnes of CO_2 equivalent. This potential could be fulfilled with a proper implementation of the nitrates directive, water legislation and a constructive implementation of measures within the rural development policy. It is up to MS to fulfil their obligations and to put potential additional measures in place. The effect of the measures being highly site-specific, a significant uncertainty is associated with these estimates.

Summarising the discussion of the Working Group Agriculture, 3 points should be stressed:

1) A lot of the technical measures under scrutiny are not just a possibility but are already being implemented!

2) Measures aimed at reducing nitrate content in waters also result in declining nitrous oxide emissions.

3) Hence, a strict implementation of existing legislation (the nitrates directive is one of the pieces of Community legislation having given rise to a number of infringement procedures) is needed, not just for water eutrophication but also for climate change reasons.

In addition, if a link between the reduction rate of greenhouse gas emissions and that of ammonia and nitrate emissions could be established on a scientific basis, there could be major synergy effects for the monitoring of the efficiency of the measures.

Beside these technical measures, a nitrogen quota and a nitrogen tax were briefly discussed in the Working Group as a political option. The advantages and disadvantages of a nitrogen tax have been discussed in several studies and publications during the last years. A quantification of the effects as well as the ecological relevance at European level is still controversial. Without referring to figures given by different studies, a nitrogen tax or quota may lead to a reduction of GHG emissions. A tax on nitrogen surplus would be a more targeted approach as it does include the N-surplus form farms with animals which (in many EU countries account for the more important N-surplus from agriculture).

3.2 Carbon sequestration potential

The most important result for the agricultural sector at the Climate Conference in Bonn is the possible use of agricultural land as sinks. There is a priori no limit on the surface of agricultural land that can be used as a sink. The only limitation is the application of a so called net-net approach for agricultural activities like cropland management, grazing land management and revegetation. Net-net accounting relies to the difference in the net emissions or removals during the commitment period and the net removals in the base year (1990 levels). The Intergovernmental Panel on Climate Change (IPCC) is going to prepare the methodology of estimating the 1990 emission levels and controlling/monitoring the reduction potential of different measures. Referring to scientific results on average 0.3 t/ha C (1,1 t CO_2) could be absorbed due to land use change activities, e.g. no tillage system.

A calculation made by DG ENV assumed that 20% of the surface of agricultural land in the EU could be used as a sink[3]. This would result in an absorption potential of 7,8 Mt C, which corresponds to 8,6% of the total EU reduction objective. This is even more as estimated for forestry management measures in the EU (5,18 Mt C without afforestation - see annex 2). However, these figures have to be interpreted carefully and there are still many questions to be answered. Which kind of measures could be appropriate to reach the aim and what are the costs of those measures?

Measures and costs of possible measures. A no-tillage land use system[4] could be one example of agricultural measures[5]. Within the rural development policy (agri environmental scheme), a measure for no tillage in combination with a mulchseed system exists e.g. in Germany, where between 25 and 60 €/ha are paid for this measure. Within the ECCP, 20 € for the reduction of 1 t CO_2 are assumed as cost

---

[3] The figure 20% is based on expert knowledge and literature review.

[4] Further calculations and considerations have to be done on possible measures. There may be other side-effects connected with a no tillage system, e.g. the additional use of herbicides due to less soil cultivation. On the other hand no tillage systems do have clear positive effects with respect to soil quality such as the prevention of erosion and soil compaction. Also, N_2O emissions could increase under no-till (Smith *et al.* (2000) *Soil Use and Management* **16:** 251-259).

[5] Any land-use change since the baseline year of 1990 could be included under Kyoto accounting. So set-aside clearly fits into this category. Set-aside may not be a future option but what has happened to the land since it was under set-aside during the 1990s clearly should be taken into account.

effective. Taking this figure and the absorption potential of 1,1 t CO_2/ha, 22 € could be paid for one ha of agricultural land.

Looking at the figures only the economic benefits from CO_2 sequestration could be source to finance additional "agri-environmental measures"[6]. The agricultural sector could receive a real additional benefit with "emission trading". In the USA farmers have already contracts with the industry, offering CO_2 credits resulting from changing their land use systems. This is reality in the USA, in spite of the fact that the government has refused to ratify the Kyoto Protocol. In case the USA shouldn't participate in the future in the Kyoto Protocol (it is still the main objective of the EU to take the USA on board), a lower price per tonne CO_2 is expected on the CO_2 market due to a reduced demand of CO_2 credits.

A large number of technical and scientific uncertainties are connected with the estimated reduction potential. These questions, surround the absorption potential of different land use systems and the sustainability of the systems are listed in Annex III. The objections were mentioned by the Working Group Agriculture and still have to be answered. Therefore a new Working Group on “Sinks – Subgroup Soils” will be established under the chairmanship of DG Agriculture. The Group will focus on the uncertainties, as well as the opportunities, for agricultural soils as sinks. It will carry out its work in 2002.

4. Bio-energy for carbon substitution

Biomass for energy could lead to significant reductions in emissions from the energy[7] and transport sectors. The use of biomass could also be combined with a small portion of carbon sequestration. The total technical potential for bioenergy from forests, agriculture and other residues could achieve 200 to 800 Mt CO_2-eq. per year, which corresponds to 5-22% of CO_2 emissions from fossil energy in 1995 (Ausilio Bauen and Martin Kaltschmitt: *Contribution of Biomass Toward CO_2 Reduction in Europe (EU)*[8] (see also annex IV).

All measures envisage a strong role for energy crops, which could be produced on set-aside land although this could have negative consequences for the nitrogen-balance, biodiversity and conservation interests on set-aside land. The experiences since 1992, however, have shown that the supply of set-aside land for non-food production has not yet led to lasting increases in the cultivation of renewable raw materials. Measures of demand policy stimulating increased use of renewable energy in the energy sector should hence be envisaged. A major proportion of the technical potential might be feasible at low cost until the first commitment period.

But not all biomass energy chains will provide the same level of CO_2 benefits, based on the relative energy intensity of biomass production and the fossil energy used in

---

[6] Another example of measures that promote the accumulation of organic matter in the soil, is the one laid out by some regions in Italy, where under the scope of rural development plans (2000-06), farmers are subsidised for the application of organic fertilisers, in particular composted products, to the tune of between 155 and 220 €/ha.

[7] Beside the energy sector renewable raw materials can also be used as for the industrial sector.

[8] Div. of Life Sciences, King's College, University of London, Campden Hill Road, London, W8 7AH, United Kingdom).

processing. This also applies to environmental and economic benefits for the agricultural sector.

Most of the biomass fuel cycles investigated in the "Biocosts Study"[9] have a clear advantage over fossil fuels regarding their contribution to global warming.

The uncertainty in the measures is relatively low because the efficiency can be easily monitored by a reduction of emissions from fossil fuel consumption.

Synergies are very important. There are evident synergies within the agricultural sector, e.g. sinks associated with bioenergy. In addition to the carbon substitution benefits, both woody and herbaceous bioenergy crops are also likely to increase soil carbon sequestration (Smith *et al.* (2000) *Global Change Biology* **6**: 525-539). These synergies should be considered in the new Working Group on Sinks.

However, C abatement activities in the agricultural sector may depend on actions taken in other sectors e.g. energy and transport, and a more integrated approach is needed.

5. Animal Husbandry

5.1 Mitigation potential of CH_4 from enteric fermentation

At first glance the more intensive forms of animal production tend to have lower GHG emissions per unit of output than the more extensive systems. But they might not be compatible (unless very well regulated) with the environmental situation for water, soil, bio-diversity and eventually landscape or animal welfare. And looking at life-time methane production, an unproductive phase of dairy cows of approximately 2.5 years (plus +- 6 months drying off periods) has to be considered. From this it follows that increasing the number of lactation periods can result in less methane production per kg milk. Final conclusions can be drawn only from a complete data set taking into account all the aspects. However, it is obvious that the practice of slaughtering cows that do not show the expected performance in the first lactation period, will result in an unnecessarily high methane production per kg milk. Increasing the age at slaughter may affect beef quality. This aspect and the consequences of an increased number of lactation periods for the economics of milk production have to be examined carefully.

Changing or improving diet composition and diet quality, or feeding additives, will only result in a reduction of GHG if there are strong nutritional deficits in different regions and countries of the EU. But generally, in the EU countries cattle are fed to their current nutritional optimum, so that there are limited possibilities for improvement. Furthermore many of the improved dietary options are still at laboratory stage or applied at a very small scale in the field. Further research and development in terms of practicality and applicability would be required to fully

[9] TOTAL COSTS AND BENEFITS OF BIOMASS IN SELECTED REGIONS OF THE EUROPEAN UNION- BIOCOSTS -", Final Report, p. 108 (Public Version - September 1998) Research funded in part by THE EUROPEAN COMMISSION in the framework of the Non Nuclear Energy Programme JOULE III.

implement these options. Also little research into the risks to animal health/welfare and the farm economics associated with feeding high energy diets has been carried out, and this surely has to be done before diets to improve rumen efficiency and control methane emissions can be implemented. There are doubts whether the ongoing research will lead to practical conclusions in the near future. Among the aspects that need to be examined is the fact that a higher milk yield increases the risk of udder health problems. Furthermore, the productive period may be reduced as a consequence of the "burning-out" phenomenon observed with high-yielding cows.

Following the outbreaks of BSE there are a number of issues related to animal welfare and consumer confidence in meat products that would suggest that cattle may be fed more forage based diets, and less emphasis may be put on concentrates and some “non-natural” additives in the future. In January 2001, when the Commission proposed its emergency 7-point plan, in order to offset the problems of oversupply in the beef sector, the existing measures designed to encourage extensification in beef production were strengthened. The logic behind this move was that, by encouraging extensive, forage-based production systems, the dependency of the sector on bought-in "concentrate feeds", associated with the origin of the BSE problem through the feeding of meat and bone meal, would be reduced. Thus, production would be better oriented to what an important number of consumers is demanding in terms of the way the beef they buy has been produced.

Another important element behind this extensification policy are the additional environmental benefits in terms of landscape enhancement, potential reduction of point-pollution of watercourses etc.. Furthermore, extensification policies have the potential benefit of decreasing artificial fertiliser use when the livestock density factor is fixed at a level that gives a disincentive to produce forage intensively.

Consequently, from 19 evaluated measures only 1, the improvement of the life time efficiency (see annex I, measure C16) can be recommended. 10 measures are providing reduction options, but are connected with considerable uncertainties.

Finally, in this context the possibility of a subsidy for the reduction of methane in the agricultural sector has been briefly discussed within the Working Group. However, a small calculation shows already the bounded practicability of a subsidy in this field. A farm with 100 cows may have a reduction potential of 10 tonnes of CH_4, which could result in 420 €, assuming a price of 20 € per tonne of CO_2 equivalent. It is questionable, whether this amount would be a sufficiently large incentive for a farmer to change the production method or invest in biogas plants.

5.2 Mitigation potential of CH_4 and N_2O from manure management

Anaerobic digestion (AD), as an alternative energy source, has been a topic of research from the end of the seventies. In the last 20 years substantive progress has been made as concerns anaerobic digestion of industrial waste and sewage sludge. In spite of the successful introduction in industry, agricultural applications have lagged behind. Now there are newed interests for AD in agriculture from a CO_2-emission point of view. There are also other reasons behind this interest such as hygiene (destroying pathogens) of manure, and the prevention of bad odours. Programmes of the EU and the member states have increased the interest in AD. But to have an impact on GHG emissions a number of technical and policy developments are required, e.g., relating to certainty of a market for energy from AD, promotion and support for distribution.

Appropriated to the average size of European farms, it would be necessary to encourage the development and introduction of simple, low cost AD units for use on small-scale farms or to find other low cost technical solutions for small scale farms. A huge number of involved farms could lead to lower costs per system, but the highest possible CO_2 savings. The introduction of centralised plants is also a possibility, but from a technological point of view there is not much innovation needed on the short term. But for a supporting distribution of plants before and within the first commitment period the farm investment scheme under the RDP would be required.

The measures referring to different types of anaerobic digestion are ranked 4 on the scale. AD provides a huge reduction potential. The total GHG savings from AD could be 17 M t CO_2-eq. But cost effectiveness is so far very low in AD-plants and so is the general knowledge of how to run the plants with good results. Consequently the Working Group estimated the realistic "cost effective"[10] potential around 1,7 Mton CO_2-eq.. This is only possible with incentives, which may be increasingly provided by the EU and MS.

Furthermore the potential of using biogas as fuel for vehicles should be mentioned. The use of biogas to replace fossil fuels in vehicles has been claimed to provide the highest reductions in greenhouse gas emissions (such as reductions in other gaseous emissions). It is worth adding that combined heat and power (CHP) is another important use of biogas. But heat-only production deserves less support since a part of the valuable fuel is not recovered. These alternatives depend very much on developments in the energy and transport sector in the EU.

---

[10] Cost effective AD depends on many factors (CH_4 production rate - additional products to digest, investment), but may be utopia for the next years without a substantive subsidy on investment and a subsidy for 'green energy'. Dutch research on the cost effectiveness of AD on dairy farms has shown that the return of investments is within 15 (optimal scenario with energy subsidy) to 27 years. In cases where no co-fermentation takes place (only manure digestion). Co-digesting other wastes (like fat, slaughterhouse waste) in any case increases gas production and may provide an income (the waste is paid for in some cases, but not sure for the future) for the farmer.

Benefits of AD plants

Farm-scale AD plants:

- Reduction of greenhouse gas, odour and ammonia emissions
- Higher quality manure for application to farmland
- Savings in energy costs and sales of electricity, fuels and heat

Centralised AD plants:

- Reduction of greenhouse gas, odour and ammonia emissions
- Profit on disposal of organic waste
- Sales of high quality fertiliser products
- Sales of energy
- Reduced slurry storage capacity necessary on individual farms

Stimulating options to speed-up the attractiveness and introduction of AD plants

Farm scale AD plants:

- More and better availability of evaluation data on cost-effectiveness
- Objective and targeted information and guidance on start-up and operational aspects, system choice, labour impact, benefits, legislation and technology suppliers
- Targeted information on the capital outlay and investment allowances
- Innovation to increase efficiency, simplify energy conversion to electricity and fuels and reduce production costs of small size AD plants

Centralised AD plants:

- Cost-effectiveness differs per country. In fact, cost-effectiveness differs from case to case (region to region) even within a certain country depending e.g. on the intensity of farming. This should be better evaluated
- Better marketing effort before starting an AD plant can ensure the availability of resources and the sales of end products
- Simplify and/or streamline the current complex legislation on co-digestion and sales of end products
- Quality certification of end products
- Tax on waste if not recycled
- Oblige power companies to purchase "green" energy
- Combine AD plant, with liquid/solid separation facilities (like all planed plants in The Netherlands)
- Feed-in laws for methane gas and electricity, and removal of taxes other than VAT on biofuels and automobiles using biofuels. These would amend the effect of the "renewable energy sources" electricity promotion directive
- Further research on the effect of applying the digestate to farmland.

6. Concluding remarks

Regarding the possibilities for the reduction potential in the agricultural sector, much of the information is still unsure. The WG stressed the uncertainties connected with laying down average figures for the reduction potential and the reduction costs on a European level[11]. First of all there are general uncertainties about the effects of different measures itself and secondly a modelling is needed, connecting the measures with concrete data like the number and type of animals, animal performance, dietary composition, animal and manure management, farm and feeding practices etc.. This applies for most of the measures considered in this paper at this stage.[12]

In spite of the uncertainties mentioned above, the agricultural sector could contribute significantly to fulfilling the reduction objective of the EU concerning the Kyoto-Protocol. Table 1 reflects that the baseline emissions will decline by around 19 M tonnes of CO_2-eq. with the political changes implemented already with Agenda 2000. This means a reduction of 4,6% of all agricultural emissions and 5,7% of the EU-Reduction objective in the first commitment period. In addition to this, agricultural soils could accumulate between 8-28 M tonnes of CO_2-eq, but this potential is subjected to a lot of questions, which will be examined by the forthcoming ECCP Working Group Sinks - Subgroup Soils in 2002.

Moreover, different measures concerning the more efficient use of different kinds of N-fertilisers could lead to a reduction of 10 M tonnes of CO_2 equivalent. This potential could be realised with a proper implementation of the nitrate directive, water legislation and a constructive implementation of measures within the rural development policy. It is up to MS to fulfil their obligations and to put additional measures in place.

Although a lot of research is carried out on CH_4 emissions caused by enteric fermentation, these measures are probably not suitable for the first commitment period. A very small potential (see table 1) could be given through an improvement in lifetime efficiency (see annex I, measure C16).

Anaerobic digestion provides considerable reduction potential and a source of income for farmers as well, but the cost-effective potential may reach only 10% of the technical potential at this stage. That means a reduction of 0,4% of agricultural emissions or a contribution to the EU-reduction objective of 0,5%.

---

[11] The cost advantages calculated and ranked are based on the presumption that the individual measure is really functioning, which demands more work on the farm and learning of new management practices. The cost for insuring all this were not calculated and are not shown in the figures under specific costs and neither were the risks for loss of total and net income calculated nor shown in the figures. Further research is needed on this issue**.**

[12] This goes as well for the projections for baseline emissions for N_2O and CH_4 based on forecast changes in fertiliser consumption and livestock numbers. These projections take into account the reform of the Common Agricultural Policy adopted in the framework of Agenda 2000. These trends were extrapolated to 2010 to provide an estimate of the change in the market for products between 1998 and 2010, at the EU level.

With this optimistic estimations, shown in table 1, the agricultural sector could contribute 9,3% to the total EU reduction objective, of which 5,7% due to the reforms already in place (baseline emissions) and 3,6% due to additional measures. Altogether the agricultural sector could reduce its emissions by 7,4%. The reduction potential of energy substitution (bioenergy except agricultural biogas plants) and the carbon sequestration potential of agricultural soils are not included in this calculation.

Table 1: Share of agriculture in total EU reduction objective

	Mt CO_2-eq.	**Reduction in EU agriculture in %**	**Share in total EU emissions in 1990 in %**	**Share in total EU reduction objective in %**
Total EU-CO_2-eq. emissions in 1990	4183		100	
EU reduction within 2008/12	331		8	100
Emissions in the agricultural sector				
1990/95 in EU	417		10,0	
Baseline emissions in 2010	-19	4,6	0,5	5,7
Reduction potential (cost effective)				
N_2O from soils	10	2,4	0,24	3,0
Sequestration soils[13]		0,0		
Enteric fermentation	0,3	0,1	0,0	0,1
Anaerobic digestion (CH_4 and N_2O)	1,7	0,4	0,04	0,5
Total agri. reduction potential inclusive baseline emissions	**31,0**	**7,4**	**0,7**	**9,3**

Table 2 reflects the share of agriculture, when considering the total reduction potential of bioenergy as an agricultural contribution. This figures shall just underline the potential of bioenergy. There exist a hazard of double counting the positive effects of bioenergy in the industrial and the agricultural sector. It should be subject of discussion, to whom the credits of bioenergy are attributed. The task of the agricultural sector would mainly be restricted to the production of raw materials.

[13] Results will be delivered by the ECCP Working Group on Sinks - Subgroup Soils.

Table 2: Emission reduction potential of bioenergy

	Mt CO_2[14]	Reduction in EU Agriculture in %	Share of total EU-emissions in 1990 in %	Share of total EU-Reduction objective in %
Further reduction potential all Bioenergy (Min. estimation without economic restrictions for heat and electricity)	200-600	53-144	5-14	60-181

Beside all the measures, which could have smaller or bigger effects on GHG reduction, the scientists underline the fact that a significant reduction is possible due to a reduction of animal stocks by changing consumer behaviour, which means less consumption of meat,[15] milk and milk products. Such major shifts in agricultural practice would also have significant implications for the impact of land use on biodiversity and landscape, and the benefits associated with extensification on this scale could be considerable. Agricultural policy can't change the consumer behaviour but there are some elements within CAP, which promote a higher consumption of meat and milk products (subsidies of butter for bakery and ice-cream industry). The implementation of measures to mitigate greenhouse gas emissions from agriculture depends on information, laws and regulation and (financial) incentives. A good integration with other environmental policies (N_2O reduction) and climate change policies in other sectors (bioenergy) is essential. The climate aspect should be integrated more in CAP[16], especially in the rural development policy[17].

Finally it shouldn't be forgotten that according to the assessment report of potential effects and adaptations for climate change in Europe[18], agriculture could become one of the main victims of climate change.

[14] The values mentioned in the table do not account for C sinks associated with bioenergy.

[15] A reduction of meat consumption in general, which means pig-, poultry- and ovinemeat.

[16] When discussing milk quotas, methane production may be one of several aspects, which should be taken into consideration.

[17] It has been proposed to offer a package of measures to the farmer to give him different options to choose from. Also the environmental side effects would depend on what kind of combination of measures is applied.

[18] Assessment of potential effects and adaptations for climate change in Europe, The Europe Acacia Project. European Commission, DG Research.

7. Annex I - VI

Annex I: List of all recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
A: N_2O emissions from agricultural soils												
A1:Enhanced spreader maintenance	EU15	-24 to –43	5	**3**	**3**	2000	5	5	5	This option is only feasible provided there is an incentive to do so [fertilizer is relatively cheap] and that sufficiently trained farmers/ specialist rural contractors are available. This could be achieved by making such maintenance a factor in agri-environment schemes [other CAP or rural development regulation to incentivise] and paying a further premium for good maintenance. There are also opportunities for rural development within the agricultural industry through subsidised training, perhaps diversity of activities for farmers. A1-A5: Measures of these types can (or should) to variable extents be found in action programmes for nitrate vulnerable zones.	4.6	
A2:Fertiliser-free zones	EU15	-15 to -45 (0) Proposed by DG AGRI	5	**3**	3	100	3,5	4	4	Potential to deliver significant wildlife and water quality benefits with 2 or 6 m fertilizer-free zones (wildflower margins and enhanced buffering ability). 50 cm (proposed) might not be very effective, and might complement other field margin management schemes. The 50cm strip would seem difficult to achieve in practise; a more workable width is required. The yield penalty would severely hamper uptake of this measure by the industry. The measure implies leaving part of the plot unfertilised so as to enhance biodiversity and prevent runoffs. The measure requires that farmers accept to neglect part of the plot and to have lower yields, as well as to make some changes in management of the spreader. On the fertilizer-free zone (ffz), plants might not be as healthful as on the rest of the field. That may imply a different type of harvesting technique and farmers might not agree to have part of their plants that doesn't look as good as they should. ESE: The ffz might attract the insects. Either it will decrease the pesticide requirements for the rest of the field (= positive side-effects thanks to the concentration of insects on the ffz), or there will be a higher pest population (= negative side-effects). Wider margins next to drainage ditches will prevent runoff more efficiently than 50 cm only.	3.8	4.0

Annex I: List of all recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
A3:Optimising distribution geometry	EU15	-2 to -33	5	4	2	110	3	5	4,5	A2 and A3 work in different parts of the field. A3 (with well-fertilised field margins) reduces the risk of higher pest populations. However, I feel that both measures should get the rating 5 in ESE since "pest" is an economic judgement, which objects biodiversity.	4.0	
A4:Improvements in fertilizer efficiency through precision farming		-24 to –270 (costs for contractors)	5	**4**	3	370	4	5	4	Usually only for bigger farms or contractors. In case of contractors doing the work this measure can also be applied to smaller farms (e.g. Sweden).	4.2	
A5:Optimising N application by allowing for manure N and residual N	EU15	0	5	4	3	262 (under-estimated)	**4**	5	**5**	The UK is currently putting a large research and technology transfer effort into ensuring this occurs more. For example there are four nutrient demonstration farms, situated on commercial units, where MAFF have paid for new manure application equipment to allow greater precision and flexibility of application combined with tools to demonstrate how best to estimate nutrient contents etc. The major outputs are farmer meetings where yields using these new systems, compared to their conventional systems on-site as discussed. The project includes a full economic and environmental assessment to demonstrates the benefits. This is a useful option to tightening up the nitrogen cycle with all the added benefits to GHG emissions, water quality, biodiversity etc, and should be encouraged EU wide. (For detailed description see Annex Text by Gert Monteny)	4.4	
A6:Continuation of set-aside	EU15	Opportunity - costs	5	3	5	6196 ?	5	5	5	Could have high potential benefits for wildlife using set-aside as a habitat, particularly if the growing of industrial crops on set-aside is discontinued. Depends on the share of set aside. Bare set-aside tends to have very positive environmental side effects which do not occur in set asided land where non-food crops are grown. In biodiversity terms the most preferable set-aside is the non rotational one.	4.8	
A7:Soil/plant testing	All	> 0	2	2	1	?	4	5	5	Can (do not have to) be part of nitrate action programmes.	3.7	4.0

Annex I: List of all recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
B5:Natural woodland regeneration (re-vegetation)	EU-15		**3**	3	5	60000-120000 (5+5b)	5	4	4	As above, No forest management might have negative effects due to fires, lack of natural regeneration in the Mediterranean Region, etc.. Countries with a very small amount of farmland, under 10 % of national area, do not really have option for gaining anything by regeneration of natural woodland. This requires abandonment of agricultural land. Afforestation is already part of agroenvironmental schemes in some MS. PS: May also improve biodiversity and leisure and amenity value of the land	4.1	
B6:Bioenergy crop production	10 % of arable Land		3,5	3	4	150000	5	4	5	This is a measure that the UK Government believes can mitigate emissions of CO2 from fossil fuels and has introduced the Energy Crops Scheme under the England Rural Development Programme to support these activities. Expenditure of £30m over the seven year life of the programme will support planting of crops and setting up of producer groups for short-rotation coppice growers. Because the bio mass fuel chain results only in some GHG emissions (sometimes nearly C-neutral-depending on the biomass chain, considered) , energy crops can make a significant contribution to Government targets on renewable energy and climate change. The Prime Minister recently announced a further £50m support for renewable energy from biomass and offshore wind. This is not carbon sequestration since the carbon is rapidly burnt to substitute for fossil fuels. The IPCC calls this "carbon substitution", replacing fossil carbon by "recent "carbon. Suggestion make a separate category for bioenergy (like A, B,..)	4.3	

Annex I: List of all recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
B12:Optimised soil management	EU-15		3	2,5	3,5		4,5	5	5	This is a combination of reduced tillage, perennial forage crops or other cover crops, and all kinds of organic amendments (compost, sludge, straw, manure, ….) Optimised soil management practices can be supported under agri-environment. As a matter of fact, several MS and regions have measures of this type in their RDPs. Compost in particular gives other positive environmental side effects, as avoided use of chemical fertilizers and pesticides, improved tilth, positive effect on trace minerals, potential sink for carbon in the soil due to the use of organic fertilisers. A quick calculation shows that overall yearly CO2 emissions from a whole nation as Italy (541.542 Gg CO2 being emitted yearly, roughly 30 millions hectares total land area) can be equaled by a lock-up of just 0,14% organic carbon in soils. This also means that loosing 0,14% SOC would mean a net transfer of a further yearly CO2 emission pool from the soil into the atmosphere.	4.2	
B18:No-till farming	EU-15		2,5	**2,5**	**3**	81000	5	3,5	4,5	This can be associated (in some cases) with some increases in pesticide usage but most of specialists agree (at least in our dear Mediterranean) that this is a most desirable practices. It deserves a higher environmental score. Connected with high initial machinery cost. N2O could go up, reduced benefits by 50-60 % (explanation, Pete). Less fossil fuel would be used. Explanation – N2O emissions may increase as soils may become more anaerobic under no-till. As a result, denitrification results in less N2 production and more N2O. Our figures suggest that when these potential increases in N2O are converted to carbon equivalents and included in the calculations, the total mitigation effect in terms of the global warming potential is reduced by about 50-60% compared to when only soil carbon sequestration is considered (Smith et al (2000) Soil Use and Management 16: 251-259)	3.8	4.0
B19:Agricultural extensification	EU-15		3	2,5	3	40000	5	5	5	Wildlife benefits, animal welfare benefits, improved soil structure.	4.3	

Annex I: List of all recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
B20:Optimised land manage-ment without bioenergy	EU-15		3	3	3	100000	5	5	5	Increased biodiversity, less N leaching, leisure and amenity benefits. This is another one of Pete Smiths scenario runs, which relies on carbon sequestration only. The scenario with bioenergy combines carbon offsets by replacing fossil fuels with bioenergy, mixing carbon sequestration (potentially non-permanent effect) with carbon substitution (permanent). (This already has the bioenergy / woodland components removed so should remain. B21 includes the bioenergy, wood C etc. that has already been deleted).	4.3	
B21:Optimised land manage-ment incl. Bioenergy	EU-15		3,5	3	3	220000	5	5	5	Deleted. This mixes bioenergy effects with carbon sequestration. The different effects should be separated in this table	4.4	
C16. Efficiency of life time			**4**	**3,5**	**3**		3,5	5	**4**	For dairy cows, this means more lactation's per cow. This is a laudable objective, but in practice, the trend is in the opposite direction. Number of lactation's per cow is falling as improving genetic merit increases milk production but brings problems with health and fertility. Even disregarding this, it is difficult to know how to induce change. For beef cows there may be no additional scope. It was proposed to use milking cows to a higher extent for producing calves. This would minimise Methane emission in calf production. The use of more bulls and less steers for beef production could reduce the methane emission as well. Bulls grow faster and methane emission is mainly proportional to lifetime But: Grassland and side effects ?	3.9	4.0
D1. Agricult. Manure farm scale anaerobic digestion cooler countries (heat & power)		-46 ??	4	4	2	667	5	4,5	4		4.1	
D2. Agricult. Manure centralised anaerobic digestion cooler countries		Probably I< 1a	5	3	3	516	5	4	4		4.1	
D5. Agricult. Manure farm scale anaerobic digestion warmer countries (heat & power)		23	3	3	3	845	5	5	4		4.1	

Annex I: List of all recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
D6. Agricult. Manure farmscale anaerobic digestion warmer countries (heat only)		38	3	3	3	2536	5	5	4		4.1	
D7. Agricult. Manure farmscale anaerobic digestion cooler countries (heat only)		143	3	3	3	2001	5	5	4		4.1	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
A: N_2O emissions from agricultural soils												
A8:Minimise fallow periods (catch crops)	All		**2,5**	**2,5**	2		**4**	4	4	In some situations would need to have unploughed stubble fields over winter to supply food for wintering birds and mammals.	3.4	
A9: Synchronise N supply with crop demand	All	>0	2,5	2,5	2	2700	5	5	3	Measures 9 and 10 belongs together. As indicated by some, this is already done by the large majority of farmers (and is part of GAP). Unless its description is more elaborated, it can not be taken into consideration. The same applies to A10.	3.7	
A11:Controlled release fertilisers	All		1	2	3	?	4	5	1	More research is needed, costs are still to high. Highly sophisticated technique which works with organic coatings, which slowly must degrade in soil before the fertiliser can be released.	2.9	
A12-a:Fertiliser placement (below surface, foliar) Slurry Injection	All		1	**2**	1	?	4	4	**3**	Chemical fertilizer can be spread at the same time as the seeds with the same machine. This is not possible with manure. Thus the manure use and spreading is more time consuming than the use of chemical fertilizers. It also affects the structure of the soil negatively when transporting heavy loads twice. If the manure is placed below surface the time required fore spreading will increase. Slow spreading increases the affect on soil structure. The increase of spreading time is even bigger when injection is concerned and the cost of machinery will increase. When using hose spreaders one gets a much lesser spreading surface for the manure and thus the emissions are smaller. The advantage of surface spreading compared with soil placement is also the effect of light that affects the manure on the surface of the land (UV –light) and thus kills hazardous bacteria faster compared to placement and injection. Further comments on this are appreciated.	2.9	
A12-b:Fertiliser placement (below surface, foliar)	All		1	2	4,5		4	2,5	**4**	It can be either pellet fertilizer that doesn't imply any environmental danger, or ammonia injected in the humid soil in the form of gas that is to be trapped by the soil. In the case of ammonia, there might be some intoxication due to some low degree of ammonia fixation by the soil, hence freed in the atmosphere. Foliar application appears to be more environmentally satisfactory in the cases where micronutrients are applied and the doses are well quantified according to soil efficiencies. However, water quality is one of the requirements for satisfactory fertilisation and this might not be always available.	3.2	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
A13:Fertiliser form	All		2	2	2	**500**	5	3	1	technical not proved, experimentally proven for Scotland only.	2.7	
A14:Nitrification inhibitors	All		1	2	2,5	?	3	2	2	Ethical question surrounding the value of end-of-pipe chemical fixes, compared to start-of pipe solutions to nitrogen cycle, plus question whether long-term impacts on soil biology are well-enough understood. There are potentially some further environmental/biosecurity implications for the use of nitrification inhibitors. These work by preventing the activity of micro-organisms that convert ammonium to nitrate, and there is some sensitivities to “knocking out” sections of the microbial community. There are also larger costs associated with their use. Contrary comment: The inhibitors only block the micro-organisms (unlike N-Serve in USA which kills the organisms). Furthermore all products are tested and approved by independent organisations. That means the inhibitors -by definition- have no adverse effects. Effect of inhibitors: 1 to 4 weeks; in this time period the crop must be able to take the nitrogen up. This is indeed somewhat ethical. We know very little about soil micro-organisms. Therefore, none of the prescribed tests can be really conclusive about impacts on microbial biodiversity. Nitrification inhibitors block the activity of abundant and ubiquitary organisms. Ecologists always suspect that such end-of-pipe fixes are too "easy", and often, trade-offs were identified only years later.	2.2	
A15: N-tax	All									Measure deleted	0.0	
A16: N-Quota	All									Measure deleted	0.0	
A17: 2. Tighten N flows in farm			**2**	**3**	**2**	>2700	**5**	**4**	**3**	Reformulate description of the measure along the lines "making farms more N self-sufficient" or something similar, unless scope totally unclear. On top of this, the measure would have to quantified (baseline and target) to make it meaningful. **In other words, how much do N flows in the farm have to be tightened? A.F.:**This depends on the farm type. Best is, to tighten the N-flows of a region, e.g. allowing for N trade among farms, e.g. to get rid of excess manure in animal farms and to save synthetic fertiliser in crop production farms. Alternatively, re-integrate animal and crop production at the farm level.	3.4	
3. Optimise water management											0.0	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
A18:Irrigation			1	1	1	?	3	1,5	5	Major implications for water resources if irrigation increases. Sustainable option may be to match crop growing patterns better to available water, rather than attempt to irrigate. The environmental impacts this measure is so big and so varied (most of them bad, but can also be positive) than measuring its environmental desirability in climate change terms does not make any sense. It's proposed to delete this measure.	2.4	
A19:Drainage			1	2	3	?	2	1	4	The environmental impacts this measure is so big and so varied (most of them bad, but can also be positive) than measuring its environmental desirability in climate change terms does not make any sense. It's proposed to delete this measure.	2.2	
A20: 4. Pasture management										Research is still needed	0.0	
A21: 5. Wetland restoration, organic soils			1	1	1	1100	5	5	2	Major biodiversity, habitat and flood prevention benefits. Technical challenges to rewetting dried peat. The environmental impacts this measure is so big and so varied that measuring its environmental desirability in climate change terms does not make any sense. Abandonment of farmed organic soils: There is no detailed reason, just a killer argument. Of course, farmed organic soils belong to the most productive areas, but this is production on the expense of the future since it burns off the peat resource and uses the released nutrients.	3.0	
B: Carbon Sequestration/renwable raw materials for bioenergy										Carbon sequestration measures are of two types: 1) change in management pertaining to most of the measures mentioned, 2) land use change (abandonment) pertaining to measures 1 and 5/5b. Carbon sequestration measures only work if they are maintained over decades!	0.0	
B1:Restoration of wetlands, all kinds of wetlands			1	1	2	480	5	5	2,5	Major amenity, landscape, flood control and biodiversity benefits. This includes farmed peatlands. The potential for GHG reduction is much higher. The number given here only reflects carbon sequestration, not the reduction of N2O and CO2 emissions originally emitted from peat oxidation. Overall effect >5000 if an adoption on 10% of farmed peatlands of either of the measures 1) no roots and tubers, 2) abandon tillage, 3) recultivation is achieved.	3.2	
B2:Restoration of eroded and salinated land	Mediterranean		1	1	1		3	5	2	Major amenity, landscape, flood control and biodiversity benefits.	2.6	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
B3:Marginal cropland re-seeded to grassland (permanent)	Temperate-dry		2	1	3	400	4	5	4	Potentially high benefits depending on end use and type of restored grassland habitat.	3.6	
B4:Surplus-cropland seeded to grassland (permanent)	Temperate-wet		1	1	3	2200	5	5	4	As above, but potential social consequences if abandonment is accelerated.	3.7	2.0
B5b:Natural woodland regeneration (human induced)	EU-15		**2**	3	2		5	3	4	Benefits potentially high if afforestation is sensitive to regional habitats and landscapes. Biodiversity and landscape will not be improved by commercial monocultures. This requires abandonment of agricultural land. Afforestation is already part of agroenvironmental schemes in some MS. PS: May also improve biodiversity and leisure and amenity value of the land	3.4	
B13:Animal manure (low)	EU-15	See A 14								Deleted, see B 14.	0.0	
B14:Animal manure (high)	EU-15		2	3	2	24000	5	3	4,5	B13&14. There would be a number of environmental side effects associated with the significantly increased transport required to enact this measure. This would results in increased transport emissions which would be relatively small (demonstrated y Pete Smith), increased demand for fuel, increased particulate losses from combustion of fuel, if fitted with catalytic converters, increased ammonia and other gaseous emissions from transport etc. Possible trace gas benefits, improved soil structure.	3.6	
B15:Sewage sludge	EU-15		3	3	2	6000	5	3	5	Worth mentioning that the use of non regulated sewage sludge or any other waste can also have negative environmental effects such as the build-up of heavy metals. The farming communities and farmers do not trust sludge. It is a question of food safety and consumer trust. The sludge could, however, be applied at below the safe EU limits.	3.8	
B16:Cereal straw (low)	EU-15	See A 17								Deleted, see A 17.	0.0	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE**) and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
B22:Grazing management, fertilisation, irrigation	Temperate-dry									Deleted. There is not enough research yet, so no detailed recommendations can be made.	0.0	
B23:Grazing management, fertilisation, species introduction	Temperate-wet									Deleted. There is not enough research yet, so no detailed recommendations can be made.	0.0	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
C: CH_4 emissions from enteric fermentation											0.0	
C1. Agric. Enteric fermentation replace roughage by concentrates non-dairy -		Neutral (?)	**4**	3	2	Less than 465	4	1	2,5	The feasibility is greatest in countries where beef production currently involves high levels of forage (grazed or conserved) such as Ireland, the UK and possibly France. There is little potential in countries where beef production is already intensive, and uses high concentrate, low forage diets. The potential reduction per day is quite small because the animal's overall DM intake increases (e.g. less than 5% reduction in daily methane output for a 30% replacement of forage with concentrate) and thus the effectiveness of this strategy is very dependent on increased animal productivity in combination with a ceiling on total beef production. Then animals reach their slaughter weight at a younger age. Another factor which reduces the potential reductions is that the measure is only likely to be implemented in the finishing period (perhaps 25 % of the animal's life). Based on a 30% replacement of roughage by concentrates for the final 6 months out of a 24 month life time which is shortened to 23 months due to the higher growth rate, one could expect an annualised reduction of approximately 3% in methane o There are doubts about the estimated negative costs. The cost will vary a lot depending on the cost of forages in different regions. It is difficult to envisage a negative cost in regions, which have cheap forage, and these are the regions with the best technical feasibility. Some negative environmental side effects are possible from the intensification of beef production in these regions. Also there are some risks to animal health (e.g. acidosis).	2.7	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
C2. Agricult. Enteric fermentation replace roughage by concentrates dairy		Neutral (?)	5	3	2	Less than 320 (160)	4	1	1,5	There is little scope for this to happen in most countries where concentrate proportion is already at a high level and to go even higher would have detrimental effects on animal health and milk composition. Some countries like Ireland have low concentrate, high forage/roughage (grazed grass) diets and therefore have the technical feasibility to increase concentrate proportion. This is unlikely in practice because from an economic point of view, farmers operating these systems strive to maximise roughage/forage proportion in the diet, but a small increase in concentrate proportion to help cope with the higher energy demands of higher genetic merit cows will probably occur. Thus while a reduction of 6.2% (AEA Technology, 2000) might be technically feasible in some limited areas of the EU, it is likely that the actual reduction would be less than half this. If the technically feasible reduction were implemented, it would have some negative environmental side effects due to the intensification and some possible negative effects on animal health and welfare (acidosis, laminitis). These would be much less where the increase is smaller	2.6	
C3. Agricult. Enteric fermentation change composition concentrates by extra fat - non-dairy -		Neutral (?)	5	3	3	113 (?)	4	4	**3**	C3 and C4: The measure is quite feasible when the animals are being fed concentrates but for some regions where beef production is largely pasture based, the measure only has feasibility during the indoor period. One concern is the large increase in demand for fat/oil if the measure were implemented. It could have positive or negative side effects on flavor / health aspects of beef fat. There is a need for more research in this area to quantify the effect of Different types of fat/oil In view of the scarcity of information on these areas, there has to be uncertainty regarding the reduction potential used in the table.	3.7	
C4. Agricult. Enteric fermentation change composition concentrates by extra fat - dairy -		Neutral (?)	5	3	3	176 (?)	4	4	**3**		3.7	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
C5. Agricult. Enteric fermentation improved level feed intake dairy - with improved genetics		-43	5	4	**3**	2170 (???)	5	**2**	3,5	C5 and C6: On C5, the reality is that there probably already is a very wide variation in milk yield per cow under similar feeding regimes and breeds on the same farm. It may be useful to examine what the extent of this is and see if the process of speeding up genetic improvement within breeds is more possible as EU dairy herds get larger. There are some doubts as to the continued availability of better (non GMO) breeds of dairy cows as world wide there is a limited gene pool being targeted by all leading milk producing countries. Improving non-dairy cattle (measure 6) to some extent follows the same pattern but perhaps even more so as the genetic resources need to be kept much more varied to respond to the very varied conditions of production. The effect of the higher intake of these animals is somewhat unsure, and thus there has to be a degree of uncertainty regarding the reduction potential. The higher yielding cows will have negative side effects from their health and welfare, and fertility viewpoints, and will lead to further intensification of the industry.	3.7	
C6. Agricult. Enteric fermentation improved level feed intake non-dairy - with improved genetics		-43	5	3	1	1928 (???)	5	**2**	3,5		3.3	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
C7. Agricult. Enteric fermentation change composition concentrates by NSC - dairy -		Neutral	4	3	3	271(???)	4	3	4	C7 and C8: This is already a very significant trend in the EU where the overall contribution of cereals to animal diets rose by 20-25 Mt since 1992. This really is the result of policy decisions then and continued in Agenda 2000. In deed the policy decisions here will also influence measures C 1+2 as they tend to change the price balance between grass, cereals, arable silage and imported substitutes. The decline in methane production from increasing the amount of **non structural carbohydrate (NSC)** in the concentrate may be overestimated by AEA Technology (2000) Thus this area needs further research to verify the existence and magnitude of this effect identify the concentrate feedstuffs most likely to bring it about. Assuming there is some potential, it is not great in many countries where NSC levels in concentrates are already high, but in some countries like Ireland, the UK and the Netherlands, concentrates contain a lot of high fibre by-product type ingredients (i.e. wheat bran from milling industry). So potential would be greatest in these countries. Side effects should be small, with some possible ne on animal health through acidosis. One problem could be sourcing the extra NSC: extra cereals would have to be grown.	3.6	
C8. Agricult. Enteric fermentation change composition concentrates by NSC - non-dairy –		Neutral	4	3	3	176 (???)	4	3	**4**		3.6	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
C9. Agricult. Enteric fermentation propionate precursors – dairy (feeding malate)		High	1	1	3	???	**3**	3	**3**	C9 and C10: Fumarate and malate are efficiently used by rumen microbes to produce propionate at the expense of CH4 and lactic acid. So, they limit the risk of acidosis when animals are fed high-starch diets, and they interact positively with concentrate diets in the reduction of CH4 production. These aspects were observed in vitro studies carried out with artificial rumen systems. They need to be confirmed in vivo. Research is needed to a)establish the magnitude of the response b) establish the long term stability of the response. If the first two are positive, grass breeding programs need to produce varieties with high levels of malate or fumarate. It is too early to specify the cost, effects on farm incomes, reduction potential, etc. of this measure. It is a promising area that needs further research. In the event of it being successful, it is unlikely to have negative side effects, and the feasibility will be greatest in areas that feed large amounts of roughage/forage. There are concerns relate to animal health and possible consumer resistance.	2.6	
C10. Agricult. Enteric fermentation propionate precursors – non dairy		Very high	1	1	3	???	**3**	3	**3**		2.6	
C11. Increasing animal productivity through the use of additives, Probiotics Ionophores Antibiotics and halogenated compounds Bovine somatotropin (BST		?	**1**	**1**	**3**	**?**	**3**	**2**	**2**	Although some of these have proven potential (Ionophores), most of them are unacceptable (e.g. BST), have unproven or short term effects, or have other unacceptable side effects. The exception is probably the Ionophores. These are currently licensed for use in non lactating animals only, and even this is under threat. From a methane viewpoint their use with lactating cows should be considered. Consumer concerns should be examined to see are they justified. Comparison with the situation in the USA should be made. The product is now out of patent, so the manufacturer will not push this.	2.1	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
C12. Improving feed conversion efficiency - mechanical treatments of feed		?	1	4	1	?	4	3	4	Research has shown that grinding/pelleting of hay/dried grass reduces methane production. These feeds are not used to a great extent in the EU. The grinding will require extra energy, which may negate the advantage gained. For grazed forages, this is not an option. For conserved silage's, there is an opportunity to manipulate particle size, but research is needed to indicate if there is an effect, and if yes to determine the optimum operational details. A comprehensive literature review of old research could help point the way.	3.1	
C13. Methane capture by mechanical filters		?	2	1	3	?	4	3	1	Probably not feasible for ventilation reasons today but it could be possible if technology was developed in relation to new dairy housing. But Methane production per day per animal is low and the technology may be to too costly.	2.4	
C14. More non methane meat production (chicken/meat			1	2	3	0	0	1	1	It is difficult to see much progress being made by 2010. It would have negative side effects because pigmeat / poultry meat production is more intensive and have more animal welfare concerns, biodiversity would be reduced, and the landscape would disapprove. Also we should not forget the great benefits ruminants have in converting forages grown in non arable areas and waste products from many industries (milling, malting, brewing, sugar, ethanol, etc.) into food edible by humans. Pigs and poultry cannot do this. Looking at the food chain, there might be even more GHG emission.	1.1	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
C15. Improved productivity										Improved productivity" is meant to as a headline for the examples under measures no C16, C17 and C18. (It also covers parts of the issues in no 1-6 and 19). This was noted as well as 'improved digestibility of forages'. Improving the digestibility of forages will have positive effects on animal productivity and on methane production per kg of food eaten. Thus methane production per unit product could be substantially reduced. Improved digestibility of forages can be brought about by better grassland management, better grass varieties, better management in forage conservation, treatment of straws (e.g. with sodium hydroxide). It is not feasible to improve the digestibility of all forage – some is near or at its maximum. But there is definite potential. For example, average grass silage digestibility in Ireland is less than 70%, whereas 75% digestibility is easily achieved on better farms. This is mainly a technology transfer issue. The problem is farmers have been encouraged to improve forage digestibility for many years, and it is difficult to achieve much progress. This is despite well demonstrated income benefits to f	0.0	
C17. Multi use of milk cows (milk and calves and meat			**3**	**2**	**3**		**4**	**5**	2	On the one hand a more systematised exchange of calves between dairy farms and beef farms could be developed. But the trend towards specialist milk cows and specialist beef cows has been evident throughout the EU for perhaps 40 years. In effect, dairy cows have been bred to have poor conformation for meat production and this mitigates against beef of the quality required by the market. To change this trend would require a move away from high yielding dairy cows, which in turn, has CH4 implications. Using calves from dairy herds for beef production is popular today but more likely to increase the concentration of production to the detriment of extensive beef and hence of bio-diversity.	3.3	
C18. more effective use of male/female, genetic choice			**3**	**4**	**3**		**3,5**	**3**	3	? Planned selection of male/female at insemination. ? Developed choice of origin and genetic set up in stockbreeding	3.2	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
C19. Lifetime -c younger slaughter male cattle			**5**	**2**	**4**	?	**3,5**	3	**4**	In beef production systems, animals often go through store periods where there is little or no weight gain. This extends the time needed to reach a given slaughter weight, and increases the lifetime methane production. If efficiency could be improved, it would result in significant improvements in lifetime methane emissions (up to 20%).This is a technology transfer issue, but the EU has an opportunity to encourage it through judicious use of the premium system. For instance, payment of the slaughter premium could be conditional on animals being under a certain age. Thus the measure would have no additional cost.	3.6	
C20. Subsidising reduction of Methane in agricultural sector(see D8)												
N_2O and CH_4 emissions from manure management											0.0	
D3. Agricult. Manure slowing down anaerobic decomposition		0	1,5	3	2	546	5	5	4		3.8	
D4. deleted		0									0.0	
D8. Subsidising reduction of Methane in agricultural sector			**3**	**3,5**	**3**		**4**	**5**	**2**	The value of a tone of methane reduction could be around 420 euros (20 euros per tone of CO2 eq. is the minimum (least cost). From a methane emissions of 100 kg per cow and 100 cows per farm may result 10 tones of CH4 per farm on the average (420 Euro per farm with an estimated reduction of 10 %).It is questionable, whether this amount is an incentive for a farmer to change the production method or invest in biogas plants. Subsidising the reduction Other areas of interest might be ? A subsidy for high fat concentrates ? A subsidy for high NSC concentrates ? A subsidy for high malate grass seeds (if such varieties exist or can be bred) ? An extra premium for early slaughtered beef animals	3.5	3.0

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Income	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE)** and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
D9. Covering of out door storaged manure			**1**	**3**	**3**		**3**	**3**	**1**	The potential decrease in nitrous oxide emissions are less certain due to the number of competing effects that need to be considered. Smaller volumes of slurry would be generated, largely by the exclusion of rain water from the stores, and need to be spread on the land. This may result in small savings in N2O. However, the slurry being less dilute, would have a higher nutrient value per application potentially increasing losses of ammonia, nitrous oxide and nitrate leaching at a later date. So to benefit, in terms of GHG's, farmers would have to ensure that they utilise their manures to maximise nutrient uptake. Current evidence suggests that this is not practised. Further analysis would be required as to the contribution of lowered fuel use from less slurry spreading to land, before a true picture of the benefits in terms of GHG loss from agriculture. This will be carried out under a MAFF project developing cost-curves for GHG emissions from agriculture.	2.3	
D10. Slurry cooling		Very high	**1**	**1**	**3**		**1**	**1**	**1**	Slurry cooling for reducing emissions from manure would be so expensive (equipment for cooling, cost for cooling (energy cost)) and would create carbon dioxide emissions from fossil fuels for electricity needed, so that this measure can not be proposed.	1.2	
D11. Filtration technology		Very high	**1**	**1**	**3**		**1**	**1**	**1**	Reducing of methane by filtration of exhaust air from stables or tanks by micro-organisms are not economic at all. The process of methane oxidation requires higher concentrations of methane >0.1 % v/v of the exhaust air and the throughput of air has to be very low (large retention time) in order to be effective. This process may really work at higher methane concentrations from landfills and from coal mines, not for low concentrations from animal buildings and storage tanks. Increasing the concentration of methane would be very cost expensive.	1.2	

Annex II: List of non recommended measures

ESE: Environmental Side Effects F(T): Technical Feasibility Av Ra.: Average Ranking (Red. Poten., ESE and F(T) x 2) Exp. Ra.: Expert Ranking

Ranking (Ra.): 1= negative 3= neutral 5= positive

Measure	Zone	Specific costs		Inco me	Labor	Emission Reduction pot. EU15		ESE	F (T)	Comments on Environmental Side Effects **(ESE**) and Technical Feasibility **(FT)**	Av Ra.	Exp. Ra.
		Euro/tCO2-eq.	Ra.	Ra.	Ra.	ktCO2-eq.	Ra.	Ra.	Ra.			
D12. Controlled decomposition of manure (composting)			**3**	**3**	**3**	**?**	**3**	**5**	**3**	Beside the anaerobic digestion, a controlled aerobic decomposition of manure (which could be worded as “controlled decay of organic matter”) could effectively cut the potential methane emissions both at the stockpiling and at the application stage. Aerobic processes lead to the production of CO2 instead of methane, and this would be considered as neutral, instead of being given negative credits, under the standpoint of GHGs. Research is going on on this fields, e.g. in the Netherlands and Italy. At this stage there is no cost-effective reduction potential.	3.4	

Annex III: Uncertainties and opportunities for agricultural soils as sinks

It can be concluded that the contribution and the extent of contribution of agricultural soils to the CO_2 reduction objective depends on the price of CO_2 credits on the market. However, there are still a number of uncertainties and questions to be answered surrounding the absorption potential of different land use systems and the sustainability of those measures. Those and other uncertainties have been mentioned by some experts of the Working Group 7, according to whom carbon sequestration should not represent a real mitigation option because of the high risks associated with carbon sinks since the sink in soil which may not be permanent. It will hence only allow to buy time in order to develop other long-term mitigation measures. Some stressed that, as the sink will saturate when a new equilibrium of soil organic matter is reached, carbon sequestration measures are only applicable for a limited time span of at maximum 50 to 100 years. However, despite the reservations of several experts in Working Group 7, others have underlined the particular importance, as to magnitude, of the potential contribution of sequestration in the soil and agree that agricultural soil carbon sinks are a reality under Article 3.4 of the Kyoto Protocol, a position that became firmer after the COP6 bis meeting in Bonn in July 2001. As such, agricultural soil carbon sinks need to be taken seriously. The biological potential for carbon sequestration in agricultural soils through optimised land management could be as high as 100 Mt CO_2-equ. a-1. Only a small fraction of that, however, will be feasible until the first commitment period (Kyoto Protocol) since carbon sequestration in agricultural soils requires a major change in crop rotations, land management and the dedication of the set-aside areas. The actual rate of carbon sequestration is highly uncertain and still, there are few adequate tools available to measure and monitor stock changes in soil carbon at a time scale as short as the first commitment period. With the accounting scheme for management measures under Article 3.4 of the Kyoto Protocol, the accountable sequestration may further shrink because the baseline of 1990 has to be subtracted. A greater research effort to study, monitor and quantify soil carbon stock changes under different agricultural management practice in Europe is urgently needed.

Further calculations and considerations have to be done on possible measures. There may be other side-effects connected with a no tillage system, e.g. the additional use of herbicides due to less soil cultivation[1].

Measures under B, B1 to B 21 (see annex II) have common characteristics of requiring change of land use. This is always a big step for a farm and has implications on the farm income and even the total possibility of farming an area for example when restoring wetlands. When changing to more grassland one needs to have animals or animals on the neighbouring farms. More animals are causing more manure, which increases the GHG emissions[2].

---

[1] Carbon sequestration means simultaneous sequestration of nitrogen in soils. There are no experimental results on how much this will affect N2O emissions, but the effect is probably small.

[2] The grass could alternatively be used for biofuels of as renewable material and does not necessarily contradict the paragraph on bioenergy production.

The change to animal farming is a very big change for a farm. Thus the change to growing bio energy crop is probably easier for a farm especially when using yearly or perennial crops than to change to more grassland.

The question of the use of set aside land has also the aspect of permanent place or rotation. Rotation is good for the fields and soil composition. Permanent place is used for the poorest land in small amounts. Thus farming may loose the beneficial effect of rotational set aside if land is used for permanent bio energy crop production, except, if bio energy crop is taken as a whole part of the rotation cropping. This approach is also the most efficient in energy farming and consistency of energy supply.
Organic matter is an emerging issue for its connection with soil fertility, stability and structure, water storage capacity, etc. Organic matter's decline in many European soils is threatening their capacity to remain fertile and to keep performing their most essential environmental functions. If the Community starts looking at soils as a medium requiring comprehensive approaches (as it is already the case of water and air) and there are good reasons to think that this will be the case, organic matter will certainly emerge as one key issues in EU policy terms. Looking at carbon stored in farm soils, it would be most sensible to make the link with the organic matter issue. By doing this both issues (climate change and soil condition) will benefit each other of this synergetic approach. The Commission has indicated its intention in the sixth Environmental Action Programme (EAP) to develop a thematic strategy on soil protection. The draft Council and Parliament decision on the 6 EAP sets the objective of the promotion of a sustainable use of soil, with particular reference to preventing erosion, deterioration, contamination and desertification. A Commission communication on soil protection is foreseen in 2002 and it is clear that ,inter alia, it will lay particular emphasis on organic matter.

It has been calculated[3] that an increase of 0.15% of organic carbon in arable soils in a Country like Italy would lock the same amount of carbon in soil as currently released into the atmosphere in one year by the use of fossil fuels.

This should be compared to the impressive decline of organic matter over past decades, whose magnitude in many areas is very frequently of some points percent and which has led its percentage below 2% in many soils. According to the European Soil Bureau, nearly 75% of the total area analysed in Southern Europe have a low (3.4%) or very low (1.7%) soil organic matter content. The problem is however not restricted to the Mediterranean. Figures for England and Wales show that the percentage of soils with less than 3.6% organic matter rose from 35% to 42% in the period 1980-1995. In the region south of Paris, soil organic matter has decreased by half in 16 years. Once we look at such figures from another point of view, they as a whole represent a huge opportunity to lock-up considerable amounts of carbon while restoring organic fertility.

An important and crucial issue are farmed organic soils. Those soils release up to 20 tonnes of CO2-equivalents per hectare and year and have hence higher greenhouse gas flux densities than any other agricultural system. In the short term, management change could save between 4 and 8 tonnes of CO2-equivalents per hectare and year if

[3] Speech by Prof. P. Sequi at the Compost Symposium, Vienna, 29-30 October 1998.

root and tuber cultures are abandoned (they have the highest impact on peat oxidation through intensive mechanical soil disturbance), or if tillage is abandoned. In the longer term, the recultivation of peatlands will perpetuate these emission reductions even if CH4 emissions increase, but this shift is a challenge for farmers who either have to switch to other cultures like Typha or so (still in experimental phase) or turn to the touristic sector. Nevertheless, this option should be carefully considered in the future. More research on long-term effects, alternative use of peatlands and environmental and social side-effects. Under B, 23 measures have been discussed. Those, dealing with improvement of soil management, are provided with the best notes. In a second step more detailed measures should be defined.

Experts are asked to clear the double-counting between A6 and B6, B12, B20 and B21.

Measures under B are applying as well for the following issue, Bio energy for carbon sequestration.

Annex IV: Carbon sinks and biomass energy: A study of linkages, options and implications

Annex V: Comments on the impact of animal manure used as crop fertiliser on greenhouse gas emissions by Gert-Jan Monteny

Introduction

Fertilisation of crops significantly contributes to the emission of greenhouse gases, especially through the emission of nitrous oxide (N2O) from soils. This is a result of incomplete transformation of ammonia to nitrate (nitrification) and/or the incomplete turnover of nitrate to nitrogen gas (denitrification). In general, incomplete denitrification is considered to be the most important of the two processes

The ECCP (European Climate Change Programme) – workgroup 7 "Agriculture" is currently composing a report with (technical) options to reduce non-CO2 greenhouse gases from agriculture.

One of the options to reduce N2O emissions is to optimise N application by accounting for N in animal manure and crop residues. This short paper contains basic thoughts in this perspective. It deals with an estimate on the N2O emission that can be reduced, as well as with the costs related, the feasibility and the environmental side effects.

An estimate of the N use in the EU 15 and the possibilities for improved use of N from animal manures

In the early days of agriculture, animal excreta were used for heating and land fertilisation. The latter aspect was derived from empirical observations: adding excreta to the soil improved crop yield. During the industrialisation, chemical fertilisers were introduced as a cheap and easy way to further increase crop production. Because of the growth of the livestock production, animal excreta became a waste product with a value at or below 'zero'. Still, that waste product was spread over the agricultural land (dumping), but the nutrient value was not or only limited taken into account. As a consequence, nowadays farming encounters severe environmental legislation aiming at a reduction of the surplus of nutrients brought to the field (nitrates directive) as a means to reduce pollution of water systems. Besides, gaseous emissions are directly or indirectly related to the use of fertilisers. Future legislation will also be put in practice to reduce emissions of ammonia (acidification) and non-CO2 greenhouse gases (climate change).

- total agricultural area EU-15 (TAA; 1998; Eurostat): 143 million ha
- area permanent grassland (Eurostat): 56 million ha
- mineral N use (Eurostat): 9.7 Mton/year (= 68 kg N/ha TAA)
- organic N (Eurostat): 7.1 Mton/year (= 50 kgN/ha TAA)
- total N: 16.8 Mton/year
- average N input: 118 kg/ha

This average N input per ha TAA seems limited, but the effective area that is fertilised with N from mineral and organic fertilisers will be (far) less. However, no data could be found. Moreover, there is a great variation in the average N input throughout the EU-15 (e.g. the Netherlands has regional values of up to 600 kg N/ha and regions in Spain and Portugal get no more than 30-40 kg N/ha).

Emission factors for nitrous oxide

Few data could be found in literature about the emission factors of N2O from fertilisers. Granli and Böckman (1994) reviewed the literature present at that date and found the following emission factors (average N2O emissions and range as % of the N applied):

- nitrate fertilisers 0.05 (0.001 – 1.3)
- ammonium nitrate fertilisers 0.4 (0.04 – 1.7)
- organic fertilisers 1.0 (0.01 – 2.05)

These data show that the N2O emissions from chemical fertilisers is higher than from organic fertilisers. The authors also discuss that much higher values for all fertilisers will be found when conditions are in favour of denitrification (e.g. moist clay soils, compacted soils).

Moreover, the authors report and increase in the emission percentage with the level of N input for some fertiliser types.

Velthof (1997) dedicated his PhD thesis entirely to N2O emissions from grasslands. His most important findings are listed below (N2O losses as % of N applied).

Soil type	Fertilisation	Grazing
Sand	0.5	1.0
Clay	1.4	2.1
Peat	2.3 – 3.9	1.5 – 7.7

These data show that grazed grassland has a higher N2O emission than fertilised grassland, most likely due to the high load of animal excreta in the grazing situation.

Contradictory to Granli and Böckman (1994), Velthof reports much higher values for the N2O emission from chemical fertilisers (5.2 – 14.1%) when compared with cattle slurry (0 – 0.4%). His experiments, however, not confirmed finding reported by Granli and Böckman (1994) about the decrease in the N2O emission factor (in % of N applied) with the N input level. Velhof (1997) found a more or less linear relationship instead:

- 300 kg N/ha.year 3.1%
- 200 kg N/ha.year 2.3%
- 100 kg N/ha.year 1.2%
- 50 kg N/ha.year 0.6%

Impact of replacement of chemical fertilisers by animal manures

Assuming a replacement rate of 50% (50% of the mineral N is replaced by manure N), the average level of N input in EU agriculture will be reduced by around 30 kg N/haTAA.year to a level of around 90 kg N/ha.year.

The reduction in N2O emission realised will be greatly depend on the assumption about the emission factor for chemical fertiliser and organic fertiliser. When Granli and Böckman (1994) are right, the replacement have little effect since mineral fertilisers have lower emission factors than organic fertilisers. However, with Velthof's findings (1997), the effect would be a dramatic decrease in N2O emissions since the emission factor for chemical fertilisers is much higher than from organic fertilisers. According to both references, the N2O emission will be lower because of the reduced level of total N fertilisation, with an additional effect of a lower emission factor related to the reduced level of N fertilisation.

Assuming a replacement of 3.5 Mton N/year of chemical fertilisers by organic fertilisers and an emission factor of 1%, the annual reduction in N2O emission would be 35 kTon of N2O-N per year.

Other reflections

A switch from chemical to organic fertilisers is likely to occur in arable farming and especially in situations where organic manure is abundantly available. Such a situation is present e.g. in the Netherlands. Due to environmental legislation, vast amounts of organic manure are being transported from the south (intensive region) to the north (arable land).

A replacement of mineral N by organic N may cause a (limited) drop in crop yield, because the total level of N input is reduced. This will reduce the level of N losses through nitrate leaching.

Also, expenses are cut (N costs around €0.15/kg) because less chemical fertilisers have to be purchased. The transport costs of manure greatly depend on the transport and storage capacity present on the receiving farm and on the transport distance. In the Netherlands, the following rule of thumb is used for the costs of transport of slurry:

Cost = €4/m3 + €0.05/m3 and km

With this rule, transporting 10 m3 of slurry over 100 km distance will cost:

€4 * 10 + €0.5 * 100 = €90 (or €9 per m3)

Furthermore, the replacement of mineral N by organic N not only cost money for transport and storage capacity. The receiving farmer will also have to invest in equipment for slurry application and this equipment will result in some more soil compaction and increased use of fuel (heavy machinery).

A positive side effect of the improved use of organic fertiliser is the long term increase of soil organic N.

Annex VI: List of Participants, Working Group Agriculture

	16.05.01 (N2O/soils)	17.05.01(Sequestration/renewable)
Chairman Secretary	• Adelmo Moreale, AGRI • Jörg Eggers, AGRI	• Adelmo Moreale, AGRI • Jörg Eggers, AGRI
Commission representatives	• VAINIO Matti (ENV) • PREVOST Francois (AGRI); • BENITO VILELLA Javier (AGRI); • CRESPO SAN JOSE Emilio (AGRI); • HAMELL Michael (ENV); • CARAZO JIMENEZ Luis (ENV); • GLAESER Hermann (AGRI); • HAENEL Leopold (AGRI); • DARGNIES-PEIRCE Cecile (ENTR)	• VAINIO Matti (ENV) • PREVOST Francois (AGRI); • BENITO VILELLA Javier (AGRI); • CRESPO SAN JOSE Emilio (AGRI); • HAMELL Michael (ENV); • CARAZO JIMENEZ Luis (ENV); • GLAESER Hermann (AGRI); • HAENEL Leopold (AGRI); • DARGNIES-PEIRCE Cecile (ENTR)

• National experts	• Annette Freibauer CarboEurope Cluster - European Office. Fax: +49 3641 686 710; E-mail: afreib@bgc-jena.mpg.de • Ann Haworth, AEA Technology. E-mail: ann.haworth@aeat.co.uk • Dr Pete Smith, Department of Plant and Soil Science, University of Aberdeen. Fax: +44 (0)1224 272703; E-mail: pete.smith@abdn.ac.uk • Enzo Favoino, Scula Agraria del Parco di Monza. Fax: +39-039-2327676; E-mail: favoinomail@tin.it • Sharon Ellis, Manager of MAFF climate change. Fax: +44 207 238 6700; E-mail: sharon.ellis@maff.gsi.gov.uk • G.J. Monteny, Dutch Institute of Agricultural and Environmental Engineering. Fax: + 33 317 425 670; E-mail: 'g.j.monteny@imag.wag-ur.nl'	• Annette Freibauer CarboEurope Cluster - European Office. Fax: +49 3641 686 710; E-mail: afreib@bgc-jena.mpg.de • Ann Haworth, AEA Technology. E-mail:ann.haworth@aeat.co.uk • Dr Pete Smith, Department of Plant and Soil Science, University of Aberdeen. Fax: +44 (0)1224 272703; E-mail: pete.smith@abdn.ac.uk • Enzo Favoino, Scula Agraria del Parco di Monza. Fax: +39-039-2327676; E-mail: favoinomail@tin.it • Sharon Ellis, Manager of MAFF climate change. Fax: +44 207 238 6700; E-mail: sharon.ellis@maff.gsi.gov.uk • G.J. Monteny, Dutch Institute of Agricultural and Environmental Engineering. Fax: + 33 317 425 670; E-mail: 'g.j.monteny@imag.wag-ur.nl'

	• Ausilio Bauen, Imperial College Centre for Energy. Fax: + 44 (0)2075949332; E-mail: a.bauen@ic.ac.uk • Abigail Fallot, PhD CIRAD-Amis-Ecopol, Fax : 33 1 43 94 73 11; E-mail : fallot@cirad.fr	• Ausilio Bauen, Imperial College Centre for Energy. Fax: + 44 (0)2075949332; E-mail: a.bauen@ic.ac.uk • Abigail Fallot, PhD CIRAD-Amis-Ecopol, Fax : 33 1 43 94 73 11; E-mail : fallot@cirad.fr
• Business representatives	• Jürgen Küsters, Hydro Agri Deutschland GmbH. Fax: +49 2594 7455; E-Mail: Juergen.Kuesters@hydro.com • Pierre Gatel, Copa. Fax: + 32 2/287.27.00; E-Mail: pgatel@agpb.fr • M. Sip de Vries, COPA/COGEGA Fax: + 32 2/287.27.00; E-mail ; s.s.de.vries@hpa.agro.nl • Mr. Prados, ENCA, Email: jprados@ence.es	• Marit Lagreid, Norsk Hydro, Porsgrunn - Norway. E-mail: Marit.Lagreid@hydro.com • Pierre Gatel, Copa. Fax: + 32 2/287.27.00; E-Mail: pgatel@agpb.fr • M. Sip de Vries, COPA/COGEGA Fax: + 32 2/287.27.00; E-mail ; s.s.de.vries@hpa.agro.nl • Mr. Prados, ENCA, Email: jprados@ence.es
• NGO representatives	• Sue Armstrong-Brown, Birdlife Interantional. Fax: +49 1767 683640 E-mail: susan.armstrong-brown@RSPB.org.uk • Nathalie Hufnagl, CEPF. E-mail: CEPF@planetinternet.be	• Sue Armstrong-Brown, Birdlife Interantional. Fax: +49 1767 683640 E-mail: susan.armstrong-brown@RSPB.org.uk • Tiina Rytila-Broere, CEPF. E-mail: CEPF@planetinternet.be

	21.3.01 (Enteric fermentation)	22.3.01 (Manure management)
Chairman Secretary	• Adelmo Moreale, AGRI • Jörg Eggers, AGRI	• Adelmo Moreale, AGRI • Jörg Eggers, AGRI
Commission representatives	• Owen Jones (AGRI A 01) • Herman Glaeser (AGRI D01) • Valery Morard (AGRI F 24) • Matti Vainio (ENV B 02) • Michael Hamell (ENV D 01) • L. Carazo-Jiminez (ENV D 01) • Cecile DARGNIES-PEIRCE (ENTR)	• Herman Glaeser (AGRI D01) • Francois Prevost (AGRI C 02) • Valery Morard (AGRI F 24) • Matti Vainio (ENV B 02) • Michael Hamell (ENV D 01)
National experts	• Ann Haworth, AEA Technology. E-mail: ann.haworth@aeat.co.uk	• Ann Haworth, AEA Technology. E-mail: ann.haworth@aeat.co.uk

	• Frank O'Mara, University College Dublin, Dept. of animal Science, Fax: 353 1 716 1103; E-mail: frank.omara@ucd.ie • Jan Pierre Junay, Research Manager in INRA. Phone: 04 73624054; E-mail: jean-pierre.jouany@clermont.inra.fr • G.J. Monteny, Dutch Institute of Agricultural and Env. Engineering. Fax: + 33 317 425 670; E-mail: 'g.j.monteny@imag.wag-ur.nl' • Heinz-Jürgen Ahlgrimm, Federal Agricultural Research Center in Braunschweig. Fax + 49531 596 363; E-mail: Heinz.Ahlgrimm@fal.de • Sharon Ellis, Manager of MAFF climate change. Fax: +44 207 238 6700; E-mail: sharon.ellis@maff.gsi.gov.uk • Abigail Fallot, PhD CIRAD-Amis-Ecopol, Fax : 33 1 43 94 73 11; E-mail : fallot@cirad.fr	• Frank O'Mara, University College Dublin, Dept. of animal Science, Fax: 353 1 716 1103; E-mail: frank.omara@ucd.ie • Jan Pierre Junay, Research Manager in INRA. Phone: 04 73624054; E-mail: jean-pierre.jouany@clermont.inra.fr • G.J. Monteny, Dutch Institute of Agricultural and Env. Engineering. Fax: + 33 317 425 670; E-mail: 'g.j.monteny@imag.wag-ur.nl' • Heinz-Jürgen Ahlgrimm, Federal Agricultural Research Center in Braunschweig. Fax + 49531 596 363; E-mail: Heinz.Ahlgrimm@fal.de • Jukka Rintala, Professor, Environmental Technology DEng. Fax: +358-14-260 2321; E-mail: jrintala@jyu.fi • Sharon Ellis, Manager of MAFF climate change. Fax: +44 207 238 6700; E-mail: sharon.ellis@maff.gsi.gov.uk • Abigail Fallot, PhD CIRAD-Amis-Ecopol, Fax : 33 1 43 94 73 11; E-mail : fallot@cirad.fr
Business representatives	• M. Sip de Vries, COPA/COGEGA Fax: + 32 2/287.27.00; E-mail ; s.s.de.vries@hpa.agro.nl • Sven Hogfors, COPA, sven.hogfors@lrf.se • Jürgen Küsters, Hydro Agri Deutschland GmbH. Fax: +49 2594 7455; E-Mail: Juergen.Kuesters@hydro.com	• M. Sip de Vries, COPA/COGEGA Fax: + 32 2/287.27.00; E-mail ; s.s.de.vries@hpa.agro.nl • Sven Hogfors, COPA, sven.hogfors@lrf.se
NGO representatives		