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COMMISSION STAFF WORKING DOCUMENT

The role of European agriculture in climate change mitigation

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Executive summary

This Working Document has been prepared as background for the debate on the Common Agricultural Policy (CAP) and climate change in the informal meeting of the Ministers of Agriculture to be held on the 15 September 2009.

The document concentrates on greenhouse gas emissions and trends in agriculture in the EU, and possibilities for reducing them. It also gives an overview of the current instruments of the CAP that facilitate climate change mitigation, examining in particular how the rural development programmes for 2007-2013 contribute to this objective. It is complementary to the recent paper on "Adapting to climate change: the challenge for European agriculture and rural areas" which accompanied the Commission White Paper on adaptation adopted in April 2009.

It concludes with orientations for future CAP actions that could enhance the contribution of EU agriculture to keeping climate change under control.

In the EU agricultural GHG emissions have declined during the past two decades, but without additional efforts this trend is not likely to continue. Appropriate policy instruments need to be maintained and further developed to stimulate an increased uptake of emission reduction measures.

The main conclusions for agriculture and rural development in the EU are the following:

– Climate change is a very serious challenge for agriculture and rural areas. While agriculture's contribution overall to mitigation will be important, but limited, its implications to agriculture itself, especially in terms of adaptation, will be highly significant.

– There is unused potential for cost-effective mitigation activities in EU agriculture. The viability of farms is a necessary basis for climate-friendly farming practices to become more wide-spread, while there is also a need to improve awareness and technical knowledge among farmers on climate change mitigation so that, in their daily decisions, they can build such knowledge into their economic decision making.

– Climate change mitigation in agriculture should be pursued as part of an integrated approach to sustainable agriculture to limit conflicts with other economic, environmental and social objectives, whilst ensuring a positive contribution to climate mitigation at the global level. Synergies between mitigation and adaptation are particularly important. The mitigation potential of agriculture in Europe can be best realized by maintaining high productivity combined with sustainability.

– Given the significant mitigation potential related to agricultural soils, the possibilities to develop stronger incentives for soil protection and management measures and for the protection of carbon-rich soils (e.g., peatland, wetlands, and grasslands) should be examined. The Commission proposal for a Soil Framework Directive (COM(2006) 232) and the revision of the accounting rules for land use, land use change and forestry under the UNFCCC and its Kyoto Protocol will be important in this regard.

– Rural development offers a wide range of possibilities to support farming practices and investments that can contribute to climate change mitigation efforts, and additionally bring adaptation benefits. However, the Member States have not utilised these possibilities fully in their programmes for 2007-2013. The Commission will examine how to ensure that this Community priority will be better reflected in the programmes, and reflect further on how to increase the mitigation potential of rural development for the next financial period.

– While mitigation actions should not be delayed, further research on emission-reduction options in the agricultural sector as well as their inter-relationship with other societal objectives should be strongly encouraged, focusing in particular on innovation in sustainable and low-gases agricultural production methods and animal and plant breeding. Sharing experiences between the Member States in addressing climate concerns can help disseminating good practices and practical application of new knowledge.

– Consumer information on the climate implications of their food consumption patterns can help to re-orientate consumption and production towards more climate friendly choices. However, it is also necessary to ensure coherence and reliability of labelling schemes, taking into account the complexity of the food chain and the need to convey clear messages to consumers.

1. INTRODUCTION

Climate change, as one of the most serious challenges facing the world, has already modified the context for agriculture as well as policy making, and will continue to do so. Emissions of greenhouse gases (GHG) over the next ten to twenty years will largely determine the trajectory of temperature increase that the world will be experiencing by the end of the century.

To face this compelling reality, the EU has agreed a climate change and energy package, which puts in place measures to achieve the EU target of curbing emissions by at least 20% below 1990 levels by 2020. As part of this commitment, a reduction of 10% in 2005-2020 has been agreed for the sectors not covered by the Emissions Trading System[1]. It would be difficult to achieve this target and wider climate objectives, such as limiting temperature rise to maximum 2°C beyond pre-industrial level, without additional efforts on reducing agricultural emissions.

At the same time, EU agriculture will need to adapt to the expected climatic changes which will have serious consequences for the availability of water resources, for the spread of pests and diseases and the quality of soils, leading to significant changes in the conditions for agriculture and livestock production.

The Commission has recently issued a White Paper presenting an EU framework for adaptation and a specific working document on adaptation of agriculture to climate change[2]. The latter outlines some no-regret options to foster adaptation and the implications for the future Common Agricultural Policy (CAP).

The purpose of this paper is to contribute to the informal ministerial meeting dedicated to climate change and agriculture in the EU, to be organised by the Swedish Presidency in September 2009. It complements the previous working document on adaptation by exploring what agriculture is doing to limit GHG emissions and what are the possibilities for the sector and for EU agricultural policy to further contribute to bringing climate change under control.

2. GREENHOUSE GAS EMISSIONS AND TRENDS IN AGRICULTURE

Emissions from agriculture and agricultural land use

All EU Member States report their GHG emissions annually according to a common UNFCCC reporting framework. For agriculture, the inventory includes methane (CH_4) and nitrous oxide emissions (N_2O). Carbon dioxide (CO_2) emissions and removals from agricultural soils are reported under the land use, land use change and forestry (LULUCF) category.

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[1] Decision No 406/2009/EC of the European parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020.

[2] COM(2009) 147/4, Adapting to climate change: Towards a European framework for action, and SEC(2009) 417, Adapting to climate change: the challenge for European agriculture and rural areas, of 1.4.2009.

At overall EU level, emissions reported in the agriculture sector are 462 million tonnes of CO_2-equivalent of greenhouse gases in 2007. This represents 9.2 % of total EU-27 emissions (against 11 % in 1990). At global level agricultural emissions account for almost 14%. Agriculture is the most important source of two powerful gases, nitrous oxide (N_2O) and methane (CH_4), which account for around 5 % and 4.2 % of total European emissions respectively (see Annex 1).

In addition, in 2007, net emissions from agricultural land use[3] were 57 million tonnes of CO_2. These comprise croplands, which are net sources, and emitted 70 million tonnes CO_2 and grasslands, which are net sinks, and removed 13 million tonnes CO_2.

Unlike other sectors, human-induced emissions in agriculture have a high degree of uncertainty as farming activities are very diverse and involve a complex and wide range of biological processes which naturally emit GHG.

In addition, agricultural activities also release carbon dioxide (CO_2) from fossil fuel use in buildings, equipment and machinery for field operations, which account for around 1% of CO_2 emissions of all sectors. Following the UNFCCC reporting scheme these emissions are not accounted in the 'agriculture' category but are included in the 'energy' inventory. Further agriculture-related emissions, such as those from the manufacturing of fertilisers and animal feed, are included in the inventory on industrial processes.

Behind this overall picture, there are considerable variations in the national situations in the EU regarding the absolute levels of emissions, their main sources, the share of agriculture in total GHG (between 2% and 26%) and in the recent and projected trends.

Trends

EU-27 agricultural emissions of *methane* and *nitrous oxide* declined by 20.2 % in the period 1990-2007. Large reductions occurred in the greatest sources of emissions, nitrous oxide from agricultural soils and methane emissions from enteric fermentation by cattle, which both fell by about 21 %. This trend contrasts to the global situation where farming emissions rose by nearly 17 %, mainly due to increases in developing countries. The global situation is however outside the scope of this paper.

The downward trend in these emissions is the result of several factors: increases in productivity and decline in cattle numbers, improvement of farm management practices, developments and implementation in agricultural and environmental policies. It has also been influenced by the adjustments of agricultural production in the new Member States following the change in the political and economic framework after 1990. Methane emissions fell primarily as a result of a significant drop in cattle numbers by about 25% in 1990-2006 following an increase in the animal productivity (milk and meat) and the related improvement in the efficiency of feed use. Nitrous oxide emissions from soils diminished mainly due to reduced use of organic and mineral nitrogen fertilisers.

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[3] Cropland and Grassland categories in the National Greenhouse Gas Inventories to the United Nations Framework Convention on Climate Change.

Methane and nitrous oxide emissions from agriculture in the EU are projected to decrease further, by 2 % by 2010, due to the continuing effects of the main driving factors and additional legislation within the energy and climate change package (see section 4 and Annex 1).

Recent trends have been partly driven by successive reforms of the CAP since 1992 that have resulted in a shift from production-based support to direct area payments (see section 5.1 and annex 3). Equally important is the progress made in the implementation of EU environmental legislation, in particular the Nitrates Directive, which limits some agricultural practices including the use of fertilisers on land to protect and improve water quality.

Net *CO_2 emissions from agricultural soils* decreased by 20.8 % in the period of 1990-2007. While removals by grasslands remained fairly constant, emissions from cropland have significantly decreased. Main drivers for this trend are the overall reduction of the cropland surface in the new Member States, the introduction of obligatory set aside, and increased protection of permanent grasslands, which has limited the conversion of grassland to cropland.

Generally, in the same period, agricultural output increased by about 12 % in EU-27. Nevertheless, the trade balance of beef is showing an increasing deficit over recent years[4], which means that some of the associated emissions have occurred elsewhere.

3. CLIMATE CHANGE MITIGATION POTENTIAL IN THE EU

Agriculture has further possibilities to reduce its influence on climate change by reducing the emissions of methane, nitrous oxide and carbon dioxide released by farming activities and by maintaining and sequestering carbon in farmland soils. Agriculture also provides an indirect contribution to emission reductions in other sectors through the supply of biomass for the production of bioenergy and renewable materials.

3.1 Reducing emissions from farming activities (methane and nitrous oxide)

The reduction of GHG emissions from farming activities is a challenge for agriculture as, globally, the sector is also called upon to increase production in order to keep pace with growing global food and energy demand. Agriculture should continue to contribute to the global food balance while increasing its overall environmental performance, including reducing its impact on the atmosphere and the climate.

Unlike other businesses, agriculture is a biological process inherently linked to GHG emissions and removals from natural systems (plants, animals, soils, agricultural by-products). When evaluating the possibilities of curbing

[4] See figures 5 and 10 in Annex 1.

emissions, account has to be taken of the limits that these natural processes set for the reduction potential[5].

Optimizing practices

There are a number of farm management options that have the potential to reduce methane and nitrous oxide emissions below current levels. These include:

- *Fertiliser and agricultural input use:*
  - Optimisation of mineral and organic nitrogen application;
  - Overall reduction of external inputs (e.g. in organic farming), which also contributes to a reduction of emissions from the usually very GHG-intensive manufacturing of fertilisers and other chemical products;
  - Use of precision farming;
- *Livestock management:*
  - Improvements in the nutrition patterns of livestock, as diet and the level of food intake influence methane releases from ruminants and manure;
  - Breeding and technical solutions (e.g. additives) to control methane from digestion processes of cattle;
  - Extensive forms of pasture management in livestock rearing, which is also beneficial for landscape conservation and bio-diversity;
- *Manure management:*
  - Improved manure storage (e.g. appropriate installations for different types of animal manure and slurry) and application (e.g. immediate incorporation into soils, better accounting of nitrogen content);
  - Processing of animal waste in anaerobic digestion plants for the production of biogas; this has been identified as one of the most promising measures and is highly cost-effective in regions with high animal densities and volumes of slurry and manure;

These technical and management options vary in cost-effectiveness and practicality, and all of them may not be compatible with each other. Some are already widely practiced and have shown positive results over the last decade

[5] Emissions inventories need to be refined so changes in management practices are more accurately reflected in the agricultural accounts, which are mainly driven by activity data such as surface and number of animals.

in a large part of European agriculture, such as improved storage of manure and the accounting of its nitrogen content when applied to the fields. Others, such as reduction of methane from enteric fermentation, still require substantial research efforts and practical experience before they could become general practice. Some of the most relevant measures, such as those linked to the nitrogen cycle, are closely related to measures aiming at controlling nitrates and ammonia emissions and thus produce a range of substantive environmental benefits.

Mitigation potential

The costs and benefits of agricultural mitigation options are diverse. The differences are influenced by a number of factors such as farm characteristics (size, location, yields, level of inputs), climatic and environmental conditions (land and soil characteristics, water availability), the degree to which mitigation measures compete with traditional agricultural practices and profitability (e.g., extensive grazing systems or fertilization), and the incentives in place such as financial support.

Because there are large regional differences in mitigation potential and in the costs and benefits of mitigation options, it is necessary to tailor policy measures to site and farming-specific conditions.

According to literature[6], better nitrogen fertiliser management is the measure with the largest positive effect on nitrous oxide emissions. Across the EU, nitrogen use has declined by over 25% in the last twenty years (by 15% in the EU-15)[7].

Efficiency in the use of nitrogen has increased from 30% in the mid-eighties to its current average level of 60%[8]. There may still be scope to further optimize nitrogen use and avoiding its leaching to the water and emissions into the atmosphere including in the processing of manure, while achieving better economic performance. For EU-27 the consumption of mineral fertilisers is expected to increase by about 4% in the next ten years, while in the EU-15the downward trend will continue[9].

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6 EU-funded projects MEACAP (2007) and PICCMAT (2008) have assessed the mitigation potential of a range of individual measures across Europe.

7 EEA databases, based on Member States' submissions of national emissions inventories to the Community monitoring mechanism. In the mean time, the utilised agricultural area has only slightly decreased and this has mainly concerned permanent grasslands, and to a lesser extent permanent crops (EU-15 data).

8 J. Lammell, Presentation given at the Conference "Agriculture, Fertilizers and Climate Change", February 2009 (http://www.efma.org/EPUB/easnet.dll/ExecReq/Page?eas:template_im=000BC2&eas:dat_im=000C22). Nitrogen (N) use efficiency is the relationship between N removed with harvested crops and N application.

9 European Fertilizer Manufacturers Association - Forecast of food, farming and fertiliser use in the European Union 2008-2018.

Improved manure and slurry storage, processing and application techniques are technically feasible measures for reducing methane and nitrous oxide releases (see Annex 3).

3.2 Reducing carbon losses from and enhancing carbon contents of soils

Agriculture and forestry are the main economic sectors that can remove CO_2 from the atmosphere and store it in vegetation (perennial crops, trees, hedgerows) and soils. Apart from the oceans, soils are the most important reservoir of carbon in the terrestrial biosphere and contain three times the amount to be found in vegetation.

It is estimated that in the EU soils contain 73-79 Gt of organic carbon[10] (equivalent to 275 Gt CO_2), or nearly ten-fold the size of European forest biomass. This represents more than fifty times the annual GHG emissions from the EU.

Fluxes in soil carbon have potentially a significant impact on climate change while climate change as such is likely to lead to higher losses of soil carbon in the future[11]. While most grasslands tend to be net carbon sinks, significant emissions result in particular from conversion of grassland into arable land and from the cropping of soils with high organic carbon content, such as peatlands. Peatlands are carbon "hot spots", which maintain their significant carbon stocks only under wet conditions and turn into sources if drained.

Maintaining and optimizing carbon levels

Experts agree that maintaining, restoring and expanding the current carbon stocks in soils is an essential and cost-effective contribution to combating climate change. However, there are difficulties and uncertainties associated with the implementation of carbon sequestration measures and the measurement of their outcomes, such as the need for a long period of continuous management changes and sink saturation. On the other hand, there are important co-benefits such as enhancing food supply and the contribution to several other soil functions, including improved soil fertility, increased water retention capacity, as well as ecosystem functions.

There is a large unused mitigation potential in agricultural soils, which however depends on many factors such as soil types, climatic conditions and land use[12]. A wide range of farming practices and land use changes are

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10 These figures result from extrapolations based on pedo-transfer rules and not from direct measurements of soil organic carbon across the EU. Report "Review of existing information on the interrelations between soil and climate change (CLIMSOIL)" (http://ec.europa.eu/environment/soil/review_en.htm).

11 SOCO (Sustainable Agriculture and Soil Conservation) project, carried out by Commission services, has assessed a range of soil conservation practices also from the perspective of keeping organic matter levels.

12 Report on the Conference "Climate change - can soil make a difference?", Brussels, 12.6.2008 (http://ec.europa.eu/environment/soil/conf_en.htm), and IPCC fourth assessment report.

generally recognized as enhancing carbon sequestration and playing an important role in improving the long-term quality and fertility of soils, such as:

- *Soil management:*
  - conservation agriculture (reduced or no tillage) which avoids or reduces soil disturbance, while providing significant energy savings;
  - maintenance of soil cover throughout the year, use of catch crops, incorporation of organic material in a sustainable manner (animal manure, sewage sludge, cereal straw, compost), green cover of bare soil in permanent cropland;
  - protection of organic matter in the soil, especially in carbon-rich soils (peatlands, wetlands, and grasslands);
  - restoration of drained peatlands and wetlands;
  - restoration of carbon in degraded soils at risk of erosion or desertification.
- *Land management:*
  - diversified crop rotations, including leguminous crops;
  - maintenance of set-aside areas and plantation of woody plants, such as hedgerows;
  - maintenance and protection of permanent pastures and conversion of arable land to permanent grassland;
  - use of crops adapted to wet soil conditions (e.g. reeds) as an alternative to wetland drainage;
  - organic farming;
  - afforestation, as wood holds considerably more carbon than most agricultural crops on a more permanent basis and may also enhance soil carbon.

  Maintaining, and where possible increasing, soil carbon levels is a major challenge for agriculture in the coming years. It will require establishing accurate baseline information, a better understanding of the interactions between ongoing climatic change and soil carbon fluxes and targeting policies and measures to where they are most cost-effective. The

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The soil type, properties and climatic conditions mostly explain the initial carbon content of soils while the land management is a crucial factor for explaining carbon dynamics. While carbon-rich areas have a higher risk of carbon loss, areas with low levels can have a higher rate of carbon sequestration.

Commission proposal for a Soil Framework Directive[13], currently under institutional discussion, is highly relevant in this respect.

Mitigation potential

The level of implementation and mitigation potential of the soil and land management options varies considerably, but overall they have the advantage of being readily available and relatively low-cost, not requiring very advanced technology (see Annex 3).

While the mitigation potential of individual measures may be limited, the combined effect of several practices can make a significant contribution to mitigation. At EU-15 level, it has been estimated that the technical potential for reduction through optimised carbon management of agricultural soils is between 60-70 Mt CO_2 per year.

Agricultural soils are very diverse across the EU, and the local effects of a change in management practices can vary considerably from one location to the other. Soil related measures have to be fine-tuned to the local conditions. Furthermore, it is uncertain how rising temperatures will affect future carbon storage capacity of soils, although it is expected that further warming will further deplete soil organic matter. These negative feed-back mechanisms will have to be examined further.

However, some general points on the effectiveness of soil and land management options can be made:

- Regarding cropland management options, cultivation methods such as zero (and reduced) tillage, have the highest mitigation potential, followed by adding legumes to crop rotations, maintaining the soil with plant cover over the whole year, incorporation of residue in the soil and diversified crop rotations[14]. In general, reduced and no-tillage methods require substantial changes in practices with an initial cost increase, but may be cost saving in the medium term and become self-financing in some areas.

- Organic agriculture is a farming system with high potential for mitigation through its efficient nutrient cycles and soil management, such as the use of green and animal manure, diversified crop rotations, use of cover crops and composting, which leads to soils that are typically enriched in carbon and soil biodiversity.

- Substantive land use changes, such as restoration of peatland or afforestation, involve a relatively high cost per hectare but offer high emission savings. In terms of cost per unit of emissions saving land use changes are among the cheapest mitigation options, and may, in addition, contribute to biodiversity conservation.

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13 COM(2006) 232 of 22.9.2006.

14 PICCMAT project (2008).

- Preserving existing carbon hotspot areas, i.e. land with high carbon stocks, such as grasslands, peatland and wetlands is of particular importance as in such areas potential carbon losses due to disturbance of the land are the highest.

It is important to consider that certain measures may lead to a reduced per-hectare production, which will contribute to lower agricultural production in the EU as a whole. This can lead to a displacement of emissions outside the EU (carbon leakage). The measures and contribution of agriculture to mitigation should be considered not only in terms of the reduction of GHG emissions in the EU, but indeed within the wider perspective of global GHG emissions.

Many of the above measures are already required or encouraged by the CAP through cross-compliance (e.g. requirements on soil cover and permanent pastures), and by agri-environment schemes. Some, such as cultivation methods still need further research to improve their economic and environmental effects, as well as training and advice to be widely adopted by farmers.

3.3 Saving energy and contributing to renewable energies

Energy efficiency

Agriculture can contribute to reducing CO_2 emissions also by savings in its own energy use (equipment, buildings, machinery for field operations), and by producing and using renewable energies. This will at the same time make agricultural systems economically more viable and resilient as energy (oil, gas and electricity) is an important part of production costs. On average, in 2006, fuel and energy accounted between 13-20% of the operating costs per hectare in specialist cereals farms[15].

The fluctuations of energy prices and the rising costs have significant consequences for EU agricultural businesses. Energy efficiency and diversification of supply is becoming an increasingly important objective. Some Member States have already adopted measures (energy audits, taxes) for improving energy performance of farm equipment, buildings and greenhouses.

For example better insulation of buildings, and conservation agriculture offer potential for energy savings on farms. Reductions of energy-related CO_2 emissions in agriculture can also be achieved by substituting fossil fuels, for example by increased use of solar energy, or by on-farm fuel production. However, if for example crop and wood residues are massively used to generate power in stead of integrating them in the soil, the impacts on soil carbon content should be fully considered.

Biomass potential for bioenergy

[15] EU cereal farms economics, Farm Accountancy Data Network Report 2008.

Moving towards a low-carbon economy through inter alia the development of renewable energy and energy efficiency is a key priority for the EU. The new Directive on the promotion of the use of energy from renewable sources[16] sets out national renewable energy targets that result in an overall EU target of at least 20% share of renewable energy in total energy consumption by 2020, and at least 10% of renewable energy in transport to be achieved by each Member State. These targets should contribute to limiting global warming to 2°C while also decreasing the EU's dependence on foreign fossil fuel sources.

It can be estimated that current biomass-based energy, which accounts for two thirds of the total renewable energies, provides about 150 million tonnes of CO_2 equivalent of GHG savings, without taking into account emissions caused by possible indirect land use change related to biomass production. Currently, most bioenergy comes from forest resources. However, agricultural biomass, such as manure and crop residues, has unused potential to supply bioenergy while being beneficial for the agricultural sector. The production of biomass for energy is increasingly important for agricultural holdings and local communities in rural areas and also favours a more balanced distribution of agricultural activities across the EU. Sustainable biomass-based energies, such as biogas from animal by-products, can provide significant mitigation potential.

However, when crops dedicated for bioenergy are produced on agricultural land, they can displace food production to countries outside the EU, leading to emissions there from land use change, such as deforestation. The Commission is currently considering how emissions caused by indirect land use change could be taken into account in the methodology for estimating emission savings from liquid biofuels[17]. It is also considering whether and which sustainability criteria should be introduced for all types of biomass.

Rural development funds are used in all Member States to support the development of biomass and renewable energies more widely (section 5.2). In their National Renewable Energy Action Plans Member States should identify further possibilities to develop and use agricultural and forestry biomass, while respecting sustainability criteria.

Potential for further emission reductions is also offered by the gradually increasing use of agricultural resources for industrial production, such as agro-materials, bioplastics and biochemicals. Numerous studies show that products including components from vegetable origin provide many advantages for the environment and human health.

3.4 Implementation challenges

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16 Directive 2009/28/EC of the European parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

17 Article 17 and Annex V of Directive 2009/28/EC.

The development of EU agriculture during the past decades has been characterized by a steady increase in productivity, in both crop and animal production, based on advances in plant and animal breeding, agricultural technology and better farm management. This has enabled a reduction in total greenhouse gas emissions while agricultural output has grown. Further improvements in productivity are possible based on continuous research in plant and animal varieties, progress in farming techniques, and the development of new fertilizers.

However, the mitigation potential linked to further productivity increases in the EU is likely to be limited and therefore the past declining trend in emissions can not be expected to continue indefinitely. For instance, there are limits to how much nitrogen fertilizer application rates can be reduced without reducing crop yields and thereby undermining EU agricultural output. However, new technological developments could influence this situation.

It is also important to bear in mind that some climate change mitigation measures may have trade-offs, which need to be managed by appropriately designing mitigation measures, and by assessing their local suitability. For example, under certain conditions, afforestation of high nature value land can damage biodiversity, and zero tillage regimes can result in increased herbicide use. Moreover, mitigation measures must be considered in a holistic manner as their effectiveness may be reduced because of side effects which themselves produce greenhouse gases. Examples include afforestation of certain carbon-rich soils, which may lead to a decline in soil carbon and carbon sequestration under zero tillage regimes, which may be partially offset by increased nitrous oxide emissions.

Reducing EU agricultural production – is it really a solution?

In the absence of an international agreement measures that moderate emissions by reducing the EU agricultural production capacity are not likely to achieve the emission reductions needed at global level. Agriculture is among the economic sectors, which are prone to the potential displacement of production, and of the associated emissions, to countries outside the EU. Following an international agreement, this risk will be assessed by the Commission as required by Decision No 406/2009/EC on effort sharing[18].

At the same time agricultural production in the EU, which has already reached high levels of productivity in many regions, should not be intensified beyond environmental sustainability levels and should, on the contrary, lead the way towards a globally more sustainable approach to farming. Farm land has an increasingly recognised wider role than just agricultural production, especially as regards water protection, biodiversity, soil and landscape. The maintenance of extensive and low-input forms of production, such as organic farming or extensive livestock production systems should be encouraged as they can

[18] Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020. OJ L 140/136 of 5.6.2009.

contribute to the rural economy, to the protection of the environment and landscapes and to the quality of life in many European regions.

Limitations

Existing technical mitigation measures in agricultural activities are not yet fully exploited. Important barriers to their uptake include:

– Limited awareness and knowledge on the part of farmers together with the complexity of dealing with gaseous emissions, and the reluctance to change established production patterns. In many cases, farmers' awareness of their farm's performance could be improved regarding energy use, GHG emissions and other environmental aspects. In the EU, the large number of farms (14.5 million) and their small average size (about 12 hectares) raises particular challenges to communicate, implement and monitor mitigation measures. The Commission will reflect on how to facilitate knowledge dissemination and how rural development could be used to encourage an on farm approach to mitigation and adaptation.

– Economic barriers to implementation can be significant for options that require costly investments and for practices which are likely to reduce profitability. The economic environment, mainly prices of agricultural products and inputs, largely determine the extent to which such mitigation options will be adopted.

4. CLIMATE POLICY DEVELOPMENTS IN THE EU

Decision No 406/2009/EC on effort sharing has set out an overall GHG reduction objective of 10% over the period 2005-2020 for the sectors that are not covered by the Emission Trading System (ETS), including emissions from agriculture, but excluding CO_2 emissions from relevant LULUCF categories.

The EU target has been shared among Member States and varies between +20% (Bulgaria) and -20% (Denmark, Ireland). These targets are not sector-specific and policies and measures in different sectors (industry, electricity generation, transport, buildings, waste etc.) can be used to leverage emission reduction. In addition, important flexibility has been built into the Decision, between sectors, between Member States and through the use of the Kyoto flexible mechanisms[19]. In this way, each Member State has freedom to achieve those targets in a cost-effective way and taking into account its own preferences.

Nevertheless, achieving the targets will require stepping up the contribution of agriculture to mitigation efforts, particularly where farming emissions have a relatively high share in the national economies.

[19] These mechanisms (Clean Development Mechanism and Joint Implementation) enable developed countries to partially fulfil their mitigation commitments under the Kyoto Protocol by emission reductions and removals in other countries.

While the EU does not exclude expanding the coverage of the ETS to other sectors in the future, agriculture is currently not included. This is due to the characteristics of the sector such as the high level of small emitters, difficulties to verify emissions and the lack of optimised and standardized EU-wide monitoring methods for soil carbon and related baseline inventories. Operational solutions are to be developed to overcome these barriers. However, the EU-ETS legislation includes an "opt-in" provision, which allows the Member States to request the inclusion of additional sectors or activities into the cap-and-trade system of emissions allowances. This opt-in possibility has so far not been used for agricultural activities, due to among others, the above technical difficulties.

The EU-ETS also provides for domestic emission-reduction projects outside the ETS sectors under harmonised rules. However, credits from projects related to carbon management on agricultural and forest areas are not yet allowed as they would require reliable monitoring, reporting and verification rules, which are not yet available.

The current accounting rules for emissions and removals resulting from land use (including agricultural soils), land use change (such as conversion from grassland to arable land) or forests are currently being examined in the context of the international negotiations under UNFCCC for the period after 2012. One important feature of the current accounting rules for LULUCF is that accounting for some LULUCF activities is obligatory (afforestation, reforestation and deforestation) while accounting for other LULUCF activities is optional (revegetation, forest management, cropland management and grazing land management).

In the context of the post-2012 UNFCCC negotiations, the EU is seeking a LULUCF accounting system that encourages national policies to deliver the mitigation potential of the sector as well as promotes the environmental integrity of the climate regime and an effective contribution of agriculture and forestry to the climate change policy frameworks, in terms of reducing emissions, protecting and enhancing sinks and carbon stocks as well as sustainable forest and land management and the sustainable supply of bioenergy and wood material.

In the working paper accompanying the Communication "Towards a comprehensive climate change agreement in Copenhagen"[20], the Commission has noted the need for harmonising the approach to account for LULUCF activities across all developed countries, ensuring that no sector can be left out that poses a risk of releasing the enormous quantities of GHG stored in soils and biomass, into the atmosphere. It is also stated that the current set of rules for the LULUCF sector does not provide for consistent incentives for industrialised countries to develop climate-friendly policies for land use, land use change and forestry, as the rules often do not encourage real additional action to mitigate GHG emissions and increase GHG removals.

The Commission will assess how emissions and removals from LULUCF could be taken into account in the Community commitment. The outcome of the international negotiations will influence the effectiveness and potential of LULUCF to contribute

[20] Commission Staff Working Document SEC(2009)101 accompanying COM(2009) 39 – Chapter 3.2 p 28 – 29.

to climate change mitigation and the way in which it can be incorporated in the Community reduction commitment.

5. THE CAP ADDRESSING CLIMATE CHANGE

5.1 The CAP – a health checked and evolving policy

The CAP is increasingly designed to meet a wide range of objectives. Its progressive orientation since the 1992 reform, most recently reinforced by the Health Check, is marked by a gradual shift of financial support linked to production towards decoupled direct aid, by the strengthening of rural development policy, and progress in the integration of environmental considerations including climate change.

Alongside to the developments in Community environmental policy, the CAP has been reformed by removing policy instruments that may have created incentives with negative consequences for environmental protection[21] and by increasingly offering measures and funding sources for a positive contribution to the environmental performance of agriculture. Annex 2.1 presents an overview of main recent reforms of the income and market support measures as well rural development and shows how this policy framework contributes to the mitigation objective.

The recent "Health Check" reform represents a further step in the direction of sustainable agriculture with specific emphasis on climate change mitigation and adaptation as well as water and biodiversity protection, for which further rural development funding has been agreed. However, the loss of obligatory set aside is likely to have the effect of reducing carbon levels in soils.

The challenge and opportunity for the EU and its Member States in the period up to the end of 2013 is to make the best possible use of the CAP tools and funds available to support actions that reduce the impact of agricultural production on climate. The Commission is encouraging Member States to further develop mitigation measures when modifying their rural development programmes.

5.2 Contribution of rural development to climate objectives

A review of the extent to which climate change is addressed in the national and regional Rural Development Programmes (RDP) for 2007-2013 has been conducted across the EU. The survey covered activities aimed at reducing GHG emissions (mitigation), enhancing carbon-conscious land and soil management, and contributing to the use and production of renewable energies in farms, agricultural holdings and rural areas[22]. Annex 2.2 presents an

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21 E.g. support for livestock production on a per head basis, which creates an incentive to increase and maintain high livestock numbers.

22 The survey has been performed by the contact point working for the EU Rural Development Network on the basis of guidelines provided by the Commission. The survey and its assessment are qualitative and based on expert judgement. No quantitative information about indicative budget expenditure is available on the level of "sub-measures". Adaptation measures were also covered in the review but the presentation in this working document is limited to how rural development delivers for mitigation and

overview of the possibilities of the rural development framework to support mitigation actions and a summary of the survey results.

The role of climate change in the rural development strategies

Climate change has been increasingly addressed in the rural development strategies and the baseline analysis for most RDPs in all Member States, shows that the challenge has been well recognised. Mitigation features as an important objective in about half of the RD strategies, and renewable energy in about one third of them.

Programming of climate-related measures in RDPs

A substantial number of actions with potential for delivering on climate change have been programmed by the Member States and regions. However, the programming of specific climate-related measures is often less well developed than the extent to which the problem has been discussed in the strategy and baseline analysis of the programmes. Only a limited number of programmes have substantially targeted measures to climate change. One third of them plan to support climate-related actions, however, often without identifying the important 'win-win' opportunities that these actions can provide both for direct economic benefits to the agricultural and rural communities while also helping to reduce emissions.

Even if it is not possible to establish a correlation between the programming of mitigation actions and the share of agriculture in national emissions, several Member States, which have relatively high agricultural emissions have a strong focus on mitigation in their national and regional programmes.

There are significant differences of emphasis between the different RDPs. While some national and regional programmes focus on mitigation objectives on farms, others give a more prominent role to supporting production and use of renewable energies; for example, promoting renewable energy is more common in the forest-rich countries.

EU-12 countries give a generally higher weight to the development of renewable energy than EU-15, which in some cases can be explained by a relatively low current share of renewable energy. In the Member States having a large number of regional RDPs, such as Germany, Italy and Spain, there are substantial differences between the regions in the definition of strategic objectives and climate change actions supported.

All three axes of the Rural Development Regulation provide possibilities to help in curbing methane and nitrous oxide emissions, reducing CO_2 emissions from energy use, and strengthening farm and local production and use of renewable energy. In most RDPs emission reduction activities are predominantly or exclusively supported by two measures: farm modernisation and agri-environment. This reflects the fact that effective mitigation can be

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renewable energies. The full report on the review will be made available on the Europa website in the near future.

achieved not only by supporting investments and technical modernisation of farms but also with farming practices with high environmental and climate benefits. Regarding renewable energy projects, most RDPs use a wider range of measures, within axis 1 and 3.

The following are the **most typical measures relevant for climate change mitigation** frequently appearing in the RDPs:

- Support for **farm modernisation** is often targeted at climate objectives, in particular the improvement of energy efficiency of farm buildings.
  - Support for **investments delivering energy savings** (e.g., new or upgraded installationsgreenhouses) and allowing agricultural holdings to develop small scale renewable energy capacity (mainly biogas from animal waste, but also use of vegetable oil and biodiesel for machinery, as well as solar and wood biomass installations), receive considerable attention in many RDPs. Energy efficiency is supported in almost three-quarters of the programmes and is targeted at climate change in almost one-third of them.
  - A large number of RDPs also support **manure facilities** (storage, processing) and improved manure management; a quarter of them target these actions to better controlling GHG emissions (methane) from livestock farms.
- The processing **of agricultural and forest biomass for bio-energy** is included in most RDP, and in almost half of them it is a targeted on climate change. There is also often a focus on promoting the use of agricultural and organic by-products for bio-energy. However, support for the cultivation of specific energy crops is available only in a few RDPs. The support for renewable energy is closely related to the national and regional resources available in the agricultural and forest sectors.
- **Agri-environment** is the only measure the inclusion of which in RDPs is compulsory. It is also by far the most important in financial terms (representing more than 51% of EAFRD funds under axis 2)[23]. While climate objectives are often not explicit, most of the actions supported are beneficial for the overall environment including some for mitigation.
  - The programming of actions to improve **efficiency of fertiliser use** concerns two thirds of all RDP.
  - **Soil management** also features as an important priority, with almost 90% of the programmes including such actions, of which 40% are targeted at helping to increase the amount of organic carbon retained in soils. However, there is no assessment in place to measure the effectiveness of these measures in terms of maintaining or increasing carbon content.

[23] European Commission (2008)- The EU rural development policy: facing the challenges.

- **Organic farming** is the most widely supported action, being included in almost all RDP; more than half report that organic farming contributes to mitigation.

- Many RDPs mention **extensive management of livestock** (e.g., reducing stocking densities) **and pastures** as actions contributing to GHG reduction as well as benefiting the whole environment. In some cases, support is offered for continued management of low-profitability pastures, conversion to grasslands, and permanent set-aside to protect the rural environment as well as to maintain carbon-rich areas, especially grasslands.

► **Afforestation** on **agricultural** land is a very common measure in many RDP and it appears to be predominantly targeted at climate objectives in half of the programmes[24].

► While support to farm physical infrastructure and farm management are the two main pillars for mitigation on which most RDPs draw, there are various other measures, in particular in axis 1, also used in some programmes for supporting mitigation. Mitigation and bio-energies can also be supported by measures oriented to **technology, product development, and co-operation**. Measures supporting adding value to agricultural and forestry products or cooperation for the development of new products processes and technologies, often aim at fostering bioenergy.

► **Training and communication** actions are frequently programmed and can be highly relevant to improving awareness and attitudes of farmers and other rural actors towards climate-conscious management. Capacity-building measures rarely focus on climate change but in many RDPs there are specifically designed actions for improving the overall environmental planning of agricultural activities. There is limited use of rural development funds to setting up farm advisory services.

► Axis 3 measures have considerable potential for contributing to efforts against climate change by supporting **diversification** of farms into bio-energy activities and local investment in renewable energies. In a number of RDPs, mainly in EU-15, axis 3 measures are relatively well oriented to climate objectives, although the picture varies both between and within Member States. The production or use of renewable energy is most commonly supported by the measure "diversification into non-agricultural activities" and, to a lesser extent, by "basic services for the economy and rural population". While some RDPs strongly emphasize agricultural and forest biomass processing (biogas, biofuels), others envisage support for a wider range of energy installations.

Overall conclusions, implementation challenges and future prospects

[24] Other forestry measures have not been assessed in detail, as the survey has focus on agriculture.

Given the broad range of relevant actions which can be supported, RDPs contribute to realizing national and EU commitments to reduce GHG emissions. They also assist in the development of agricultural and rural sectors that are well-adapted to the challenges of climate change, and in the diversification of energy resources and increased use of renewable energies.

However, the analysis has shown that current RDPs do not fully use the potential to address climate change. Many programmes do not identify the 'win-win' opportunities of contributing to climate change mitigation while providing both environmental and economic benefits to the agricultural and rural communities[25]. Furthermore, measures may not achieve their optimal effect, as their application is generally confined to the farm-level without being integrated into a comprehensive (national or regional) mitigation strategy in the agricultural sector.

The extent to which rural development policy effectively delivers on climate change depends on the degree to which Member States, regions and farmers and rural actors make use of existing measures on offer, and on the effectiveness of the chosen actions. In particular, the most complex and costly activities may need to be accompanied by training and technical advice to attract the interest of farmers and other rural actors, and to ensure effective implementation.

In the light of EU and international climate policy development (chapter 4) and in particular the agreement that could be reached on LULUCF, the possibilities to strengthen and measure the contribution of RDPs to the climate change challenge will be examined. This could imply a stronger focus in the strategies on regional climate conditions, considering higher support rates for integrated farm management plans that provide multiple benefits in terms of GHG emissions and environmental efficiency, a more systematic inclusion of climate-relevant actions in all measures with more focus on synergies, improved monitoring of their effectiveness vis-à-vis climate objectives and possibilities for implementation of actions on a territorial scale.

6. THE ROLE OF CONSUMERS AND FOOD LABELLING

Consumer attitudes have a crucial role in orienting consumption patterns and in indirectly steering production. Climate conscious consumer behaviour can become an important factor in mitigation. Many consumers are already trying to reduce their "carbon footprint"[26] through consumption choices, such as buying local and seasonal products to reduce emissions from food transport.

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[25] For example, saving costs is commonly cited in the RDP as the main reason for implementing energy efficiency measures, but the associated GHG emissions savings and climate benefits are not always mentioned.

[26] The carbon footprint is a measure of the impact our activities have on climate change. It relates to the amount of GHG produced in our day-to-day lives through consumption, use of energy, transportation etc., expressed in CO_2 equivalent.

Another important aspect related to consumer behaviour is the food waste generated yearly. This is costly for the consumer but also causes costs for the society from dealing with the waste produced. Food not consumed also contributes to climate change through the GHG emissions associated with growing, processing, packaging, transporting and refrigerating it. Reducing food waste has significant win-win potential for reducing emissions.

Carbon footprint and food labelling schemes

In the context of a more market-oriented CAP, consumer demand for climate-friendly products may become an important incentive for farmers, food producers and retailers to market such products. If consumers want to choose products that have been produced in a "climate-friendly" way, and possibly pay a higher price, farmers and producers should have a tool for communicating this added value, which in turn may allow them to recover some of the additional costs incurred in production.

"Carbon footprint" labelling for agricultural products is being developed by a range of actors worldwide, albeit under different methodologies. The wide range of products and production environments is posing significant practical problems in the development of a generally recognised methodology. In terms of labelling options, an alternative to specific figures for GHG emissions per quantity of product is to highlight the fact that the a climate-friendly production method has been used. While this latter option is much less demanding in terms of data, it still requires validation by a respected authority in order to become the commonly accepted standard in the field.

In December 2008, the Council requested the Commission to look at labelling options in the complex area of carbon footprint, its potential inclusion in the existing EU environmental labelling, such as the eco-label, and to start working on common calculation methodologies. Regarding agricultural products, carbon footprint and the corresponding labelling would need to take account a wide range of policy issues and in particular wider environmental considerations, policy towards developing countries, and coherence with existing certification schemes such as organic farming.

7. CONCLUSIONS AND ORIENTATIONS FOR FUTURE ACTIONS

7.1 Building a mitigation strategy for agriculture

Agriculture is the indispensable basis for the production of food. At the same time farmers manage a large share of land in the EU, and sustainable agriculture delivers a wide range of ecosystem services, as well as being the basis for a living countryside and the wellbeing of millions of inhabitants in rural areas. Agriculture's contribution to climate change mitigation therefore needs to be put into the wider perspective of the overall challenges facing the sector and rural areas in the coming decades.

In the EU agricultural GHG emissions have declined sharply during the past two decades, but without additional efforts this trend is not likely to continue. However, there is unused potential for cost-effective mitigation actions. Appropriate policy instruments to stimulate and support an increased uptake of

emission-reduction measures, could be maintained and developed to encourage farmers to realize this potential. Economic viability of farms is a necessary basis for mitigation techniques to become more wide spread, in particular taking into account that the already inevitable impacts of climate change could increase the costs of sustainable farming in many parts of the EU.

Efficient production should be maintained

The mitigation potential of agriculture can best be realized by maintaining high productivity combined with sustainability. The importance of production efficiency is particularly apparent in the light of the estimate that global food production has to increase almost by 2% per year to respond to the growing world population and changes in consumption patterns. In addition, there are increasing demands for agriculture to contribute to energy production.

Mitigation measures that would lower EU agricultural production may be effective in achieving a reduction in GHG emissions in Europe, but in the absence of a comprehensive international agreement they risk to contribute to the transfer of production and related emissions elsewhere. The Commission will assess the impact of the international agreement on the agricultural sector, including carbon leakage risks, as agreed within the energy and climate package.

Mitigation as part of an integrated approach

Climate change mitigation in agriculture should be pursued as part of an integrated approach to sustainable agriculture to build synergies and avoid conflicts with other economic, environmental and social objectives. This integrated approach should also take full account of biodiversity, water and other land related environmental objectives.

Measures that combine mitigation, adaptation and other environmental benefits with improvements in efficiency and profitability of farming – such as those aiming at saving energy, improving nitrogen management and sequestering carbon in soils – should form the core of a coherent mitigation strategy for agriculture. Identifying and prioritising measures that provide co-benefits in terms of reducing emissions and increasing resilience of farming is the key to addressing the double challenge of reducing GHG emissions while at the same time increasing the resilience of agriculture to a changing climate and ensuring its future sustainability.

From global to local

Addressing climate change is a global concern but due to the diverse nature of agricultural, environmental and climatic conditions across the EU the choice of best measures for mitigation needs to be made at regional and local level. There is no one-size-fits-all approach to addressing climate change.

The impact of most mitigation measures will only be visible in the medium term. As the investments and structural changes needed take time, the start of their implementation should not be delayed.

7.2 Orientations for a mitigation policy for EU agriculture

Possible orientations to enhance mitigation efforts in agriculture are outlined below. These are proposals for future work, which complement and build synergies with those made in the Working Document on adaptation[27].

Strengthening mitigation actions in agriculture

Given the fact that the highest share of agricultural emissions are methane and nitrous oxide emissions from livestock, manure management, and agricultural soils, improved practices in these activities are likely to represent the highest mitigation potential in the agricultural sector in the EU.

Preserving and enhancing carbon stocks in agricultural soils

There is a significant mitigation potential in preserving and enhancing carbon stocks in agricultural soils. Possibilities to develop stronger incentives for soil management measures and for the protection of carbon-rich agricultural areas as well as related risks, uncertainties and the interactions with climate change should be carefully examined. This could also enhance the long-term productivity of European soils and facilitate coping with the effects of climate change, such as expected prolonged water shortages and more frequent periods of intense rain.

This needs to be combined with the development of cost effective carbon measuring and monitoring system for agricultural soils in the EU. Carbon dynamics, and the extent to which processes leading to emissions from farmland can be reduced, need further work to be better understood and quantified, especially in the light of an already changing climate. In proposing the Soil Framework Directive, the Commission has intended to improve the way in which European soils are used, including from the viewpoint of carbon measurement, monitoring and management.

In this context, the critical role of international accounting rules for land use, land use change and forestry (LULUCF) should be noted, which will be revised under the UNFCCC Copenhagen agreement.

Exchange national approaches and experiences

The Commission can play a useful role in facilitating cooperation between the Member States to share experiences on approaches and measures towards mitigation in agriculture. The EU Rural Development Network as well as the European sectoral social dialogue committee in agriculture are possible fora for enhancing such exchanges.

Enhance research and development

Despite the significant amount of information available, further research on emission-reduction options in the agricultural sector, as well as their inter-

[27] Adapting to climate change: the challenge for European agriculture and rural areas. SEC(2009)417.

relation with other societal objectives, should be further supported at national and EU levels. A particular focus should lie on innovation in agricultural production methods and animal and plant breeding.

Improve farmers' awareness of climate change impacts on agriculture

There is a need to improve awareness of climate change aspects among farmers and other rural actors on climate-conscious management and to improve technical knowledge and guidance on appropriate measures for climate change mitigation at farm level. Specific focus on win-win measures will speed their uptake by farmers.

Currently, there is limited use of rural development funds to setting up farm advisory services, which could play a key role in the dissemination of appropriate information and advice to farmers. In the future, the farm advisory tool within the CAP could be reinforced towards this objective.

Assess the feasibility of improving consumer information on the climate implications of food

Consumers need to receive reliable information about the possibilities for climate conscious food choices and of the negative impacts of food wastage.

As requested by the Council, the Commission will assess the usefulness and feasibility of GHG labelling for food, taking account of the complexity of the food chain and the need for labels to convey clear messages to consumers while preserving environmental integrity in a holistic way. Thus, co-benefits for society and the environment associated with certain production techniques have to be assessed in an integrated manner.

However, as stated in the recent Communication on agricultural product quality policy[28], the Commission also intends to ensure coherence in future EU agricultural product quality schemes by assessing the added value of any new future schemes and at the same time developing good practice guidelines for the operation of the schemes and improving the recognition of EU quality schemes outside the EU.

Further integrate climate concerns in the future development of the CAP

In the preparation of the review of the CAP post-2013, and in the light of the results of the Copenhagen conference on climate change, the Commission will examine ways to further and better integrating adaptation and mitigation objectives in CAP instruments. In particular, measures to enhance incentives for better management of GHG fluxes within the context of changing climate conditions will be explored. A balanced approach between binding requirements and positive incentives for mitigation efforts should be maintained and fitted into the future CAP framework.

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[28] COM(2009) 234 on agricultural product quality policy, of 28.5.2009 (http://ec.europa.eu/agriculture/quality/policy/communication_en.htm).

In the light of the review of the uptake of climate change mitigation activities in the rural development programmes, the Commission will examine possibilities to better ensure that climate change is effectively and efficiently reflected in the current programmes. This implies examining how funds could be better targeted for climate change purposes, how to better encourage uptake of relevant measures and to assess their effectiveness. The applicability of measures on a wider territorial scale beyond the farm level should also be examined to help ensure a more effective implementation of measures across the EU.

ANNEXES

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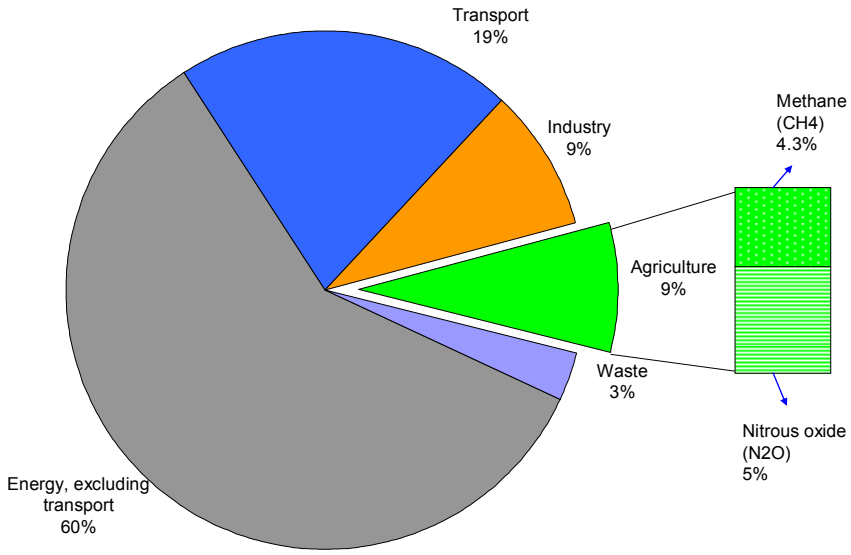
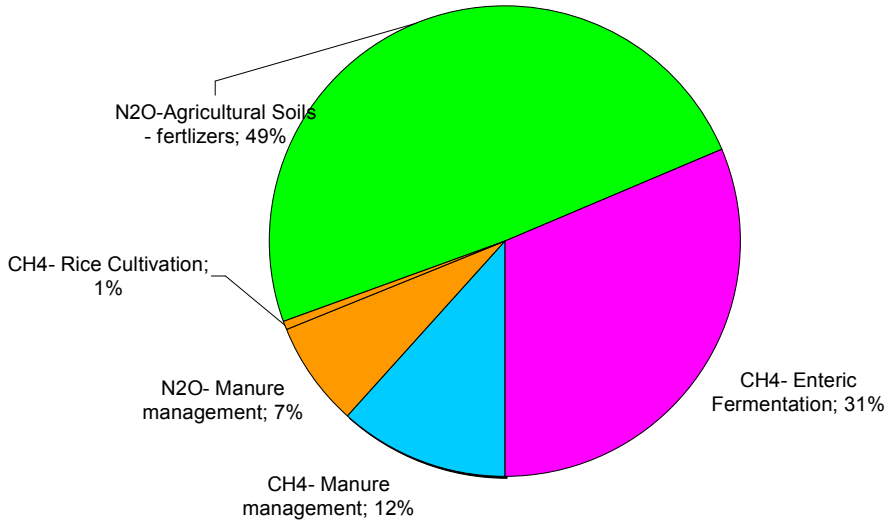
Annex 1 – Agricultural GHG emissions and trends

Figure 1 – Share of agricultural GHG emissions in total EU emissions – 2007 (CO2 equivalent)



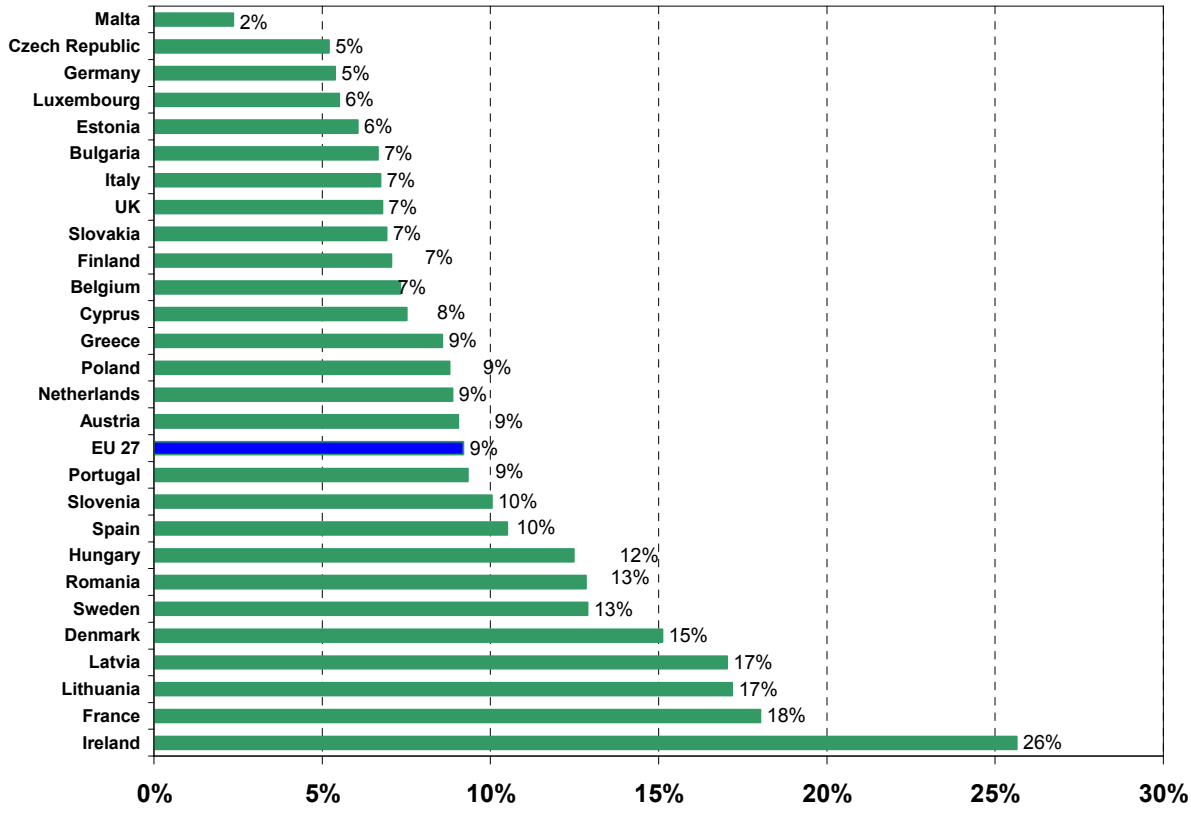
Source: Own elaboration on the basis of EEA databases (based on EU Member States greenhouse gas inventories and projections).

Figure 2 – Breakdown of agricultural GHG emissions in the EU-27 - 2007



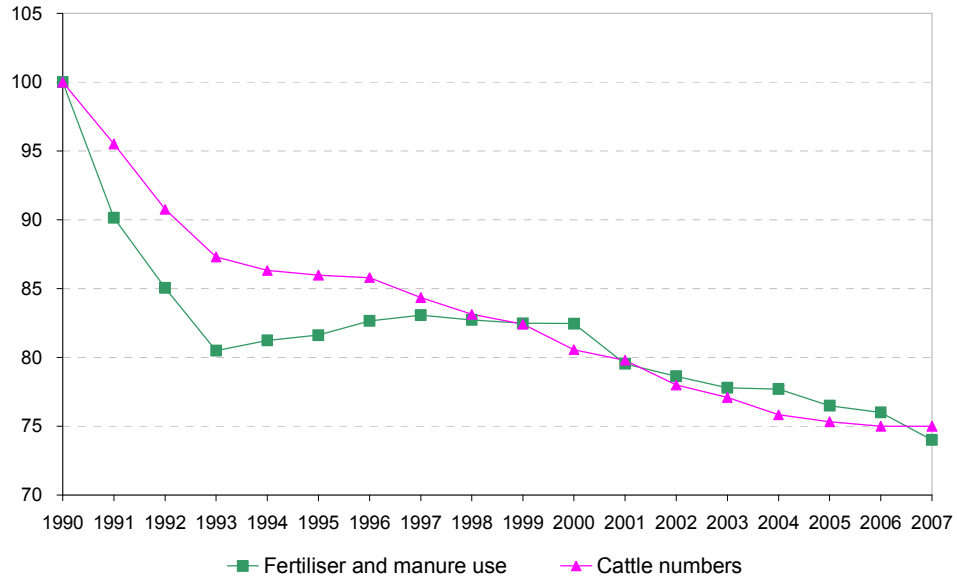
Source: Own elaboration on the basis of EEA databases (based on EU Member States greenhouse gas inventories and projections).

Figure 3 – Share of agricultural sector in total national GHG emissions in EU-27 Member States-2007



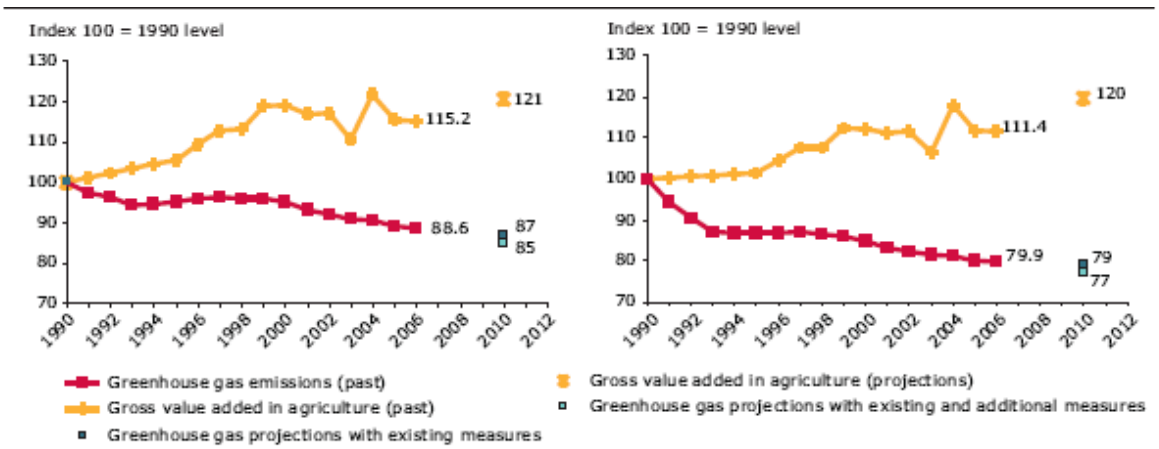
Source: Own elaboration on the basis of EEA data (based on EU Member States greenhouse gas inventories and projections).

Figure 4 – Trends in cattle numbers and nitrogen use in the EU-27 – 1990-2007 (indexed relative to 1990 levels)



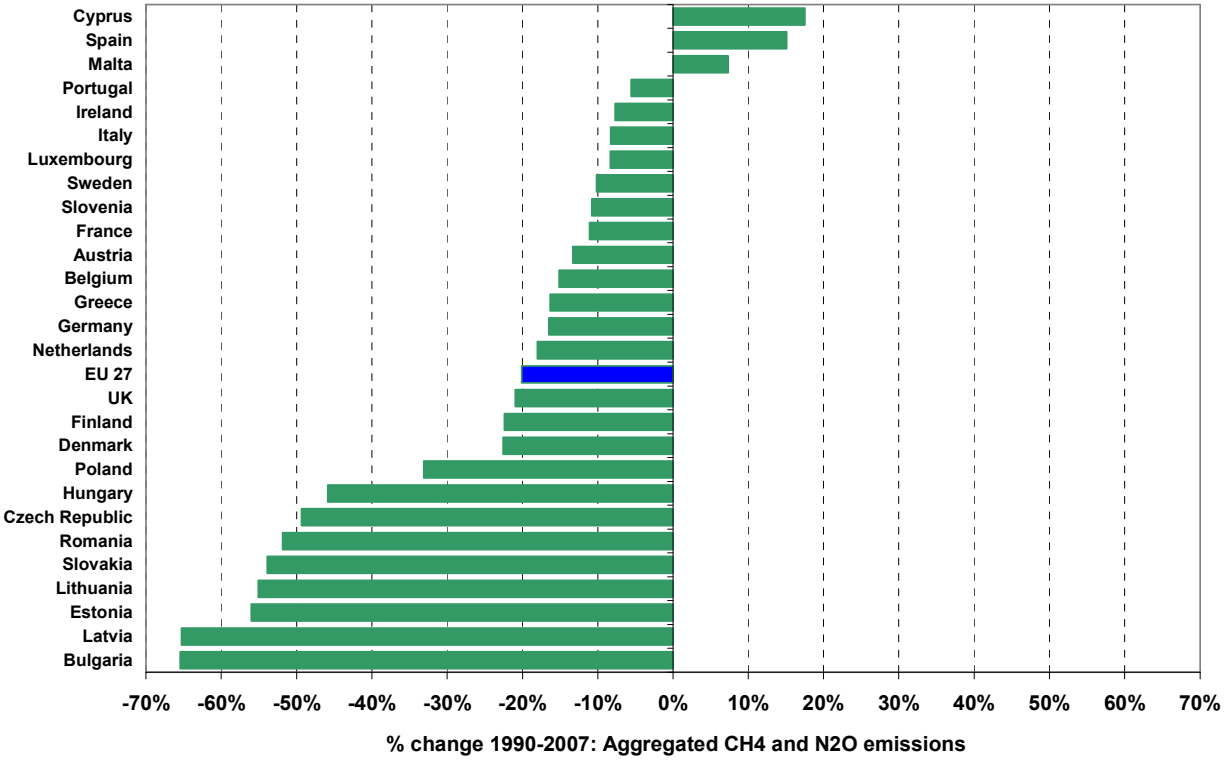
Source: Own elaboration on the basis of EEA data (based on EU Member States greenhouse gas inventories and projections).

Figure 5 – EU-15 (left) and EU-27 (right) past and projected GHG emissions from agriculture and gross value added (1990–2006)



Source: EEA report N° 5, 2008, "Greenhouse gas emission trends and projections in Europe 2008 - Tracking progress towards Kyoto targets".

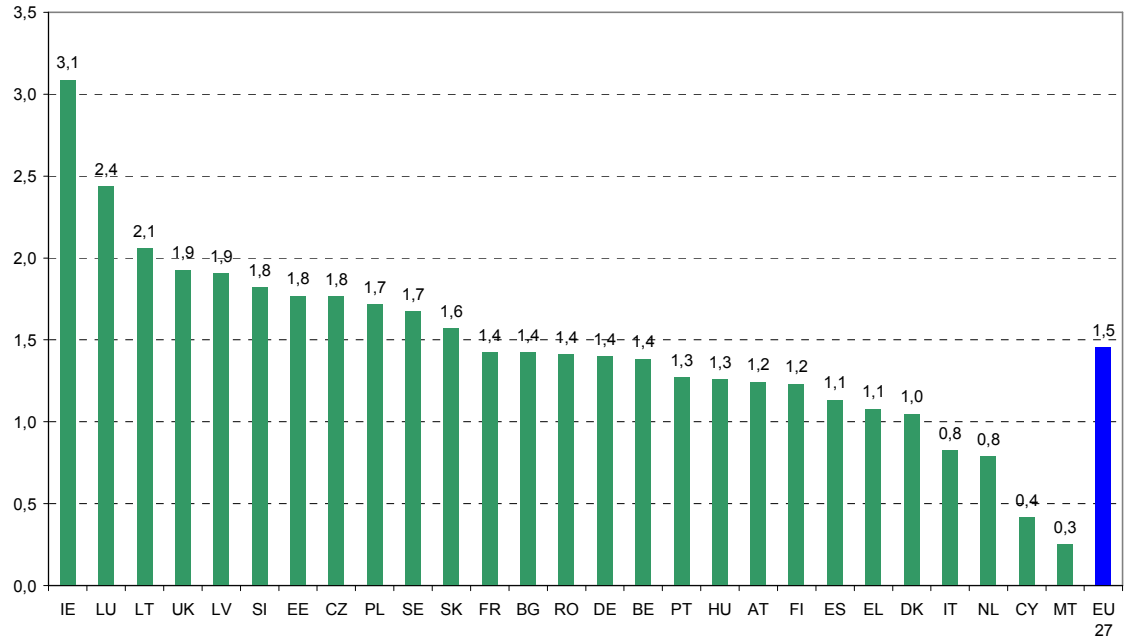
Figure 6 – Change in agricultural GHG emissions in EU-27 Member States - 1990-2007



Source: Own elaboration on the basis of EEA data (based on EU Member States greenhouse gas inventories and projections).

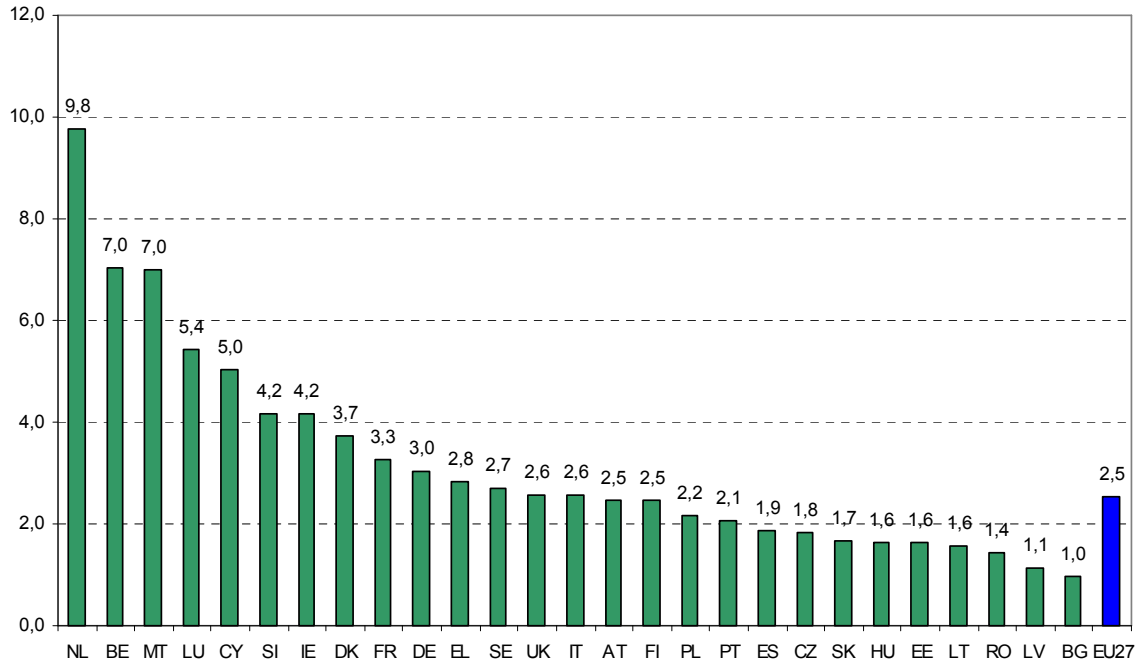
Figure 7 – GHG emissions per unit of output value-2007 (Gg[29] CO_2 eq / mio €)

[29] 1 Gg (Gigagram) is equivalent to 1000 Tonnes.



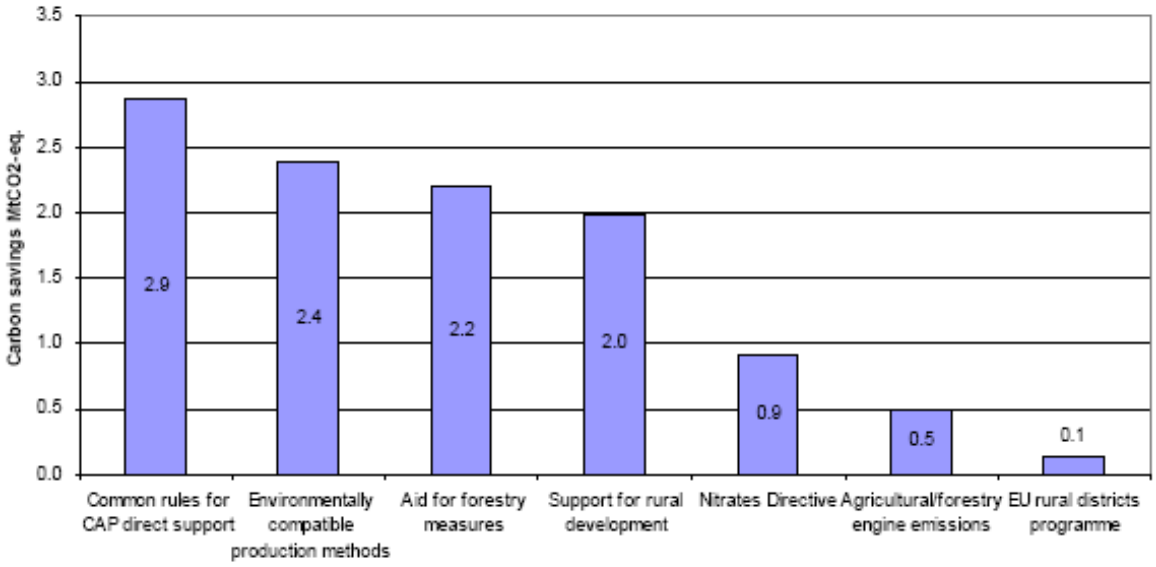
Source: Own elaboration on the basis of Eurostat and EEA data (based on EU Member States greenhouse gas inventories and projections).

Figure 8 – GHG emissions per unit of UAA- 2007 (Ton CO_2 eq/Ha)



Source: Own elaboration on the basis of Eurostat and EEA data (based on EU Member States greenhouse gas inventories and projections).

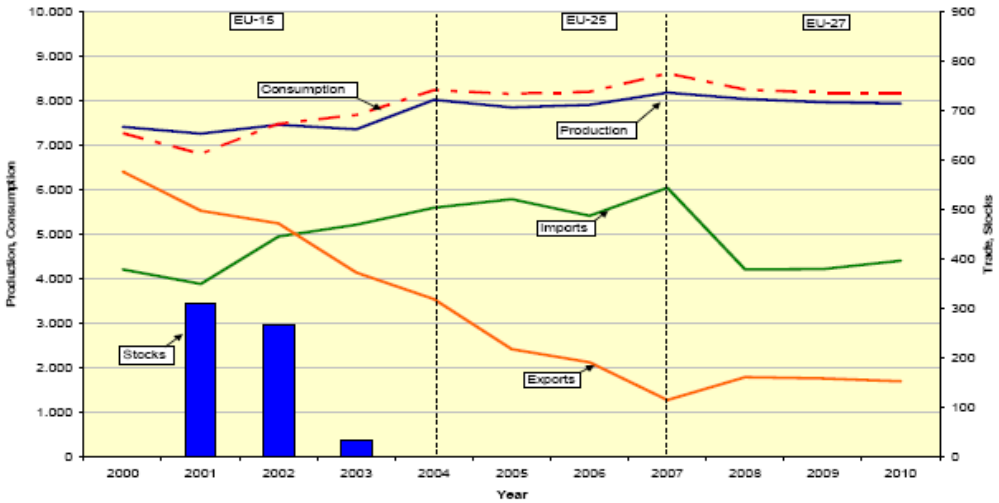
Figure 9 - Estimated emission reduction potential of policies and measures in the agricultural sector in 2010, EU27



Note: This figure highlights a number of policies and measures targeting or addressing emissions in the agricultural sector and projected to result in 11 Mt CO2-eq. reductions across the EU-27 in 2010, equivalent to a decline of 2% below current levels.

Source: EEA report 5/2008 Greenhouse gas emission trends and projections in Europe- Annex, on the basis of a database on policies and measures based on the submissions of Member States.

Figure 10 - EU beef and veal market balance 2000-2010 (in 1000 t carcass weight)



Annex 2 – Contribution of the Common Agricultural Policy (CAP) to mitigating climate change[30]

1.3. 2.1 Recent reforms of the CAP

The orientation of the CAP since the 1992 reform, reinforced by the Health Check, is marked by a progressive integration of environmental considerations including climate change:

In the 1992 CAP reform, accompanying measures funded by the Community budget were included for **agro forestry and agri-environment**. Those measures are still available within the current rural development policy.

The 2003 CAP reform and subsequent reforms of several Common Market Organizations (olive oil, tobacco, cotton, sugar, fruit and vegetables, and wine) introduced a set of measures, mainly:

- **Decoupled direct payments**, no longer linked to the production of a specific product. This form of income support, not only allows farmers to be more responsive to various external forces, including market signals, but also helps farmers to orient their production according to the biophysical environment evolving with climate change.
- **Compulsory modulation** which allows shifting money from direct payments to Rural Development.
- **Farm Advisory System (FAS)** ensures availability of advice to farmers on farm and land management including the basic of environmental requirements (SMR and GAEC). The FAS is an important tool to improve farm management and can play a role in the integration of findings from the physical and agronomic sciences with local knowledge from farmers and land managers, making it an effective tool also for sustaining adaptation and mitigation efforts in agriculture. An evaluation of the functioning of the FAS is in process and a report will presented by the Commission in 2010 with the view of improving its application if needed.
- **Cross compliance** links the financial support to farmers to the respect of environmental, animal welfare and food quality legislative standards (Statutory Management Requirements, SMR) as well as to the maintenance of agricultural land in Good Agricultural and Environmental Conditions (GAEC). Farmers who do not respect the rules face cuts in their financial support under the CAP. In particular requirements on the maintenance of permanent pastures and specific soil practices are essential to keeping organic carbon in agricultural soils as well as to their sustainable use.

[30] The information presented in this Annex focus on mitigation actions. The dimension of adaptation of agriculture and rural areas to climate change has been addressed in a recent Working Document on adaptation (SEC(2009) 417, Adapting to climate change: the challenge for European agriculture and rural areas, of 1.04.2009).

§ Within the **operational programmes in the fruit and vegetables** sector, which are partly financed by the EU budget, producer organisations can support investments aimed at energy savings, use of renewable energies, and introduction of co-generation systems. Operational programmes can also include other environmental actions (e.g., improved thermal insulation of greenhouses and warehouses, replacement of road transport with transport by rail or ship, recycling of packaging), as well as training and setting up of advisory services, which can be relevant for adoption of GHG savings actions in this sector.

Those measures have been strengthened by the **Health Check** decisions[31]:

§ **Further decoupling**: while during the period 2003-2007 some Member States chose to maintain some "coupled" – i.e. production-linked – payments, these remaining coupled payments will now be phase-out to achieve more market orientation. Exceptions are the suckler cow, goat and sheep premia. In these sectors where the coupled premia represent an important share of farmer's income and agricultural regional production, the full decoupling would have detrimental effects for the environment as well as for the vitality of rural areas.

§ **Modulation**: the current rate of 7% will be progressively increased to 10 percent by 2012. An additional cut of 4 percent will be made on payments above €300,000 a year. The funding obtained this way may be used by Member States to reinforce programmes in the fields of climate change, renewable energy, water management, biodiversity, innovation, and restructuring of milk sector. New measures will be co-financed by the EU at a rate of 75 %, and 90 % in convergence regions where average GDP is lower.

§ **Other measures**, namely, "article 68" of Council Regulation (EC) 73/2009 (assistance to sectors with special problems) and insurance schemes for natural disasters and mutual funds have also been strengthened but these are more relevant for adaptation to climate change as underlined in the working document on agriculture adaptation.

§ **Cross compliance:** new standards have been introduced in the GAEC framework to address issues relating to water management and pollution. Moreover, the standard relating to the protection of landscape feature has been specified.

1.4. 2.2 Possibilities offered by the rural development policy to support farmer's mitigation efforts[32]

The EU regulation[33] and the Community Strategic Guidelines[34] on rural development for the period 2007–2013 set out climate change mitigation as one of the key priority

[31] http://ec.europa.eu/agriculture/healthcheck/index_en.htm

[32] The focus is on mitigation actions, as possibilities for supporting adaptation have been addressed in the recent Working Document on adaptation.

[33] Regulation (EC) No 1698/2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) (http://ec.europa.eu/agriculture/rurdev/leg/index_en.htm)

[34] Council Decision (20 February 2006) on Community strategic guidelines for rural development (programming period 2007 to 2013)

objectives for rural development policy. Many actions supported under rural development can contribute to both mitigation and adaptation objectives and have synergies vis-à-vis other environmental objectives (► table 1).

The current framework

There is a wide range of measures that can contribute to tackle climate change in the three strands of rural development: competitiveness, improving the environment, and diversification and quality of life in rural areas. Even if the measures are not specifically tailored to reducing GHG emissions, many of the actions that can be funded produce benefits also from a climate perspective. Actions supported by rural development cover agriculture and forest, as well as the development of wider renewable energies, using agricultural and forest biomass as well as other alternative energy sources, in rural areas. Annex 2 presents an indicative list of the main rural development measures relevant to climate change. The main actions available under the three axis are as follows:

Under the **competitiveness** axis:

- **Farm modernisation** can support, for instance, the improvement of energy efficiency of equipment and buildings, adequate manure storage installations, which are crucial to limit methane emissions from manure, and equipment for more efficient fertilizer application, the main action to reduce nitrous oxide emissions.

- **Processing of agricultural (and forest) biomass** for renewable energy, such as on–farm and local biogas facilities using organic waste, and development of perennial energy crops can also be funded within the modernisation measure.

- Support for the **improvement and development** of infrastructure, adding value to agricultural and forest biomass, and for co-operation for new products, processes and technologies offer scope for the processing of biomass for renewable energy.

- Investing in human capital is an EU priority for rural development, and will also be a key factor with a view of copying with GHG emission reductions. All Member States devote support to training, information and diffusion of knowledge oriented to the improvement of farm management or methods for cropping and livestock production, and environmental land management, which can be of relevance for mitigation. Support can also be given to setting up of farm management and advisory services and for their use by farmers. Providing information on on-farm emissions sources and energy use and on workable solutions for farmers is essential to help them plan their activities better.

Within the **environmental and land management** axis:

- **Agri-environmental schemes** targeted to better fertilisation and management of soils have an important role for diminishing the climate impacts of agricultural activities and enhancing carbon sinks. In particular, agri-environmental measures that contribute to improving efficiency of nitrogen fertiliser, such as reduced use, accurate timing of application in relation to crop requirements, and use of

precision farming techniques, can greatly contribute to diminishing nitrous oxide emissions from soils. Payments are also available for a wide range of soil management practices (conservation agriculture e.g., tillage methods, catch crops) and land use actions (e.g., improved management of pastures and organic soils), beyond what is required by cross-compliance, which help maintain and enhance the carbon sink capacity of agricultural soils. Measures to enhance carbon sequestration in soils through reducing soil disturbance and building up soil organic matter offer potential for mitigating climate change as well as for improving soil protection.

- **Organic farming** has potential for mitigation through its efficient nutrient cycles and soil management and it usually implies higher diversity and high level of knowledge of the functioning of the farm ecosystem, which it is also likely to benefit farmer's mitigation actions. However, when considering organic farming as an instrument for climate change mitigation, both the amount of amount of emissions per hectare and per unit of production needs to be considered[35].

- **Forestry actions**, such as aforestation of agricultural land, establishment of agro-forestry systems, forest-environment measures, and non productive investments, are important measures to protect and increase carbon sinks in forests.

Measures for **diversification and quality of life** in rural areas can help realizing the wider potential for agriculture and forest to supply renewable energy. Support for diversifying agricultural activities, and local installations and infrastructure for renewable energy using biomass and other energy sources (e.g., solar, wind power) is available.

Additional funding

The recent Health Check of the CAP has increased the focus on climate change and development of renewable energies as new challenges for agriculture, forests, and rural areas (alongside with water management, biodiversity, innovation and restructuring of milk sector). Approximately 3,24 billion euros will be shifted to rural development, which will be completed by national funding at a co-financing rate of 25% and 10% in convergence regions. Member States which will receive additional funds via de increased modulation[36] will have to present revised rural development programmes to better respond to the various new challenges. This represents an important opportunity to ensure that additional activities and resources are directed to climate change. Additional funding has also been made available as part of the European Economic Recovery Plan.

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[35] Diverse studies show contrasting results of emissions per unit of product in organic farming, particularly regarding methane. A recent German study (referenced by PICCMAT final report) show lower GHG emissions per unit of product in organic farming than conventional methods for wheat, pig and milk production, while results for beef production are more ambiguous due to the variety pf production systems.

[36] For the UK and Portugal, there will not be a net increase in the rural development funding from the EU budget because these countries were already using funds from previous voluntary modulation commitments. For the 10 Member States (EU-10) that entered the EU in 2004, modulation will only apply in 2012. Approximately 3,24 billion euros will be shifted to Rural development, which will completed by national funding at a co-financing rate of 25% (standard) and 10% in convergence regions.

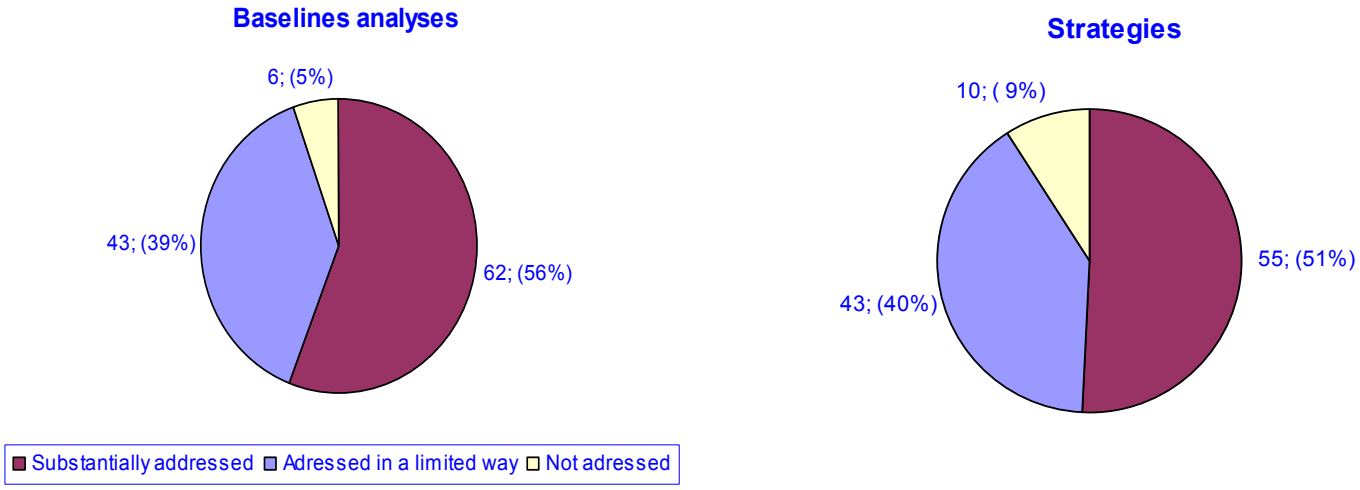
Table 1 – Indicative list of the main rural development measures that can be used to support mitigation in agriculture and rural areas (on the basis of the rural development regulation as modified by the Health Check)

Mitigation domain	Examples of actions	Possible supporting measures of Rural development Regulation	Potential effects
Reduction of farm-level emissions of CH_4 and N_2O	§ Investments in on-farm biogas plants (using animal manure) § Investments in manure storage facilities § Investments in equipment for better application of fertiliser (e.g., spreader, precision farming	Article 26: modernisation of agricultural holdings	Support for investments in costly equipment is essential to motivate farmers economically to improve agricultural performance in term of GHG emissions
	§ Reduction of fertilisers use (reduced use, timing of application, diversified crop rotations) § Extensification of livestock (e.g., reduction stocking density) § Organic farming	Article 39: agri-environment payments	Agri-environmental measures hold an important potential to stimulate adoption of targeted or climate-relevant measures to reduce methane (CH_4) and nitrous oxide (N_2O) emissions
Reduction of farming emissions of CO_2	§ Investments in energy-efficient equipment and buildings (e.g., insulation) § Investments for on-farm use of renewable energies (e.g., biogas, use of renewable fuels, solar heating and power)	Article 26: modernisation of agricultural holdings	Energy efficiency and diversification if energy supply in farms is becoming increasingly important. Insulation of buildings, increased use of solar energy, vegetal oils, biofuels, and biomass heat and power offer the greatest potential for reducing energy-related CO_2 emissions
Soil sequestration in agricultural soils	§ zero or reduced tillage systems which avoid or reduce soil disturbance; § diversified crop rotations (to reduce fertilizer use) § use of catch crops (green manure crops), protein crops, reduce the removal of residues (stubble), incorporation to soil of organic material; § Conversion of arable land to permanent pastures § Maintenance of permanent fallows areas § maintenance of green cover of soil rows in permanent crops plantations; § establishment of permanent set-aside areas with green cover;	Article 39: agri-environment Article 41: Non-productive investments	By increasing the ability of agricultural soils to store carbon, CO_2 can be removed from the atmosphere, while also playing an important role in improving the long-term quality and fertility of soils

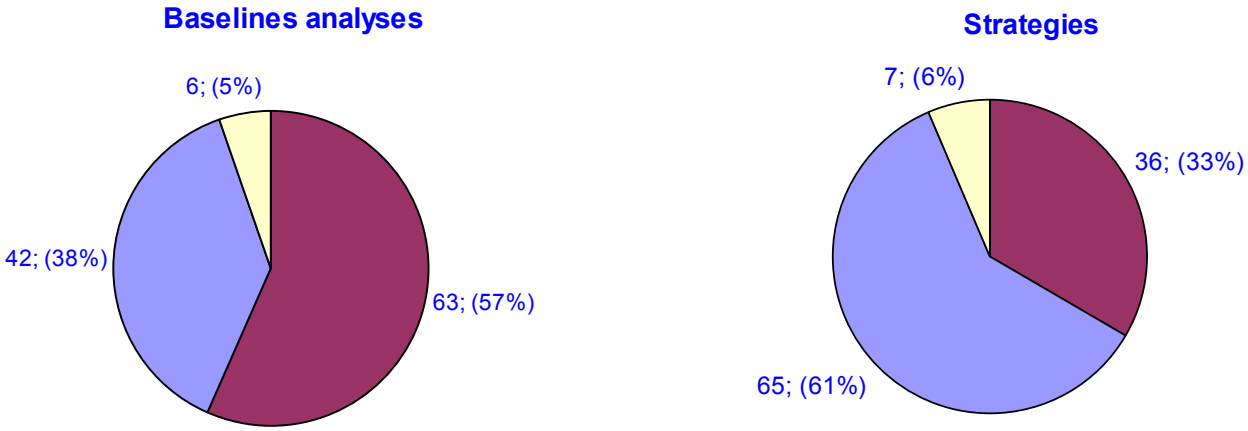
	§ maintenance of permanent pastures, as they hold important stocks of carbon, and conversion of arable land to grassland;		
Forest measures	§ Improving the wood production (e.g., thinning, changes in the tree species composition)	Article 27 : Improvement in the economic value of forests	Substitution of fossil fuels or high energy content material as steal or concrete by bioenergy from forest biomass
	§ First afforestation of agricultural land or of non agricultural land § Forest-environment	Articles 43 and 45: first afforestation of agricultural and non-agricultural land Article : Forest-environment	Enhance carbon sequestration in forests areas
Development of renewable energies	§ Support to investments in biogas plants (using animal manure), on farm and local production § Plantation of multi-annual energy crops (e.g., herbaceous grasses, short rotation coppice) § Processing of agricultural/forest biomass for renewable energy § Installations/infrastructure for renewable energy using biomass and other renewable energy sources (solar and wind power, geothermal)	Article 26: modernisation of agricultural holdings Article 28: adding value to agricultural and forestry products Article 29: cooperation for development of new products, processes and technologies in the agriculture and food sector and in the forestry sector Article 53: diversification into non agricultural activities (for local production) Article 54: support for business creation and development (for local production)	Agriculture, and forests, also provides an indirect contribution to emission reductions in other sectors, through the supply of biomass for the production of bioenergy and substitution of fossil fuels.
Diffusion of knowledge, capacity building	§ Training and use of farm advisory services in relation to climate change	Article 21: vocational training and information actions Article 24: use of advisory services Article 58: training and information	Information and dissemination of knowledge and advice to farmers (and local communities) in relation to climate change mitigation and possibilities for using and producing renewable energies
Innovation	Development of new technologies, products and processes in the agriculture and forest sectors	Article 29: Co-operation for development of new products, technologies, and processes in the agriculture and food sector and in the forestry sector Article 28: Adding value of forestry products	Innovation can underpin efforts to tackle climate change. As regards forests, increasing of the use of low-value timber, small-sized wood and wood residues for energy production.

Figure 1 - Assessment to the extent of which climate change has been addressed within the baseline analyses and Rural Development Strategies (figures refer to the number of RDP and share in each class) [1]

Mitigation[2]



Renewable energies[2]



[1] Based on a survey on the extent to which climate change is addressed in the baselines analysis and strategies for rural development and the programming of climate change related actions in the national and regional Rural Development Programmes for 2007-2013. The survey has been performed by the contact point working for the EU Rural Development Network on the basis of guidelines provided by the Commission. The survey and its assessment are entirely qualitative and based on expert judgement. The survey has look into a total of 111 RD strategies and baselines analyses covering: all the RDP (109, including all the "Documents Régionaux de Développement rural") de France-Hexagone) and 2 national network programmes (Portugal and Spain).

[2] Includes actions listed in table 2 and 3 respectively.

Table 2 – Summary of programming of mitigation actions within Rural development Programmes 2007-2013 [1]

Domain	Types of operations	Code of main RD measures used [2]	Number of national/regional RDPs with		
			No measures	Non-targeted	Targeted
Manure management	Investments on manure storage facilities, and on installations for better manure treatment and processing (including anaerobic digesters)	121	49 [45 %]	34 [31 %]	26 [24 %]
Manure management	Improved manure management (e.g., manure management plans, frequent removal of manure from animal housing to covered storage)	214	41 [38 %]	44 [40 %]	24 [22 %]
Fertilisation efficiency	Investments in equipment for better application of mineral fertilisers, mineral and manure (e.g. spreader, equipment for precision farming)	121	64 [59 %]	34 [31 %]	11 [10 %]
Fertilisation efficiency	Actions to improve efficiency of fertiliser use (e.g., reduction of use, changing practices, improved spreading techniques, calculation N balance)	214	24 [22 %]	52 [48 %]	33 [30 %]
Energy efficiency	Energy-savings investments (e.g., energy efficient buildings, installations, greenhouses, use new materials)	121, 123, 124	30 [28 %]	47 [43 %]	32 [29 %]
Farm management	Organic farming	214	3 [3 %]	46 [42 %]	60 [55 %]
Farm management	Integrated production (including fertiliser reduction, extended crop rotations)	214	41 [37 %]	29 [27 %]	39 [36 %]
Soil, land management	Soil conservation techniques (e.g., reduced tillage methods, permanent green cover, catch crops, management stubble)	214	20 [18 %]	48 [44 %]	41 [38 %]
Soil, land management	Reduced use / restoration of organic soils (peat land)	214	67 [61 %]	26 [24 %]	16 [15 %]
Livestock management	Extensification of livestock (e.g., reduction stocking density, increase grazing)	214	52 [48 %]	42 [39 %]	15 [14 %]
Pastures management	Extensification of pastures management (e.g., reduced/no fertilisation, practices to maintain/increase soil organic levels such as diversification of grass species)	214	35 [32 %]	44 [40 %]	30 [28 %]
Land use change	Permanent set-aside (long-term fallow)	214, 216	85 [78 %]	15 [14 %]	9 [8 %]
Land use change	Conversion of arable land to permanent	214, 216	79	14	16

	pastures		[72 %]	[13 %]	[15 %]
Land use change	Conversion of agricultural land into forest (afforestation)	221	46 [42 %]	11 [10 %]	52 [48 %]
Building capacity	Training, demonstration projects, information actions (in relation to climate change, mitigation actions)	111	37 [34 %]	52 [48 %]	20 [18 %]
Building capacity	Setting up and use of advisory services (in relation to climate change, mitigation actions)	114, 115	70 [64 %]	23 [21 %]	16 [15 %]
Innovation	Development of new technologies and processes	124	80 [73 %]	16 [15 %]	13 [12 %]
Average			**48 [44%]**	**34 [31%]**	**27 [25%]**

[1] A total of **109 RDPs** have been analysed: 18 national programmes (all except the National programme of France Hexagone), 90 regional programmes (including the 21 "Documents Régionaux de Développement rural" of France), and 1 the national framework (Germany).

[2] Codes used are: 111-Training, 114-Use of advisory services, 115-Setting-up farm advisory services, 121-Modernisation, 123-Adding value to agricultural and forest products, 124-Cooperation for development of new products, processes and technologies, 214- Agri-environment, 216-Non-productive investments

Source: Synthesis report of the results of a survey of climate change measures in Rural Development Plans (2007-2013) across the European Union

Table 3 – Summary of programming of actions to support renewable energies within Rural development Programmes 2007-2013

Domain	Types of operations	Code of main RD measures used [1]	Number of national/regional RDPs with		
			No measures	Non-targeted	Targeted
Biomass-based energy	Investments for on-farm production and use of biogas	121	71 [65 %]	12 [11 %]	26 [24 %]
Renewable energies	Investments support for on-farm use of other renewable energies for electricity and heating (e.g., glasshouses, buildings)	121, 125	49 [45 %]	20 [18 %]	40 [37 %]
Biomass	Plantation perennial energy crops (e.g., short rotation coppice and herbaceous grasses)	121	73 [67 %]	20 [18 %]	16 [15 %]
Biomass based energy	Processing of agricultural/forest biomass for renewable energy (e.g., biofuels) (on farm and local actions)	121, 123, 124, 311, 312	17 [16 %]	39 [36 %]	53 [49 %]
Renewable energies	Investment support for local energy supply: installations/infrastructure for renewable energy using biomass and other renewable energy sources (solar, wind power)	311, 312, 321	45 [41 %]	29 [27 %]	35 [32 %]
Building capacity	Training, demonstration projects, information actions in relation with production and use of bio-energies	111, 331	50 [46 %]	45 [41 %]	14 [13 %]
Average			**50 [51 %]**	**27 [24 %]**	**30 [25 %]**

[1] 121-Modernisation, 123-Adding value to agricultural and forest products, 124-Cooperation for development of new products, processes and technologies, 125-Improving and developing infrastructure, 311-Diversification into non-agricultural activities, 312-Suppot for business creation and development, 321- Basic services for the economy and rural population, 331-Training and information for rural actors

Source: Synthesis report of the results of a survey of climate change measures in Rural Development Plans (2007-2013) across the European Union

Annex 3 – Overview of selected technical and management mitigation options in agriculture [1]

Category	Measure	GHG [2] concerned	Technical mitigation potential (per ha/unit product)	Potential implementation cost	Technical feasibility	Comments
Management and processing of manure	Increase removal frequency (from housing buildings to covered storage)	NH3, CH4	High for pigs, (no/low potential for cattle)	High	High	High electricity needs
	Improved outdoor storage techniques (e.g., natural crusting, straw, plastic or rigid covers	NH3, N2O,CH4	Low	High	High	Slightly decreased costs for pig farms
	Improved application techniques (e.g., trailing hose, trailing shoe, injection)	NH3, N2O	Medium/High	Medium/high	High	Need specific equipment for some application techniques, such as direct injection
	Optimized manure storage	CH4	Medium/High	High	Medium	New storage facilities can have large capital cost. Reducing emissions from manure storage is a complex process and attention needs to be paid to the emissions of other gases such as N2O and ammonia
	Anaerobic digestion for biogas production	CH4, N2O	Very high	High costs needing investment support but cost-effective depending on the use of heat produced	Medium/High	Significant variability in potential. Remunerative feed-in tariffs for electricity generated are required. The process reduces GHG from the input material, while delivering renewable energy
Mineral nitrogen fertilizers	Use of controlled-release nitrogen fertilisers	N2O	Medium	Low	Medium	Fertilizers in which N is slowly released, so there might be less losses of fertilizer. They can potentially increase the efficiency of N use, bus still substantial gaps in research and are more expensive.

	Application of nitrification inhibitors	N2O	Medium	Low	Medium	Compounds added to fertiliser that prevent the turnover of ammonia into nitrate and lead to a decrease of fertilizer use or a higher N uptake. Substantial research gaps
	Improved management (appropriate timing avoiding leaching risk periods, split of application)	N2O	Medium	Low (if there no opportunity cost from output loss)	Medium	To split applications needs increased labour and machinery use.
Infrastructure (animal housing)	Livestock housing straw to slurry–based	N2O,CH4	Low/Medium	Increased costs	High	Not recommended as negative effects for animal welfare
	Natural ventilation of animal housing	NH3, CH4, CO2	Medium	Decreased energy costs, low investment costs	Medium	
	Cages and aviaries instead of floor system for layer hens	NH3, N2O	Medium	Decreased	High	Unenriched cages not recommended because unacceptable for animal welfare reasons and to be phased out by 2012 according to Council Directive 1999/74/EC on the protection of laying hens.
	Use of bedding material in livestock housing	NH3, N2O	Medium	Decreased	High	
	Increased grazing periods, summer half day grazing system in comparison with year-round animal housing	NH3, N2O,CH4	Medium	Medium	Medium/High	High variability of feasibility, according to regional and farm land resources
	Phase feeding systems for pigs (according to their age class)	CH4	Medium/High	Decreased costs as greater efficiency of feed use	High	
Animal, breeding	Genetic improvement to improve feed efficiency	CH4	High	High research and farm costs	Medium	This is only a long-term measure with potential negative implications for animal welfare
Land and soil management	Conservation agriculture-No tillage (minimal soil disturbance)	CO2 (carbon fixation and energy savings), (N2O)	Medium/high	High (at least during the conversion period)	Medium/High (but variable)	These cultivation methods are often associated with the use of permanent soil cover (cover/catch crops, mulches), and diversified crop rotations/ crop combinations to control weeds and pests.

Conservation agriculture-Reduced tillage	CO2 (carbon fixation), (N2O)	Medium/high	Medium (at least during the conversion period)	High	Capital cost of buying or hiring new equipment. Potential for opportunity cost of lost production in areas less suited to reduced tillage. Significant GHG reductions due to energy savings and increased accumulation of carbon. Farmers need extensive training and access to specific advisory services
Cover crops (temporary vegetative cover between two main crops)	CO2 (carbon fixation), (N2O)	Low	No / low	High	Positive environmental effects: improvement soil structure and nitrate absorption, reducing leaching
Residue management (no removal)	N2O	Medium/high	No / low	High	Benefits water conservation, soil quality, biodiversity. It may conflict with efforts to use residues as biomass for energy production
Adding nitrogen-fixing leguminous crops (e.g., lucerne, beans, peas, clover) to rotations	CO2 (carbon fixation), N2O	High	No / low	High	The measure is a low cost practice (legume seed and opportunity cost if this lead to a reduction of a more profitable crop). Generally, it increases productivity as reduces fertilizer needs
Management of organic soils (peatland)	CH4, CO2	Medium/high	High	Medium	Opportunity cost of abandoning cropping, small cost of drain blocking
Permanent set-aside	CO2, N2O	Medium/high	Medium/high (opportunity cost from output loss)	Low	The overall implications for the large GHG balance need to be considered as set aside may lead to intensification on other parts of the land and in some cases may cause currently non-agricultural systems to be brought in to production. Field strips or extended field margins, can have some benefits for mitigation and also biodiversity while having less impact in terms of lost production.
Agro-Forestry systems (combining annual and permanent crops or trees)	CO2	Medium/high	Medium	Medium	Costs involve: opportunity cost of lost production and cost of trees. It can improve biodiversity (depending on the permanent crop)

[1] This table shows some possible technical and management solutions for reducing farming GHG emissions and maintain and enhancing carbon stocks. The mitigation potential, costs, technical feasibility of these options are only indicative as there are significant spatial disparities according to the types of soils, climate, farm characteristics and other factors.

[2] NH_3 (ammonia) is not a GHG but an important polluting gas closely linked to livestock activities and a source of additional GHG emissions.

Source: EU-funded projects MEACAP-Impact of Environmental Agreements on the CAP and PICMAT- Policy Incentives for Climate Change Mitigation Agricultural Techniques. These projects have assessed the mitigation potential of a range of measures on the basis of case studies and expert knowledge. Outcomes from project SOCO (Sustainable Agriculture and Soil Conservation), carried out by Commission services, have also been used. This project has assessed a range of soil conservation practices also from the perspective of keeping organic matter.