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Agricultural GHG emissions in the EU: an exploratory economic assessment of mitigation policy options

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Thomas Fellmann

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Foreword

This report provides a quantitative assessment of possible implications of the implementation of specific policy options to mitigate agricultural greenhouse gas (GHG) emissions in the EU. The mitigation policy scenarios proposed and analysed within this report are all exploratory, i.e. it is intended to explore what could happen if policies would be implemented that explicitly force farmers in the EU to reach certain GHG emission reduction targets. It has to be stressed that all policy scenarios are rather theoretical and hypothetical and do not necessarily reflect mitigation policies that are already agreed on, or are under formal discussion.

The report forms part of the project "Development of Quantitative Tools for the Economic Analysis of Greenhouse Gas Emissions in Agriculture (CAPRI-ECC Project)" (Contract IPTS No 151467-2009 A08/NL) initiated and carried out by the European Commission's Joint Research Centre - Institute for Prospective Technological Studies (JRC-IPTS, Spain) in cooperation with the Agricultural Economics Research Institute (LEI, the Netherlands), EuroCARE (Germany), the Swedish University of Agricultural Sciences (SLU, Sweden) and the collaboration of the von Thünen Institute (vTI, Germany).

Some of the policy scenarios presented in this report were also conducted in course of the study "Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS)", commissioned by the European Commission's Directorate-General for Agriculture and Rural Development (DG AGRI).[1] However, the CAPRI model used for the study has been further elaborated and some of the policy scenarios have been adjusted. Thus, results presented in the report at hand differ from those in the GGELS report.

We particularly thank Franz Weiss and Adrian Leip (both Joint Research Centre - Institute for Environment and Sustainability, Italy) for their detailed and valuable comments as well as different types of technical support. Special thanks also to Alison Burrell for many detailed and valuable comments. Furthermore we are grateful for the thorough review and constructive comments we received during the GGELS project from the members of the advisory board and of the steering group of the project: Maria Fuentes (DG AGRI.H04), Joao Silva (DG AGRI.H04), Zoltan Rakonczay (DG ENV.B01), Luisa Samarelli (DG ENV.B01), Myriam Driessen (DG AGRI.H04), Jana Polakova (DG ENV.B01), Christel Cederberg (Swedish Institute for Food and Biotechnology, Sweden), Pierre Gerber (FAO, Italy), Stanislav Jas (Copa-Cogeca, Organization of the European Farmers and European Agri-Cooperatives, Belgium), Ceris Jones (National Farmers Union, UK), Liam Kinsella (Department of Agriculture, Fisheries and Food, Irish Government, Ireland), Søren O. Petersen (Aarhus University, Department of Agroecology and Environment, Denmark), Frank O'Mara (Teagasc, Agriculture and Food Development Authority, Ireland), Henk Westhoek (Netherlands Environmental Assessment Agency, The Netherlands). We would also like to thank all people behind the CAPRI network, since this exercise would not have been possible without many people keeping different modules up-to-date and providing useful technical feedback through the 'capritalks' distribution list.

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[1] Leip, A., F. Weiss, T. Wassenaar, I. Perez, T. Fellmann, P. Loudjani, F. Tubiello, D. Grandgirard, S. Monni, K. Biala (2010): Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS). European Commission, Joint Research Centre, Brussels. http://ec.europa.eu/agriculture/analysis/external/livestock-gas/index_en.htm

Sole responsibility for remaining shortcomings of this report rests, of course, with the authors.

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Acronyms

AD	Activity Data
AMMO	Ammonia Emission Abatement Techniques
BALF	Balanced Fertilization
CAC	Command and control
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regional Impact Analysis
CDM	Clean Development Mechanism
CEIP	Centre on Emission Inventories and Projections
CGE	Computable General Equilibrium
CH4	Methane
CMO	Common Market Organisation
CO2	Carbon Dioxide
CO2-eq	Carbon Dioxide equivalent
COP	Conference of the Parties
CPI	Consumer Price Index
DDA	Doha Development Agenda
DG AGRI	Directorate General 'Agriculture and Rural Development'
DG CLIMA	Directorate General 'Climate Action'
DG ECFIN	Directorate General 'Economic and Financial Affairs'
DG ENV	Directorate General 'Environment'
EC	European Commission
ECC	Economics of Climate Change
EDGAR	Emissions Database for Global Atmospheric Research
EF	Emission Factor
EMEP	European Monitoring and Evaluation Programme
ENECE	United Nations Economic Commission for Europe
ESA	Effort Sharing Agreement
ESAA	Effort Sharing Agreement for Agriculture (hypothetical scenario)
ESD	Effort Sharing Decision
ESIM	European Simulation Model
ETS	Emission Trading System
ETSA	Emission Trading System for Agriculture (hypothetical scenario)
ETSBL	Scenario with ETSA, Balanced Fertilization and Low Nitrogen Feed
EU	European Union
EU-12	12 EU Member States of the 2004 and 2007 enlargements
EU-15	15 EU Member States before May 2004
EU-2	2 EU Member States of the 2007 enlargement (Bulgaria and Romania)
EU-25	25 EU Member States after 2004 enlargement
EU-27	27 EU Member States after 2007 enlargement
FAO	Food and Agriculture Organization of the United Nations
FAPRI	Food and Agricultural Policy Research Institute, USA
GDP	Gross Domestic Product

GGELS	Greenhouse Gas Emissions from Livestock Systems (EU Project)
GHG	Greenhouse Gas(es)
IES	Institute for Environment and Sustainability
ILUC	Indirect Land Use Change
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPTS	Institute for Prospective Technological Studies
JI	Joint Implementation
JRC	Joint Research Centre
KP	Kyoto Protocol
LCA	Live Cycle Assessment
LNF	Low Nitrogen Feed
LTAX	Livestock Emission Tax (hypothetical scenario)
LUC	Land Use Change
MAC	Marginal Abatement Cost
MS	Member State(s)
MTR	Mid-Term Review
N	Nitrogen
N2O	Nitrous Oxide
NEC	National Emission Ceilings
NECD	National Emission Ceiling Directive
NH3	Ammonia
NIR	National Inventory Reports
NMS	New Member States (=EU-12)
NREAP	National Renewable Energy Action Plans
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Co-operation and Development
PE	Partial Equilibrium
PRIMES	PRIMES Energy System Modelling
REF	Reference scenario (baseline)
SAPS	Single Area Payment Scheme
SFP	Single Farm Payment
SMP	Skimmed Milk Powder
STD	Emission Standard (hypothetical scenario)
TRQ	Tariff Rate Quotas
TSAP	Thematic Strategy on Air Pollution
UAA	Utilized Agricultural Area
UNFCCC	United Nations Framework Convention on Climate Change
USD	U.S. Dollar
USDA	U.S. Department of Agriculture
WMP	Whole Milk Powder
WTO	World Trade Organization

Executive Summary

Background

The Kyoto Protocol legally binds developed countries that signed the protocol to greenhouse gas (GHG) emission reduction targets. The first commitment period of the Kyoto Protocol started in 2008 and ends in 2012. Independent of a possible future multilateral agreement on the reduction of GHG emissions, the European Union (EU) made an unilateral commitment to cut its GHG emissions by at least 20% of 1990 levels by 2020. This commitment is implemented through a package of binding legislation. The EU has also offered to increase its GHG emissions reduction to 30% by 2020, on the condition that other major emitting countries (developed and developing) commit themselves to comparable emission reductions under a future global climate agreement. In the EU climate and energy package of 2009 a decision was taken to distribute the 20% reduction obligation for the EU-27 to Member States (under the Effort Sharing Decision, ESD) and industry (under the Emission Trading Scheme, ETS). The agricultural sector, as non-CO2 emitter, was included under the ESD and, therefore, excluded from the ETS (c.f. Council of the European Union, 2009).

The agricultural sector is specifically covered under the Kyoto Protocol (with respect to non-CO2 emissions), but GHG emission reduction targets are specific for countries, not sectors and thus so far there is no legal need for a sectoral approach on agriculture for developed countries. With regard to the ESD in the EU, Member States have binding GHG emission abatement targets that also include agriculture. However, up to now no explicit policy measures are implemented that would specifically force GHG emission abatement in the agricultural sector.

Agricultural GHG emissions account for almost 14% of global emissions and the agricultural sector is especially a large contributor of non-CO2 GHG emissions, namely methane from ruminants and nitrous oxide from fertilizer application and management. According to GHG inventories of the EU Member States, GHG emissions in the agriculture sector represent 9.2% of total EU emissions, with methane and nitrous oxide accounting for around 5% and 4.3% of total EU GHG emissions respectively (European Commission, 2009). In general, the contribution of the agricultural sector to climate change is gaining more and more visibility and therewith interest is growing on policy options to reduce agricultural GHG emissions (FAO 2006; Smith et al. 2007; FAO 2010). To design reasonable mitigation policies it is important to understand the impact of such policies on GHG mitigation on the one hand and agricultural production and trade on the other hand.

Scope of the report

The main objective of this report is to assess the GHG emission reduction potential of a selected number of policy options and to quantify related production and economic impacts for the agricultural sector in the EU. Therefore the possible future evolution of agricultural GHG emissions in the EU are assessed through the simulation of scenarios including expected macro- and micro-economic changes. *The proposed mitigation policy scenarios are all exploratory*, i.e. it is intended to explore what could happen if policies would be implemented that explicitly force farmers in the EU-27 to reach certain

GHG emission reduction targets. It has to be stressed that all policy scenarios are rather theoretical and hypothetical and do not necessarily reflect mitigation policies that are already agreed on, or are under formal discussion.

Specification of the modelling approach

In order to quantify GHG emissions in the agricultural sector as well as production and economic impacts linked to mitigation of GHG emissions the CAPRI (Common Agricultural Policy Regional Impact Analysis) modelling system was adjusted and applied. CAPRI is an economic large-scale comparative-static agricultural sector model with a focus on EU-27, but covering global trade of agricultural products as well.

CAPRI consists of two interacting modules: the supply module and the market module. The supply module consists of about 270 independent aggregate optimisation models representing all regional agricultural activities (28 crop and 13 animal activities) in a Nuts 2 region within the EU-27. The market module consists of a spatial, non-stochastic global multi-commodity model for 40 primary and processed agricultural products, covering 40 countries or country blocks. The behavioural functions for supply, feed, processing and human consumption in the market module apply flexible functional forms, so that calibration algorithms ensure full compliance with micro-economic theory. The link between the supply and market modules is based on an iterative procedure. The regional supply models in CAPRI capture links between agricultural production activities in detail. The modelling system was adapted to be able to calculate activity based agricultural emission inventories. Based on the differentiated lists of production activities, inputs and outputs define GHG emission effects of agriculture in response to changes in the policy or market environment. CAPRI also incorporates a detailed nutrient flow model per activity and region, including explicit feeding and fertilizing activities, i.e. balancing of nutrient needs and availability. With this information, CAPRI is able to calculate endogenously GHG emission coefficients following the 2006 IPCC guidelines (mostly Tier 2). Furthermore the optimization structure of the supply module enables CAPRI to conduct detailed mitigation policy scenarios for the EU-27 regional aggregate (i.e. emission limits introduced as constraints within the existing non-linear optimization framework).

Within this project the CAPRI model was also adjusted to account for emission leakage, i.e. the indirect effect on emissions in non-EU countries induced by a GHG emission abatement policy implemented in the EU. For determining the emission leakage effects, commodity-based emission factors needed to be calculated, because in CAPRI, production outside EU takes place by commodity, not by production activities. The computation of such coefficients (and the subsequent computation of leakage) can be split into three steps: (1) Compute commodity specific emission factors in the EU based on the activity based accounting. The methodology used is related to input-output-modelling techniques, and delivers coefficients per commodity that compare very well with the activity based ones in aggregate. (2) Estimate GHG coefficients for non-EU countries, based on GHG inventories, production and EU coefficients. (3) In the simulation scenarios: re-application of step 1 to account for changes in activity levels and production technology in the EU in each scenario.

Scenario overview

To assess the possible future evolution of agricultural GHG emissions in the EU several scenarios have been constructed. The reference scenario (also called baseline) serves as comparison point in the year 2020 for counterfactual analysis of all other scenarios. The core of the scenarios is about GHG emission mitigation policy scenarios; however we also conducted some complementary technological abatement scenarios.

Reference and mitigation policy scenarios

The GHG emission mitigation policy scenarios are all characterised by a target of 20% GHG emission reduction in the year 2020 compared to EU-27 emissions in the year 2004 (three-year average of 2003-2005). The policy scenarios comprise an emission standard (emission standard with a regionally homogeneous cap), a specific effort sharing agreement for agriculture (emission standard with regionally differentiated caps based on the EU effort sharing decision), a specific emission trading scheme for agriculture (regionally homogenous cap, with trade in emission rights at regional and EU-wide level) and a tax on livestock emissions (regionally homogenous taxes per tonne of CO$_2$ equivalent livestock emissions).

Scenario acronym	Scenario Name	Policy Instrument	GHG abatement
REF	Reference Scenario	No specific policy measures implemented for GHG emission abatement in agriculture	Trend-driven
STD	Emission Standard Scenario	Emission standard with a regionally homogeneous cap (no trade in emission rights)	20% reduction with respect to EU-27 emissions in the year 2004
ESAA	Effort Sharing Agreement for Agriculture Scenario	Emission standard with heterogeneous emission caps per MS based on the EU effort sharing decision (ESD +8.7%, no trade in emission rights)	
ETSA	Emission Trading Scheme for Agriculture Scenario	Tradable emission permits (regionally homogenous cap, with trade in emission rights at regional and EU-wide level)	
LTAX	Livestock Emission Tax Scenario	Tax on livestock emissions (regionally homogenous taxes of 229 € per tonne of CO2 equivalent livestock emissions, independent from animal type)	

Complementary technological abatement scenarios

Due to restrictions in the CAPRI model, the mitigation policy scenarios do not consider technological responses to policy measures, like for example farmers adapting their stables or livestock keeping methods in order to respond to the mitigation policies imposed. To get an idea of the magnitude of the effects that technological

Scenario acronym	Scenario Name	Technological abatement measures	GHG abatement
AMMO	Ammonia Measures Scenario	Combination of various measures targeting ammonia (stable adaptation, covered manure storage, bio filtration, low ammonia application of manure, urea substitution by ammonia nitrate, incineration of poultry manure)	No predefined abatement target (effects on GHG emissions are a scenario outcome)
BAL	More Balanced Fertilization Scenario	More efficient (organic and mineral) fertilizer management	
LNF	Low Nitrogen Feeding Scenario	Lower nitrogen content in feed, decrease in the uptake of nitrogen and therefore decrease in the possible losses of N2O	
ETSBL	Combination of BAL, LNF and ETSA Scenario	Introduction of the measures for a more balanced fertilization (BAL Scenario) and low nitrogen feeding (LNF Scenario) into the Emission Trading Scheme for Agriculture	20% reduction compared to 2004

changes may have on GHG emissions, we also assess some complementary technological abatement scenarios where the changes in production technology are pre-defined (i.e. not endogenously calculated by the CAPRI model). We selected three technological abatement scenarios: a combination of various technological measures that actually target ammonia emissions, a more balanced fertilization, and low nitrogen feeding. To get also an idea on the effects that the technological abatement measures would have in combination with the emission mitigation policies, we run one scenario where we introduce the measures of a more balanced fertilization and low nitrogen feeding into a scenario with an emission trading scheme for agriculture.

Summary of the reference scenario results

The baseline serves as a reference for the policy simulations and is meant to provide a consistent view on the likely evolution of the agricultural markets over the projection period under a specific set of assumptions about exogenous drivers. The CAPRI baseline for this study assumes status quo policy and includes all future policy changes already agreed and scheduled in the current legislation (based on the information available at the end of November 2010). Hence, the reference scenario incorporates a full implementation of the Health Check and the EU biofuels directive, as well as the sugar and milk market reform. However, although the agricultural sector is included in the GHG emission reduction obligation of the climate and energy package of 2009, no explicit policy measures are considered for GHG emission abatement in the reference scenario[2].

Projection results show that total GHG emissions (in CO2 equivalent) in the EU-27 would decline by 3% from the 2003-2005 base period to the projection year 2020. The overall decrease in GHG emissions is due to a decrease in methane emissions (-16.7%), while nitrous oxide emissions are projected to increase by 7.2%[3]. For the EU-15 the reduction of methane emissions in the reference scenario is projected at 13.2%, with highest reductions achieved in Sweden (-32.9%), Denmark (-26.1%) and Germany (-23.8%) whereas the Netherlands are projected to be the only EU-15 MS increasing methane emissions (+0.8%). The EU-10 and Bulgaria/Romania are projected to experience methane emission reductions of 36.8% and 32.5% respectively, with Malta (+5.5%) and Cyprus (+0.4%) being the only EU-12 MS showing an increase in methane emissions. The increases in emissions of nitrous oxide are projected to be +14% for the EU-10, +17% for Romania/Bulgaria and +5% for the EU-15, with Slovenia, Greece, Finland and Denmark being the only MS with decreases in nitrous oxide emissions.

The general emission reduction at EU level is mostly based on emissions linked to ruminants (methane from digestion and manure management and nitrous oxide from grazing, due to emission of ammonia and atmospheric deposition). These emission reductions can therefore mostly be attributed to the reduced policy incentives for beef cattle and sheep/goats after the conversion of coupled supports for beef production into (mainly) decoupled payments, and the reform in the dairy market. The adjustments in emissions are generally larger in the EU-12 compared to EU-15. Crop yields continue to grow moderately, provoking an increase in emissions linked to crop residues, and to lesser extent, to the application of mineral nitrogenous fertilizers. That the latter contributes to a lesser extend to emission increases can be attributed to a more efficient use of both organic and mineral fertilizers.

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[2] While EU Member States actually have binding GHG emission abatement targets that also include agriculture, there are so far no explicit policy measures implemented that would specifically force GHG emission abatement in the agricultural sector. Consequently, no explicit policy measures for GHG emission abatement are considered in this reference scenario.

[3] It is assumed in CAPRI that by 2020 stable adaptation gains in importance as an ammonia emission reducing technique. This technique has the side effect of causing an increase in the emissions of nitrous oxide.

Summary of the GHG mitigation policy and complementary technological abatement scenarios

While the complementary technological abatement scenarios are not aiming at a predefined abatement target, the defined GHG emission abatement policy scenarios could all be designed to almost achieve the reduction goal of 20% emission reduction in the EU-27 compared to the reference year 2004 (three year average 2003-2005). A small error margin was tolerated for under- or overachievement of the reduction goal.

The GHG emissions reduction effect per Member State is quite different from the EU-27 average in each scenario, depending on the one hand on the countries' emission developments in the baseline (i.e. without additional measures), and on the other hand on the production level and the composition of the agricultural activities. In the policy scenarios, GHG emission reductions are generally bigger in the EU-15 than in the EU-12, which is not surprising as the EU-15 have shown generally less GHG emission decreases in the baseline projections than the EU-12, and thus have to reduce relatively more to meet the reduction obligation. On aggregate, the EU-15 MS reduce emissions most under a specific effort sharing agreement for agriculture, whereas in this scenario the reduction obligations for the EU-12 would be lowest (with some MS being allowed to even increase their emissions compared to the reference scenario). The changes in GHG emissions (in CO2 equivalent) per EU Member State according to each scenario are presented in Table 1.

Table 1. Changes in GHG emissions per EU Member State according to each scenario

Changes in agricultural GHG Emissions (CO2 equivalents), 2020									
	[% to BAS]	[% to REF]							
	REF	STD	ESAA	ETSA	LTAX	AMMO	BALF	LNF	ETSBL
Austria	-5,6	-14,8	-19,9	-12,6	-17,4	6,4	-1,8	-1,4	-12,0
Belgium_Lux	-2,8	-15,9	-19,8	-13,6	-20,7	1,7	-3,4	-2,8	-14,5
Denmark	-11,3	-8,5	-18,5	-10,7	-18,0	4,3	-3,6	-2,3	-14,5
Finland	-5,6	-15,2	-20,2	-29,0	-8,2	1,1	-2,7	-0,8	-25,8
France	-3,6	-16,4	-19,2	-12,4	-15,8	5,8	-4,0	-1,7	-13,4
Germany	-6,4	-14,3	-17,1	-11,5	-12,6	0,2	-3,8	-1,2	-12,6
Greece	-6,0	-14,3	-6,9	-11,8	-14,2	3,0	-8,5	-1,3	-15,9
Ireland	0,3	-19,9	-28,6	-24,8	-29,7	-1,1	-2,5	-0,5	-20,0
Italy	0,3	-19,6	-21,3	-11,8	-16,9	2,3	-2,8	-1,9	-12,1
Netherlands	0,8	-19,4	-24,2	-8,5	-11,6	-0,1	-3,7	-2,4	-11,7
Portugal	-3,9	-16,2	-4,5	-22,0	-27,1	5,9	-4,2	-2,0	-20,3
Spain	7,5	-24,8	-23,7	-21,4	-24,5	6,1	-6,3	-2,3	-21,0
Sweden	-10,4	-10,5	-16,9	-16,6	-11,4	0,0	-3,4	-1,8	-17,1
United Kingdom	-3,4	-16,5	-21,4	-32,6	-21,3	0,9	-3,3	-0,6	-28,1
EU-15	-2,7	-17,2	-20,3	-17,6	-17,9	2,7	-3,8	-1,5	-17,2
Cyprus	16,2	-30,2	-24,6	-7,7	-9,0	5,3	-6,3	-12,5	-23,3
Czech Republic	-17,5	-1,6	2,7	-11,8	-12,7	2,1	-9,1	-1,5	-17,8
Estonia	-16,0	-3,3	2,3	-16,1	-13,0	1,4	-7,0	-3,2	-20,3
Hungary	2,5	-21,3	-1,8	-11,9	-8,8	4,5	-5,3	-2,1	-15,1
Latvia	-9,1	-10,5	2,3	-25,9	-13,2	2,4	-6,7	-2,0	-24,3
Lithuania	-10,0	-9,5	1,1	-14,1	-8,3	2,3	-4,8	-1,5	-15,6
Malta	7,5	-24,3	-9,0	-7,4	-10,7	0,2	-3,8	-5,5	-12,6
Poland	1,3	-20,4	-1,3	-13,0	-13,4	2,2	-5,9	-1,6	-15,4
Slovenia	-14,6	-5,4	3,1	-11,7	-17,1	5,9	-10,2	-1,5	-19,8
Slovak Republic	-15,7	-4,4	2,7	-4,9	-8,2	1,5	-6,6	-2,2	-11,5
EU-10	-3,4	-16,3	-0,5	-12,9	-12,2	2,6	-6,3	-1,8	-16,0
Bulgaria	-5,6	-14,2	1,7	-14,3	-13,8	0,0	-5,2	-2,7	-15,7
Romania	-8,5	-11,7	0,9	-11,7	-15,3	0,0	-6,9	-2,3	-15,3
Bulgaria/Romania	-7,8	-12,3	1,1	-12,3	-15,0	0,0	-6,5	-2,4	-15,4
EU-27	-3,0	-16,8	-16,8	-16,8	-17,1	2,5	-4,3	-1,6	-17,0

Table 2. Change in EU-27 emissions per inventory position according to each scenario

	Changes in emissions per inventory position (2020)								
	[% to BAS]	[% to REF]							
	REF	STD	ESAA	ETSA	LTAX	AMMO	BALF	LNF	ETSBL
Methane emissions from enteric fermentation (IPCC)	-17,3	-18,8	-19,4	-17,5	-26,1	-0,4	0,1	0,8	-11,0
Methane emissions from manure management (IPCC)	-12,7	-15,1	-16,0	-13,1	-20,3	-1,5	0,1	0,5	-8,5
Methane emissions	-16,7	-18,4	-19,0	-17,0	-25,4	-0,5	0,1	0,8	-10,7
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	22,6	-13,7	-13,0	-11,7	-18,1	18,6	-0,1	-4,2	-11,9
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	-5,2	-23,9	-25,2	-23,8	-33,4	-0,5	0,2	-4,9	-19,5
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	3,5	-17,0	-14,6	-14,4	-2,5	-2,4	-23,7	-1,8	-32,8
Direct nitrous oxide emissions from crop residues (IPCC)	11,4	-17,1	-16,1	-15,9	-10,4	-0,2	0,6	-2,3	-12,3
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	55,6	-17,4	-18,9	-15,9	-14,6	-0,2	-7,6	-6,9	-23,3
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	-4,1	-9,0	-9,5	-8,7	-3,8	-0,1	-0,3	-0,8	-6,9
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	-6,4	-14,2	-12,8	-11,9	-14,4	-9,3	-4,5	-4,2	-15,7
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	3,6	-16,3	-15,0	-16,0	-16,5	-6,3	-21,4	-6,8	-36,5
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	-2,4	-14,4	-17,2	-30,5	-5,2	-0,0	-0,3	-0,6	-25,6
Nitrous oxide emissions	7,2	-16,0	-15,5	-16,7	-12,3	4,3	-6,8	-3,0	-20,6
Carbon dioxide equivalent	-3,0	-16,8	-16,8	-16,8	-17,1	2,5	-4,3	-1,6	-17,0

The detailed accounting of methane and nitrous oxide sources in Table 2 shows that the mayor savings in all scenarios come from the key sources of agricultural GHG emissions, namely enteric fermentation, losses from mineral fertilizer application, and manure management and application. As in the livestock emission tax scenario the 20% emission reduction burden is put entirely on livestock, this results in the biggest reductions in the beef cattle sector (with regard to animal numbers and production) and consequently also in the biggest reductions in methane emissions from enteric fermentation and nitrous oxide emissions from manure management and application.

Among the four ‘pure’ mitigation policy scenarios, nitrous oxide emissions from the application of mineral fertilizer are reduced most in the emission standard scenario. This is also the scenario with the biggest decline in cereals production at EU-27 level. The additional technological measures introduced in the ETSBL scenario help to significantly reduce the losses from mineral fertilizer application compared to the ‘pure’ emission trading scenario ETSA.

In all scenarios most of the adjustments to the policy measures is attained with lower activity levels. Following the decrease in supply (i.e. less production units) and the resulting increase in producer prices in the EU-27, the agricultural sector increases its income per production unit in the mitigation policy scenarios. However, the increase in income per production unit might not compensate for the reduction in quantities (cf. Table 3).

Table 3. Changes in EU-27 income, production, herd size and area according to each scenario

Activity aggregate		% change to REF STD	ESAA	ETSA	LTAX	AMMO	BALF	LNF	ETSBL
Dairy cow sector	Production	-4	-4	-3	-5	0	0	0	-2
	Herd size	-4	-3	-3	-6	0	0	0	-2
Beef sector	Production	-12	-12	-10	-16	0	0	1	-13
	Herd size	-28	-29	-29	-39	-1	0	2	-23
	Income per head (Euro)	137	145	133	271	-4	2	-5	72
Cereals sector	Production	-12	-10	-9	-4	0	0	0	-5
	Crop area	-12	-8	-9	-1	0	0	1	-6
	Income per ha (Euro)	20	15	15	-12	0	-5	-1	5
UAA	Area	-7	-7	-8	-3	0	0	0	-6
	Income per ha (Euro)	14	13	13	12	0	-1	0	10

In all scenarios the largest deceases in agricultural activity are projected to take place in beef meat activities. Beef herd sizes decrease significantly more than beef production, implying a more intensive production per production unit (high yielding beef activities are increased at the expense of low yield activities). As could be expected, production in the beef meat sector decreases most in the scenario with the livestock emission tax. With a reduction of the beef herd size by 39% and a decrease of 16% in production, income per head beef cattle increases considerably. However, the introduced livestock emission tax is the only scenario that has also adverse effects on income per ha cereals due to the strongest demand decrease for feed. EU-27 beef production would be least affected in the policy scenario with an emission trading system (due to less decrease in EU-15 beef meat production), whereas in the scenario with the specific effort sharing agreement for agriculture the overall effect on beef production would be mitigated by increases in beef meat production in the EU-12.

Changes in the dairy cow sector are between -2% and -6% at EU-27 level in all mitigation policy scenarios, and hence rather small compared to the developments in the cattle sector. This is related to the relative competiveness of the dairy sector compared to the beef cattle sector, which implies that GHG emission reduction costs per production unit are higher in the dairy cow than in the cattle sector, i.e. milk production is more profitable than beef production and hence it is less costly to reduce beef cattle production in order to achieve the GHG mitigation obligations in the scenarios.

The EU-27 cereal sector would be most affected by an emission standard, with reductions in production being higher in the EU-12 (-15%) than in the in the EU-15 (-12%). In the scenario with the specific effort sharing agreement for agriculture, the overall effect on cereal production would be smaller because the higher reductions in the EU-15 (-14%) would be partially compensated by more production in the EU-12, which shows almost no change in the ESAA scenario compared to baseline projections. In the scenarios with an emission trading system, cereal production in the EU-15 would also be less affected than in the EU-12. A livestock emission tax generally affects the cereal sector least in terms of overall production, as the production surplus that arises from decreased feed demand would be exported. However, with respect to income, the livestock emission tax is the only mitigation policy scenario where a decrease in income per ha cereals is projected.

Effects of introducing emission leakage into the scenario analysis

All GHG mitigation policy scenarios show an impact on agricultural production in the EU. The changed production in the EU influences prices, production and trade also in other regions of the world, thereby indirectly also affecting the global GHG emissions. Thus, any GHG emission reduction achievement in the EU could be diminished in terms of its global impact due to emission leakage, i.e. a shift of GHG emissions from the EU to the rest of the world. For determining the emission leakage effects, the commodity based emission factors developed in this study were applied to the change in global production.

The analysis on emission leakage reveals that all GHG emission mitigation policies in the EU induce increased emissions in the rest of the world. However, the effect on emissions outside of the EU is different depending on the way in which the emission abatement in the EU is achieved. In the LTAX scenario, the tax on livestock emissions in the EU induces an increase of about 25 million tonnes of CO2 equivalents outside the EU, which is 10 million tonnes more than in the ETSA scenario, and even three times the 8.2 million tonnes of CO2 equivalent in the ETSBL scenario, where a tradable emission permit scheme for agriculture is combined with the technological abatement measures of a more balanced fertilization and low nitrogen feeding (cf. Table 4).

Table 4. GHG emissions (MMt CO2eq) and emission reductions (%) (2020 compared to the base year (2004)

	BAS	REF	STD	ESAA	ETSA	LTAX	AMMO	BALF	LNF	ETSBL
Total GHG emissions EU-27	460	446.2	371	371.4	371.3	370	457	427	439	370
% reduction to BAS (2004)		-3,0	-19,3	-19,3	-19,3	-19,6	-0,7	-7,2	-4,6	-19,6
Net increase in emission in the rest of the world due to emission leackage			16.7	17.1	14.6	25.6	0.3	-0.1	0.1	8.3
% reduction to BAS (2004)		-3,0	-15,7	-15,5	-16,1	-14,0	-0,6	-7,2	-4,5	-17,8

A look into the detailed accounting of methane and nitrous oxide emissions per inventory position reveals that the main explanation for the differences between the scenarios should be found in the ruminant sector, since the difference between the scenarios with regard to GHG emission changes outside the EU is most strongly influenced by the difference in methane emissions from enteric fermentation. In the livestock emission tax scenario, some of the reduction in EU beef meat production is replaced by imports from primarily Mercosur countries such as Brazil and Argentina, where the estimated emission factors per tonne of beef are higher than those of the EU (0.74 kg CH4 from enteric fermentation per kilo beef produced in Argentina as opposed to 0.43 in the EU). In the other scenarios, the GHG emission abatement is spread across more agricultural sectors, where imported substitutes have emission factors that are smaller than or more similar to the EU emission factors.

The results indicate that from a global GHG emission abatement point of view, the tradable emission permit policy is most efficient for reducing global GHG emissions (this is because it allocates the emission abatement within the EU-27 according to where it costs least to achieve), whereas the livestock emission tax is the least efficient (because it does not discriminate according to the potential for reducing emissions and loads the adjustment cost onto just one production factor). Combining the ETSA scenario with technical measures as balanced fertilization and low nitrogen feed is even more efficient. In the combined ETSBL scenario the use of low nitrogen feed contributed to a slower decrease in number of animals. Therefore the shift of methane emission is less than in the other policy scenarios and the emission of nitrous oxide from manure management and application is lower. In addition, the more balanced fertilization contributes to a decrease in the use of mineral fertilizer which in turn reduces also indirect emission of nitrous oxide compared to the other policy scenarios.

Concluding remarks

When looking at the results of the 'pure' emission mitigation policy scenarios it has to be kept in mind that technological responses to the GHG mitigation policy measures, like the adaptation of stables or livestock keeping methods, are not considered. As a consequence, the system responds only in form of price and production quantity changes, i.e. farmers react to the mitigation policies only by adjusting their production (e.g. by decreasing the number of cows or their production intensity) but not their production management techniques. However, in reality it is very likely that farmers would also try to reduce their GHG emissions by changing their production techniques (i.e. using technical measures like introducing low-nitrogen feeding, covering of manure storage, or switching to minimum tillage or no-till techniques).

With the complementary technological abatement scenarios, where the changes in production technology are pre-defined (i.e. not endogenously calculated by the CAPRI model), we tried to at least partially tackle this limitation. The complementary technological abatement scenarios help to get an idea of the magnitude of the effects that technological changes may have on agricultural GHG emissions. Furthermore, by introducing the measures of a more balanced fertilization and low nitrogen feeding into the scenario with an emission trading scheme for agriculture, we reveal that changes in production techniques certainly alter the results of the mitigation policy scenarios.

Even though the study is limited with respect to technological responses to policy measures, the scenario results provide valuable insights for policy making, as they clearly reveal the differences of how the specific mitigation policy instruments impact on the one hand the GHG emissions per EU Member State and on the other hand production, cost-effectiveness and income redistribution within the agricultural sector. To this end, the estimates provided can feed the discussion on the feasibility of (further) integrating the agricultural sector in multi-sectoral emission abatement policies currently in place or under consideration.

1 Introduction

1.1 Background

The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty that countries joined to cooperatively consider what they could do to limit average global temperature increases and the resulting climate change, and to cope with whatever impacts were, by then, inevitable. The UNFCCC sets the ultimate objective of stabilising GHG concentrations 'at a level that would prevent dangerous human induced interference with the climate system' (cf. UNFCCC, 1992). In 1995, counties launched negotiations to strengthen the global response to climate change with respect to emission reduction provisions. The outcome of these negotiations was the Kyoto Protocol, adopted in 1997. The Kyoto Protocol legally binds developed countries that signed the protocol to emission reduction targets. The first commitment period of the Kyoto Protocol started in 2008 and ends in 2012. As an outcome of the 15th session of the Conference of Parties (COP 15) to the UNFCCC in December 2009, the continuation of the Kyoto Protocol was endorsed in the Copenhagen Accord, signed by 138 countries in January 2010. Furthermore, it was recognised that the rise in global temperatures should be limited to no more than 2 degrees Celsius beyond pre-industrial levels. Even if not legally binding, the Copenhagen Accord includes for the first time the signature of the five main GHG emitters in the world (US, China, Russia, India and the EU) and established the reference for a future agreement (cf. UNFCCC, 2010).

Independent of a possible future multilateral agreement on the reduction of GHG emissions, the European Union (EU) made an unilateral commitment that the EU would cut its GHG emissions by at least 20% of 1990 levels by 2020. This commitment is being implemented through a package of binding legislation. The EU has also offered to increase its emissions reduction to 30% by 2020, on the condition that other major emitting countries in the developed and developing worlds commit themselves to comparable emission reductions under a future global climate agreement (Council of the European Union, 2009). In the EU climate and energy package of 2009 a decision was taken to distribute the 20% reduction obligation for the EU-27 to MS (under the Effort Sharing Decision, ESD) and industry (under the Emission Trading Scheme, ETS). The agricultural sector, as non-CO2 emitter, was included under the ESD and, therefore, excluded from the ETS (Council of the European Union (2009).

While the agricultural sector is specifically covered under the Kyoto Protocol (with respect to non-CO2 emissions), emission reduction targets are specific for countries, not sectors. Thus, there is so far no legal need for a sectoral approach on agriculture for developed countries. With regard to the ESD in the EU, Member States actually have binding GHG emission abatement targets that also include agriculture. Nonetheless, there are so far no explicit policy measures implemented that would specifically force GHG emission abatement in the agricultural sector. However, the contribution of the agricultural sector to climate change is gaining more and more visibility and therewith interest is growing on policy options to reduce agricultural GHG emissions (FAO 2006; Smith et al. 2007; FAO 2010). To design reasonable mitigation policies it is important to understand the impact of such policies on GHG mitigation on the one hand and agricultural production and trade on the other hand. However, for the EU there is so far hardly any empirical evidence on the possible impacts of specific agricultural GHG abatement policies on production and agricultural commodity markets.

Assessing the implications of alternative GHG abatement policy options implies three major challenges for agro-economic modeling: (1) a proper quantification of GHG emissions in the agricultural sector, (2) the quantification of agricultures' potential for GHG mitigation and (3) the quantification of the production and economic impacts linked to mitigation of GHG emissions in the agricultural sector. To tackle these challenges, an Administrative Agreement was launched between the European Commission's Joint Research Centre (JRC) and the Directorate General Agriculture and Rural Development (DG AGRI)[4] and a related additional project initiated and carried out by the European Commission's Joint Research Centre-Institute for Prospective Technological Studies (JRC-IPTS, Spain) in cooperation with the Agricultural Economics Research Institute (LEI, the Netherlands), EuroCARE (Germany), the Swedish University of Agricultural Sciences (SLU, Sweden) and the collaboration of the von Thünen Institute (vTI, Germany).

1.2 Objectives of the study and scope of the report

The specific objectives of the JRC-IPTS study have been to

- adapt and further improve the accounting of EU GHG emissions from agriculture in the CAPRI model,
- extend the analysis to cover trade-related agricultural emissions from agricultural production in other regions of the world in order to account for emission leakage from European domestic mitigation policies as a result of changing trade balances,
- conduct an additional exploratory work to adapt the CAPRI model to include alternative technological agricultural measures for GHG emission abatement,
- provide and discuss baseline projections for the EU-27 in year 2020, stressing the most relevant agricultural emission sources;
- construct and quantify the effects of different emission abatement policy instruments on GHG emissions from EU agriculture.

The main objective of this report is to assess the GHG emission reduction potential of a selected number of policy options and to quantify related production and economic impacts for the agricultural sector in the EU. Therefore the possible future evolution of agricultural GHG emissions in the EU are assessed through the simulation of scenarios including expected macro- and micro-economic changes.[5] *The proposed mitigation policy scenarios are all exploratory*, i.e. it is intended to explore what could happen if policies would be implemented that explicitly force farmers in the EU-27 to reach certain GHG emission reduction targets. It has to be stressed that all policy scenarios are rather theoretical and hypothetical and do not necessarily reflect mitigation policies that are already agreed on, or are under formal discussion.

In order to calculate the emission scenarios, the CAPRI (Common Agricultural Policy Regional

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[4] The primary outcome of the Administrative Agreement is the report Leip, A., F. Weiss, T. Wassenaar, I. Perez, T. Fellmann, P. Loudjani, F. Tubiello, D. Grandgirard, S. Monni, K. Biala (2010): Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS). European Commission, Joint Research Centre, Brussels. http://ec.europa.eu/agriculture/analysis/external/livestock-gas/index_en.htm. It has to be noted that the scope of the GGELS study was different from the scope of the study at hand. Furthermore, the CAPRI model used for the GGELS report has been further elaborated and some of the policy scenarios have been adjusted. Thus, the results of the policy scenarios presented in the report at hand differ from those in the GGELS report.

[5] While not being a GHG, Ammonia (NH3) is also an important polluting gas from agriculture (for more information see Annex 2). Thus, even though the study focuses on the development of GHG emissions, the effect of the policy options on the development of NH3 emissions are also reported (but not analysed in detail).

Impact Analysis) modelling system is applied. To assess the possible future evolution of agricultural GHG emissions in the EU we constructed several scenarios, including a reference scenario that serves as comparison point in the year 2020 for counterfactual analysis of all other scenarios. The core of the scenario analysis is about mitigation policy scenarios; however we also conducted some complementary technological abatement scenarios. The mitigation policy scenarios are designed to achieve a 20% GHG emission reduction in the year 2020 compared to EU emissions in 2004 (three-year average of 2003-2005). The policy scenarios comprise an Emission Standard (emission standard with a regionally homogeneous cap), a specific Effort Sharing Agreement for Agriculture (emission standard with regionally differentiated based on the EU effort sharing decision), an Emission Trading Scheme for Agriculture (regionally homogenous cap, with trade in emission rights at regional and EU-wide level) and a tax on livestock emissions.

The mitigation policy scenarios do not consider technological responses to the policy measures. To get an idea of the magnitude of the effects that technological changes may have on GHG emissions, we also assess some complementary technological abatement scenarios where the changes in production technology are pre-defined (i.e. not endogenously calculated by the CAPRI model). We selected three technological abatement scenarios: a combination of various technological measures that actually target ammonia emissions, a more balanced fertilization, and low nitrogen feeding. To get also an idea on the effects that the technological abatement measures would have in combination with the emission mitigation policies, we run one scenario where we introduce the measures of a more balanced fertilization and low nitrogen feeding into an Emission Trading Scheme for Agriculture scenario.

1.3 Structure of the report

This report is designed as follows. In chapter 2 a brief overview on agricultural GHG emissions in the EU and their and historical development is given. Chapter 3 provides a description of the methodological framework of the study. The background and definition of the simulation scenarios is presented in chapter 4. Baseline results of the reference scenario are reported and discussed in chapter 5. Chapter 6 presents the results and analysis of the mitigation policy scenarios as well as the complementary technological abatement scenarios. Effects of introducing emission leakage into the scenario analysis are delineated in chapter 7 and concluding remarks are given in chapter 8.

2 Agricultural GHG emissions in the EU: overview and historical developments

The agricultural sector is especially a large contributor of non-CO2 GHG emissions, namely methane (CH4) from ruminants and nitrous oxide (N2O) from fertilizer application and management. In this chapter we give a brief overview on agricultural GHG emissions in the EU (section 2.1) and their historical developments (section 2.2).

2.1 Overview on agricultural GHG emissions in the EU

EU Member States have to report their GHG emissions annually according to a common reporting framework of the United Nations Framework Convention on Climate Change (UNFCCC). Following the UNFCCC reporting scheme, the inventory for the agricultural sector includes emissions of methane and nitrous oxide. The two main sources of methane emissions from agriculture are enteric fermentation by ruminants and emissions from manure management. The main sources for agricultural nitrous oxide emissions are manure management and emissions from agricultural soils, which can be subdivided in a) direct soil emissions from the application of mineral fertilizers and animal manure, direct emissions from crop residues and the cultivation of histosols, ii) direct emissions from manure produced in the meadow during grazing, and iii) indirect emissions from nitrogen leaching and runoff, and from nitrogen deposition (cf. IPCC, 2006).

It has to be noted that emissions (and removals) of carbon dioxide (CO2) from agricultural soils are not accounted for in the 'agriculture' category, but under the category 'land use, land use change and forestry (LULUCF)'. Likewise, carbon dioxide emissions released by agricultural activities related to fossil fuel use in buildings, equipment and machinery for field operations are assigned to the 'energy' sector. Further agriculture-related emissions, like those from the manufacturing of fertilizers and animal feed, are included in the inventory on industrial processes (UNFCCC, 2006). As a consequence, GHG emissions related to agricultural production and activity are greater if the emission accounting is done in form of a life cycle assessment (LCA). The LCA approach helps to get a more thorough idea of emissions created by agricultural products as it considers also emissions caused by the production of the inputs used.[6] However, official emission values of the national inventories are not reported based on products but based on activities. Therefore the calculation of agricultural emission inventories in this study is also based on agricultural activities, hence mimicking the reporting on emissions by the EU Member States to the UNFCCC.

Following the emission reporting scheme of the UNFCCC, agricultural GHG emissions account for almost 14% of global GHG emissions. According to GHG inventories of the EU Member States, GHG emissions in the agriculture sector represent 9.2% of total EU GHG emissions, with methane and nitrous oxide accounting for around 5% and 4.3% of total European GHG emissions respectively (European Commission, 2009, cf. Figure 1.

The share of the agricultural emissions in total national GHG emissions varies considerably within the EU Member States, depending on the relative size and importance of the agricultural sector. The share is highest in Ireland (26%) and France (18%) and lowest in Malta (2%), the Czech Republic and Germany (both 6%) (cf. Figure 2.

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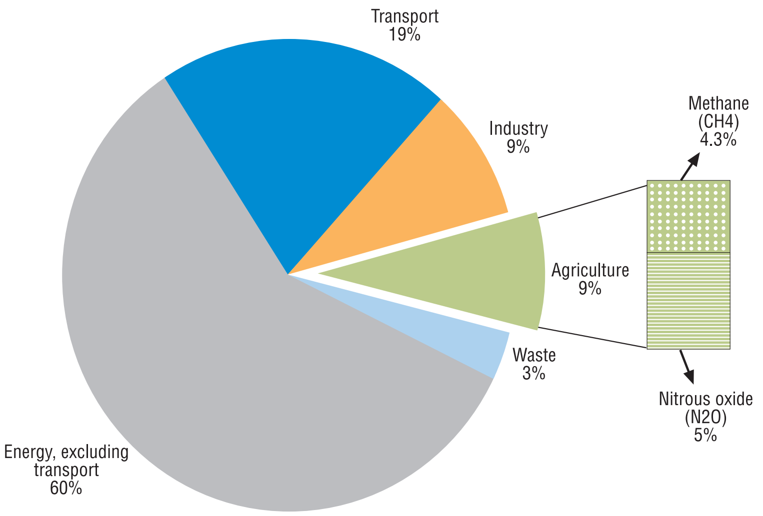
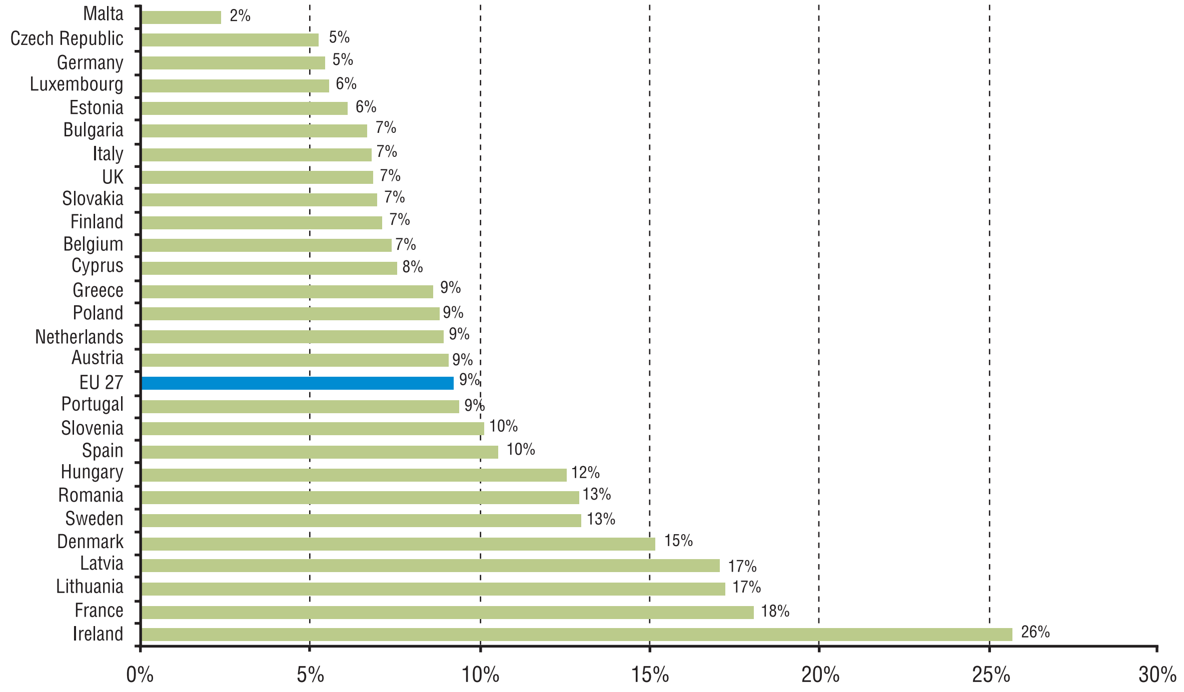
[6] For example, in the GGELS project the CAPRI model was adapted to account for product based GHG emissions from agriculture in order to quantify GHG emissions of EU livestock production in form of a life cycle assessment. For more information see Leip et al. (2010).

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



Source: European Commission (2009), primary source EEA (2008)

Figure 2. Share of agricultural GHG emissions in total national emissions in EU MS, 2007

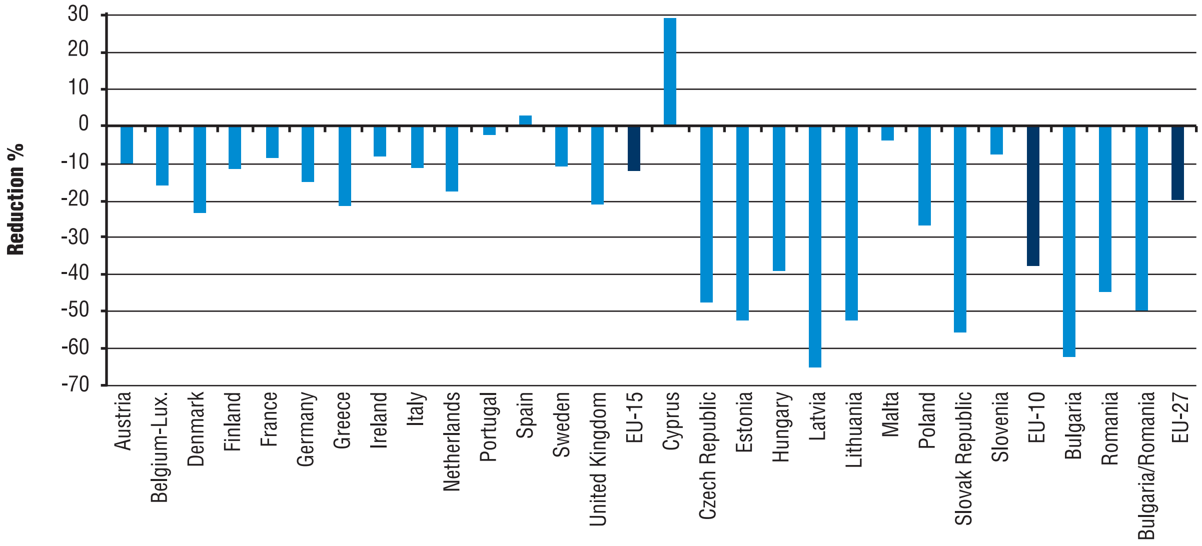


Source: European Commission (2009), primary source EEA (2008)

2.2 Historical developments of agricultural GHG emissions in the EU

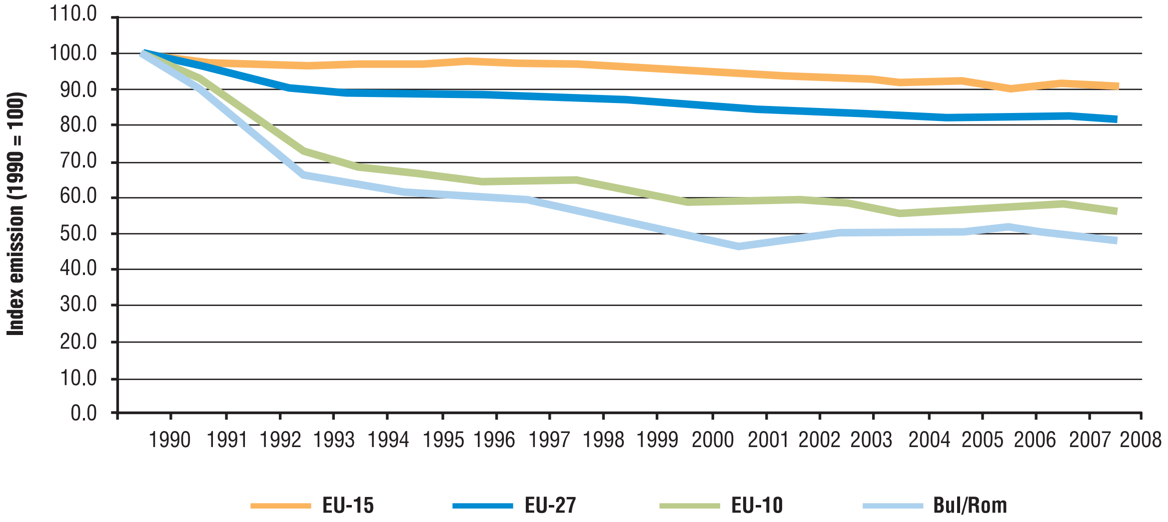
The historical developments of agricultural GHG emissions show a rather steady downward trend on EU-27 level. This trend can be attributed to several factors, most of all to productivity increases and a decreases in cattle numbers, as well as improvements in farm management practices and also developments and implementation of agricultural and environmental policies. Furthermore, the developments have been considerably influenced by adjustments of agricultural production in the EU-12 following the

Figure 3. Change in agricultural GHG emissions in CO2 equivalents per MS, 1990-2008



Source: EEA database (cf. Annex 1)

Figure 4. Change in methane emissions in agriculture between 1990 and 2008



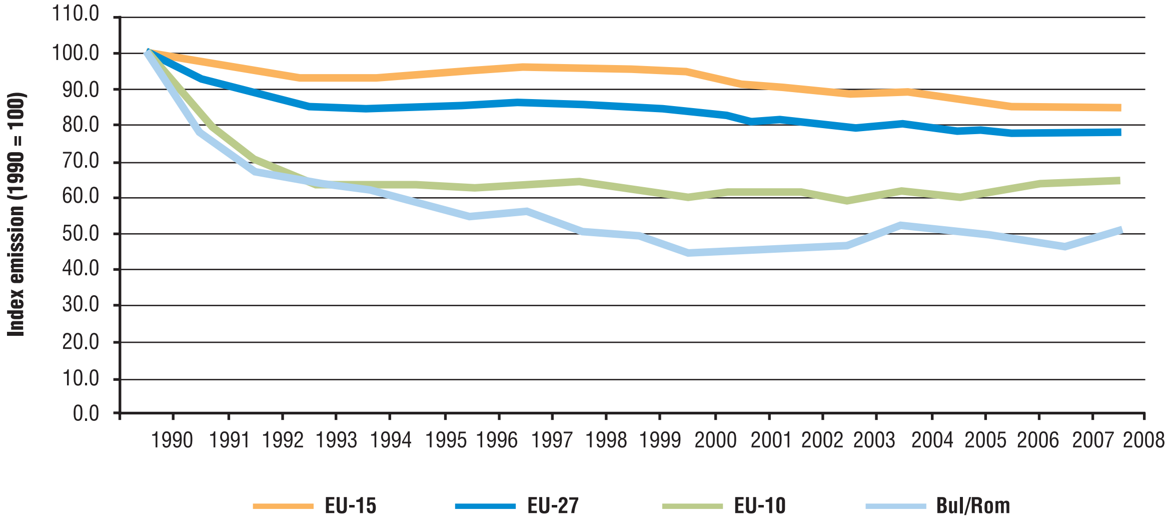
Source: EEA database (cf. Annex 1)

changes in the political and economic framework after 1990 (European Commission, 2009).

In Figure 3 the average change of agricultural GHG emissions in terms of CO2 equivalents between 1990 and 2008 are presented per MS. On average, the emissions have been reduced by 20.2% in the EU-27, 12.2% in the EU-15, 37.9% in EU-10 and 49.8% in Bulgaria/Romania (cf. Annex 1).

During the period 1990-2008 the emissions of methane from the agricultural sector decreased by 18.4% in the EU-27 (cf. Figure 4). However, across MS, the historical evolution of methane emissions rather varied. On average the EU-15 experienced a decrease of methane emissions by 9%, with developments ranging from an increase of +16% in Spain to a decrease of 22% in Germany. With the exception of Cyprus (+25%)

Figure 5. Change in emission of nitrous oxide in agriculture between 1990 and 2008



Source: EEA database (cf. Annex 1)

all EU-12 MS showed decreases in methane emissions, and several MS like Bulgaria, the Baltic States and the Slovac Republic reduced emissions by more than 50% (cf. Annex 1). The reductions in methane emissions can mainly be attributed to significant decreases in cattle numbers that followed increases in animal productivity (milk and meat) and related improvements in the efficiency of feed use.

Agricultural emissions of nitrous oxide have been reduced by 21.5% in the EU-27 between 1990 and 2008 (cf. Figure 5 and Annex 1). Nitrous oxide emissions from soils diminished mainly due to reduced use of organic and mineral nitrogen fertilizers (following productivity increases and declines in the cattle herds). Reductions of nitrous oxide emissions have been reported in all EU-15 MS, on average by14.6%, with lowest decreases in Spain and Austria (-5.6% each) and highest in Greece (-31.6%) and Denmark (-31.5%). Also in the EU-12 all MS report decreases in nitrous oxide emission (except Cyprus), with an overall decrease in the EU-10 of 34.4%. However, within the last years a slight increase of nitrous oxide emissions can be observed in the EU-12. This effect is probably well related with the modernization of agriculture and the increase in use of fertilizer (and increased yields).

3 Overview of the methodological framework

In order to calculate the emission scenarios, the CAPRI (Common Agricultural Policy Regional Impact Analysis) modelling system is applied. The general CAPRI modelling approach and the calculation of agricultural emission inventories are briefly described in section 3.1. In section 3.2 the main features of the spatial trade model for emission permits trading is delineated. The approach to calculate for emission leakage is explained in section 3.3.

3.1 The CAPRI model and calculation of agricultural emission inventories

CAPRI is an economic large-scale comparative-static agricultural sector model with a focus on EU-27, but covers global trade with agricultural products as well (Britz and Witzke, 2008). CAPRI consists of two interacting modules: the supply module and the market module. The supply module consists of about 270 independent aggregate optimisation models representing all regional agricultural activities in a Nuts 2 region (28 crop and 13 animal activities). These supply models combine a Leontief technology for intermediate inputs covering a low and high yield variant for the different production activities with a non-linear cost function which captures the effects of labour and capital on farmers' decisions. This is combined with constraints relating to land availability, animal requirements, crop nutrient needs and policy restrictions (e.g. production quotas). The non-linear cost function allows for perfect calibration of the models and a smooth simulation response rooted in observed behaviour (cf. Britz and Witzke, 2008; Pérez Dominguez et al., 2009).

The market module consists of a spatial, non-stochastic global multi-commodity model for 40 primary and processed agricultural products, covering 40 countries or country blocks. Bilateral trade flows and attached prices are modelled based on the Armington assumption of quality differentiation (Armington, 1969). The behavioural functions for supply, feed, processing and human consumption in the market module apply flexible functional forms, so that calibration algorithms ensure full compliance with micro-economic theory. The link between the supply and market modules is based on an iterative procedure (cf. Britz and Witzke, 2008; Pérez Dominguez et al., 2009).

The specific structure of CAPRI is suitable for the analysis of GHG emissions. The regional supply models capture links between agricultural production activities in detail. The modelling system was adapted to be able to calculate activity based agricultural emission inventories. Based on the differentiated lists of production activities, inputs and outputs define GHG emission effects of agriculture in response to changes in the policy or market environment. The CAPRI model incorporates a detailed nutrient flow model per activity and region (including explicit feeding and fertilizing activities, i.e. balancing of nutrient needs and availability) and calculates yields per agricultural activity endogenously (for more information see Pérez Dominguez 2006; Leip et al., 2010). With this information, CAPRI is able to calculate endogenously GHG emission coefficients following the IPCC guidelines (cf. IPCC, 2008). The IPCC guidelines provide various methods for calculating a given emission. The same general structure is used, but the level of detail at which the calculations are carried out can vary. The IPCC methods for estimating emissions are divided into 'Tiers', encompassing different levels of activity, technology and regional detail. Tier 1 methods are generally straightforward (activity multiplied by default emissions factor) and require less data and expertise than the more advanced Tier 2 and Tier 3 methods. Tier 2 and Tier 3 methods have higher levels of complexity and require more detailed country-specific information on things such as technology type or livestock characteristics. In CAPRI a Tier 2 approach is used for the calculations, however for activities where the respective information is missing a Tier 1 approach is applied to calculate the GHG emissions (e.g. rice cultivation).

Agricultural emissions in CAPRI are calculated per production activity and aggregated to regional and national scale. The emissions per activity are the sum of different items per activity multiplied by an emission factor. Changes in activity numbers (i.e. number of hectares or heads) and/or intensities (i.e. yields) will lead to changes in emissions. The emissions of N in the form of GHGs are closely related to manure and fertilizer management. The main methane sources in agriculture are enteric fermentation and manure management. Flooded rice cultivation is also an agriculture source of methane, but apart from some regions in Italy and Spain rice production is currently not relevant in the EU and therefore not taken into account in the GHG emission calculation within this study.

Emissions can also be classified into direct emissions and indirect emissions. Direct emissions in agriculture are emissions directly from the emission source (manure or fertilizer). Indirect emissions of N2O happen due to losses of nitrogen to water, soil and atmosphere.

An example for activity based emission calculation in CAPRI:

An activity is for instance keeping dairy cows. Cows can be kept inside and outside a stable (grazing and housing). The time period outside/inside depends on the country. Emissions of nitrous oxide are closely related to the management of the manure, which can be stored in separated storages and thereafter spread on the field. Thus the manure emissions from keeping cows can be differentiated according to where they are produced: stable, storage, grazing's or through application on cropland. IPCC (2006) defines and regularly updates detailed guidelines[7] how to calculate emissions per gas source and activity. The emission calculation in CAPRI is based on these rules. For each of the items related to the activity emission factors are available. The basic formula for the calculations of emissions of GHGs is

$$\text{Emission}_{act,item,reg} = \text{ActLevel}_{act,item,reg} * \text{Emfac}_{act,item,reg}$$

with

Emission = emission
ActLevel = activity level (could be number of animals or cropland hectares)
Emfac = emission factor per activity
Act = production activity
Item = emission source
Reg = regional unit (Nuts 2 region, country or country aggregate)

Reporting of emissions can take place by aggregating to the desired aggregation level. The output as given in this report (see Table 5) is mimicking the reporting on emissions by the EU to the UNFCCC (cf. Pérez Dominguez, 2006; Pérez Dominguez et al., 2007; Pérez Dominguez et al., 2009).

A more detailed description of the calculations of agricultural emission inventories on activity level in CAPRI is given in Pérez Dominguez (2006) and Leip et al. (2010).

3.2 Spatial trade model for emission permits in agriculture

One of the emission mitigation policy scenarios conducted in this study deals with a specific Emission Trading Scheme for Agriculture. For this a spatial trade model has to be applied

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[7] See IPCC (2006): http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Table 5. Reporting items to the UNFCCC and emission sources calculated and reported in CAPRI

UNFCCC Reporting Sector 4 Agriculture		**CAPRI reporting and modelling**	
Methane	A: Enteric fermentation	CH4ENT	Enteric fermentation
	B: Manure management	CH4MAN	Manure management
	C: Rice cultivation	CH4RIC*	Rice cultivation
Nitrous dioxide	B: Manure management	N2OMAN	Manure management (stable and storage and application)
	D: Agricultural soils		
	D1: synthetic fertilizer	N2OSYN	Synthetic fertilizer
	D2: Animal waste	N2OWAS	included into manure management
	D3: N fixing crops	N2OFIX	Biological fixation
	D4: Crop residuals	N2OCRO	Crop residuals
	D5: Cultivation of Histosols	N2OHIS	Histosols
	D6: Animal production	N2OGRA	Excretion on pasture
	D7: Atmospheric deposition	N2ODEP	Atmospheric deposition
		N2OAMM	Deposition of ammonia
	D8: Nitrogen leaching	N2OLEA	Emissions due to leaching of nitrogen
	E: Prescribed burning of savannahs		not covered in CAPRI
	E: Field burning of agricultural residues		not covered in CAPRI

Note: Rice is not taken into account in this study

that allows trading emission permits in CAPRI. The main features of this spatial trade model are described below.[8]

The stylised spatial equilibrium model described here follows the general framework developed by Takayama and Judge (1971) and is specifically tailored to represent regional (spatial) trade of non-CO2 emission permits. The permit trading scheme is graphically depicted in Figure 6 (for a mathematical description see Pérez Dominguez and Britz, 2010). Starting with a given permit distribution based on a percentage reduction of historical emissions, the regional supply models are solved, generating dual values related to the maximum permissible emissions. This has an effect on production since, for instance, high emitting activities (e.g. intensive cattle production in the Netherlands) are expected to experience a higher loss in income than low emitting activities (e.g. rain-fed cereal production in south Portugal). These changes in supply and feed demand quantities enter the international market and trade model, where price adjustments for agricultural outputs allow for market clearing (cf. Figure 6). At this stage, the permission trade module re-distributes permits from regions with low marginal abatement costs to other regions with high marginal abatement costs, allowing for welfare gains between the regions involved in the permit trading. According to the distributed emission permits, a new maximum of emissions permitted enter the supply models in the next solve, generating a new vector of regional marginal abatement costs which are also depending on the updated output price. Again, the market model is solved at updated supply and feed demand quantities. Market clearing of agricultural products and of regional emission permits iterate

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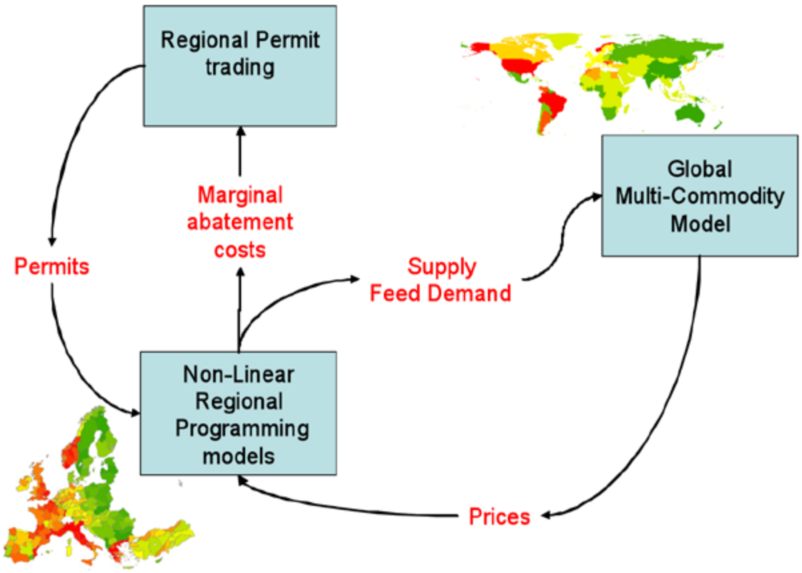
[8] Further and more detailed description is given in Pérez Dominguez (2006) and Pérez Dominguez and Britz (2010).

Figure 6. CAPRI model flow with explicit consideration of regional emission permit trading



Source: Pérez Dominguez et al. (2010)

until convergence is achieved, i.e. changes between iterations for both quantities and prices of agricultural products and emission permits fall beyond pre-defined relative thresholds of 0.05%. The solution characterizes a simultaneous equilibrium in EU agricultural permit markets and regional as well as global primary and secondary agricultural product markets.

3.3 Estimation of GHG emission leakage in the EU

The detailed GHG emission coefficients in CAPRI for agricultural production activities within the EU can be used to assess the direct GHG emissions from EU agriculture from the supply side. However, if the issue of GHG emissions is viewed from the demand side for agricultural products, then it is no longer sufficient to assess only the impact of mitigation policies on EU agricultural production. The agricultural markets of the EU are closely linked with other regions around the world via trade flows, and significant shares of consumption, depending upon the product considered, can be imported. Thus, if EU agricultural production is affected by the implementation of GHG mitigation policies this can also trigger changes in agricultural production in other regions of the world, which in turn can result in adverse effects on the overall amount of GHGs emitted. Consequently, a more comprehensive assessment of GHG emissions should also take into account emissions that occur due to import substitution. In this section we provide a brief overview on the methodological approach developed in CAPRI to estimate GHG coefficients per commodity and world regions in order to capture emission leakage in the EU.

As mentioned in section 3.1 the CAPRI system contains a fairly detailed trade model, where 28 world regions trade bilaterally in around 40 agricultural commodities. If per-commodity emission coefficients were estimated for those commodities, the trade model would be capable of computing indirect effects on global GHG emission of EU policy changes. In order to estimate such per-commodity emission coefficients, three sources of information were combined:[9]

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[9] More detailed information on this approach is given in Jansson et al. (2010) and in Annex III.

1. GHG inventory estimates for world regions provided by the JRC-IES (Joint Research Centre -Institute for Environment and Sustainability). The data set is called the EDGAR database[10], and it contains time series of inventories for a large set of countries, similar to the regions used by FAOSTAT.

2. Agricultural production statistics from the FAO, also in time series.

3. Emission factors per commodity for the EU. Those coefficients are used as *priors*[11] in the estimation.

The EDGAR inventories are structured in a way similar to the IPCC Tier 2, with gross emissions per gas (N2O and CH4) and source (enteric fermentation, fertilizer application, etc.), occasionally differentiated by production type, where in particular beef and milk production has separate entries. However, the EDGAR inventories do not give any information about emissions per product as required in CAPRI.

The production statistics from FAO were aggregated to obtain the product classification used in CAPRI, and the objective of the estimation is to find emission factors per tonne of commodity in the FAO dataset such that the EDGAR inventories are recovered, or, to find coefficients b such that

$$y_{it} = \Sigma_k(b_{ik}x_{tk}), \ (1)$$

where y is the EDGAR data on inventory position i in year t, and x is the FAOSTAT production data on product k in year t.

Since there is only a limited number of years with data for each region that covers the relevant product in both EDGAR and FAO, the problem of inferring product specific coefficients is generally ill-posed (underdetermined). This means that there can be many different sets of emission factors that all equally well reproduce the EDGAR data.

If a country produces few commodities and there are many years of data, there may be no coefficients at all that exactly satisfies the EDGAR data for all years, in particular as we require the coefficients to be constant over time. Therefore, equation (1) needs to have error terms. It seems reasonable to assume that the error in the inventory y is much larger than that of x, because x is physically measurable whereas y depends on computations, which in turn depend on some output measurement. Therefore, we assume that our data on inventories in the EDGAR database (Y) relate to the true emissions (y) with a multiplicative error (e), i.e. $Y_{it} = y_{it}e_{it}$, where $e_{it} \sim N(1,\sigma_t^2)$ for all i, whereas x is assumed to have no measurement errors.

In order to resolve the ill-posedness some method is needed to distinguish between any two alternative sets of coefficients that equally well satisfy equation (1). We achieve this by introducing the assumption that *a-priori* (i.e. before seeing the data), the emission factors are the same as in the EU, and then letting the estimates deviate from the priors insofar this is needed in order to satisfy equation (1). As prior distribution of emission factors we choose the density $b_{ik} \sim b_{ik}N(1,1/(r_{ik}s_{ik}))$, where the prior emission factor is b and rs is the so-called precision. The greater the precision, the less are the estimates b allowed to deviate from the prior. This particular functional form for the prior density function was chosen because, if the factor s of the precision is appropriately set and the sample small, then any deviations from the

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[10] Emissions Database for Global Atmospheric Research (EDGAR, cf. http://edgar.jrc.ec.europa.eu/index.php). We used the EDGAR database v4.00, including data of agricultural emissions for 1970-2005 for all available countries split by IPCC categories.

[11] In Bayesian statistical inference, a prior probability distribution (called simply the prior) of an uncertain quantity p is the probability distribution that would express one's uncertainty about p before the "data" are taken into account. A prior is often the purely subjective assessment of an experienced expert, in our case "average EU emission factors per agricultural commodity".

priors that is necessary in order to meet the data constraints is inversely proportional to r, which we call the "reliability factor". For example, if r_{ik} is for some inventory positions i the same for all products k (e.g. $r_{ik} = 1\ \forall\ k$), then a deviation is uniformly distributed across all commodities, and if for some commodity r would be twice as high as for the other commodities (coefficient *a-priori* twice as reliable) then the associated coefficient is adjusted only half as much for that commodity as other commodities. The derivation of the factor s to obtain those properties mentioned above is considered too technical to fit in this report (see Jansson et al. 2010).

The prior expectation $\underline{b}$ was set to equal the average (across regions) of all EU emission factors, and the reliability factor r was set to the inverse of the variance of $\underline{b}$. The latter implies that if factors are generally similar in all EU regions, the factor is considered "reliable", but if it is generally different across EU regions, then it is also a less reliable prior for a region outside of the EU.

The more observations that are available (years of data), the less important the prior will be. When only a few years of observations are available, the relative importance of the data versus the prior is influenced by the ratio of $\sigma_t^2 / (1/rs)$. Obtaining an estimate of σ is not trivial. We opted for the naïve but transparent approach of introducing a prior distribution of σ_t^2 too, stating that $\sigma_t = 0.1(T - t + 1)$, where T is the total number of years, for all commodities and regions. This means that, based on the "three-sigma-rule" and based on the fact that 1/s2 is the weight of an observation in the estimation, essentially all outcomes are within ±30% of the mean in the latest year, but that greater deviations are considered more likely in older years.

A complete documentation of the estimation methodology is given in the Annex III.

4 Background and definition of the simulation scenarios

The main objective of this study is to assess the GHG emission reduction potential of a selected number of policy options. Therefore the possible future evolution of agricultural GHG emissions in the EU is assessed through the simulation of scenarios including expected macro- and microeconomic changes. Projection year for all scenarios is 2020. It has to be highlighted that the proposed and examined policy scenarios are meant to be exploratory, i.e. it is intended to explore what could happen if policies would be implemented that explicitly force farmers in the EU-27 to reach certain GHG emission reduction targets. Thus, the policy scenarios are rather theoretical and hypothetical and do not necessarily reflect mitigation policies that are already agreed on, or are under formal discussion.

This chapter deals with the building and definition of the GHG mitigation scenarios and proceeds along the following structure. First, a brief overview on all proposed simulation scenarios is presented in section 4.1. Afterwards, the scenarios are described in more detail. For each scenario a brief literature background is given, and related variables and assumptions are described.

The description of the scenarios is split into specific *mitigation policy scenarios* (including the reference scenario for 2020) in section 4.2 and complementary *technological abatement scenarios* in section 4.3.

4.1 Scenario overview

To assess the possible future evolution of agricultural GHG emissions in the EU we constructed several scenarios. First, a reference scenario (REF) is constructed and examined. The reference scenario (also called baseline) serves as comparison point in the year 2020 for counterfactual analysis of all other scenarios. The core of the scenarios is about *mitigation policy scenarios,* however we also conducted some complementary *technological abatement scenarios*.

Reference and mitigation policy scenarios

The emission mitigation policy scenarios are constructed by selecting a restricted number of policy options, including regulatory tools and market based instruments for emission abatement. For this project three main sets of emission abatement scenarios are proposed: the implementation of emission standards, tradable emission permits and a tax on livestock emissions. The mitigation policy scenarios are all characterised by a target of 20% GHG emission reduction in the year 2020 compared to EU-27 emissions in the year 2004[12]. The policy scenarios for a detailed analysis are (cf. Table 6):

- *Reference or Baseline Scenario (REF):* This scenario takes into account the most likely developments of agricultural markets, including the full implementation of the Health Check of the Common Agricultural Policy (CAP). The REF Scenario serves as comparison point in the year 2020 for counterfactual analysis of all other scenarios.

- *Emission Standard Scenario (STD):* This scenario is linked to an emission abatement standard homogenous across MS, with an equal emission cap set on total GHG emissions in all Nuts 2 regions.

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[12] In CAPRI we take the three-year average of 2003-2005

Table 6. Overview on the reference and mitigation policy scenarios

Scenario acronym	Scenario Name	Policy Instrument	GHG abatement
REF	Reference Scenario	No specific policy measures implemented for GHG emission abatement in agriculture	Trend-driven
STD	Emission Standard Scenario	Emission standard with a regionally homogeneous cap (no trade in emission rights)	20% reduction with respect to EU-27 emissions in the year 2004
ESAA	Effort Sharing Agreement for Agriculture	Emission standard with emission caps per MS based on the EU effort sharing agreement (no trade in emission rights)	
ETSA	Emission Trading Scheme for Agriculture	Tradable emission permits (regionally homogenous cap, with trade in emission rights at regional and EU-wide level)	
LTAX	Livestock Emission Tax Scenario	Emission tax on livestock livestock (regionally homogenous taxes per livestock emissions)	

- *Emission Standard Scenario according to a specific Effort Sharing Agreement for Agriculture (ESAA):* This scenario is linked to emission abatement standards that are heterogeneous across MS, with emission caps based on the EU effort sharing agreement.

- *Tradable Emission Permits Scenario according to an Emission Trading Scheme for Agriculture (ETSA):* This scenario is linked to a regionally homogenous emission cap set on total GHG emissions in all Nuts 2 regions. According to this cap tradable emission permits are issued to farmers and trade of emission permits is allowed at regional and EU-wide level.

- *Livestock Emission Tax Scenario (LTAX)*: This scenario tries to tackle emission reduction targets by introducing regionally homogenous taxes per livestock emissions.

Complementary technological abatement scenarios

The mitigation policy scenarios do not consider technological responses to policy measures, like for example farmers adapting their stables or livestock keeping methods in order to respond to the mitigation policies imposed. This is because CAPRI is currently not able to capture such changes in the production technology. In the CAPRI system, farmers can only respond to the policies by shifts in the activity mix, including for example lower livestock production, and those adjustments in intensity levels that are possible with given parameters (like shifts between the high and low yield variant of each crop activity). However, in reality it is very likely that farmers would also try to reduce their GHG emissions by changing their production techniques (i.e. using technical measures like introducing low-nitrogen feeding, covering of manure storage, or switching to minimum tillage or no-till techniques).

To get an idea of the magnitude of the effects that technological changes may have on GHG emissions, we also assess some complementary technological abatement scenarios where the changes in production technology are pre-defined (i.e. not endogenously calculated by the CAPRI model). In making use of available information in other CAPRI projects, we selected three technological abatement scenarios: a combination of various technological measures that actually target ammonia emissions (AMMO Scenario), a more balanced fertilization (BAL Scenario), and low nitrogen feeding (LNF Scenario). The three technological abatement scenarios are not designed to achieve a certain GHG emission reduction target, but to see what effect the change in production technology would have on the development of GHG emissions. To get also an idea on the effects that the technological abatement measures would have in combination with the emission mitigation policies, we run one scenario where

Table 7. *Overview on the complementary technological abatement scenarios*

Scenario acronym	Scenario Name	Technological abetment measures	GHG abatment
AMMO	Ammonia Measures Scenario	Combination of various measures targeting ammonia (stable adaptation, covered manure storage, bio filtration, low ammonia application of manure, urea substitution by ammonia nitrate, incineration of poultry manure)	No predefined abatement target (effects on GHG emissions are a scenario outcome)
BAL	More Balanced Fertilization Scenario	More efficient (organic and mineral) fertilizer management	
LNF	Low Nitrogen Feeding Scenario	Lower nitrogen content in feed, decrease in the uptake of nitrogen and therefore decrease in the possible losses of N20	
ETSBL	Combination of BAL, LNF and ETSA Scenario	Introduction of the measures for a more balanced fertilization (BAL Scenario) and low nitrogen feeding (LNF Scenario) into the Emission Trading Scheme for Agriculture	20% reduction compared to 2004

we introduce the measures of a more balanced fertilization and low nitrogen feeding into the Emission Trading Scheme for Agriculture scenario (ETSBL Scenario).

4.2 Definition of the reference and mitigation policy scenarios

In this section we describe the reference and mitigation policy scenarios in more detail. For each scenario a brief literature background, where appropriate, is given, and related variables and assumptions are described.

4.2.1 Reference Scenario (REF)

The construction of a reference scenario (also called baseline) combines trends predicted by experts with trends as projected by statistical analysis (Britz and Witzke, 2008). The baseline serves as a reference for the policy simulations and is meant to provide a consistent view on the likely evolution of the agricultural markets over the projection period under a specific set of assumptions about exogenous drivers. Hence the reference scenario provides a projection in time that does not intend to constitute a forecast of what the future will be, but represents a description of what may happen under a specific set of assumptions and circumstances, which at the time of projections were judged plausible (cf. Blanco Fonseca 2010, Nii-Naate, 2011).

The CAPRI baseline for this study assumes status quo policy and includes all future policy changes already agreed and scheduled in the current legislation, based on the information available at the end of December 2010. The changes in legislation proposed or adopted since that date have not been taken into account. Hence, the reference scenario incorporates a full implementation of the Health Check and the biofuels directive, as well as the sugar and milk market reform. However, although the agricultural sector is included in the GHG emission reduction obligation of the so-called climate and energy package of 2009, no explicit policy measures are considered for GHG emission abatement in the reference scenario[13].

The first step of the CAPRI baseline process mainly relies on an analysis of historical trends and on expert information for particular markets (e.g. specific regional market developments). The

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[13] While MS actually have binding GHG emission abatement targets that also include agriculture, there are so far no explicit policy measures implemented that would specifically force GHG emission abatement in the agricultural sector. Consequently, no explicit policy measures for GHG emission abatement are considered in this reference scenario.

Table 8. Summary of assumptions and scenario characteristics: Reference Scenario

	REF
GHG abatement policy	No specific policy measures implemented for GHG emission abatement in the agricultural sector
Projection year	2020
GHG abatement	Not explicit, i.e. only linked to the development of agricultural markets (same feeding habits and emission factors)

most important expert information used for these baseline projections is the 2009 version of the Aglink-Cosimo model (medium-term projections 2009-2019)[14] and extended to 2020 by IPTS and DG-AGRI[15]. The variables considered within the calibration process are: supply, demand (food, feed, biofuels and other use), production, yields and prices. The EU baseline considered includes recent assumptions on macroeconomic drivers (GDP, population, oil price) and the evolution of the CAP. However, the regional resolution of the Aglink-Cosimo baseline in the EU is limited to the aggregates of EU-15 and EU-12. Therefore, the CAPRI baseline needs to disaggregate this information at MS and regional level. Furthermore the CAPRI baseline includes specific expert information from the PRIMES energy model for the biofuel sector and expert projections from the seed manufacturer KWS on the sugar sector. Trends and expert information from various sources together are almost sure to be inconsistent in some aspect and to violate basic technical constraints such as adding up of crop areas or balances on young animals. As a consequence all expert information is usually provided in the form of target values. Deviations from them are penalised within the statistical calibration framework if necessary.

The second step of the CAPRI baseline process supplements the consistent price-quantity framework with a detailed policy specification. The policy specifications for the reference scenario reflect the Health Check agreement (including in particular un updated direct payment regime to reflect further decoupling, abolition of set aside, market reforms for milk and sugar markets. EU agricultural trade policy measures are governed by the Uruguay Round Agreement on Agriculture (URAA) and no assumptions are made concerning bilateral trade agreements currently under negotiation. These policy assumptions complete the definition of the CAPRI baseline and they determine via the parameter calibration the starting point for the subsequent scenario analysis. However, the quantitative projections for the baseline year 2020 are more crucially determined from step one, the baseline process and thus from the integration of trends, expert information, and technical constraints.

4.2.2 Emission Standard Scenario (STD)

Scenario background

Command and control (CAC) policy instruments are the most commonly used instruments to address environmental negative externalities such as urban air pollution, nitrogen leaching or CH4 emissions. CAC regulation commonly uses the setting of standards, i.e. a mandated level of performance that is enforced by law. As the name indicates, a CAC approach consists of a ‘command’ and a ‘control’ variable. Whereas the ‘command’ sets a standard or maximum level (‘cap’) of permissible pollution, the ‘control’ enforces and monitors the implementation of this standard. There

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[14] The OECD and the FAO produce on a yearly basis a joint publication with a world medium-term outlook. It has not been possible to use the 2010 baseline for the study at hand, as it was available too late to be used for the re-run of the baseline scenario.

[15] For background information on the baseline construction process of the DG AGRI outlook see Nii Naate (2011).

Table 9. Summary of assumptions and characteristics: Emission Standard Scenario

	STD
GHG abatement policy	Emission standard with homogenous emission restrictions in EU-27 regions and farming systems (emission cap equally applied)
Projection year	2020
GHG abatement	20% reduction compared to a three-year average 2003-2005 Methane and nitrous oxide emissions covered (aggregated to CO2 equivalents by using IPCC global warming potentials)

are different types of standards that could be applied on agriculture in order to reduce GHG emissions[16], but due to technical restrictions related to the CAPRI model we have to focus in this project on emission standards that put a cap on the level of GHG emissions. Restrictions on GHG emissions have not been directly implemented yet in EU agriculture, but indirectly through restrictions on the rate of fertilizations within nitrates vulnerable zones (within the nitrate directive).

Scenario description

In this emission standard scenario a regionally homogeneous cap is set on GHG emissions from agriculture in the EU-27. The level of GHG emissions will be reduced by 20% in the year 2020 compared to emissions in the three-year average 2003-2005. The emission reduction targets are equally applied across all regions at Nuts 2 level (thus independent from regional differences in emission abatement costs) and are assumed to be binding in year 2020 on top of the legislation lined out in the reference scenario.

4.2.3 Effort Sharing Agreement for Agriculture Scenario (ESAA)

This emission standard scenario describes a redistribution of a 20% GHG emission reduction commitment in EU-27 agriculture between the years 2004 and 2020 across MS based on the socalled "Effort Sharing Decision" (ESD) (c.f. Decision No 406/2009/EC, adopted jointly by the European Parliament and the Council). According to ESD, the overall GHG emission reduction objective is distributed across MS, corresponding to a non-uniform GHG emission standard. Thus, under the ESD some MS (e.g. Germany) have to reduce GHG emissions by a certain level, while other MS (e.g. Romania) are potentially allowed to even increase their emissions up to a defined level (cf. Table 10). This effort sharing mechanism was allowed by the Kyoto Protocol to parties acting jointly such as the EU.

For the ESAA scenario the distribution key of the ESD is taken as a starting point for an uneven distribution of GHG emission limits at MS level. These limits at MS level are applied to agricultural emissions according to a linear modification, such that a 20% emission reduction is achieved for the EU-27 (for further details see the respective chapter of the scenario, Chapter 6.2).

It has to be noted that this scenario effectively assumes that the agricultural sector is taken out of the existing ESD, so that the current ESD targets remain for the non-agricultural sectors and new targets are created for agriculture alone, as to match an overall 20% reduction of agricultural emissions in the EU-27 against the base year in CAPRI (three year average 2003-2005). The rationale behind this scenario is to model an uneven distribution of MS targets; however it is clear that any such new distribution key would be an ultimately political decision. So for the sake of this modelling exercise the distribution key of the ESD is taken as the only existing approximation of such an uneven distribution. Here, as in the

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[16] Basically there are three types of standards: ambient standards, emission standards and technology standards.

Table 10. MS GHG emission limits in 2020 compared to 2005 emission levels according to the ESD

Member State	GHG emission limits (%)	Member State	GHG emission limits (%)
Belgium	-15	Luxembourg	-20
Bulgaria	20	Hungary	10
Czech Republic	9	Malta	5
Denmark	-20	Netherlands	-16
Germany	-14	Austria	-16
Estonia	11	Poland	14
Ireland	-20	Portugal	1
Greece	-4	Romania	19
Spain	-10	Slovenia	4
France	-14	Slovakia	13
Italy	-13	Finland	-16
Cyprus	-5	Sweden	-17
Latvia	17	United Kingdom	-16
Lithuania	15		

Source: 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.

Table 11. Summary of assumptions and characteristics: Effort Sharing Agreement for Agriculture Scenario

	ESAA
GHG abatement policy	Emission standard with heterogeneous emission restrictions in EU-27 regions and farming systems (emission caps according to a specific effort sharing agreement for agriculture)
Projection year	2020
GHG abatement	20% reduction compared to a three-year average 2003-2005 Methane and nitrous oxide emissions covered (aggregated to CO_2 equivalents by using IPCC global warming potentials)

emission standard scenario, all agricultural CO2 equivalent emissions are taken into account. These targets are defined at the MS level (as in the Table above) and homogeneously applied to all regional production systems within the respective MS. Therefore, all agricultural producers in a given MS would be given emission quotas (caps) above or below their current level without the ability to exchange them.

4.2.4 Emission Trading Scheme for Agriculture Scenario (ETSA)

Scenario background

In an Emission Trading System (ETS) GHG emissions of all participants are limited and target amounts ('caps') are decided on, usually amounting to less emission than encountered at present (depending on the agreed emission target, which in rare cases also allows increase in emission). According to the allocation procedure participants are assigned a certain amount of emission rights for a trading period that then can be made use of. The initial distribution of the emission permits can be done in different ways: a) free distribution according to historical emission rates (so-called 'grandfathering'), b) equal distribution among all emitters, c) auctioning to the highest bidder, or d) combined systems (e.g. all emitters receive a basic volume of emission permits and the reminder of the permits is auctioned). However, in a well-functioning emission permits market the way the initial rights are allocated affects only the initial distribution but should not affect the final distribution after emission permits are traded[17].

In October 2003 the EU adopted a proposal for a directive on CO2 emission trading to be operable by January 2005 (Council of the European Union, 2003), establishing a coordinated EU Emission Trading System (EU ETS) over all MS within the EU. Applying to a list of energy and industrial production activities and covering all GHG included in Annex A of the Kyoto Protocol, the legislation aims at reductions of GHG emissions in a costeffective and economically efficient manner (Article 1 of the Kyoto Protocol). However, only CO2 emissions are effectively covered by the directive according to the categories of polluting activities defined in Annex 1. Whereas trading is first applied only to industrial and energy producing activities, other sectors might be included in the future with a view to further improving the economic efficiency of the scheme[18] through possible amendments (Article 30). This is an important point with regard to the potential extension of an ETS to the agricultural sector.

The possible inclusion of agriculture in an existing ETS or alternatively the implementation of an ETS explicitly for the agricultural sector is an issue that is already controversially discussed in several countries. Sadler et al. (2008) highlight the current debate in Australia and stress the need to include incentives to adopt best-practice methods of emission abatement in the agricultural sector, without effectively taxing production through any rigid emission abatement mechanism. The Australian Government is expected to take a decision on the inclusion of agriculture in its Carbon Pollution Reduction Scheme in 2013, which would raise the coverage of overall Australian GHG emissions from 75% to 90%. Lennox et al. (2008) and Kerr et al. (2008) describe the main characteristics of the New Zealand ETS, where agriculture is foreseen to be included in a 'cap and trade' scheme by January 2013, covering then 90% of total GHG emissions in New Zealand. Breen (2008) outlines the importance of targeting GHG emission from agriculture in Australia and New Zealand, countries where this sector shows considerably larger emissions shares (16% and 48% in 2006 respectively) than in the EU (10% in 2006). On these grounds, Breen (2008) also discusses the introduction of Irish agriculture in an ETS, since CH4 and N2O emissions represent about 25% of total Irish GHG emissions. Radov et al. (2007) analyse the scope and feasibility of an ETS for the UK, but do not include a quantitative assessment of its relative merits compared to other regulatory approaches.

Scenario description

This tradable emission permits scenario assumes the explicit implementation of an Emission Trading Scheme for Agriculture (ETSA) in the EU-27[19] . The ETSA is meant to implement a European market of agricultural GHG emission permits affecting all agricultural production activities (i.e. livestock and crop activities are

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[17] It has to be acknowledged that from a policy perspective, there are income/wealth implications for participants depending on how the allocation is made.

[18] The list of activities included in annex I of the directive might be subject to future revision.

[19] In this hypothetical scenario, the inclusion of the agricultural sector in a agricultural specific ETS should also require its exclusion from the ESD.

Table 12. Summary of assumptions and characteristics: Emission Trading Scheme for Agriculture Scenario

	ETSA
GHG abatement policy	Emission trading scheme for the agricultural sector, with EU-27 wide trade of emission permits (1 permit = 1 tonne of CO_2 equivalent)
Projection year	2020
GHG abatement	20% reduction compared to a three-year average 2003-2005 Methane and nitrous oxide emissions covered (aggregated to CO_2 equivalents by using IPCC global warming potentials)
Transaction costs	Variable: 5€ per permit transaction Fix: 10 MM€ (2 MM€ per year to amortise in 5 years)

both included in this ETSA). With this purpose, information on transaction costs (TC) related to existing emission trading schemes is explicitly considered, since TC are expected to have an important effect on the economic performance of such a policy instrument as tradable permits[20].

In the modelling exercise the target is to achieve a 20% GHG emission reduction in the year 2020 compared to EU-27 emissions in a three-year average 2003-2005 (i.e. the base year in the CAPRI model). Therefore a regionally homogeneous emission cap is set on total GHG emissions in all Nuts 2 regions. According to this cap and historical emission levels the emission permits are allocated to agricultural producers (1 permit equals 1 tonne of CO2 equivalent, where CH4 and N2O emissions from agricultural sources are considered). While the emission reduction target is enforced for the aggregate of all EU-27 in this ETSA scenario, trade of emission permits is allowed between regions (i.e. Nuts 2 level), MS and EU-27 wide level. Hence, regions specialised in livestock production are allowed to trade with regions specialised in arable production. The direction of permit trade will depend on the emission-intensity of the farmers' respective production-mix and the corresponding burden imposed by the selected policy instrument.

Variable and fix transaction costs (TC) are introduced, both with the effect of increasing marginal abatement costs (MAC). Variable TC consist of mainly brokerage fees and are paid by permit buyers. In the scenario TC are assumed to vary around 5 % of the transaction value (c.f. Eckermann et al. 2003, p. 16). For the selection of the 'appropriate' TC value in relation to the final permit price, a 'sensitivity analysis' for different values was carried out with the CAPRI model. Moreover, institutional costs of the trading scheme (approximately 50 Million Euro) are proposed as fix costs for setting up and maintaining the emission trading market. These fix costs are also assumed to be paid by permit buyers and therefore distributed over transactions. The assumptions on the TC in this scenario are defined based on information found in the literature for the Clean Development Mechanism (CDM) and Joint Implementation (JI) projects in different economic sectors and size of the markets (compilation by Eckermann et al. 2003, pp. 68). In order to test the effect of TC to the performance of the ETSA scenario, different levels of TC have been subject to a sensitivity analysis.

With respect to the transaction costs it has to be further noted that in this ETSA scenario farmers would be directly trading emission permits with each other but not with other sectors (isolated market). Although we are talking about fairly small entities, farms in the EU are already subject to large reporting obligations in terms of nutrient loads and activity numbers. Therefore we assume that through a hypothetical stock market for emissions, additional transaction

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[20] Transaction costs as defined in this scenario are those costs that arise from setting up and maintaining the emission trading system, initiating and completing transactions, such as finding partners, holding negotiations, consulting with lawyers or other experts, etc.

costs for the farmers could be kept at reasonable levels. In our exercise, transaction costs are defined per emission permit and include also monitoring/verification costs as part of the fix costs. However, it has to be highlighted that the available information on transaction costs with respect to the emission trading scheme is rather weak and that therefore no robust conclusions can be derived from this exercise regarding the real transaction costs of a specific emission trading scheme for agriculture.

4.2.5 Livestock Emission Tax Scenario (LTAX)

Scenario background

Livestock activities emit considerable amounts of GHGs. While direct emissions from livestock come from the respiratory process of all animals in the form of carbon dioxide, ruminants in particular emit CH4 as part of their specific digestive process. A further important source of livestock GHG emissions is animal manure (cf. FAO, 2006, Leip et al., 2010). In order to reduce the contribution of ruminants on GHGs, one possibility would be to directly reduce emissions by capping animal herd sizes or enforcing new technologies. Another possibility would be to indirectly affect livestock emissions through the implementation of livestock taxes. Although such a livestock tax is not yet implemented in any MS of the EU, press reports indicate that it has been recently under consideration in Ireland. The Irish Times reported suggestions to impose a tax set at 5€ per tonne of CO2 emitted per ruminant (which should generate revenue worth 104€ million for the Irish Government). Converted into a tax per ruminant livestock head, such a livestock emission tax would imply an annual levy of 13€ per dairy cow (0.27€ cent per kg[21]), 7€ per non-dairy cow and 1€ per sheep (Irish Times, 2009). Other countries like Denmark and the USA also have discussed the implementation of a livestock tax. For example the Danish tax commission recommended that a cow tax should be imposed and suggested an amount as high as €80 per animal, however this levy proposal did not went through the Danish parliament.

It is not clear whether the rates of levy on livestock as proposed in Ireland or Denmark would have significant impacts on production of milk and meat and, therefore, reduce GHG emissions. Furthermore, no formal initiatives have been taken up to now to implement a livestock tax within the EU. Nevertheless, and as the literature does not provide information or case studies about possible effects, it can be considered as a reasonable exploratory approach to analyse the effects of a possible implementation of a livestock tax.

Scenario description

For this exploratory exercise we modelled the effect of an EU-wide livestock emission tax per tonne of CO2 equivalent emissions (independent of animal type), including not only CH4 but also N2O from manure management activities[22]. The livestock emission tax is set at an amount so that a GHG emission reduction of 20% will be met in the year 2020 in the EU-27 (as in the other policy simulation scenarios). By conducting some trial simulation runs using different tax levels, we found that a tax of about 229 € per tonne of CO2 equivalent livestock emissions would be necessary in order to achieve the envisaged reduction in overall EU agricultural GHG emissions of 20%. The tax is split across the livestock types according to their emission intensities, so that ruminants receive a higher tax than non-ruminants. It has to be noted, that in this study the generated revenues from the livestock tax system would not revert into the system[23].

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[21] Assumed production of 5000 kg per cow.

[22] Emissions from manure management are included in the system. The calculations in CAPRI are performed at IPCC Tier 2 level, so that nutrient intake and excretion by animals, as well as intensity, is considered in the simulation.

[23] In practice the tax revenue raised could for example be used to pay for emission reduction efforts in the agricultural or other sectors.

Table 13. Summary of assumptions and characteristics: Livestock Emission Tax Scenario

	LTAX
GHG abatement policy	229 € per tonne of CO2 equivalent from livestock (regional homogenous, i.e. independent of animal type))
Projection year	2020
GHG abatement	20% reduction compared to a three-year average 2003-2005 Methane and nitrous oxide emissions covered (aggregated to CO_2 equivalents by using IPCC global warming potentials)

4.3 Complementary technological abatement scenarios

As already explained in section 4.1, technological responses to the policy measures by the farmers are not specifically considered in the mitigation policy scenarios. Thus famers only respond to the mitigation policies by shifts in the activity mix, but not by changing their production techniques in order to mitigate GHG emissions. To get an idea of the magnitude of the effects that technological changes may have on GHG emissions, we also assess some complementary technological abatement scenarios. In these complementary scenarios the changes in production technology are pre-defined (i.e. not endogenously calculated by the CAPRI model).

There are various technological options how farmers could reduce GHG emissions. A list of specific, available management techniques across all agricultural sectors that could be implemented to achieve GHG mitigation in the EU is given in Leip et al. (2010, particularly in chapter 7). Based on the availability of emission reduction factors and applicability of the available information to the CAPRI model, Leip et al. also quantify the emission production potential of some technological measures. The quantification in Leip et al. (2010) covers the following technological measures:

- Various abatement measures targeting ammonia (stable adaptation, covered storage, low ammonia application, urea substitution).
- Replacement of grazing with indoor feeding to reduce nutrient needs for animal activity.
- Biogas production on the basis of manure.

While we will run a scenario with various abatement measures targeting ammonia, the replacement of grazing will not be investigated as according to Leip et al. (2010) this measure does not decrease GHG emissions. Biogas production, on the contrary, seems to be a promising alternative for GHG emission abatement. However, biogas production would have to be co-ordinated with the biogas assumptions in the baseline that are inherited from the PRIMES[24] biomass component. The PRIMES biomass component delivers detailed information on various forms of bioenergy that is used as expert information in the CAPRI projection modules. Furthermore, there is a need to acknowledge the significant biogas production based on green maize that has developed in Germany and other countries. This is an area of on-going model improvement in the CAPRI modelling system but so far is not suitable for an ex ante impact assessment and therefore could not be analysed within the study at hand.

Besides a scenario with various abatement measures targeting ammonia (AMMO Scenario, section 4.3.1), we selected two other types of technical measures based on a CAPRI project for the European Commission Directorate-General for

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[24] PRIMES is an energy model with detailed coverage of European energy demand and supply subsectors that usually underlies European Commission outlooks in the energy sector (Capros et al., 2010).

Environment (DG ENV)[25]. The measures analysed are a more balanced fertilization (BAL Scenario, section 4.3.2) and the measure to reduce nitrogen import into agriculture through low nitrogen feeding (LNF Scenario, section 4.3.3).

The three complementary technological abatement scenarios are not designed to achieve a certain GHG emission reduction target, but to see what effect the change in production technology would have on the development of GHG emissions. To get also an idea on the effects that the technological abatement measures would have in combination with the emission mitigation policies, we run one scenario where we introduce the measures of a more balanced fertilization and low nitrogen feeding into the Emission Trading Scheme for Agriculture scenario (ETSBL Scenario, section 4.3.4).

As a matter of course there are many technological GHG abatement options. Some of these options, like e.g. increasing the nutrient concentration in ruminant diets, are certainly more promising for GHG abatement than the ones that can be investigated in this report. However, when selecting the technological measures for our study we had to make use of available information in other CAPRI projects, because the appropriate translation of further technological GHG abatement measures into changes of CAPRI parameters would be a project on its own and therefore was not possible within this study. Nonetheless we expect to gain valuable information on the magnitude of the effects that technological changes may have on GHG emissions.

4.3.1 Combination of Various Measures Targeting Ammonia Scenario (AMMO)

The CAPRI system includes assumptions on the use of various ammonia abatement options that originally have been compiled for scenarios with the RAINS/GAINS[26] and MITERRA[27] models:

1. Stable adaptation by improved design and construction of the floor (applicable for cattle, pigs and poultry), flushing the floor, climate control (for pigs and poultry), or wet and dry manure systems for poultry.

2. Covered manure storage (low efficiency options with floating foils or polystyrene, and high efficiency options using tension caps, concrete, corrugated iron or polyester).

3. Bio filtration (air purification) by treatment of ventilated air, applicable mostly for pigs and poultry, using biological scrubbers to convert the ammonia into nitrate or biological beds where ammonia is absorbed by organic matter.

4. Low ammonia application of manure, distinguishing high efficiency (immediate incorporation, deep and shallow injection of manure) and medium to low efficiency techniques, including slit injection, trailing shoe, slurry dilution, band spreading, sprinkling (spray boom system).

5. Urea substitution, substitution of urea with ammonium nitrate.

6. Incineration of poultry manure.

In the AMMO scenario it is assumed that the "penetration" of these measures in agriculture would increase. More precisely we adopted the

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[25] For further information on this project see http://www.scammonia.wur.nl

[26] GAINS is short for "Greenhouse Gas and Air Pollution Interactions and Synergies" which is a model describing the evolution of various pollutants and their abatement options developed by the International Institute for Applied Systems Analysis (IIASA), see http://gains.iiasa.ac.at/.

[27] MITERRA is a model to assess the effects of implementation of nitrate and ammonia measures and policies on the emission of ammonia and greenhouse gasses, the leaching of nitrate to ground and surface water and the phosphorus balance on both EU-27, country and regional level (Velthof et al., 2007)

application rates determined by IIASA with the GAINS model as cost effective to meet the targets of the Thematic Strategy on Air Pollution for NH3 emission (Amann et al., 2006a and 2006b) that has also been investigated in Witzke and Oenema (2007). According to earlier findings it can be expected that this package will reduce ammonia emissions but that GHG emissions would increase. Nonetheless it may still be an interesting option as the full influence of ammonia emissions may be insufficiently accounted for in CAPRI. The importance of ammonia is underestimated if the atmospheric deposition of nitrogen it treated as an exogenous input into the system whereas in reality the reactive nitrogen in the atmosphere is originating to an important degree in ammonia emissions from agriculture. Furthermore ammonia is known to exacerbate the consequences of GHG emissions in the atmosphere. However, to make this link explicit requires the integration of atmospheric models that needs to be left to future work.

The increased use of ammonia abatement measures causes additional cost to the farmers that have been adopted from the IIASA work to increase the "other cost" component in the CAPRI model (CAPRI input item "INPO") of animal activities accordingly.

4.3.2 More Balanced Fertilization Scenario (BAL)

Nutrient balancing in CAPRI is described in some detail in Britz and Witzke (2008; section 2.5.4). Basically there are two parameters in CAPRI that account for the fact that in total, nitrogen supply to crops considerably exceeds the demand for harvested material. One of the parameters reflects the partial availability of nutrients from manure relative to mineral fertilizer and the second parameter reflects the fact that farmers tend to apply more fertilizer than needed, even after accounting for partial availability of nutrients from manure. For the BAL scenario we assume are a more efficient (organic and mineral) fertilizer management, be it autonomous or enforced through more stringent environmental legislation. For a more technical description of the working of this measure and its implementation into CAPRI see Annex VII.

Balanced fertilization means that the crop need/uptake and the applying of fertilizer and or manure are more geared to each other. In this scenario the tuning was technically implemented in CAPRI by lowering the difference between the amount of nitrogen applied by manure and fertilizer and the relation between the availability of manure to mineral fertilizer. In other words: a reduction of over-fertilization through less application of nitrogen and an increase of applied nitrogen from manure compared to mineral fertilizer (i.e. less fertilizer use).

More balanced fertilizer use in total implies a more efficient (organic and mineral) fertilizer management, including more careful establishments of fertilizer plans, more frequent soil analyses, perhaps split applications of fertilizer and more demanding crop management in general to bring about the increase in efficiency implied by a reduction in fertilizer input while maintaining output. As the overall N input into agriculture would be reduced, both NH3 and N2O emissions may be expected to decline. To account for the additional management efforts we assumed a flat rate cost of 25 € per ha for a full elimination of over fertilization (12.5 € for a 50% cut) as in Witzke and Oenema (2007).

4.3.3 Low Nitrogen Feeding Scenario (LNF)

Lowering the nitrogen in feed decreases the uptake of nitrogen and therefore the possible losses of N2O. Usually certain luxury consumption is implied in the CAPRI database. In particular farmers seem to feed more protein than required according to the animal nutrition literature (a typical excess is 20%). The reasons may be risk considerations to lose some yield if the recommendations turn out wrong or if the protein content of own produced fodder is lower than expected. In fact the data usually also reveal some waste or luxury consumption of feed energy

Table 14. Assumed protein reduction rates in EU-15 countries as a function of initial protein and energy surpluses

energy surplus (%)	**protein surplus (%)**				
	10	20	30	50	100
0	-2,1	-4,2	-6,4	-10,6	-21,2
5	-2,0	-4,0	-6,0	-10,0	-20,2
20	-1,7	-3,4	-5,1	-8,5	-17,1
50	-1,3	-2,7	-4,0	-6,6	-13,3
100	-1,0	-1,9	-2,9	-4,8	-9,6

but this is smaller than for protein (a typical value is 5%). The LNF scenario assumes that with intensified extension work for feed management, the excess protein consumption might be reduced by half in the typical case (20% excess protein, 5% excess energy) if all farmers could be persuaded to participate. However, a penetration rate of 100% is evidently unrealistic and therefore we assume a penetration rate of about 40% in EU-15 and 35% in EU-12 (considering that the amount of very small farmers is bigger in the EU-12 than in the EU-15). Furthermore we have to consider that a high energy surplus may be indicative of general waste (more difficult to tackle than "just" waste of protein) or of statistical problems. Therefore the feasible reduction in the protein surplus is assumed to be inversely related to the energy surplus according to a formula that gives the reduction rates for this scenario as presented in Table 14.

Accordingly, in the typical case (5% energy surplus), the average initial protein surplus of 20% will be reduced to 16% only. These are cautious assumptions[28], made in view of the fact that extension measures require the successful interaction of several communication partners from the policy level down to the individual farmer.

To reduce luxury consumption of protein, the requirements of animals as assumed in the CAPRI model have been reduced accordingly. This will reduce the N content of excretions. It has been further assumed that extension services may also convince farmers that it is not necessary to counteract less N in manure with additional mineral fertilizer application, such that the availability factor has been adjusted in such a way that farmers do not neutralise the decline in supply of N in manure.

To account for the additional management efforts and potentially additions of particular amino acids, a top-up has been specified in CAPRI for the "other cost" component of each animal activity as a function of the reduction in the protein surplus. For (high yielding) dairy cows, this top-up is 113 Euros per cow[29]. However, a reduced demand for protein allows for endogenous feed cost savings through substitution of protein feeds (oil cakes) by cheaper alternative feed ingredients. Furthermore the EU feed demand will also decline due to lower meat and milk production. Both effects combine to yield a net cost increase of about 20 Euros only per average (high yielding) dairy cow in EU-27. This is a low estimate compared to the assumption in GAINS (where a cost increase of +55 Euros is considered), but our analysis is also cautious in

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[28] In fact the table needs to be considered a scenario assumption even though it is technically obtained through an (adjustable) formula in the CAPRI code.

[29] This is specified as a function of the cut in the protein surplus relative to the initial surplus to obtain an automatic adjustment to the data driven scope of the LNF measure (top up = constant*relative surplus/(1-relative surplus)*initial feed cost).

terms of the likely penetration of this measure (the average surplus reduction is only 4 percentage points => 40 % penetration * 10% reduction for the participating farmer).

4.3.4 Combination of ETSA with BALF and LNF Scenario (ETSBL)

In contrast to the mitigation policy scenarios, the three complementary technological abatement scenarios are not designed to achieve a certain GHG emission reduction target, but to see what effect the changes in production technology would have on the development of GHG emissions. As a result, the technological abatement measures are insufficient to meet the 20% reduction target of the mitigation policy scenarios. To get also an idea on the effects that the technological abatement measures would have in combination with the emission mitigation policies, it was decided that the technological measures are included in combination with one of the policy scenarios to achieve the desired 20% reduction in GHG emission. We did not combine the technological scenarios with all policy scenarios, because we needed to keep the number of scenarios limited in order to keep the overview. The AMMO scenario was not used for the scenario combination because it turned out to increase emission of N2O. Therefore we opted to combine the scenarios with balanced fertilization (cf. Section 4.3.2), low nitrogen feed (cf. Section 4.3.2) and the emission trading scheme for agriculture (cf. Section 4.2.4).

5 Results of the Reference Scenario

In this chapter we present the main results of the reference scenario. We first provide results for the developments of major EU agricultural markets (section 5.1) as these developments influence the developments of the GHG emissions. Projection results for agricultural emission inventories in the EU are then presented in section 5.2. In the calculation of baseline emission inventories (i.e. projected changes of emissions over time) two important variables have to be considered: activity data and emission factors. Activity data show the evolution of agricultural markets in a certain period. This is linked to historical trends, inclusion of new policies (e.g. the CAP Health Check, cf. section 4.2.1) and expert judgements. Emission factors are related to energy requirements by animals, nutrient availability to crops (e.g. data on mineral fertilizer application by the International Fertilizer Association) and, therefore, are indirectly related to activity data (e.g. yield changes). As a consequence, emission factors may change over time, depending on their determinants according to the IPCC Tier 2 approach.

5.1 Projection of agricultural market developments between 2004 and 2020

In this section the projected developments of agricultural markets between 2004 and 2020 are presented. In addition to looking 16 years ahead from the base year 2004 (three year average 2003-2005) to year 2020 the following tables include for selected variables also a comparison with the situation in 1991, to put the changes in some perspective. The year 1991 is chosen because it is the first year in the CAPRI database with fairly settled data for Germany after reunification and it immediately precedes the MacSharry reform of the CAP.

In the dairy sector production changes in the EU-15 have been historically limited to small percentage changes by the milk quota regime, i.e. the milk production was nearly constant at the EU-15 level (Table 15). Only some exceptional quota increases in Greece, Italy and Portugal permitted a stronger growth in production. Austria developed to a systematic over-producer in the historical period. The quota regime imposed a continuous decline of dairy herds in the past to comply with increasing yields, in particular where yield growth has been very strong (e.g. Austria). Projection results for the year 2020 indicate that the removal of the quota constraint as of 2015 is likely to lead to a slight milk production increase in EU-15 (+3%), with growing dairy herd sizes only in the Netherlands (+5%) and Ireland (+1%). All other EU-15 MS (except Belgium and Luxembourg) see a decline in dairy herd size, most likely following the pressure form historical declining prices on the one hand and increases in milk yields on the other hand (most pronounced in Finland, Portugal, Germany). But even in competitive regions like Austria continuous yield growth may be so strong that dairy herds decline in spite of an increase in production.

The EU-12 countries have made the transition from a centrally planned system to the market system, which involved a strong drop in milk production in most countries except Slovenia and Romania and yield growth lagging behind the progress in EU-15 countries. The baseline indicates that yield growth in the EU-12 will be stronger than in the EU-15, given that they are further away from the technical frontier and intra EU technology transfer is rather easy, except for Bulgaria and Romania where restructuring is expected to imply stagnating yields. Nonetheless this baseline assumes, in line with many specific studies on dairy markets, that EU-12 countries will lose market shares and that their production and dairy herds are likely to decline.

Table 15. Dairy sector development by EU MS, base year compared to the baseline year 2020

	Base year (2004)						Reference year (2020)		
	Dairy herd [1000 hd]	**Yield [1000 t]**	**Production [1000 t]**	**Dairy herd [% to '91]**	**Yield [% to '91]**	**Production [% to '91]**	**Dairy herd [% to BAS]**	**Yield [% to BAS]**	**Production [% to BAS]**
Austria	552,2	5215,2	2879,6	-39,9	88,4	13,3	-8,8	23,5	12,6
Belgium-Lux.	610,3	5320,3	3247,1	-37,0	44,0	-9,2	-0,0	9,8	9,8
Denmark	579,2	7765,5	4498,1	-25,8	30,4	-3,3	-13,6	12,7	-2,6
Finland	327,0	7352,1	2404,2	-28,1	9,1	-21,6	-27,5	15,2	-16,5
France	3927,1	6025,0	23661,0	-30,6	37,2	-4,8	-13,6	14,7	-0,8
Germany	4318,7	6400,6	27642,0	-27,9	38,8	1,0	-17,0	27,2	5,6
Greece	149,0	4823,9	718,9	-34,3	81,1	18,9	-10,0	17,7	6,0
Ireland	1139,7	4641,4	5289,9	-18,2	20,9	-1,2	0,7	8,4	9,1
Italy	2007,2	5464,7	10968,6	-29,1	61,6	14,7	-7,9	15,5	6,4
Netherlands	1517,4	7063,2	10717,5	-24,0	29,0	-2,0	5,0	4,5	9,7
Portugal	329,6	5971,5	1968,3	-20,2	80,8	44,3	-19,5	15,7	-6,9
Spain	1093,0	5758,6	6294,3	-32,8	75,5	17,8	-10,1	16,4	4,6
Sweden	400,7	7933,1	3178,8	-30,5	32,7	-7,7	-16,3	16,8	-2,3
United Kingdom	2085,4	6888,9	14366,1	-30,0	36,2	-4,7	-14,9	12,8	-4,0
EU15	19036,5	6189,9	117834,2	-29,0	41,0	0,1	-11,2	15,7	2,8
Cyprus	25,5	5356,0	136,5	45,9	23,4	80,1	-4,9	8,6	3,2
Czech Republic	413,8	6314,6	2612,9	-63,4	52,9	-44,0	-46,3	32,5	-28,8
Estonia	114,8	4950,6	568,1	-62,0	27,6	-51,5	-36,7	22,1	-22,8
Hungary	293,7	6080,7	1786,1	-44,0	22,2	-31,6	-33,8	15,7	-23,4
Latvia	167,3	3639,5	608,8	-69,4	-8,0	-71,9	-17,4	4,8	-13,4
Lithuania	427,8	3432,9	1468,7	-50,0	-3,3	-51,6	-24,6	21,7	-8,2
Malta	7,1	5403,4	38,6	27,1	-2,9	23,5	21,4	30,0	57,9
Poland	2667,3	4059,6	10828,2	-47,3	48,0	-22,0	-37,8	27,8	-20,5
Slovac Republic	128,3	4248,4	545,0	-60,7	-11,7	-65,3	-17,7	57,6	29,7
Slovenia	156,7	5719,0	896,2	12,8	73,1	95,2	-32,6	-13,8	-42,0
10 New MS	4402,3	4427,1	19489,1	-50,6	32,9	-34,3	-35,2	23,3	-20,1
Bulgaria	364,9	3471,2	1266,6	-40,9	-0,3	-41,1	-1,3	-4,2	-5,4
Romania	1484,8	3378,3	5016,3	-12,7	25,6	9,7	-19,7	1,7	-18,4
Bulgaria/Romania	1849,7	3396,6	6282,9	-20,2	17,1	-6,5	-16,1	0,4	-15,8
EU27	25288,5	5678,7	143606,2	-33,5	40,2	-6,8	-15,7	17,3	-1,1

Production of beef has been declining in the EU-15 countries by -13% since 1991, but this decline is expected to be reversed to an increase by 2020 (+4.7% compared to 1991 and +20.5 % compared to 2004). On the other hand, decrease in the beef herd is projected to further continue (-8.8% in EU-15). Strongest production increases are projected for Spain, Greece and Portugal, although achieved with rather slight increases in beef herd size. In EU-12 the restructuring difficulties in the livestock sector are expected to contribute to a further decline of production and beef herd.

Demand of beef is expected to slightly decline in the baseline by 2.5% against 2004 for EU-27, which is a stabilisation of the reduction over the previous decade (-17% change from 1991 to 2004). The decline in demand for beef is stronger in EU-10 (-29%) than in the EU-15 (-0.4%), but with a remarkable heterogeneity between single MS. In part this heterogeneity is already visible in the ex post data, considering examples like Germany (strong decline) and Denmark (strong increase), where historical trends are expected to persist. In other cases like Finland, Cyprus, Malta and Latvia the very recent

Table 16. Beef sector development by EU MS, base year compared to the baseline year 2020

	Base year (2004)						Reference year (2020)			
	Beef* herd [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Production [% to '91]**	**Demand [% to '91]**	**Beef* herd [% to BAS]**	**Production [% to BAS]**	**Demand [% to BAS]**	**Net trade [D to BAS]**
Austria	661,2	213,6	155,3	58,3	-12,2	-4,6	-19,4	-14,8	-17,3	-4,6
Belgium-Lux.	810,2	309,7	212,5	97,1	-7,8	-3,4	-18,4	-12,2	-1,5	-34,5
Denmark	430,8	142,2	145,2	-3,0	-34,3	92,7	-24,8	-22,6	45,7	-98,5
Finland	237,7	92,3	95,4	-3,1	-30,0	-21,8	-4,1	-15,5	20,1	-33,5
France	6677,3	1834,4	1835,2	-0,9	-8,4	8,2	-4,5	-6,9	-9,9	54,6
Germany	3082,1	1296,0	1083,3	212,7	-43,1	-49,1	-47,1	-28,6	-46,1	128,6
Greece	289,6	49,9	169,6	-119,7	-32,7	-12,3	11,8	-7,2	-11,9	16,6
Ireland	2650,8	570,3	83,4	486,9	10,0	-19,3	0,1	8,9	29,6	26,2
Italy	2800,7	973,2	1230,0	-256,8	9,9	-17,0	-7,6	-3,6	3,5	-77,7
Netherlands	159,9	373,1	295,6	77,5	-22,5	5,9	-62,5	-13,2	21,2	-112,2
Portugal	621,8	117,0	191,9	-74,9	3,2	36,8	7,8	13,7	15,7	-14,1
Spain	4152,6	680,0	615,1	64,9	58,5	41,1	8,3	6,2	33,0	-160,8
Sweden	451,0	141,1	205,1	-64,0	-10,3	17,6	-22,3	-12,1	42,7	-104,7
United Kingdom	3862,9	844,6	1199,0	-354,4	-8,4	0,1	-6,2	-3,4	13,8	-194,2
EU15	26888,5	7637,3	7516,6	120,6	-13,1	-10,6	-8,8	-8,4	-0,4	-608,8
Cyprus	11,0	4,2	6,1	-1,8	5,8	-36,4	83,4	30,0	48,8	-1,7
Czech Republic	291,9	100,4	94,2	6,2	-71,2	-72,7	-57,4	-40,2	-59,4	15,6
Estonia	48,7	18,3	18,8	-0,5	-70,5	-65,9	-55,9	-36,2	-78,1	8,1
Hungary	92,9	44,5	44,7	-0,2	-63,8	-45,8	-42,7	-26,0	-10,0	-7,1
Latvia	62,4	20,2	19,5	0,7	-85,2	-84,9	10,8	8,5	16,8	-1,6
Lithuania	150,2	50,5	42,6	7,9	-77,8	-77,2	-57,9	-35,7	-73,2	13,2
Malta	3,0	1,3	6,9	-5,6	31,8	-30,5	6,0	6,9	35,7	-2,4
Poland	824,2	361,7	319,2	42,5	-44,0	-46,4	-7,6	-10,0	-30,3	60,6
Slovac Republic	138,4	54,6	54,7	-0,1	-44,9	-44,6	-73,1	-42,0	-37,0	-2,7
Slovenia	70,4	40,7	41,3	-0,5	6,0	3,7	75,8	27,6	65,4	-15,7
10 New MS	1693,1	696,5	647,8	48,7	-58,7	-58,3	-24,6	-17,4	-29,0	66,3
Bulgaria	123,0	47,8	80,0	-32,2	-63,7	-37,0	86,6	31,3	10,7	6,4
Romania	957,7	233,0	234,8	-1,8	-3,2	29,4	-8,8	-12,2	-2,3	-23,0
Bulgaria/Romania	1080,7	280,8	314,8	-33,9	-24,6	2,0	2,0	-4,8	1,0	-16,6
EU27	29662,2	8614,6	8479,2	135,4	-20,6	-17,5	-9,3	-9,0	-2,5	-559,1

* *'Beef herd' = suckler cows + adult cattle for fattening in this table.*

ex post data show already that the historical decline has come to a halt with some recovery, however this is not visible in the table. It has to mentioned that there are also some cases with rather irregular historical data, partly influenced by stock changes in the total demand data like Ireland, which makes it rather difficult to predict future demand evolution.

The sheep sector (Table 17) is next important to cattle with respect to CH4 emissions, but with a much lower weight. The key producers in EU-15, France, Greece, Spain and the UK are projected to see a decline in production. This development would be a revision of the past growth in the case of Spain, based on national expert information. For the largest producer UK a stabilisation at moderately reduced level is projected, such that the past decline in production and in the sheep herd of EU-15 would be moderated. For the largest producer in the EU-12 group it also appears that the strong drop in production will continue but level off. The evolution in EU-12 countries may be seen to be very diverse and often showing large changes. It should be recognised, however that markets in EU-12 are rather small, with the

Table 17. Sheep sector development by EU MS, base year compared to the baseline year 2020

	Base year (2004)						Reference year (2020)			
	Ewes & goats [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Production [% to '91]**	**Demand [% to '91]**	**Ewes & goats [% to BAS]**	**Production [% to BAS]**	**Demand [% to BAS]**	**Net trade [D to BAS]**
Austria	84,9	7,0	9,4	-2,4	95,0	79,7	-5,1	2,6	-10,4	1,2
Belgium-Lux.	67,6	2,6	22,9	-20,3	-40,5	27,2	-17,2	-10,5	-10,5	2,1
Denmark	70,7	2,2	7,2	-5,0	67,1	82,6	2,2	-0,5	-0,1	0,0
Finland	21,7	0,8	2,1	-1,3	-6,7	65,4	8,1	9,3	-3,8	0,2
France	6235,7	133,5	270,4	-136,9	-11,1	3,2	-22,8	-22,4	-19,4	22,5
Germany	591,1	44,7	84,0	-39,4	3,9	14,0	4,4	10,4	-12,6	15,3
Greece	7512,5	114,8	130,7	-15,9	-9,3	-7,4	-23,0	-12,7	0,7	-15,5
Ireland	2927,7	68,9	20,4	48,5	25,6	-15,5	-29,8	-29,6	-31,0	-14,1
Italy	3940,2	25,7	48,9	-23,3	-48,6	-47,4	-8,5	-1,5	40,4	-20,1
Netherlands	488,8	21,9	26,2	-4,3	11,1	161,5	18,1	10,8	-8,2	4,5
Portugal	1023,2	24,2	32,8	-8,6	-16,8	-0,9	-18,0	-28,5	-13,3	-2,5
Spain	19501,8	245,5	231,7	13,9	6,5	3,4	-19,2	-23,9	-12,5	-29,9
Sweden	170,5	4,4	9,8	-5,4	-3,6	56,9	1,2	-7,0	2,5	-0,6
United Kingdom	13396,9	333,5	372,3	-38,8	-7,0	-6,7	-19,4	-13,6	-7,1	-19,2
EU15	56033,2	1029,5	1268,7	-239,2	-4,4	-2,0	-19,2	-16,5	-9,0	-56,1
Cyprus	102,8	8,4	9,5	-1,1	-6,0	-2,8	-53,6	-13,4	21,6	-3,2
Czech Republic	53,9	4,4	5,1	-0,7	-65,5	-29,3	-33,1	-29,1	-94,1	3,5
Estonia	6,7	0,4	0,4	0,0	-82,7	-84,1	-79,8	-2,4	189,5	-0,7
Hungary	347,6	10,4	10,3	0,1	-11,9	131,9	-32,3	-17,0	-6,8	-1,1
Latvia	10,0	0,6	0,6	-0,0	-86,3	-85,3	37,6	-9,1	86,4	-0,6
Lithuania	4,9	0,7	2,5	-1,8	-64,3	16,4	-79,7	-10,4	14,3	-0,4
Malta	1,1	0,1	0,2	-0,1	5,9	-87,2	-80,0	-9,1	17,6	-0,0
Poland	40,6	4,7	4,8	-0,0	-88,9	-83,9	1,7	-13,3	43,2	-2,7
Slovac Republic	5,9	0,4	0,5	-0,1	-95,9	-95,2	692,7	680,5	813,0	-1,0
Slovenia	85,0	3,4	3,4	0,0	3330,0	2026,9	-87,6	-85,4	-82,5	-0,1
10 New MS	658,6	33,5	37,1	-3,6	-64,6	-47,3	-34,1	-15,1	3,2	-6,2
Bulgaria	589,8	65,5	60,5	5,1	-25,6	3,0	-79,7	-23,9	87,6	-68,7
Romania	2335,2	78,9	68,6	10,3	-13,9	-11,1	-79,8	5,4	-15,9	15,2
Bulgaria/Romania	2924,9	144,5	129,1	15,4	-19,6	-5,0	-79,8	-7,9	32,6	-53,5
EU27	59616,7	1207,4	1434,9	-227,5	-10,6	-4,4	-22,4	-15,4	-4,9	-115,8

entire demand in EU-10 barely exceeding that of Portugal in the base year. This low initial level of demand in EU-10 contributes to large percentage changes possible. In general EU-27 demand is declining less than production, and therefore the EU net trade position is further deteriorated.

Even though the pig sector is not a big source of CH4 it is an important source of nitrogen and hence N2O. In the past several large producers have developed with strong dynamics, most importantly Denmark and Spain (Table 18). However, national expert information has confirmed that increasingly stringent environmental regulation will bring this growth to a halt (Denmark) or strongly dampen the future growth of supply. This is often put forward to explain the decline of Dutch pig production whereas the drop in the UK and Greece may have more to do with a loss in competitiveness. Demand growth has been a reliable support for the evolution of EU-15 pork markets in the past, but this stimulus may be seen to weaken in the projection period.

Pork markets in the EU-12 have suffered during the transition phase as may be read from the past changes. An important exception is

Table 18. Pig sector developments by EU MS, base year compared to the baseline year 2020

	Base year (2004)						Reference year (2020)			
	Fattened pigs [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Production [% to '91]**	**Demand [% to '91]**	**Fattened pigs [% to BAS]**	**Production [% to BAS]**	**Demand [% to BAS]**	**Net trade [D to BAS]**
Austria	4731,8	476,9	430,6	46,3	4,5	-6,7	-4,2	4,9	12,1	-28,8
Belgium-Lux.	10799,2	1027,4	500,1	527,3	27,4	4,0	11,8	18,3	14,6	115,2
Denmark	24403,1	1873,0	410,0	1463,0	60,3	23,1	0,5	1,6	-38,4	187,7
Finland	2279,2	198,5	177,4	21,1	28,5	18,7	-15,1	-4,3	14,3	-33,9
France	25561,1	2335,7	2216,0	119,7	31,3	5,2	11,3	13,5	4,3	218,0
Germany	40939,8	4163,3	4299,3	-136,0	10,0	-2,2	14,3	15,1	1,3	571,2
Greece	2064,2	131,3	301,2	-169,9	-17,8	39,7	-34,7	-34,6	20,4	-106,8
Ireland	2698,3	222,6	160,6	62,0	55,4	28,5	-13,8	-8,2	30,1	-66,6
Italy	12377,9	1498,2	2206,9	-708,7	30,0	28,9	7,9	9,8	30,9	-536,1
Netherlands	16167,8	1491,5	747,8	743,7	-21,8	8,7	-7,2	-1,0	-26,2	180,5
Portugal	4946,5	330,2	442,1	-111,9	45,5	79,1	-5,9	-10,3	26,1	-149,4
Spain	36636,0	3201,9	2676,1	525,8	88,2	54,0	16,5	21,6	5,2	551,8
Sweden	3192,6	287,2	318,6	-31,4	-3,8	14,6	-14,2	-4,6	4,8	-28,5
United Kingdom	8713,4	681,3	1230,3	-548,9	-33,2	-13,5	-13,4	-3,2	14,6	-201,3
EU15	195510,6	17918,9	16116,8	1802,0	21,4	12,3	6,4	10,4	7,4	673,1
Cyprus	668,2	55,5	54,8	0,7	97,5	116,7	18,2	20,5	52,4	-17,3
Czech Republic	4474,6	439,3	465,5	-26,3	-37,1	-33,2	-20,8	-10,3	13,7	-108,9
Estonia	481,7	40,5	50,3	-9,8	-62,4	-53,6	1,4	13,1	21,3	-5,4
Hungary	5023,4	511,0	480,4	30,6	-46,5	-43,0	-20,4	-10,9	0,6	-58,6
Latvia	322,9	32,7	33,5	-0,8	-77,6	-78,0	0,0	-12,7	5,4	-6,0
Lithuania	1293,4	100,1	118,2	-18,2	-56,0	-40,9	-2,1	8,7	39,7	-38,3
Malta	109,0	8,6	12,8	-4,2	24,3	48,2	-5,2	2,1	25,2	-3,0
Poland	22865,9	1989,4	1881,4	108,0	11,0	7,3	4,1	7,3	3,3	83,3
Slovac Republic	406,4	35,6	54,0	-18,4	-84,2	-76,8	123,6	101,5	171,9	-56,7
Slovenia	1703,8	151,7	171,5	-19,8	234,8	192,0	-83,0	-81,1	-66,2	-9,6
10 New MS	37349,2	3364,3	3322,4	42,0	-20,5	-18,5	-4,9	-0,6	6,0	-220,5
Bulgaria	1004,1	90,9	113,4	-22,5	-77,4	-65,7	-77,0	-73,8	-34,2	-28,3
Romania	5867,0	516,8	641,3	-124,5	-40,0	-14,9	-32,6	-20,3	29,2	-292,0
Bulgaria/Romania	6871,1	607,7	754,7	-147,0	-51,9	-30,4	-39,1	-28,3	19,7	-320,3
EU27	239731,0	21890,9	20193,9	1697,0	8,1	3,5	3,3	7,6	7,6	132,3

Poland's pork sector that turned out quite resistant in the evolving market economy and may be expected to grow strongly and come close to France soon in terms of the pig population. While both supply and demand growth is losing momentum (with EU12 production even decreasing), supply growth is still ahead of demand growth in the EU-27 and therefore net exports would tend to increase by 0.1 million tonnes in 2020 relative to the base year.

Poultry markets have shown the strongest growth in the past among all meats, both on the supply and demand side (Table 19). With a few exceptions poultry production has also grown in the EU12, where a strong decline of animal production in the recent past was experienced in other sectors. However, this dynamic is likely to even out. On the demand side saturation may be seen to clearly dampen the future demand growth in EU-15 MS. On the supply side it appears that environmental regulations also limit the growth of the poultry sector which is in line with expert information from several MS. Nonetheless, supply growth would tend to further run ahead of demand growth such that net exports would increase by about 1.5 million tonnes compared to the base year.

Table 19. Poultry sector development by EU MS, base year compared to the baseline year 2020

	Base year (2004)						Reference year (2020)			
	Fattened poultry [1000 hd]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	Production [% to '91]	Demand [% to '91]	Fattened poultry [% to BAS]	Production [% to BAS]	Demand [% to BAS]	Net trade [D to BAS]
Austria	56,0	113,3	151,5	-38,2	37,9	54,7	-1,7	9,4	15,2	-11,8
Belgium-Lux.	66,5	178,2	173,0	225,6	17,2	1,8	6,3	12,4	-6,6	-187,6
Denmark	130,7	212,5	137,8	74,7	74,5	133,6	26,2	28,3	7,9	48,3
Finland	51,7	86,1	83,6	2,5	161,6	154,8	11,0	12,2	6,9	5,1
France	899,7	1991,5	1431,4	560,1	37,4	32,5	-1,1	10,7	-7,4	319,9
Germany	594,3	1142,7	1605,4	-462,6	99,0	65,0	74,1	68,0	17,7	494,0
Greece	90,6	170,6	233,7	-63,2	14,2	51,7	-0,5	8,8	2,4	9,2
Ireland	111,0	124,7	114,8	10,0	66,3	55,1	-10,8	-10,5	-11,9	0,0
Italy	383,9	1039,1	978,6	60,5	-3,1	-10,8	-16,3	-2,5	-29,3	260,5
Netherlands	274,3	527,1	228,4	298,7	7,1	-6,8	1,8	3,9	7,3	3,3
Portugal	253,0	284,1	299,7	-15,6	62,9	69,1	12,6	-0,7	-7,3	19,6
Spain	646,8	1342,2	1385,8	-43,5	63,9	62,5	40,3	26,0	0,7	338,6
Sweden	70,6	104,0	125,7	-21,7	86,9	124,8	26,9	12,9	18,3	-8,9
United Kingdom	851,0	1573,8	1729,6	-155,8	37,0	47,2	15,9	22,3	11,9	145,4
EU15	4479,9	8890,0	8458,6	431,4	38,9	35,5	19,0	20,3	4,3	1435,5
Cyprus	15,9	32,9	34,2	-1,3	103,5	105,1	15,4	21,5	11,3	3,3
Czech Republic	192,0	242,4	257,9	-15,5	267,1	331,1	37,3	32,6	19,8	27,8
Estonia	5,7	14,2	25,7	-11,5	-39,4	-23,3	-10,1	-3,0	8,8	-2,8
Hungary	148,0	364,1	263,2	101,0	1,3	132,4	-6,1	2,8	11,0	-18,8
Latvia	0,0	1,2	1,1	0,1	-95,7	-97,7	0,0	-24,6	981,1	-11,2
Lithuania	18,8	37,7	50,3	-12,6	-37,1	-30,7	14,0	11,6	56,6	-24,3
Malta	3,5	6,7	10,5	-3,8	28,7	99,8	-12,4	-3,6	44,4	-4,8
Poland	459,1	934,0	840,8	93,2	173,6	160,7	93,9	110,6	102,3	172,6
Slovac Republic	27,3	60,3	54,4	5,9	101,5	72,5	157,5	73,6	89,4	-4,3
Slovenia	58,0	87,7	97,0	-9,3	69,0	346,6	-51,1	-20,9	-25,0	5,7
10 New MS	928,3	1781,1	1634,9	146,2	81,5	125,3	55,1	65,0	62,0	143,4
Bulgaria	39,1	63,4	93,7	-30,3	-65,4	-36,2	-3,8	-18,7	41,7	-51,2
Romania	191,1	291,8	394,6	-102,9	-31,8	1,6	-2,8	5,9	22,1	-70,1
Bulgaria/Romania	230,3	355,1	488,3	-133,1	-41,9	-8,8	-3,0	1,5	25,9	-121,3
EU27	5638,5	11026,2	10581,8	444,4	38,0	41,0	24,0	26,9	14,2	1457,6

Animal sector developments are linked to the crop sector via feed demand which is clearly dominating food demand in the EU-27. The net effect on cereals markets (Table 20) of declining cattle and sheep sectors and expanding pigs and poultry sectors, supplemented with a moderate growth in food demand is an increase of total demand. Production growth is mainly based on yield growth as cereal area is slightly declining. As cereals occupy the largest share of arable land such a decline may be expected with a small share of utilised agricultural area (UAA) lost each year to non-agricultural purposes. Yield growth is projected to be quite similar in EU-15 and EU-12 countries with the extreme values often influenced by composition effects (low yield growth in Cyprus due to reallocation in favour of durum, high yield growth in Estonia due to reallocation away from oats). With supply outpacing demand net exports of EU-27 would increase by almost 17 million tonnes.

While cereal demand is influenced by the whole animal sector, fodder demand is evidently dominated by ruminants. Another difference is that there is no trade of fodder across countries such that any additional demand has to be met in the region. Finally another driver is that EU

Table 20. Cereal sector development by EU MS, base year compared to the baseline year 2020

	Base year (2004)						Reference year (2020)			
	Area [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Area [% to '91]**	**Demand [% to '91]**	**Area [% to BAS]**	**Production [% to BAS]**	**Demand [% to BAS]**	**Net trade [D to BAS]**
Austria	807,2	5041,0	5009,6	31,4	-17,3	-8,2	-11,0	11,5	1,9	488,5
Belgium-Lux.	341,6	2682,8	5708,5	-3025,8	-14,4	14,7	-18,8	-5,4	34,3	-2102,3
Denmark	1487,2	9371,6	9024,1	347,5	-6,3	12,8	4,2	11,5	4,2	692,4
Finland	1203,4	4010,1	3628,9	381,2	0,1	6,9	4,2	15,0	4,8	427,1
France	9149,3	63728,3	31832,2	31896,1	-0,0	13,3	-3,1	11,6	5,2	5739,1
Germany	6875,1	46603,9	40520,6	6083,3	3,0	-0,0	-1,9	17,5	7,0	5299,3
Greece	1261,5	4460,7	6036,2	-1575,5	-12,0	-13,2	-19,1	-3,5	-2,1	-31,9
Ireland	297,1	2284,1	3006,6	-722,5	-8,8	-0,0	-2,1	10,1	7,5	5,9
Italy	4140,2	20921,0	26880,8	-5959,8	-5,3	25,2	-3,9	14,8	2,3	2488,7
Netherlands	223,5	1750,6	7600,9	-5850,3	13,5	42,8	7,4	24,2	28,4	-1732,8
Portugal	430,8	1161,8	4452,3	-3290,5	-46,5	-16,4	-39,2	-15,4	3,6	-338,3
Spain	6601,0	20581,2	28304,1	-7722,8	-15,6	-13,3	-8,4	7,7	16,3	-3050,7
Sweden	1091,9	5493,8	4445,3	1048,6	-19,4	11,5	-7,8	0,9	-15,4	734,7
United Kingdom	3049,6	21871,8	21235,4	636,4	-21,9	1,8	-10,1	-4,9	11,9	-3578,0
EU15	36959,4	209962,7	197685,4	12277,3	-8,1	5,2	-5,3	10,3	8,4	5041,9
Cyprus	67,6	108,8	796,1	-687,3	14,4	-29,1	-26,5	-24,8	5,8	-73,1
Czech Republic	1610,9	7423,2	6383,4	1039,8	-4,0	-0,5	-1,5	10,4	-22,2	2186,6
Estonia	269,2	709,3	758,9	-49,7	-31,2	59,5	34,2	99,4	407,3	-2386,1
Hungary	2892,0	14112,6	10697,2	3415,4	2,9	-6,1	3,9	15,6	-38,8	6350,9
Latvia	443,5	1168,8	987,2	181,6	-30,1	4,1	2,9	26,2	-1,6	321,0
Lithuania	899,7	3039,2	2194,5	844,7	-8,3	22,8	-10,6	21,9	16,7	300,5
Malta	0,1	0,5	160,6	-160,2	-96,5	-94,6	-44,4	-32,6	5,6	-9,1
Poland	8289,0	29150,4	28891,2	259,2	-1,1	8,1	8,4	33,6	29,2	1337,4
Slovac Republic	98,2	526,1	982,8	-456,7	-88,1	-88,2	731,5	589,9	164,5	1487,2
Slovenia	806,5	3307,1	2725,7	581,4	519,9	493,5	-90,4	-86,5	-71,7	-907,5
10 New MS	15376,7	59545,8	54577,6	4968,3	-3,2	1,5	4,9	24,6	11,1	8607,9
Bulgaria	1720,8	6230,6	5905,3	325,4	-18,0	-30,4	-21,5	0,4	-18,6	1121,9
Romania	5853,5	19653,2	19550,3	103,0	-0,1	-1,3	-19,2	-14,2	-24,5	2000,2
Bulgaria/Romania	7574,4	25883,9	25455,5	428,3	-4,9	-10,3	-19,7	-10,7	-23,2	3122,2
EU27	59910,4	295392,4	277718,5	17673,9	-6,5	2,9	-4,5	11,3	6,0	16771,9

policy requires that permanent grassland, the largest part of fodder area, must not decline in significant amounts in view of the environmental benefits expected from it. As a consequence we would typically expect only moderate changes in grassland and hence fodder areas in the projection period. The largest losses of grassland in EU-15 are expected in countries that saw also considerable losses in the past (Germany, Ireland, and Netherlands) (Table 21). It has to be noted that fodder area has declined considerably in EU-12 MS in the historical period. This is in line with the decline of their cattle and sheep sectors, but it needs to be acknowledged that some changes may have been influenced by data weaknesses related to the 1991 data. The highest percentage decline in Cyprus grassland is due to very small initial absolute level of grassland.

Other changes in the area allocation between crops are not reported in detail here. While they may have an influence on emissions if more intensive crops are expanding at the expense of less intensive ones (like arable fodder), the key drivers for changes in emissions are in the animal sector that has been reviewed above.

Table 21. Fodder sector developments by EU MS, base year compared to the baseline year 2020

	Base year (2004)						Reference year (2020)			
	Fodder area [1000 ha]	Fodder prod. [1000 t]	Grassland [1000 ha]	Grass prod. [1000 t]	Fodder area [% to '91]	Grassland [% to '91]	Fodder area [% to BAS]	Fodder prod. [% to BAS]	Grassland [% to BAS]	Grass prod. [% to BAS]
Austria	2115,7	44514,6	1881,8	37974,9	-5,0	-4,5	-2,0	9,3	-2,9	11,2
Belgium-Lux.	868,7	33176,8	590,9	20228,0	-0,6	-13,8	0,3	0,4	3,2	-3,9
Denmark	672,6	25862,9	182,9	6212,8	-19,9	-15,2	-10,5	-12,9	-4,7	-4,0
Finland	632,7	9448,8	604,9	9015,8	-9,0	-12,9	-6,6	-20,1	-8,7	-22,5
France	14841,5	342366,2	10013,3	201601,3	-15,4	-13,6	-5,9	3,3	-3,8	2,7
Germany	6663,4	237764,6	4936,8	167774,6			-14,9	-7,3	-10,3	-2,5
Greece	2092,6	20452,9	1789,0	16713,1	16,8	0,0	5,2	-6,8	3,1	-13,1
Ireland	3939,4	149041,7	3097,6	109280,9	-10,4	-22,3	0,7	13,4	-10,0	-2,9
Italy	6211,3	91804,7	4380,4	51150,3	-5,0	-10,6	-2,0	-1,0	4,8	5,7
Netherlands	1217,1	55321,6	776,0	34863,3	-7,7	-28,1	0,9	-1,7	-10,0	-21,4
Portugal	2036,2	29244,8	1482,0	21706,5	71,3	53,5	18,7	21,0	30,0	28,5
Spain	11517,8	138846,1	10458,8	121681,1	0,8	2,4	0,4	5,0	1,1	6,1
Sweden	1518,6	38605,1	499,9	10650,8	10,6	-10,7	-3,5	18,9	-10,0	12,5
United Kingdom	11349,5	319899,5	9972,2	272164,3	-15,0	-14,1	-4,5	-1,3	-2,6	0,5
EU15	65677,0	1536350,0	50666,5	1081017,8	3,3	0,8	-3,2	1,7	-1,7	0,8
Cyprus	24,9	213,7	0,3	2,3	113,3	-88,6	59,1	34,7	-12,5	-40,1
Czech Republic	1279,4	22086,2	861,7	12385,3	-34,3	4,0	-17,9	-24,1	-0,3	-3,1
Estonia	429,9	8139,6	246,5	4388,4	-56,7	-25,3	-25,0	-5,3	-10,0	15,5
Hungary	1439,0	20680,2	1067,0	14031,4	-26,7	-11,8	-22,9	-2,9	-10,0	19,2
Latvia	954,0	14088,2	621,0	8897,6	-43,9	-25,7	-19,5	1,1	-3,3	25,2
Lithuania	1277,3	23210,3	939,6	16704,9	-37,5	-33,0	-18,2	7,9	-9,4	18,8
Malta	4,8	46,3			365,8		7,8	-5,5		
Poland	4122,5	71245,0	3339,7	50647,9	-39,1	-15,1	-15,8	-7,2	-10,0	-7,3
Slovac Republic	383,0	5930,4	320,1	4242,8	-68,6	-59,3	79,1	22,1	71,8	2,8
Slovenia	859,2	11858,2	611,2	7269,0	101,2	52,9	-54,8	-48,8	-48,1	-46,2
10 New MS	10773,8	177498,0	8007,1	118569,7	-36,9	-17,7	-17,5	-7,8	-8,0	1,2
Bulgaria	1963,3	22066,9	1826,8	20247,0	-34,2	-9,8	11,5	25,8	17,6	33,5
Romania	5717,5	97413,8	4809,8	82492,1	0,9	9,3	-11,8	5,4	-4,8	12,9
Bulgaria/Romania	7680,8	119480,7	6636,6	102739,2	-11,2	3,3	-5,8	9,2	1,4	17,0
EU27	84131,5	1833328,8	65310,1	1302326,6	-5,8	-1,7	-5,3	1,3	-2,1	2,1

5.2 Projection of agricultural emission inventories between 2004 and 2020

Table 22 presents the development of emissions of individual gases and CO2 equivalent for all EU MS from the 2003-2005 base period to the projection year 2020. Projections show that total GHG emissions (in CO2 equivalent) in the EU-27 would decline by 3%, with a somewhat higher reduction in the EU-12 compared to EU-15. However, given that GHG emissions in EU-15 in the base year are almost five times higher than in EU-12, the reduction in EU-15 from 2004 to 2020 is more significant in absolute terms.

When looking into the emission components in the reference scenario we observe that the overall decrease in GHG emissions is due to a decrease in methane emissions (-16.7%), while nitrous oxide emissions are projected to increase by 7.2%[30]. For the EU-15 the reduction of methane emissions in the reference scenario is projected

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[30] It is assumed in CAPRI that by 2020 stable adaptation gains in importance as an ammonia emission reducing technique due to stricter implementation of environmental legislation like the NEC directive. This technique has the side effect of causing an increase in the emission of N2O (for more information see section 4.2.3.2 in Leip et al., 2010).

Table 22. Change in emissions per EU Member State between 2004 and 2020

	Base year (2004)				Reference year (2020)			
	Methane [1000t]	**Nitrous Oxide [1000t]**	**CO2 eq. [1000t]**	**Ammonia [1000t]**	**Methane [% to BAS]**	**Nitrous Oxide [% to BAS]**	**CO2 eq. [% to BAS]**	**Ammonia [% to BAS]**
Austria	189,8	12,4	7835,2	47,8	-13,8	3,0	-5,6	3,4
Belgium_Lux	231,9	17,9	10411,7	69,7	-10,1	3,6	-2,8	6,1
Denmark	204,3	21,6	10969,8	99,2	-26,1	-1,9	-11,3	-22,5
Finland	90,0	24,8	9575,0	22,0	-10,2	-4,4	-5,6	-16,2
France	1716,9	143,1	80399,9	501,5	-15,6	6,2	-3,6	-4,1
Germany	1405,8	109,7	63522,5	500,5	-23,8	8,7	-6,4	-13,6
Greece	151,0	10,3	6364,8	30,8	-6,6	-5,4	-6,0	-12,4
Ireland	557,3	36,7	23064,9	106,4	-4,9	5,6	0,3	-2,7
Italy	797,3	53,9	33442,9	322,7	-7,1	7,8	0,3	-4,3
Netherlands	384,8	34,6	18799,0	101,6	0,8	0,8	0,8	-8,9
Portugal	158,8	10,3	6520,1	52,6	-11,4	4,1	-3,9	-17,8
Spain	773,9	66,5	36866,8	299,0	-3,6	16,2	7,5	-2,4
Sweden	174,7	20,6	10066,6	48,6	-32,9	2,5	-10,4	-16,8
United Kingdom	1028,1	126,6	60845,7	230,2	-12,8	1,7	-3,4	-10,9
EU15	7864,5	688,8	378685,1	2432,7	-13,2	5,5	-2,7	-7,7
Cyprus	11,2	0,8	468,1	5,0	0,4	32,0	16,2	-11,0
Czech Republic	128,7	13,8	6992,3	59,5	-55,3	6,3	-17,5	-28,8
Estonia	25,9	2,2	1214,7	7,9	-45,7	8,3	-16,0	-23,0
Hungary	89,9	18,3	7561,6	68,3	-44,6	18,2	2,5	-21,1
Latvia	36,4	4,4	2139,3	12,1	-37,7	7,0	-9,1	-13,6
Lithuania	83,4	9,5	4707,9	27,3	-35,9	5,3	-10,0	-18,8
Malta	1,8	0,1	82,9	1,1	5,5	14,3	7,5	8,3
Poland	511,2	70,1	32450,7	261,5	-32,2	17,8	1,3	8,8
Slovenia	44,0	2,9	1807,7	13,3	-15,7	-13,3	-14,6	-7,2
Slovak Republic	49,5	4,7	2499,5	19,1	-46,7	6,4	-15,7	-35,3
EU10	981,9	126,8	59924,6	475,0	-36,8	14,1	-3,4	-5,3
Bulgaria	105,2	8,7	4918,7	26,3	-27,2	12,0	-5,6	-17,4
Romania	407,1	25,6	16491,4	105,0	-33,8	18,9	-8,5	-17,8
Bulgaria/Romania	512,3	34,4	21410,1	131,3	-32,5	17,1	-7,8	-17,7
EU27	9358,7	849,9	460019,8	3039,0	-16,7	7,2	-3,0	-7,8

at 13.2%, with highest reductions achieved in Sweden (-32.9%), Denmark (-26.1%) and Germany (-23.8%) whereas the Netherlands are projected to be the only EU-15 MS increasing methane emissions (+0.8%). The EU-10 and Bulgaria/Romania are projected to experience methane emission reductions of 36.8 and 32.5% respectively, with Malta (+5.5%) and Cyprus (+0.4%) being the only EU-12 MS showing an increasing in methane emissions.

The changes in emissions of nitrous oxide are projected to be +14% for the EU10, +17% for Romania/Bulgaria and +5% for the EU-15. In the EU-12, all countries except Slovenia are projected to increase nitrous oxide emissions and in the EU-15 the only countries projected to decrease nitrous oxide emission are Denmark, Finland and Greece. The emission of ammonia are projected to be -7.7% for EU-15, - 5.3% for EU10 and -17.7% for BUR.

As can be seen in Table 23, the general emission reduction at EU level is mostly based on emissions linked to ruminants (CH4 from digestion and manure management and N2O from grazing, due to emission of ammonia and atmospheric deposition). These emission reductions can therefore mostly be attributed to the reduced policy incentives for beef cattle and sheep/goats after the conversion of coupled

Table 23. Change in emissions per inventory position for the EU between 2004 and 2020

	Base year (2004)				Reference year (2020)			
	EU15 [1000t]	EU10 [1000t]	BUR [1000t]	EU27 [1000t]	EU15 [% to BAS]	EU10 [% to BAS]	BUR [% to BAS]	EU27 [% to BAS]
Methane emissions from enteric fermentation (IPCC)	6926.81	890.62	475,7	8293.1	-13,6	-38,2	-32,1	-17,3
Methane emissions from manure management (IPCC)	937.66	91.34	36,6	1065.61	-10,7	-22,6	-37,6	-12,7
Methane emissions	7864.47	981.96	512.28	9358.71	-13,2	-36,8	-32,5	-16,7
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	179,2	34,5	9,3	223,0	21,5	32,1	10,0	22,6
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	76.51	6.12	4,7	87.34	-4,1	-16,7	-7,4	-5,2
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	179.16	39.32	7,6	226.11	-2,1	17,7	62,5	3,5
Direct nitrous oxide emissions from crop residues (IPCC)	64.48	11.58	7,3	83.37	13,5	7,2	-1,0	11,4
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	7.62	0.82	0,5	8.92	56,4	30,5	85,4	55,6
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	15.25	3.03	1,9	20.16	-3,5	-4,3	-8,5	-4,1
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	42	7.9	2,3	52.23	-7,5	-0,5	-5,2	-6,4
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	12.18	2.29	0,6	15.02	-1,6	12,7	81,8	3,6
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	112.43	21.21	0,2	133.84	-2,6	-1,9	5,0	-2,4
Nitrous oxide emissions	688.8	126.8	34,4	849.96	5,5	14,1	17,1	7,2

Note: BUR = Bulgaria and Romania

supports for beef production into (mainly) decoupled payments, and the reform in the dairy market. The adjustments in emissions are generally larger in the EU-12 compared to EU-15. Crop yields continue to grow moderately, provoking an increase in emissions linked to crop residues, and to lesser extent, to the application of mineral nitrogenous fertilizers. That the latter contributes to a lesser extend to emission increases can be attributed to a more efficient use of both organic and mineral fertilizers.

At EU-15 level the projected methane emission reductions of 13.2% is mainly due to the reduction of methane emissions coming from the enteric fermentation (-13.6%). Methane emission reduction from manure management also decreases by 10.7%, but methane emissions from ruminations are more important to determine the overall reduction in methane emissions due to their high level in absolute terms. The EU-10 and EU-15 present a similar distribution of methane emission reduction among the components, while Bulgaria/Romania is projected to achieve a higher methane emission reduction coming from manure (-37.6%) than from the enteric fermentation (-32.1%).

Looking at the nitrous oxide emissions at EU-27 level, there are several components expected to be responsible for the 7.2% emission increase, especially direct nitrous oxide emissions from manure management and application (+22.6%), direct nitrous oxide emissions from crop residues (+11.4%) and nitrous oxide emissions from nitrogen fixing crops (+55.6%). While direct nitrous oxide emissions from mineral fertilizer application are projected to decrease in the EU-15 by 2.1%, the respective emissions increase considerably in the EU-10 (+17.7%) and Bulgaria/Rumania (+62.5%).

6 Scenarios results

The most important scenario results are presented and analysed in this chapter. First we present the results of the GHG mitigation policy scenarios in the sections 6.1 to 6.4. The results of the complementary technological abatement scenarios are presented in section 6.5 followed by the results of the combined scenario in section 6.6.

While the complementary technological abatement scenarios are not aiming at a predefined abatement target, the defined GHG emission abatement policy scenarios could be designed to almost achieve the reduction goal of 20% emission reduction in the EU-27 compared to the reference year 2004 (three year average 2003-2005). A small error margin was tolerated for under- or overachievement of the reduction goal.

6.1 Emission Standard Scenario (STD)

With the Emission Standard Scenario (STD) we are interested in looking at the effects of a regionally homogeneously distributed emission cap of 20% on GHG emissions (cf. chapter 4). This scenario serves as starting point for our scenario analysis of mitigation policies in agriculture. It has to be mentioned that this STD scenario does not reflect any existing EU GHG abatement policy, and as the ESD is not taken into account the burden of emission abatement is distributed equally amongst all regions. In other words, under this hypothetical scenario each region is forced to reduce emissions by 20%, regardless of their historical emissions, costs of production or type of specialisation when facing the emission abatement (i.e. their differentiated marginal abatement costs according to specialisation and location are not taken into account).

6.1.1 Changes in GHG emissions

Table 24 presents the changes in GHG emissions between the emission standard scenario and the reference scenario (changes in year 2020). The STD scenario has been designed to achieve a GHG emission reduction of 16.8% (in CO2 equivalents) in the EU-27 compared to the emissions in the REF scenario [31].

It is interesting to see in Table 24 how the model allocates the emission cap differently to gases and MS after clearance of agricultural markets. On the aggregates, higher emission reductions are observed in the EU-15 than in the EU-12. In both EU-aggregates there are countries that have to reduce GHG emissions by more than 20% compared to the REF scenario. This is due to the fact that in these MS emissions in the baseline increased compared to the base year 2004 (cf. Table 22).

In EU-27 the N2O emissions (-16.0%) are on average less affected than CH4 emissions (-18.4%), despite the fact that on average it is more costly for farmers to achieve the emission standard through the reduction of CH4 emission activities compared to N2O-emitting activities. There are a few measures to reduce methane emissions. Among those, decreasing the number of animals is often the most effective one but also very costly. For reducing nitrous oxide emission there are a lot more reduction options available, to start with reducing over-fertilization. As can be observed in Table 25 the highest reductions (when taking absolute terms into account) are achieved by reducing N2O emissions from application of mineral fertilizer and from manure management and application.

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[31] Adding the -3% GHG emission reduction in the REF scenario to the 16.8% reduction achieved in this STD scenario results in a total reduction in GHG emission of 19.8% in the EU-27compared to the reference year 2004 (three year average 2003-2005).

Table 24. Change in emissions per EU Member State according to the STD scenario

	Baseline (REF, 2020)				Emission standard in agriculture (STD, 2020)			
	Methane [1000t]	Nitrous Oxide [1000t]	CO2 equivalents [1000t]	Ammonia [1000t]	Methane [% to REF]	Nitrous Oxide [% to REF]	CO2 equivalents [% to REF]	Ammonia [% to REF]
Austria	163,5	12,8	7399,1	49,4	-16,4	-13,4	-14,8	-8,5
Belgium_Lux	208,6	18,5	10119,8	74,0	-18,4	-14,0	-15,9	-10,8
Denmark	151,0	21,2	9727,1	76,9	-11,5	-7,1	-8,5	-4,9
Finland	80,8	23,7	9040,8	18,5	-9,9	-16,4	-15,2	-5,4
France	1449,1	151,9	77527,2	480,8	-19,6	-14,2	-16,4	-13,1
Germany	1070,8	119,2	59451,0	432,6	-13,2	-15,0	-14,3	-8,3
Greece	141,1	9,7	5980,9	27,0	-17,2	-11,5	-14,3	-12,0
Ireland	530,3	38,7	23136,3	103,5	-20,9	-18,9	-19,9	-20,2
Italy	740,8	58,1	33557,8	309,0	-21,8	-17,6	-19,6	-15,9
Netherlands	387,8	34,8	18942,5	92,6	-16,4	-21,7	-19,4	-19,5
Portugal	140,7	10,7	6267,7	43,2	-15,5	-16,7	-16,2	-9,9
Spain	746,3	77,3	39622,9	291,7	-30,8	-20,9	-24,8	-17,0
Sweden	117,3	21,2	9020,4	40,4	-9,1	-11,0	-10,5	-4,8
United Kingdom	896,7	128,8	58771,0	205,2	-15,8	-16,8	-16,5	-10,5
EU15	6824,6	726,6	368564,5	2244,7	-18,8	-16,1	-17,2	-12,7
Cyprus	11,2	1,0	544,0	4,5	-31,9	-28,3	-30,2	-31,2
Czech Republic	57,5	14,7	5766,4	42,3	-5,3	-0,6	-1,6	-0,9
Estonia	14,1	2,3	1019,8	6,1	-4,7	-3,0	-3,3	0,8
Hungary	49,8	21,6	7749,7	53,9	-18,2	-21,8	-21,3	-18,1
Latvia	22,7	4,7	1944,8	10,5	-7,1	-11,6	-10,5	-6,4
Lithuania	53,4	10,1	4237,2	22,2	-7,1	-10,3	-9,5	-6,6
Malta	1,9	0,2	89,1	1,2	-28,6	-25,0	-24,3	-15,4
Poland	346,8	82,6	32872,4	284,4	-23,0	-19,7	-20,4	-17,7
Slovenia	37,0	2,5	1543,5	12,3	-7,1	-3,6	-5,4	-3,2
Slovak Republic	26,4	5,0	2107,0	12,4	-4,4	-4,4	-4,4	-5,4
EU10	620,8	144,7	57873,8	449,6	-17,0	-16,1	-16,3	-14,5
Bulgaria	76,5	9,8	4641,8	21,7	-10,5	-16,1	-14,2	-10,7
Romania	269,4	30,5	15097,5	86,3	-13,6	-10,6	-11,7	-8,3
Bulgaria/Romania	346,0	40,2	19739,3	108,1	-12,9	-12,0	-12,3	-8,8
EU27	7791,3	911,5	446177,6	2802,4	-18,4	-16,0	-16,8	-12,8

Table 25. Change in emissions per inventory position for the EU according to the STD scenario

	Baseline (REF, 2020)				Emission standard in agriculture (STD, 2020)			
	EU15 [1000t]	EU10 [1000t]	BUR [1000t]	EU27 [1000t]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Methane emissions from enteric fermentation (IPCC)	5987,7	550,1	323,1	6860,9	-19,3	-16,9	-13,0	-18,8
Methane emissions from manure management (IPCC)	836,9	70,7	22,8	930,5	-15,0	-17,7	-11,6	-15,1
Methane emissions	6824,6	620,8	346,0	7791,4	-18,8	-17,0	-12,9	-18,4
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	217,7	45,6	10,2	273,5	-13,7	-14,8	-9,6	-13,7
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	73,4	5,1	4,4	82,8	-25,2	-14,7	-13,1	-23,9
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	175,4	46,3	12,4	234,1	-16,5	-19,6	-13,8	-17,0
Direct nitrous oxide emissions from crop residues (IPCC)	73,2	12,4	7,2	92,8	-17,2	-18,8	-13,4	-17,1
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	11,9	1,1	0,9	13,9	-18,8	-3,7	-14,6	-17,4
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	14,7	2,9	1,7	19,3	-9,7	-7,9	-5,2	-9,0
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	38,8	7,9	2,2	48,9	-14,1	-15,8	-10,0	-14,2
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	12,0	2,6	1,0	15,6	-16,4	-16,3	-14,0	-16,3
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	109,6	20,8	0,2	130,6	-14,9	-12,0	-4,8	-14,4
Nitrous oxide emissions	726,6	144,6	40,2	911,5	-16,1	-16,1	-12,0	-16,0
Carbon dioxide equivalent	368564,5	57873,8	19739,3	446177,6	-17,2	-16,3	-12,3	-16,8

6.1.2 Analysis of production and economic effects

An emission standard in agriculture provokes a general reduction in production in the EU-27, some extensification effects in the crop sector, a decrease in beef herd sizes with an intensification of the remaining beef meat activities and general increases in prices. The increase in prices leads to income increases per production unit; however this might not compensate the farmers for the income losses due to the reduction in quantities.

Table 26 shows how the effect of the emission standard is distributed across activities in the EU-27. Large drops in production in the cattle sector (especially beef meat activities with herd sizes decreasing by 27.6%) lead to higher producer prices and higher income per production unit (+48,6% for all cattle activities). This is also the case for the arable sector, with utilised agricultural area being reduced by 7.2% (the increase in set aside and fallow land does not fully compensate the decrease of fodder and arable areas) and income per ha UAA increasing on average by 13.8%.

Table 26. Change in income, area, yield and supply for the EU-27 for activity aggregates according to the STD scenario

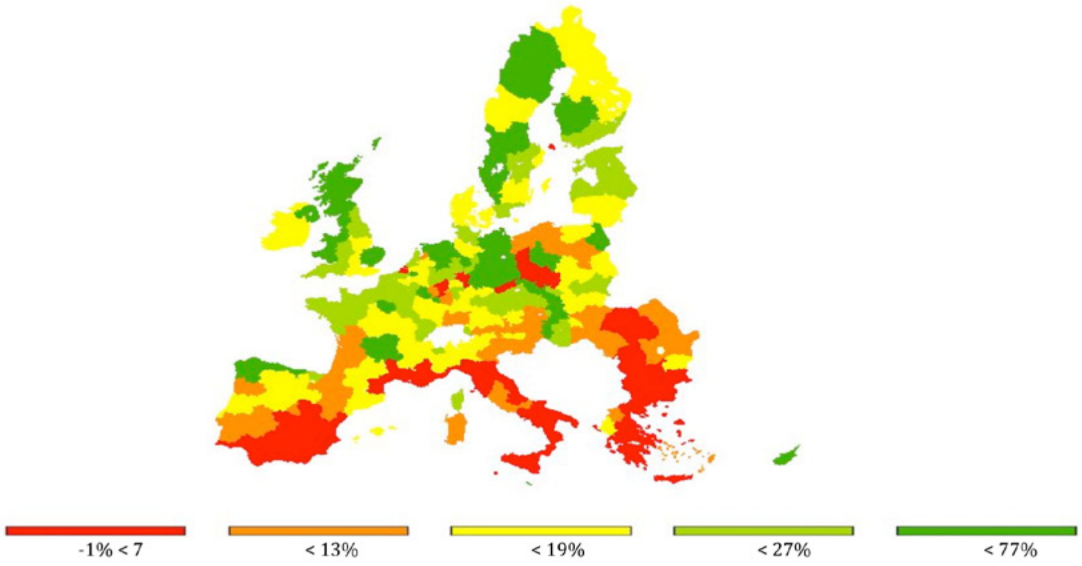
	Baseline (REF 2020)				**Emission standard in agriculture (STD, 2020)**			
	Income [Euro/ha or head]	**Area or Herd Size [1000 ha or hds]**	**Yield [kg/ha or head]**	**Supply [1000 t]**	**Income [% to REF]**	**Area or Herd Size [% to REF]**	**Yield [% to REF]**	**Supply [% to REF]**
Cereals	332	57214	5749	328905	20,1	-11,5	-0,6	-12,0
Oilseeds	460	8882	3010	26737	16,5	-7,9	-0,8	-8,7
Other arable crops	1125	7771	na	na	11,8	-4,7	na	na
Vegetables and Permanent crops	4455	21612	na	na	0,3	0,1	na	na
Fodder activities	279	79668	23303	1856480	-1,6	-11,1	-11,4	-21,3
Set aside and fallow land	140	13265	na	na	2,4	22,2	na	na
Utilized Agricultural Area	1148	188413	na	na	13,8	-7,2	na	na
All cattle activities	455	84117	na	na	48,6	-22,1	na	na
Beef meat activities	123	26904	na	7842	136,8	-27,6	na	-11,5
Pig fattening	30	247670	92	22754	43,7	-2,5	-0,1	-2,6
Pig Breeding	117	14728	17281	254512	9,9	-16,7	1,1	-15,8
Milk Ewes and Goat	54	77576	59	4561	20,7	-15,3	5,4	-10,7
Sheep and Goat fattening	35	46278	14	628	18,7	-0,4	0,0	-0,5
Laying hens	3973	464	16339	7588	73,1	-7,0	0,1	-6,9
Poultry fattening	320	6993	1909	13352	85,7	-9,4	-0,3	-9,6

Note: na = not applicable; total supply of beef includes beef from dairy cows and calves.

Taking into account the considerable emission cap introduced, cereal areas are expected to decrease only moderately (-11.5%) in the EU-27, with proportionally higher decreases in the EU-10 than the EU-15. With almost no changes in yields at EU-27, the reduction in cereal areas results in a decrease in cereal production of 12%. The net exporter position of the EU-27 is weakened, since demand drops less than supply, resulting in a net effect of about 12.7 Mio tonnes less export (cf. Table 64 in the annex).

Looking closer into the projected changes in the dairy cow supply balances (cf. Table 65 in the annex) it can be seen that the size of the dairy herd decreases by 4.1% on average in the EU-27 (with decreases of 3.4% and 7.4% in the EU-15 and EU-10 respectively). Highest percentage reductions in the size of the dairy herds are projected for Cyprus, Malta and Poland. However, when taking the absolute size of dairy herds into account, the highest reductions in number of heads are projected in Poland, the Netherlands, France and Italy. Milk production follows the dairy cattle changes, with some very slight intensification effects (yield in dairy milk production is projected to increase by 0.4% in the EU-27) (cf. Table 65 in the annex).

Figure 7. Change in agricultural income per utilised agricultural area according to the STD scenario (in %)



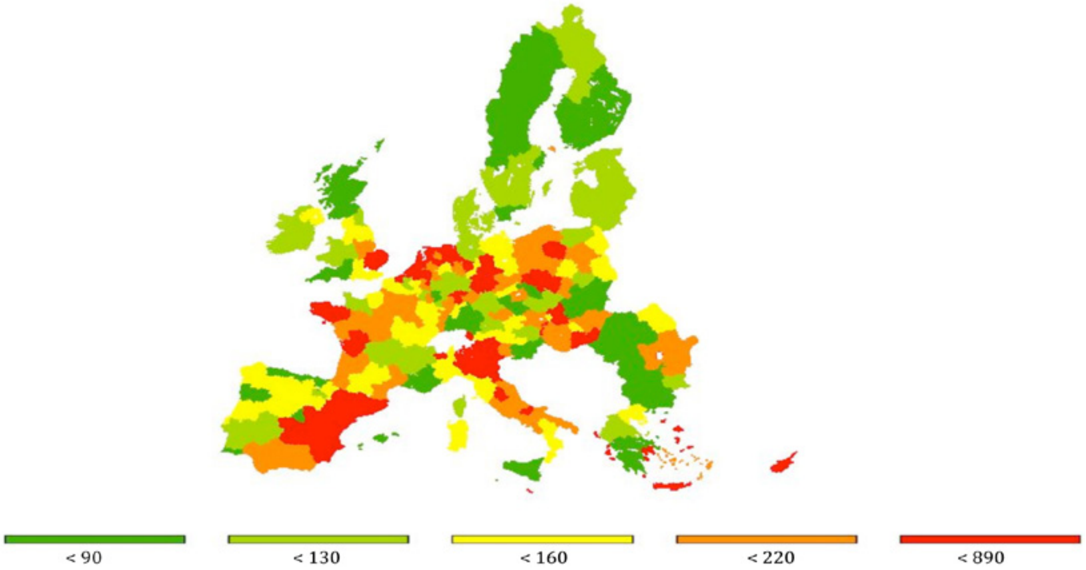
Beef cattle is the agricultural activity most hit by the emission standard. The reduction in herd sizes are in the range of 27.6% for the EU-27, 29.2% for EU-15 and 23.5% for EU-10. Highest percentage reductions in the size of the beef herds are projected for Spain (-38.1%, Belgium-Luxembourg (-34.1%), Greece (-31.3%), France (-30.7%) and Ireland (-30.5%) in the EU-15 and Poland (-35.2%), Malta (-29.5%) and Hungary (-28.5%) in the EU-12. When taking absolute numbers into account, the highest reductions in number of heads are projected in the EU-15 for France, Spain, Ireland and Italy and in the EU-12 for Poland. The reduction of herd sizes is accompanied by an intensification effect projected for the remaining beef production (with beef yields increasing by 17% in the EU-27), so that overall beef production decreases only by 11.5% in the EU-27. Since demand is projected to decrease only by 3.3%, the net trade position of the EU would be further deteriorated by additional beef net imports of about 630 thousand tonnes (Table 66 in the annex).

Following the decrease in supply and the resulting increase in producer prices in the EU-27, the agricultural sector increases its income per production unit (cf. Table 26). For example agricultural income per UAA is increasing by 13.8% in the EU-27. As can be seen in Figure 7 only few regions experience some income losses: Aland, Provence, Koblenz, Opolski and Kriti. Furthermore it is important to note that some large effects, such as in Sweden and Finland, are affecting very low production numbers, so that even if the percentage effect is large, the overall effect on European agricultural income is fairly small.

6.1.3 Analysis of emission abatement costs

Figure 8 highlights the large differences in marginal abatement costs across EU agriculture after the implementation of an emission standard with a 20% emission reduction. The high absolute levels of abatement cost in some regions like for example in Spain, the Netherlands, the United Kingdom and Italy can be mostly attributed to the fact that in these regions the emission levels in 2020 do not change (much) in the baseline compared to the base year 2004 (cf. Table 22) and therefore the GHG emission reduction requirements are higher than for example in Denmark and Sweden.

Figure 8. Marginal abatement costs with an emission standard (in €/t CO2 eq)



Correspondingly relatively low levels of abatement costs in some regions can be attributed to already large baseline reductions compared to 2004, i.e. these regions are less affected by the emission standard. Sizeable differences between regions in the same MS are linked to different specialization. Generally, abatement costs are low where larger adjustments (i.e. GHG reductions) have been already projected for the baseline between 2004 and 2020, such as for example in the Massif Central in France with its extensive beef cattle production. On the contrary, regions favourable and specialized on arable cropping as for example in the Eastern part of England or some regions in Germany, as well as regions with high organic nutrient loads such as Western parts of Germany or the Po flats in Northern Italy are characterized by rather high abatement costs. The distribution diagram also reveals that average marginal abatement costs in agriculture – at least given the limited mitigation offered by the model – are rather high compared to current prices in EU emission markets (average marginal abatement costs are 159 €/t CO2 eq)[32].

6.1.4 Analysis of environmental effects with regard to nitrogen balances

The introduction of an emission standard of 20% stimulates extensification effects in the crop sector and intensification in the animal sector. In Figure 9, yield changes for extensive fodder production and beef production are depicted. On average for the EU-27 yields in fodder activities (mostly fodder maize and intensive grazing) are reduced by 11% whereas the yields in beef meat activities (without beef from dairy cows and calves) increase by 17% on average (cf. Table 26).

With the emission standard, nitrogen surplus is reduced in the EU-27 by 16.5% (cf. Table 27). This has to do with large extensification effects in arable crops, with most savings being achieved by a reduced "import of nitrogen by mineral fertilizer application", i.e. by a reduced application of nitrogen through mineral fertilizer (-14.4%).

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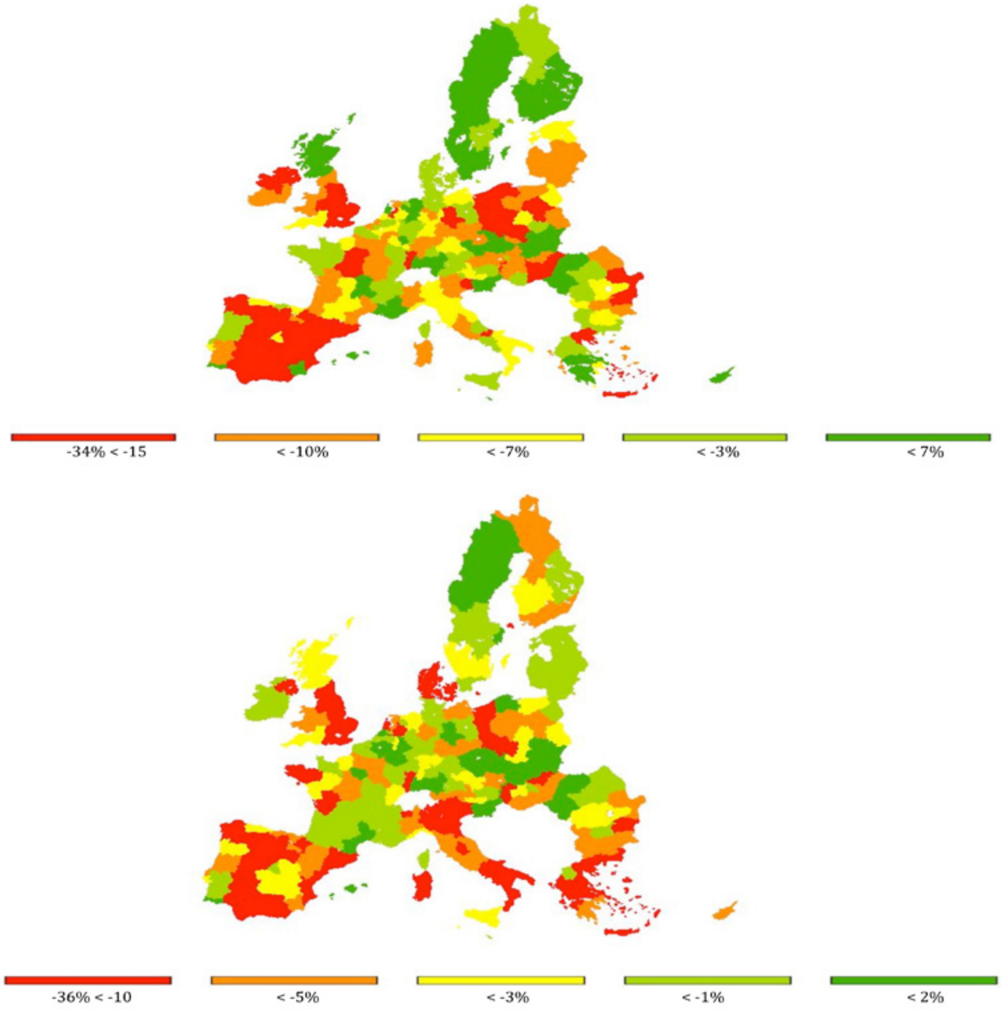
[32] Carbon prices in the ETS have varied between 0 and 30€ per tonne of CO2 eq in the first two phases since its implementation (between 2005 and 2009). These low prices were mostly attributable to very moderate abatement efforts and over-supply of emission permits (see Ellermann and Buchner, 2007).

Figure 9. *Yield changes in fodder (upper) and beef (lower) according to the STD scenario.*



Note: The yield of beef meat activities excludes beef from dairy cows and calves

Table 27. *Changes in the nitrogen balance according to the STD scenario*

	Baseline (REF 2020)				Emission standard in agriculture (STD, 2020)			
	EU15 [1000t N]	**EU10 [1000t N]**	**BUR [1000t N]**	**EU27 [1000t N]**	**EU15 [% to REF]**	**EU10 [% to REF]**	**BUR [% to REF]**	**EU27 [% to REF]**
Import by mineral fertilizer	8445	2261	602	11309	-14,2	-15,5	-12,5	-14,4
Import by manure	7739	1138	411	9288	-14,4	-11,0	-11,3	-13,8
Import by crop residues	4764	878	512	6153	-16,3	-15,3	-12,9	-15,9
Biological fixation	861	76	62	999	-15,8	-0,5	-10,7	-14,3
Atmospheric deposition	1671	326	191	2188	-7,5	-6,5	-4,0	-7,0
Nutrient retention by crops	14586	2835	1262	18683	-13,7	-13,2	-11,1	-13,4
Surplus total	8894	1844	516	11254	-15,2	-14,1	-11,9	-14,9
Gasseous loss	2966	610	173	3749	-12,4	-12,0	-10,7	-12,3
Run off mineral	246	122	51	419	-14,6	-15,6	-13,8	-14,8
Run off manure	347	83	38	468	-13,7	-11,1	-11,2	-13,0
Surplus at soil level	5335	1028	254	6617	-16,9	-15,4	-12,4	-16,5

6.2 Effort Sharing Agreement in Agriculture Scenario (ESAA)

In Chapter 4.2.3 we outlined the emission reduction commitments as given in the ESD (Effort Sharing Decision), where the overall GHG emission reduction objective is distributed across the MS. This is done by a non-uniform GHG emission standard, and while some MS have to reduce GHG emissions by a certain level (e.g. Germany by -14%) others are actually allowed to increase their emission up to a defined level (e.g. Romania +19%). However, if the respective commitments are transferred to the agricultural sector, then this would result in an agricultural GHG emission abatement of about 9.2% in the EU-27 (cf. Table 28)[33]. Thus, in order to also achieve a 20% GHG emission reduction in the ESAA scenario (i.e. as in the other mitigation policy scenarios) all MS would have to be obliged to reduce more than the assigned reduction objectives by the ESD. Therefore we take the distribution of the ESD commitment as starting point and adjusted it by a homogeneous top-up for all MS in order to achieve the envisaged overall reduction of 20% GHG emissions in the EU-27. This manual adjustment resulted in a shifter of about 8.7%, i.e. on top of the ESD commitment each MS would need to get an additional reduction obligation of 8.7% in order to achieve in CAPRI an

Table 28. Emission commitments in the ESD and commitments introduced in CAPRI for the ESAA scenario (reductions in 2020 compared to the emissions in the base year 2004)

	ESD commitment	ESD + 8.7% commitment (ESAA)		ESD commitment	ESD + 8.7% commitment (ESAA)
Austria	-16.0	-24.7			
Belgium_Lux.	-15.0	-23.7			
Denmark	-20.0	-28.7	Bulgaria	20.0	11.3
Finland	-16.0	-24.7	Cyprus	-5.0	-13.7
France	-14.0	-22.7	Czech Republic	9.0	0.3
Germany	-14.0	-22.7	Estonia	11.0	2.3
Greece	-4.0	-12.7	Hungary	10.0	1.3
Ireland	-20.0	-28.7	Latvia	17.0	8.3
Italy	-13.0	-21.7	Lithuania	15.0	6.3
Netherlands	-16.0	-24.7	Malta	5.0	-3.7
Portugal	1.0	-7.7	Poland	14.0	5.3
Spain	-10.0	-18.7	Romania	19.0	10.3
Sweden	-17.0	-25.7	Slovak Republic	13.0	4.3
United Kingdom	-16.0	-24.7	Slovenia	4.0	-4.7

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[33] Note: the ESD was designed for all sectors not included in the Emission Trading Scheme (ETS) of the EU (such as transport, buildings, agriculture and waste). In the ESD it is stated that at the EU-27 level, the ESD will deliver an approximately 10% reduction of emissions from the covered sectors in 2020 compared with 2005 levels. Thus, the 9.2% reduction in the EU-27 is because we look only at the agricultural sector, and furthermore because in CAPRI we use the three year average of 2003-2005 as base year.

overall GHG emission reduction in the EU-27 of about 20%. The respective distribution per MS is given in Table 28.

6.2.1 Changes in GHG emissions

Table 29 presents the changes in GHG emissions between the ESAA scenario and the

Table 29. Emissions per Member State according to the ESAA scenario

	Baseline (REF, 2020)				Effort sharing agreement (ESAA, 2020)			
	Methane [1000t]	Nitrous Oxide [1000t]	CO2 equivalents [1000t]	Ammonia [1000t]	Methane [% to REF]	Nitrous Oxide [% to REF]	CO2 equivalents [% to REF]	Ammonia [% to REF]
Austria	163,5	12,8	7399,1	49,4	-21,8	-18,1	-19,9	-11,9
Belgium_Lux	208,6	18,5	10119,8	74,0	-22,8	-17,5	-19,8	-14,0
Denmark	151,0	21,2	9727,1	76,9	-21,2	-17,3	-18,5	-13,1
Finland	80,8	23,7	9040,8	18,5	-13,2	-21,8	-20,2	-7,8
France	1449,1	151,9	77527,2	480,8	-23,0	-16,8	-19,2	-15,4
Germany	1070,8	119,2	59451,0	432,6	-15,8	-17,9	-17,1	-10,0
Greece	141,1	9,7	5980,9	27,0	-9,5	-4,4	-6,9	-4,8
Ireland	530,3	38,7	23136,3	103,5	-29,6	-27,7	-28,6	-28,6
Italy	740,8	58,1	33557,8	309,0	-23,9	-19,1	-21,3	-17,3
Netherlands	387,8	34,8	18942,5	92,6	-20,3	-27,2	-24,2	-24,5
Portugal	140,7	10,7	6267,7	43,2	-4,1	-5,0	-4,5	-1,2
Spain	746,3	77,3	39622,9	291,7	-29,6	-19,8	-23,7	-15,9
Sweden	117,3	21,2	9020,4	40,4	-15,0	-17,6	-16,9	-9,0
United Kingdom	896,7	128,8	58771,0	205,2	-20,1	-22,0	-21,4	-13,6
EU15	6824,6	726,6	368564,5	2244,7	-21,7	-19,4	-20,3	-14,7
Cyprus	11,2	1,0	544,0	4,5	-25,2	-24,2	-24,6	-25,6
Czech Republic	57,5	14,7	5766,4	42,3	2,4	2,8	2,7	2,8
Estonia	14,1	2,3	1019,8	6,1	2,9	1,7	2,3	3,6
Hungary	49,8	21,6	7749,7	53,9	-0,8	-1,9	-1,8	-0,7
Latvia	22,7	4,7	1944,8	10,5	2,9	1,9	2,3	3,0
Lithuania	53,4	10,1	4237,2	22,2	1,0	1,2	1,1	1,7
Malta	1,9	0,2	89,1	1,2	-10,4	-6,3	-9,0	-5,1
Poland	346,8	82,6	32872,4	284,4	-0,3	-1,5	-1,3	-0,7
Slovenia	37,0	2,5	1543,5	12,3	4,2	2,0	3,1	2,8
Slovak Republic	26,4	5,0	2107,0	12,4	3,2	2,6	2,7	3,0
EU10	620,8	144,7	57873,8	449,6	0,1	-0,7	-0,5	-0,1
Bulgaria	76,5	9,8	4641,8	21,7	0,6	2,3	1,7	1,2
Romania	269,4	30,5	15097,5	86,3	-0,1	1,6	0,9	1,4
Bulgaria/Romania	346,0	40,2	19739,3	108,1	0,0	1,8	1,1	1,4
EU27	7791,3	911,5	446177,6	2802,4	-19,0	-15,5	-16,8	-11,8

Table 30. Change in emissions per inventory position for the EU according to the ESAA scenario

	Baseline (REF, 2020)				Effort sharing agreement (ESAA, 2020)			
	EU15 [1000t]	EU10 [1000t]	BUR [1000t]	EU27 [1000t]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Methane emissions from enteric fermentation (IPCC)	5987,7	550,1	323,1	6860,9	-22,2	0,1	0,0	-19,4
Methane emissions from manure management (IPCC)	836,9	70,7	22,8	930,5	-17,8	0,4	0,2	-16,0
Methane emissions	6824,6	620,8	346,0	7791,4	-21,7	0,1	0,0	-19,0
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	217,7	45,6	10,2	273,5	-16,5	0,3	1,3	-13,0
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	73,4	5,1	4,4	82,8	-28,4	-0,4	-0,0	-25,2
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	175,4	46,3	12,4	234,1	-19,5	-1,3	4,2	-14,6
Direct nitrous oxide emissions from crop residues (IPCC)	73,2	12,4	7,2	92,8	-20,2	-1,9	0,6	-16,1
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	11,9	1,1	0,9	13,9	-21,5	-6,5	0,0	-18,9
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	14,7	2,9	1,7	19,3	-12,2	-0,7	-0,6	-9,5
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	38,8	7,9	2,2	48,9	-16,2	-0,4	2,3	-12,8
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	12,0	2,6	1,0	15,6	-19,3	-1,2	0,0	-15,0
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	109,6	20,8	0,2	130,6	-20,3	-1,0	-4,8	-17,2
Nitrous oxide emissions	726,6	144,6	40,2	911,5	-19,4	-0,7	1,8	-15,5
Carbon dioxide equivalent	368564,5	57873,8	19739,3	446177,6	-20,3	-0,5	1,1	-16,8

reference scenario (changes in year 2020). The ESAA scenario has been designed to achieve a GHG emission reduction of -16.8% (in CO2 equivalents) in the EU-27 compared to the emissions in the REF scenario[34]. While in the STD scenario a homogenous reduction cap of -20% was set on all MS, the caps in the ESAA scenario are unevenly distributed among the MS to achieve the overall reduction of 20% in the EU. As a consequence of this uneven reduction burden, and because most of the EU-12 MS already reduce their GHG emissions in the REF scenario below their reduction limits in the ESAA scenario, the 16.8% reduction in the EU-27 is achieved almost entirely by the EU-15 MS. Thus, while GHG emissions are reduced in the EU-15 by 20.3%, EU-10 MS reduce their emissions by only 0.5% compared to the REF scenario.

It can be observed that the EU-15 considerably reduces both emissions of

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[34] Adding the -3% GHG emission reduction in the REF scenario to the 16.8% reduction achieved in this STD scenario results in a total reduction in GHG emission of 19.8% in the EU-27compared to the reference year 2004 (three year average 2003-2005).
However, it has to noted that in a direct comparison of GHG emissions between the ESAA results for 2020 and the emissions in the base year 2004, the overall reduction is down to 19.3%. This is because in the modelling of the scenarios the reduction requirements are set relative to the REF scenario. Thus if 3% of 100 units are reduced in the REF, 97% are left and a further reduction of 16.8% on 97% makes (1-0.168)*97% = 80.73% left over from the start, i.e. a reduction of 19.3%.

methane (-21.7%) and nitrous oxide (-19.4 %) compared to the reference scenario. The highest reductions are projected in Ireland (-28.6%) and the Netherlands (-24.2%). On the contrary, the EU-12 do not fully exploit their extra emission allowances. The EU-10 is projected to increase methane emissions only slightly by 0.1% and to even decrease nitrous oxide emissions by 0.7%.

We observe in Table 30 that the reductions in methane emissions almost entirely come from reductions in enteric fermentation in the EU-15. In EU-27 direct nitrous oxide emissions from grazing are - in relative terms - reduced most. Taking absolute terms into account, most of the additional 15.5% reduction of nitrous oxide emissions achieved in the EU-27 are attributable to the 15.5% reduction of N2O emissions from manure management and application (except grazing) and the 19.5% reductions in mineral fertilizer application in the EU-15%.

6.2.2 Analysis of production and economic effects

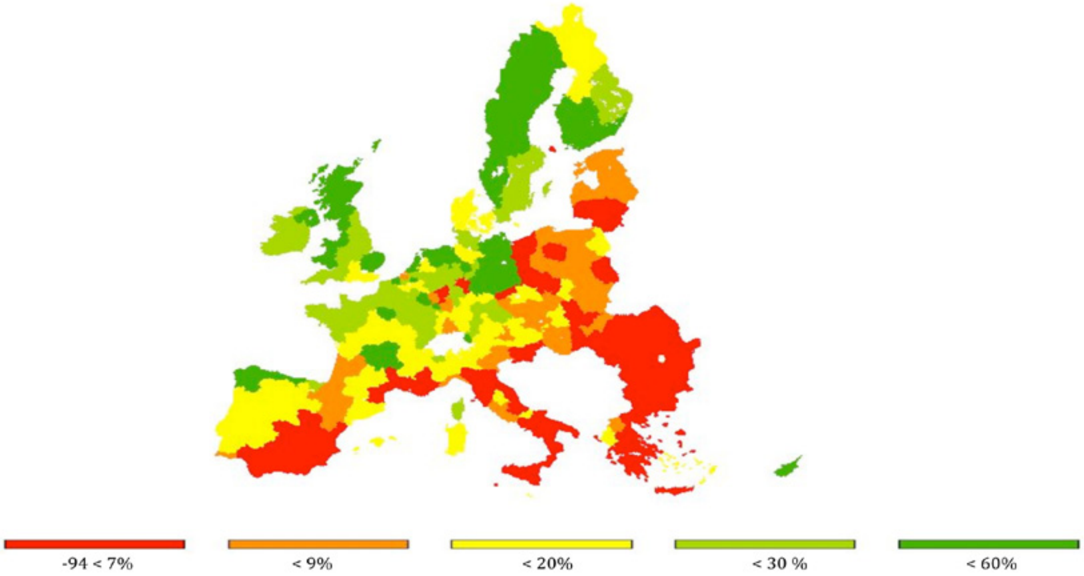
In Table 31 it can be seen that the production and economic effects of the ESAA are of similar nature as the ones projected and described in the STD scenario (cf. Table 26). However, as emission reduction commitments are less binding in EU-12, distribution of economic and income effects is different in the ESAA than in the STD scenario. Most of all beef meat activities in the EU-15 are affected in the ESAA. With the beef herd being reduced by 29.4% in the EU-27, this reduction is due to a reduced number of beef cattle in the EU-15 by 33.3%, while the EU-10 is projected to see an increase in the number of beef cattle by 8.8% and Bulgaria/Romania by 12.7% (cf. Table 70 in the annex). The highest reduction in the beef

Table 31. Change in income, area, yield and supply for the EU-27 for activity aggregates according to the ESAA scenario

	Baseline (REF 2020)				**Effort sharing agreement (ESAA, 2020)**			
	Income [Euro/ha or head]	**Area or Herd Size [1000 ha or hds]**	**Yield [kg/ha or head]**	**Supply [1000 t]**	**Income [% to REF]**	**Area or Herd Size [% to REF]**	**Yield [% to REF]**	**Supply [% to REF]**
Cereals	332	57214	5749	328905	14,6	-7,8	-2,2	-9,8
Oilseeds	460	8882	3010	26737	12,1	-5,7	-1,7	-7,3
Other arable crops	1125	7771	na	na	14,0	-5,0	na	na
Vegetables and Permanent crops	4455	21612	na	na	0,3	0,1	na	na
Fodder activities	279	79668	23303	1856480	-0,9	-11,2	-11,4	-21,3
Set aside and fallow land	140	13265	na	na	4,8	12,3	na	na
Utilized Agricultural Area	1148	188413	na	na	13,2	-6,7	na	na
All cattle activities	455	84117	na	na	49,8	-22,8	na	na
Beef meat activities	123	26904	na	7842	145,3	-29,4	na	-11,9
Pig fattening	30	247670	92	22754	45,2	-2,2	-0,1	-2,4
Pig Breeding	117	14728	17281	254512	5,8	-14,5	-0,2	-14,7
Milk Ewes and Goat	54	77576	59	4561	19,5	-13,5	6,6	-7,7
Sheep and Goat fattening	35	46278	14	628	17,4	-0,2	-0,2	-0,5
Laying hens	3973	464	16339	7588	77,6	-5,2	-0,9	-6,0
Poultry fattening	320	6993	1909	13352	82,0	-7,8	-0,0	-7,8

Note: na = not applicable; total supply of beef includes beef from dairy cows and calves.

Figure 10. Change in agricultural income per utilised agricultural area according to the ESAA scenario (in %)



cattle herd is projected for Ireland (-44%). On the contrary, an increase in the beef herd is projected for all EU-12 MS (except Cyprus and Malta). The projections show, that the decrease in beef meat activity in the EU-15 on the one hand, and the increase in the EU-12 on the other hand, results in a similar overall reduction of herd size (-29.4%) and production (-11.9%) in the EU-27 as projected in the STD scenario (where the herd size decreases by 27.6% and production by 11.5%).

For the dairy sector there are no severe changes projected in the ESAA scenario, and developments show a similar pattern as in the STD scenario, albeit with slightly bigger production reductions in the EU-15 (-4.2%) than in the STD scenario (-3.3%), whereas there are almost no changes projected for the EU-12 (cf. Table 70 in the annex).

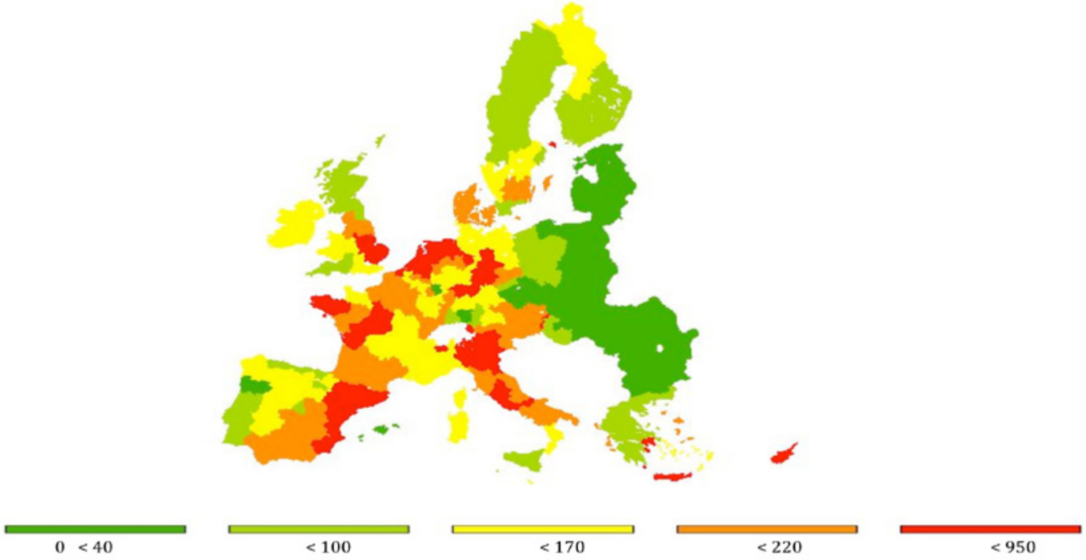
Projections for the cereal sector show a reduction in cereal area of 7.8% in the EU-27, with reductions of 12.7% in the EU-15 and 1.2% in the EU-10, whereas Bulgaria/Romania would increase the cereal area by 2.7%. While these changes are in the EU-15 similar to those in the STD scenario (-10.8%), the respective changes are different for the EU-12, as in the STD scenario the EU-10 is projected to decrease cereal area by 14.5% and Bulgaria/Romania by 8%. The net exporter position of the EU-27 would also be weakened in the ESAA scenario (with about 0.9 Mio tonnes less export), however less than in the STD scenario (-12.7 Mio tonnes net export) (cf. Table 68 in the annex).

Following the overall decrease in supply and the resulting increase in producer prices in the EU-27, the agricultural sector increases its income per production unit. For example with regard to agricultural income per UAA, on average (EU-27) income effects in the ESAA scenario are similar (+13.2% increase) to the STD scenario (+13.8%) but differently distributed over the regions (cf. Figure 10).

6.2.3 Analysis of emission abatement costs

Figure 11 shows the marginal abatement costs across EU agriculture after the implementation of the effort sharing agreement. Just like in the STD scenario the highest abatement costs can be found in the Netherlands and in some regions of Spain, Italy, UK and Germany. In the EU-12 countries

Figure 11. Marginal abatement costs under the ESAA scenario (in €/t CO2 eq)



the costs are low and even lower compared to the STD-scenario. This is due to the relatively low emission reduction targets in the EU-12 MS. The average marginal costs in the ESAA scenario are 147 €/t CO2 eq and thus lower compared to the costs in the STD scenario (159 €/t CO2 eq).

6.2.4 Analysis of environmental effects with regard to nitrogen balances

In Table 32 it can be observed that the surplus of nitrogen is projected to be reduced by -11.5% in 2020 under the ESAA scenario

Table 32. Changes in the nitrogen balance according to the ESAA scenario

	Baseline (REF 2020)				Effort sharing agreement (ESAA, 2020)			
	EU15 [1000t N]	EU10 [1000t N]	BUR [1000t N]	EU27 [1000t N]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Import by mineral fertilizer	8445	2261	602	11309	-3,2	-0,3	-0,2	-2,4
Import by manure	7739	1138	411	9288	-20,9	-19,1	-19,1	-20,6
Import by crop residues	4764	878	512	6153	-11,2	-5,8	-9,8	-10,3
Biological fixation	861	76	62	999	-13,8	-14,5	-13,3	-13,8
Atmospheric deposition	1671	326	191	2188	-3,0	-1,1	-2,6	-2,7
Nutrient retention by crops	14586	2835	1262	18683	-9,3	-4,8	-8,2	-8,5
Surplus total	8894	1844	516	11254	-13,8	-8,3	-7,7	-12,6
Gasseous loss	2966	610	173	3749	-15,2	-13,1	-13,3	-14,8
Run off mineral	246	122	51	419	-3,1	-0,3	-0,2	-1,9
Run off manure	347	83	38	468	-19,9	-19,3	-19,1	-19,7
Surplus at soil level	5335	1028	254	6617	-13,1	-5,4	-3,6	-11,5

Figure 12a. Yield changes in fodder activities according to the ESAA scenario (in %)

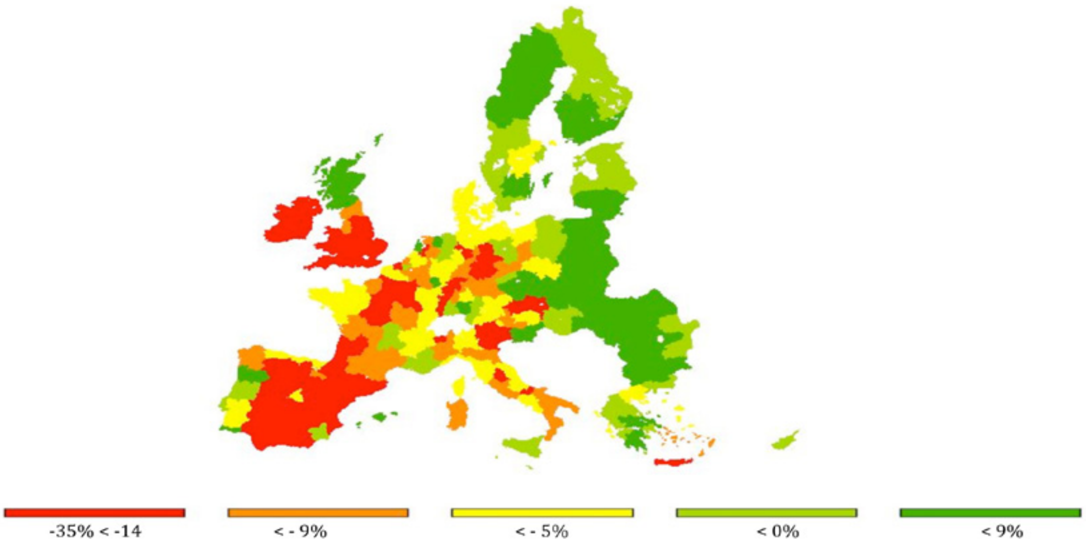
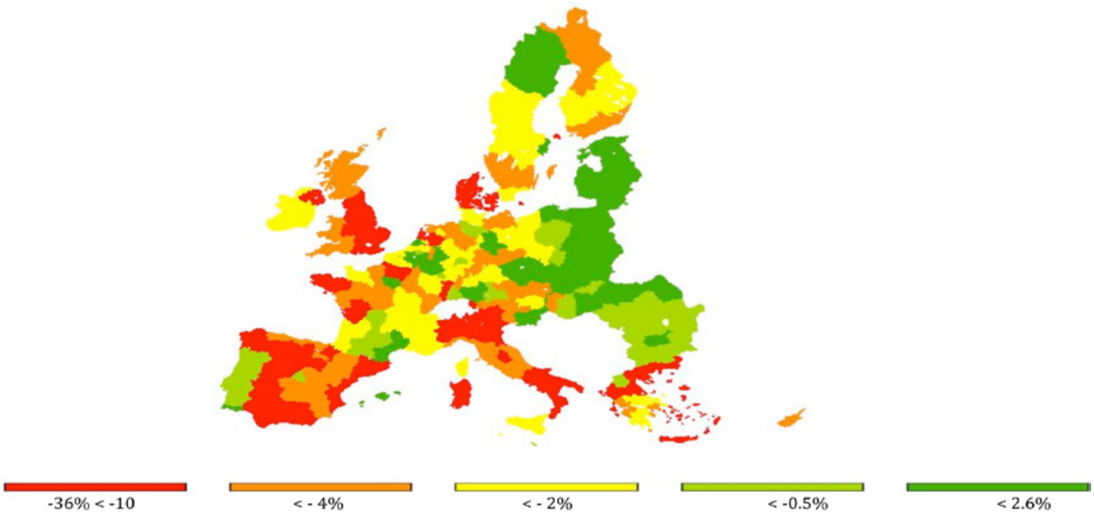


Figure 12b. Yield changes in beef meat activities according to the ESAA scenario (in %)



Note: The yield of beef meat activities excludes beef from dairy cows and calves

compared to the REF scenario. This reduction is mainly caused by a reduction of 13.1% expected in the EU-15, while in the EU-10 the surplus of nitrogen would be decreased by only 5.4% and in Bulgaria/Romania by 3.6%.

When comparing the changes in the nitrogen balance according to the ESAA scenario (Table 32) with the projected changes according to the STD scenario (Table 27) we can see that under the ESAA scenario the reduction in import by manure in the

EU-15 contributes most to the overall reduction in nitrogen surplus, whereas in the STD scenario, also the reduction of mineral fertilizer contributes considerably to overall reductions.

The changes with respect to nitrogen balances are mostly attributable to the changes in the beef cattle activities. The introduction of an ESAA stimulates the extensification of fodder production and intensification of beef meat production. As can be seen in Figure 12, on average yields in fodder and beef meat activities experience larger changes in the EU-15 MS than in the EU-12 MS. In the STD scenario the developments in beef and fodder yields had been more widely spread throughout the whole EU-27.

6.3 Emission Trading Scheme for Agriculture Scenario (ETSA)

As described in chapter 4.2.3, this tradable emission permits scenario assumes the explicit implementation of an Emission Trading Scheme for Agriculture (ETSA) in the EU-27, with the target to achieve a 20% GHG emission reduction in the year 2020 compared to 2004 (three-year average 2003-2005). Therefore a regionally homogeneous emission cap of -20% is set on total GHG emissions in all Nuts 2 regions. According to this cap and historical emission levels the emission permits are allocated to agricultural producers (1 permit equals 1 tonne of CO2 equivalent, where CH4 and N2O emissions from agricultural sources are considered). Trade of emission permits is allowed between regions (i.e. Nuts 2 level), MS and EU-27 wide level. Hence, e.g. regions specialised in livestock production are allowed to trade permits with regions specialised in arable production. The direction of permit trade will depend on the emission-intensity of the farmers' respective production-mix and the corresponding burden imposed by the selected policy instrument.

Emission trading belongs to the family of market-based instruments for emission mitigation. These instruments use market signals in the form of a modification of relative prices to influence behaviour and reward environmental performance through the market. By doing this, a higher economic efficiency compared to command and control mechanisms should be achieved since polluters are allowed to vary their pollution level according to their marginal costs of abatement.

6.3.1 Changes in GHG emissions

In Table 33 projected changes of GHG emissions in 2020 under the ETSA scenario compared with the reference scenario in 2020 are presented. On the aggregated level of the EU-27 an emission reduction of 16.8% is achieved. All EU-27 MS are projected to decrease their GHG emissions, with highest percentage reductions in CO2 equivalents being projected for the United Kingdom (-32.6%), Finland (-29%), Latvia (-25.9%) and Ireland (-24.8%).

While the overall reduction of GHG emissions in the EU-27 is the same in the ETSA scenario as in the previous two scenarios, the achievement of this reduction is distributed quite differently than in the STD and ESAA scenario (cf. Table 34).

In the STD scenario all MS had to reduce GHG emissions by 20% compared to the base year 2004. The reduction commitments in the ESAA scenario forced EU-15 MS to reduce their GHG emissions more than the EU-12 MS (where the emission reduction commitments were in most cases not binding or where the MS were even allowed increasing emissions). On the contrary, in this ETSA scenario MS/regions are allowed to make use of their right to emit, or trade the rights in case these results to be more profitable. As a consequence, a reallocation of GHG emissions between EU-12 and EU-15 MS can be observed in the ETSA scenario, which corresponds to the market signals given to producers based on the costs they face for emission abatement. Thus, in contrast to the ESAA scenario where the EU-12 does not reduce emissions, in the ETSA scenario EU-10 and Bulgaria/Romania are projected to reduce GHG emissions of CO2 equivalents

Table 33. Emissions per Member State according to the ETSA scenario

	Baseline (REF, 2020)				Emission trading scheme agriculture (ETSA, 2020)			
	Methane [1000t]	Nitrous Oxide [1000t]	CO2 equivalents [1000t]	Ammonia [1000t]	Methane [% to REF]	Nitrous Oxide [% to REF]	CO2 equivalents [% to REF]	Ammonia [% to REF]
Austria	163,5	12,8	7399,1	49,4	-14,1	-11,3	-12,6	-8,0
Belgium_Lux	208,6	18,5	10119,8	74,0	-15,7	-12,0	-13,6	-8,6
Denmark	151,0	21,2	9727,1	76,9	-13,0	-9,6	-10,7	-7,4
Finland	80,8	23,7	9040,8	18,5	-17,7	-31,7	-29,0	-12,4
France	1449,1	151,9	77527,2	480,8	-15,5	-10,5	-12,4	-9,4
Germany	1070,8	119,2	59451,0	432,6	-11,8	-11,3	-11,5	-7,1
Greece	141,1	9,7	5980,9	27,0	-14,1	-9,5	-11,8	-11,0
Ireland	530,3	38,7	23136,3	103,5	-25,7	-23,9	-24,8	-24,9
Italy	740,8	58,1	33557,8	309,0	-13,1	-10,7	-11,8	-9,3
Netherlands	387,8	34,8	18942,5	92,6	-7,2	-9,4	-8,5	-8,9
Portugal	140,7	10,7	6267,7	43,2	-20,7	-23,2	-22,0	-14,7
Spain	746,3	77,3	39622,9	291,7	-27,7	-17,4	-21,4	-13,3
Sweden	117,3	21,2	9020,4	40,4	-13,2	-17,9	-16,6	-8,6
United Kingdom	896,7	128,8	58771,0	205,2	-24,1	-36,7	-32,6	-15,7
EU15	6824,6	726,6	368564,5	2244,7	-17,4	-17,8	-17,6	-10,7
Cyprus	11,2	1,0	544,0	4,5	-8,9	-6,1	-7,7	-7,4
Czech Republic	57,5	14,7	5766,4	42,3	-14,6	-11,1	-11,8	-10,2
Estonia	14,1	2,3	1019,8	6,1	-13,9	-17,1	-16,1	-8,1
Hungary	49,8	21,6	7749,7	53,9	-10,7	-12,1	-11,9	-10,2
Latvia	22,7	4,7	1944,8	10,5	-13,6	-30,0	-25,9	-16,6
Lithuania	53,4	10,1	4237,2	22,2	-9,2	-15,8	-14,1	-10,5
Malta	1,9	0,2	89,1	1,2	-8,9	-6,3	-7,4	-2,6
Poland	346,8	82,6	32872,4	284,4	-16,0	-12,1	-13,0	-11,4
Slovenia	37,0	2,5	1543,5	12,3	-14,6	-8,9	-11,7	-9,1
Slovak Republic	26,4	5,0	2107,0	12,4	-6,0	-4,4	-4,9	-5,2
EU10	620,8	144,7	57873,8	449,6	-14,1	-12,6	-12,9	-10,9
Bulgaria	76,5	9,8	4641,8	21,7	-12,7	-15,1	-14,3	-12,0
Romania	269,4	30,5	15097,5	86,3	-13,5	-10,6	-11,7	-9,1
Bulgaria/Romania	346,0	40,2	19739,3	108,1	-13,3	-11,7	-12,3	-9,7
EU27	7791,3	911,5	446177,6	2802,4	-17,0	-16,7	-16,8	-10,7

by 12.9% and 12.3% respectively, after selling emission permits to several EU-15 MS. The EU-15 is projected to reduce GHG emissions of CO2 equivalents by 17.6% in the ETSA scenario compared to the reference scenario, which makes 2.7% points less emission reduction than in the ESAA scenario (-20.3%) but is only a bit more than in the STD scenario (-17.2%). However, there are again large differences in the emissions per MS between the ETSA and STD scenario results. The most significant difference are projected for the United Kingdom, Latvia and Finland, who

Table 34. *Changes in GHG emissions under the ETSA scenario compared to the STD and ESAA scenarios (CO2 equivalents)*

	Changes in agricultural GHG Emissions (CO2 equivalents), 2020			
	[% to BAS]	[% to REF]		
	REF	**STD**	**ESAA**	**ETSA**
Austria	-5,6	-14,8	-19,9	-12,6
Belgium_Lux	-2,8	-15,9	-19,8	-13,6
Denmark	-11,3	-8,5	-18,5	-10,7
Finland	-5,6	-15,2	-20,2	-29,0
France	-3,6	-16,4	-19,2	-12,4
Germany	-6,4	-14,3	-17,1	-11,5
Greece	-6,0	-14,3	-6,9	-11,8
Ireland	0,3	-19,9	-28,6	-24,8
Italy	0,3	-19,6	-21,3	-11,8
Netherlands	0,8	-19,4	-24,2	-8,5
Portugal	-3,9	-16,2	-4,5	-22,0
Spain	7,5	-24,8	-23,7	-21,4
Sweden	-10,4	-10,5	-16,9	-16,6
United Kingdom	-3,4	-16,5	-21,4	-32,6
EU-15	-2,7	-17,2	-20,3	-17,6
Cyprus	16,2	-30,2	-24,6	-7,7
Czech Republic	-17,5	-1,6	2,7	-11,8
Estonia	-16,0	-3,3	2,3	-16,1
Hungary	2,5	-21,3	-1,8	-11,9
Latvia	-9,1	-10,5	2,3	-25,9
Lithuania	-10,0	-9,5	1,1	-14,1
Malta	7,5	-24,3	-9,0	-7,4
Poland	1,3	-20,4	-1,3	-13,0
Slovenia	-14,6	-5,4	3,1	-11,7
Slovak Republic	-15,7	-4,4	2,7	-4,9
EU-10	-3,4	-16,3	-0,5	-12,9
Bulgaria	-5,6	-14,2	1,7	-14,3
Romania	-8,5	-11,7	0,9	-11,7
Bulgaria/Romania	-7,8	-12,3	1,1	-12,3
EU-27	-3,0	-16,8	-16,8	-16,8

are projected to further reduce GHG emissions compared to the STD scenario by 16.1, 15.5 and 13.9 percentage points respectively. In contrast, apart from Cyprus and Malta, the Netherlands (+11 percentage points) and Italy (+7.8 percentage points) are the MS that show the biggest increase in GHG emissions when comparing the results of the ETSA and STD scenarios.

It can be seen in Table 35 that, similar to the results of the ESAA scenario, the major reductions of methane emissions are projected for emissions coming from the enteric fermentation. However, unlike in the ESAA scenario, the respective methane emissions are also reduced in the EU-12. The biggest reductions in direct nitrous oxide emissions (both in relative and absolute terms) are achieved through

Table 35. Change in emissions per inventory position for the EU according to the ETSA scenario

	Baseline (REF, 2020)				Emission trading scheme agriculture (ETSA, 2020)			
	EU15 [1000t]	EU10 [1000t]	BUR [1000t]	EU27 [1000t]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Methane emissions from enteric fermentation (IPCC)	5987,7	550,1	323,1	6860,9	-18,0	-14,0	-13,4	-17,5
Methane emissions from manure management (IPCC)	836,9	70,7	22,8	930,5	-13,0	-14,5	-12,4	-13,1
Methane emissions	6824,6	620,8	346,0	7791,4	-17,4	-14,1	-13,3	-17,0
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	217,7	45,6	10,2	273,5	-11,8	-11,2	-10,5	-11,7
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	73,4	5,1	4,4	82,8	-25,1	-12,5	-13,8	-23,8
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	175,4	46,3	12,4	234,1	-14,2	-15,5	-12,5	-14,4
Direct nitrous oxide emissions from crop residues (IPCC)	73,2	12,4	7,2	92,8	-16,3	-15,3	-12,8	-15,9
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	11,9	1,1	0,9	13,9	-17,2	-4,7	-11,2	-15,9
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	14,7	2,9	1,7	19,3	-9,7	-6,2	-4,7	-8,7
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	38,8	7,9	2,2	48,9	-12,1	-12,0	-10,0	-11,9
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	12,0	2,6	1,0	15,6	-16,9	-14,0	-11,0	-16,0
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	109,6	20,8	0,2	130,6	-34,6	-8,7	-9,5	-30,5
Nitrous oxide emissions	726,6	144,6	40,2	911,5	-17,8	-12,6	-11,7	-16,7
Carbon dioxide equivalent	368564,5	57873,8	19739,3	446177,6	-17,6	-12,9	-12,3	-16,8

reduced emissions from the cultivation of histosols, in which the organic matter content dominates the problems related to agricultural land use. In absolute terms, further big reductions are also achieved by reductions in the in the application of mineral fertilizer as well as by reduced emissions stemming from manure management and application.

6.3.2 Analysis of production and economic effects

The production changes in the ETSA scenario are presented in Table 36 for activity aggregates in the EU-27. The production changes vary with respect to the previous scenarios as the effects across activities are more homogeneous, being beef meat activities less affected and arable crops in turn more affected. Nonetheless, the cattle sector is also in the ETSA scenario the most affected sector by the introduced emission abatement policy, with the beef herd size in the EU-27 being reduced by 28.7% and production by 10.4%.

Looking closer into the results for the most important sectors, it can be observed that all EU

Table 36. *Change in income, area, yield and supply for the EU-27 for activity aggregates according to the ETSA scenario*

	Baseline (REF 2020)				Emission trading scheme agriculture (ETSA, 2020)			
	Income [Euro/ ha or head]	Area or Herd Size [1000 ha or hds]	Yield [kg/ ha or head]	Supply [1000 t]	Income [% to REF]	Area or Herd Size [% to REF]	Yield [% to REF]	Supply [% to REF]
Cereals	332	57214	5749	328905	14,8	-9,2	0,4	-8,9
Oilseeds	460	8882	3010	26737	12,5	-6,7	0,0	-6,6
Other arable crops	1125	7771	na	na	10,9	-3,4	na	na
Vegetables and Permanent crops	4455	21612	na	na	0,2	0,1	na	na
Fodder activities	279	79668	23303	1856480	3,2	-13,6	-9,6	-21,9
Set aside and fallow land	140	13265	na	na	-0,1	18,7	na	na
Utilized Agricultural Area	1148	188413	na	na	12,8	-7,7	na	na
All cattle activities	455	84117	na	na	42,2	-20,2	na	na
Beef meat activities	123	26904	na	7842	133,4	-28,7	na	-10,4
Pig fattening	30	247670	92	22754	27,5	-1,6	-0,1	-1,6
Pig Breeding	117	14728	17281	254512	7,6	-10,7	0,6	-10,1
Milk Ewes and Goat	54	77576	59	4561	16,8	-13,1	6,8	-7,2
Sheep and Goat fattening	35	46278	14	628	16,2	-0,1	-0,3	-0,4
Laying hens	3973	464	16339	7588	45,6	-4,5	0,0	-4,5
Poultry fattening	320	6993	1909	13352	58,8	-7,0	0,4	-6,6

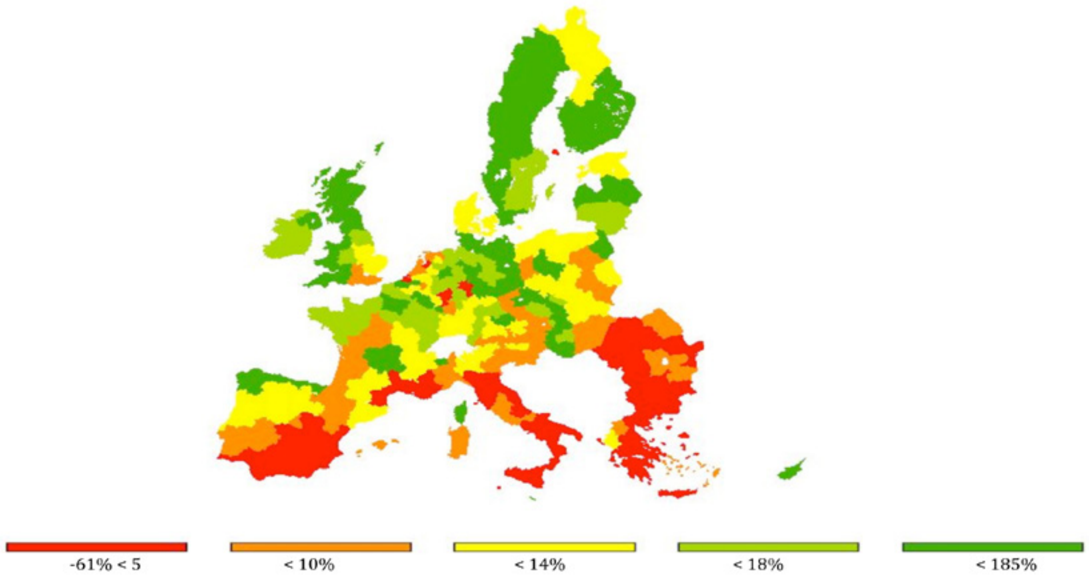
Note: na = not applicable; total supply of beef includes beef from dairy cows and calves.

MS are projected to face reductions in beef herd size except Malta, Cyprus and Romania. For the EU-15 biggest reductions in absolute numbers can be seen in France, Spain and the United Kingdom. In the EU-12, the biggest percentage reduction in beef herd size is projected for the Czech Republic whereas in absolute terms the reductions are biggest in Poland (cf. Table 73 in the annex).

When comparing results of the ETSA and the STD scenario, it is most remarkable that beef herd size in the Netherlands and Italy are reduced by 14.1 and 12.1 percentage points respectively less than in the STD scenario. On the contrary, beef herds decrease by a further 18.3 and 15.7 percentage points respectively in Finland and the United Kingdom compared to the STD scenario. On aggregate of the EU-10, the reductions in beef herd size and production are comparable to those in the STD scenario, however they are quite different at MS level with e.g. the Czech Republic and Estonia showing further decreases in beef cattle herds by 27.1 and 26.9 percentage points compared to the STD scenario.

Results for the dairy sector are rather similar to the ones in the STD scenario. The most significant difference between the ETSA and the STD scenario is that dairy cattle herds in the Netherlands, Poland and Italy would be reduced

Figure 13. Change in agricultural income per utilised agricultural area according to the ETSA scenario (in %)



respectively by 4.3, 3.5 and 3 percentage points less in the ETSA scenario compared to the STD scenario (cf. Table 72 in the annex).

Cereal area is projected to decrease by 9.2% in the EU-27; with yields only increasing by 0.4 % this results in an overall decrease in production of 8.9%. Utilized agricultural area is projected to decrease by 7.7% while set aside and fallow land increases by 18.7% (cf. Table 71 in the annex).

Biggest decreases in cereal production are projected for Malta, Latvia and Finland. When compared to the STD scenario, the production decreases in Latvia and Finland imply respectively 35.4 and 17.2 percentage points more decrease than in the STD. On the contrary, for Cyprus, the Netherlands, Italy and Poland cereal production decreases less than in the STD scenario, by 24.5, 15.1, 8.7 and 8.4 percentage points respectively (cf. Table 71 in the annex).

On average, the ETSA scenario leads to increases in income per production unit, however these increases are unevenly distributed within the MS. With respect to income per UAA the lowest income increases (also decrease is possible) can be found around the Mediterranean, Romania and Bulgaria (Figure 13).

6.3.3 Analysis of emission abatement costs and the emission permit market

Figure 14 shows that the marginal abatement costs are rather low (compared to the STD and ESAA scenarios). The highest costs can be found in some NUTS2 regions spread through EU-15, Estonia and Jihozápad in Czechoslovakia. On average at MS level, marginal abatement costs are lowest in EU-12 (except Estonia and Jihozápad).

Regarding the emission permits market, Figure 15 shows the purchases of emission permits in the EU. Regions in EU-12 countries are net sellers of permits, and therefore show low numbers of permits bought, with some exceptions in Poland and Romania. It can be observed that the intensive EU-15 regions are main buyers of emission permits. On average,

Figure 14. Marginal abatement costs under the ETSA scenario (in thousand €/t CO2 eq)

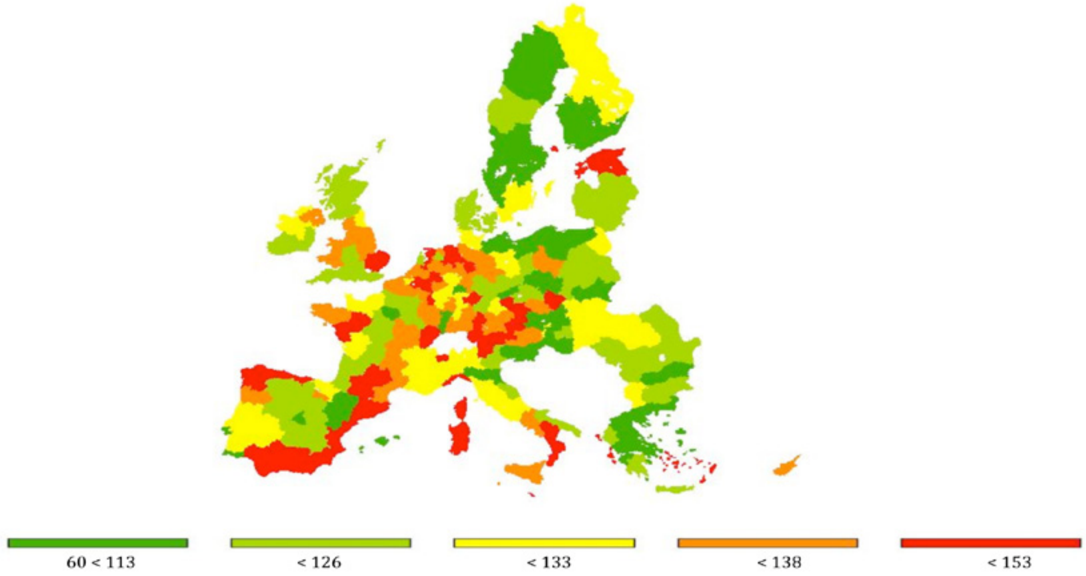
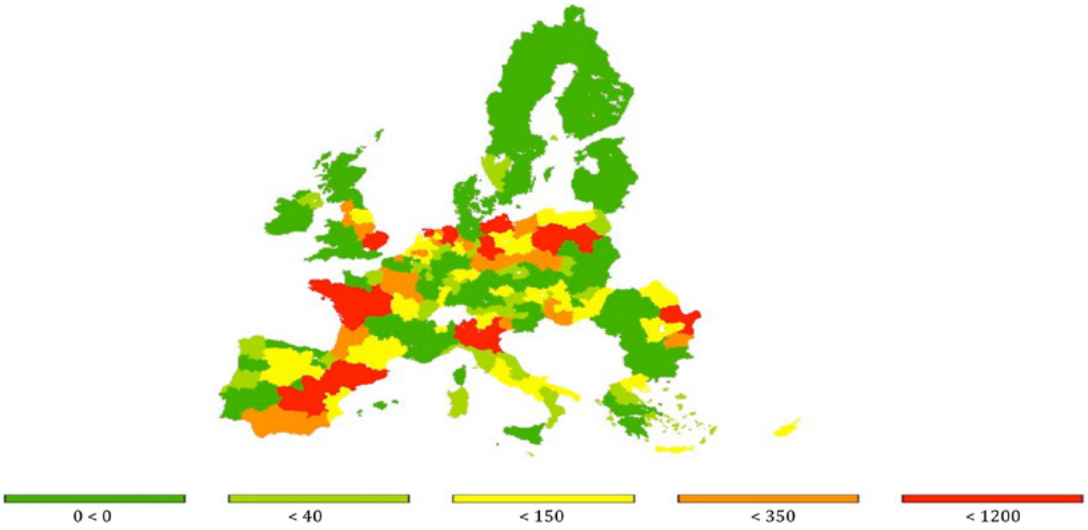


Figure 15. Purchases of emission permits in the ETSA scenario (1000 CO2 equivalents)



800 MM tonnes of permits are traded in the market, under the prevailing assumptions on transaction costs.

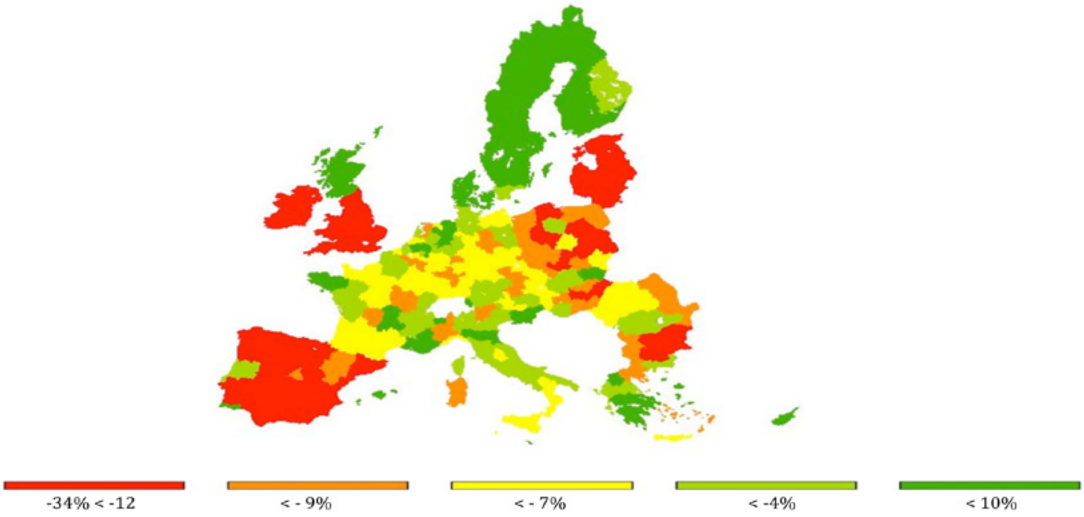
6.3.4 Analysis of environmental effects with regard to nitrogen balances

Table 37 presents data on the percentage changes of surplus of nitrogen in the ETSA scenario compared to the reference scenario. The overall reduction in nitrogen surplus is 17.3% in the EU-27, which is more than the reduction in the ESAA (-11.5%) and STD (-16.5%) scenarios. It is further noticeable that the reduction is projected to be 21% in EU-15, 2.4% in EU-10 while in Bulgaria/Romania nitrogen surplus would slightly increase by 0.7%. Even though the overall reduction of nitrogen surplus at EU-

Table 37. *Changes in the nitrogen balance according to the ETSA scenario*

	Baseline (REF 2020)				Emission trading scheme agriculture (ETSA, 2020)			
	EU15 [1000t N]	EU10 [1000t N]	BUR [1000t N]	EU27 [1000t N]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Import by mineral fertilizer	8445	2261	602	11309	-19,5	-1,3	4,2	-14,6
Import by manure	7739	1138	411	9288	-18,2	0,1	0,7	-15,1
Import by crop residues	4764	878	512	6153	-20,1	-1,9	0,6	-15,8
Biological fixation	861	76	62	999	-20,4	-7,7	-1,7	-18,2
Atmospheric deposition	1671	326	191	2188	-9,7	-0,9	-0,0	-7,5
Nutrient retention by crops	14586	2835	1262	18683	-18,0	-0,9	1,8	-14,1
Surplus total	8894	1844	516	11254	-19,3	-1,5	1,4	-15,4
Gasseous loss	2966	610	173	3749	-16,6	-0,3	1,8	-13,1
Run off mineral	246	122	51	419	-18,0	-0,6	4,1	-10,2
Run off manure	347	83	38	468	-17,0	0,4	0,8	-12,5
Surplus at soil level	5335	1028	254	6617	-21,0	-2,4	0,7	-17,3

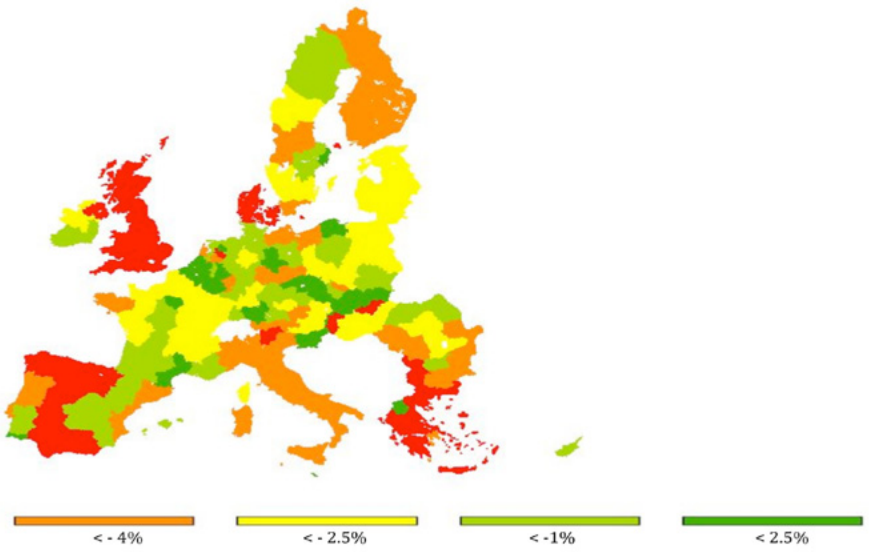
Figure 16a. *Yield changes in fodder activities according to the ETSA scenario (in %)*



27 level is quite comparable to the STS scenario, the composition within the aggregated country blocks is quite different as in the STD scenario the overall reduction in nitrogen surplus was projected to be achieved by a decrease of 16.9% in the EU-15, 15.4% in the EU-10 and 12.4% in Bulgaria/Rumania.

On average under the ETSA scenario the crop production is (slightly) more affected than the animal production compared with the ESAA and STD scenario. The production decreases in the arable sector and beef meat activities are only slightly compensated by rather small increases in yields. Increases in fodder yields can

Figure 16b. Yield changes in beef meat activities according to the ETSA scenario (in %)



Note: The yield of beef meat activities excludes beef from dairy cows and calves

only be seen in Scandinavia, Scotland and some other Nuts 2 regions in EU-27, whereas in most regions fodder yields are projected to decrease. Considerable increases are projected in yields of beef meat activities (+20% on average for the EU-27), with only some regions experiencing slight decreases in beef meat yields (cf. Figure 16a and 16b).

6.4 Livestock Emission Tax Scenario (LTAX)

Livestock is the major contributor to GHG emissions in the agricultural sector, and therefore much attention is given to specific options on how to reduce the GHG emissions in the livestock sector (cf. FAO, 2006, Leip et al., 2010, FAO, 2010). One possibility to reduce the contribution of livestock on GHG emissions would be to indirectly affect livestock emissions through the implementation of livestock emission taxes (cf. chapter 4.2.4).

Different to the other mitigation policy scenarios in this study, the burden of achieving a 20% emission reduction in EU agricultural GHG emissions is put in the LTAX scenario entirely on the livestock sector. As a consequence the tax for livestock emissions had to be set very high in order to achieve the overall emission reduction goal of 20%. By conducting some trial simulation runs using different tax levels, we found that a tax of about 229 € per tonne of CO2 equivalent livestock emissions (independent of animal type) would be necessary in order to achieve the envisaged reduction in overall EU agricultural GHG emissions of 20%. Such a livestock emission tax would be clearly very high, as it would translate for example into a tax per cow of about 950 € in Germany and Estonia and about 1400 € per cow in France. On average in the EU-27, the tax of 229 € per tonne of CO2 equivalent livestock emissions would imply a tax of about 1000 € per cow, about 21 € per fattening pigs and about 100 € per sow.

6.4.1 Changes in GHG emissions

Table 24 presents the changes in GHG emissions between the emission standard scenario and the reference scenario (changes in year 2020). The livestock emission tax scenario has been designed to achieve a 17.1%

Table 38. Change in emissions per Member State according to the LTAX scenario

	Baseline (REF, 2020)				Livestock emission tax (LTAX, 2020)			
	Methane [1000t]	Nitrous Oxide [1000t]	CO2 equivalents [1000t]	Ammonia [1000t]	Methane [% to REF]	Nitrous Oxide [% to REF]	CO2 equivalents [% to REF]	Ammonia [% to REF]
Austria	163,5	12,8	7399,1	49,4	-22,0	-13,5	-17,4	-12,6
Belgium_Lux	208,6	18,5	10119,8	74,0	-26,7	-16,1	-20,7	-13,7
Denmark	151,0	21,2	9727,1	76,9	-21,9	-16,0	-18,0	-14,2
Finland	80,8	23,7	9040,8	18,5	-24,7	-4,3	-8,2	-14,0
France	1449,1	151,9	77527,2	480,8	-24,6	-10,1	-15,8	-12,3
Germany	1070,8	119,2	59451,0	432,6	-19,9	-8,2	-12,6	-8,9
Greece	141,1	9,7	5980,9	27,0	-20,9	-7,6	-14,2	-12,6
Ireland	530,3	38,7	23136,3	103,5	-32,7	-26,9	-29,7	-31,0
Italy	740,8	58,1	33557,8	309,0	-23,2	-11,4	-16,9	-13,6
Netherlands	387,8	34,8	18942,5	92,6	-11,7	-11,6	-11,6	-14,3
Portugal	140,7	10,7	6267,7	43,2	-28,8	-25,6	-27,1	-19,3
Spain	746,3	77,3	39622,9	291,7	-36,9	-16,3	-24,5	-15,7
Sweden	117,3	21,2	9020,4	40,4	-19,4	-8,4	-11,4	-13,1
United Kingdom	896,7	128,8	58771,0	205,2	-30,5	-16,9	-21,3	-17,5
EU15	6824,6	726,6	368564,5	2244,7	-25,6	-13,1	-17,9	-14,0
Cyprus	11,2	1,0	544,0	4,5	-12,1	-6,1	-9,0	-7,2
Czech Republic	57,5	14,7	5766,4	42,3	-26,3	-9,2	-12,7	-13,5
Estonia	14,1	2,3	1019,8	6,1	-19,7	-10,3	-13,0	-7,6
Hungary	49,8	21,6	7749,7	53,9	-21,1	-6,9	-8,8	-12,8
Latvia	22,7	4,7	1944,8	10,5	-23,1	-10,1	-13,2	-15,0
Lithuania	53,4	10,1	4237,2	22,2	-17,3	-5,1	-8,3	-10,1
Malta	1,9	0,2	89,1	1,2	-14,1	-12,5	-10,7	-0,9
Poland	346,8	82,6	32872,4	284,4	-27,3	-9,4	-13,4	-15,1
Slovenia	37,0	2,5	1543,5	12,3	-26,1	-8,1	-17,1	-12,0
Slovak Republic	26,4	5,0	2107,0	12,4	-13,2	-6,4	-8,2	-9,5
EU10	620,8	144,7	57873,8	449,6	-24,5	-8,6	-12,2	-14,0
Bulgaria	76,5	9,8	4641,8	21,7	-22,3	-9,4	-13,8	-17,0
Romania	269,4	30,5	15097,5	86,3	-23,1	-10,7	-15,3	-14,0
Bulgaria/Romania	346,0	40,2	19739,3	108,1	-22,9	-10,4	-15,0	-14,6
EU27	7791,3	911,5	446177,6	2802,4	-25,4	-12,3	-17,1	-14,0

reduction of agricultural GHG emissions in 2020 in the EU-27 compared to the reference scenario. All EU-27 MS would see GHG emission reductions, with highest reductions in being projected for Ireland (-29.7%) and Portugal (-27.1%), Spain (-24.5%) and the United Kingdom (-21.3%). The same countries show also the highest decreases with respect to methane emissions. Lowest reductions in GHG emissions in the EU-15 can be seen in Finland (-8.2%) and in the EU-12 in Slovak Republic (-8.2%) and Lithuania (-8.3).

Table 39. Change in emissions per inventory position for the EU according to the LTAX scenario

	Baseline (REF, 2020)				Livestock emission tax (LTAX, 2020)			
	EU15 [1000t]	**EU10 [1000t]**	**BUR [1000t]**	**EU27 [1000t]**	**EU15 [% to REF]**	**EU10 [% to REF]**	**BUR [% to REF]**	**EU27 [% to REF]**
Methane emissions from enteric fermentation (IPCC)	5987,7	550,1	323,1	6860,9	-26,4	-24,5	-23,0	-26,1
Methane emissions from manure management (IPCC)	836,9	70,7	22,8	930,5	-19,8	-25,0	-21,5	-20,3
Methane emissions	6824,6	620,8	346,0	7791,4	-25,6	-24,6	-22,9	-25,4
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	217,7	45,6	10,2	273,5	-17,9	-19,1	-17,7	-18,1
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	73,4	5,1	4,4	82,8	-34,8	-22,0	-23,4	-33,4
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	175,4	46,3	12,4	234,1	-3,2	-0,3	-0,2	-2,5
Direct nitrous oxide emissions from crop residues (IPCC)	73,2	12,4	7,2	92,8	-11,2	-5,8	-9,7	-10,4
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	11,9	1,1	0,9	13,9	-14,8	-14,0	-12,4	-14,6
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	14,7	2,9	1,7	19,3	-4,3	-1,4	-2,9	-3,8
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	38,8	7,9	2,2	48,9	-14,8	-13,0	-12,7	-14,4
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	12,0	2,6	1,0	15,6	-18,0	-11,6	-10,0	-16,5
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	109,6	20,8	0,2	130,6	-6,0	-1,2	-4,8	-5,2
Nitrous oxide emissions	726,6	144,6	40,2	911,5	-13,1	-8,6	-10,3	-12,3
Carbon dioxide equivalent	368564,5	57873,8	19739,3	446177,6	-17,9	-12,2	-15,0	-17,1

Differently than in the other scenarios, the burden of emission reduction is put only on livestock emissions and therefore falls on animal numbers. As a direct consequence, percentage reductions in methane emissions are generally bigger in almost all MS than in the other policy scenarios. Actually most of the overall reduction in GHG emissions in the EU-27 is achieved by reductions in methane emissions. As can be seen in Table 39, methane emissions from enteric fermentation are reduced by 26.1% in the EU-27. With respect to reductions of nitrous oxide emissions, reductions in emissions stemming from manure management and application contribute most in absolute terms, while emissions stemming from the application of mineral fertilizer are only reduced by 2.5%. These developments in emissions per inventory position let already predict big changes in production patterns due to the livestock emission tax. These changes are presented in the following section.

6.4.2 Analysis of production and economic effects

The effects on income, area, yield and supply for the EU-27 for activity aggregates according to the LTX scenario are presented in Table 40. The introduced livestock emission tax increases the costs per animal activity in the supply model depending on their emission intensities, which leads to a reduction in livestock, with a particular high impact on ruminants. The livestock emission tax causes a decrease in beef cattle herd size of 38.6%, however, beef meat yields increase on average by 27.4%, resulting in a production decrease of 16%. With supply decreasing and demand decreasing rather only slightly, an increase in income of about 88.8% per head in all cattle activities is projected. As consequence of the supply drop, higher prices and rather stable demand, imports of beef meat in the EU-27 would further increase and the EU would become a net beef importer of about 1.3 Mio tonnes of beef (cf. Table 76 in the annex).

Looking closer into the results for the developments on the beef meat market, it can be seen that all EU-27 MS are projected to experience decreases in the beef cattle herd, with the exceptions of Cyprus, Malta and Romania. Absolute reductions would be biggest in France, Spain, the United Kingdom and Ireland. The regional reductions in beef cattle herd size are presented in Figure 17 as percentage change compared to the reference scenario. The reduction is very high in most regions but there are still regions where an increase of the herd size is projected, like e.g. areas in Spain, the Netherlands and Eastern

Table 40. Change in income, area, yield and supply for the EU-27 for activity aggregates according to the LTAX scenario

	Baseline (REF 2020)				**Livestock emission tax (LTAX, 2020)**			
	Income [Euro/ha or head]	**Area or Herd Size [1000 ha or hds]**	**Yield [kg/ ha or head]**	**Supply [1000 t]**	**Income [% to REF]**	**Area or Herd Size [% to REF]**	**Yield [% to REF]**	**Supply [% to REF]**
Cereals	332	57214	5749	328905	-11,7	-0,9	-2,9	-3,7
Oilseeds	460	8882	3010	26737	-3,1	2,9	-0,8	2,1
Other arable crops	1125	7771	na	na	-7,6	1,1	na	na
Vegetables and Permanent crops	4455	21612	na	na	0,0	-0,0	na	na
Fodder activities	279	79668	23303	1856480	3,6	-7,7	-11,5	-18,3
Set aside and fallow land	140	13265	na	na	0,2	10,0	na	na
Utilized Agricultural Area	1148	188413	na	na	11,5	-2,6	na	na
All cattle activities	455	84117	na	na	88,8	-30,4	na	na
Beef meat activities	123	26904	na	7842	271,5	-38,6	na	-16,0
Pig fattening	30	247670	92	22754	68,6	-2,4	-0,1	-2,5
Pig Breeding	117	14728	17281	254512	47,4	-17,9	1,4	-16,8
Milk Ewes and Goat	54	77576	59	4561	40,1	-21,0	10,7	-12,5
Sheep and Goat fattening	35	46278	14	628	32,1	-0,6	-0,4	-1,0
Laying hens	3973	464	16339	7588	95,5	-7,2	-0,1	-7,3
Poultry fattening	320	6993	1909	13352	142,0	-11,2	0,9	-10,4

Note: na = not applicable; total supply of beef includes beef from dairy cows and calves.

Figure 17. Change in herd sizes for beef meat activities according to the LTAX scenario (in %)

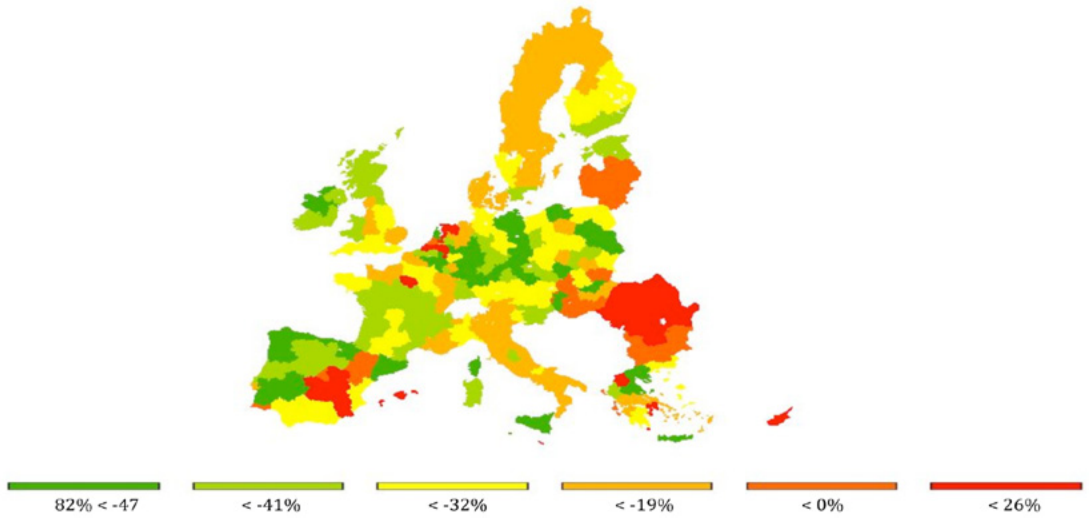
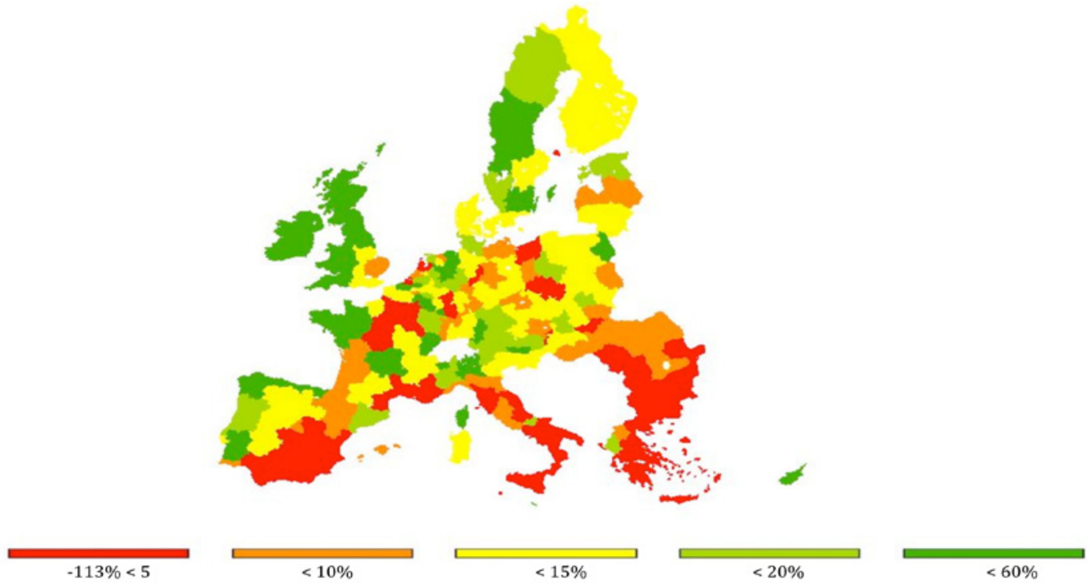


Figure 18. Change in agricultural income per utilized agricultural area according to the LTAX scenario (in %)



Europe. These regional increases in the cattle herd size might look relatively big as percentage changes, however they are relatively small in absolute terms.

While there are no severe changes in the EU-15 with respect to the size of dairy cow herds (-4.4%) and production (-4.2%), reductions in the EU-10 are more pronounced (with -10.2% in herd size and -9.5% in production), resulting in an overall EU-27 reduction in herd size of 5.6% and 5% in production (cf. Table 75 in the annex).

Following the reductions in the livestock sector, fodder activities would be reduced by 7.7 % and set aside and fallow land show an increase of about 10%. In total, utilized agricultural area would be reduced by 2.6% in the EU-27. While total cereal area is projected to be reduced by 0.9% in the EU-27, yields would decrease by about 2.9%, resulting in a production decrease of 3.7%. However, at MS level, Slovenia, Belgium-Luxembourg and the Netherlands would increase their cereal production. Demand for cereals is projected to decrease by a considerable 7.8% at EU-27 level (cf. Table 74 in the annex). This demand decrease for cereals is mainly attributable to the severe decreases in the livestock sector, as this triggers less demand for animal feed and hence cereals. As a consequence, income per ha cereals declines by about 11.7% in the LTAX scenario (whereas it is increasing in the other scenarios).

Figure 18 presents the regional percentage changes of income per ha utilized agricultural area after the livestock emission tax is introduced. In this scenario exercise it is assumed that no tax money is re-distributed to the farmer and that the tax is part of the variable cost of production. The average income increase per ha UAA in the EU-27 is projected to be 11.5% and hence the lowest compared to the STD, ESAA and ETSA scenarios. The lowest income increase (or even decrease) per ha UAA can be seen in parts of Spain, Italy, Greece, Bulgaria and Romania. The highest income increases per ha UAA are spread over several Nuts 2 regions in the EU-15.

6.4.3 Analysis of environmental effects with regard to nitrogen balances

The implementation of a livestock emission tax results in the highest decreases in nitrogen surplus compared to the other mitigation policy scenarios (cf. Table 41). The reduction in the number of animals creates a reduction in methane and in N2O emissions. The overall reduction of 18.5% in the EU-27 is mostly due to less use of nitrogen from mineral fertilizer, less nutrient retention by crops and the reduction of nitrogen import by manure.

Yield in fodder activities (mainly fodder maize) decrease by 11.5% in the EU-27, driven by the reduction in the cattle herd size. For beef meat activities the reduction of herd sizes is accompanied by increases in yields, with yields in beef meat activities (without beef from dairy cows and calves) increasing by 27.4% on average in the EU-27. There is regional differentiation so "classical beef cattle production regions" in UK, France and Spain are more affected and face larger reduction in herd sizes, larger reduction in fodder consumption and larger intensification effects (figure 18).

Table 41. Changes in the nitrogen balance according to the LTAX scenario

	Baseline (REF 2020)				Livestock emission tax (LTAX, 2020)			
	EU15 [1000t N]	**EU10 [1000t N]**	**BUR [1000t N]**	**EU27 [1000t N]**	**EU15 [% to REF]**	**EU10 [% to REF]**	**BUR [% to REF]**	**EU27 [% to REF]**
Import by mineral fertilizer	8445	2261	602	11309	-16,6	-19,7	-13,7	-17,0
Import by manure	7739	1138	411	9288	-15,7	-14,4	-10,7	-15,3
Import by crop residues	4764	878	512	6153	-17,2	-18,8	-13,4	-17,1
Biological fixation	861	76	62	999	-18,0	2,1	-13,1	-16,2
Atmospheric deposition	1671	326	191	2188	-7,6	-8,4	-4,2	-7,4
Nutrient retention by crops	14586	2835	1262	18683	-15,2	-16,7	-10,8	-15,1
Surplus total	8894	1844	516	11254	-16,8	-17,8	-14,6	-16,8
Gasseous loss	2966	610	173	3749	-14,4	-15,8	-10,4	-14,4
Run off mineral	246	122	51	419	-15,2	-16,9	-16,8	-15,9
Run off manure	347	83	38	468	-14,7	-13,5	-10,8	-14,2
Surplus at soil level	5335	1028	254	6617	-18,3	-19,3	-17,6	-18,5

Figure 19a. Yield changes in fodder activities according to the LTAX scenario (in %)

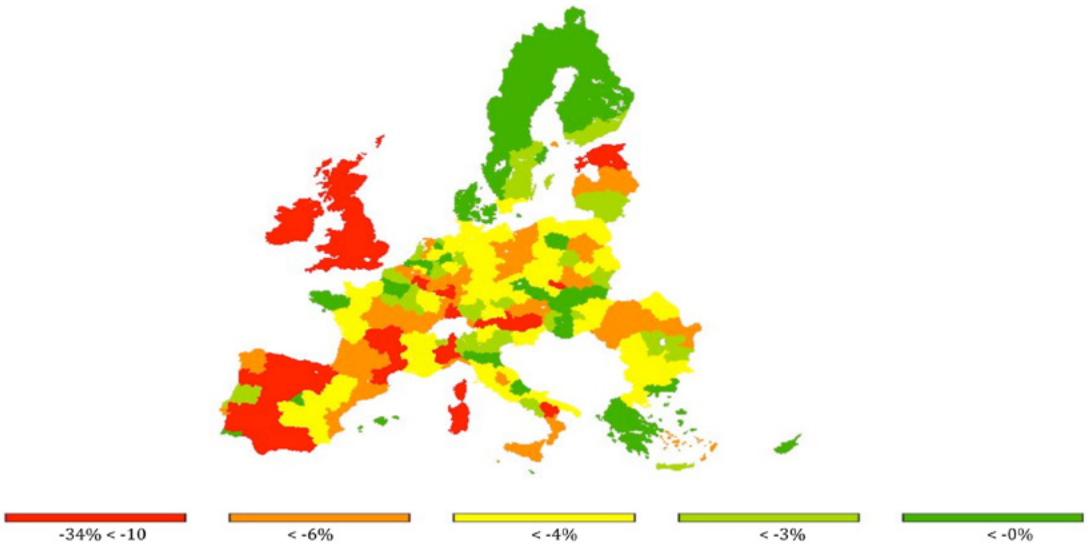
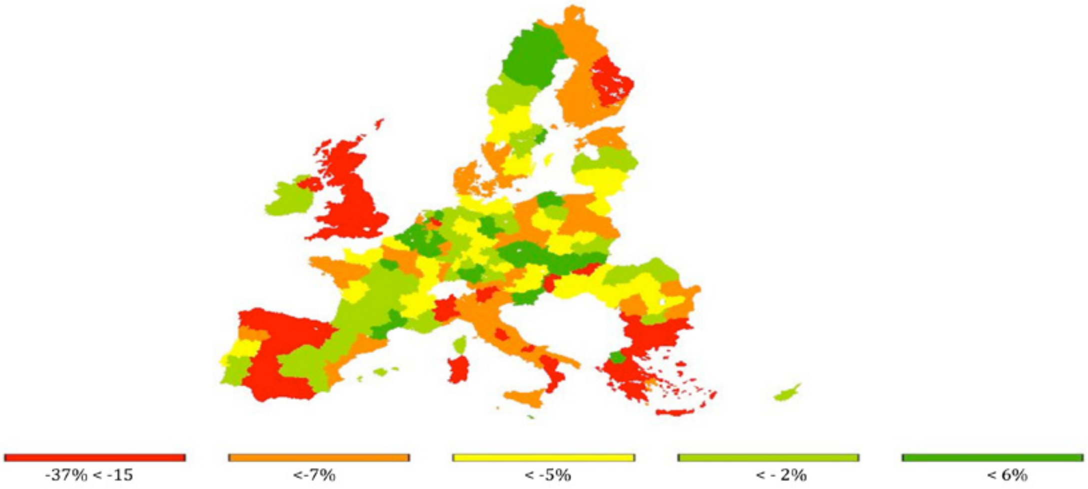


Figure 19b. Yield changes in beef meat activities according to the LTAX scenario (in %)



Note: The yield of beef meat activities excludes beef from dairy cows and calves

6.5 Complementary technological abatement scenarios

In this chapter we present the most important results of the complementary technological abatement scenarios. It has to be reminded that the three technological abatement scenarios presented in the sections 6.5.1 to 6.5.3 are not designed to achieve a certain GHG emission reduction target, but to see what effect the specific changes in production technology would have on the development of GHG emissions. To get also an idea on the effects that the technological abatement measures would have in combination with the emission mitigation policies, we run one scenario where we introduce the measures of a more balanced fertilization and low nitrogen feeding into the Emission Trading Scheme for Agriculture scenario. The results of this combined scenario are presented in section 6.6.

6.5.1 Combination of Various Measures Targeting Ammonia Scenario (AMMO)

This technological abatement scenario assumes the application of a set of various abatement measures (stable adaptation, covered storage, low ammonia application, urea substitution) that actually target ammonia emissions in agriculture (cf. section 4.3.1). The AMMO scenario includes MS-specific (cost effective) packages of measures, so the impacts will also vary between MS. This is comparable with the ESAA scenario that also involved a non-homogeneous implementation of policy.

Changes in GHG emissions

In Table 42 it can be seen that ammonia emissions will decline by about 10% in the EU-27 with market differences among MS, ranging from a slight increase in Malta (+0.9%) to reductions of 28% in Slovenia and almost 26% in Denmark. If ammonia emissions are reduced, more N will be lost as N2O (+4.3% for EU-27). However, the increase in costs for these measures also implies that livestock production tends to decline, which leads to reductions of methane emissions (by about 0.5% for EU-27). On balance overall GHG emissions in terms of CO2 equivalents

Table 42. Change in emissions per Member State according to the AMMO scenario

	Baseline (REF, 2020)				Ammonia measures scenario (AMMO, 2020)			
	Methane [1000t]	Nitrous Oxide [1000t]	CO2 equivalents [1000t]	Ammonia [1000t]	Methane [% to REF]	Nitrous Oxide [% to REF]	CO2 equivalents [% to REF]	Ammonia [% to REF]
Austria	163,5	12,8	7399,1	49,4	-0,9	12,7	6,4	-22,1
Belgium_Lux	208,6	18,5	10119,8	74,0	-0,4	3,3	1,7	-3,3
Denmark	151,0	21,2	9727,1	76,9	-0,5	6,6	4,3	-25,6
Finland	80,8	23,7	9040,8	18,5	-0,8	1,6	1,1	-6,0
France	1449,1	151,9	77527,2	480,8	-0,4	9,7	5,8	-17,6
Germany	1070,8	119,2	59451,0	432,6	-0,4	0,6	0,2	-2,0
Greece	141,1	9,7	5980,9	27,0	-1,0	6,9	3,0	-18,0
Ireland	530,3	38,7	23136,3	103,5	-2,7	0,3	-1,1	-7,4
Italy	740,8	58,1	33557,8	309,0	-0,1	4,4	2,3	-10,1
Netherlands	387,8	34,8	18942,5	92,6	-0,7	0,3	-0,1	-1,6
Portugal	140,7	10,7	6267,7	43,2	-0,8	11,9	5,9	-18,2
Spain	746,3	77,3	39622,9	291,7	-0,0	10,1	6,1	-13,7
Sweden	117,3	21,2	9020,4	40,4	-0,2	0,1	0,0	-1,1
United Kingdom	896,7	128,8	58771,0	205,2	-0,4	1,5	0,9	-7,5
EU15	6824,6	726,6	368564,5	2244,7	-0,5	4,7	2,7	-10,5
Cyprus	11,2	1,0	544,0	4,5	-0,2	10,1	5,3	-14,2
Czech Republic	57,5	14,7	5766,4	42,3	-0,5	2,8	2,1	-6,0
Estonia	14,1	2,3	1019,8	6,1	0,1	1,7	1,4	-7,3
Hungary	49,8	21,6	7749,7	53,9	-0,6	5,3	4,5	-10,1
Latvia	22,7	4,7	1944,8	10,5	-0,2	3,2	2,4	-14,2
Lithuania	53,4	10,1	4237,2	22,2	-0,4	3,2	2,3	-14,0
Malta	1,9	0,2	89,1	1,2	0,5	0,0	0,2	0,9
Poland	346,8	82,6	32872,4	284,4	-0,1	2,8	2,2	-6,0
Slovenia	37,0	2,5	1543,5	12,3	-2,9	15,0	5,9	-28,1
Slovak Republic	26,4	5,0	2107,0	12,4	0,0	2,0	1,5	-5,0
EU10	620,8	144,7	57873,8	449,6	-0,3	3,4	2,6	-7,7
Bulgaria	76,5	9,8	4641,8	21,7	0,0	0,0	0,0	0,0
Romania	269,4	30,5	15097,5	86,3	0,0	0,0	0,0	0,1
Bulgaria/Romania	346,0	40,2	19739,3	108,1	0,0	0,0	0,0	0,1
EU27	7791,3	911,5	446177,6	2802,4	-0,5	4,3	2,5	-9,7

Table 43. Change in emissions per inventory position for the EU according to the AMMO scenario

	Baseline (REF, 2020)				Ammonia measures scenario (AMMO, 2020)			
	EU15 [1000t]	EU10 [1000t]	BUR [1000t]	EU27 [1000t]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Methane emissions from enteric fermentation (IPCC)	5987,7	550,1	323,1	6860,9	-0,4	-0,3	0,0	-0,4
Methane emissions from manure management (IPCC)	836,9	70,7	22,8	930,5	-1,7	-0,7	-0,0	-1,5
Methane emissions	6824,6	620,8	346,0	7791,4	-0,5	-0,4	0,0	-0,5
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	217,7	45,6	10,2	273,5	20,4	14,0	0,2	18,6
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	73,4	5,1	4,4	82,8	-0,5	-0,2	-0,2	-0,5
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	175,4	46,3	12,4	234,1	-2,8	-1,6	-0,1	-2,4
Direct nitrous oxide emissions from crop residues (IPCC)	73,2	12,4	7,2	92,8	-0,2	0,0	-0,1	-0,2
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	11,9	1,1	0,9	13,9	-0,3	0,0	-0,0	-0,2
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	14,7	2,9	1,7	19,3	-0,1	0,0	0,0	-0,1
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	38,8	7,9	2,2	48,9	-10,2	-7,5	0,5	-9,3
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	12,0	2,6	1,0	15,6	-7,6	-3,1	1,0	-6,3
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	109,6	20,8	0,2	130,6	-0,0	0,0	-4,8	-0,0
Nitrous oxide emissions	726,6	144,6	40,2	911,5	4,7	3,4	0,0	4,3
Carbon dioxide equivalent	368564,5	57873,8	19739,3	446177,6	2,7	2,6	0,0	2,5

slightly increase by 2.5% in the EU-27, indicating that this package of technological measures is counterproductive from the exclusive viewpoint of GHG emissions.

The detailed accounting of N2O and CH4 sources in Table 43 shows that the additional N2O emissions stem from manure management (+18.3% for EU-27, including application). At the same time there are savings in N2O emissions from leaching (-6.5%) and from conversion of ammonia losses into N2O (-9.4%), but given that these savings are smaller both in relative terms and given the initial weights also in terms of tonnes, they cannot compensate for the increased N2O emissions from manure management. The savings in methane emissions may be seen to relate predominantly to enteric fermentation.

Analysis of production and economic effects

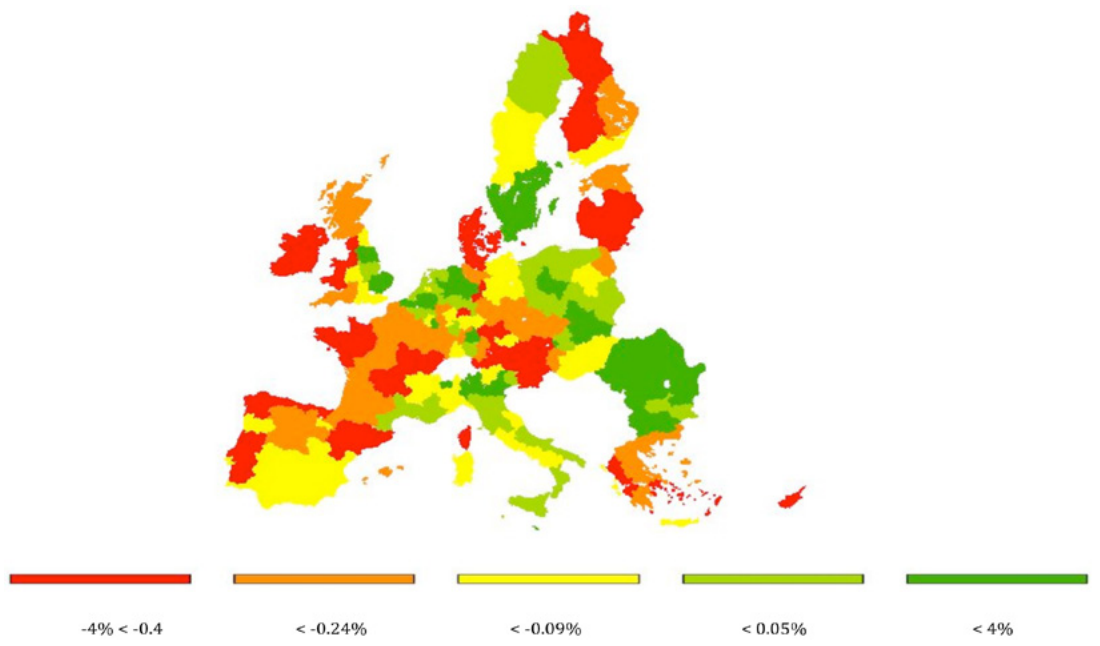
The ammonia measures increase costs of livestock activities different, because the

Table 44. *Change in income, area, yield and supply for the EU-27 for activity aggregates according to the ammonia measures scenario*

	Baseline (REF 2020)				Ammonia measures scenario (AMMO, 2020)			
	Income [Euro/ ha or head]	Area or Herd Size [1000 ha or hds]	Yield [kg/ ha or head]	Supply [1000 t]	Income [% to REF]	Area or Herd Size [% to REF]	Yield [% to REF]	Supply [% to REF]
Cereals	332	57214	5749	328905	-0,1	-0,0	-0,0	-0,1
Oilseeds	460	8882	3010	26737	0,1	0,0	-0,0	0,0
Other arable crops	1125	7771	na	na	-0,2	0,0	na	na
Vegetables and Permanent crops	4455	21612	na	na	-0,0	-0,0	na	na
Fodder activities	279	79668	23303	1856480	0,3	-0,1	-0,2	-0,2
Set aside and fallow land	140	13265	na	na	0,0	0,1	na	na
Utilized Agricultural Area	1148	188413	na	na	-0,3	-0,0	na	na
All cattle activities	455	84117	na	na	-0,9	-0,5	na	na
Beef meat activities	123	26904	na	7842	-3,9	-0,8	na	-0,3
Pig fattening	30	247670	92	22754	-0,4	-0,3	0,1	-0,2
Pig Breeding	117	14728	17281	254512	-1,1	-0,3	0,0	-0,3
Milk Ewes and Goat	54	77576	59	4561	-0,0	0,1	-0,0	0,1
Sheep and Goat fattening	35	46278	14	628	0,8	0,1	0,0	0,1
Laying hens	3973	464	16339	7588	-0,5	-0,3	0,1	-0,2
Poultry fattening	320	6993	1909	13352	-4,5	-0,4	0,0	-0,4

Note: na = not applicable; total supply of beef includes beef from dairy cows and calves.

Figure 20. *Change in agricultural income per utilizable agricultural according to the AMMO scenario (in %)*



scenario is based on the cost-effective mix of abatement measures, specific for each MS that was determined in the analysis underlying the EU Thematic Strategy on Air Pollution with the GAINS model (cf. section 4.3.1). As a consequence there is a heterogeneous increase in abatement costs per animal activity. The resulting tendency to reduce supply causes EU prices of animal products to increase. Given substitutability on the demand side, output price increases even spread to those (meat) products that are hardly affected by ammonia measures like sheep meat. Furthermore a decline in fodder demand on the part of cattle also benefits sheep. The final result is thus a rather complex consequence of the initial economic shock in terms of additional costs and various market interactions. However compared to the mitigation policy scenarios designed to meet the 20% reduction target, the impacts are overall tiny, even on the beef sector (decline in aggregate beef meat activity with 0.8%) (Table 44).

As may be expected, the decline in beef meat activities also triggers a small decline in fodder area (0.1%). In line with the heterogeneous (cost effective) implementation of additional ammonia measures, supply changes may be expected to be heterogeneous as well. For the beef meat activities the price increases fall short of the increases in costs such that income decreases to some extent (on average by 3.9%). For the whole of agriculture, however, the change in income due to the ammonia measure scenario is very small (reduction on average 0.3%).

The effect of application shares on costs can also be seen in the changes in income. In those areas where the application shares are increased compared to 2020, the income effect is lower than in the other regions (Figure 20). In the Netherlands the rate of emission reducing application is in 2004 (2003-2005) already rather high, so the effect is less than in other countries.

Analysis of environmental effects with regard to nitrogen balances

Targeting all abatement measures at one pollutant, ammonia, is known to involve the risk of "pollution swapping" (see http://www.

Table 45. Changes in the nitrogen balance according to the ammonia measures scenario

	Baseline (REF 2020)				Ammonia measures scenario (AMMO, 2020)			
	EU15 [1000t N]	EU10 [1000t N]	BUR [1000t N]	EU27 [1000t N]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Import by mineral fertilizer	8445	2261	602	11309	-2,8	-1,6	-0,1	-2,4
Import by manure	7739	1138	411	9288	-0,4	-0,1	0,1	-0,3
Import by crop residues	4764	878	512	6153	-0,2	-0,1	-0,0	-0,2
Biological fixation	861	76	62	999	-0,2	-0,2	-0,0	-0,2
Atmospheric deposition	1671	326	191	2188	-0,0	-0,0	-0,0	-0,0
Nutrient retention by crops	14586	2835	1262	18683	-0,1	-0,0	-0,0	-0,1
Surplus total	8894	1844	516	11254	-2,9	-2,0	-0,0	-2,6
Gasseous loss	2966	610	173	3749	-7,6	-5,6	0,0	-6,9
Run off mineral	246	122	51	419	-3,2	-1,6	-0,1	-2,3
Run off manure	347	83	38	468	-15,7	-6,0	0,1	-12,7
Surplus at soil level	5335	1028	254	6617	0,6	0,4	-0,0	0,6

scammonia.wur.nl/). Pollution swapping is the increase in one pollutant as a result of an introduced measure to reduce another different pollutant. The ammonia measures decrease gaseous losses of ammonium nitrogen by 9.7 % in EU-27 (cf. Table 42), but N2O emissions are increasing by 4.3%. However, less gaseous losses and reduced runoff also imply that more nutrients remain in the manure, partly benefiting the crops, and partly leading to additional leaching. As can be seen in Table 45, the effect on the surplus at soil level is minimal (0.6% increase) because farmers are assumed to apply less mineral fertilizer, knowing that their manure is more concentrated. This tends to benefit the environmental balance. It should be mentioned that in the model CAPRI there is no feedback from reduced ammonia emissions to reduced atmospheric deposition, which would improve the environmental balance for ammonia measures.

6.5.2 More Balanced Fertilization Scenario (BALF)

This complementary technological abatement scenario assumes a more efficient (organic and mineral) fertilizer management, which results in a more balanced fertilization. More balanced fertilization means that the crop need/uptake and the application of fertilizer and or manure are more geared to each other, i.e. less over-fertilization occurs (cf. section 4.3.2).

Changes in GHG emissions

This scenario mainly reduces N2O emissions because more balanced fertilization implies less application of mineral fertilizer which is the residual source of nitrogen after accounting for other nitrogen deliveries, most importantly from manure. This reduction of mineral fertilizer is smaller in countries with a moderate "over-fertilization" (like Austria or Italy in our baseline) than in countries with a high nutrient surplus relative to crop need (like Czech Republic, Greece, or Slovenia). However, in countries with a high share of nutrients and hence N2O emissions coming from manure (like the Netherlands or Belgium) even a strong relative decline of mineral fertilizer cannot make a big impact on N2O emissions. These differences explain why the savings in N2O and hence GHG emissions as shown in Table 46 are distributed quite heterogeneously across EU-27 even though conceptually the measure is implemented qualitatively in the same manner all across EU-27.

The detailed accounting of N2O and CH4 sources in Table 47 shows that the savings in N2O emissions are mainly due to reduced mineral fertilizer application (-23.7% in EU-27). Savings from reduced emissions of N2O after transport in leaching are also large in relative terms but have a far lower weight in absolute terms. Other less relevant savings come from a decline in pulses area and thus losses from biological fixation (-7.6%) and from reduced conversion from ammonia (-4.5%). The impacts on the animal sector are negligible in terms of emissions.

Analysis of production and economic effects

Reducing the over-fertilization by 50% requires additional costs for more efficient fertilizer management of about 13-17 Euros per ha according to our assumptions[35]. On the other hand, there are savings in fertilizer cost which are proportional to fertilizer use in the baseline. Both aspects tend to favour more intensive crop activities compared to more extensive ones. This applies in particular to extensive grass land which is reduced in favour of intensive grassland (benefiting from more efficient fertilizer management in this scenario). This change increases supply of grass, which drives down the shadow price of grass, contributing to the overall decline in fodder area. Similar shifts are occurring in the cereal sector with soft wheat and maize expanding at the expense of less intensive cereals, but here the aggregate change in cereal

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[35] Regions in Nitrate Vulnerable Zones (NVZs) are assumed to implement a weak form of 'balanced fertilization' already in the baseline such that the marginal effect on cost and emissions is lower here than in areas outside of NVZs.

Table 46. Change in emissions per Member State according to the BALF scenario

	Baseline (REF, 2020)				Reduced over-fertilisation (BALF, 2020)			
	Methane [1000t]	Nitrous Oxide [1000t]	CO2 equivalents [1000t]	Ammonia [1000t]	Methane [% to REF]	Nitrous Oxide [% to REF]	CO2 equivalents [% to REF]	Ammonia [% to REF]
Austria	163,5	12,8	7399,1	49,4	-0,0	-3,3	-1,8	0,2
Belgium_Lux	208,6	18,5	10119,8	74,0	0,3	-6,3	-3,4	-0,5
Denmark	151,0	21,2	9727,1	76,9	-1,9	-4,4	-3,6	-1,9
Finland	80,8	23,7	9040,8	18,5	0,7	-3,5	-2,7	0,9
France	1449,1	151,9	77527,2	480,8	-0,0	-6,5	-4,0	-0,0
Germany	1070,8	119,2	59451,0	432,6	0,1	-6,1	-3,8	0,2
Greece	141,1	9,7	5980,9	27,0	0,2	-17,1	-8,5	0,2
Ireland	530,3	38,7	23136,3	103,5	0,6	-5,3	-2,5	0,6
Italy	740,8	58,1	33557,8	309,0	0,1	-5,4	-2,8	0,2
Netherlands	387,8	34,8	18942,5	92,6	0,1	-6,6	-3,7	-0,5
Portugal	140,7	10,7	6267,7	43,2	0,2	-8,1	-4,2	0,3
Spain	746,3	77,3	39622,9	291,7	0,3	-10,5	-6,3	0,5
Sweden	117,3	21,2	9020,4	40,4	0,1	-4,7	-3,4	0,2
United Kingdom	896,7	128,8	58771,0	205,2	0,7	-5,1	-3,3	0,6
EU15	6824,6	726,6	368564,5	2244,7	0,2	-6,4	-3,8	0,1
Cyprus	11,2	1,0	544,0	4,5	-0,4	-10,1	-6,3	-0,2
Czech Republic	57,5	14,7	5766,4	42,3	0,0	-11,6	-9,1	0,2
Estonia	14,1	2,3	1019,8	6,1	0,1	-9,8	-7,0	-0,2
Hungary	49,8	21,6	7749,7	53,9	0,0	-6,1	-5,3	0,1
Latvia	22,7	4,7	1944,8	10,5	0,1	-9,1	-6,7	-0,2
Lithuania	53,4	10,1	4237,2	22,2	0,1	-6,6	-4,8	0,0
Malta	1,9	0,2	89,1	1,2	0,0	-6,3	-3,8	0,0
Poland	346,8	82,6	32872,4	284,4	0,1	-7,6	-5,9	-0,0
Slovenia	37,0	2,5	1543,5	12,3	0,4	-21,1	-10,2	0,4
Slovak Republic	26,4	5,0	2107,0	12,4	-0,0	-9,0	-6,6	-0,1
EU10	620,8	144,7	57873,8	449,6	0,1	-8,1	-6,3	0,0
Bulgaria	76,5	9,8	4641,8	21,7	-0,1	-8,0	-5,2	-0,1
Romania	269,4	30,5	15097,5	86,3	-0,4	-10,8	-6,9	-0,1
Bulgaria/Romania	346,0	40,2	19739,3	108,1	-0,4	-10,1	-6,5	-0,1
EU27	7791,3	911,5	446177,6	2802,4	0,1	-6,8	-4,3	0,1

Table 47. Change in emissions per inventory position for the EU according to the BALF scenario

	Baseline (REF, 2020)				Reduced over-fertilisation (BALF, 2020)			
	EU15 [1000t]	EU10 [1000t]	BUR [1000t]	EU27 [1000t]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Methane emissions from enteric fermentation (IPCC)	5987,7	550,1	323,1	6860,9	0,2	0,1	-0,4	0,1
Methane emissions from manure management (IPCC)	836,9	70,7	22,8	930,5	0,1	0,1	-0,3	0,1
Methane emissions	6824,6	620,8	346,0	7791,4	0,2	0,1	-0,4	0,1
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	217,7	45,6	10,2	273,5	-0,1	0,1	-0,2	-0,1
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	73,4	5,1	4,4	82,8	0,3	0,0	-0,5	0,2
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	175,4	46,3	12,4	234,1	-23,7	-22,4	-28,4	-23,7
Direct nitrous oxide emissions from crop residues (IPCC)	73,2	12,4	7,2	92,8	0,7	-0,3	1,0	0,6
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	11,9	1,1	0,9	13,9	-7,5	-9,3	-7,9	-7,6
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	14,7	2,9	1,7	19,3	-0,3	-0,3	0,0	-0,3
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	38,8	7,9	2,2	48,9	-4,0	-6,4	-6,8	-4,5
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	12,0	2,6	1,0	15,6	-19,6	-25,2	-33,0	-21,4
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	109,6	20,8	0,2	130,6	-0,2	-0,3	-4,8	-0,3
Nitrous oxide emissions	726,6	144,6	40,2	911,5	-6,4	-8,1	-10,1	-6,8
Carbon dioxide equivalent	368564,5	57873,8	19739,3	446177,6	-3,8	-6,3	-6,5	-4,3

area turns out to be low, even though EU cereal prices also decline slightly[36]. Declining prices and additional managerial cost lead to declining income per ha, which is larger in percentage terms where the baseline margins (revenues less cost) are small (cereals and fodder compared to other arable crops). On the aggregate level a certain decline in grassland can be expected which is not compensated by the increase in arable land such that the total agricultural area used would decline as well (by -0.2%). Other assumptions on the efficiency improvements (lower on grassland than on arable land) would have reduced these differences, but we preferred to select a rather straightforward scenario.

The knock-on effects on the animal sector are cheaper fodder and in many countries reduced shadow values of manure. The net effect is heterogeneous across the MS. However any change in supply will also lead to changes

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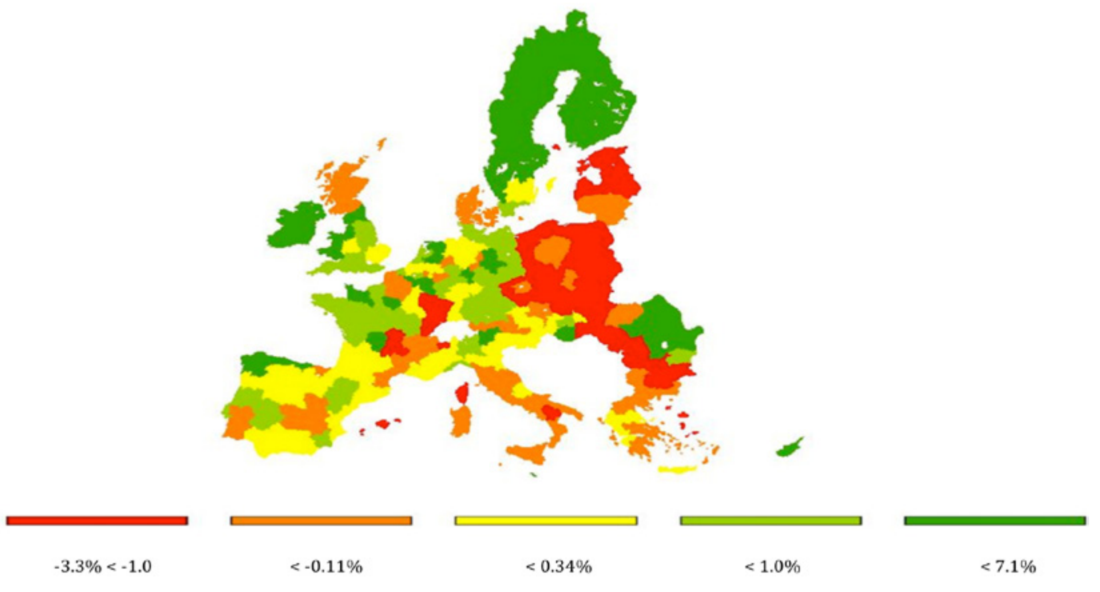
[36] The decline is 2.4% for grass and 0.6% for cereals as shown in the detailed CAPRI GUI table with results on prices. It is given here as supplementary information where useful rather than augmenting all tables with price results.

Table 48. *Change in income, area, yield and supply for the EU-27 for activity aggregates according to the BALF scenario*

	Baseline (REF 2020)				Reduced over-fertilisation (BALF, 2020)			
	Income [Euro/ha or head]	Area or Herd Size [1000 ha or hds]	Yield [kg/ha or head]	Supply [1000 t]	Income [% to REF]	Area or Herd Size [% to REF]	Yield [% to REF]	Supply [% to REF]
Cereals	332	57214	5749	328905	-5,1	0,1	0,2	0,3
Oilseeds	460	8882	3010	26737	-3,2	0,1	0,2	0,3
Other arable crops	1125	7771	na	na	-2,3	-0,2	na	na
Vegetables and Permanent crops	4455	21612	na	na	-0,3	-0,1	na	na
Fodder activities	279	79668	23303	1856480	-4,2	-0,7	1,6	0,8
Set aside and fallow land	140	13265	na	na	0,2	0,4	na	na
Utilized Agricultural Area	1148	188413	na	na	-0,6	-0,2	na	na
All cattle activities	455	84117	na	na	0,8	0,2	na	na
Beef meat activities	123	26904	na	7842	2,0	0,3	na	0,1
Pig fattening	30	247670	92	22754	3,6	-0,2	0,0	-0,2
Pig Breeding	117	14728	17281	254512	5,2	-0,2	-0,0	-0,2
Milk Ewes and Goat	54	77576	59	4561	0,6	0,1	-0,1	-0,0
Sheep and Goat fattening	35	46278	14	628	1,2	0,2	0,0	0,2
Laying hens	3973	464	16339	7588	1,7	0,0	-0,0	-0,0
Poultry fattening	320	6993	1909	13352	2,9	-0,0	-0,0	-0,0

Note: na = not applicable; total supply of beef includes beef from dairy cows and calves

Figure 21: Change in agricultural income per utilizable agricultural according to the BALF scenario (in %)



in output prices that equilibrate markets and dampen supply movements. Thus we may see in Table 48 a small increase of beef meat activities because the savings in fodder costs were dominating, whereas pig fattening is declining because manure value is declining in some important in pig producing regions[37].

Given the small impacts on animal activity levels, market impacts are very small in general as well, in particular for the major producers. A 1.7% decline in Danish beef production and an increase of 0.6% in the UK's beef production are among the largest impacts (cf. Table 82 in the annex). The aggregate changes in income vary within a small range of -4 and +7 % (Figure 21). This variation depends on several factors, whereas the initial cost increase for enhanced managerial efforts was quite uniform in the EU (+13-17 Euros per ha, as mentioned above). The savings in fertilizer costs tend to favour more intensive production. However there may be counteracting effects from animal production and the percentage changes are furthermore depending on the initial (baseline) level of income per ha.

Analysis of environmental effects with regard to nitrogen balances

Reduced over-fertilization decreases the total nitrogen input through lower mineral fertilizer application which gives a significant improvement in the total nitrogen surplus (Table 49). The largest part of decrease in nitrogen also becomes a reduction in the surplus at the soil level, but ammonia losses and run off are also improving to some extent. Given a lower surplus at the soil level (-37.5%) leaching may be expected to decline significantly.

Table 49. Changes in the nitrogen balance according to the BALF scenario

	Baseline (REF 2020)				Reduced over-fertilisation (BALF, 2020)			
	EU15 [1000t N]	EU10 [1000t N]	BUR [1000t N]	EU27 [1000t N]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Import by mineral fertilizer	8445	2261	602	11309	-23,8	-22,5	-28,5	-23,8
Import by manure	7739	1138	411	9288	0,1	0,1	-0,3	0,0
Import by crop residues	4764	878	512	6153	0,7	-0,3	1,0	0,6
Biological fixation	861	76	62	999	-0,7	-1,9	-1,6	-0,8
Atmospheric deposition	1671	326	191	2188	-0,1	-0,3	-0,3	-0,2
Nutrient retention by crops	14586	2835	1262	18683	0,6	-0,4	0,9	0,5
Surplus total	8894	1844	516	11254	-23,3	-27,2	-35,0	-24,5
Gasseous loss	2966	610	173	3749	-4,2	-6,3	-7,3	-4,7
Run off mineral	246	122	51	419	-23,7	-21,5	-27,0	-23,5
Run off manure	347	83	38	468	0,1	0,1	-0,3	0,0
Surplus at soil level	5335	1028	254	6617	-35,4	-42,6	-60,8	-37,5

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[37] These data can be found in the detailed CAPRI GUI table reproducing the dual value decomposition for activities.

6.5.3 Low Nitrogen Feeding Scenario (LNF)

In animal husbandry there is usually a certain degree of waste or luxury consumption of feed. In particular farmers seem to feed more protein than required according to the animal nutrition literature. In this complementary technological abatement scenario we assume that with intensified extension work for feed management, the excess protein consumption might be reduced by half in the typical case (20% excess protein, 5% excess energy). We consider a penetration rate of this measure of about 40% in the EU-15 and 35% in the EU-12, and also account for the additional management efforts and potentially additions of particular amino acids by adding a top-up for the "other" cost component of each animal activity (cf. section 4.3.3).

Changes in GHG emissions

This scenario mainly reduces N2O (and ammonia) emissions because a lower protein intake also reduces the N content of excretions and hence all kinds of N losses in collecting, storing and applying manure. This reduction of mineral fertilizer will be smaller in countries with a moderate "luxury consumption"[38] of protein (for example Finland) compared to those with a higher excess protein use (like Portugal). Regarding production costs, two issues have to be kept in mind. On the one hand reduction of excess protein consumption requires additional effort and hence cost for better management. On the other hand farmers save some quantities of protein rich feedstuffs (like oilcakes) and this reduced feed demand also triggers declining prices, leading to additional savings in feed cost due to the market mechanism. Depending on which effect weights more, on balance net revenues of animal activities will increase or decline. However, even with the same absolute effect on net revenues, activity levels will respond differently when comparing different countries. This is because the PMP parameters in CAPRI differ among regions, reflecting heterogeneous supply conditions but also because the initial net revenues may be close to zero or even negative in one country and generously positive in another. Therefore we observe a quite heterogeneous pattern of impacts[39] on emissions across EU-27 even though conceptually the measure is implemented qualitatively in the same manner all across EU-27 (Table 50).

The detailed accounting of N2O and CH4 sources in Table 51 shows that the main savings of lower protein intake per animal and hence lower nitrogen excretions arise in manure management (4.2% for EU-27, in non-grazing and grazing systems) and from ammonia volatilisation (4.2%). Additional savings from lower mineral fertilizer application (1.8%) are indirect consequences of changes in activity levels, including a decline in fodder area and total agricultural area (Table 51). This also applies to the increase in methane emissions which is due to a slight shift in animal production from pigs to cattle in this scenario.

Analysis of production and economic effects

Low nitrogen feeding, even in the moderate extent assumed for this scenario, would have considerable impacts on markets. As protein intake would be reduced (by definition of the scenario) feed demand would shift from protein rich feedstuffs like oilcakes to cereals or energy rich feedstuffs. EU-27 net imports of oilcakes would decrease by 14% and their price by 12%. This causes significant savings in feed costs that even over-compensate the assumed increase of other costs related to increased managerial efforts or amino acid supplementary feeding for some animal types. Other market linkages also help to alleviate the economic

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[38] With the term 'luxury consumption' we refer to the nutrient absorption by an organism in excess of that required for optimum growth and productivity (www.fao.org).

[39] The large impact in Cyprus is due to a collapse of pig production in this scenario which in turn can be traced to a data particularity (very high cereal and energy rich prices that tend to be increased in this scenario, whereas prices of protein rich feed, in particular oil cakes are declining. It is advisable therefore to treat this result with some scepticism.

Table 50. Change in emissions per Member State according to the LNF scenario

	Baseline (REF, 2020)				Low nitrogen feeding (LNF, 2020)			
	Methane [1000t]	Nitrous Oxide [1000t]	CO2 equivalents [1000t]	Ammonia [1000t]	Methane [% to REF]	Nitrous Oxide [% to REF]	CO2 equivalents [% to REF]	Ammonia [% to REF]
Austria	163,5	12,8	7399,1	49,4	0,7	-3,1	-1,4	-4,7
Belgium_Lux	208,6	18,5	10119,8	74,0	0,7	-5,5	-2,8	-6,9
Denmark	151,0	21,2	9727,1	76,9	0,7	-3,7	-2,3	-5,2
Finland	80,8	23,7	9040,8	18,5	-1,9	-0,5	-0,8	-1,0
France	1449,1	151,9	77527,2	480,8	-0,2	-2,7	-1,7	-4,1
Germany	1070,8	119,2	59451,0	432,6	-0,4	-1,7	-1,2	-2,3
Greece	141,1	9,7	5980,9	27,0	-1,2	-1,4	-1,3	-1,2
Ireland	530,3	38,7	23136,3	103,5	4,4	-5,0	-0,5	-3,1
Italy	740,8	58,1	33557,8	309,0	0,0	-3,5	-1,9	-4,9
Netherlands	387,8	34,8	18942,5	92,6	0,1	-4,2	-2,4	-4,5
Portugal	140,7	10,7	6267,7	43,2	2,1	-5,8	-2,0	-7,3
Spain	746,3	77,3	39622,9	291,7	-0,9	-3,3	-2,3	-3,6
Sweden	117,3	21,2	9020,4	40,4	1,2	-2,9	-1,8	-6,8
United Kingdom	896,7	128,8	58771,0	205,2	4,0	-2,8	-0,6	-3,0
EU15	6824,6	726,6	368564,5	2244,7	0,8	-2,9	-1,5	-3,9
Cyprus	11,2	1,0	544,0	4,5	-2,7	-20,2	-12,5	-31,7
Czech Republic	57,5	14,7	5766,4	42,3	0,6	-2,1	-1,5	-3,3
Estonia	14,1	2,3	1019,8	6,1	-1,2	-4,3	-3,2	-3,5
Hungary	49,8	21,6	7749,7	53,9	1,4	-2,7	-2,1	-4,9
Latvia	22,7	4,7	1944,8	10,5	4,9	-4,4	-2,0	-4,1
Lithuania	53,4	10,1	4237,2	22,2	0,0	-2,1	-1,5	-3,7
Malta	1,9	0,2	89,1	1,2	-1,0	-12,5	-5,5	-12,0
Poland	346,8	82,6	32872,4	284,4	1,5	-2,5	-1,6	-4,4
Slovenia	37,0	2,5	1543,5	12,3	-0,8	-2,4	-1,5	-2,4
Slovak Republic	26,4	5,0	2107,0	12,4	0,5	-3,2	-2,2	-4,2
EU10	620,8	144,7	57873,8	449,6	1,1	-2,7	-1,8	-4,5
Bulgaria	76,5	9,8	4641,8	21,7	0,4	-4,3	-2,7	-5,2
Romania	269,4	30,5	15097,5	86,3	0,6	-4,1	-2,3	-3,4
Bulgaria/Romania	346,0	40,2	19739,3	108,1	0,6	-4,1	-2,4	-3,8
EU27	7791,3	911,5	446177,6	2802,4	0,8	-3,0	-1,6	-4,0

pressure on the animal sector from "imposed" (extension driven) efficiency improvements: Meat prices tend to increase, in particular for pork (+5.6% in EU-27 for producers), as pork production would decline (about -1.3% in EU-27). Also beef production increases with 0.6% while beef prices only show a small change (-0.4%).

One reason for this development is that the scenario assumes that increased managerial efforts are directed towards all animals but that the achievable efficiency gains are particularly large in absolute terms where the initial inefficiency was largest, in particular higher for cattle activities than for pig or poultry

Table 51. Change in emissions per inventory position for the EU according to the LNF scenario

	Baseline (REF, 2020)				Low nitrogen feeding (LNF, 2020)			
	EU15 [1000t]	**EU10 [1000t]**	**BUR [1000t]**	**EU27 [1000t]**	**EU15 [% to REF]**	**EU10 [% to REF]**	**BUR [% to REF]**	**EU27 [% to REF]**
Methane emissions from enteric fermentation (IPCC)	5987,7	550,1	323,1	6860,9	0,8	1,1	0,6	0,8
Methane emissions from manure management (IPCC)	836,9	70,7	22,8	930,5	0,5	0,9	0,2	0,5
Methane emissions	6824,6	620,8	346,0	7791,4	0,8	1,1	0,6	0,8
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	217,7	45,6	10,2	273,5	-3,9	-5,5	-4,7	-4,2
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	73,4	5,1	4,4	82,8	-4,8	-6,5	-5,7	-4,9
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	175,4	46,3	12,4	234,1	-2,1	0,0	-4,1	-1,8
Direct nitrous oxide emissions from crop residues (IPCC)	73,2	12,4	7,2	92,8	-2,3	-2,3	-2,1	-2,3
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	11,9	1,1	0,9	13,9	-6,5	-14,0	-4,5	-6,9
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	14,7	2,9	1,7	19,3	-0,9	-0,7	0,0	-0,8
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	38,8	7,9	2,2	48,9	-4,1	-4,3	-4,1	-4,2
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	12,0	2,6	1,0	15,6	-6,7	-6,2	-10,0	-6,8
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	109,6	20,8	0,2	130,6	-0,6	-0,2	-9,5	-0,6
Nitrous oxide emissions	726,6	144,6	40,2	911,5	-2,9	-2,7	-4,1	-3,0
Carbon dioxide equivalent	368564,5	57873,8	19739,3	446177,6	-1,5	-1,8	-2,4	-1,6

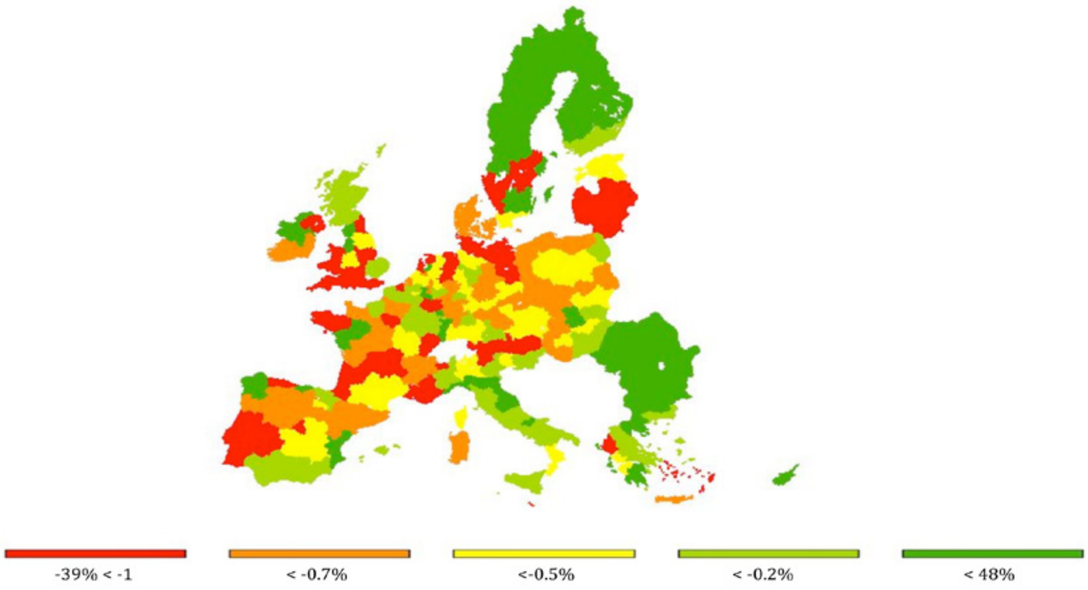
fattening. The former therefore benefit from substantial feed cost savings. For livestock types or countries that are already quite efficient, for example with an excess protein consumption of 9%, it is assumed that the efforts and increased managerial costs are similar to the cattle sector where the initial luxury consumption may have been 30%. However with similar relative efficiency gains the excess may decline from 9% to 6% in the pig sector and from 30% to 20% in the cattle sector. The latter yields larger savings in feed costs at about equal increases in managerial costs such that the profitability of cattle improves relative to pigs and poultry in this scenario. Other relevant aspects are different reliance on fodder (with declining prices) but also different initial net revenues and parameters. A relative increase of beef production relative to pork causes CH4 emissions to increase. Again the final result is thus a rather complex consequence of various market interactions.

Table 52. Change in income, area, yield and supply for the EU-27 for activity aggregates according to the LNF scenario

	Baseline (REF 2020)				Low nitrogen feeding (LNF, 2020)			
	Income [Euro/ha or head]	Area or Herd Size [1000 ha or hds]	Yield [kg/ha or head]	Supply [1000 t]	Income [% to REF]	Area or Herd Size [% to REF]	Yield [% to REF]	Supply [% to REF]
Cereals	332	57214	5749	328905	-0,5	0,7	-0,2	0,5
Oilseeds	460	8882	3010	26737	-1,3	0,9	-0,3	0,6
Other arable crops	1125	7771	na	na	-2,0	-0,6	na	na
Vegetables and Permanent crops	4455	21612	na	na	-0,2	-0,1	na	na
Fodder activities	279	79668	23303	1856480	-0,2	-1,8	-1,7	-3,4
Set aside and fallow land	140	13265	na	na	0,2	1,4	na	na
Utilized Agricultural Area	1148	188413	na	na	0,2	-0,4	na	na
All cattle activities	455	84117	na	na	-1,4	1,0	na	na
Beef meat activities	123	26904	na	7842	-4,7	1,6	na	0,6
Pig fattening	30	247670	92	22754	8,9	-1,3	0,1	-1,2
Pig Breeding	117	14728	17281	254512	-1,0	-1,2	-0,1	-1,3
Milk Ewes and Goat	54	77576	59	4561	-2,0	1,2	-1,1	0,1
Sheep and Goat fattening	35	46278	14	628	3,6	1,2	0,1	1,3
Laying hens	3973	464	16339	7588	1,3	-1,0	-0,1	-1,1
Poultry fattening	320	6993	1909	13352	2,1	-0,3	0,1	-0,2

Note: na = not applicable; total supply of beef includes beef from dairy cows and calves.

Figure 22. Change in agricultural income per utilizable agricultural according to the LNF scenario (in %)



With the exception of some MS, the expansion in beef meat activities is generally quite small (in the EU-27 supply increases by 0.6%) (Table 52). As already indicated by the increases in methane emissions in Latvia (+4.9%), Ireland (+4.4%) and United Kingdom (4.0%) (Table 50), these countries show increases in beef herd size of 7.4%, 6.7% and 6.2% respectively (Table 85 in the annex). Demand changes are more uniform and small in all MS. Apart from the demand side parameter differences among MS, reflecting consumer preferences, there are also different consumer margins that explain why consumer prices change somewhat differently (in terms of percentages) even among the countries of the same CAPRI trading block (EU-15, EU-10 or Bulgaria/Romania) where percentage changes in producer prices are uniform due to the proportional mapping of regional aggregate prices to the Member States.

On average there is not much change in income (0.2% increase) and the income change is moving between -39% and +48%, more spread than in the balanced fertilizing scenario (Figure 22). This is related to a greater dispersion in the key determinants for the income changes as discussed earlier.

Analysis of environmental effects with regard to nitrogen balances

Reducing nitrogen excretions (by 5% in EU-27) via reduced protein intake of animals benefits the nutrient balance markedly (Table 53). All losses that are dependent on the total nitrogen import are declining but even mineral fertilizer consumption slightly decreases. As mentioned before this is due to changes in crop areas (also implying in total a decline in agricultural area of 0.4%) (cf. Table 52).

Table 53. Changes in the nitrogen balance according to the low nitrogen feeding scenario

	Baseline (REF 2020)				Low nitrogen feeding (LNF, 2020)			
	EU15 [1000t N]	EU10 [1000t N]	BUR [1000t N]	EU27 [1000t N]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Import by mineral fertilizer	8445	2261	602	11309	-2,1	0,0	-4,1	-1,8
Import by manure	7739	1138	411	9288	-4,6	-5,9	-5,0	-4,8
Import by crop residues	4764	878	512	6153	-2,3	-2,3	-2,0	-2,3
Biological fixation	861	76	62	999	-6,8	-16,0	-6,1	-7,5
Atmospheric deposition	1671	326	191	2188	-0,5	-0,3	-0,4	-0,5
Nutrient retention by crops	14586	2835	1262	18683	-1,5	-0,5	-0,9	-1,3
Surplus total	8894	1844	516	11254	-5,5	-4,6	-9,5	-5,5
Gasseous loss	2966	610	173	3749	-4,0	-4,2	-4,6	-4,1
Run off mineral	246	122	51	419	-2,0	0,1	-3,8	-1,6
Run off manure	347	83	38	468	-4,6	-5,8	-5,1	-4,8
Surplus at soil level	5335	1028	254	6617	-6,5	-5,3	-14,6	-6,6

6.6 Combination of ETSA with BALF and LNF Scenario (ETSBL)

In this scenario we combine the abatement policy scenario ETSA (emission trading scheme for agriculture) with the measures of the complementary technological scenarios BALF (more balanced fertilization) and LNF (low nitrogen feeding). As in the other abatement policy scenarios, the goal is a reduction of agricultural GHG emissions in the EU-

27 of 20% in 2020 compared to the base year 2004 (three-year average 2003-2005).

6.6.1 Changes in GHG emissions

The emission trading scheme ensures that the same GHG emission reduction goal is attained as in the abatement policy scenarios, i.e. a reduction of 17% of GHG emissions (CO2 equivalents) compared to the baseline. However, as both reduced over-fertilization and low nitrogen feeding tend to reduce N2O, this combined scenario does not have to reduce CH4 in the same amount as the "pure" ETSA scenario in section 6.2.3. The regional contributions to emission abatement also differ at the MS level as before. In terms of the contributions to abatement from EU-15 and EU-12, the presence of the technical measures "reduced over fertilization" and "low nitrogen feeding" does not make a great difference, at least in the quantitative specification assumed in this study (Table 54).

Table 54. Change in emissions per Member State according to the ETSBL scenario

	Baseline (REF, 2020)				Combination of ETSA, BALF and LNF (ETSBL, 2020)			
	Methane [1000t]	**Nitrous Oxide [1000t]**	**CO2 equivalents [1000t]**	**Ammonia [1000t]**	**Methane [% to REF]**	**Nitrous Oxide [% to REF]**	**CO2 equivalents [% to REF]**	**Ammonia [% to REF]**
Austria	163,5	12,8	7399,1	49,4	-9,7	-13,9	-12,0	-9,6
Belgium_Lux	208,6	18,5	10119,8	74,0	-9,4	-18,4	-14,5	-12,7
Denmark	151,0	21,2	9727,1	76,9	-11,2	-16,1	-14,5	-12,4
Finland	80,8	23,7	9040,8	18,5	-13,8	-28,6	-25,8	-8,3
France	1449,1	151,9	77527,2	480,8	-10,1	-15,6	-13,4	-9,7
Germany	1070,8	119,2	59451,0	432,6	-9,1	-14,8	-12,6	-6,8
Greece	141,1	9,7	5980,9	27,0	-8,5	-23,1	-15,9	-6,8
Ireland	530,3	38,7	23136,3	103,5	-14,5	-25,2	-20,0	-19,2
Italy	740,8	58,1	33557,8	309,0	-8,7	-15,1	-12,1	-10,4
Netherlands	387,8	34,8	18942,5	92,6	-4,8	-16,8	-11,7	-11,5
Portugal	140,7	10,7	6267,7	43,2	-12,8	-27,0	-20,3	-16,4
Spain	746,3	77,3	39622,9	291,7	-17,9	-23,0	-21,0	-10,9
Sweden	117,3	21,2	9020,4	40,4	-8,4	-20,3	-17,1	-12,1
United Kingdom	896,7	128,8	58771,0	205,2	-12,7	-35,3	-28,1	-13,3
EU15	6824,6	726,6	368564,5	2244,7	-11,1	-21,2	-17,2	-10,5
Cyprus	11,2	1,0	544,0	4,5	-8,7	-34,3	-23,3	-34,4
Czech Republic	57,5	14,7	5766,4	42,3	-9,0	-20,2	-17,8	-9,6
Estonia	14,1	2,3	1019,8	6,1	-10,0	-24,4	-20,3	-8,7
Hungary	49,8	21,6	7749,7	53,9	-5,5	-16,6	-15,1	-11,6
Latvia	22,7	4,7	1944,8	10,5	-4,0	-31,0	-24,3	-15,3
Lithuania	53,4	10,1	4237,2	22,2	-6,1	-19,0	-15,6	-10,7
Malta	1,9	0,2	89,1	1,2	-5,7	-18,8	-12,6	-13,7
Poland	346,8	82,6	32872,4	284,4	-9,2	-17,1	-15,4	-11,4
Slovenia	37,0	2,5	1543,5	12,3	-11,4	-28,3	-19,8	-8,5
Slovak Republic	26,4	5,0	2107,0	12,4	-2,4	-14,8	-11,5	-7,3
EU10	620,8	144,7	57873,8	449,6	-8,3	-18,3	-16,0	-11,3
Bulgaria	76,5	9,8	4641,8	21,7	-7,5	-20,1	-15,7	-12,5
Romania	269,4	30,5	15097,5	86,3	-7,9	-19,7	-15,3	-8,9
Bulgaria/Romania	346,0	40,2	19739,3	108,1	-7,8	-19,8	-15,4	-9,6
EU27	7791,3	911,5	446177,6	2802,4	-10,7	-20,6	-17,0	-10,6

Table 55. Change in emissions per inventory position for the EU according to the ETSBL scenario

	Baseline (REF, 2020)				Combination of ETSA, BALF and LNF (ETSBL, 2020)			
	EU15 [1000t]	EU10 [1000t]	BUR [1000t]	EU27 [1000t]	EU15 [% to REF]	EU10 [% to REF]	BUR [% to REF]	EU27 [% to REF]
Methane emissions from enteric fermentation (IPCC)	5987,7	550,1	323,1	6860,9	-11,4	-8,2	-7,9	-11,0
Methane emissions from manure management (IPCC)	836,9	70,7	22,8	930,5	-8,5	-8,9	-7,3	-8,5
Methane emissions	6824,6	620,8	346,0	7791,4	-11,1	-8,3	-7,8	-10,7
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	217,7	45,6	10,2	273,5	-11,8	-12,5	-10,8	-11,9
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	73,4	5,1	4,4	82,8	-20,2	-14,1	-13,8	-19,5
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	175,4	46,3	12,4	234,1	-33,0	-31,0	-36,6	-32,8
Direct nitrous oxide emissions from crop residues (IPCC)	73,2	12,4	7,2	92,8	-12,6	-12,7	-8,1	-12,3
Direct nitrous oxide emissions from nitrogen fixing crops (IPCC)	11,9	1,1	0,9	13,9	-23,7	-21,5	-20,2	-23,3
Direct nitrous oxide emissions from atmosferic deposition (IPCC)	14,7	2,9	1,7	19,3	-7,6	-5,2	-4,1	-6,9
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	38,8	7,9	2,2	48,9	-15,3	-17,6	-16,7	-15,7
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	12,0	2,6	1,0	15,6	-35,2	-38,4	-47,0	-36,5
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	109,6	20,8	0,2	130,6	-29,3	-6,4	-9,5	-25,6
Nitrous oxide emissions	726,6	144,6	40,2	911,5	-21,2	-18,3	-19,8	-20,6
Carbon dioxide equivalent	368564,5	57873,8	19739,3	446177,6	-17,2	-16,0	-15,4	-17,0

The detailed accounting of N2O and CH4 sources in Table 55 shows that the mayor savings come from abatement at the key sources of agricultural GHG emissions, manure management (-11.9% for EU-27), losses from mineral fertilizer (-32.8%), grazing (-19.5%) and enteric fermentation (-11%). The additional technical measures mainly increase the savings from mineral fertilizer losses whereas the abatement of GHG emissions from manure management is quite similar in this combined scenario to the "pure" ETSA scenario. Instead the combined scenario does not impose stringent savings in CH4 (-10.7% compared to -17.0% in the ETSA scenario) such that it can be expected that the cattle sector is bearing a lower share of the adjustment needs compared to the ETSA scenario.

6.6.2 Analysis of economic effects

As the technical measures included in the combination scenario make only moderate

Table 56. *Change in income, area, yield and supply for the EU-27 for activity aggregates according to the ETSBL scenario*

	Baseline (REF 2020)				Combination of ETSA, BALF and LNF (ETSBL, 2020)			
	Income [Euro/ha or head]	Area or Herd Size [1000 ha or hds]	Yield [kg/ha or head]	Supply [1000 t]	Income [% to REF]	Area or Herd Size [% to REF]	Yield [% to REF]	Supply [% to REF]
Cereals	332	57214	5749	328905	4,9	-5,6	0,4	-5,2
Oilseeds	460	8882	3010	26737	4,8	-4,2	-0,0	-4,2
Other arable crops	1125	7771	na	na	4,8	-3,0	na	na
Vegetables and Permanent crops	4455	21612	na	na	-0,2	-0,0	na	na
Fodder activities	279	79668	23303	1856480	-1,6	-11,9	-5,7	-16,9
Set aside and fallow land	140	13265	na	na	0,5	13,8	na	na
Utilized Agricultural Area	1148	188413	na	na	10,2	-6,1	na	na
All cattle activities	455	84117	na	na	33,3	-13,6	na	na
Beef meat activities	123	26904	na	7842	71,7	-22,5	na	-13,1
Pig fattening	30	247670	92	22754	32,3	-3,3	0,1	-3,2
Pig Breeding	117	14728	17281	254512	35,9	-3,5	0,3	-3,3
Milk Ewes and Goat	54	77576	59	4561	22,8	-5,7	2,4	-3,5
Sheep and Goat fattening	35	46278	14	628	-7,1	-5,2	1,0	-4,4
Laying hens	3973	464	16339	7588	40,1	-4,5	-0,1	-4,7
Poultry fattening	320	6993	1909	13352	54,0	-5,9	0,4	-5,5

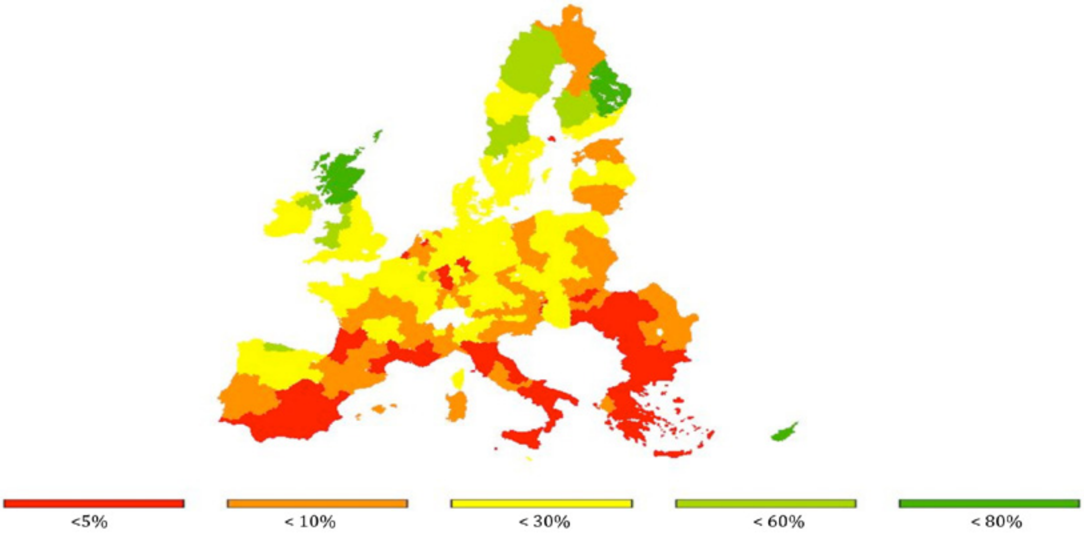
Note: na = not applicable; total supply of beef includes beef from dairy cows and calves.

contributions towards attaining the reduction targets it follows that the bulk of the adjustment has to be attained with reductions in herd sizes and lower activity levels, as in the "pure" ETSA scenario. However, the required activity shifts are smaller in this scenario, in particular for cattle activities (-13.6% heads in EU-27 here compared to -20.2% under ETSA). Even though less pronounced, this difference also applies to the crop sector and total UAA area (-6.1% here compared to -7.7% under ETSA) (Table 56).

Table 56 shows that the combination scenario triggers an overall decline in beef herd size that is clearly smaller than the decline in the "pure" ETSA scenario. The reduction in nitrogen due to the balanced fertilization and the use of low nitrogen feed allows the animal sector to decrease their herd sizes less compared to the "pure" ETSA scenario. As a consequence, the intensification effect in the beef sector is less pronounced than in the ETSA scenario, where high yielding beef activities are more increased at the expense of low yield activities. For that reason the overall decrease in beef supply is higher in the ETSBL scenario (-13.1%) than in the ETSA scenario (-10.4%).

Comparing the agricultural income per UAA of the ETSA and the combined ETSBL scenario, income is less (only increasing by 11.2% relative to REF) in the combined than in the ETSA scenario. In most southern regions the change in income is lower compared with the northern countries (Figure 23). This difference in income changes between the two scenarios can be found at almost all kinds of agricultural activities. The effect of the technological measures dampens the reduction in agricultural production and therefore leads to smaller increases

Figure 23. Change in agricultural income per utilizable agricultural area according to the ETSBL scenario (in %)



in prices and income. The change in income in Scotland is 147% and looks like an outlier.

6.6.3 Analysis of emission abatement costs and the emission market

The marginal abatement costs in the combination scenario are around 25% less as in the "pure" ETSA scenario. The average costs in the combination scenario are 103 Euro and in the ETSA scenario 125 Euros per tonne. The regional pattern of marginal abatement costs does not differ a lot between the combined and the ETSA-scenario (Figure 24). Or in other words: regions with relative high emission marginal abatement costs under the ETSA-scenario had also higher costs under the ETBL-scenario but on average the marginal abatement costs are higher under the ETSA-scenario.

Figure 24. Marginal abatement costs with the ETSBL scenario (in €/t CO2 eq)

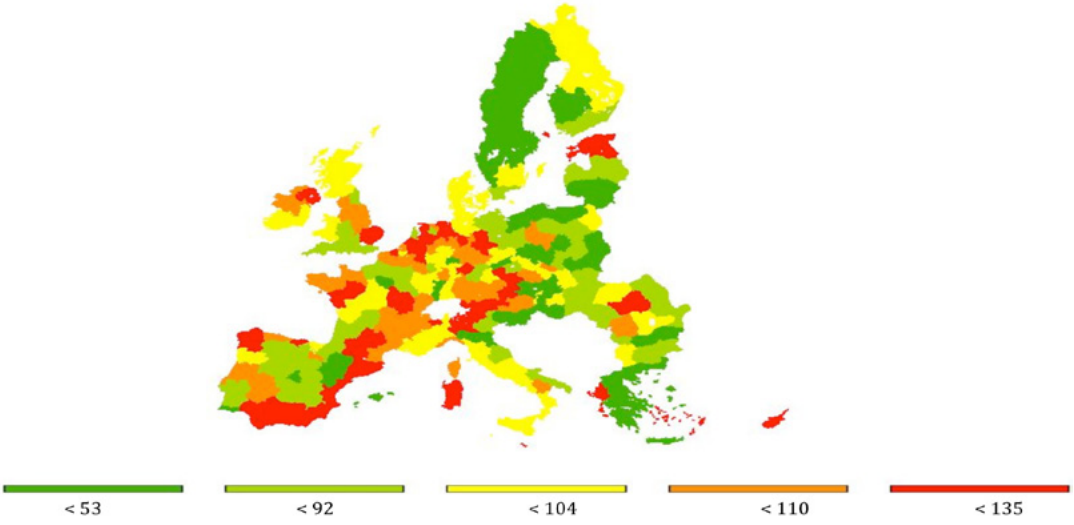
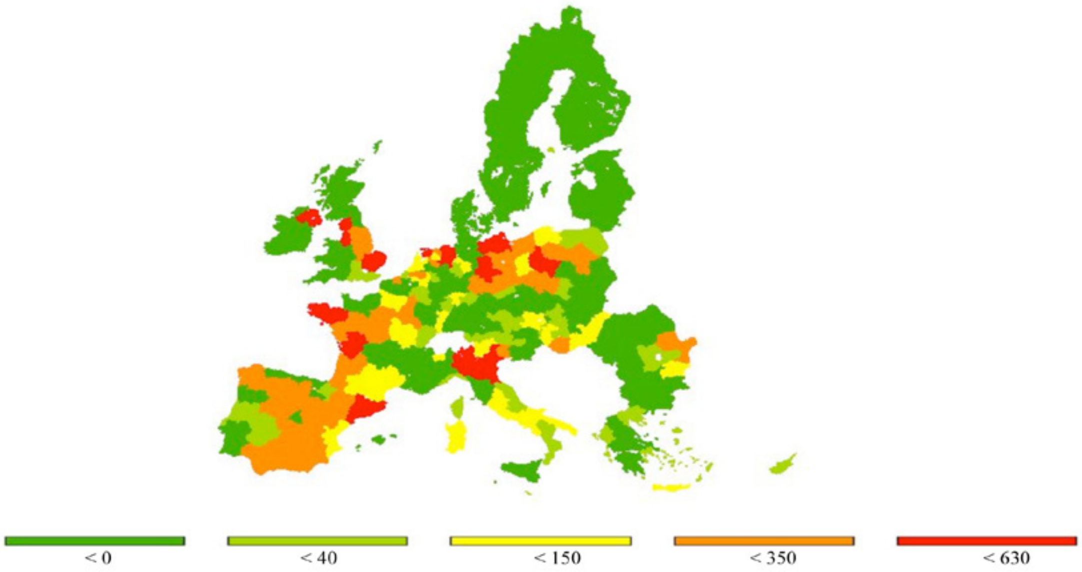


Figure 25. Purchases of emission permits in the combined (ETSBL) scenario for agriculture (1000 CO2 equivalents)



The amount of permits bought would also be lower under the ETSBL-scenario compared to the ETSA-scenario (Figure 25). The effect of low nitrogen feed and balanced fertilization already decrease the emission of N2O and therefore fewer permits would have to be bought.

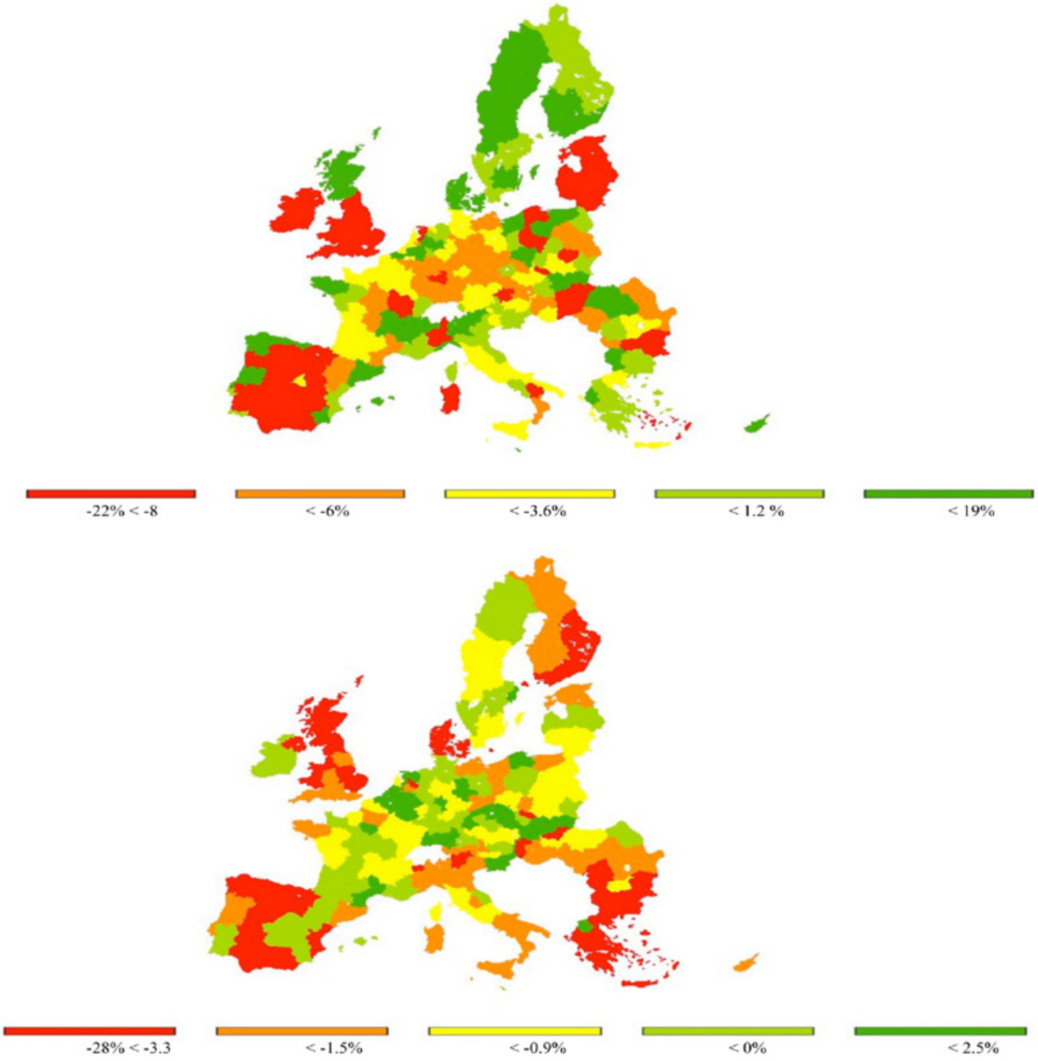
6.6.4 Analysis of environmental effects with regard to nitrogen balances

Table 57 shows the impacts on the aggregate balance for nitrogen. Some of these impacts are expected based on changes in gaseous emission sources and overall activity levels. Reduced over-fertilization causes mineral fertilizer application to decline by almost 33% in EU-27, which evidently improves the overall nutrient balance (-50.9% for the surplus at soil level in EU-27). By contrast the nitrogen import by manure declines less (-12% in EU-27) and thus very similar to the ETSA scenario. Apparently the additional savings in terms of low nitrogen feeding and the higher beef meat activity levels under ETSBL compared to ETSA are approximately cancelling. On the level of the large regional aggregates (EU-15, EU-10), the impacts are quite uniform compared with EU-27.

Table 57. Changes in the nitrogen balance according to the ETSBL scenario

	Baseline (REF 2020)				Combination of ETSA, BALF and LNF (ETSBL, 2020)			
	EU15 [1000t N]	**EU10 [1000t N]**	**BUR [1000t N]**	**EU27 [1000t N]**	**EU15 [% to REF]**	**EU10 [% to REF]**	**BUR [% to REF]**	**EU27 [% to REF]**
Import by mineral fertilizer	8445	2261	602	11309	-33,0	-31,0	-36,7	-32,8
Import by manure	7739	1138	411	9288	-13,6	-12,6	-11,9	-13,4
Import by crop residues	4764	878	512	6153	-12,6	-12,8	-8,1	-12,2
Biological fixation	861	76	62	999	-17,7	-13,1	-14,0	-17,1
Atmospheric deposition	1671	326	191	2188	-5,7	-5,0	-2,9	-5,3
Nutrient retention by crops	14586	2835	1262	18683	-10,1	-9,7	-6,1	-9,7
Surplus total	8894	1844	516	11254	-36,1	-38,4	-48,3	-37,0
Gasseous loss	2966	610	173	3749	-15,7	-17,5	-17,4	-16,1
Run off mineral	246	122	51	419	-33,1	-30,3	-36,2	-32,7
Run off manure	347	83	38	468	-13,1	-12,6	-11,9	-12,9
Surplus at soil level	5335	1028	254	6617	-49,1	-53,8	-77,2	-50,9

Figure 26. Yield changes in fodder (upper) and beef activities (lower map) according to the ETSBL scenario



Note: The yield of beef meat activities excludes beef from dairy cows and calves

7 Effects of introducing emission leakage into the scenario analysis

In this report emission leakage is defined as the indirect effect on GHG emissions in non-EU countries induced by a GHG emission abatement policy implemented in the EU. As shown in the previous sections on the emission abatement policy scenarios, all the policies analysed show an impact on agricultural production in the EU. The changed production in the EU influences prices, production and trade also in other regions of the world, thereby indirectly also affecting the global GHG emissions. Thus, any GHG emission reduction achievement in the EU could be diminished in terms of its global impact due to emission leakage, i.e. a shift of emissions from the EU to the rest of the world. Using the commodity-specific emission factors estimated in section 3.3 the changes in production in the rest of the world can be translated into changes in emissions outside of the EU. The results of such a computation are shown in Table 58 and Table 59.

Table 58 shows that all GHG emission abatement policies in the EU induce increased emissions in the rest of the world. However, the effect on emissions outside of the EU is different depending on the way in which the emission abatement in the EU is achieved. In the LTAX scenario, the tax on livestock emissions in the EU induces an increase of about 25 million tonnes of CO2 eq. outside the EU, which is 10 million tonnes more than in the ETSA scenario, and even three times the 8.2 million tonnes of CO2 eq. in the ETSBL scenario, where a tradable emission permit scheme for agriculture is combined with the technological abatement measures of a more balanced fertilization and low nitrogen feeding.

A look into the detailed rows of the tables reveals that the main explanation for the differences between the scenarios should be found in the ruminating livestock sector, since the difference between the scenarios with regard to GHG emission changes outside the EU is most strongly influenced by the difference in the first line of the Table 58, "CH4 emissions from enteric fermentation". In the livestock tax scenario, some of the reduction in EU beef meat production is replaced by imports, primarily from Mercosur countries such as Brazil and Argentina, where the estimated emission factors per tonne of beef are higher than those of the EU (0.74 kg CH4 from enteric fermentation per kilo beef produced in Argentina as opposed to 0.43 in the EU (Table iii.1; Annex III).

In the other scenarios, the GHG emission abatement is spread across more agricultural sectors, where imported substitutes have emission factors that are smaller than or more similar to the EU emission factors.

The results indicate that from a global emission abatement point of view, the tradable emission permit policy is most efficient for reducing global emissions (this is because it allocates the emission abatement within the EU-27 according to where it costs least to achieve), whereas the livestock tax policy is the least efficient (because it does not discriminate according to the potential for reducing emissions and loads the adjustment cost onto just one production factor). Combining the ETSA scenario with technical measures as balanced fertilization and low nitrogen feed is even more efficient. In the combined ETSBL scenario the use of low nitrogen feed contributed to a slower decrease in number of animals. Therefore the shift of methane emission is less than in the other policy scenarios and the emission of N2O from manure is lower. The balanced fertilization contributes to the decrease in fertilizer use. Due to less use of fertilizer the indirect emission of nitrous oxide reduces compared with the other policy scenarios.

Table 58. Change in emissions outside of the EU induced by the policies in the EU, relative to the reference scenario (1000 t per year)

	Scenarios							
	AMMO	**BALF**	**LNF**	**ETSBL**	**STD**	**ESAA**	**ETSA**	**LTAX**
Methane emissions from enteric fermentation (IPCC)	9,9	3,5	30,0	206,3	344,4	359,4	309,1	637,4
Methane emissions from manure management (IPCC)	-0,1	0,3	1,5	-2,8	20,3	21,0	18,1	42,2
Methane emissions	9,8	3,8	31,5	203,5	364,7	380,3	327,2	679,6
Direct nitrous oxide emissions stemming from manure managment and application except grazings (IPCC)	-0,2	0,0	0,2	48,5	2,3	2,5	1,9	3,0
Direct nitrous oxide emissions stemming from manure managment on grazings (IPCC)	0,3	0,1	0,5	11,3	10,4	10,9	9,4	20,8
Direct nitrous oxide emissions from anorganic fertilizer application (IPCC)	-0,0	-0,3	-0,6	-0,2	3,8	2,8	2,8	-3,4
Direct nitrous oxide emissions from cultivation of histosols (IPCC via Miterra)	0,2	-0,1	-0,5	6,1	11,0	11,5	9,4	15,5
Indirect nitrous oxide emissions from leaching (IPCC via Miterra)	-0,0	-0,0	-0,3	-82,7	0,1	0,1	0,1	-0,4
Direct nitrous oxide emissions from crop residues (IPCC)	-0,1	-0,1	-1,2	69,2	0,6	0,5	0,4	-3,6
Indirect nitrous oxide emissions from ammonia volatilisation (IPCC)	0,1	0,0	0,2	-39,4	1,0	1,0	0,8	1,3
Nitrous oxide emissions	0,3	-0,5	-1,8	12,8	29,2	29,2	24,8	33,3
Carbon dioxide equivalents	48,0	-58,0	100,6	8253,3	16702,2	17050,2	14563,4	24598,3

Although emission leakage occurs through an increase in GHG emissions in the rest of the world, the net effect of the scenarios (except the AMMO-scenario) at world level is a net standstill or a slight decline in GHG emissions (Table 59).

Table 59. Net-effect of mitigation policy and technological measures on world-wide GHG emissions (index REF=100)

	Total emissions in CO2 equivalents			Total emissions of N2O			Total emissions of CH4		
	EU27	**RoW**	**World**	**EU27**	**RoW**	**World**	**EU27**	**non-EU27**	**World**
REF	100	100	100	100	100	100	100	100	100
STD	88	101	99	87	101	99	89	100	99
ESAA	88	101	99	88	101	99	88	101	99
ETSA	86	100	99	85	100	98	89	100	99
LTAX	88	101	99	92	101	99	83	101	99
AMMO	103	100	100	104	100	101	100	100	100
BALF	96	100	100	93	100	99	100	100	100
LNF	98	100	100	81	100	98	101	100	100
ETSBL	86	100	99	81	100	98	93	100	100

RoW = rest of the world.

8 Concluding remarks

When looking at the results of the emission mitigation policy scenarios several issues that are not covered in the current analysis should be kept in mind. Firstly, emission abatement in CAPRI is related strictly to agricultural direct emissions and does not cover indirect emissions, like e.g. N2O related to fertilizer production, or emissions from other pollutants, like e.g. SO2, nor changing carbon sequestration resulting from changes in land management techniques and introduction of alternative crop rotations (as in Lal, 2004; Reilly et al. 2007, p.178). Secondly, due to the restriction to agriculture, changes in the forestry or energy sectors resulting from adjustment in agricultural production are not considered (as in Böhringer, 2000, p.780; Truong et al., 2007). Moreover, agricultural processing activities for explicit mitigation of GHG emissions, e.g. biofuel or biogas production (Gielen et al. 2003, pp.179-180; Pathak et al. 2009, p.408) are subject to further research. The analysis, hence, builds up on a simplified emission accounting scheme and not on on-farm measurements of emissions or more elaborated emission coefficients depending on single processes as in Moran (2009).

It has to be also kept in mind that in the 'pure' emission mitigation policy scenarios technological responses to policy measures are only considered to some extend within the general CAPRI modelling system. However, specific technological responses to the GHG mitigation policy measures, like the adaptation of stables or livestock keeping methods, are not considered. Therefore, the system responds only in form of price and production quantity changes, i.e. farmers react to the mitigation policies only by adjusting their production (e.g. by decreasing the number of cows or their intensity) but not their production management techniques. However, in reality it is very likely that farmers would also try to reduce their GHG emissions by changing their production techniques (i.e. using technical measures like introducing low-nitrogen feeding, covering of manure storage, or switching to minimum tillage or no-till techniques). With the complementary technological abatement scenarios, where the changes in production technology are pre-defined (i.e. not endogenously calculated by the CAPRI model), we tried to at least partially tackle this limitation.

With respect to the technological abatement scenarios it has to be acknowledged that these scenarios mainly illustrate that CAPRI is able to investigate technological abatement options together with endogenous shifts in activity levels and intensity of production. But the range of technologies investigated is very narrow as the collection of costs and abatement effects is an activity that requires considerable resources and technological expertise. Furthermore there is a key limitation due to the fact that the technological scenarios are currently treated as scenarios: the type and extend of technological abatement measures are exogenous scenario assumptions, whereas it would be desirable that these choices are made simultaneously with decisions on the activity mix and production intensity. Such a simultaneous optimisation over activity mix, intensity and technologies has been achieved in a few examples of LP type models (EUFASOM (Schneider et al, 2008), AROPAJ (De Cara and Javet, 2006)) which are known to have weakness in other areas. While in principle it is conceivable to expand the array of technological options beyond the current set (for dairy cows for example, CAPRI has high and low yielding cows), such an expansion of the array of technological options may be a challenging task in computational terms for the NLP framework of CAPRI if more than a few options are required per activity. Nonetheless, the complementary technological abatement scenarios conducted in this study help to get an idea of the magnitude of the effects that technological changes may have on agricultural GHG emissions. Furthermore, by introducing the technological abatement measures of a more balanced fertilization and low nitrogen feeding into the scenario with an emission trading scheme for agriculture, we reveal that changes in production techniques certainly alter the results of the mitigation policy scenarios.

Even though the study is limited with respect to technological responses to policy measures, the scenario results provide valuable insights for policy making, as they clearly reveal the differences of how the specific mitigation policy instruments impact on the one hand the GHG emissions per EU Member State and on the other hand production, cost-effectiveness and income redistribution within the agricultural sector. To this end, the estimates provided can feed the discussion on the feasibility of (further) integrating the agricultural sector in multi-sectoral emission abatement policies currently in place or under consideration.

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Annex I: Development of agricultural GHG emissions in EU Member States between 1990 and 2008

Table 60. Agricultural GHG emissions (methane and nitrous oxide) in EU Member States between 1990 and 2008 (Tg or million tonnes CO_2 equivalents)

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	8,6	8,7	8,3	8,1	8,6	8,7	8,2	8,2	8,2	8,1	7,9	7,9	7,8	7,5	7,4	7,4	7,4	7,5	7,6
Belgium-Lux.	12,3	12,2	12,1	12,2	12,2	12,4	12,2	12,2	12,2	12,3	11,5	11,4	11,1	10,6	10,6	10,4	10,3	10,4	10,3
Denmark	13,1	13,0	12,6	12,5	12,2	12,0	11,7	11,5	11,4	10,9	10,7	10,5	10,3	10,0	9,9	9,9	9,7	9,8	10,0
Finland	6,6	6,2	5,8	5,9	5,9	6,0	6,0	6,0	5,8	5,7	5,8	5,8	5,8	5,8	5,7	5,7	5,7	5,7	5,8
France	107,6	104,8	104,8	100,4	100,9	101,7	102,4	103,5	103,2	102,4	103,4	101,1	101,0	97,8	97,6	97,0	95,5	95,7	98,1
Germany	78,0	71,5	69,2	68,8	66,7	68,4	68,9	68,1	68,0	68,9	68,7	68,2	66,2	65,1	66,0	65,4	64,1	63,8	66,2
Greece	11,3	11,2	10,9	10,2	10,0	10,3	10,4	10,3	10,3	10,2	10,0	9,9	9,9	9,7	9,8	9,4	9,3	9,6	8,9
Ireland	19,2	19,3	19,4	19,6	19,7	19,9	20,2	20,4	21,0	20,7	19,6	19,1	19,0	19,0	18,8	18,7	18,4	17,7	17,6
Italy	40,6	41,4	40,9	41,2	40,6	40,3	40,1	41,2	40,4	40,8	39,9	39,0	38,3	38,1	37,9	37,2	36,6	37,2	35,9
Netherlands	22,5	23,0	23,6	23,5	22,8	23,5	22,9	22,6	22,0	21,6	20,4	19,9	18,9	18,4	18,5	18,5	18,4	18,3	18,5
Portugal	8,0	8,1	8,0	7,8	8,0	8,0	8,4	8,2	8,2	8,4	8,7	8,5	8,6	8,0	8,2	8,0	7,9	7,9	7,8
Spain	37,7	37,7	36,9	35,3	37,4	36,6	40,7	39,7	41,6	42,6	44,0	43,3	42,2	44,5	42,9	40,6	41,3	42,3	39,0
Sweden	9,5	9,3	9,3	9,6	9,7	9,5	9,4	9,5	9,3	9,0	8,9	8,9	8,8	8,7	8,8	8,7	8,7	8,5	8,5
United Kingdom	55,3	54,8	53,0	52,3	53,2	53,1	53,4	53,7	52,8	52,2	50,1	47,1	47,3	46,7	46,7	46,5	44,9	44,1	43,6
EU-15	430,5	421,2	414,9	407,3	408,0	410,4	415,2	415,1	414,7	413,9	409,6	400,6	395,1	390,0	388,8	383,3	378,3	378,6	377,8
Cyprus	0,6	0,7	0,7	0,7	0,7	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,9	0,9	0,8	0,8	0,7	0,8	0,8
Czech Republic	15,9	14,2	12,3	10,8	10,0	9,9	9,5	9,3	8,9	8,9	8,7	8,9	8,6	8,0	8,4	8,1	7,9	8,1	8,3
Estonia	3,1	2,9	2,5	1,9	1,7	1,5	1,4	1,4	1,4	1,2	1,3	1,3	1,2	1,3	1,3	1,3	1,3	1,3	1,4
Hungary	14,5	11,7	10,1	9,0	9,0	8,7	8,8	8,6	9,2	9,4	9,1	9,3	9,4	9,2	9,3	8,8	8,8	8,9	8,8
Latvia	6,0	5,6	4,4	2,9	2,5	2,1	2,1	2,1	1,9	1,7	1,7	1,9	1,9	1,9	1,9	2,0	2,0	2,1	2,1
Lithuania	10,6	9,7	6,6	5,6	4,9	4,7	5,1	5,1	4,9	4,7	4,4	4,6	4,8	5,0	5,0	5,0	5,5	5,2	5,0
Malta	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Poland	50,8	43,0	39,2	37,8	37,8	38,0	37,0	37,8	38,7	37,1	35,4	35,1	34,9	34,3	34,2	34,6	36,1	37,1	37,1
Slovac Republic	7,0	6,0	5,1	4,4	4,2	4,4	4,2	4,0	3,7	3,5	3,5	3,5	3,5	3,4	3,2	3,2	3,2	3,2	3,1
Slovenia	2,1	2,0	2,2	2,0	2,1	2,0	2,0	2,0	2,0	2,0	2,1	2,1	2,2	2,1	2,0	2,0	2,0	2,1	2,0
EU-10	110,7	95,9	83,3	75,2	72,8	72,2	70,9	71,1	71,6	69,4	67,1	67,6	67,6	66,1	66,2	65,8	67,7	69,0	68,8
Bulgaria	13,3	10,7	8,7	7,3	6,8	6,1	5,9	5,9	5,5	5,9	5,7	4,9	5,2	5,1	5,4	5,1	5,0	5,0	5,0
Romania	37,0	31,1	27,2	25,7	25,0	24,0	23,3	23,4	21,5	20,1	18,3	19,0	19,2	19,6	20,8	20,9	20,7	19,7	20,3
Bulgaria/Romania	50,3	41,8	35,9	33,1	31,8	30,1	29,2	29,2	27,0	26,0	24,0	23,8	24,4	24,6	26,2	26,0	25,7	24,7	25,2
EU-27	591,6	559,0	534,1	515,6	512,7	512,7	515,2	515,4	513,2	509,3	500,7	492,1	487,1	480,8	481,2	475,2	471,7	472,3	471,8

Source: EEA database.

Table 61. Emissions of methane from agriculture in EU Member States between 1990 and 2008 (Tg or million tonnes CO_2-equivalents)

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	4,2	4,1	4,0	4,0	4,0	4,0	4,0	3,9	3,9	3,8	3,8	3,7	3,7	3,6	3,6	3,6	3,5	3,6	3,5
Belgium-Lux.	6,2	6,1	6,1	6,2	6,2	6,3	6,2	6,2	6,2	6,2	5,9	5,9	5,7	5,5	5,5	5,4	5,4	5,5	5,5
Denmark	4,1	4,1	4,1	4,2	4,1	4,1	4,1	4,0	4,0	3,8	3,9	3,9	3,9	3,9	3,8	3,7	3,8	3,9	3,9
Finland	2,2	2,1	2,0	2,0	2,0	1,9	1,9	2,0	1,9	1,9	1,9	1,9	1,9	1,9	1,9	1,9	1,9	1,9	1,8
France	44,8	44,2	43,6	43,4	43,6	43,8	43,9	43,5	43,3	43,3	43,8	44,0	43,5	42,7	42,2	42,2	42,2	42,4	42,8
Germany	32,6	29,3	28,5	28,3	28,5	28,4	28,5	27,8	27,5	27,5	27,0	27,3	26,4	26,1	25,4	25,4	24,8	24,9	25,3
Greece	3,5	3,4	3,4	3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,6	3,6	3,6	3,6	3,5	3,5	3,5	3,5	3,5
Ireland	11,8	11,9	12,0	12,1	12,0	12,0	12,3	12,6	12,7	12,4	11,8	11,7	11,6	11,5	11,5	11,4	11,4	11,0	11,0
Italy	17,2	17,4	17,0	16,9	16,9	17,2	17,3	17,3	17,2	17,3	16,8	16,1	15,7	15,8	15,5	15,5	15,1	15,6	15,3
Netherlands	10,5	10,7	10,5	10,5	10,2	10,5	10,1	10,0	9,7	9,6	9,3	9,4	8,9	8,8	8,9	8,9	8,8	9,0	9,1
Portugal	4,1	4,2	4,0	3,9	4,1	4,2	4,3	4,2	4,4	4,5	4,5	4,5	4,6	4,5	4,6	4,6	4,7	4,6	4,6
Spain	16,3	16,5	16,6	16,6	16,8	16,8	17,8	17,9	18,5	18,7	19,1	19,5	19,5	20,0	19,6	19,2	19,4	19,8	18,9
Sweden	3,4	3,3	3,4	3,6	3,6	3,5	3,5	3,5	3,4	3,4	3,3	3,3	3,3	3,2	3,3	3,3	3,3	3,2	3,2
United Kingdom	22,2	21,8	21,9	21,7	21,9	21,6	21,8	21,1	21,1	21,1	20,2	19,0	18,7	18,8	18,9	19,1	18,8	18,6	18,2
EU-15	183,1	179,3	177,2	176,9	177,3	177,9	179,2	177,4	177,3	177,1	174,8	173,8	171,0	169,8	168,2	167,7	166,5	167,5	166,6
Cyprus	0,3	0,3	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,5	0,5	0,4	0,4	0,4	0,4	0,4
Czech Republic	5,9	5,6	5,0	4,4	3,8	3,7	3,7	3,5	3,3	3,3	3,2	3,2	3,1	3,0	2,9	2,9	2,8	2,9	2,9
Estonia	1,3	1,2	1,0	0,8	0,7	0,6	0,6	0,6	0,6	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Hungary	5,6	5,1	4,3	3,8	3,3	3,3	3,4	3,2	3,3	3,4	3,3	3,2	3,2	3,2	2,9	2,8	2,8	2,8	2,7
Latvia	2,4	2,3	1,9	1,2	1,0	1,0	0,9	0,9	0,8	0,7	0,7	0,8	0,8	0,7	0,7	0,8	0,7	0,8	0,8
Lithuania	4,5	4,1	3,0	2,5	2,3	2,2	2,1	2,1	2,0	1,8	1,7	1,7	1,8	1,9	1,8	1,8	1,9	2,0	1,9
Malta	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Poland	19,0	17,6	16,3	14,9	14,8	14,4	13,8	14,1	14,5	14,1	13,1	12,7	12,9	12,7	12,2	12,6	12,9	13,0	12,6
Slovac Republic	2,4	2,2	1,9	1,7	1,6	1,7	1,6	1,4	1,3	1,3	1,3	1,3	1,3	1,2	1,1	1,1	1,1	1,1	1,0
Slovenia	1,1	1,1	1,1	1,1	1,1	1,1	1,0	1,0	1,1	1,0	1,1	1,1	1,2	1,1	1,1	1,1	1,1	1,2	1,1
EU-10	42,6	39,5	35,0	30,8	29,1	28,4	27,7	27,4	27,4	26,6	25,3	25,0	25,2	24,8	23,8	24,1	24,4	24,6	24,0
Bulgaria	5,2	4,7	3,9	3,0	2,5	2,4	2,3	2,2	2,3	2,3	2,2	1,7	2,0	2,0	2,0	1,9	1,9	1,8	1,7
Romania	14,3	12,9	11,2	9,9	9,8	9,4	9,4	9,3	8,6	8,0	7,5	7,4	7,6	7,7	7,8	7,9	8,1	8,0	7,7
Bulgaria/Romania	19,5	17,6	15,1	12,9	12,3	11,8	11,7	11,5	11,0	10,4	9,7	9,1	9,5	9,7	9,8	9,8	10,0	9,8	9,4
EU-27	245,1	236,4	227,3	220,6	218,7	218,2	218,6	216,3	215,7	214,1	209,8	207,9	205,7	204,4	201,8	201,6	200,9	201,8	200,0

Source: EEA database

Table 62. Emissions of nitrous oxide from agriculture in EU Member States between 1990 and 2008 (Tg or million tonnes CO_2-equivalents)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	4,4	4,6	4,3	4,1	4,6	4,7	4,3	4,3	4,4	4,3	4,1	4,1	4,1	3,9	3,8	3,8	3,9	3,9	4,1
Belgium-Lux.	6,1	6,1	6,0	6,0	6,0	6,1	6,0	6,0	6,0	6,0	5,6	5,5	5,4	5,1	5,1	5,0	5,0	4,9	4,9
Denmark	9,0	8,8	8,5	8,3	8,1	7,9	7,7	7,5	7,4	7,1	6,8	6,6	6,4	6,1	6,1	6,2	6,0	5,9	6,2
Finland	4,5	4,2	3,8	3,9	3,9	4,1	4,1	4,0	3,9	3,8	3,9	3,9	3,9	3,9	3,9	3,9	3,9	3,9	4,0
France	62,8	60,6	61,1	56,9	57,3	57,8	58,5	60,0	59,9	59,1	59,6	57,1	57,5	55,1	55,5	54,9	53,3	53,3	55,3
Germany	45,5	42,2	40,7	40,6	38,3	40,0	40,4	40,4	40,5	41,4	41,7	41,0	39,8	39,0	40,6	40,0	39,3	38,8	40,9
Greece	7,9	7,7	7,5	6,7	6,5	6,8	6,9	6,8	6,8	6,6	6,4	6,4	6,3	6,2	6,2	5,9	5,8	6,0	5,4
Ireland	7,4	7,4	7,4	7,5	7,7	7,9	8,0	7,8	8,3	8,3	7,8	7,4	7,3	7,5	7,3	7,2	7,1	6,7	6,6
Italy	23,4	24,0	23,9	24,3	23,7	23,1	22,8	23,9	23,3	23,5	23,1	22,9	22,5	22,3	22,3	21,7	21,5	21,6	20,6
Netherlands	11,9	12,2	13,1	12,9	12,5	13,1	12,8	12,7	12,3	12,0	11,1	10,6	10,0	9,6	9,6	9,6	9,6	9,3	9,4
Portugal	4,0	4,0	3,9	3,9	3,9	3,8	4,0	4,0	3,9	4,0	4,2	4,0	4,0	3,5	3,6	3,4	3,2	3,3	3,2
Spain	21,5	21,2	20,3	18,7	20,6	19,7	22,8	21,8	23,1	23,9	24,9	23,8	22,7	24,5	23,2	21,3	21,9	22,6	20,1
Sweden	6,1	6,0	5,9	6,0	6,1	5,9	5,9	6,0	5,9	5,7	5,7	5,6	5,6	5,5	5,5	5,4	5,4	5,3	5,3
United Kingdom	33,2	33,0	31,2	30,6	31,4	31,5	31,6	32,6	31,7	31,1	29,9	28,1	28,6	27,9	27,8	27,4	26,2	25,4	25,4
EU-15	247,5	242,0	237,7	230,4	230,7	232,5	235,9	237,6	237,4	236,8	234,8	226,9	224,1	220,2	220,6	215,7	211,8	211,1	211,2
Cyprus	0,3	0,3	0,3	0,3	0,3	0,3	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,3	0,3	0,3	0,4
Czech Republic	10,1	8,6	7,3	6,4	6,2	6,2	5,8	5,9	5,6	5,6	5,5	5,7	5,5	5,0	5,5	5,2	5,1	5,3	5,4
Estonia	1,8	1,7	1,5	1,1	1,0	0,8	0,8	0,8	0,8	0,7	0,8	0,7	0,7	0,8	0,8	0,8	0,8	0,8	0,9
Hungary	8,9	6,6	5,8	5,3	5,6	5,4	5,4	5,4	5,8	6,0	5,8	6,2	6,3	6,1	6,4	6,0	6,1	6,1	6,1
Latvia	3,5	3,3	2,5	1,7	1,5	1,1	1,1	1,1	1,1	1,0	1,0	1,1	1,1	1,2	1,2	1,3	1,3	1,4	1,3
Lithuania	6,1	5,5	3,6	3,0	2,6	2,5	2,9	3,0	2,9	2,8	2,8	2,9	3,0	3,2	3,2	3,1	3,6	3,3	3,1
Malta	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Poland	31,8	25,4	23,0	22,9	23,0	23,6	23,2	23,6	24,1	23,1	22,3	22,4	22,0	21,5	21,9	22,0	23,1	24,1	24,5
Slovac Republic	4,7	3,9	3,2	2,7	2,6	2,7	2,6	2,6	2,4	2,2	2,2	2,2	2,3	2,2	2,1	2,1	2,1	2,2	2,1
Slovenia	1,0	0,9	1,1	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9	0,9	0,9	0,9	0,9
EU-10	68,2	56,4	48,3	44,4	43,8	43,7	43,2	43,7	44,2	42,8	41,8	42,7	42,4	41,3	42,3	41,7	43,3	44,4	44,7
Bulgaria	8,1	6,0	4,8	4,3	4,3	3,7	3,6	3,6	3,2	3,6	3,4	3,1	3,2	3,1	3,4	3,2	3,1	3,2	3,2
Romania	22,7	18,2	16,0	15,8	15,2	14,6	13,9	14,1	12,8	12,0	10,8	11,6	11,6	11,8	13,0	13,0	12,6	11,7	12,6
Bulgaria/Romania	30,8	24,2	20,8	20,1	19,5	18,2	17,4	17,7	16,0	15,6	14,2	14,7	14,8	14,9	16,4	16,2	15,7	14,9	15,8
EU-27	346,5	322,6	306,8	295,0	293,9	294,5	296,6	299,1	297,5	295,2	290,9	284,2	281,4	276,4	279,4	273,6	270,8	270,4	271,8

Source: EEA database

Annex II: Agriculture and ammonia emissions

While not being a GHG, Ammonia (NH3) is another important polluting gas from agriculture. Thus, while the study focuses on the development of GHG emissions, the effect of the policy options on the development of NH3 emissions are also reported (but not analysed in detail).

The current policy on abatement of NH3 emissions originated in the formulation of the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (UNECE, 2011). The protocol sets emission ceilings for 2010 for four acidifying pollutants: sulphur dioxide, nitrogen oxides, non-CH4 volatile organic compounds and NH3. The EU incorporated this policy of emission ceilings into their own regulations starting with the Directive 2001/81/EC of the European Parliament and the Council on National Emission Ceilings for certain pollutants (NEC Directive). The Directive of 2001 included only the EU-15 MS but in 2007 the NEC Directive has been amended and the consolidated version includes also national emission ceilings for the new Member States. In 2005, the EU Commission has adopted the Thematic Strategy on Air Pollution (TSAP). In the TSAP interim environmental objectives were (re)defined for the pollutants mentioned in the Gothenburg protocol. It was also announced that to achieve the new (interim) objectives the NEC Directive should be revised and new ceilings for 2020 should be defined (cf. European Commission, 2011b).

When looking at the historical developments of NH3 from agriculture in the EU, it can be observed that emissions decreased by about 22% in the EU-27. In EU-15 the reduction was about 13% while in the EU-10 and Bulgaria/Romania the reduction of NH3 emissions decreased by -46 and -43% respectively. Detailed data (emissions per country) can be found in the next table.

Table 63. Emissions of ammonia from agriculture in EU Member States between 1990 and 2007 (Gg or 1000 tonnes NH3)

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Austria	66,0	66,6	64,3	64,2	65,1	66,6	64,8	65,0	64,9	63,6	62,1	61,8	60,7	61,3	60,5	60,4	60,9	61,7
Belgium-Lux.	110,2	108,4	106,7	104,9	102,8	101,1	97,9	94,8	91,5	88,4	85,2	83,0	80,8	78,0	73,4	73,6	72,6	69,4
Denmark	133,1	128,8	126,8	124,2	119,6	112,1	107,9	107,3	108,4	103,2	102,6	101,7	98,8	94,7	94,8	89,6	87,1	72,6
Finland	36,8	36,2	35,7	35,1	34,6	34,0	35,4	36,8	34,6	32,3	32,2	32,2	32,1	32,1	32,0	31,8	32,5	31,3
France	772,1	756,9	762,8	743,0	750,3	753,3	754,0	766,5	762,7	754,3	762,9	748,7	750,1	723,7	713,4	708,0	717,7	714,6
Germany	726,3	642,3	625,5	625,6	604,8	612,5	614,3	606,0	612,5	618,4	614,1	628,6	618,2	617,6	610,5	590,2	590,2	595,8
Greece	78,0	76,0	73,0	73,0	71,0	80,0	71,0	69,0	72,0	72,0	72,0	72,0	72,0	72,0	72,0	72,0	72,6	62,7
Ireland	112,3	114,4	116,9	116,6	118,2	119,2	121,3	122,6	126,4	125,6	120,7	120,6	116,8	114,0	110,7	110,1	107,2	103,0
Italy	397,4	409,5	404,2	411,7	405,2	404,0	396,7	409,6	408,9	415,0	401,9	410,0	411,3	401,1	391,2	400,2	395,1	395,5
Netherlands	237,8	226,3	214,7	203,2	191,6	180,1	173,6	167,3	160,7	154,6	140,2	130,7	124,5	118,7	122,1	122,6	121,3	122,0
Portugal	40,6	46,6	47,2	46,2	48,3	48,5	48,6	51,2	50,2	50,1	49,8	51,5	50,2	50,1	50,0	59,7	57,8	46,1
Spain	300,7	293,2	295,1	277,5	292,7	279,2	309,7	304,5	322,1	332,3	349,8	343,9	340,0	351,2	362,8	366,4	390,5	391,5
Sweden	49,0	49,0	49,0	55,3	55,3	56,5	54,0	54,2	53,2	50,7	49,7	48,0	47,9	46,6	47,0	46,2	45,8	44,3
United Kingdom	353,0	353,1	338,2	332,4	333,5	321,9	321,3	325,3	319,6	321,7	301,4	294,3	284,6	275,6	304,4	285,5	287,8	264,3
EU-15	3413,2	3307,3	3259,9	3212,9	3192,9	3169,0	3170,5	3180,0	3187,6	3182,2	3144,6	3126,9	3088,2	3036,6	3044,5	3016,3	3039,1	2974,6
Cyprus	4,5	4,7	4,9	5,1	5,3	5,5	5,6	5,8	6,0	6,2	6,4	6,6	5,3	5,6	5,5	5,3	5,2	5,0
Czech Republic	153,0	132,0	109,0	92,0	84,0	83,0	79,0	79,0	78,0	73,0	72,2	76,6	70,2	80,0	66,8	63,8	60,0	56,6
Estonia	25,4	22,7	18,3	14,6	13,6	11,8	10,7	10,9	10,9	9,2	8,5	8,7	8,7	9,1	9,2	8,7	8,7	9,1
Hungary	121,4	91,1	82,4	75,4	74,3	75,4	76,2	74,3	71,9	69,5	69,1	64,9	63,1	65,5	72,7	78,0	78,8	68,5
Latvia	47,0	43,6	32,1	19,9	16,7	15,0	14,2	13,9	13,0	11,8	11,9	13,4	13,2	13,8	12,9	13,5	14,2	14,8
Lithuania	79,2	70,0	60,8	51,5	42,3	33,0	35,1	37,1	39,1	41,1	43,1	44,3	45,6	46,9	48,2	38,9	34,4	35,4
Malta	0,7	0,7	0,7	0,8	0,8	0,8	0,8	0,9	0,9	0,9	1,0	1,0	0,8	0,8	0,8	1,0	0,9	1,8
Poland	451,0	397,0	374,0	336,0	342,0	356,0	341,0	328,0	350,0	321,0	302,0	317,2	313,8	311,8	305,1	314,6	279,7	283,9
Slovac Republic	59,8	52,3	44,9	40,4	38,0	39,0	37,3	35,3	31,3	29,3	29,2	29,7	29,9	28,0	25,4	25,8	23,9	26,1
Slovenia	24,2	23,5	23,5	23,0	22,1	21,6	21,6	19,3	19,5	19,6	19,4	19,0	19,2	18,4	16,3	17,3	17,6	17,7
EU-10	966,3	837,7	750,6	658,6	639,0	641,0	621,5	604,4	620,5	581,6	562,6	581,3	569,7	579,9	563,0	566,9	523,3	518,9
Bulgaria	94,0	83,0	67,0	58,0	54,0	48,0	42,1	38,9	39,6	39,2	33,4	34,1	37,2	35,9	36,5	37,5	39,7	41,1
Romania	264,1	245,3	226,4	207,6	188,7	169,9	178,9	187,9	196,9	205,9	214,9	222,2	229,5	236,9	244,2	244,2	165,7	163,5
Bulgaria/Romania	358,1	328,3	293,4	265,6	242,7	217,9	221,0	226,8	236,5	245,1	248,3	256,3	266,8	272,8	280,7	281,7	205,4	204,5
EU-27	4737,6	4473,3	4303,9	4137,1	4074,6	4027,9	4013,0	4011,2	4044,6	4008,9	3955,5	3964,5	3924,7	3889,3	3888,2	3864,8	3767,8	3698,1

Source: CEIP/EMEP – website

Annex III: Methodological documentation of the estimation of commodity-based emission factors for EU and its trading partners

1 Introduction

This annex documents the methodology for estimating GHG emission coefficients per commodity and region for the entire world in order to aid quantification of GHG emissions and the effects of GHG abatement policies on a global scale. The estimates are based on inventories compiled at the Institute of Environmental Sustainability (EDGAR database[40]) following the methodology proposed by the International Panel on Climate Change (IPCC). These are then disaggregated to agricultural commodities using (i) supply tables from the FAOSTAT for agricultural commodities outside the EU, and (ii) detailed computations of emission coefficients per gas source and region in the EU-27.

The estimation problem is that of filling a matrix of emission coefficients given production (from FAOSTAT) weighted row sums (the Edgar inventories). It resembles the economic problem of estimating a Social Accounting Matrix given row and column sums, as discussed by Golan et al. (1994). The disaggregation is made using a Bayesian estimator that has been developed specifically for this purpose.

2 Methodology

The current study requires the estimation of commodity specific GHG emission coefficients for a set of 177 FAO world regions (EU excluded) and 25 agricultural commodities. Bottom-up computation of so many emission coefficients would be prohibitively expensive. Instead, we develop an estimation method that uses (1) existing GHG emission inventories per region, (2) production data per region, and (3) existing disaggregated emission coefficients for the EU countries and expert judgments to derive a complete dataset. The Bayesian approach proposed selects point estimates for coefficients by maximizing a prior probability distribution derived from existing information (e.g. from other models or case studies) and expert information on the precision of the prior modes, subject to moment (data) constraints requiring consistency with existing aggregate inventories reported in the EDGAR database . This is in line with the general approach for inference in ill-posed inverse problems described by O'Sullivan (1986). The necessary prior information on GHG emission coefficients is calculated with the CAPRI (Common Agricultural Policy Regionalized Impact) model at product level, i.e. emissions per kg of meat or litre of milk.

2.1 Derivation of commodity emission factors for the EU

CAPRI calculates GHG emission coefficients following the IPCC guidelines (IPCC 2006), based on *production activities*. However, each activity may have several outputs (e.g meat, milk, calves) and use intermediate outputs from other activities (e.g. young animals). In order to derive commodity-based coefficients from activity-based ones, consider a set of j = 1...J production activities that produce or use a set of i = 1...N commodities. Suppose that the production technology is of Leontief type with multiple inputs and outputs. Let the following coefficients and other data be given:

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[40] EDGAR database v4.00, including data of agricultural emissions for 1970-2005 for all available countries split by IPCC categories

l_{rj}	Activity levels of activity *j* in region *r*
x_{ri}	Output (net of losses) of commodity *i* in region *r*
u_{rji}	Input coefficients of commodity *i* to industry *j* (only non-tradable fodder and young animals) in region *r*.
m_{erj}	Emission of gas *e* in the process of industry *j* of region *r*, not accounting for indirect emissions via inputs accounted for in other industries
s_{erji}	Share of emission *e* from industry *j* allocated to product *i* in region *r*

The output b_{eri} of emission e attributable to production of commodity *i* in region r is then given by the following three equations:

$$b_{eri} x_{ri} = \sum_j \left[l_{rj} s_{erji} \left(\sum_k u_{rjk} c_{erk} + m_{erj} \right) \right] \qquad \text{for all e, r and i} \qquad \text{(iii.1)}$$

$$d_{ei} = \frac{\sum_r \max\left[0, x_{ri} - \sum_j l_{rj} u_{rji} \right] b_{eri}}{\sum_r \max\left[0, x_{ri} - \sum_j l_{rj} u_{rji} \right]} \qquad \text{(iii.2)}$$

$$c_{eri} \sum_j l_{rj} u_{rji} = b_{eri} \min\left[x_{ri}, \sum_j l_{rj} u_{rji} \right] + d_{ei} \max\left[0, \sum_j l_{rj} u_{rji} - x_{ri} \right] \qquad \text{(iii.3)}$$

The first equation (iii.1) states that the total emissions of e attributable to commodity i in region r (left hand side) is equal to the emissions given by the activity based accounting (right hand side), with consideration of input-output relationships. The inner bracket of the right hand side contains, for each activity, the sum of emissions due to input use of all *intermediate inputs* k (subset of all commodities *i*) plus the emissions produced in the process of industry j. The outer sum adds all such activity specific emissions and allocates them to the relevant commodity using the shares s, times the activity levels, to get the total emissions attributable to the relevant product.

Since young animals are tradable across regions, it is assumed that the commodity based emission coefficient of an input (*cerk*) is not necessarily the same as the coefficient of the same commodity as an output, if the input was (partly) produced in another region. The interregional trade is handled by the two equations (iii.2) and (iii.3).

Equation (iii.2) defines the pool-market average coefficient d_{ei} as the weighted sum of the emission coefficients of all net exports of the relevant commodity. The numerator sums up the emissions of all net exports of the commodity, and the denominator divides by the sum of net exports, to obtain the average coefficient of all net exporting regions.

Equation (iii.3) defines the emission factor for an input as the weighted sum of inputs produced in the region (assumed to be the smaller of production and demand) and imports from the pool (any net imports times the pool market coefficient d).

The above system of equations is in fact a square system (equal number of equations and unknowns) that is solved for the unknowns b, c and d using numerical techniques (the CPLEX linear programming solver or similar software). The resulting commodity-based emission coefficients are such that the sum of emissions from non-intermediate commodities almost exactly matches the sum of emissions from activities, but with two qualifications:

1. Trade in intermediate products takes place at the country level, due to the need to be able to run the above equation system for individual member states. Therefore, when countries in fact import young animals from other countries, we only compute input emission factors (d) from an envisaged *national* pool market.

2. In the model as in reality, some stock changes of animal herds take place. This implies that some young animals may be produced but never slaughtered or vice versa, causing the activity and commodity based accountings to deviate.

A final technicality worth mentioning concerns the emissions from the non-productive activities fallow land and set-aside. In order to also account for those in the commodity-based system, an artificial output called "rotational benefit" was invented, that is produced by the fallow land and consumed in proportion to crop shares by all activities. In that way, the emissions associated with non-productive land is indirectly mapped to commodities, corresponding to the view of the entire crop rotation as one system.

2.2 Deriving priors for emission factors from EU emission factors

The average emission factors per commodity computed for all EU regions are used as prior information in the rest of the world. The EU is a large and geographically heterogeneous region in the sense that production technologies and climate conditions differ widely between regions. In order to somewhat reflect the uncertainty in the prior, the standard error of each average EU emission factor was computed, and used as a measure of the inverse precision. The logic behind this step is that if the coefficient is stable across the diverse conditions of the EU, then it may also be stable across diverse conditions of the world. A more satisfactory approach, that is beyond the resource frame of this project, would be to regress each EU emission factor on biophysical and other condition of the EU regions, and use similar data for each World region to derive priors there as fitted values.

2.3 Estimation of emission factors for non-EU countries

The world is partitioned into 177 regions (excluding the EU) where EDGAR data is available, listed in Table A3 of the annex. Let *R* denote the set of regions for which we want to estimate the commodity based factors.

Let *K* denote the positions of the EDGAR inventories. The elements of *K* are listed in Table 2. Furthermore, let *J* denote the set of commodities, listed in Table 3, for which the estimations are to be performed. We want to estimate emission factors per region, commodity and emission category β_{rjk} for all $r \quad R$, $j \in J$ and $k \in K$ that are "as consistent as possible" with available annual inventories per year t,

$$\varepsilon_{rkt} \sum_{j} \beta_{rjk} x_{rjt} = Y_{rkt} \qquad \text{for all } r \in R \text{ and all k, t} \qquad \text{(iii.4)}$$

where x_{rj} is the total production of commodity *j* in region *r*, and ε_{rkt} is a multiplicative equation error. A multiplicative error was chosen based on the assumption that when the inventories Y were computed the errors in those computations were proportional to the magnitude of production, and that the errors in the production data is much smaller than the other errors in the computation. Only those years where there was both production data x and inventory data Y were used in the estimation. In general, this implied using the time series from 1990 to 2003.

The estimation problem as described above is generally ill-posed, because the number of emission factors to estimate is greater than the number of constraints except if the region produces fewer commodities than there are years of inventory and production data.

To resolve the ill-posed, additional information about the values of the emission factors is used, as discussed above, i.e. derived from existing emission computations for EU regions available in the CAPRI model. The prior density of the emission factors is assumed to be such that its mode is equal to the weighted average emission factor of the EU and its precision inversely proportional to the variance of the weighted mean and proportional to the prior total emissions attributable to each product. The latter requirement is chosen because it implies that if for some emission type k, the variance of the weighted means of the commodity specific emission factors are equal, and only a single year t is available for the estimation, then changing both factors with the same proportion of the mode will result in the same reduction in the posterior density, making the prior in a sense less informative when combined with the likelihood function below. The functional form of the prior density function is discussed in a separate section below. The equation errors e are assumed to come from normal distribution with mean 1 and standard deviation of 0.1(T - t + 1), implying, by the three-sigma-rule, that essentially all outcomes are in the range 0.7 to 1.3 in the last year but with greater dispersion in earlier years to render the estimation less sensitive to an unspecified trend error. The following Bayesian estimator is proposed in order to ensure consistency with any existing IPCC inventories and at the same time using any available prior information:

$$\max f\left(\mathbf{Y}_r \mid \mathbf{x}_r, \boldsymbol{\beta}_r \boldsymbol{\varepsilon}_r\right) p(\boldsymbol{\beta}_r \mid \mathbf{x}_r) p\left(\boldsymbol{\varepsilon}_r\right) \qquad \text{for each } r \in R \qquad \text{(iii.5)}$$

where *p*(·) are the prior density functions, *and* the likelihood function $f(Y_r|x_r,\beta_r,\varepsilon_r)$ is defined by

$$f\left(\mathbf{Y}_r \mid \mathbf{x}_r, \boldsymbol{\beta}_r, \boldsymbol{\varepsilon}_r\right) = \begin{cases} 1 & \text{if } \varepsilon_{rkt} \sum_{j} {}_{rjk} x_{rjt} = Y_{rkt} \\ 0 & \text{otherwise} \end{cases} \qquad \text{(iii.6)}$$

The likelihood function (iii.6) implies that any matrix β_r and error matrix ε_r that together with the production row vector $\mathbf{x}_r$ satisfy the data constraint (iii.4) are equally likely as any other to be the true emission factor matrix, whereas matrices not satisfying it are considered completely unlikely to be the true matrix. The posterior mode is used as point estimate of the emission factors. The posterior density function could be used to derive further inference about the parameters, such as posterior mean and variance, in a way similar to that described by Jansson and Heckelei (2010).

2.4 Prior density function for b

We were given the following expression of prior information from researchers involved in the computation of GHG inventories: "If the a-priori emission factor for commodity i is d times as reliable as that for commodity j, and the given inventory is such that there is a mismatch between a-priori information and data, then the necessary adjustment of a-priori factors shall be such that the factor for commodity j is d times more adjusted than that for commodity i."

The statement above refers to the behaviour of the point estimate resulting from the posterior mode estimation, and it can be used to derive the functional form of the prior density function. Assuming for simplicity that there is a single inventory Y and production data x_j for j = 1...J, and no equation error present, we note that the first order conditions to the problem

$$\arg\max_{h}\left\{\sum_{j} -d_j\alpha_j\left(h_j-1\right)^2 : \sum_{j}\tilde{\beta}_j h_j x_j = Y\right\} \quad \text{(iii.7)}$$

where α_j are unknown parameters of the prior density function for β, imply that

The verbal statement of the prior requires that

$$\frac{h_i-1}{h_j-1}=\frac{d_i}{d_j}$$

and it is easily seen that this is obtained if. $\frac{\alpha_i}{\alpha_j}=\frac{\tilde{\beta}_i x_i}{\tilde{\beta}_j x_j}$ Since the objective function of (iii.7) is the logarithm of the kernel of a normal density function, and the maximum is constant under monotonous transformations such as logarithms, this leads us to choosing the prior density

$$f\left(\beta_i \mid \mathbf{x},\tilde{\beta}_i\right)=C\exp\left[-d_i\frac{x_i\tilde{\beta}_i}{\sum_j x_j\tilde{\beta}_j}\left(\frac{\beta_i}{\tilde{\beta}_i}-1\right)^2\right] \quad \text{(iii.8)}$$

where C is a scaling factor which would make the function integrates to 1, $\tilde{\beta}$ is the prior mode defined by the mean emission factor computed for the EU, and d is the reliability index defined as the inverse of the variance of $\tilde{\beta}$.The chosen prior satisfies the verbal definition only with a single observation and no equation error. With many observation and equation errors, the data (Y) will increasingly determine the estimates, making the prior less and less relevant.

3 Data and results

3.1 Database on emissions

For our estimation exercise, we have used the EDGAR v4.0 database (http://edgar.jrc.ec.europa.eu), which covers 35 years (1970-2005) of greenhouse gas emissions by country and emission sector. The dataset does not only cover carbon dioxide (CO2) but also the other relevant greenhouse gases: methane (CH4), nitrous oxide (N2O), hydrofluorcarbons (HFCs), perfluorcarbons (PFCs) and sulfur hexafluoride (SF6). As the most relevant gases for agriculture, in our deliverable we concentrate on the estimation of emission coefficients for different sources for N2O and CH4. The EDGAR set of inventories were compiled from the perspective of providing good quality reference estimates of anthropogenic emission sources per source category, based on scientifically sound input data and recent guidelines on emission calculation methodologies. This was done be using (a) international statistics as activity data, since these are comparable between countries in definition and units, (b) emission factors from the relevant scientific literature, also common across countries when judged comparable, and (c) grid maps for allocating sectorial emissions of a country to a grid, in principle common per sector, thus achieving spatial consistency per sector across compounds and years. (Van Aardenne et al., 2001; Olivier et al., 1996)

3.2 Production and trade statistics

FAOSTAT (http://www.faostat.fao.org/) provides time-series and cross sectional data relating to food and agriculture for some 200 countries. Supply utilisation accounts (SUAs) are time series data dealing with statistics on supply (production, imports and stock changes) and utilisation (exports, feed + seed, food, and other use-including waste) which are kept physically together to allow the matching of food availability with food use. The statistical framework of SUAs has been developed with the aim of providing a useful statistical tool for the preparation, conduct and appraisal of government action aimed at developing and improving the agricultural and food sectors of national economies. The TradeSTAT module provides comprehensive, comparable and up-to-date annual trade statistics by country, region and economic country groups for about 600 individual food and agriculture commodities since 1961.

3.3 Results of estimations

The result of this research is a comprehensive set of GHG coefficients, disaggregated by product and region and consistent with existing EDGAR emission inventories. Such a dataset is highly valuable in itself, as it allows comparing agricultural across different countries on a product basis. Yet the final use for the results is to contribute to the on-going discussion about emission leakage (IPCC 2003).

As summary information, the presented exercise makes use of 23608 observations (information from EDGAR over countries, emission sources and years) and returns 3419 emission coefficients (for CAPRI-regions). In Table iii.1 we present a selection of results for 4 commodities, 7 countries and 2 emission sources[41].

The presented results show that a tonne of beef produced in EU (the prior) implies 429 kg of enteric fermentation methane emissions (CH4EN2), which is low or very low compared with the other countries in the table. In particular, Brazilian beef causes more than the double amount of emissions. Emissions

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[41] The full set of results is available in the CAPRI system

Table iii.1 Emission coefficients for selected countries, products and gas sources (in kg of methane or nitrous oxide per tonne of product)

		Potatoes		Wheat		Beef		Milk	
Region	**Gas**	**prior**	**est**	**prior**	**est**	**prior**	**est**	**prior**	**est**
ANZ	CH4EN2	-	-	-	-	429.22	617.59	29.30	43.71
	N2OSYN	0.08	0.08	0.50	0.28	3.07	1.35	0.18	0.17
ARG	CH4EN2	-	-	-	-	429.22	741.23	29.30	62.03
	N2OSYN	0.08	0.03	0.50	0.32	3.07	0.00	0.18	0.00
BRA	CH4EN2	-	-	-	-	429.22	904.31	29.30	77.16
	N2OSYN	0.08	0.06	0.50	0.45	3.07	0.34	0.18	0.04
CAN	CH4EN2	-	-	-	-	429.22	465.94	29.30	32.95
	N2OSYN	0.08	0.07	0.50	0.43	3.07	2.50	0.18	0.12
CHN	CH4EN2	-	-	-	-	429.22	719.89	29.30	65.30
	N2OSYN	0.08	0.09	0.50	0.51	3.07	3.45	0.18	0.21
ROW	CH4EN2	-	-	-	-	429.22	711.58	29.30	53.45
	N2OSYN	0.08	0.08	0.50	0.42	3.07	3.03	0.18	0.17
USA	CH4EN2	-	-	-	-	429.22	385.51	29.30	24.71
	N2OSYN	0.08	0.08	0.50	0.49	3.07	2.64	0.18	0.16

Note: Prior: prior mode for the emission coefficient (calculated for the EU-27), Est: average estimated emission coefficient (over years), ANZ: Australia and New Zealand, ARG: Argentina, BRA: Brazil, CAN: Canada, CHN: China, ROW: Rest of the world.

of N2O caused by application of synthetic fertilizers (N2OSYN) show a different pattern. For the crop products wheat and potatoes, the emissions per tonne of product are generally higher in the EU than in the compared countries except for China, which is on par.

Because of the use of fertilizers on some fodder crops (e.g. silage maize), considerable amounts N20SYN are also allocated to beef meat and milk. For the EU (prior) we computed about 3 kg emissions per tonne of meat. In all cases except for China, the emissions of N20SYN related to beef and milk are lower or much lower in the third countries shown. In particular, Brazilian beef appears to be responsible for only a tenth of the EU amount per ton, and in Argentina the estimated N2OSYN coefficients for beef and milk are zero.

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Annex IV: Balanced Fertilization in CAPRI

One of the technical scenarios in this study simulates a more balanced fertilization. Balanced fertilization means that crop need/uptake and the use of fertilizer and manure are more tuned to each other (cf. section 4.3.2). In this annex we delineate in a bit more technical detail how balanced fertilization is implemented in CAPRI.

Basically there are two parameters that account for the fact that in total, nitrogen supply to crops considerable exceeds the demand for harvested material:

- NAVFAC: Reflects the partial availability of nutrients from manure relative to mineral fertilizer. In the ex-post data consolidation process this is the key variable to accommodate the difference between nutrient retention by crops and nutrient supply from mineral and organic fertilizer and other sources. In many EU-15 countries this factor was trending upwards, reflecting efficiency improvements in fertilizer management, be it autonomous or enforced through more stringent environmental legislation.

- NUTFAC (with a multiplicative and additive component): This reflects the fact that farmers tend to apply more fertilizer than needed, even after accounting for partial availability of nutrients from manure. This is strongly pulled towards the expected mean (125%) in the ex-post data consolidation such that any trends or fluctuations are often weaker than for the NAVFACs. Nonetheless we may often observe in MS15 that their NUTFACs are slightly trending downwards whereas those from MS12 are often more irregular and sloping upwards, mirroring some catching up in fertilizer application after the turmoil of the transition phase.

In scenario BAL the difference of these parameters (from the baseline calibration) to one was reduced by 50% (unless the calibration result yielded NAVFAC > 1 or NUTFAC < 1). Such a pull towards one implies was a more efficient (organic and mineral) fertilizer management, including more careful establishments of fertilizer plans, more frequent soil analyses, perhaps split applications of fertilizer and more demanding crop management in general to bring about the increase in efficiency implied by a reduction in fertilizer input while maintaining output. As the overall N input into agriculture would be reduced, both NH3 and N2O emissions are be expected to decline.

To account for the additional management efforts we assumed a flat rate cost of 25 € per ha for a full elimination of over fertilization (12.5 € for a 50% cut) as in Witzke and Oenema (2007).

Annex V: Changes in consumer and producer prices for several activities under different scenarios

	REF		ESAA		ETSA		LTAX		STD		AMMO		BALF		LNF		ETSBL	
	Consumer Price	Producer Price	Consumer Price	Producer Price	Consumer Price	Producer Price	Consumer Price	Producer Price	Consumer Price	Producer Price	Consumer Price	Producer Price	Consumer Price	Producer Price	Consumer Price	Producer Price	Consumer Price	Producer Price
All primary agricultural output	2316,2	106,2	2358,4	122,0	2349,9	121,4	2359,6	117,3	2361,2	122,5	2318,2	106,7	2315,4	106,1	2319,9	107,9	2352,4	120,1
Cereals	2472,6	104,5	2485,9	112,6	2489,3	112,4	2465,5	98,2	2494,9	115,8	2472,5	104,2	2470,0	103,1	2470,7	103,6	2478,2	107,3
Oilseeds	2249,0	251,6	2252,0	270,3	2261,9	270,5	2234,2	247,3	2265,0	277,6	2248,6	251,5	2246,7	248,9	2239,5	249,0	2246,8	259,3
Other arable field crops	940,2	83,3	944,8	97,9	945,0	95,3	943,4	77,1	944,6	96,6	940,3	83,1	938,4	82,1	940,7	80,6	942,0	88,7
Vegetables and Permanent crops	1911,3	630,4	1916,0	632,9	1914,1	632,3	1911,3	629,8	1915,3	633,2	1911,3	630,4	1911,4	630,7	1910,7	629,1	1913,3	631,5
All other crops		1336,5		1336,0		1336,1		1336,1		1336,1		1336,5		1336,7		1336,4		1336,3
Fodder		11,8		12,1		12,5		12,2		12,1		11,8		11,8		11,9		12,3
Meat	5242,9	1594,6	5524,0	1818,9	5461,8	1764,8	5597,0	1870,3	5541,3	1827,5	5259,4	1608,8	5243,8	1596,7	5280,4	1632,8	5513,9	1815,0
Beef	7974,5	2932,6	8701,2	3616,8	8581,4	3524,2	8988,4	3934,3	8673,0	3597,6	7997,4	2954,1	7968,8	2927,3	7965,3	2922,1	8739,2	3685,4
Pork meat	5188,1	1263,6	5338,3	1410,8	5285,6	1355,0	5341,4	1407,1	5347,2	1412,4	5203,2	1278,6	5194,1	1269,8	5262,7	1334,6	5363,8	1429,9
Sheep and goat meat	9464,7	5246,7	9902,5	5696,2	9839,7	5683,0	10089,3	5987,6	9906,3	5725,8	9468,4	5249,9	9457,1	5240,3	9415,0	5186,5	9859,2	5667,7
Poultry meat	3058,7	1135,6	3273,7	1287,0	3224,5	1253,7	3316,0	1323,7	3305,3	1308,2	3071,9	1144,0	3056,2	1134,2	3063,0	1139,5	3193,1	1232,4
Cow and buffalo milk		291,8		330,1		321,8		340,7		330,4		292,6		291,8		292,4		313,3
Sheep and goat milk		743,5		847,9		830,1		888,0		857,5		745,5		743,8		747,8		807,5
Eggs	2982,4	665,0	3149,9	846,6	3098,7	775,6	3166,2	841,3	3160,9	837,6	2989,0	670,2	2980,7	664,0	3014,8	696,0	3100,9	778,8

	ESAA		ETSA		LTAX		STD		AMMO		BALF		LNF		ETSBL	
index REF = 100	**Consumer Price**	**Producer Price**	**Consumer Price**	**Producer Price**	**Consumer Price**	**Producer Price**	**Consumer Price**	**Producer Price**	**Consumer Price**	**Producer Price**	**Consumer Price**	**Producer Price**	**Consumer Price**	**Producer Price**	**Consumer Price**	**Producer Price**
All primary agricultural output	101,8	114,9	101,5	114,3	101,9	110,5	101,9	115,4	100,1	100,5	100,0	99,9	100,2	101,7	101,6	113,1
Cereals	100,5	107,8	100,7	107,6	99,7	94,0	100,9	110,8	100,0	99,8	99,9	98,7	99,9	99,2	100,2	102,8
Oilseeds	100,1	107,5	100,6	107,5	99,3	98,3	100,7	110,3	100,0	100,0	99,9	98,9	99,6	99,0	99,9	103,1
Other arable field crops	100,5	117,5	100,5	114,4	100,3	92,6	100,5	116,0	100,0	99,8	99,8	98,6	100,0	96,8	100,2	106,5
Vegetables and Permanent crops	100,2	100,4	100,1	100,3	100,0	99,9	100,2	100,4	100,0	100,0	100,0	100,0	100,0	99,8	100,1	100,2
All other crops		100,0		100,0		100,0		100,0		100,0		100,0		100,0		100,0
Fodder		102,7		105,5		103,0		102,2		100,2		99,6		100,3		103,7
Meat	105,4	114,1	104,2	110,7	106,8	117,3	105,7	114,6	100,3	100,9	100,0	100,1	100,7	102,4	105,2	113,8
Beef	109,1	123,3	107,6	120,2	112,7	134,2	108,8	122,7	100,3	100,7	99,9	99,8	99,9	99,6	109,6	125,7
Pork meat	102,9	111,6	101,9	107,2	103,0	111,4	103,1	111,8	100,3	101,2	100,1	100,5	101,4	105,6	103,4	113,2
Sheep and goat meat	104,6	108,6	104,0	108,3	106,6	114,1	104,7	109,1	100,0	100,1	99,9	99,9	99,5	98,9	104,2	108,0
Poultry meat	107,0	113,3	105,4	110,4	108,4	116,6	108,1	115,2	100,4	100,7	99,9	99,9	100,1	100,3	104,4	108,5
Cow and buffalo milk		113,1		110,3		116,7		113,2		100,3		100,0		100,2		107,3
Sheep and goat milk		114,0		111,6		119,4		115,3		100,3		100,0		100,6		108,6
Eggs	105,6	127,3	103,9	116,6	106,2	126,5	106,0	126,0	100,2	100,8	99,9	99,8	101,1	104,7	104,0	117,1

Annex VI: Tables supporting the economic analysis of the Emission Standard Scenario (STD)

Table 64. Cereal area and market balances per Member State according to the emission standard scenario

	Baseline REF (2020)				Emission standard in agriculture (STD, 2020)			
	Cereal area [1000 ha]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	Cereal area [% to REF]	Production [% to REF]	Demand [% to REF]	Net trade [Δ to REF]
Austria	718	5622	5103	520	-3,6	-4,4	-8,4	180
Belgium-Lux.	277	2538	7666	-5128	-2,6	-0,5	-6,8	511
Denmark	1549	10447	9407	1040	-0,5	1,8	-6,1	764
Finland	1253	4610	3802	808	-15,5	-13,8	-6,2	-400
France	8864	71125	33490	37635	-11,0	-9,8	-12,2	-2859
Germany	6748	54746	43364	11383	-15,2	-16,5	-7,1	-5964
Greece	1020	4305	5912	-1607	-9,2	-9,2	-13,3	394
Ireland	291	2514	3231	-717	-7,2	-5,9	-14,3	312
Italy	3979	24023	27494	-3471	-17,6	-20,7	-10,0	-2221
Netherlands	240	2175	9758	-7583	-17,7	-20,0	-18,7	1388
Portugal	262	982	4611	-3629	-0,5	-7,6	-4,5	133
Spain	6046	22157	32931	-10774	-7,0	-13,5	-13,5	1441
Sweden	1006	5542	3759	1783	-14,0	-9,4	-6,0	-297
United Kingdom	2743	20810	23752	-2942	-3,9	-4,2	-4,9	293
EU15	34997	231599	214280	17319	-10,8	-11,7	-9,7	-6325
Cyprus	50	82	842	-760	-19,3	-23,5	-28,3	219
Czech Republic	1586	8192	4966	3226	-0,8	2,1	-3,4	342
Estonia	361	1414	3850	-2436	5,3	9,7	1,8	67
Hungary	3004	16318	6552	9766	-20,7	-22,8	-12,9	-2871
Latvia	456	1474	972	503	-10,3	-6,2	-3,2	-61
Lithuania	804	3705	2560	1145	-8,1	-6,0	-3,1	-144
Malta	0	0	170	-169	-80,0	-87,1	-12,3	21
Poland	8982	38931	37335	1597	-17,6	-18,4	-8,3	-4057
Slovac Republic	817	3630	2599	1030	-2,4	0,8	-7,5	222
Slovenia	77	447	773	-326	-1,1	3,0	-10,2	92
10 New MS	16137	74194	60618	13576	-14,5	-14,6	-7,7	-6169
Bulgaria	1351	6255	4808	1447	-17,2	-16,4	-9,4	-574
Romania	4729	16857	14753	2103	-5,6	-3,7	-7,0	400
Bulgaria/Romania	6080	23112	19561	3550	-8,2	-7,1	-7,5	-174
EU27	57214	328905	294459	34446	-11,5	-12,0	-9,2	-12669

Table 65. Change in dairy cow supply balances according to the emission standard scenario

	Baseline REF (2020)			Emission standard in agriculture (STD, 2020)		
	Dairy herd [1000 hd]	**Yield kg/hd**	**Production [1000 t]**	**Dairy herd [% to REF]**	**Yield [% to REF]**	**Production [% to REF]**
Austria	504	6442	3244	-3,6	0,1	-3,5
Belgium-Lux.	610	5844	3566	-3,6	0,0	-3,5
Denmark	501	8752	4381	-2,0	0,1	-1,9
Finland	237	8469	2008	-1,3	0,1	-1,2
France	3395	6911	23462	-3,1	0,0	-3,1
Germany	3585	8142	29187	-2,4	-0,1	-2,5
Greece	134	5677	762	-5,2	0,3	-5,0
Ireland	1147	5031	5772	-2,5	0,2	-2,4
Italy	1849	6314	11676	-5,6	-0,0	-5,6
Netherlands	1593	7383	11760	-7,2	0,2	-7,0
Portugal	265	6911	1833	-1,9	0,2	-1,7
Spain	982	6700	6581	-4,2	0,5	-3,7
Sweden	335	9267	3107	-1,5	0,1	-1,4
United Kingdom	1774	7772	13786	-1,8	0,2	-1,6
EU15	16911	7162	121124	-3,4	0,1	-3,3
Cyprus	24	5816	141	-11,7	0,5	-11,3
Czech Republic	222	8365	1860	-0,8	0,1	-0,7
Estonia	73	6045	439	-1,0	0,1	-0,9
Hungary	195	7036	1369	-5,4	0,1	-5,2
Latvia	138	3816	527	-3,8	0,2	-3,6
Lithuania	323	4178	1348	-4,8	0,2	-4,6
Malta	9	7027	61	-11,6	0,3	-11,4
Poland	1659	5188	8610	-10,3	0,4	-9,9
Slovac Republic	106	6697	707	-1,9	0,2	-1,7
Slovenia	106	4927	520	-0,9	0,1	-0,8
EU10	2854	5460	15581	-7,4	0,6	-6,8
Bulgaria	360	3327	1198	-4,7	0,1	-4,6
Romania	1192	3434	4095	-5,7	0,2	-5,5
Bulgaria/Romania	1553	3409	5293	-5,5	0,2	-5,3
EU27	21317	6661	141998	-4,1	0,4	-3,8

Table 66. Beef cattle herds and beef market balances per Member State according to the emission standard scenario

	Baseline REF (2020)				Emission standard in agriculture (STD, 2020)			
	Beef herd [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Beef herd [% to REF]**	**Production [% to REF]**	**Demand [% to REF]**	**Net trade [Δ to REF]**
Austria	533	182	128	54	-26,5	-11,6	-0,8	-20
Belgium-Lux.	661	272	209	63	-34,1	-14,8	-0,2	-40
Denmark	324	110	212	-102	-12,2	-3,1	-1,8	0
Finland	228	78	115	-37	-13,6	-5,5	-0,1	-4
France	6379	1708	1654	54	-30,7	-12,4	-0,8	-198
Germany	1630	925	584	341	-27,7	-12,7	-0,6	-114
Greece	324	46	149	-103	-31,3	5,9	-4,4	9
Ireland	2654	621	108	513	-30,5	-9,5	-1,9	-57
Italy	2589	939	1273	-334	-29,0	-20,0	-1,5	-168
Netherlands	60	324	358	-35	-27,2	-6,1	-2,1	-12
Portugal	670	133	222	-89	-30,0	-1,2	-2,0	3
Spain	4498	722	818	-96	-38,1	-11,4	-4,5	-45
Sweden	350	124	293	-169	-14,1	-6,1	-1,1	-4
United Kingdom	3625	816	1364	-549	-18,7	-5,9	-2,0	-21
EU15	24524	7000	7488	-488	-29,2	-11,5	-1,7	-671
Cyprus	20	6	9	-4	-8,2	-14,0	-6,0	-0
Czech Republic	124	60	38	22	-8,6	-3,1	-15,4	4
Estonia	21	12	4	8	-0,7	1,5	-23,5	1
Hungary	53	33	40	-7	-28,5	-12,7	-25,2	6
Latvia	69	22	23	-1	5,5	4,3	-12,4	4
Lithuania	63	33	11	21	6,2	2,6	-6,5	2
Malta	3	1	9	-8	-29,5	-23,6	-6,0	0
Poland	761	326	223	103	-35,2	-30,2	-8,9	-79
Slovac Republic	37	32	34	-3	1,8	-0,1	-21,1	7
Slovenia	124	52	68	-16	-9,6	2,9	-13,6	11
10 New MS	1277	575	460	115	-23,5	-17,8	-12,6	-44
Bulgaria	229	63	89	-26	-1,5	-1,1	-26,5	23
Romania	873	205	229	-25	4,6	2,4	-25,6	64
Bulgaria/Romania	1102	267	318	-51	3,3	1,6	-25,9	86
EU27	26904	7842	8266	-424	-27,6	-11,5	-3,3	-629

Annex VII: Emission reduction commitments for the ESAA Scenario and the issue of "Hot Air"

In section 6.2 on the results of the ESAA scenario we describe, that when the respective GHG emission reduction commitments as given in the ESD (Effort Sharing Decision) are transferred to the agricultural sector, this would result in an agricultural GHG emission abatement of about 9.2% in the EU-27 (cf. column 2 in Table 67). Thus, to align the ESAA scenario with the emission abatement objective in the other policy scenarios (i.e. -20%), we take the distribution of the ESD commitment as starting point and adjusted it by a homogeneous top-up for all MS in order to achieve the envisaged overall reduction of 20% GHG emissions in the EU-27. This manual adjustment resulted in a shifter of about 8.7%, i.e. on top of the ESD commitment each MS would need to get an additional reduction obligation of 8.7% in order to achieve in CAPRI an overall GHG emission reduction in the EU-27 of about 20% (cf. column 3 in Table 67).

The complex part for the ESAA scenario construction was to achieve the overall 20% reduction by also taking into account the fact that for some MS/regions the respective reduction commitments are not binding, since the emission projections in the Reference Scenario (REF) for those entities are already lower than the commitments applied for the respective MS (cf. Table 23). This is the case in most EU-12 MS, as presented in the column "Hot Air" of Table 67. The modelling effect in CAPRI is that, depending on the number of iterations, the bounds around the reduction objectives can vary the result for the overall emission reduction in the EU-27. This variation is due to the fact that other constraints that have to do with agricultural production prevent some of the MS from fully using the emission possibilities they are actually allowed to. In order to get hold of the variation, we had to concentrate in the modelling on the achievement of the overall 20% emission reduction in the EU-27. As a result of this variation, the ESD +8.7% emission reduction objectives per MS actually get a bit softened, as can be seen in column 4 in Table 67.

Table 67. Emission commitments and effective emission reductions under the ESAA scenario for 2020 compared to the emissions in the base year 2

	ESD commitment	ESD + 8.7% commitment (ESAA)	ESD + 8.7% commitment (incl. Hot Air)	Hot Air
Austria	-16.0	-24.7	-24.3	
Belgium_Lux.	-15.0	-23.7	-22.1	
Denmark	-20.0	-28.7	-27.8	
Finland	-16.0	-24.7	-24.6	
France	-14.0	-22.7	-22.1	
Germany	-14.0	-22.7	-22.4	
Greece	-4.0	-12.7	-12.5	
Ireland	-20.0	-28.7	-28.4	
Italy	-13.0	-21.7	-21.0	
Netherlands	-16.0	-24.7	-23.6	
Portugal	1.0	-7.7	-8.2	
Spain	-10.0	-18.7	-17.9	
Sweden	-17.0	-25.7	-25.5	
United Kingdom	-16.0	-24.7	-24.1	
Bulgaria	20.0	11.3	-4.0	15.3
Cyprus	-5.0	-13.7	-12.4	
Czech Republic	9.0	0.3	-15.3	15.6
Estonia	11.0	2.3	-14.1	16.4
Hungary	10.0	1.3	0.7	
Latvia	17.0	8.3	-7.0	15.3
Lithuania	15.0	6.3	-9.0	15.3
Malta	5.0	-3.7	-2.2	
Poland	14.0	5.3	0.0	5.3
Romania	19.0	10.3	-7.6	17.9
Slovenia	4.0	-4.7	-12.0	7.3
Slovak Republic	13.0	4.3	-13.4	17.7
EU-27	9.2		-19.3	

Annex VIII: Tables supporting the economic analysis of the Effort Sharing Agreement in Agriculture Scenario (ESAA)

Table 68. Cereal area and market balances per Member State according to the effort sharing agreement in agriculture scenario

	Baseline REF (2020)				Effort sharing agreement (ESAA, 2020)			
	Cereal area [1000 ha]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	Cereal area [% to REF]	Production [% to REF]	Demand [% to REF]	Net trade [Δ to REF]
Austria	718	5622	5103	520	-5,4	-7,8	-9,1	23
Belgium-Lux.	277	2538	7666	-5128	-5,0	-2,8	-8,5	584
Denmark	1549	10447	9407	1040	-3,6	-2,5	-14,0	1050
Finland	1253	4610	3802	808	-21,3	-19,6	-7,6	-617
France	8864	71125	33490	37635	-13,0	-11,9	-13,3	-4009
Germany	6748	54746	43364	11383	-18,3	-19,8	-7,9	-7442
Greece	1020	4305	5912	-1607	-2,4	0,6	-10,0	617
Ireland	291	2514	3231	-717	-16,9	-15,9	-15,7	107
Italy	3979	24023	27494	-3471	-19,0	-22,5	-10,5	-2521
Netherlands	240	2175	9758	-7583	-25,3	-29,1	-22,6	1570
Portugal	262	982	4611	-3629	2,1	5,9	-0,6	85
Spain	6046	22157	32931	-10774	-6,5	-12,6	-12,6	1367
Sweden	1006	5542	3759	1783	-21,5	-16,7	-8,0	-624
United Kingdom	2743	20810	23752	-2942	-7,0	-8,3	-5,3	-465
EU15	34997	231599	214280	17319	-12,7	-14,2	-10,5	-10275
Cyprus	50	82	842	-760	-17,4	-26,7	-21,4	158
Czech Republic	1586	8192	4966	3226	2,0	3,5	1,1	228
Estonia	361	1414	3850	-2436	3,5	5,0	1,1	29
Hungary	3004	16318	6552	9766	-1,5	-1,4	-0,3	-216
Latvia	456	1474	972	503	5,3	7,5	1,9	93
Lithuania	804	3705	2560	1145	2,8	4,6	0,9	145
Malta	0	0	170	-169	-80,0	-87,1	-4,1	7
Poland	8982	38931	37335	1597	-2,7	-2,5	-1,4	-468
Slovac Republic	817	3630	2599	1030	0,4	1,8	0,4	56
Slovenia	77	447	773	-326	1,3	3,2	2,4	-4
10 New MS	16137	74194	60618	13576	-1,2	-0,7	-0,9	28
Bulgaria	1351	6255	4808	1447	3,0	5,0	-0,7	346
Romania	4729	16857	14753	2103	2,6	4,4	-0,9	872
Bulgaria/Romania	6080	23112	19561	3550	2,7	4,6	-0,8	1218
EU27	57214	328905	294459	34446	-7,8	-9,8	-7,9	-9029

Table 69. Change in dairy cow supply balances according to the effort sharing agreement in agriculture scenario

	Baseline REF (2020)			Effort sharing agreement (ESAA, 2020)		
	Dairy herd [1000 hd]	**Yield kg/hd**	**Production [1000 t]**	**Dairy herd [% to REF]**	**Yield [% to REF]**	**Production [% to REF]**
Austria	504	6442	3244	-4,9	0,1	-4,8
Belgium-Lux.	610	5844	3566	-4,5	0,0	-4,5
Denmark	501	8752	4381	-5,2	0,1	-5,1
Finland	237	8469	2008	-2,0	0,2	-1,8
France	3395	6911	23462	-3,9	-0,0	-3,9
Germany	3585	8142	29187	-3,2	-0,0	-3,2
Greece	134	5677	762	-2,3	0,2	-2,1
Ireland	1147	5031	5772	-3,8	0,2	-3,6
Italy	1849	6314	11676	-6,1	-0,0	-6,2
Netherlands	1593	7383	11760	-9,2	0,3	-9,0
Portugal	265	6911	1833	1,2	0,1	1,4
Spain	982	6700	6581	-3,7	0,5	-3,2
Sweden	335	9267	3107	-2,7	0,1	-2,6
United Kingdom	1774	7772	13786	-2,6	0,2	-2,4
EU15	16911	7162	121124	-4,3	0,1	-4,2
Cyprus	24	5816	141	-8,8	0,3	-8,5
Czech Republic	222	8365	1860	0,7	0,1	0,7
Estonia	73	6045	439	1,0	-0,0	1,0
Hungary	195	7036	1369	-0,3	0,0	-0,3
Latvia	138	3816	527	0,9	0,0	0,9
Lithuania	323	4178	1348	0,6	0,0	0,6
Malta	9	7027	61	-4,0	0,0	-4,0
Poland	1659	5188	8610	-0,3	0,1	-0,2
Slovac Republic	106	6697	707	1,3	-0,0	1,3
Slovenia	106	4927	520	0,7	0,0	0,7
EU10	2854	5460	15581	-0,0	0,0	0,0
Bulgaria	360	3327	1198	0,1	0,0	0,2
Romania	1192	3434	4095	-0,0	0,0	-0,0
Bulgaria/Romania	1553	3409	5293	0,0	0,0	0,0
EU27	21317	6661	141998	-3,4	-0,1	-3,5

Table 70. Beef cattle herds and beef market balances per Member State according to the effort sharing agreement in agriculture scenario

	Baseline REF (2020)				Effort sharing agreement (ESAA, 2020)			
	Beef herd [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Beef herd [% to REF]**	**Production [% to REF]**	**Demand [% to REF]**	**Net trade [Δ to REF]**
Austria	533	182	128	54	-36,3	-17,7	-1,2	-31
Belgium-Lux.	661	272	209	63	-42,2	-19,3	-0,6	-51
Denmark	324	110	212	-102	-24,9	-12,8	-2,2	-9
Finland	228	78	115	-37	-19,8	-9,9	-0,5	-7
France	6379	1708	1654	54	-35,9	-15,4	-1,3	-242
Germany	1630	925	584	341	-34,2	-16,6	-1,0	-147
Greece	324	46	149	-103	-15,2	13,4	-5,0	14
Ireland	2654	621	108	513	-44,0	-16,9	-2,4	-102
Italy	2589	939	1273	-334	-31,4	-21,9	-2,0	-180
Netherlands	60	324	358	-35	-34,4	-9,7	-2,6	-22
Portugal	670	133	222	-89	-9,8	12,1	-2,4	21
Spain	4498	722	818	-96	-36,1	-8,9	-5,1	-22
Sweden	350	124	293	-169	-26,1	-13,8	-1,5	-13
United Kingdom	3625	816	1364	-549	-24,6	-9,4	-2,5	-42
EU15	24524	7000	7488	-488	-33,3	-14,3	-2,2	-834
Cyprus	20	6	9	-4	-8,4	-12,2	-3,7	-0
Czech Republic	124	60	38	22	9,3	8,4	-10,6	9
Estonia	21	12	4	8	16,1	11,7	-18,4	2
Hungary	53	33	40	-7	5,9	4,7	-17,0	8
Latvia	69	22	23	-1	15,4	13,3	-8,3	5
Lithuania	63	33	11	21	14,2	8,7	-4,6	3
Malta	3	1	9	-8	-4,7	-5,0	-3,6	0
Poland	761	326	223	103	7,6	6,1	-6,3	34
Slovac Republic	37	32	34	-3	13,4	8,7	-14,2	8
Slovenia	124	52	68	-16	10,3	11,1	-9,3	12
10 New MS	1277	575	460	115	8,8	7,2	-8,7	81
Bulgaria	229	63	89	-26	11,7	9,3	-26,4	29
Romania	873	205	229	-25	12,9	10,2	-25,5	79
Bulgaria/Romania	1102	267	318	-51	12,7	10,0	-25,7	109
EU27	26904	7842	8266	-424	-29,4	-11,9	-3,5	-644

Annex IX: Tables supporting the economic analysis of the Emission Trading Scheme in Agriculture Scenario (ETSA)

Table 71. Cereal area and market balances per Member State according to emission trading scheme for agriculture scenario

	Baseline REF (2020)				Emission trading scheme agriculture (ETSA, 2020)			
	Cereal area [1000 ha]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	Cereal area [% to REF]	Production [% to REF]	Demand [% to REF]	Net trade [Δ to REF]
Austria	718	5622	5103	520	-2,9	-3,9	-7,6	165
Belgium-Lux.	277	2538	7666	-5128	-4,1	-3,5	-4,7	273
Denmark	1549	10447	9407	1040	-1,7	-0,7	-8,5	734
Finland	1253	4610	3802	808	-32,4	-30,9	-9,1	-1082
France	8864	71125	33490	37635	-7,0	-5,6	-9,1	-932
Germany	6748	54746	43364	11383	-10,3	-10,9	-5,6	-3508
Greece	1020	4305	5912	-1607	-6,7	-8,5	-11,3	302
Ireland	291	2514	3231	-717	-10,3	-10,3	-15,3	235
Italy	3979	24023	27494	-3471	-11,0	-12,0	-5,7	-1331
Netherlands	240	2175	9758	-7583	-4,0	-4,8	-10,5	919
Portugal	262	982	4611	-3629	-6,0	-20,6	-6,2	83
Spain	6046	22157	32931	-10774	-4,3	-9,9	-9,0	770
Sweden	1006	5542	3759	1783	-19,7	-16,2	-7,0	-635
United Kingdom	2743	20810	23752	-2942	-2,1	-2,9	-2,4	-22
EU15	34997	231599	214280	17319	-8,2	-8,3	-7,1	-4030
Cyprus	50	82	842	-760	-8,7	1,1	-8,5	73
Czech Republic	1586	8192	4966	3226	-9,2	-9,6	-9,3	-329
Estonia	361	1414	3850	-2436	-7,5	-6,7	0,6	-119
Hungary	3004	16318	6552	9766	-11,7	-11,8	-7,2	-1456
Latvia	456	1474	972	503	-41,7	-41,6	-5,5	-561
Lithuania	804	3705	2560	1145	-16,0	-16,9	-3,1	-544
Malta	0	0	170	-169	-100,0	-90,3	-3,1	5
Poland	8982	38931	37335	1597	-10,8	-10,0	-5,5	-1836
Slovac Republic	817	3630	2599	1030	-2,5	-0,3	-4,8	113
Slovenia	77	447	773	-326	2,0	4,1	-10,8	102
10 New MS	16137	74194	60618	13576	-11,4	-10,7	-5,6	-4553
Bulgaria	1351	6255	4808	1447	-15,1	-14,4	-9,8	-432
Romania	4729	16857	14753	2103	-8,1	-7,2	-7,4	-116
Bulgaria/Romania	6080	23112	19561	3550	-9,7	-9,2	-8,0	-548
EU27	57214	328905	294459	34446	-9,2	-8,9	-6,8	-9130

Table 72. Change in dairy cow supply balances according to emission trading scheme for agriculture scenario

	Baseline REF (2020)			Emission trading scheme agriculture (ETSA, 2020)		
	Dairy herd [1000 hd]	**Yield kg/hd**	**Production [1000 t]**	**Dairy herd [% to REF]**	**Yield [% to REF]**	**Production [% to REF]**
Austria	504	6442	3244	-3,1	0,1	-3,0
Belgium-Lux.	610	5844	3566	-2,7	0,1	-2,6
Denmark	501	8752	4381	-2,6	0,1	-2,5
Finland	237	8469	2008	-2,8	0,1	-2,7
France	3395	6911	23462	-2,1	0,1	-2,0
Germany	3585	8142	29187	-2,5	0,1	-2,4
Greece	134	5677	762	-3,2	0,4	-2,8
Ireland	1147	5031	5772	-3,2	0,2	-3,0
Italy	1849	6314	11676	-2,6	0,2	-2,4
Netherlands	1593	7383	11760	-2,9	0,1	-2,8
Portugal	265	6911	1833	-3,0	0,1	-2,9
Spain	982	6700	6581	-4,0	0,3	-3,7
Sweden	335	9267	3107	-2,3	0,1	-2,2
United Kingdom	1774	7772	13786	-2,8	0,2	-2,6
EU15	16911	7162	121124	-2,7	0,1	-2,5
Cyprus	24	5816	141	-3,1	0,1	-2,9
Czech Republic	222	8365	1860	-2,8	0,1	-2,7
Estonia	73	6045	439	-4,5	0,2	-4,3
Hungary	195	7036	1369	-3,2	0,1	-3,1
Latvia	138	3816	527	-6,7	0,2	-6,5
Lithuania	323	4178	1348	-6,3	0,2	-6,1
Malta	9	7027	61	-3,5	0,1	-3,3
Poland	1659	5188	8610	-6,8	0,2	-6,7
Slovac Republic	106	6697	707	-1,8	0,1	-1,8
Slovenia	106	4927	520	-2,3	0,1	-2,2
EU10	2854	5460	15581	-5,7	0,4	-5,3
Bulgaria	360	3327	1198	-6,0	0,1	-6,0
Romania	1192	3434	4095	-5,8	0,2	-5,7
Bulgaria/Romania	1553	3409	5293	-5,9	0,2	-5,7
EU27	21317	6661	141998	-3,3	0,4	-3,0

Table 73. Beef cattle herds and beef market balances per Member State according to the ETSA scenario

	Baseline REF (2020)				Emission trading scheme agriculture (ETSA, 2020)			
	Beef herd [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Beef herd [% to REF]**	**Production [% to REF]**	**Demand [% to REF]**	**Net trade [Δ to REF]**
Austria	533	182	128	54	-23,8	-10,1	-0,8	-17
Belgium-Lux.	661	272	209	63	-30,1	-12,5	-0,2	-33
Denmark	324	110	212	-102	-16,4	-5,8	-1,6	-3
Finland	228	78	115	-37	-31,9	-17,2	-0,1	-13
France	6379	1708	1654	54	-25,4	-9,6	-0,8	-150
Germany	1630	925	584	341	-26,5	-12,3	-0,6	-110
Greece	324	46	149	-103	-31,5	5,7	-4,3	9
Ireland	2654	621	108	513	-38,6	-15,3	-2,0	-93
Italy	2589	939	1273	-334	-17,0	-8,0	-1,5	-57
Netherlands	60	324	358	-35	-13,1	1,0	-2,0	10
Portugal	670	133	222	-89	-39,9	-7,2	-1,8	-6
Spain	4498	722	818	-96	-39,8	-9,8	-4,2	-36
Sweden	350	124	293	-169	-24,3	-12,8	-1,0	-13
United Kingdom	3625	816	1364	-549	-34,4	-15,2	-2,0	-97
EU15	24524	7000	7488	-488	-30,5	-10,5	-1,7	-609
Cyprus	20	6	9	-4	10,7	6,4	-5,0	1
Czech Republic	124	60	38	22	-35,7	-16,8	-13,4	-5
Estonia	21	12	4	8	-27,6	-16,4	-22,6	-1
Hungary	53	33	40	-7	-15,4	-5,3	-21,8	7
Latvia	69	22	23	-1	-6,9	-6,7	-10,7	1
Lithuania	63	33	11	21	-0,5	-1,8	-5,7	0
Malta	3	1	9	-8	1,6	-0,7	-5,0	0
Poland	761	326	223	103	-23,2	-20,0	-7,9	-47
Slovac Republic	37	32	34	-3	-6,2	-1,8	-18,1	6
Slovenia	124	52	68	-16	-23,9	-6,1	-11,8	5
10 New MS	1277	575	460	115	-21,1	-14,6	-11,0	-34
Bulgaria	229	63	89	-26	-5,2	-4,1	-24,2	19
Romania	873	205	229	-25	2,4	0,8	-23,4	55
Bulgaria/Romania	1102	267	318	-51	0,9	-0,3	-23,6	74
EU27	26904	7842	8266	-424	-28,7	-10,4	-3,0	-569

Annex X: Tables supporting the economic analysis of the Livestock Emission Tax Scenario (LTAX)

Table 74. Cereal area and market balances per Member State according to the livestock emission tax scenario

	Baseline REF (2020)				Livestock emission tax (LTAX, 2020)			
	Cereal area [1000 ha]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Cereal area [% to REF]**	**Production [% to REF]**	**Demand [% to REF]**	**Net trade [Δ to REF]**
Austria	718	5622	5103	520	-0,2	-3,5	-3,6	-12
Belgium-Lux.	277	2538	7666	-5128	12,4	9,6	-2,9	470
Denmark	1549	10447	9407	1040	1,8	-0,5	-13,4	1209
Finland	1253	4610	3802	808	-2,2	-4,4	-9,4	156
France	8864	71125	33490	37635	-2,2	-4,2	-7,3	-581
Germany	6748	54746	43364	11383	-0,4	-3,6	-4,1	-226
Greece	1020	4305	5912	-1607	-2,0	-4,9	-8,8	311
Ireland	291	2514	3231	-717	-0,2	-2,9	-28,7	853
Italy	3979	24023	27494	-3471	-2,1	-5,1	-5,7	340
Netherlands	240	2175	9758	-7583	6,3	3,5	-10,7	1119
Portugal	262	982	4611	-3629	5,9	-6,7	-10,1	401
Spain	6046	22157	32931	-10774	1,0	-4,3	-11,8	2921
Sweden	1006	5542	3759	1783	-2,5	-4,8	-3,7	-129
United Kingdom	2743	20810	23752	-2942	4,2	-0,7	-6,3	1339
EU15	34997	231599	214280	17319	-0,3	-3,5	-7,6	8170
Cyprus	50	82	842	-760	-3,1	-10,8	-5,4	37
Czech Republic	1586	8192	4966	3226	-0,7	-3,2	-13,9	425
Estonia	361	1414	3850	-2436	2,9	0,7	0,5	-10
Hungary	3004	16318	6552	9766	-2,5	-5,0	-9,2	-213
Latvia	456	1474	972	503	1,6	-1,3	-16,3	140
Lithuania	804	3705	2560	1145	2,0	-0,9	-7,0	146
Malta	0	0	170	-169	-100,0	-90,3	-1,5	2
Poland	8982	38931	37335	1597	-1,6	-4,1	-7,1	1057
Slovac Republic	817	3630	2599	1030	-0,6	-2,5	-6,1	66
Slovenia	77	447	773	-326	37,7	39,8	-1,3	188
10 New MS	16137	74194	60618	13576	-1,1	-3,5	-7,4	1836
Bulgaria	1351	6255	4808	1447	-3,6	-6,1	-10,5	120
Romania	4729	16857	14753	2103	-3,9	-7,2	-10,9	395
Bulgaria/Romania	6080	23112	19561	3550	-3,8	-6,9	-10,8	514
EU27	57214	328905	294459	34446	-0,9	-3,7	-7,8	10520

Table 75. Change in dairy cow supply balances according to the livestock emission tax scenario

	Baseline REF (2020)			Livestock emission tax (LTAX, 2020)		
	Dairy herd [1000 hd]	**Yield kg/hd**	**Production [1000 t]**	**Dairy herd [% to REF]**	**Yield [% to REF]**	**Production [% to REF]**
Austria	504	6442	3244	-4,5	0,1	-4,4
Belgium-Lux.	610	5844	3566	-4,6	0,1	-4,4
Denmark	501	8752	4381	-5,6	0,2	-5,4
Finland	237	8469	2008	-4,5	0,2	-4,3
France	3395	6911	23462	-3,7	0,1	-3,6
Germany	3585	8142	29187	-4,5	0,2	-4,3
Greece	134	5677	762	-5,5	0,7	-4,8
Ireland	1147	5031	5772	-3,7	0,3	-3,4
Italy	1849	6314	11676	-4,8	0,3	-4,5
Netherlands	1593	7383	11760	-4,8	0,1	-4,6
Portugal	265	6911	1833	-5,5	0,2	-5,3
Spain	982	6700	6581	-6,8	0,5	-6,3
Sweden	335	9267	3107	-3,1	0,1	-3,1
United Kingdom	1774	7772	13786	-3,9	0,2	-3,7
EU15	16911	7162	121124	-4,4	0,2	-4,2
Cyprus	24	5816	141	-4,3	0,2	-4,2
Czech Republic	222	8365	1860	-5,9	0,2	-5,7
Estonia	73	6045	439	-7,1	0,3	-6,8
Hungary	195	7036	1369	-6,3	0,2	-6,1
Latvia	138	3816	527	-11,8	0,4	-11,5
Lithuania	323	4178	1348	-12,1	0,5	-11,7
Malta	9	7027	61	-5,2	0,2	-5,0
Poland	1659	5188	8610	-11,7	0,4	-11,3
Slovac Republic	106	6697	707	-4,2	0,1	-4,1
Slovenia	106	4927	520	-4,5	0,2	-4,3
EU10	2854	5460	15581	-10,2	0,8	-9,5
Bulgaria	360	3327	1198	-10,7	0,2	-10,5
Romania	1192	3434	4095	-10,5	0,4	-10,1
Bulgaria/Romania	1553	3409	5293	-10,5	0,3	-10,2
EU27	21317	6661	141998	-5,6	0,6	-5,0

Table 76. Beef cattle herds and beef market balances per Member State according to the livestock emission tax scenario

	Baseline REF (2020)				Livestock emission tax (LTAX, 2020)			
	Beef herd [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Beef herd [% to REF]**	**Production [% to REF]**	**Demand [% to REF]**	**Net trade [Δ to REF]**
Austria	533	182	128	54	-36,3	-15,4	-1,1	-27
Belgium-Lux.	661	272	209	63	-51,0	-21,7	-0,2	-59
Denmark	324	110	212	-102	-20,3	-9,7	-2,4	-6
Finland	228	78	115	-37	-34,1	-17,9	-0,1	-14
France	6379	1708	1654	54	-38,5	-15,6	-1,2	-246
Germany	1630	925	584	341	-43,2	-21,2	-0,8	-192
Greece	324	46	149	-103	-36,5	11,3	-6,6	15
Ireland	2654	621	108	513	-47,3	-19,4	-3,3	-117
Italy	2589	939	1273	-334	-29,1	-15,4	-2,2	-117
Netherlands	60	324	358	-35	-20,5	1,6	-3,0	16
Portugal	670	133	222	-89	-50,0	-12,3	-2,8	-10
Spain	4498	722	818	-96	-45,3	-13,1	-6,7	-40
Sweden	350	124	293	-169	-34,2	-17,8	-1,5	-18
United Kingdom	3625	816	1364	-549	-40,9	-16,9	-3,2	-94
EU15	24524	7000	7488	-488	-40,6	-15,7	-2,6	-907
Cyprus	20	6	9	-4	20,3	12,5	-9,2	2
Czech Republic	124	60	38	22	-54,9	-34,2	-20,3	-13
Estonia	21	12	4	8	-45,8	-25,9	-27,2	-2
Hungary	53	33	40	-7	-26,1	-11,2	-35,7	11
Latvia	69	22	23	-1	-14,3	-14,1	-16,5	1
Lithuania	63	33	11	21	-4,8	-6,1	-10,4	-1
Malta	3	1	9	-8	3,8	0,0	-9,2	1
Poland	761	326	223	103	-41,0	-35,2	-13,5	-85
Slovac Republic	37	32	34	-3	-15,6	-6,3	-29,9	8
Slovenia	124	52	68	-16	-41,9	-12,6	-19,9	7
10 New MS	1277	575	460	115	-36,9	-26,9	-18,2	-71
Bulgaria	229	63	89	-26	-7,6	-6,6	-33,3	25
Romania	873	205	229	-25	6,0	2,6	-32,5	80
Bulgaria/Romania	1102	267	318	-51	3,2	0,4	-32,7	105
EU27	26904	7842	8266	-424	-38,6	-16,0	-4,6	-873

Annex XI: Tables supporting the economic analysis of the Ammonia Measures Scenario (AMMO)

Table 77. Cereal area and market balances per Member State according to the ammonia measures scenario

	Baseline REF (2020)				Ammonia measures scenario (AMMO, 2020)			
	Cereal area [1000 ha]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	Cereal area [% to REF]	Production [% to REF]	Demand [% to REF]	Net trade [Δ to REF]
Austria	718	5622	5103	520	0,1	0,2	-1,3	77
Belgium-Lux.	277	2538	7666	-5128	0,6	0,7	-0,0	20
Denmark	1549	10447	9407	1040	-0,0	-0,1	-1,5	129
Finland	1253	4610	3802	808	-0,1	-0,1	0,1	-9
France	8864	71125	33490	37635	-0,0	-0,1	-0,4	57
Germany	6748	54746	43364	11383	-0,0	-0,0	0,2	-108
Greece	1020	4305	5912	-1607	-0,1	-0,1	-1,5	85
Ireland	291	2514	3231	-717	0,5	0,4	-3,7	129
Italy	3979	24023	27494	-3471	-0,1	-0,2	0,1	-60
Netherlands	240	2175	9758	-7583	0,0	-0,1	0,3	-28
Portugal	262	982	4611	-3629	0,1	-0,2	-0,4	15
Spain	6046	22157	32931	-10774	-0,1	-0,2	-0,2	34
Sweden	1006	5542	3759	1783	-0,1	-0,1	0,3	-17
United Kingdom	2743	20810	23752	-2942	0,0	-0,1	0,2	-66
EU15	34997	231599	214280	17319	-0,0	-0,1	-0,2	258
Cyprus	50	82	842	-760	-0,0	-0,1	-0,9	8
Czech Republic	1586	8192	4966	3226	-0,0	-0,0	-0,1	3
Estonia	361	1414	3850	-2436	-0,0	-0,0	0,0	-0
Hungary	3004	16318	6552	9766	-0,1	-0,1	-0,1	-7
Latvia	456	1474	972	503	0,0	-0,0	-0,9	9
Lithuania	804	3705	2560	1145	0,1	0,0	-0,4	13
Malta	0	0	170	-169	100,0	64,5	0,2	-0
Poland	8982	38931	37335	1597	-0,0	-0,0	0,1	-41
Slovac Republic	817	3630	2599	1030	-0,0	-0,0	-0,0	-1
Slovenia	77	447	773	-326	1,7	1,9	-4,7	45
10 New MS	16137	74194	60618	13576	-0,0	-0,0	-0,1	28
Bulgaria	1351	6255	4808	1447	-0,0	-0,0	0,0	-5
Romania	4729	16857	14753	2103	-0,0	-0,0	0,1	-19
Bulgaria/Romania	6080	23112	19561	3550	-0,0	-0,0	0,1	-24
EU27	57214	328905	294459	34446	-0,0	-0,1	-0,2	262

Table 78. Change in dairy cow supply balances according to the ammonia measures scenario

	Baseline REF (2020)			Ammonia measures scenario (AMMO, 2020)		
	Dairy herd [1000 hd]	**Yield kg/hd**	**Production [1000 t]**	**Dairy herd [% to REF]**	**Yield [% to REF]**	**Production [% to REF]**
Austria	504	6442	3244	-0,3	0,0	-0,3
Belgium-Lux.	610	5844	3566	-0,0	0,0	-0,0
Denmark	501	8752	4381	-0,1	0,0	-0,1
Finland	237	8469	2008	-0,2	0,0	-0,2
France	3395	6911	23462	-0,0	0,0	-0,0
Germany	3585	8142	29187	-0,1	0,0	-0,1
Greece	134	5677	762	-0,2	0,0	-0,2
Ireland	1147	5031	5772	-0,1	0,0	-0,0
Italy	1849	6314	11676	-0,0	0,0	-0,0
Netherlands	1593	7383	11760	0,0	0,0	0,0
Portugal	265	6911	1833	-0,0	0,0	-0,0
Spain	982	6700	6581	-0,1	0,0	-0,1
Sweden	335	9267	3107	-0,0	0,0	-0,0
United Kingdom	1774	7772	13786	-0,2	0,0	-0,1
EU15	16911	7162	121124	-0,1	0,0	-0,1
Cyprus	24	5816	141	-0,3	0,0	-0,3
Czech Republic	222	8365	1860	-0,1	0,0	-0,1
Estonia	73	6045	439	0,0	-0,0	-0,0
Hungary	195	7036	1369	-0,1	0,0	-0,1
Latvia	138	3816	527	-0,3	0,0	-0,2
Lithuania	323	4178	1348	-0,5	0,0	-0,5
Malta	9	7027	61	0,0	0,0	0,0
Poland	1659	5188	8610	-0,1	0,0	-0,1
Slovac Republic	106	6697	707	0,0	-0,0	0,0
Slovenia	106	4927	520	-0,8	0,0	-0,7
EU10	2854	5460	15581	-0,2	0,0	-0,1
Bulgaria	360	3327	1198	0,0	0,0	0,0
Romania	1192	3434	4095	0,0	-0,0	0,0
Bulgaria/Romania	1553	3409	5293	0,0	0,0	0,0
EU27	21317	6661	141998	-0,1	0,0	-0,1

Table 79. Beef cattle herds and beef market balances per Member State according to the ammonia measures scenario

	Baseline REF (2020)				Ammonia measures scenario (AMMO, 2020)			
	Beef herd [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Beef herd [% to REF]**	**Production [% to REF]**	**Demand [% to REF]**	**Net trade [Δ to REF]**
Austria	533	182	128	54	-0,8	-0,4	-0,0	-1
Belgium-Lux.	661	272	209	63	-0,2	-0,2	0,0	-1
Denmark	324	110	212	-102	-1,1	-0,8	-0,0	-1
Finland	228	78	115	-37	-0,2	-0,4	-0,0	-0
France	6379	1708	1654	54	-0,5	-0,3	-0,0	-5
Germany	1630	925	584	341	-1,2	-0,6	-0,0	-5
Greece	324	46	149	-103	-4,1	-1,1	-0,1	-0
Ireland	2654	621	108	513	-3,5	0,2	0,0	1
Italy	2589	939	1273	-334	-0,6	-0,2	-0,0	-1
Netherlands	60	324	358	-35	-0,4	-0,4	-0,1	-1
Portugal	670	133	222	-89	-1,4	-0,3	-0,0	-0
Spain	4498	722	818	-96	0,1	-0,3	-0,1	-1
Sweden	350	124	293	-169	-0,3	-0,2	-0,0	-0
United Kingdom	3625	816	1364	-549	-0,3	-0,3	-0,0	-2
EU15	24524	7000	7488	-488	-0,8	-0,3	-0,0	-18
Cyprus	20	6	9	-4	-0,5	0,0	0,0	0
Czech Republic	124	60	38	22	-1,4	-0,3	-0,3	-0
Estonia	21	12	4	8	-0,7	-0,4	-0,5	-0
Hungary	53	33	40	-7	-0,2	-0,1	-0,5	0
Latvia	69	22	23	-1	-1,0	-0,7	-0,2	-0
Lithuania	63	33	11	21	-2,1	-1,2	-0,1	-0
Malta	3	1	9	-8	0,0	-0,7	-0,1	-0
Poland	761	326	223	103	0,0	0,0	-0,1	0
Slovac Republic	37	32	34	-3	0,2	0,0	-0,4	0
Slovenia	124	52	68	-16	-5,1	-2,3	-0,2	-1
10 New MS	1277	575	460	115	-0,8	-0,3	-0,2	-1
Bulgaria	229	63	89	-26	0,1	0,0	-0,6	1
Romania	873	205	229	-25	0,0	0,0	-0,5	1
Bulgaria/Romania	1102	267	318	-51	0,1	0,0	-0,6	2
EU27	26904	7842	8266	-424	-0,8	-0,3	-0,1	-17

Annex XII: Tables supporting the economic analysis of the More Balanced Fertilization Scenario (BALF)

Table 80. Cereal area and market balances per Member State according to the more balanced fertilization scenario

	Baseline REF (2020)				Reduced over-fertilisation (BALF, 2020)			
	Cereal area [1000 ha]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	Cereal area [% to REF]	Production [% to REF]	Demand [% to REF]	Net trade [Δ to REF]
Austria	718	5622	5103	520	-0,3	-0,7	1,1	-94
Belgium-Lux.	277	2538	7666	-5128	2,1	2,3	-0,3	82
Denmark	1549	10447	9407	1040	2,7	3,3	-2,2	550
Finland	1253	4610	3802	808	-0,0	-0,2	1,1	-50
France	8864	71125	33490	37635	1,0	0,9	0,0	638
Germany	6748	54746	43364	11383	-0,1	-0,0	0,5	-223
Greece	1020	4305	5912	-1607	-0,1	0,2	0,6	-25
Ireland	291	2514	3231	-717	0,4	0,4	-0,3	18
Italy	3979	24023	27494	-3471	-0,9	-0,7	0,5	-320
Netherlands	240	2175	9758	-7583	1,7	3,1	-0,5	121
Portugal	262	982	4611	-3629	-3,2	1,1	-0,3	23
Spain	6046	22157	32931	-10774	0,0	1,1	-0,6	442
Sweden	1006	5542	3759	1783	0,7	0,5	0,7	3
United Kingdom	2743	20810	23752	-2942	-0,1	-0,1	0,5	-148
EU15	34997	231599	214280	17319	0,3	0,5	0,1	1018
Cyprus	50	82	842	-760	2,3	9,3	-0,3	10
Czech Republic	1586	8192	4966	3226	0,1	0,3	0,0	27
Estonia	361	1414	3850	-2436	-1,8	-1,9	-0,1	-25
Hungary	3004	16318	6552	9766	-0,2	-0,0	0,1	-6
Latvia	456	1474	972	503	-1,7	-1,3	-0,4	-15
Lithuania	804	3705	2560	1145	-0,5	-0,1	-0,3	5
Malta	0	0	170	-169	-80,0	-67,7	-0,6	1
Poland	8982	38931	37335	1597	-0,7	-0,5	-0,1	-172
Slovac Republic	817	3630	2599	1030	-0,2	-0,1	0,1	-5
Slovenia	77	447	773	-326	2,6	3,1	1,2	4
10 New MS	16137	74194	60618	13576	-0,5	-0,3	-0,0	-177
Bulgaria	1351	6255	4808	1447	0,2	-0,0	0,9	-46
Romania	4729	16857	14753	2103	1,3	1,2	0,1	188
Bulgaria/Romania	6080	23112	19561	3550	1,0	0,9	0,3	142
EU27	57214	328905	294459	34446	0,1	0,3	0,1	983

Table 81. Change in dairy cow supply balances according to the more balanced fertilization scenario

	Baseline REF (2020)			Reduced over-fertilisation (BALF, 2020)		
	Dairy herd [1000 hd]	**Yield kg/hd**	**Production [1000 t]**	**Dairy herd [% to REF]**	**Yield [% to REF]**	**Production [% to REF]**
Austria	504	6442	3244	0,0	0,0	0,0
Belgium-Lux.	610	5844	3566	0,0	-0,0	0,0
Denmark	501	8752	4381	-0,6	0,0	-0,6
Finland	237	8469	2008	0,2	-0,0	0,2
France	3395	6911	23462	-0,0	-0,0	-0,1
Germany	3585	8142	29187	0,0	-0,0	0,0
Greece	134	5677	762	0,0	0,0	0,1
Ireland	1147	5031	5772	0,1	-0,0	0,1
Italy	1849	6314	11676	0,0	-0,0	0,0
Netherlands	1593	7383	11760	0,1	-0,0	0,1
Portugal	265	6911	1833	-0,1	0,0	-0,1
Spain	982	6700	6581	-0,2	-0,0	-0,2
Sweden	335	9267	3107	0,0	-0,0	0,0
United Kingdom	1774	7772	13786	0,1	-0,0	0,1
EU15	16911	7162	121124	-0,0	-0,0	-0,0
Cyprus	24	5816	141	-0,1	-0,0	-0,1
Czech Republic	222	8365	1860	0,0	-0,0	0,0
Estonia	73	6045	439	0,0	-0,0	0,0
Hungary	195	7036	1369	0,0	-0,0	-0,0
Latvia	138	3816	527	0,0	0,0	0,0
Lithuania	323	4178	1348	0,0	-0,0	0,0
Malta	9	7027	61	-0,1	0,0	-0,1
Poland	1659	5188	8610	0,0	0,0	0,0
Slovac Republic	106	6697	707	0,0	-0,0	-0,0
Slovenia	106	4927	520	0,1	-0,0	0,1
EU10	2854	5460	15581	0,0	-0,0	0,0
Bulgaria	360	3327	1198	-0,1	0,0	-0,1
Romania	1192	3434	4095	-0,3	0,0	-0,2
Bulgaria/Romania	1553	3409	5293	-0,2	0,0	-0,2
EU27	21317	6661	141998	-0,0	0,0	-0,0

Table 82. *Beef cattle herds and beef market balances per Member State according to the more balanced fertilization scenario*

	Baseline REF (2020)				Reduced over-fertilisation (BALF, 2020)			
	Beef herd [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Beef herd [% to REF]**	**Production [% to REF]**	**Demand [% to REF]**	**Net trade [Δ to REF]**
Austria	533	182	128	54	-0,2	-0,0	0,0	-0
Belgium-Lux.	661	272	209	63	0,7	0,3	0,0	1
Denmark	324	110	212	-102	-3,3	-1,7	0,0	-2
Finland	228	78	115	-37	1,1	0,5	0,0	0
France	6379	1708	1654	54	-0,0	-0,0	0,0	-1
Germany	1630	925	584	341	-0,0	0,0	0,0	-0
Greece	324	46	149	-103	0,3	0,1	0,1	-0
Ireland	2654	621	108	513	0,9	0,5	0,1	3
Italy	2589	939	1273	-334	0,1	0,1	0,0	1
Netherlands	60	324	358	-35	-0,6	-0,1	0,0	-0
Portugal	670	133	222	-89	0,6	0,0	0,0	0
Spain	4498	722	818	-96	0,4	0,3	0,0	2
Sweden	350	124	293	-169	0,1	0,0	0,0	0
United Kingdom	3625	816	1364	-549	1,1	0,6	0,0	5
EU15	24524	7000	7488	-488	0,3	0,1	0,0	8
Cyprus	20	6	9	-4	-0,3	0,4	0,1	0
Czech Republic	124	60	38	22	-0,1	-0,2	0,1	-0
Estonia	21	12	4	8	0,1	0,0	0,2	-0
Hungary	53	33	40	-7	-0,2	-0,1	0,2	-0
Latvia	69	22	23	-1	0,1	0,2	0,1	0
Lithuania	63	33	11	21	0,1	0,1	0,0	0
Malta	3	1	9	-8	-0,6	-1,4	0,0	-0
Poland	761	326	223	103	0,0	0,0	0,1	-0
Slovac Republic	37	32	34	-3	-0,1	-0,2	0,1	-0
Slovenia	124	52	68	-16	0,7	0,2	0,1	0
10 New MS	1277	575	460	115	0,1	0,0	0,1	-0
Bulgaria	229	63	89	-26	-0,3	-0,3	0,1	-0
Romania	873	205	229	-25	-0,5	-0,4	0,1	-1
Bulgaria/Romania	1102	267	318	-51	-0,4	-0,4	0,1	-1
EU27	26904	7842	8266	-424	0,3	0,1	0,0	6

Annex XIII: Tables supporting the economic analysis of the Low Nitrogen Feeding Scenario (LNF)

Table 83. Cereal area and market balances per Member State according to the low nitrogen feeding scenario

	Baseline REF (2020)				Low nitrogen feeding (LNF, 2020)			
	Cereal area [1000 ha]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	Cereal area [% to REF]	Production [% to REF]	Demand [% to REF]	Net trade [Δ to REF]
Austria	718	5622	5103	520	0,4	0,3	-2,4	143
Belgium-Lux.	277	2538	7666	-5128	-0,4	-0,5	1,5	-126
Denmark	1549	10447	9407	1040	0,6	0,5	-3,2	353
Finland	1253	4610	3802	808	-0,1	-0,2	0,0	-11
France	8864	71125	33490	37635	0,2	0,1	-3,8	1357
Germany	6748	54746	43364	11383	0,5	0,4	-0,4	386
Greece	1020	4305	5912	-1607	0,3	-0,0	-0,6	32
Ireland	291	2514	3231	-717	3,5	3,7	25,8	-741
Italy	3979	24023	27494	-3471	0,5	0,1	-0,1	52
Netherlands	240	2175	9758	-7583	1,0	0,8	-1,5	168
Portugal	262	982	4611	-3629	1,1	0,4	1,1	-46
Spain	6046	22157	32931	-10774	0,8	0,1	-0,2	101
Sweden	1006	5542	3759	1783	0,6	0,4	9,7	-343
United Kingdom	2743	20810	23752	-2942	2,1	1,7	6,4	-1163
EU15	34997	231599	214280	17319	0,6	0,4	0,3	161
Cyprus	50	82	842	-760	-0,4	0,4	-8,7	74
Czech Republic	1586	8192	4966	3226	0,4	0,2	-3,8	207
Estonia	361	1414	3850	-2436	2,7	2,5	1,4	-17
Hungary	3004	16318	6552	9766	0,5	0,4	1,5	-35
Latvia	456	1474	972	503	3,5	3,0	10,5	-58
Lithuania	804	3705	2560	1145	3,5	3,0	3,1	32
Malta	0	0	170	-169	-100,0	-90,3	-0,3	0
Poland	8982	38931	37335	1597	0,4	0,3	0,8	-181
Slovac Republic	817	3630	2599	1030	-0,1	-0,2	-0,2	-2
Slovenia	77	447	773	-326	-2,3	-2,8	-0,7	-7
10 New MS	16137	74194	60618	13576	0,7	0,5	0,6	14
Bulgaria	1351	6255	4808	1447	1,1	1,2	2,8	-59
Romania	4729	16857	14753	2103	1,5	1,6	2,1	-38
Bulgaria/Romania	6080	23112	19561	3550	1,4	1,5	2,3	-97
EU27	57214	328905	294459	34446	0,7	0,5	0,5	79

Table 84. Change in dairy cow supply balances according to the Low Nitrogen Feeding scenario

	Baseline REF (2020)			Low nitrogen feeding (LNF, 2020)		
	Dairy herd [1000 hd]	**Yield kg/hd**	**Production [1000 t]**	**Dairy herd [% to REF]**	**Yield [% to REF]**	**Production [% to REF]**
Austria	504	6442	3244	0,1	0,0	0,1
Belgium-Lux.	610	5844	3566	0,0	0,0	0,0
Denmark	501	8752	4381	0,2	-0,0	0,2
Finland	237	8469	2008	-0,8	0,0	-0,8
France	3395	6911	23462	-0,1	-0,0	-0,1
Germany	3585	8142	29187	-0,2	0,0	-0,1
Greece	134	5677	762	-0,1	0,1	0,0
Ireland	1147	5031	5772	0,8	0,0	0,9
Italy	1849	6314	11676	0,0	-0,0	0,0
Netherlands	1593	7383	11760	-0,1	0,0	-0,1
Portugal	265	6911	1833	0,2	-0,0	0,2
Spain	982	6700	6581	-0,4	0,1	-0,3
Sweden	335	9267	3107	0,3	-0,0	0,3
United Kingdom	1774	7772	13786	0,7	-0,0	0,7
EU15	16911	7162	121124	0,0	-0,0	0,0
Cyprus	24	5816	141	-0,1	-0,0	-0,1
Czech Republic	222	8365	1860	0,4	-0,0	0,4
Estonia	73	6045	439	-0,2	0,1	-0,1
Hungary	195	7036	1369	0,4	-0,0	0,4
Latvia	138	3816	527	2,2	-0,1	2,1
Lithuania	323	4178	1348	0,3	-0,0	0,3
Malta	9	7027	61	-0,3	0,0	-0,3
Poland	1659	5188	8610	1,0	-0,0	1,0
Slovac Republic	106	6697	707	0,3	-0,0	0,3
Slovenia	106	4927	520	-0,1	-0,0	-0,1
EU10	2854	5460	15581	0,8	-0,1	0,7
Bulgaria	360	3327	1198	0,2	0,0	0,2
Romania	1192	3434	4095	-0,1	0,1	-0,0
Bulgaria/Romania	1553	3409	5293	-0,0	0,0	0,0
EU27	21317	6661	141998	0,1	-0,0	0,1

Table 85. Beef cattle herds and beef market balances per Member State according to the Low Nitrogen Feeding scenario

	Baseline REF (2020)				Low nitrogen feeding (LNF, 2020)			
	Beef herd [1000 hd]	**Production [1000 t]**	**Demand [1000 t]**	**Net trade [1000 t]**	**Beef herd [% to REF]**	**Production [% to REF]**	**Demand [% to REF]**	**Net trade [Δ to REF]**
Austria	533	182	128	54	1,4	1,2	0,0	2
Belgium-Lux.	661	272	209	63	1,6	0,8	0,0	2
Denmark	324	110	212	-102	3,4	2,1	0,1	2
Finland	228	78	115	-37	-2,8	-1,0	0,0	-1
France	6379	1708	1654	54	-0,3	-0,2	0,1	-5
Germany	1630	925	584	341	-1,0	0,0	0,0	0
Greece	324	46	149	-103	-1,7	0,7	0,2	-0
Ireland	2654	621	108	513	6,7	2,6	0,5	16
Italy	2589	939	1273	-334	0,1	-0,4	0,1	-5
Netherlands	60	324	358	-35	-0,4	0,9	0,1	3
Portugal	670	133	222	-89	5,2	0,0	0,1	-0
Spain	4498	722	818	-96	-0,8	-0,5	0,2	-5
Sweden	350	124	293	-169	2,0	1,2	0,1	1
United Kingdom	3625	816	1364	-549	6,2	3,2	0,2	24
EU15	24524	7000	7488	-488	1,6	0,6	0,1	34
Cyprus	20	6	9	-4	-0,9	-0,4	0,2	-0
Czech Republic	124	60	38	22	3,1	0,6	0,9	0
Estonia	21	12	4	8	-0,8	0,2	1,5	-0
Hungary	53	33	40	-7	2,2	0,6	1,5	-0
Latvia	69	22	23	-1	7,4	6,6	0,7	1
Lithuania	63	33	11	21	0,6	-0,2	0,4	-0
Malta	3	1	9	-8	-1,3	-1,4	0,2	-0
Poland	761	326	223	103	2,4	2,0	0,6	5
Slovac Republic	37	32	34	-3	0,8	0,1	1,2	-0
Slovenia	124	52	68	-16	-0,6	-1,7	0,8	-1
10 New MS	1277	575	460	115	2,2	1,3	0,8	4
Bulgaria	229	63	89	-26	0,3	0,0	1,5	-1
Romania	873	205	229	-25	0,2	0,1	1,1	-2
Bulgaria/Romania	1102	267	318	-51	0,3	0,1	1,2	-4
EU27	26904	7842	8266	-424	1,6	0,6	0,2	34

Annex XIV: Tables supporting the economic analysis of the Combination of ETSA with BALF and LNF Scenario (ETSBL)

Table 86. Cereal area and market balances per Member State according to the combination scenario

	Baseline REF (2020)				Combination of ETSA, BALF and LNF (ETSBL, 2020)			
	Cereal area [1000 ha]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	Cereal area [% to REF]	Production [% to REF]	Demand [% to REF]	Net trade [Δ to REF]
Austria	718	5622	5103	520	-2,4	-4,1	-5,9	70
Belgium-Lux.	277	2538	7666	-5128	0,9	1,2	-2,7	233
Denmark	1549	10447	9407	1040	4,9	7,0	-12,2	1873
Finland	1253	4610	3802	808	-26,6	-25,4	-5,1	-980
France	8864	71125	33490	37635	-3,9	-2,9	-8,7	823
Germany	6748	54746	43364	11383	-6,4	-6,9	-3,7	-2190
Greece	1020	4305	5912	-1607	-4,1	-4,9	-6,5	175
Ireland	291	2514	3231	-717	-6,5	-6,5	12,3	-560
Italy	3979	24023	27494	-3471	-8,3	-8,3	-3,5	-1030
Netherlands	240	2175	9758	-7583	2,8	4,8	-10,3	1107
Portugal	262	982	4611	-3629	-7,2	-12,2	-5,1	118
Spain	6046	22157	32931	-10774	-2,6	-5,9	-7,2	1060
Sweden	1006	5542	3759	1783	-14,3	-11,8	4,5	-825
United Kingdom	2743	20810	23752	-2942	-0,6	-1,5	6,0	-1745
EU15	34997	231599	214280	17319	-5,1	-4,8	-4,3	-1872
Cyprus	50	82	842	-760	0,3	16,3	-14,1	133
Czech Republic	1586	8192	4966	3226	-5,5	-5,5	-9,8	34
Estonia	361	1414	3850	-2436	-6,0	-5,7	1,6	-142
Hungary	3004	16318	6552	9766	-8,8	-8,6	-3,7	-1171
Latvia	456	1474	972	503	-28,2	-28,1	6,6	-478
Lithuania	804	3705	2560	1145	-9,5	-10,2	0,6	-394
Malta	0	0	170	-169	-60,0	-22,6	-2,2	4
Poland	8982	38931	37335	1597	-7,5	-6,8	-3,0	-1561
Slovac Republic	817	3630	2599	1030	-1,8	-0,3	-3,8	87
Slovenia	77	447	773	-326	-4,3	-3,6	-9,3	56
10 New MS	16137	74194	60618	13576	-7,9	-7,3	-3,3	-3433
Bulgaria	1351	6255	4808	1447	-8,1	-7,6	-3,4	-316
Romania	4729	16857	14753	2103	-1,7	-0,8	-2,4	217
Bulgaria/Romania	6080	23112	19561	3550	-3,1	-2,6	-2,6	-99
EU27	57214	328905	294459	34446	-5,6	-5,2	-4,0	-5404

Table 87. Change in dairy cow supply balances according to the combination scenario

	Baseline REF (2020)			Combination of ETSA, BALF and LNF (ETSBL, 2020)		
	Dairy herd [1000 hd]	**Yield kg/hd**	**Production [1000 t]**	**Dairy herd [% to REF]**	**Yield [% to REF]**	**Production [% to REF]**
Austria	504	6442	3244	-2,1	0,1	-2,1
Belgium-Lux.	610	5844	3566	-1,9	0,0	-1,8
Denmark	501	8752	4381	-2,8	0,0	-2,8
Finland	237	8469	2008	-2,6	0,1	-2,5
France	3395	6911	23462	-1,6	0,0	-1,6
Germany	3585	8142	29187	-2,1	0,1	-2,0
Greece	134	5677	762	-1,8	0,3	-1,5
Ireland	1147	5031	5772	-1,5	0,1	-1,4
Italy	1849	6314	11676	-1,5	0,0	-1,5
Netherlands	1593	7383	11760	-1,9	0,0	-1,9
Portugal	265	6911	1833	-1,9	0,0	-1,9
Spain	982	6700	6581	-3,0	0,2	-2,9
Sweden	335	9267	3107	-1,4	0,0	-1,4
United Kingdom	1774	7772	13786	-1,4	0,1	-1,3
EU15	16911	7162	121124	-1,9	0,0	-1,8
Cyprus	24	5816	141	-3,1	0,1	-2,9
Czech Republic	222	8365	1860	-2,3	0,1	-2,3
Estonia	73	6045	439	-4,3	0,3	-4,0
Hungary	195	7036	1369	-2,5	0,1	-2,4
Latvia	138	3816	527	-3,7	0,1	-3,6
Lithuania	323	4178	1348	-5,0	0,2	-4,8
Malta	9	7027	61	-3,3	0,1	-3,3
Poland	1659	5188	8610	-5,2	0,2	-5,0
Slovac Republic	106	6697	707	-1,6	0,0	-1,6
Slovenia	106	4927	520	-2,5	0,1	-2,5
EU10	2854	5460	15581	-4,4	0,3	-4,1
Bulgaria	360	3327	1198	-5,6	0,1	-5,6
Romania	1192	3434	4095	-5,8	0,3	-5,6
Bulgaria/Romania	1553	3409	5293	-5,8	0,2	-5,6
EU27	21317	6661	141998	-2,5	0,3	-2,2

Table 88. Beef cattle herds and beef market balances per Member State according to the combination scenario

	Baseline REF (2020)				Combination of ETSA, BALF and LNF (ETSBL, 2020)			
	Beef herd [1000 hd]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	Beef herd [% to REF]	Production [% to REF]	Demand [% to REF]	Net trade [Δ to REF]
Austria	533	182	128	54	-20,5	-12,8	-1,2	-22
Belgium-Lux.	661	272	209	63	-18,8	-11,3	-0,5	-30
Denmark	324	110	212	-102	-34,4	-20,0	-2,2	-17
Finland	228	78	115	-37	-34,0	-21,8	-0,4	-17
France	6379	1708	1654	54	-17,8	-10,6	-1,3	-159
Germany	1630	925	584	341	-28,9	-18,4	-0,9	-165
Greece	324	46	149	-103	-20,9	-1,1	-6,2	9
Ireland	2654	621	108	513	-25,7	-17,6	-2,8	-106
Italy	2589	939	1273	-334	-14,5	-10,5	-2,1	-72
Netherlands	60	324	358	-35	-11,9	-5,9	-2,7	-9
Portugal	670	133	222	-89	-25,3	-9,2	-2,6	-6
Spain	4498	722	818	-96	-30,8	-16,4	-5,9	-70
Sweden	350	124	293	-169	-20,8	-13,8	-1,5	-13
United Kingdom	3625	816	1364	-549	-25,1	-14,9	-2,9	-82
EU15	24524	7000	7488	-488	-23,2	-13,4	-2,4	-758
Cyprus	20	6	9	-4	5,3	2,7	-5,8	1
Czech Republic	124	60	38	22	-31,3	-13,8	-15,2	-2
Estonia	21	12	4	8	-35,1	-18,5	-23,8	-1
Hungary	53	33	40	-7	-14,7	-3,8	-24,4	9
Latvia	69	22	23	-1	-5,6	-3,7	-12,2	2
Lithuania	63	33	11	21	-13,2	-5,5	-6,8	-1
Malta	3	1	9	-8	0,6	-1,4	-5,7	1
Poland	761	326	223	103	-19,6	-15,7	-9,1	-31
Slovac Republic	37	32	34	-3	-2,8	0,6	-20,3	7
Slovenia	124	52	68	-16	-23,6	-5,9	-13,4	6
10 New MS	1277	575	460	115	-19,2	-11,8	-12,5	-11
Bulgaria	229	63	89	-26	-9,7	-6,6	-29,8	22
Romania	873	205	229	-25	-9,7	-7,8	-28,9	50
Bulgaria/Romania	1102	267	318	-51	-9,7	-7,5	-29,2	73
EU27	26904	7842	8266	-424	-22,5	-13,1	-4,0	-696

European Commission
EUR 25288 – Joint Research Centre – Institute for Prospective Technological Studies

Title: Agricultural GHG emissions in the EU: an exploratory economic assessment of mitigation policy options

Authors: Ignacio Pérez Domínguez, Thomas Fellmann, Heinz-Peter Witzke, Torbjörn Jansson and Diti Oudendag, with the collaboration of Alexander Gocht and David Verhoog

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Abstract

The contribution of the agricultural sector to climate change is gaining more and more visibility and therewith interest is growing on policy options to reduce agricultural greenhouse gas (GHG) emissions.

This report provides a quantitative assessment of possible implications of the implementation of specific policy options to mitigate agricultural GHG emissions in the EU. The scenario analysis comprises both the GHG emission reduction potential of the policy options as well as related production and economic impacts for the agricultural sector in the EU.

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