PROJECT N. 037033

EXIOPOL

A NEW ENVIRONMENTAL ACCOUNTING FRAMEWORK USING EXTERNALITY DATA AND INPUT-OUTPUT TOOLS FOR POLICY ANALYSIS

EXIOPOL DELIVERABLE DIV.3.a-1

EXIOPOL DELIVERABLE DIV.3.a-2

Report on selected policy measures and quantified emissions from agricultural activities including the Report on impacts and damage costs of the analysed policy measures

Report of the EXIOPOL project

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Preamble

The present deliverable combines the deliverables DIV.3.a-1 “Report on selected policy measures and quantified emissions from agricultural activities” and DIV.3.a-2 “Report on impacts and damage costs of the analysed policy measures”. Starting from the selected policy measures, emission scenarios were developed. Reference scenarios were defined and emission changes due to the implemented policy measures were analysed. Finally, impacts were identified and, by monetary valuation, damage costs were determined.

Focus of the policy measures to be considered was on the EU’s climate change policies and climate change mitigation measures. Two emission scenarios were analysed:

- A biomass scenario was developed based on the EU’s 2020-policy that shows the increase in area for biomass production to be used as energy crops.
- A scenario on human diets was developed with a reduction in beef and dairy product consumption outbalances by an increase in consumption of pork and poultry.

The scenarios were studies regarding their non-climate impact on the environment. The emissions included in the impact analysis were air pollutants (ammonia (NH_3), particulate matter (PM_{10}, $PM_{2.5}$)), nutrients (nitrogen and phosphorous inputs into soils) and pesticides.

The impacts covered were impacts on human health, biodiversity and eutrophication.

Wolf Müller

Coordinator of WS IV.3

EXIOPOL project

August 2011

Executive Summary

Overview

This is the report of the EXIOPOL project on selected policy measures and quantified emissions from agricultural activities. The selected measures and developed scenarios analyse the impact of climate change mitigation measures regarding other environmental impacts such as air pollution, biodiversity loss and eutrophication. Two scenarios were developed for the target year 2020. The first scenario examines the European Union's policy on climate change and energy security and its effect on biomass production to be used as energy crops. Biomass use is said to be CO_2-neutral and thus beneficial for the climate as well as it helps to secure energy supply in the EU. The second scenario studies a change in human diets. Cattle contribute considerably to climate change by producing methane. A scenario for climate protection which has been widely discussed is a reduction in the consumption of beef and dairy products and an increase in pork and poultry. However, a detailed analysis of non-climatic impacts was still missing. This gap will be closed in this report. Both biomass production as well as a change in human diets will be examined not only regarding their climate change mitigation potential but also regarding their emissions of air pollutants (ammonia, NH_3, particulate matter (PM_{10}, $PM_{2.5}$) and nutrients (nitrogen N and phosphorous P input into soils and resulting eutrophication of water bodies. Emissions of particulate matter cause respiratory and cardio-vascular diseases and can lead to premature deaths. Ammonia on the one hand reacts with nitrogen and sulphur oxides in the atmosphere and forms secondary particles and thus contributes as well to human health problems. On the other hand it leads to acidification of soils and eutrophication and thus to biodiversity loss. Similarly, nitrogen and phosphorous surplus in soils may lead to eutrophication. The mentioned effects will be analysed and impacts will be monetarily valued and damage costs will be derived.

The project has started in March 2007 and will run until March 2011.

Approach

Starting point for the scenario on biomass production is the EU's objective to have a share of 20% renewables in all primary energy use in the year 2020 and the 20% reduction of greenhouse gases in the year 2020 compared to the Kyoto base year, set by EU-27. In order to determine the amount of energy supply needed from biomass as a renewable energy source, the PAN-European energy-system model TIMES was applied. TIMES covers energy demands for oil seeds, sugar crops, starch crops and woody biomass. Based on energy content and projection of yields, the respective crop area was determined.

The human diet scenario is based on a reference scenario taken from the GAINS model database run at IIASA (International Institute for Applied Systems Analysis). It was assumed that the beef and dairy production was reduced by 20% in the year 2020 compared to a reference scenario. In order to outbalance protein supply, numbers of pig and poultry were increased accordingly.

After that, N and P fertiliser input as well as emissions of NH_3 and N_2O and N and P loads were determined. PM_{10} and $PM_{2.5}$ emissions were considered as well. Impacts were valued based on the values determined in Deliverable DII.2b.-1 of the EXIOPOL project for N and P input. CH_4 and N_2O emissions were valued with their contribution to global warming. Values for impacts caused by NH_3 and PM_{10} and $PM_{2.5}$ were taken from the Clean Air for Europe (CAFE) project.

Results

In the biomass scenario, starch crops cause the highest damage costs per energy unit (Mega joule) of primary energy, followed by oil crops and woody crops. Sugar crops show the lowest damage costs. Biomass production, especially the use of woody biomass and sugar crops, does not only protect the

climate but also causes nearly no other environmental impacts and damage costs. Amongst the biomass options, these are the most beneficial.

In the human diets scenario, a reduction of cattle and dairy products lead to a reduction in methane emissions. However, NH_3 and PM emissions as well as N and P input increase considerably so that in the end damage costs caused by non-climatic effects are higher than climatic damages avoided. Reduction of cattle in favour of pork and poultry is neither beneficial for the climate nor for other environmental issues.

For the calculation of damages due to intake of pesticides also the increase in biomass production was considered. However, damages that can be avoided by reducing pesticide emissions and application amounts in Europe according to the 2020 reduction scenario are relatively marginal, i.e. in most countries less than one Euro per kg applied pesticide.

Table of contents

1 Biomass

1.1 Scenario description

The demand for energy from biomass was determined by application of the Pan-European TIMES energy system model (Blesl et al. 2010). The reference scenario describes the development of an energy system without any additional energy or climate policies implemented after the year 2012. The climate scenario includes the 20% GHG reduction target for 2020 compared to Kyoto base set by the EU-27. Additionally, the EU goal of a 20% share of renewables of final energy consumption in 2020 is implemented. This includes a reduction of emissions of 21% in 2020 compared to 1990 in the sectors covered by the ETS. In the transport sector, emission standard EU VI is to be introduced in 2014.

TIMES model results to meet biomass energy demand were received in terms of petajoule (PJ) per year for oil seeds, sugar crops, starch crops, woody biomass and grassy biomass (Figure 1). The energy demand per crop category refers to the raw product as it is harvested.

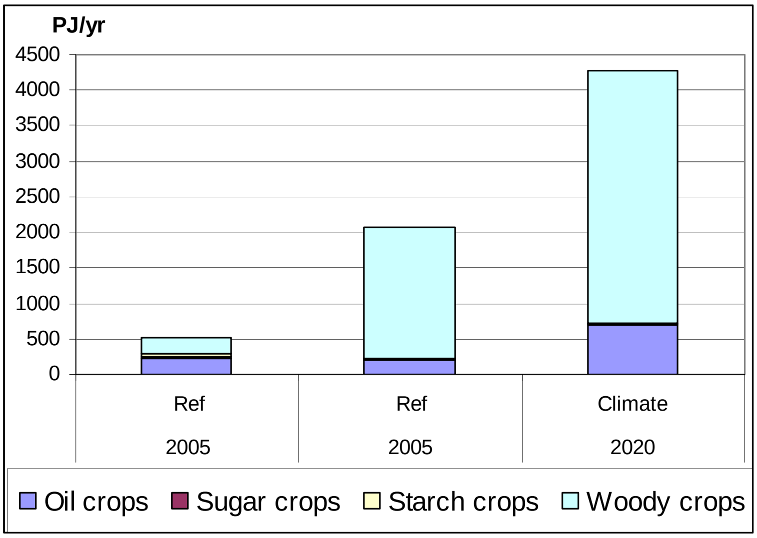

Figure 1. Biomass energy demand in EU-27 (TIMES model results, PJ/yr)

Applying energy content conversion factors (in gigajoule (GJ) per ton of fresh matter (FM) (Table 1), the amount of harvested biomass per crop category which is required to meet biomass energy demand was derived. According to TIMES results, no demand for energy from grassy biomass exists.

Table 1. Energy content of biomass

TIMES category	Crop category	Energy content (GJ/t FM)
Oil crops	Rape seed	23.8
	Sunflower	26.38
Sugar crops	Sugar beet	18
Starch crops	Wheat	17
Woody biomass	Willow	11.11

Source: Schröder et al (2006)

After the amount of crops needed had been calculated, the respective area was to be estimated. First the average yield per crop for the base year was determined based on Eurostat data (Table "apro_cpp_crop"). The mean of average yield of 2004 to 2006 was calculated in order to even weather impacts. Starting with the average yields for the year 2005, future yields were estimated. It was assumed that crop yields would increase by 1% annually (EEA 2006). Based on the assumed yield developments, the area of biomass crops required to meet biomass energy demand in 2020 was derived (Figure 2).

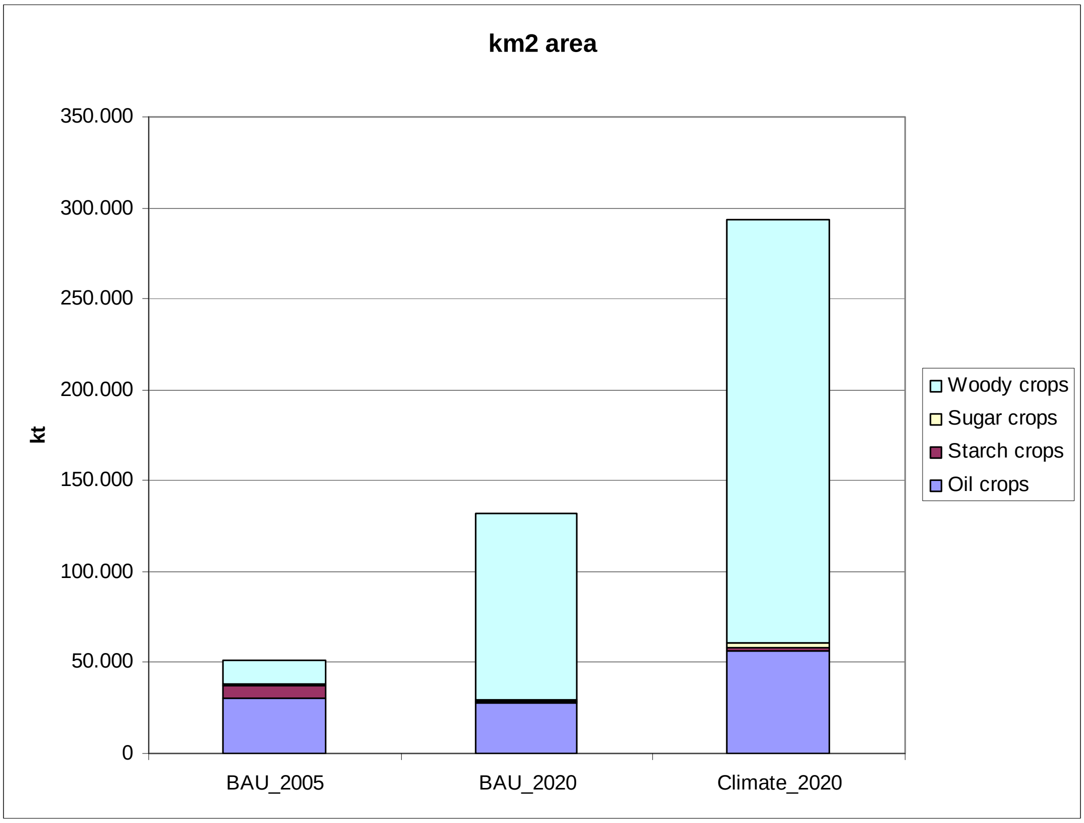

Figure 2. Biomass area required to meet TIMES biomass energy demand in EU-27 (km²)

1.2 Inputs and emissions

In the next step, N and P fertiliser inputs and emissions of NH_3 and N_2O as well as the N and P loads were estimated for each crop category. N fertiliser and P fertiliser application rates for oil crops, starch crops and sugar crops were taken from the EXIOPOL Deliverable DII.2.a-2 (Hansen et al., 2009 and Fantke et al., 2009). The N application rate for woody biomass was taken from Schröder et al. (2006). The P application rate for woody biomass was assumed to be 20% of the N application rate (Brown and Driessche 2005). The amount of N applied was split into N from manure and N from mineral fertiliser according to the fractions identified in DII.2.a-2. The amount of NH_3-emissions was calculated distinguishing between specific NH_3 emission factors from manure and from mineral fertiliser. Emission factors for NH_3 from manure were derived from the data set in DII.2.a-2; NH3 emission factors for mineral fertiliser use were derived from the GAINS model data considering the amount of urea and non-urea fertilisers used in 2020 (http://gains.iiasa.ac.at/gains/). N_2O emission factors were the same as in DII.2.a-2.

Biofixation was estimated applying the same coefficients as in DII.2.a-2. The N and P input from seeds were derived from the DII.2.a-2 data set for oil crops and starch crops. Coefficients for N and P input from seeds for sugar beet were not available and can be neglected due to the size of the seeds. Coefficients for woody biomass were not available. Crop uptake was estimated based on the coefficients applied in the DII.2.a-2 data set and the amount of crop production derived from the TIMES model results. The N uptake coefficient for poplar (short rotation coppice) is 34 kg/ha and year (Rödl, 2008). P uptake was assumed to be the same as P input based on the finding that N input equals N uptake.

Concerning emissions of PM_{10} and $PM_{2.5}$, a distinction has been made between the moderate climate in Northern European countries and warmer climates in Southern Europe (Bulgaria, Cyprus, Greece, Hungary, Italy, Malta, Portugal, Romania and Spain). Emission factors for a moderate climate were taken from Hinz & Hoek (2007) and Öttl and Funk (2007). For the warmer climate, emission factors were taken from Cassel et al. (2003) and Yu and Gaffney (2003).

The emissions are depicted in Figure 3 and Figure 4 below for the reference Business-As-Usual (BAU_2020) scenario and Climate (Climate_2020) scenario respectively. The green line ‘Sum; N input to soil’ is the sum of the inputs and outputs. A positive value hence reflects a net N release to soil which is the case for most of the countries.

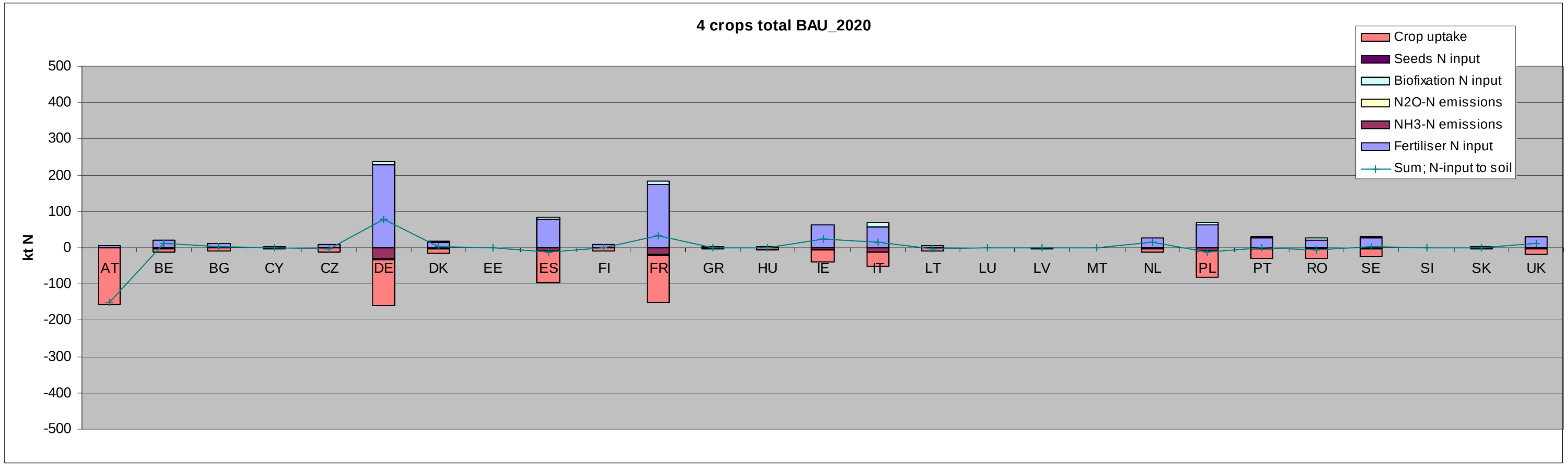

Figure 3. N balance, BAU_2020

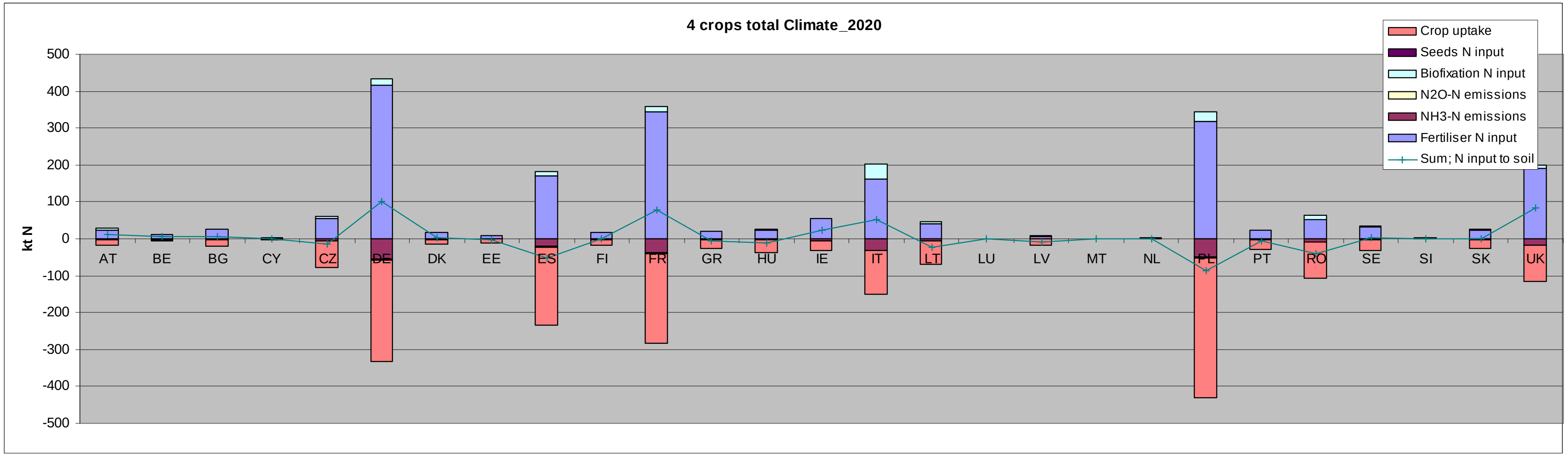

Figure 4. N balance, Climate_2020

Some of the emissions are summed for all EU27 per crop category in Table 2.

Table 2. N input, NH_3 emissions, N_2O emissions, P input PM_{10} and $PM_{2.5}$ emissions per crop category in EU-27 in 2020 (kt)

EU-27	BAU	Climate	BAU	Climate	BAU	Climate	BAU	Climate	BAU	Climate	BAU	Climate
(kt)	N input		NH3 emissions		N2O emissions		P input		PM10 emissions		PM2.5 emissions	
Oil crops	157.78	104.22	74.98	205.68	6.30	16.81	-18.11	-112.00	17.10	56.83	2.12	7.06
Starch crops	5.98	1.54	2.61	0.77	0.22	0.06	0.01	0.02	0.63	0.22	0.08	0.03
Sugar crops	0.31	-0.03	0.27	0.07	0.02	0.01	-0.13	-0.07	0.01	0.01	0.00	0.00
Woody crops	-148.22	9.18	56.58	112.55	4.52	8.64			8.51	16.91	0.90	1.85

Similarly, the P emissions are depicted in Figure 5 and Figure 6 for the two scenarios BAU_2020 and Climate_2020. The green line 'Sum; P input to soil' is the sum of the inputs and outputs. A positive value hence reflects a net N release to soil.

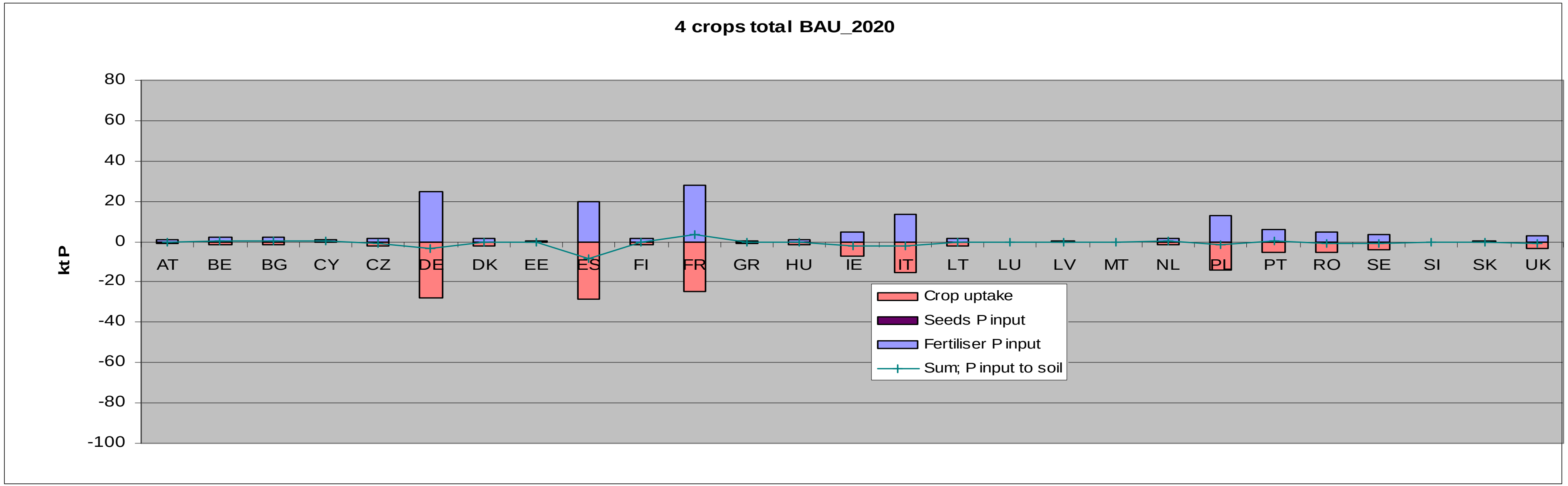

Figure 5. P balance, BAU_2020

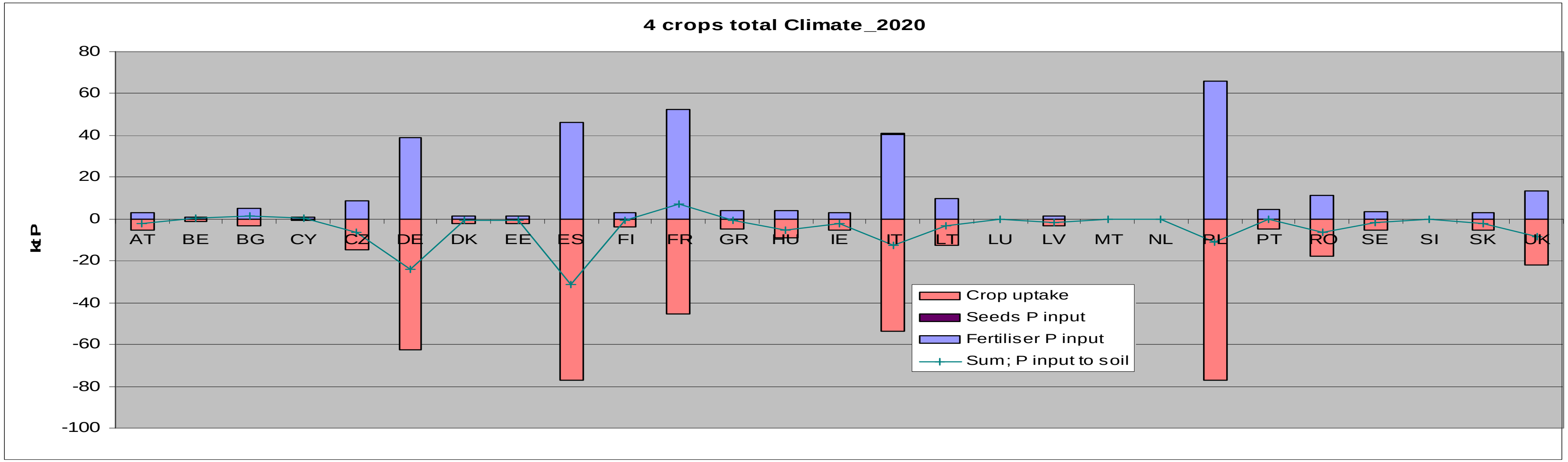

Figure 6. P balance, Climate_2020

The particle emission ($PM_{2.5}$) is shown in Figure 7.

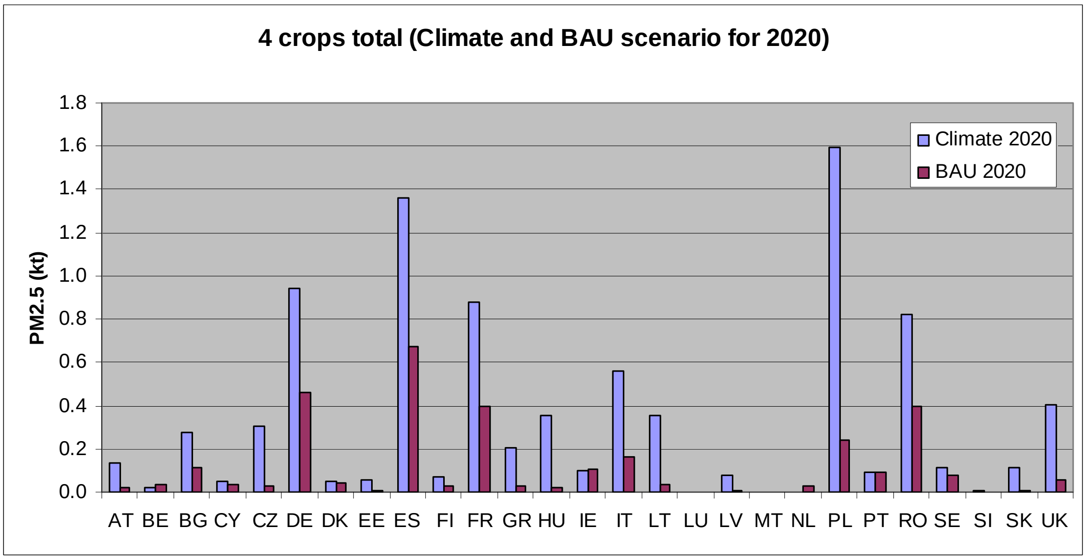

Figure 7. Particle emission, kt $PM_{2.5}$, BAU_2020 and Climate_2020

1.3 Cost calculations

The prices used to calculate the externalities of the nutrients applied are given in Table 3 below. The columns ‘Mineral N’, ‘Manure N’ and ‘P’ are values determined within the deliverable DII.2b.-1 of the EXIOPOL project (Hansen and Andersen, 2009). The values for mineral N and manure N were subtracted a value of N_2O contribution to global warming, as this is calculated separately in the present project.

The values for NH_3 and $PM_{2.5}$ are from the Clean Air For Europe (CAFÉ) project (Holland et al., 2005). As values for Bulgaria, Cyprus and Romania were not included in the CAFÉ data, the value for Greece was used for NH_3 and $PM_{2.5}$.

CH_4 and N_2O are valuated with their contribution to global warming, 25 kgCO_2-equivalents/kg CH_4 and 298 kg CO_2-equivalents /kg N_2O (Forster et al., 2007), and with a value of 20€/ton CO_2 equivalents.

Table 3. Prices used

	NH_3	Mineral N	Manure N	P	$PM_{2.5}$
Country	€/kg emission	€/kg applied	€/kg applied	€/kg applied	€/kg emission
AT	12,000	1.60	1.77	0.012	37,000
BE	30,000	3.09	3.42	0.017	61,000
BG	3,200	1.05	1.17	0.000	8,600
CY	3,200	0.83	0.92		8,600
CZ	20,000	1.64	1.81	0.005	32,000
DE	18,000	1.84	2.04	0.026	48,000
DK	7,900	0.43	0.48	0.020	16,000
EE	2,800	0.38	0.42	0.000	4,200
ES	4,300	1.71	1.89	0.003	19,000
FI	2,200	0.18	0.21	0.000	5,400
FR	12,000	1.10	1.22	0.003	44,000
GR	3,200	1.17	1.30	0.004	8,600
HU	11,000	0.24	0.26	0.009	25,000
IE	2,600	1.19	1.32	0.000	15,000
IT	11,000	0.70	0.78	0.008	34,000
LT	1,700	0.07	0.09	0.001	8,400
LU	25,000	1.30	1.43	0.010	41,000
LV	3,100	0.38	0.42	0.001	8,800
MT	8,200	0.38	0.42		9,300
NL	22,000	3.72	4.11	0.037	63,000
PL	10,000	1.07	1.18	0.003	29,000
PT	3,700	1.70	1.88	0.003	22,000
RO	3,200	1.24	1.38	0.001	8,600
SE	5,900	0.25	0.28	0.000	12,000
SI	13,000	0.48	0.54	0.001	22,000
SK	14,000	0.78	0.86	0.003	20,000
UK	17,000	3.80	4.20	0.002	37,000

Figure 8 and Figure 9 below show the total cost for all 4 crops.

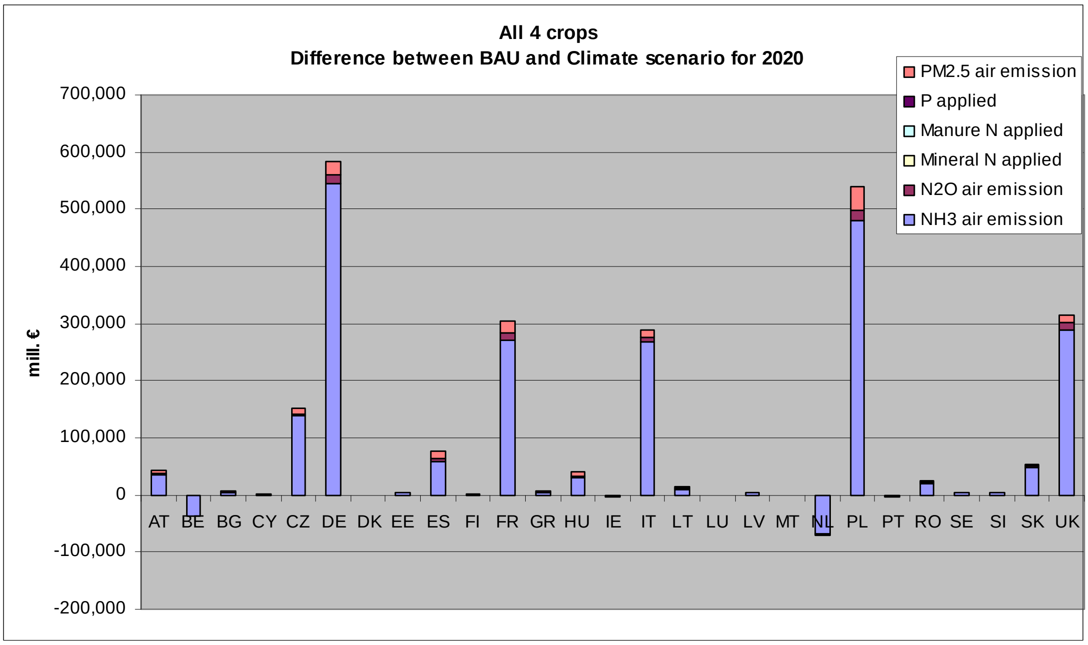

Figure 8. External costs for the difference between the BAU and the Climate scenario for 2020 per emission category

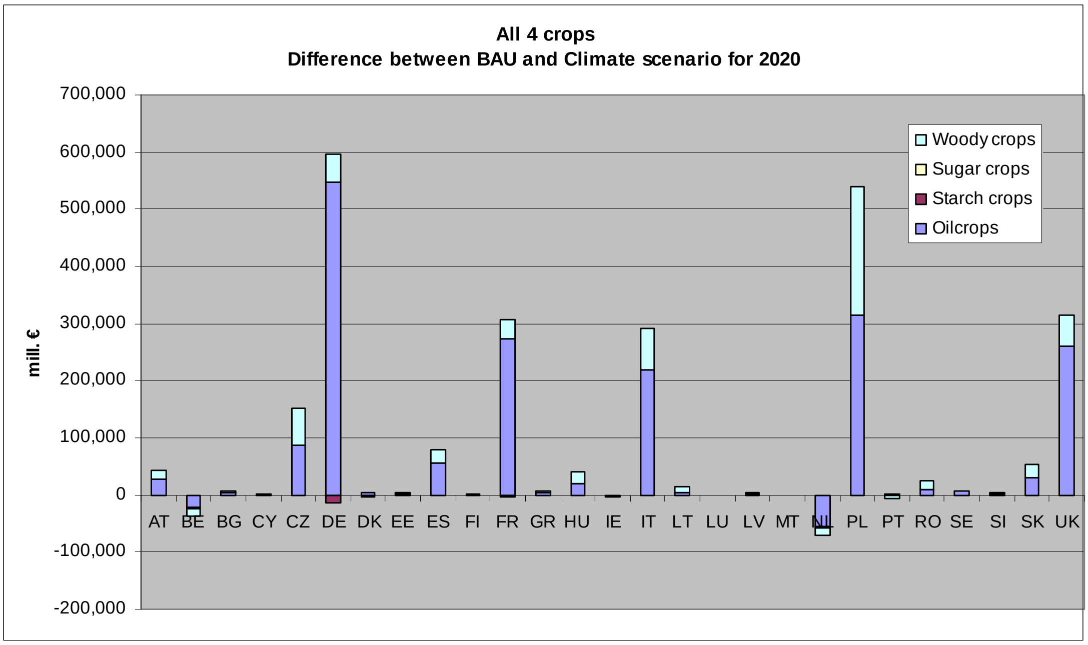

Figure 9. External costs for the difference between the BAU and the Climate scenario for 2020 per crop category

The cost depicted in Figure 8 and Figure 9 covers the total cost of converting from the BAU to the Climate scenario. It can clearly been seen from the figures that the external costs are highest for Germany, followed by Poland, UK, France and Italy. For these countries the estimated potential available land for energy crop cultivation is highest. Thus, in these countries most of the energy crops would be cultivated leading to a high level of NH_3 emissions which account for the largest share or the estimated costs.

In Table 4 and Figure 10 this is converted to the cost per MJ.

This unit cost is per MJ in fresh biomass and not per MJ of final energy. If e.g. losing 50% when converting to electricity the unit cost will be double.

Furthermore, the unit costs only cover the externalities from producing the energy from biomass. The externalities saved from not producing the energy in a conventional way from fossil fuel are not included.

Table 4. External cost per MJ per emission category

	NH_3 air emission	N_2O air emission	Mineral N applied	Manure N applied	P applied	$PM_{2.5}$ air emission	Sum
Oil crops	2.63	0.10	0.00131	0.00102	0.00000119	0.23	2.96
Starch crops	4.09	0.16	0.00178	0.00185	0.00000225	0.28	4.53
Sugar crops	0.30	0.01	0.00014	0.00014	0.00000032	0.00	0.32
Woody crops	0.34	0.02	0.00015	0.00011	0.00000016	0.01	0.36

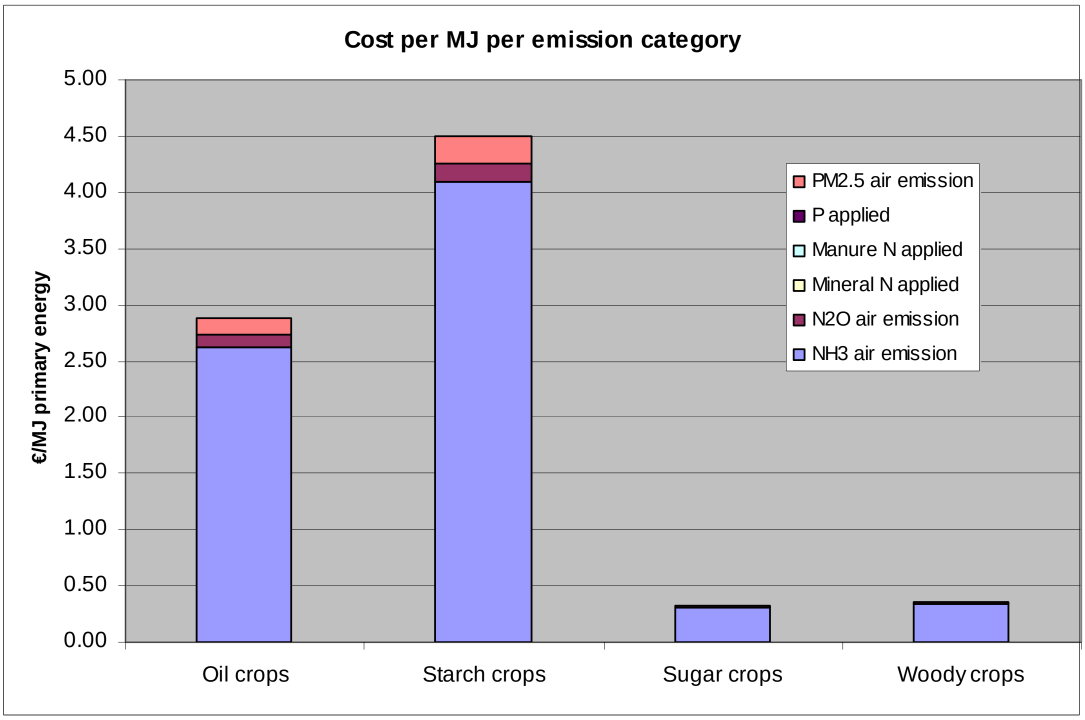

Figure 10. External cost per MJ per emission category

The cost per MJ covers the increasing emissions from increasing biomass production. The avoided emissions from switching away from fossil fuel are not included. This has to be done in order to evaluate the total consequence of the scenario.

As seen the externalities covered in the present calculations amount to between 0.3€ and 4.5€ per MJ depending on the crop type. The externalities are heavily dominated by NH_3, which is related to the secondary particle formation and the following health effects.

'Mineral N applied', 'Manure N applied' and 'P applied' which are the externalities covered in the work package DII.2b of the EXIOPOL project contribute less than 1 €-cent as seen in Table 4 and are not visible in Figure 10.

2 Human diet

2.1 Description of the human-diet-scenario "reduced cattle protein scenario"

The animal numbers for the reference scenario were taken from the GAINS model Climate & Energy scenario (current policy).[1]

It was assumed that heads of cattle (i.e. beef and dairy cows and thus the milk yield) would be reduced by 20% in 2020 compared to reference scenario data. It was also assumed that the amount of protein consumed by human beings in the EU-27 was kept constant, i.e. the amount of protein reduced via reduced cattle product consumption was to be balanced by an increase in pig and poultry product consumption. The protein content in beef, milk, pork, poultry meat and eggs is shown in Table 5. The average protein content of beef and milk served as the base for the protein equivalents of pork, poultry meat and eggs. Starting from protein equivalents, the increased numbers of pigs and poultry were calculated. The historic share of consumption between pork, poultry meat and eggs was kept constant in each country.

Table 5. Protein content of products

	Beef	Milk	Pork	Poultry	Eggs
kg protein/ kg product	0.22	0.03	0.18	0.20	0.13

Country-specific milk yields per dairy cow were considered based on GAINS data (Table 6)

Table 6. Country-specific milk yields (kg milk (cow/year)

	2020
AT	6685
BE	6700
BG	0
CY	6000
CZ	6900
DE	8719
DK	10600
EE	7000
ES	6500
FI	9631
FR	7300
GR	3800
HU	7000
IE	5900
IT	6500
LT	4300
LU	7200
LV	5000
MT	0
NL	8199
PL	6000
PT	6200
RO	0
SE	8500
SI	5658
SK	6200
UK	7422

[1] http://gains.iiasa.ac.at/gains/EUR/index.login?logout=1

For Bulgaria, Malta and Romania, milk yields from Greece were assumed.

In the GAINS model database, no information on slaughter weight and number of eggs was given. Therefore for slaughter weights and number of eggs per laying hen and year, average values were assumed. For other poultry including ducks, geese, turkey, the average weight of broilers was assumed.

Animal numbers for sheep and goats and other animals were not changed.

2.2 Inputs and emissions

Figure 11 below shows the applications and emissions for the BAU_2020 and HD_2020 scenarios. As expected from the scenario construction the emissions and applications from dairy and other cattle decrease, and emissions from pigs and poultry increase. The sum of the emission changes slightly, and varying from emission to emission.

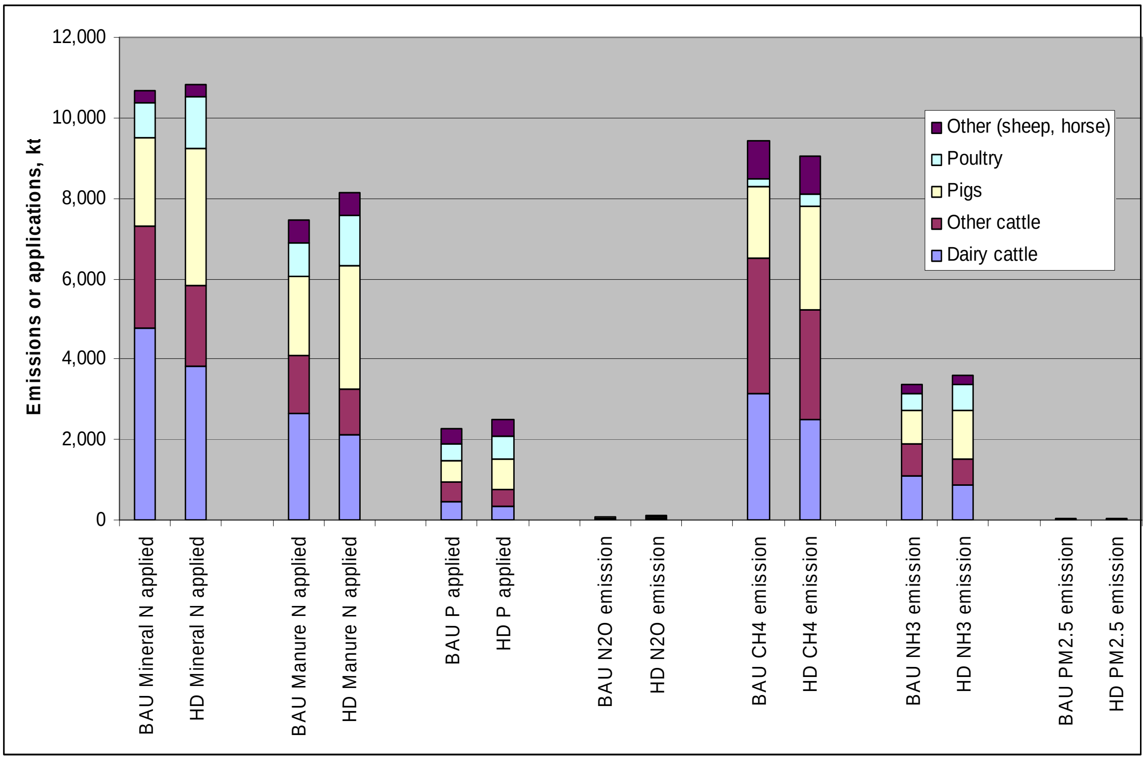

Figure 11. Applications and emission, BAU_2020 and HD_2020

However, the absolute emissions and applications from Figure 11 give no indication of the severity of the substance emissions and applications. This is handled further in the next chapter.

2.3 Cost calculations

Prices used the as described in Table 3, and CH_4 and N_2O are valuated with their contribution to global warming as described in Chapter 1.3.

2.3.1 Cost per emission category

In Figure 12 it can be seen that the externality cost from NH_3 is dominating, and with minor effects from particles ($PM_{2.5}$).

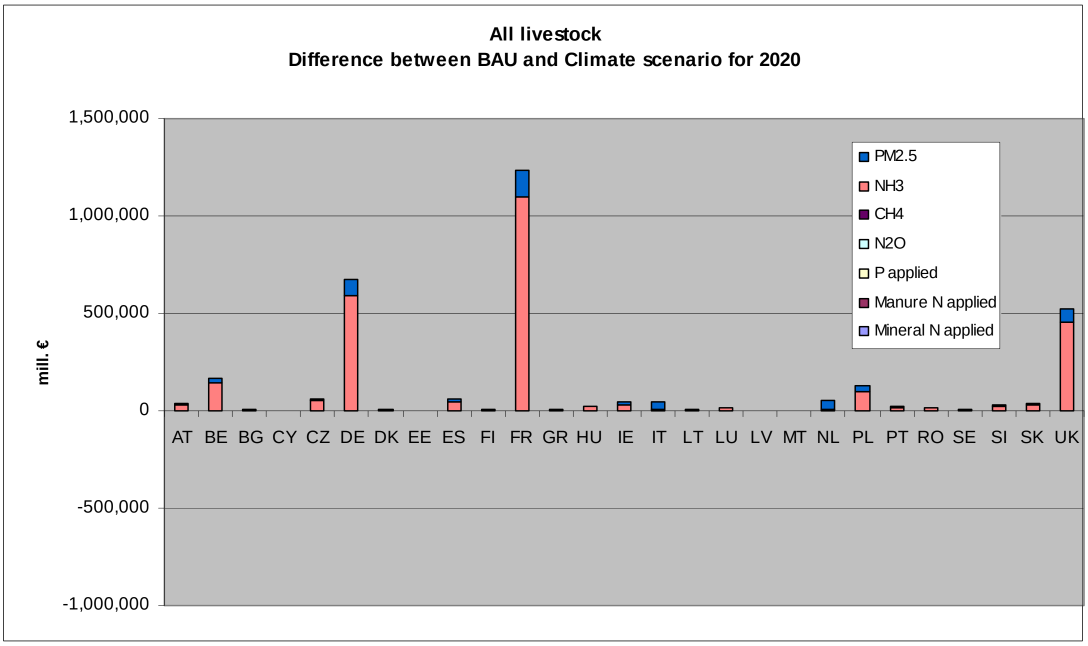

Figure 12. All livestock, difference between BAU_2020 and HD_2020

Figure 13 below show the effect excl. NH_3 and $PM_{2.5}$ but otherwise the data is identical to Figure 12.

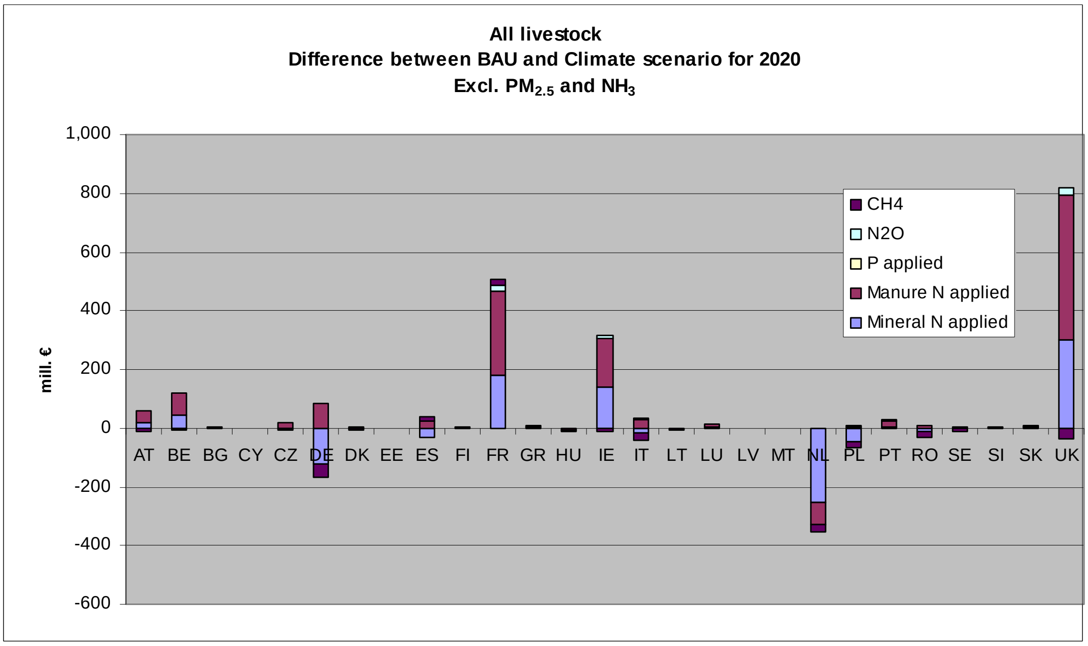

Figure 13. All livestock, difference between BAU_2020 and HD_2020, excl. $PM_{2.5}$ and NH_3.

The data in Figure 14 is identical to Figure 12 and Figure 13 but showing only the effect from methane (CH_4) and N_2O.

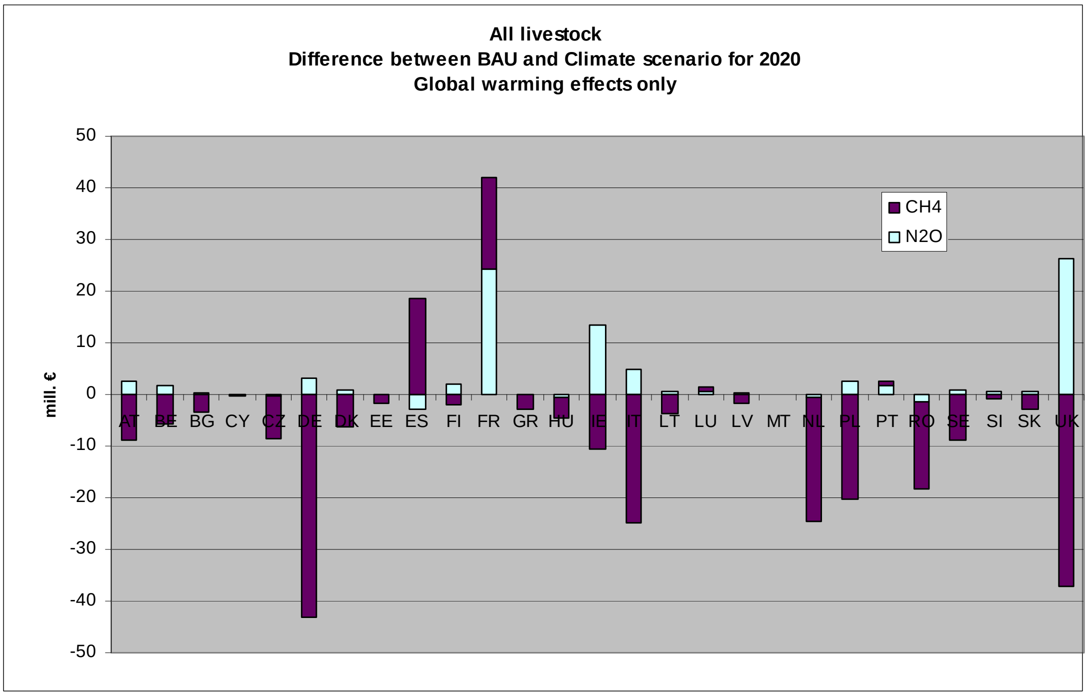

Figure 14. All livestock, difference between BAU_2020 and HD_2020, global warming only

2.3.2 Cost per livestock category

Figure 15 shows the same cost as in chapter 2.3.1, i.e. changing from BAU_2020 to HD_2020, but shown per livestock category. The line 'Sum of all livestock' show the aggregated cost per livestock category for each country, i.e. the net cost of going from BAU_2020 to HD_2020.

It is not seen in Figure 15 but can be deducted from Figure 12 that the cost is heavily dominated by effects from NH_3.

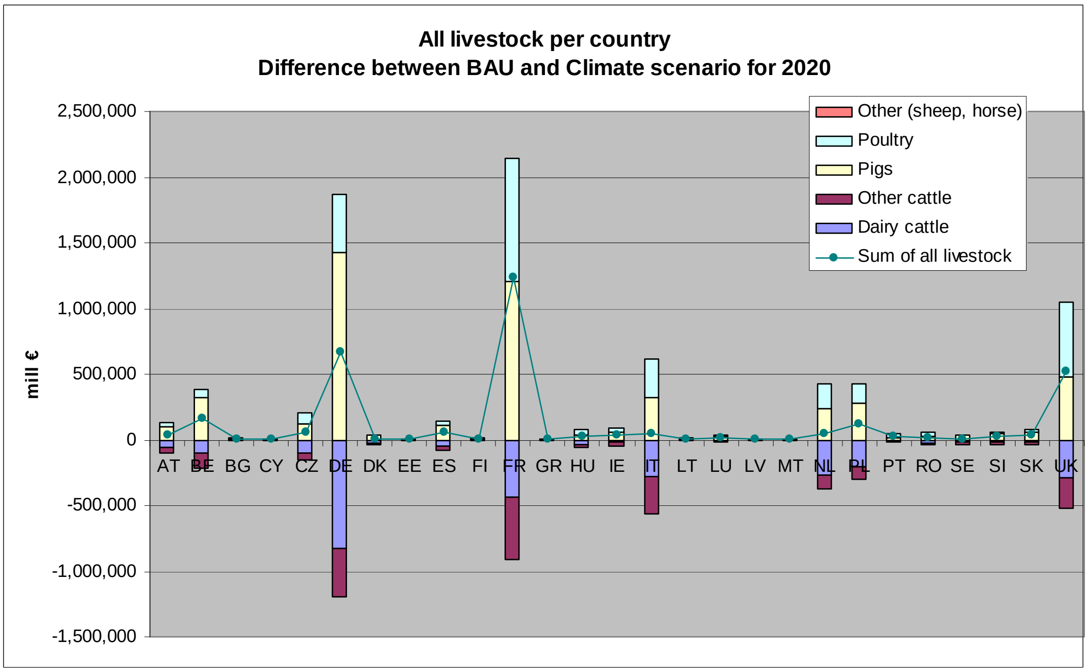

Figure 15. Cost per livestock category, difference between BAU_2020 and HD_2020

Figure 16 below shows the same data as in Figure 15 above but aggregated over EU-27. The cost is as expected negative (a gain) for the dairy cattle and other cattle as the animal number is reduced by 20%. The costs from pigs and poultry are positive as they are increased according to the protein equivalents (see chapter xx). The sum of all the scenarios are positive equivalent to a total cost of approx. $3*10^{12}$€ over all EU-27.

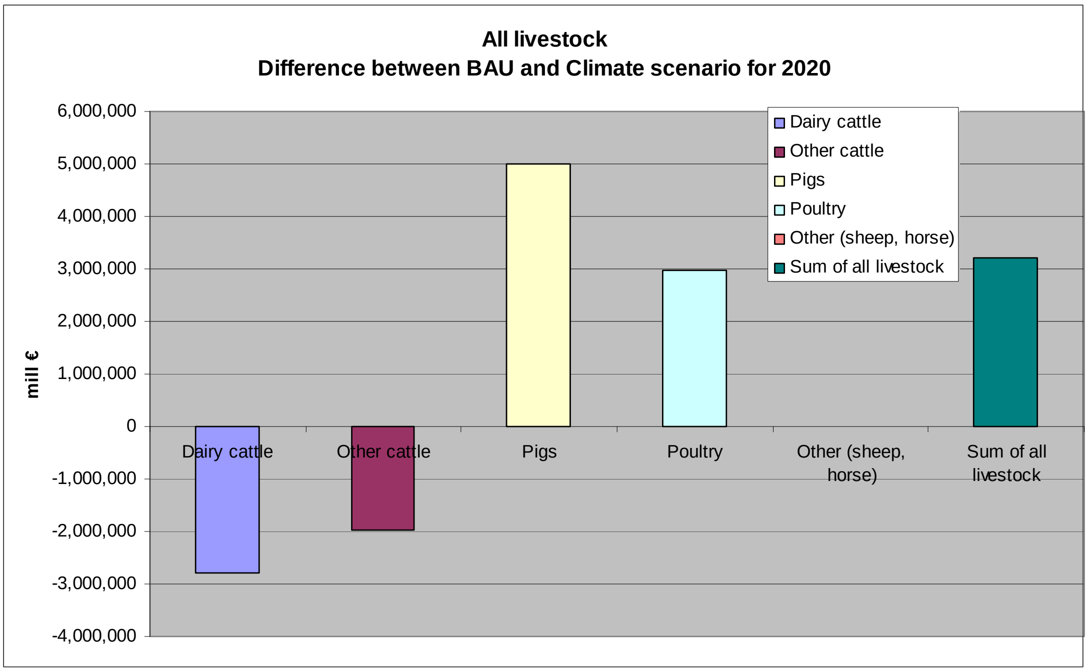

Figure 16. Cost per livestock category going from BAU_2020 to HD_2020

An onset of the HD_2020 scenario is the prospect of lowering the global warming effect associated with the consumption of beef. For this reason Figure 15 and Figure 16 are repeated as Figure 17 and Figure 18 respectively but showing only the externality cost related to global warming.

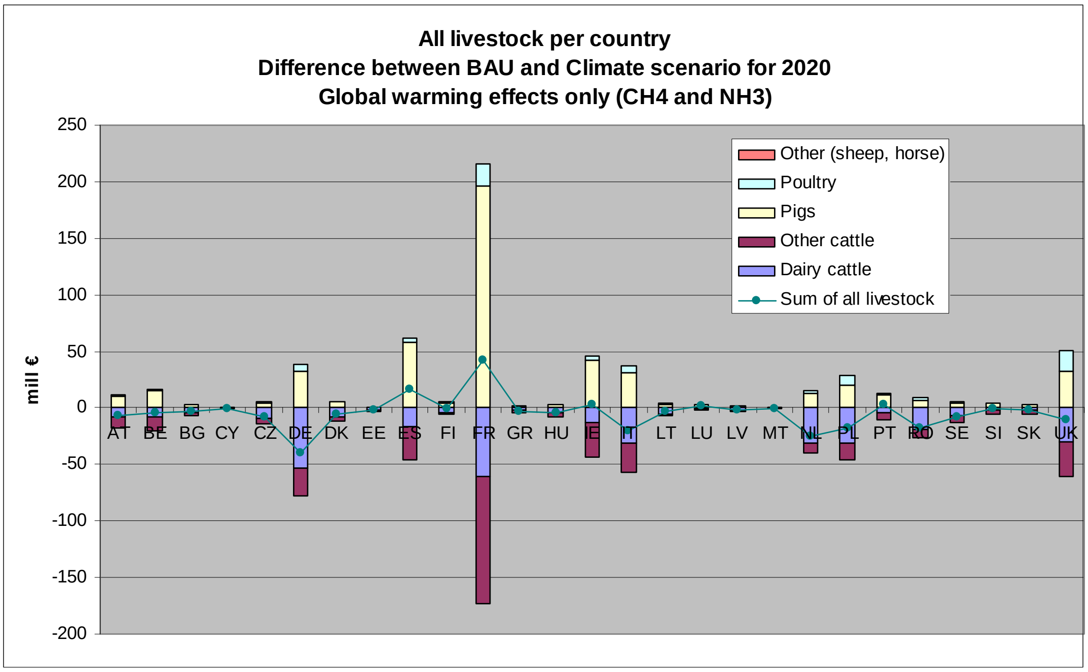

Figure 17. Cost per livestock category, difference between BAU_2020 and HD_2020, global warming only

It is seen from Figure 17 that the green line showing the added cost per country is now most often below zero indicating a net gain in the cost related to global warming going from BAU_2020 to HD_2020, as opposed to Figure 15. The total net result seen in Figure 18 ('Sum of all livestock') indicates a net gain of just over 100 million € in global warming going from BAU_2020 to HD_2020.

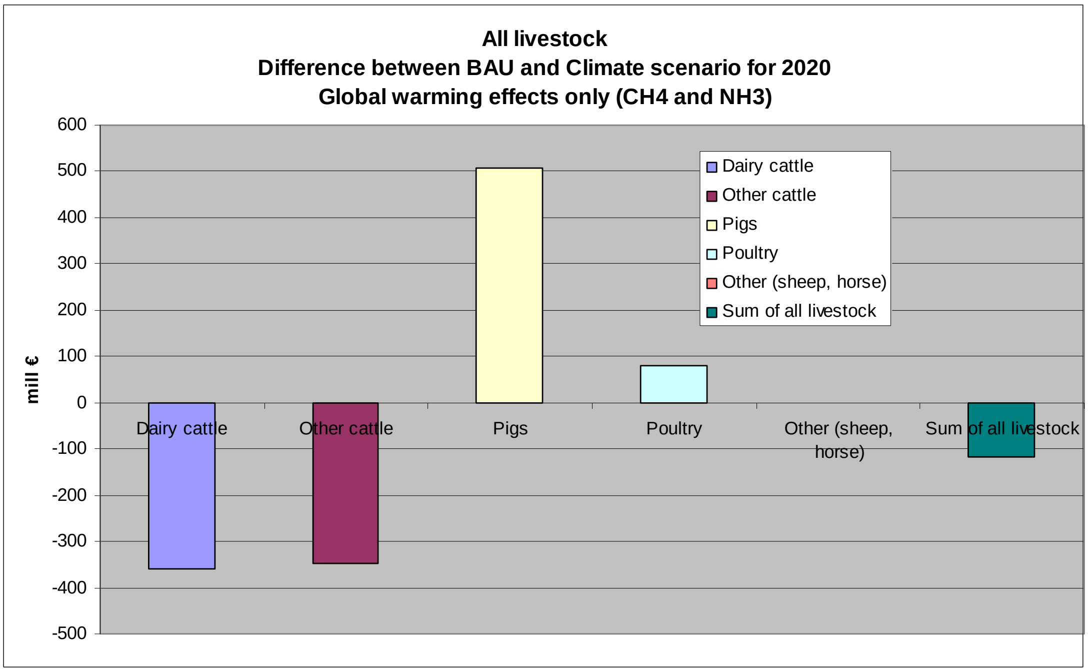

Figure 18. Cost per livestock category, difference between BAU_2020 and HD_2020, global warming only.

The values of kg manure N applied per kg of final product as calculated in the input-output calculations of DII.2b.-2 are shown in Figure 19.

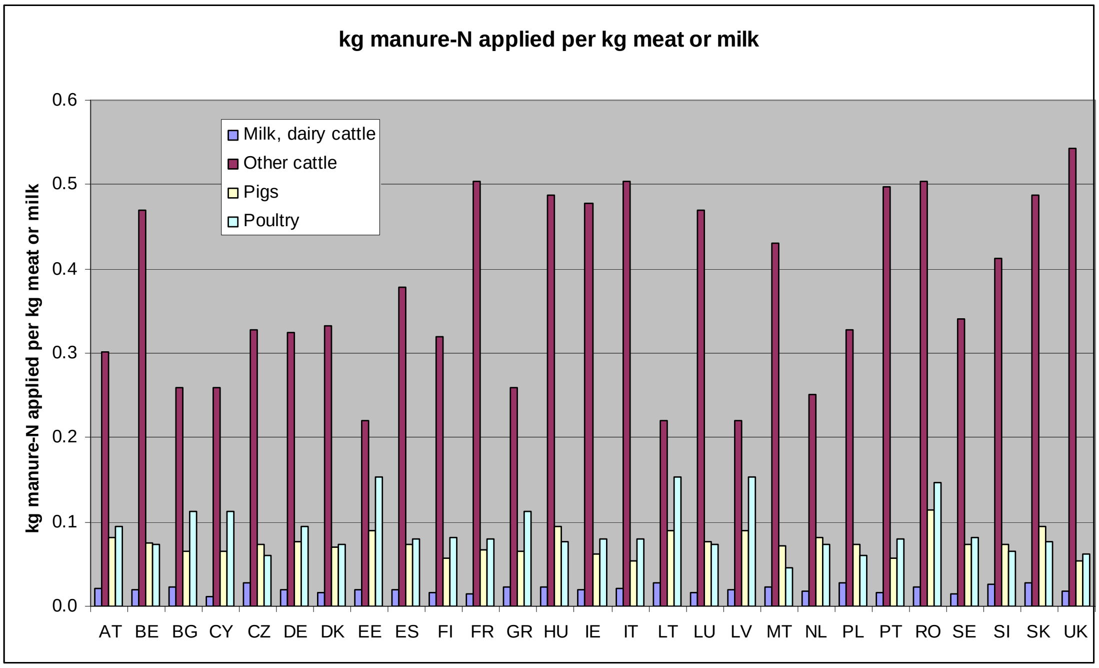

Figure 19. kg manure-N applied per kg meat or milk

The values of kg manure N per kg product are used to calculate the kg of final products removed or introduced as part of the Human Diet scenario, and the following externalities per kg of final product are shown in Figure 20. Negative value is gain per kg product removed and positive value is cost per kg product introduced

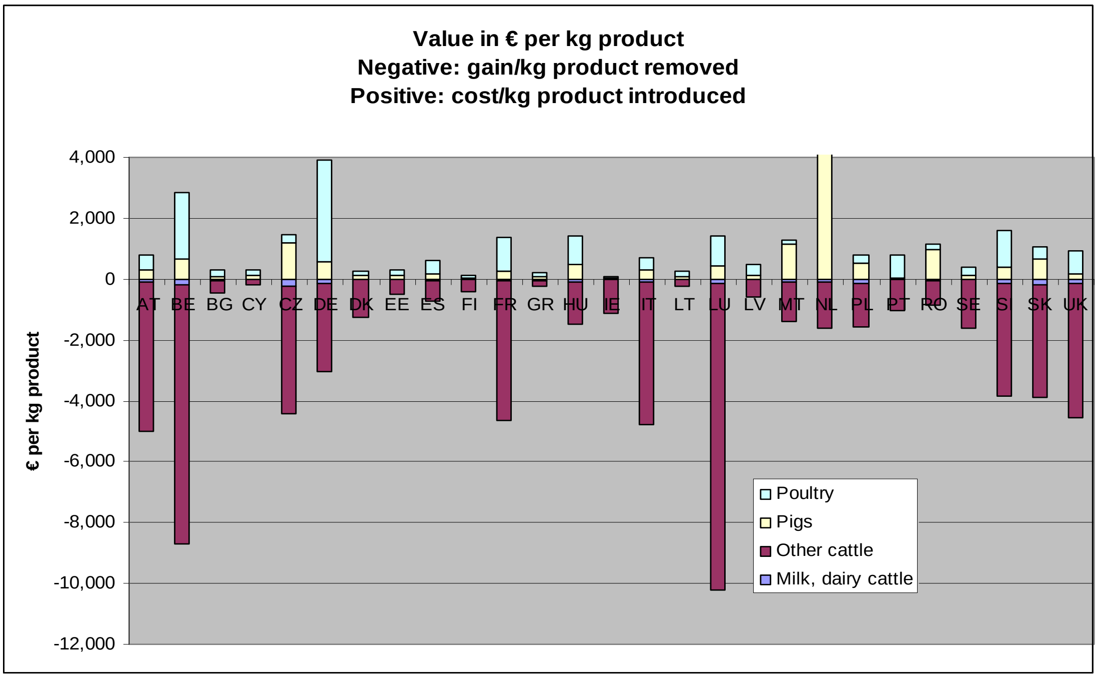

Figure 20. Value in € per kg product

An average of 95.8% of the value is made up of the externality related to emission of NH_3 and 4.1% related to $PM_{2.5}$. The remaining 0.1% is made up of the remaining 5 emission categories and are shown in Figure 21.

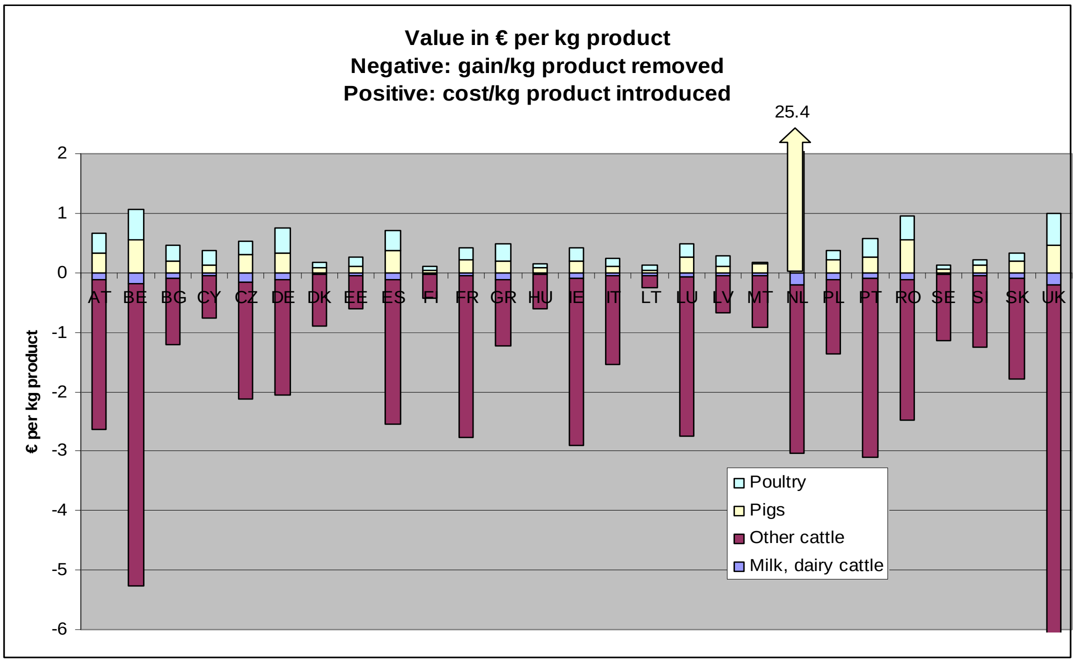

Figure 21. Value in € per kg product, excl. NH_3 and $PM_{2.5}$

3 Damage costs due to ingestion of pesticides

3.1 Description of the scenario

For the present scenario, quantities of plant protection products applied to crops are estimated on the basis of the ‘average pesticide dosage’ per country (the reported applied Active Substance-AS quantity over the respective cultivated area) and the modelled crop area in 2020 as provided by the HEIMTSA project. The HEIMTSA project, however, is still in progress and the respective data related to pesticide application amount per country will be available through the final project report due in spring 2011 and its accompanying deliverables (see official HEIMTSA project website: http://www.heimtsa.eu).

Most of the information related to emission inventory and/or direct application amount data of plant protection products is given aggregated on the basis of the classification according to target organisms, and in addition, most of the information about pesticides related to human health effects, e.g. derived from occupational studies, is given either for particular active ingredients or aggregated on the basis of the classification according to the mode of action. This makes it extremely difficult to link emission inventory data to related human health effect data. Hence, an overview of the variety of chemical classes according to Eurostat, 2007 and Tomlin, 2009 as well as the procedure how to combine emission/application data with human effect information is explained in detail in another report of the EXIOPOL project, namely the “Report on Unit Values of Pesticides”.

3.2 Definition of input data

The type and quantities of Active Substances (AS) used in agriculture differ from country to country depending on crop type, specific climate conditions, pesticide brands marketed by various manufacturers and other factors. For health impact assessment studies, the major problem regarding pesticides in Europe is that there is generally no legal requirement for reporting pesticides use, although routine reporting is done in some countries. Furthermore, a pesticides data-base is maintained by Eurostat, which is of undetermined accuracy and incomplete. Suffice it to point out here that serious data gaps exist in the Eurostat tables, whereby for well known active substances the designation “c” (i.e. “confidential”) is employed in place of specific quantities used. Nevertheless, the Eurostat data were utilized here in order to prepare a list of pesticides appropriate for the present case study.

According to Eurostat, five countries (France, Spain, Italy, Germany and the United Kingdom) account for nearly 75% of the total quantities (in tones) of plant protection products used in EU-25. France alone accounts for 28%, Spain and Italy 14% each, Germany 11% and the United Kingdom 7% (Eurostat, 2007).According to Eurostat, five countries (France, Spain, Italy, Germany and the United Kingdom) account for nearly 75% of the total quantities (in tones) of plant protection products used in EU-25. France alone accounts for 28%, Spain and Italy 14% each, Germany 11% and the United Kingdom 7% (Eurostat, 2007). The amount of pesticides used in the present scenario calculated based on the difference between the business as usual (BAU) and climate reduction scenario in the year 2020 is shown in the following table.

Table 7. Application amount of pesticides (aggregated) per country in year 2020 [kg applied per country]

Country		Application amount [kg applied]		
Code	Name	2020 BAU	2020 climate	difference
AT	Austria	434939	434967	-28.4
BE	Belgium	449031	449062	-31.2
BG	Bulgaria	545666	545789	-122.4
CZ	Czech Republic	1327524	1327716	-192.3
DK	Denmark	1135105	1135090	14.7
EE	Estonia	60334	60338	-4.4
FI	Finland	545806	545805	0.9
FR	France	11445196	11457052	-11856.5
DE	Germany	6850434	6851568	-1134.8
GR	Greece	313859	313536	322.7
HU	Hungary	1925237	1925530	-293.3
IE	Ireland	347780	347791	-10.5
IT	Italy	2167214	2170903	-3689.2
LV	Latvia	99323	99345	-21.9
LT	Lithuania	289509	289550	-41.4
LU	Luxembourg	24363	24363	0.4
NL	Netherlands	1103641	1117155	-13514.1
PL	Poland	4876268	4871657	4610.6
PT	Portugal	216318	245994	-29675.8
RO	Romania	3931346	3931582	-236.1
SK	Slovakia	659647	659817	-170.5
SI	Slovenia	109477	109513	-36.3
ES	Spain	3123481	3140164	-16682.5
SE	Sweden	1253286	1253320	-34.1
UK	United Kingdom	5783571	5758533	25039.0

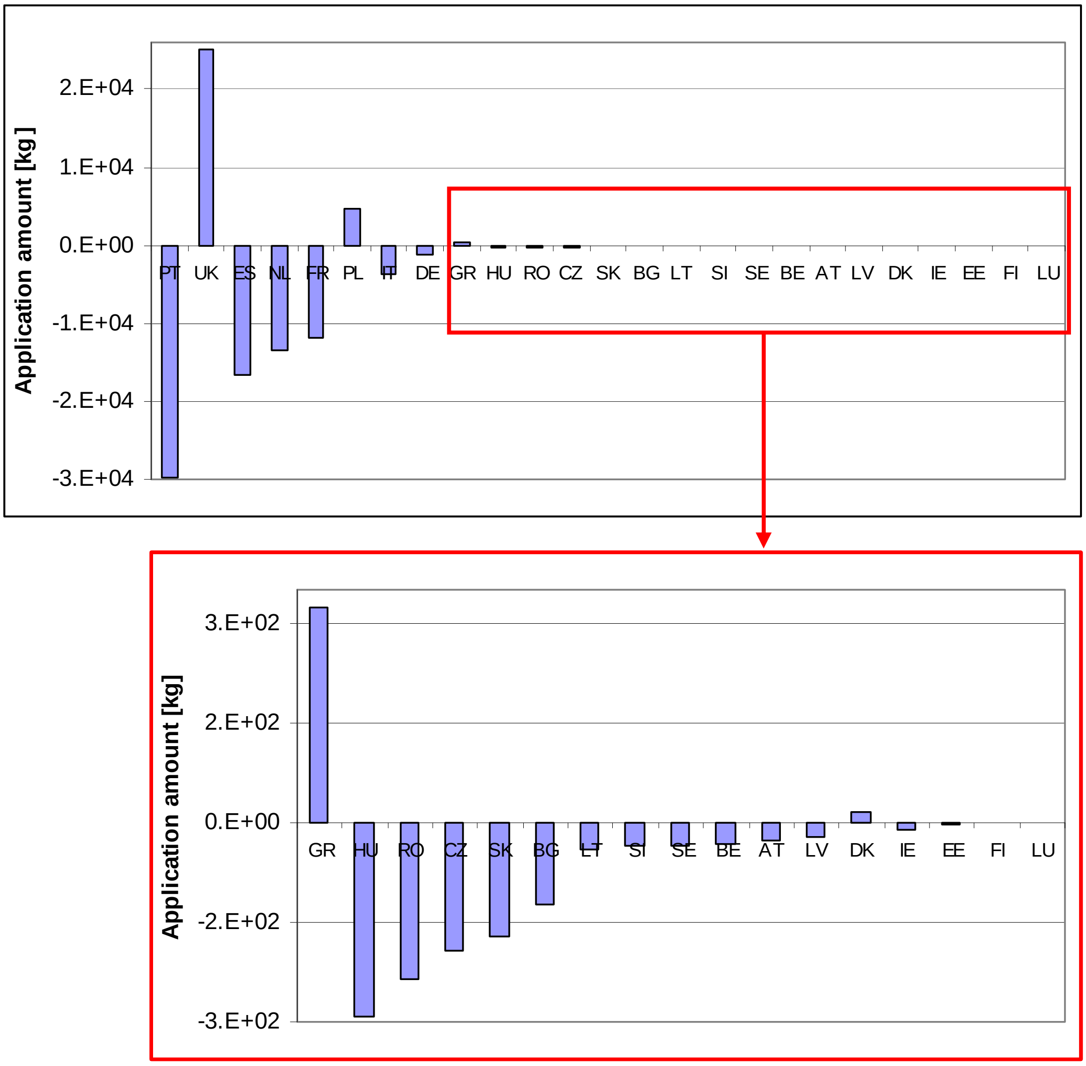

Figure 22. Application amount of pesticides per country in year 2020.

It is shown in the above table and in the above figure that in some countries the political measures to reduce overall health effects in year 2020 lead to an increased amount of applied plant protection products, while in other countries the applied amount is reduced compared to the business as usual scenario. This is mainly due to the effect of changing climate conditions (i.e. in northern European countries the crop yield generally increases due to overall temperature increase, while in southern European countries the crop yield generally decreases due to increasing drought stress) as well as changes in future energy demand and corresponding increase in crop production for energy use in particular countries. However, all assumptions underlying the scenario definition are fully described in the final report and accompanying deliverables of the HEIMTSA project.

The human exposure assessment builds on a dynamic model describing the plant uptake of pesticides and subsequent translocation towards food crops as described in Fantke et al. (2011). Once the concentrations in all food crops are calculated, we can relate these concentrations to the human intake rates of the respective items to arrive at the intake per person. Finally, as output of the human exposure assessment, we want to arrive at human intake fractions by relating the intake to the source strength, i.e. the applied amount of pesticides of the present case study. All data related to the human exposure assessment are described in the EXIOPOL deliverable “Report on Unit Values of Pesticides”. Crop-specific values are, in addition, fully defined and provided in the EXIOPOL deliverable “Scoping Paper on I/O-Methodology” accompanying the “Report on Unit Values of Pesticides”.

3.3 Calculation of damage costs

After having calculated the intake of substance by humans, the number of cases caused by the substance intake can be derived. This is based on the risk to get a particular effect, like cancer. The concept of assessing human health risks is based on slope factors for different exposure pathways.

An uplifting factor was introduced consisting of a conversion component for damages expressed in $Euro_{2000}$ to $Euro_{2010}$ for an emission in year 2000 and an uplift component of 1.7% uplift per year for 20 years between 2000 and 2020. This way, the damage costs related to the present case study in year 2020 can be expressed in $Euro_{2020}$, thereby taking into account economic growth and individua time preferences of the harmed population.

Aggregated unit values as well as resulting (avoided) damage costs in the 2020 scenario are given in the following table.

Table 8. Unit values [$Euro_{2000}$·$kg^{-1}_{applied}$·$year^{-1}$] for human health aggregated over the whole aricultural sector and all human health end-points for the year 2000 for pesticides and total damage costs in 2020 expressed in Euro uplifted to an emission in the year 2020 [$Euro_{2020}$].

Country		Damage costs	
Code	Name	Unit values [$Euro_{2000}$/kg]	Damage costs [$Euro_{2020}$]
AT	Austria	111.7	-5614
BE	Belgium	254	-14025
BG	Bulgaria	n/a	n/a
CZ	Czech Republic	177.3	-60340
DK	Denmark	5.1	132.6
EE	Estonia	74.5	-580.1
FI	Finland	482.6	768.7
FR	France	15.8	-331539
DE	Germany	1.1	-2209
GR	Greece	363.9	207827
HU	Hungary	500.2	-259643
IE	Ireland	134.8	-2504
IT	Italy	1345	-8781647
LV	Latvia	36.7	-1422
LT	Lithuania	265.2	-19431
LU	Luxembourg	242.6	171.7
NL	Netherlands	22.2	-530959
PL	Poland	189.8	1548728
PT	Portugal	n/a	n/a

Country		Damage costs	
Code	Name	Unit values [$Euro_{2000}$/kg]	Damage costs [$Euro_{2020}$]
RO	Romania	63.2	-26407
SK	Slovakia	268.1	-80898
SI	Slovenia	149.8	-9623
ES	Spain	313.3	-9250028
SE	Sweden	2.5	-150.9
UK	United Kingdom	593.2	26286916

Figure 23. Damage costs in Europe in 2020 expressed in Euro uplifted to an emission in the year 2020 [$Euro_{2020}$].

In line with the previous section, it can be seen from the table and figure above that some countries show a reduction of damage costs due to the implementation of overall human health reduction measures in year 2020, most essentially Spain and Italy. In contrast, some countries face an increase in damage costs due to the higher amount of pesticides used, most importantly United Kingdom and Poland.

All in all, there are no obvious conclusions to draw based on the pesticide reduction scenario due to the highly varying underlying assumptions with respect to future climate conditions, energy demand and production system etc. However, when looking at some particular countries, we have a reduction potential of health effects and – along with it – damage costs, whereas in other countries additional damages might occur.

4 Discussion

4.1 NH_3 externality

The secondary particle formation from NH_3 and the following loss of lifetime is valued very high and dominates the result completely.

The value per kg emission of NH_3 is dominated by the formation of secondary particles and the following years of life lost (YOLL) in the population. In (Holland et al., 2005) a value of 50,000€ YOLL is used. A central value of 40,000€ YOLL was decided upon in the EXIOPOL project; hence the difference in valuation between the CAFÉ and EXIOPOL project is unlikely to alter the effect of including NH_3 into the valuation.

The high value of NH_3 ranging from just below 2€/kg emission to 30€/kg emission depending on the nation of emission is also confirmed in (Brandt et al., 2011) which is publicised in 2011 and includes advanced state-of-the-art atmospheric modelling and health evaluation.

4.2 Biomass scenario

Is the inclusion of arable land to produce fuel a problematic issue? The use and conversion into arable land is affected far beyond the country of growth and consumption, see e.g. (Kløverpris et al., 2008).

The estimates show highest external costs for Germany, Poland, UK, France and Italy which are the countries where the potential available area for cultivation of energy crops in the climate scenario is largest. These external costs are clearly dominated by the effects of NH_3 emissions into the air.

The unit cost calculated is per MJ in fresh biomass and conversion into final energy leads to some kind of loss. If e.g. losing 50% when converting to electricity the unit cost will be double.

The unit costs only cover the externalities from producing the energy from biomass. The externalities saved from not producing the energy in a conventional way from fossil fuel are not included. This has to be done to accurately reflect the consequence of changing the fuel source.

4.3 Human diet scenario

The normal political discussion is on reducing consumption of cattle meat as the global warming cost is much lower on poultry and pork. This is also the onset of the scenario construction in the present report. This conclusion is confirmed; that the global warming cost determined by the CO_2 quota trading price is lowered when replacing protein from cattle meat and milk with protein from poultry and pigs.

However, including NH_3 into the calculation alters the result completely and the opposite is now the case.

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Annex I: Contributors to the report

This report is the result of discussions between all partners in the EXIOPOL consortium. It has been edited by Susanne Wagner. The different chapters were written by the following persons:

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Annex II: Estimations

The values for $PM_{2.5}$ emission from the Climate_2020 scenario seemed unchanged from the BAU_2020 scenario which seemed unrealistic, since the PM_{10} values did change. Therefore the $PM_{2.5}$ values were estimated.

Where the factor between PM_{10} and $PM_{2.5}$ could be calculated for the exact same country and crop combination for the BAU scenario, this was used for estimation.

Otherwise the average value of this factor from the specific crop type in the BAU scenario was used for estimation.