EXIOPOL

A new enviromental accounting framework using externality data and input-output for policy analysis

Bottom-up approach

EXIOPOL // Bottom-up approach

This publication summarises the main results of the EXIOPOL project: "A new environmental accounting framework using Externality Data and Input-Output tools for policy analysis", sponsored by the European Commission from March 2007 until October 2011.

The present publication is divided in two parts: the front side is dedicated to the "EXIOPOL Bottom-Up approach", while the reverse side is dedicated to the "EXIOPOL Top-Down approach".

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SIXTH FRAMEWORK PROGRAMME

The research project EXIOPOL "A new environmental accounting framework using Externality Data and Input-Output tools for policy analysis" (2007-2011) is sponsored by the European Commission under the Sixth Framework Programme (Project n° 037033-2).

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EXIOPOL // Bottom-up approach

This project was a key contributor in expanding and synthesising a database on the costs of environmental burdens within the EU, measured in monetary terms. EXIOPOL evaluated, analysed, and assessed damages from the emissions of pollutants into air and water. The project therefore updated and detailed external costs by type of emission, industry sector, and country, as well as for a range of themes, namely: health, agriculture, biodiversity, forestry and wastes. Each theme corresponds to a different Policy Brief.

This set of Policy Briefs details externalities by sector. It is complemented by two Policy Case studies, which focus on agriculture and energy under different scenarios in 2020.

Agriculture

• What are the external costs in each member state of energy production from biomass to meet the requirement of a 20% share of renewables in all primary energy use in the EU by 2020? These costs emerge from the application of nitrogen and phosphate fertilisers, which generate harmful emissions in the form of NH_3, N_2O, PM_{10} and $PM_{2.5}$. These damage costs concern human health, eutrophication, acidification and biodiversity loss.

• What are the external cost implications of a 20% reduction in the number of cattle and an equivalent increase in pig and poultry consumption to meet the same amount of protein consumed by the EU's population? The switch is motivated by the desire to reduce methane emissions, which are harmful greenhouse gases.

Energy

• What are the external benefits of the EU's 20-20-20 strategy, which targets a 20% share of renewables in gross energy consumption as well as a 10% share of biofuels? The benefits of this strategy have been separately estimated for electricity generation, heat generation, and the use of biofuels in transport.

The analysis of the biomass from energy production was carried out using the TIMES model. It analyses the changes in land use and crops throughout the EU, which are needed to meet the biomass requirements. It reveals that environmental costs are a little over € 2 billion for the entire EU- 27 area. These externality costs are dominated by NH_3 emissions, which account for 88 to 94% of total costs. The countries with the highest costs are Germany, Poland, the United Kingdom, France, and Italy. At the same time small benefits emerge in Belgium and the Netherlands due to the decrease in the surface area allocated to oil crops and biomass.
Regarding the changes in diet, a reduction of cattle and dairy products obviously leads to a reduction in methane emissions. However, NH_3 and PM emissions, as well as N and P input, increase considerably. The study finds that the damages caused by non-climatic effects are higher than climatic damages avoided. A reduction of cattle, and an increase in pork and poultry would lead to benefits of about € 120 million, due to the reductions in GHG emissions. At the same time, damages due to non-GHG emissions amount to about € 3,200 million.

Regarding energy, the study finds that the 20-20-20 strategy can occasionally have negative impacts on ecosystems. This mainly occurs in the transport sector with the production of biofuels. Overall, such effects are small compared to the benefits. In the case of electricity generation, net benefits are estimated to be around € 6.7 billion in 2020, with the largest share represented by human health, followed by reductions in climate change. In the case of heat generation, benefits amount to € 1.2 billion, climate change benefits being the largest, followed by gains in human health. Finally, in the case of transport, gross benefits amount to around € 7 billion. However, there are also damages from the application of nutrients to increase cultivation of energy crops, which amount to € 3.6 billion. Thus net benefits from the additional use of biofuels are estimated to be € 3.4 billion, with the highest share coming from climate change.

Policy analysis using Bottom-Up approach

This Policy Brief presents examples of **policy analyses using the Bottom-Up approach** developed within EXIOPOL

Energy (IER)

Scenario

The **EU Directive 2009/28/EC** is the starting point for the policy analysis. It is in line with the EU 20-20-20 strategy, which targets a share of 20% of renewables in gross energy consumption as well as a 10% share of biofuels to be used for transport energy consumption in the EU-27 Member States.

The changes resulting from the increasing use of renewable technologies within electricity generation, heat generation, and transport sectors were assessed separately. The differences in the emissions were assessed to estimate the Directive's **success in reducing climate change**, as well as to calculate the **impacts on human health and the ecosystem**.

The Directive 2009/28/EC negatively impacts the ecosystems, but only marginally, considering that these costs only make up for less than 2% of the total estimated externalities, which largely represent benefits to human health and even more for climate change.

Methodology

The work began with an analysis of the energy sector in 2020, with and without the implementation of the Directive, thanks to the TIMES model. The work has been carried out for the electricity and heat sectors, as well as for the road transport sector, where the Directive 2009/28/EC[1] set the objective to 10% of biofuels.

For each of the three sectors (electricity, heat, and transport), the emissions were calculated for both the **operational phase, and for all the other phases** through a Life Cycle Assessment (LCA). The emissions estimated are: greenhouse gases [methane (CH_4), nitrogen oxide (N_2O), carbon dioxide (CO_2)] and airborne pollutants [ammonia (NH_3), nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOC)], particulate matter (PM_{10}, $PM_{2.5}$) and sulphur dioxide (SO_2).

For each of the EU-27 countries, the **external costs** associated with these emissions were estimated for human health, ecosystems, and climate change.

Main results

Electricity generation: there is a distinction between emissions during the operational phase of the electricity generating process and the other life cycle phases such as the construction, the provision of fuels, the maintenance, and the dismantling of the power plants.

Assuming that the implementation of the Directive reaches its 20% share of renewables (replacing fossil fuels), the **operational phase of electricity generation** would provide benefits in the amount of approximately € **5.1 billion in 2020**[2] to human health, ecosystems, and the climate. More than **80% of these monetised benefits come from climate change mitigation**[3]. This fact can easily be explained by the high emissions of greenhouse gases, especially CO_2 from fossil energy carriers such as coal, compared to the very low emissions of renewable energy technologies.

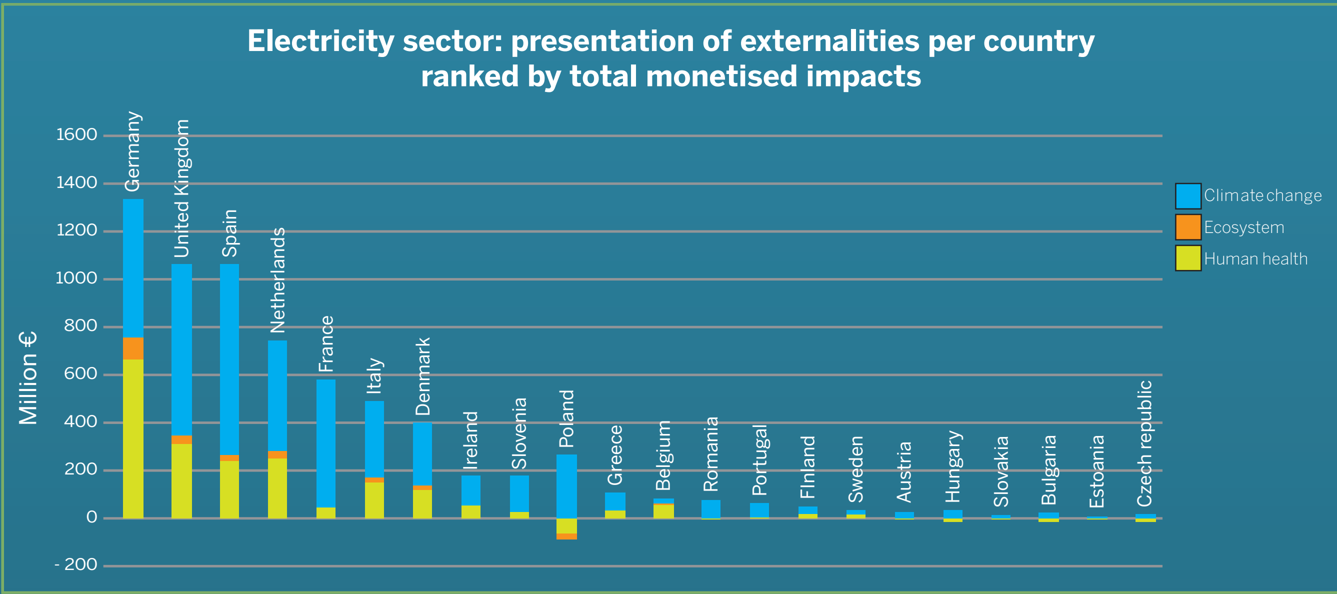
Altogether, with the implementation of the directive, the emissions of greenhouse gases such as CH_4, N_2O and especially CO_2 would decrease significantly in the electricity sector; for instance, the emissions of CO_2 would decrease by almost 150,000 kt in 2020.

Regarding the LCA phases of the different electricity generating technologies, the benefits would amount to about € **1.6 billion in 2020**, with more than **60% accounting for health effects**. The major reason for this is that there is a lower level of emissions in highly populated, urban areas, under a greater use of renewables.

Considering these two components of the electricity generation sector, **about € 6.7 billion of benefits in 2020** have been estimated. This is due to the fall in emissions when electricity is produced by the targeted 20% share of renewables rather than the fossil energy carriers.

[1] The scenario estimations have been performed using the TIMES model within the EU-funded HEIMTSA project: www.heimtsa.eu/TheProject/tabid/170/Default.aspx. Blesl, M., T. Kober, D. Bruchof, R. Kuder (2010): Effects of climate and energy policy related measures and targets on the future structure of the European energy system in 2020 and beyond. Energy Policy, 38, 6278-6292.
[2] All values are given in Euro2000
[3] Substitution factors for different renewable and fossil technologies were provided by data from the German Federal Environmental Agency. German Federal Environment Agency (2010): Emissionsbilanz erneuerbarer Energieträger - Durch Einsatz erneuerbarer Energieträger vermiedene Emissionen im Jahr 2009, Umweltbundesamt, Aktualisierung der Ausgabe Climate Change, 12/ 2009.

The differences in the benefits significantly vary across regions. The countries with high levels of population density, which produce most of their electricity by fossil energy technologies, enjoy the major benefits from the implementation of the Directive 2009/28/EC.



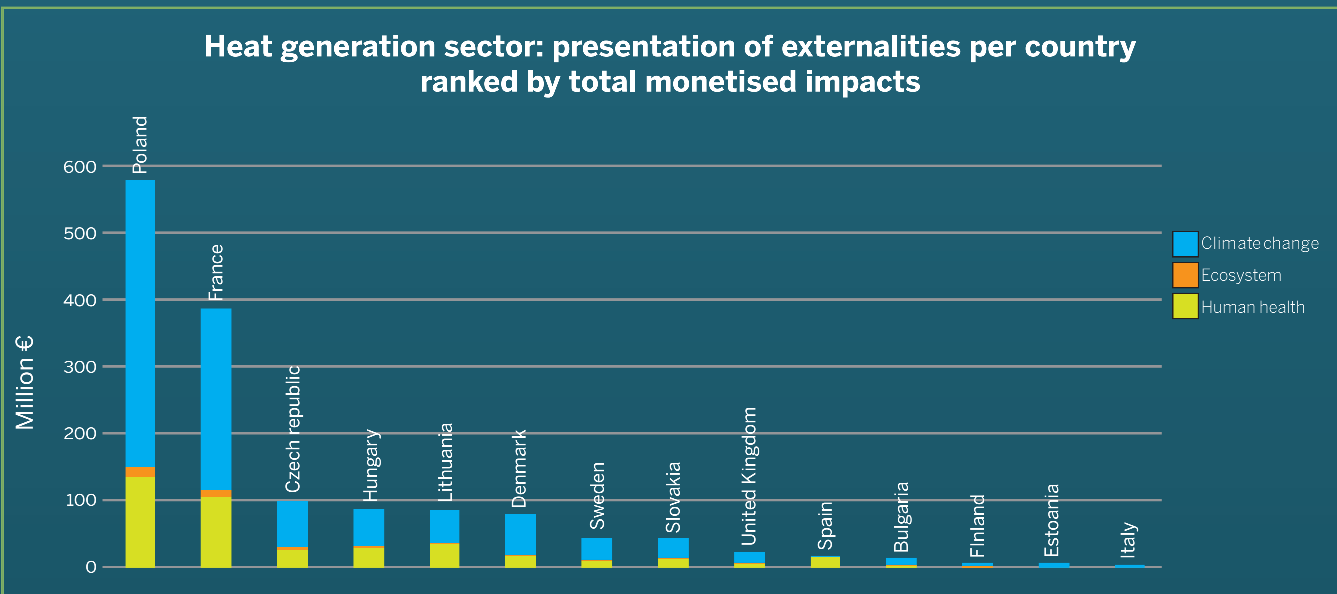
This is especially true for Germany where the human health benefits exceed those related to climate change mitigation. Germany is the only country among the EU-27 Member States showing this effect, mainly for two reasons. The first one is the high level of population density in Germany, meaning that more people are affected by health impacts. The second reason is that standards with respect to GHG emissions are already relatively strict, lowering the expected benefits related to climate change from the application of the Directive.

Heat generation: similar to electricity generation, the effects of the Directive 2009/28/EC in the Heat sector will distinctively target emission patterns during the operational and the LCA phases.

Regarding the operational phase of heat generation, implementing the Directive would amount to **approximately € 1.2 billion in 2020**[4] **in benefits to human health, the ecosystem, and climate change**. Once again, almost 80% of the monetised damages can be attributed to climate change impacts. This can be explained by the high changes in emissions of greenhouse gases, especially CO_2. Around 20% of emissions are related to human health impacts, while impacts on ecosystems are not relevant in this context.

The assessment of the LCA phases of heat generation activities focused on the fuel supply chain result in total benefits of about € **304 million** in 2020. As for the LCA phases of heat generation, the benefits for human health account for more than 50% of the total benefits.

In summary, benefits of almost € **1.5 billion in 2020**[5] have been estimated, due to the implementation of the Directive, which promotes the use of renewable heat generating technologies by 2020.



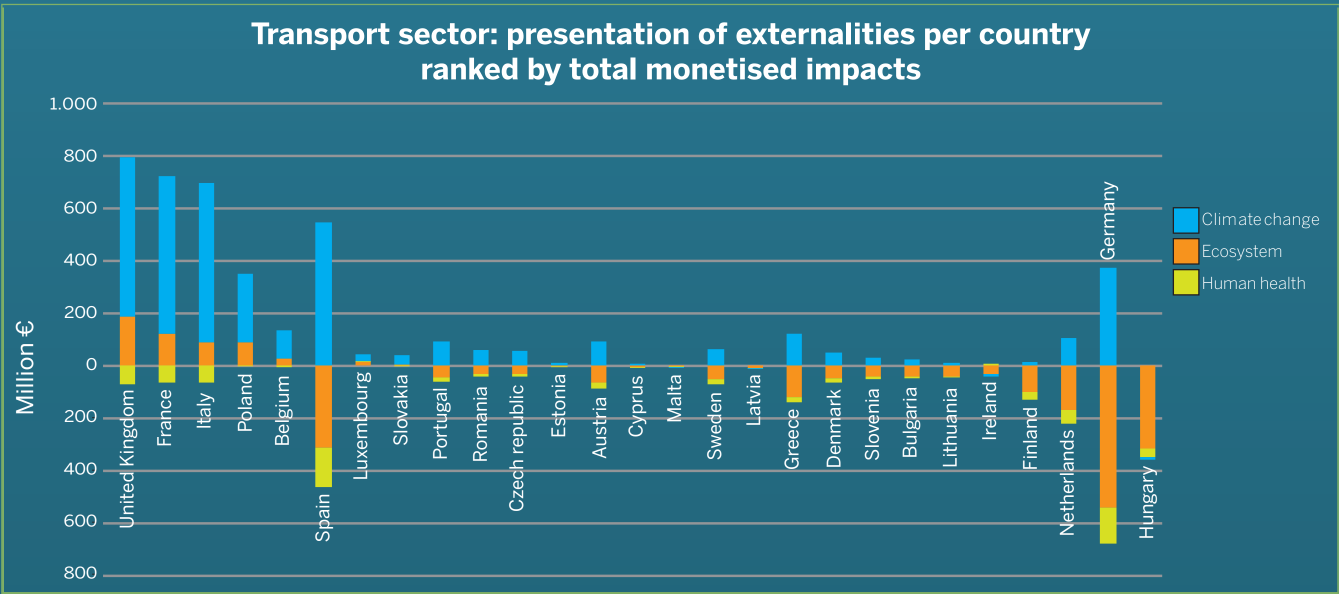
4 These benefits were estimated by applying emission factors from the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model.
5 For the estimation of benefits in the LCA phases of heat production emission factors from the ecoinvent 2.0 database have been applied (www.ecoinvent.ch)

With respect to the distribution of these benefits among the EU-27 member states, a graphical representation clearly shows that Poland and France received the largest share of the overall benefits, followed by the Czech Republic, Hungary, and Lithuania. A shift towards the use of renewable technologies would lead to substantial benefits for the countries where the current production of heat is dominated by fossil technologies.

Use of biofuels in transport: for both the bio and the classical fuels, a distinction between operational and LCA phases is still necessary. The LCA analysis regards the cultivation of plants for the production of biofuels and the refining of fossil fuels. The operational phase is related to the emissions occurring during combustion.

Overall, **an 8% decrease in total emissions** can be achieved in the transport sector thanks to the implementation of the Directive. Replacing conventional diesel and gasoline with biofuels in the road transport sector would largely decrease greenhouse gases such as CH_4, N_2O and especially CO_2 (72,000 kt in 2020).

The analysis of the pre-combustion phase for biofuel production only concerns the **application of nutrients** to increase the cultivation of energy crops, with estimated **monetary damages of about € 3.6 billion in 2020 for the EU-27**[6]. The impacts on human health are the highest due to the emissions of $PM_{2.5}$, PM_{coarse}[7] and NH_3, followed by impacts on ecosystems and climate change, which are caused only by NH_3 and N_2O, respectively.



The pre-combustion activities[8] for the production of gasoline and diesel concern the processes of extraction and refining. With the implementation of the Directive, the total estimated **benefits for pre-combustion activities of diesel and gasoline would amount to about** € **3 billion in 2020**. About 75% of the total monetised benefits relate to human health, while climate change impacts would account for about 21% and ecosystem quality for about 4% of the total.

Summing up the two opposite contributions of **pre-combustion activities**, the negative impacts amount to **€ 0.6 billion**.

In the operational phase, the changes in emissions resulting from the substitution of conventional fuels, for instance, diesel and gasoline from biofuels, amount to € **4 billion in 2020**[9], in benefits to human health, the ecosystem, and climate change. The majority of these benefits come from avoided greenhouse gases emissions, especially CO_2 from diesel and gasoline vehicles, compared to the substantially lower emissions from biofuel combustion.

In summary, the total benefits caused by the additional use of biofuel engines as contemplated by the Directive are about € 3.4 billion in 2020, with the highest share due to climate change mitigation.

However, there are some countries, for instance Spain, Finland, Hungary, Latvia and Malta, reporting monetary damages. This is mainly due to the increase in externalities related to the cultivation of biofuels.

6 For these estimations emission factors were derived in EXIOPOL by Wagner, S., Kokborg, M.S. and Fantke, P. (2011). Report on selected policy measures and quantified emissions from agricultural activities including the Report on impacts and damage costs of the analysed policy measures. EXIOPOL Deliverable DIV.3.a-1 and DIV.3.a-2.
7 PMcoarse refers to particulate matter with a diameter between 2.5μm and 10μm.
8 Emission factors from ecoinvent database were applied (www.ecoinvent.ch).
9 Estimated by using emission factors from TREMOVE (www.tremove.org) and by calculating the differences in amount of driven vehicle kilometres.

Conclusions

Bringing together all the analysed energy sectors, the implementation of the **EU Directive 2009/28/EC would generate around € 11.6 billion in 2020 in benefits for the EU-27**. Greenhouse gases mitigation accounts for the largest share of total external benefits estimated for each of the sectors, with a share of about 70% of the monetised estimation damages being assigned to these pollutants.

This clearly indicates that the Directive of the EU targeting the use of renewable energies reaches its overarching goal to reduce climate change impacts. In addition, the estimated external costs for human health impacts that can be saved by implementing the Directive will serve as a positive side effect.

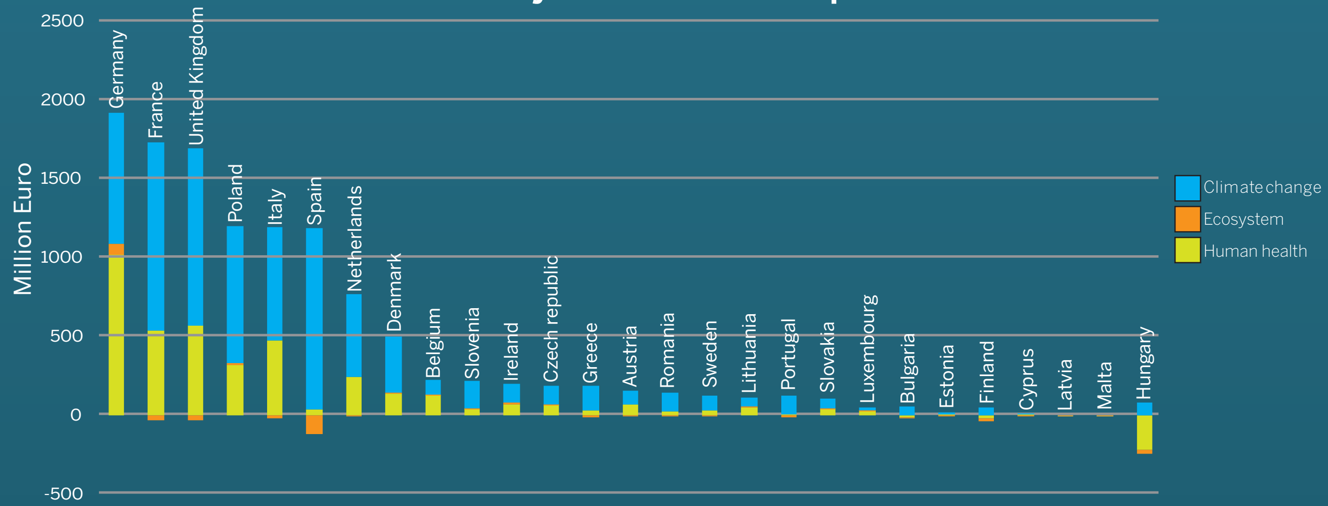
However, the **impacts on ecosystem quality** result in an overall negative value, meaning that the implementation of the Directive would lead to increasing impacts on ecosystems, covered as biodiversity losses due to acidification and eutrophication. This increase in impacts comes from the additional need of agricultural area to cultivate the plants, which are later used for producing the biofuels. The increase in agricultural area goes along with an increasing use of nutrients resulting in additional emissions of especially NH_3, which affects biodiversity negatively.

At the same time it is important to bear in mind that the estimated impacts on ecosystems only account for 1.8% of externalities estimated. Thus, when compared to the benefits for human health and even more for climate change, the overall benefits of the implications caused by the directive clearly outweigh these costs.

The benefits are the highest for Germany, France, and UK, which account for large shares in the activities of electricity production, heat generation, and transport. A switch towards an increase in the use of renewables in the production of heat and electricity and biofuels in the transport sector would lead to substantial reductions in GHG and other pollutant emissions, reducing total impacts by almost € 5.3 billion in these three countries. This amount is almost half of the total benefits for all EU-27 member states.

The negative benefits for Hungary show the effect of an increasing cultivation of energy crops. In Hungary, this effect dominates the positive effects of the Directive in the electricity and heat production sectors.

Electricity, heat and transport sector: presentation of externalities per country ranked by total monetised impacts



Policy analysis using Bottom-Up approach

This Policy Brief presents examples of **policy analyses using the Bottom-Up approach** developed within EXIOPOL

Agriculture (IER)

Biomass for EU 20-20-20 strategy

Scenario

The starting point for the policy analysis is the EU 20-20-20 strategy. The European Union's objective is to have a 20% share of **renewables in all primary energy use**, as well as a 20% reduction of greenhouse gases in the year 2020 compared to the Kyoto base year.

Biomass is considered to be **carbon neutral and capable of guaranteeing energy security**. On the other hand, it may also create other critical environmental impacts, such as air pollution, biodiversity loss, and eutrophication.

The monetary values of the environmental impacts caused from such a biomass policy have been calculated to be over **€ 2,000 billion for the entire EU-27 area**, significantly varying between countries. Overall, it appears that **oil and starch crops cause the highest damage costs** per energy unit of primary energy - mainly because of the role of NH_3- while woody biomass and sugar crops lead to nearly no damage costs.

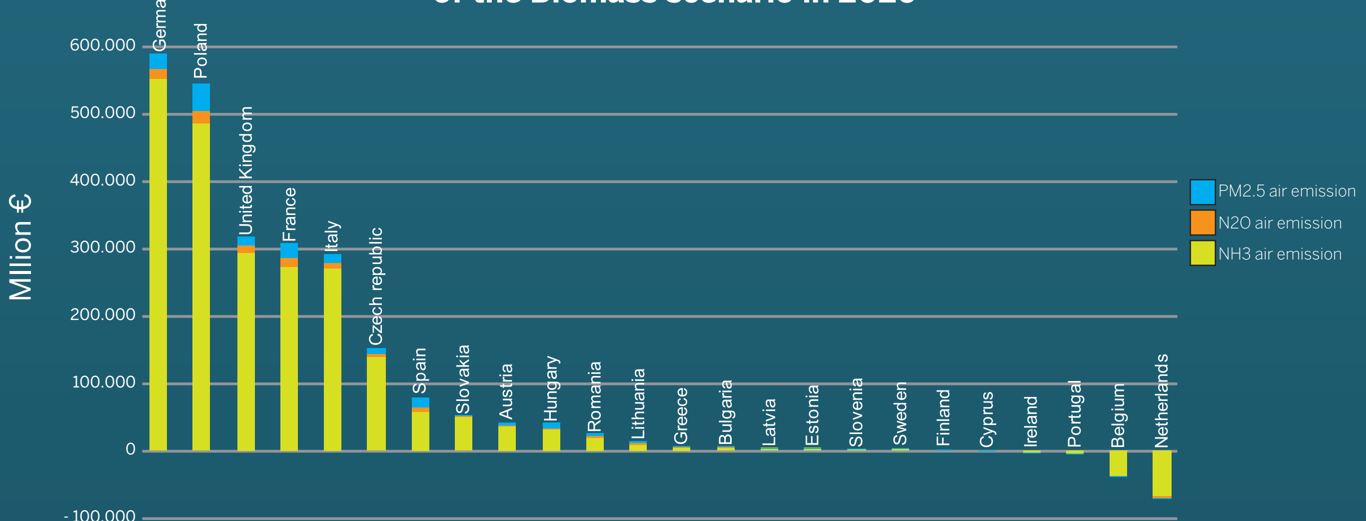
Methodology

The TIMES[1] energy model was used to estimate three important factors: the demand in terms of **energy from Biomass** in 2020, the corresponding **amount of harvested biomass** per crop category (oil, sugar and starch crops, and wood biomass), and finally an estimated **surface area** needed to cultivate these crops.

For each crop, the Nitrogen (Azote, both Manure and Mineral) and Phosphate fertiliser **inputs were assessed together with the resulting emissions** of NH_3, N_2O, PM_{10} and $PM_{2.5}$.

For each of the EU-27 countries, the **external costs** associated with Manure and Mineral Azote, and Phosphate fertilisers, NH_3, N_2O, PM_{10} and $PM_{2.5}$ were quantified, using the unit values calculated from the EXIOPOL bottom-up estimates[2]. The most critical sources of external costs are damages to human health, eutrophication, acidification, and biodiversity losses.

Cost and benefits, per type of emission, from the implementation of the Biomass scenario in 2020



This figure represents the major costs and benefits for a selection of European countries. Clearly, the highest external costs occur in Germany, followed by Poland, France, Italy and the UK. For these countries, the surface area used for cultivation of energy crops is the largest. In Belgium and the Netherlands, benefits result from a decrease in the surface area, to cultivate oil crops and biomass.

1 Blesl, M., T. Kober, D. Bruchof, R. Kuder (2010): Effects of climate and energy policy related measures and targets on the future structure of the European energy system in 2020 and beyond. Energy Policy, 38, 6278-6292

2 For further details, see EXIOPOL Deliverable DIV.3.a-1 and DIV.3.a-2

The externality costs from NH_3 severely dominate the picture, with minor effects from $PM_{2.5}$ particles, as confirmed by the results presented below. Each type of crop is associated with the external cost in Euro per MJ per emission category.

[€ per MJ]	NH_3 air emission	N_2O air emission	Mineral N applied (unprotected forest)	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

Change in human diet

Scenario

The starting point for this policy analysis is the European strategy on Climate Change. It has often been discussed how a change in human diets, considering a reduction in the consumption of beef and dairy products and an increase in pork and poultry, could considerably reduce methane emissions.

We assume there will be a 20% reduction in the number of cattle. The increase in pig and poultry product consumption by 2020 would correspond to the same amount of protein that was formerly supplied by the cattle. What are the consequences, if in addition to the climate benefits we also add the environmental and health impacts caused by NH_3 and PM emissions, as well as N and P inputs?

Although a reduction of cattle and dairy products obviously leads to a reduction in methane, NH_3 and PM emissions, N and P inputs increase considerably. Damage costs caused by non-climatic effects are higher than avoided climatic damages. A reduction of cattle in favour of pork and poultry would lead to **benefits of about €120 million due to reductions in GHG emissions** while, **damages due to non-GHG emissions amount to about €3,200 million**.

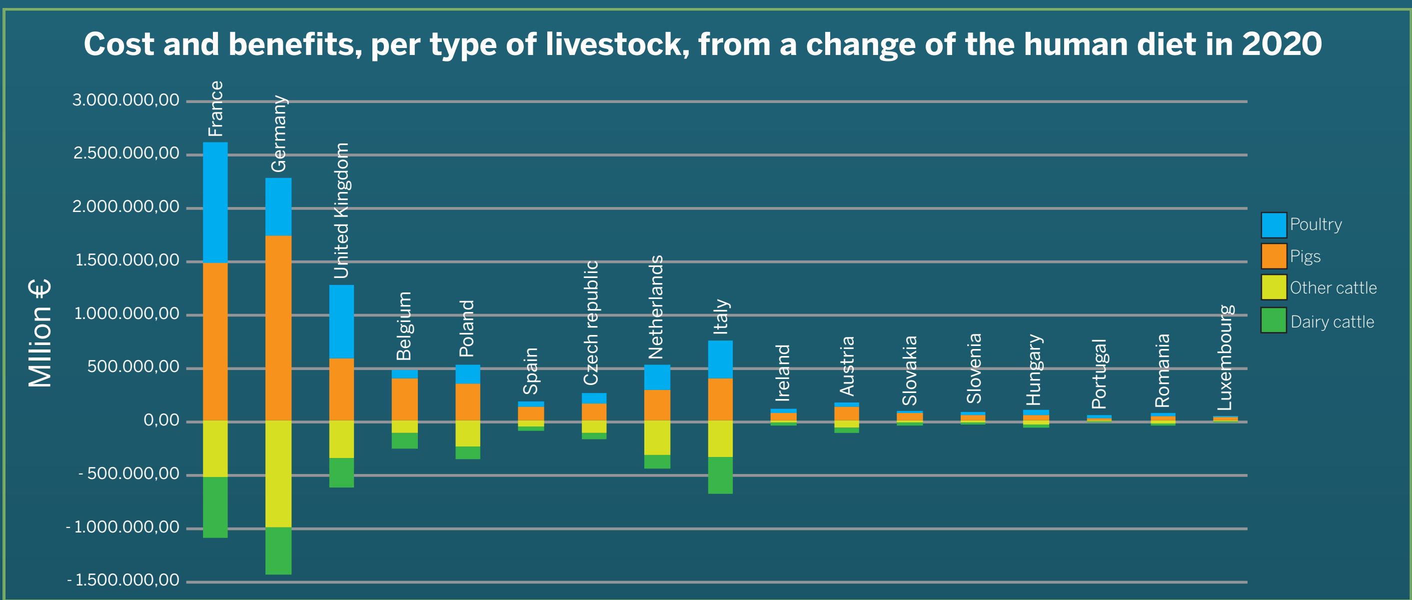
Methodology

The number of livestock for the reference scenario was calculated thanks to the GAINS model Climate & Energy scenario (current policy) available at IIASA[3]. For each of the livestock considered, the Manure and Mineral Azote and Phosphate **inputs were assessed together with** NH_3, CH_4, PM_{10} and $PM_{2.5}$ emissions.

For each of the EU-27 countries, the **external costs** of Mineral Nitrogen and Phosphate inputs were assessed together with NH_3, CH_4, PM_{10} and $PM_{2.5}$ emissions.

Results

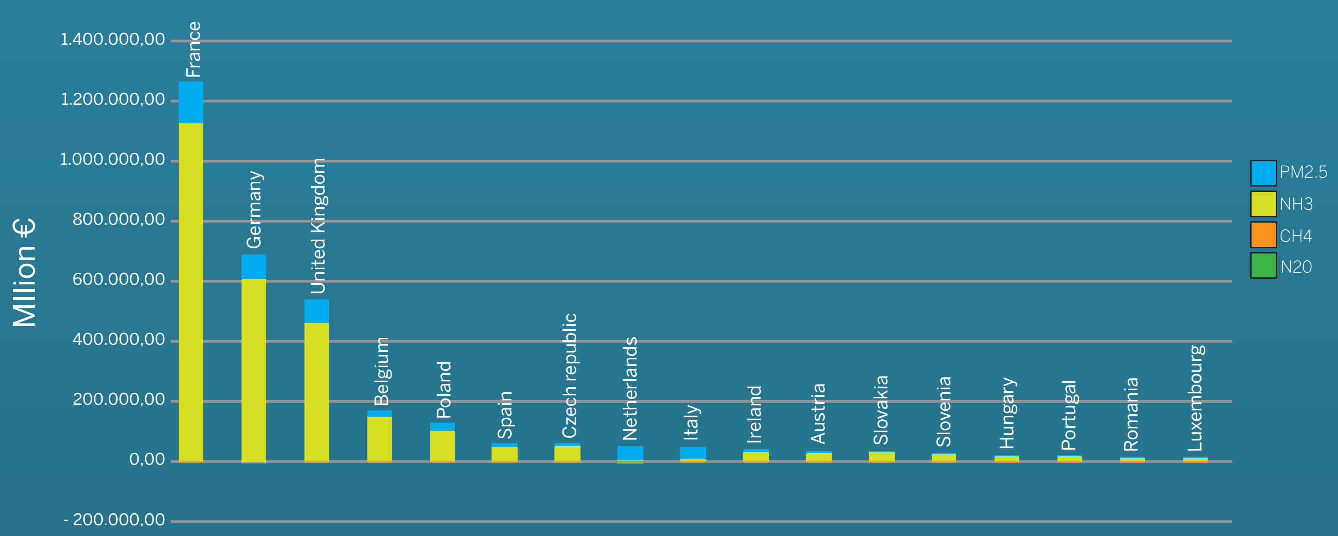
The sum of the emissions slightly changes due to the implementation of the above scenario. As anticipated, the emissions and applications from dairy and other cattle decrease, while emissions from pigs and poultry increase.



3 gains.iiasa.ac.at

The calculations (see figure below) show that an average of 95.8% of the value accounts for the externality related to NH_3 emissions and 4.1% accounts for $PM_{2.5}$. The residual 0.1% accounts for the remaining 5 emission categories.

Cost and benefits, per type of emission, from a change of the human diet in 2020



The global warming cost determined by the CO_2 quota trading price is lowered when protein from cattle meat and milk is replaced with protein from poultry and pigs. However, including NH_3 in the calculation alters the result completely and overall damages must be taken into account.

Pesticides ingestion

Scenario

The starting point for the policy analysis is the **European strategy on Climate Change**, which has been analysed in the EU-funded HEIMTSA[4] project. Scenarios build upon differences in crop production areas based on changing climate conditions (temperature and relative humidity in the air).

Methodology

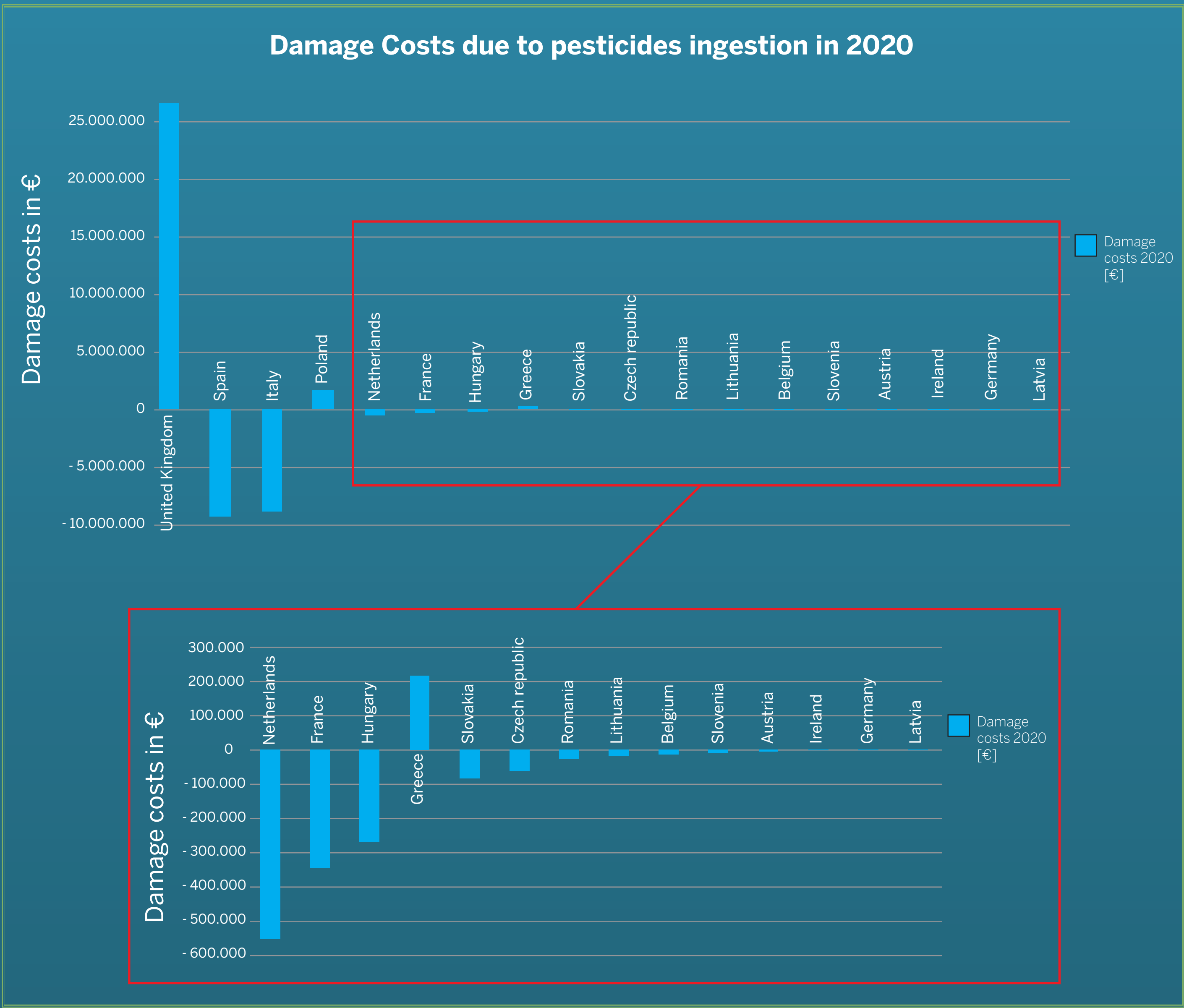
Calculating the **amounts of applied pesticides and the intake of substances into the human diet can determine the number of health cases** based on the risk of particular consequences, like cancer[5]. The concept of assessing human health risks is based on slope factors for different exposure pathways[6].

Results

The study shows an **increased amount of applied plant protection products in 2020 for some countries**, while the applied amount is reduced in other countries. Reasons for these variations are related to changing climate conditions as well as changes in future energy demand and corresponding increases in crop production for energy use in particular countries.

The decreasing applied amounts of plant protection products reduces **damage costs for some countries**, especially for Spain and Italy. In contrast, some countries face an **increase in damage costs when higher amounts of pesticides are used**, especially for the United Kingdom and Poland.

4 www.heimtsa.eu
5 Fantke, P., Charles, R., de Alencastro, L.F., Friedrich, R., Jolliet, O., 2011. Plant uptake of pesticides and human health: Dynamic modelling of residues in wheat and human intake. Chemosphere. (in press)
Fantke, P., Juraske, R., Antón, A., Friedrich, R., Jolliet, O., 2011. Dynamic multi-crop model to characterise impacts of pesticides in food. Environ. Sci. Technol. (in press)
6 Huijbregts, M.A.J., Rombouts, L.J.A., Ragas, A.M.J., van de Meent, D., 2005. Human-toxicological effect and damage factors of carcinogenic and non-carcinogenic chemicals for life cycle impact assessment. Integrated Environ. Assess. Manag. 1, 181-244.



Conclusions agriculture

Both biomass production as well as a change in human diets have been examined not only regarding their climate change mitigation potential, but also regarding their emissions of pollutants; for instance ammonia (NH_3), particulate matter (PM_{10}, $PM_{2.5}$) and nutrients (nitrogen N and phosphorous P), input into soils, and resulting impacts on health and eutrophication of water bodies.

Emissions of particulate matter cause respiratory and cardio-vascular diseases and can lead to premature deaths.

On the one hand, ammonia reacts with nitrogen and sulphur oxides in the atmosphere and forms secondary particles and thus contributes 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 secondary particle formation from NH_3 and the following loss of lifetime is valued very high and dominates the result completely.

High externality values for NH_3 emissions have been estimated in this study: they range from just below **2€/kg emissions to 30€/kg** emissions, depending on the nation/nature of the emissions.

Key findings from EXIOPOL Bottom-up estimates

Mortality risks (FEEM)

The benefits of environmental policies and regulations that reduce premature mortality are **typically calculated as the number of Lives saved by the program multiplied by the Value of a Prevented Fatality** (VPF), also known as the Value of a Statistical Life (VSL[1]), a summary measure of the Willingness To Pay for mortality risk reductions. The concept of VPF is generally deemed as the appropriate construct for ex ante policy analyses, because the identities of the people whose lives are saved by the policy are not known. Concerns[2] have been raised about the appropriateness of much policy practice today, which uses compensating wage studies or literature about transportation accidents to calculate the VPF.

Some academic and policy circles propose an alternate approach to valuing the mortality benefits of environmental policies, which requires computing **life expectancy gains (losses) and multiplying them by a metric known as the Value of a Statistical Life Year** (VOLY[3]). Until recently, however, most estimates of the VOLY were derived from estimates of the VSL, which, in turn were taken from labor market studies.

Methodology

The EXIOPOL surveys[4] on mortality risks were conducted in Italy, the UK and the Czech Republic. They employed conjoint choice experiments because this technique allows us to study how people respond to variations in the attributes of the risks being valued, to the cause of death, and to the risk context (environmental exposures v. others).

We incorporated **several methodological treatments in our questionnaires**, including the use of follow-up conjoint choice questions, and comparisons between internet-administered (CAWI) and computer-assisted in-person interviews (CAPI), which we hope will provide useful information for future research.

Results

Briefly, we find that the VSL[5] (averaged across all variants of the questionnaire within a country) is € 2.273 Million in Italy, € 0.877 Million in the UK and about € 2.183 million in the Czech Republic. **However, there are sharp differences in the VSL estimates when we do and we do not inform people about the life expectancy gain implied** by the risk reductions shown to them in the conjoint choice questions.

When no such mention is made, the VSL is typically much larger: It is about € 5.766 million in Italy, € 6.254 in the UK, and € 4.252 million in the Czech Republic. These figures are comparable to those estimated in earlier DG-funded projects[6] where respondents examined mortality risk reduction profiles, and are slightly higher than the VPF figures commonly used by DG-Environment in its policy analyses[7].

When respondents are informed about realistic life expectancy gains associated with the risk reductions they are to value, the VPF is only € 0.220 million in Italy and € 1.096 million in the Czech Republic. The model does not converge for the UK sample (in other words, we are unable to produce meaningful estimates). When respondents are told about somewhat "inflated" life expectancy gains, the VPFs are € 0.562 million (Italy), € 0.136 million (UK) and € 1.531 million (Czech Republic).

The impact of the life expectancy extension reminders is especially strong in the UK. This effect cannot be attributed to income, since the UK sample was wealthier than the Italy and Czech samples and had the highest VPF when no mention of life expectancy gains was made.

We also find that people have **higher VSL values when the risk being reduced are those associated with environmental exposures**, and find **no difference in the VSL by cause of death**. These results are potentially very important for policy purposes. Regarding the effects of environmental risks, we believe that people are willing to pay more to reduce these risks because they perceive them as involuntary. By contrast, others risks such as transportation risks or risks associated with lifestyle are often perceived as voluntary and controllable.

1 For further details on VSL, refer to Chapter 2 of the EXIOPOL deliverable DII.1.b5

2 The preferences observed in labor markets are those of workers—not those of the elderly and children, the primary beneficiaries of environmental health protection—and because workplace and transportation risks are very different from the mortality risks associated with environmental exposures (see Robinson, Lisa A. (2007), "How US Government Agencies Value Mortality Risk Reductions," Review of Environmental and Economic Policy, 1(2): 283-299).

3 The concept of Value of a Statistical Life Year (VOLY) is related to the VSL. The notion of VOLY is used in policy analyses in addition to or instead of that of VSL, but, depending on the age of the people whose lives are saved by the policy, can offer recommendations in conflict with those obtained by using VSL. For further details on VSL, refer to Chapter 4 the EXIOPOL deliverable DII.1.b5

4 We used internet-administered (CAWI) in Italy and the UK, and, in separate samples, CAWI and computer-assisted in-person interviews (CAPI) in the Czech Republic.

5 2010 PPP €

6 VERHI-Children, cCASHH, and others.

7 ec.europa.eu/environment/enveco/others/pdf/recommended_interim_values.pdf . Clean Air for Europe (CAFE) Programme: europa.eu/legislation_summaries/environment/air_pollution/l28026_en.htm

Key findings from EXIOPOL Bottom-up estimates

Pesticides in agriculture (IER)

A wide range of pesticides is commonly used in the European Union for agricultural production. EXIOPOL has quantified the **effects of pesticides (herbicides and insecticides) application on human health and ecosystems**. Regarding impacts on human health, the focus has been on the ingestion pathway, that is, the **consumption of effectively harvested and processed agricultural produces**. Regarding impacts on ecosystems, the focus has been on the **fraction of an applied pesticide that undergoes run-off** from soil to surface water, or **leaching** from surface soil to sub-surface soil and further to the groundwater table.

Methodology

The **selection of pesticides of concern** is challenging considering a territory as wide as the EU: the numbers of different target organisms, and various weather, soil, and water conditions necessarily imply the use of a wide range of different pesticides. At the risk of somewhat overly simplifying the analysis performed, EXIOPOL began with the inventory of the five most extensively applied pesticides for each country, leading to a short list of all substances of concern[1], which were then classified and aggregated[2] to finally be able to cover the vast majority of used pesticides.

Substances show different patterns of behaviour, interacting with different deposition surfaces (usually crop surface area) and advection uptake pathways into the crop (for instance, uptake via the root system as a function of transpiration). **A new dynamic modelling approach[3] was developed** to provide a better understanding of the complex behaviour of pesticides in the plant-environment system. It allows the estimation of residues in food products effectively harvested and processed for human consumption. From these, the **human intake fraction [$kg_{intake}/kg_{applied}$]** is combined with the total mass of applied pesticides in each country, to arrive at human health[4] effects in terms of unit values, and the fraction of applied pesticide that is lost to the environment serves as basis for arriving at ecosystem effects in terms of potentially affected fractions of species for each considered country.

Results

Unit values for human health aggregated over the whole agricultural sector and all human health end-points for the year 2000[5]

	Austria	Belgium	Bulgaria	Cyprus	Czech Republic	Germany	Denmark	Estonia	Spain	Finland	France	Greece	Hungary	Ireland	Italy	Lithuania	Luxembourg	Latvia	Malta	Netherlands	Poland	Portugal	Romania	Sweden	Slovenia	Slovakia	United Kingdom
Insecticides [€/kg.yr]	100.6	227.6	n/a	0.7	161	1.1	1.8	0	258.3	372.5	0	300.3	437.8	111	1273	229.6	217.6	0	0	0	156.9	n/a	0	0.9	117.7	235.1	538.7
Herbicides [€/kg.yr]	10.8	24.9	n/a	5.2	16.3	0	1.3	74.5	42.2	19.4	15.8	51.5	62.2	19.5	47.3	35.5	23.3	34	0	22.2	19.9	n/a	61.6	0.6	31.3	33	53.8

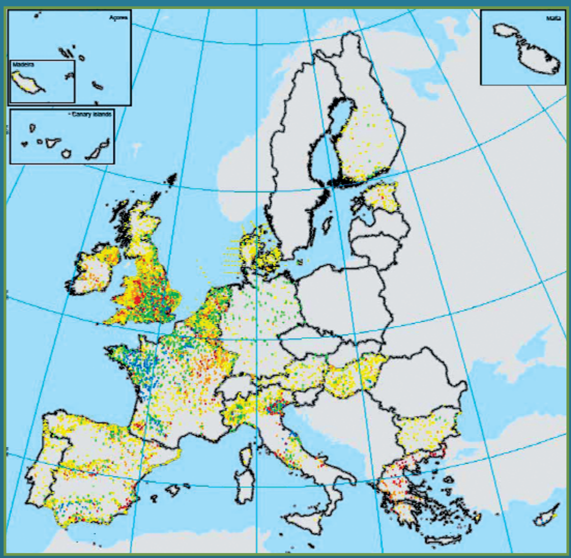
The nature of this integrated approach, combining a wide range of scientific fields from chemistry and applied physics, mathematics and biology to economics and toxicology, is to incorporate a variety of data at different scales. Some of the various data come from crop-specific conditions of a pesticide application to the aggregated area of the annual production of the same crop, or from the pH-dependent behaviour of a contaminant in the field to rather generic effect information with respect to human health and ecosystem toxicity as discussed for a wide range of pesticides applied to six major crop archetypes[6]. One of **the major sources of uncertainty**, thus, comes from the data manipulation required as an input for the present assessment. Another source of uncertainty is the information available with respect to human health and ecosystem effects, either based on toxicological studies or, whenever available for the former, based on epidemiology. Finally, we still face considerable uncertainties in the evaluation of health and other endpoints.

[1] Deliverable DII.2.c-1: Section 1.1 Definition of the substances of concern.
[2] Deliverable DII.2.c-1: Section 1.2 Classification and aggregation of substances of concern.
[3] Fantke, P., Charles, R., de Alencastro, L.F., Friedrich, R., Jolliet, O., 2011. Plant uptake of pesticides and human health: Dynamic modeling of residues in wheat and human intake. Chemosphere, doi:10.1016/j.chemosphere.2011.08.030. (in press)
[4] The focus of the resulting unit values is on the producer's perspective, for example, the agricultural sector is directly linked to the caused unit value results. Furthermore, generic effect data for human health have been considered for the present approach rather than endpoint-specific values from epidemiological studies of occupational health, which is due to the fact that only rare, if at all, data are available for a comprehensive estimation of related health impacts at the European scale.
To be able to compare different diseases and human health burdens, the Disability Adjusted Life Year (DALY) approach was used to account for both, cancer and non-cancer effects. One DALY represents one year of life lost, or an equivalent in the case of morbidity effects: in EXIOPOL this has been set to an overall value of 40,000 Euro2000 per DALY. Note that this value is only valid for Europe as decided in the frame of the NEEDS international project as of 2007 (for further details refer to the final project reports of the NEEDS project, available online at: www.needs-project.org/index.php?Itemid=66).
[5] All the classification of substances of concern, application rates of selected substances, phyisicochemical properties of selected substances, human health characterisation factors, eco-toxicity characterisation factors, disaggregated unit values, and potentially affected fractions of species are available in annexes of the Deliverable DII.2.c-1.
[6] Fantke, P., Juraske, R., Antón, A., Friedrich, R., Jolliet, O., 2011. Dynamic multi-crop model to characterize impacts of pesticides in food. Environmental Science and Technology, doi:10.1021/es201989d. (in press)

Key findings from EXIOPOL Bottom-up estimates

Nitrogen fertilisers in agriculture (NERI)

Nitrogen fertilisers are extensively used in the European Union for agricultural production. EXIOPOL has quantified **external effects of nitrogen (mineral and organic) applications on human health and ecosystems**. Regarding impacts on human health, the focus has been on the **intake with potable water** while for ecosystems, the focus has been on the **fraction of applied nitrogen that reaches surface waters and affects water clarity**.



NITRATES DIRECTIVE EU-27
Reporting period 4 (2004-2007)

Surface water
Trend nitrate concentrations

Trend NO_3 mg/l

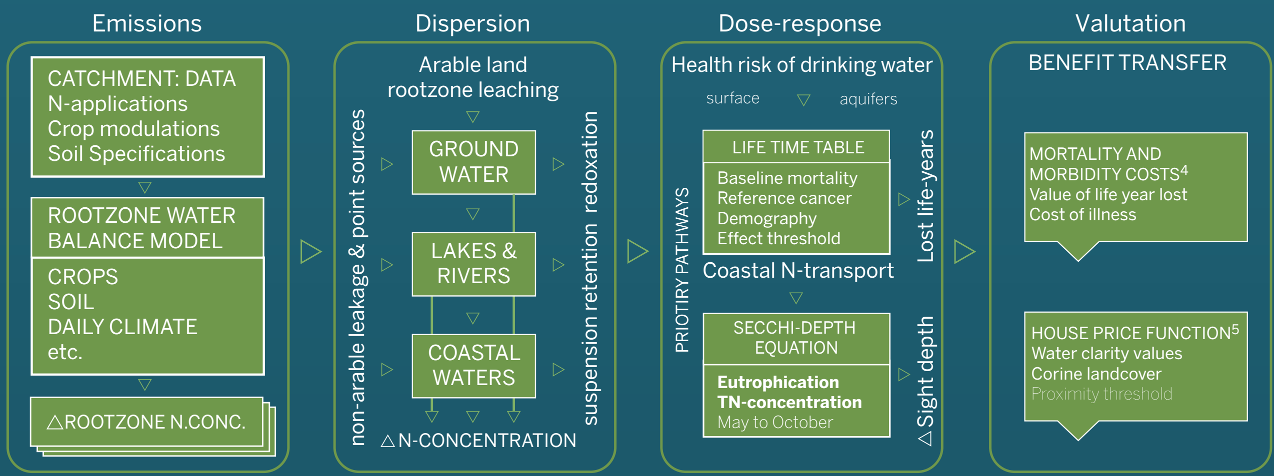
▼	< -5	strong decrease
▼	-5 to -1	weak decrease
—	-1 to +1	stable
▲	+1 to +5	weak increase
▲	> +5	strong increase

Trends of nitrate concentrations in surface water between reporting period 3 (2000-2003) and 4 (2004-2007). (Greece is revising data on surface water trends).

Methodology

EXIOPOL builds on a calibrated **nutrient modelling tool**[1] applied in previous EU funded research to most member states. Proceeding from a meta-review of dose-response functions[2], extensive modelling has been undertaken to explore implications of different scenarios of marginal changes in nutrients applications[3]. Different aquatic recipients, as well as the various weather, soil, and run-off conditions imply a range of different outcomes that are highly catchment-specific.

EXIOPOL has applied the 'impact pathway approach (IPA)' as a novel analytical method in the area of water management. It can identify site-specific benefits associated with management measures by linking economic and hydrological data through consecutive modelling stages, allowing for monetization of specific end point effects. Damages of nitrate pollution in six European catchments have been explored within an IPA-framework that addresses surface water quality as well as water as a healthy resource for abstraction of drinking water, as shown in the figure below.



1 EUROHARP: Towards European Harmonised Procedures for Quantification of Nutrient Losses from Diffuse Sources. www.iis.niva.no/php/euroharp/index.htm
2 Deliverable DII.2.a-1: Dose-response function paper & Deliverable DII.2.a-2: Impact-pathway modeling of agricultural nutrients in six European catchments.
3 Deliverable DII.2.b-1: External costs of nutrients – first estimates.
4 Desaigues B, et. al. 2011. Economic valuation of air pollution mortality: A 9-country contingent valuation survey of value of a life year (VOLY), Ecological Indicators 11: 902-910.
5 Boyle, K. J., Poor, P. J., Taylor, L. O., 1999, Estimating the Demand for Protecting Freshwater Lakes from Eutrophication. American Journal of Agricultural Economics 81:5, 1118-1122.

Results

EXIOPOL has explored the potential scale of benefits of controlling nitrate pollution as underpinned by available epidemiological research in order to obtain monetary estimates per unit of nitrogen applied. Benefits depend crucially on the number of water consumers potentially affected. Due to differences in population densities, the analysed catchments provide a range of results per kg of N-loss, underlining the significance of being highly site-specific in efforts addressing nitrogen pollution of drinking water.

The table below provides illustrative estimates of average external costs of nitrogen per member state derived in the EXIOPOL project. These result from scaling pilot catchment characteristics, whereby several key factors are taken into account, including the share of surface water for potable water supply, the exceeding of nitrate limits as well as population density. Differences in leakage rates to groundwater aquifers according to soil types have been reflected too. The table suggests strongly, that certain member states (UK, Belgium) are more profoundly affected by nitrogen pollution than others, presumably due to their reliance on surface abstraction for potable water. A switch of water abstraction from surface water to groundwater aquifers might in some catchments prove more cost-effective than land-use changes or restrictions to agricultural practices, but it would require a careful cost-benefit analysis to resolve which alternatives that deserve priority.

Effect information corrected unit values aggregated over the whole agricultural sector and all human health end-points for potable water for the year 2000.

	Austria	Belgium	Bulgaria	Cyprus	Czech Republic	Germany	Denmark	Estonia	Spain	Finland	France	Greece	Hungary	Ireland	Italy	Lithuania	Luxembourg	Latvia	Malta	Netherlands	Poland	Portugal	Romania	Sweden	Slovakia	Slovenia	United Kingdom
Organic nitrogen in [€/(kg.yr)]	0.03	1.34	0.01	0.07	0.32	0.16	0.16	0.03	0.09	0.00	0.24	0.02	0.02	0.02	0.05	0.00	0.51	0.00	0.40	0.36	0.06	0.07	0.03	0.00	0.03	0.07	1.42
Mineral nitrogen in [€/(kg.yr)]	0.03	1.22	0.01	0.06	0.29	0.14	0.14	0.03	0.08	0.00	0.22	0.02	0.02	0.02	0.05	0.00	0.46	0.00	0.40	0.32	0.05	0.06	0.02	0.00	0.03	0.07	1.29

For the valuation of sight depth loss, the framework has been applied on catchment level in order to establish the site-specific relations between nutrient load, loss of sight depth and impacts on house prices. No appropriate modelling framework is readily available at European scale to account for the wider dispersion of nitrogen and the resulting implications for sight depth at a regional level. Future studies to address the significance of this omission would be very important for policy support. Further externalities from nitrogen, such as ammonia emissions and greenhouse gases emitted from nitrogen fertilisers, are being addressed in other ongoing research projects[6], so that it is important to bear in mind that the results obtained here refer to priority pathways for the aquatic environment.

6 For instance CEEH; www.ceeh.dk

Key findings from EXIOPOL Bottom-up estimates

Biodiversity in agriculture (FEEM)

In recent decades the loss of biodiversity has accelerated in the EU. If we are to address this problem, we need to have a better idea of the biodiversity dimensions that people value and what they are willing to pay in support of different programmes. To shed light on these questions EXIOPOL reviewed multiple experiences of biodiversity preservation around the world, and studied citizens preferences towards various hypothetical conservation policies assessed in surveys using stated preferences techniques[1].

Methodology

Two different questionnaires were designed to study citizens' preferences in the EU towards various biodiversity conservation policies. The first survey was conducted in a sample of Italian households to assess citizens' preferences towards the recovery of traditional rice landscapes and plantation techniques in the Pavia area. The second panel survey was conducted via internet in the UK, Spain, and Italy. This survey collected opinions regarding a common biodiversity policy that would be implemented in the respective countries. Its focus is on traditional cereal cultivation techniques, which aim to increase biodiversity levels, cultural heritage[2], and other related services.

Results

The biodiversity services[3] valued in the survey are related to the recovery of traditional rice landscapes and plantation techniques. Among these services, mosquito reduction is the most important service for the respondents. They understood that an amelioration of the rice-field ecosystem would lead to a reduction of mosquitoes. Thus, the reduction of externalities of current plantation techniques seems to be the leading concern, followed by re-naturalisation and biodiversity preservation. The highest value associated with the reduction of mosquitoes would imply that **stressing more direct-use anthropocentric-related benefits in the biodiversity policies might encourage more support from people with different environmental attitudes**.

The second survey developed in the UK, Spain, and Italy used a payment reallocation mechanism by which individuals would be able to redistribute existing funds towards the preservation of biodiversity. We found that **preferences of European citizens** diverge considerably with respect to biodiversity preservation and their valuation or ranking of the evaluated services[4]. In particular, Spanish and Italian citizens are more likely to reallocate the current public budget and forego some of the current public services to enhance agricultural areas and biodiversity. On the other hand, UK citizens are not likely to reallocate the existing public budget to enhance biodiversity protection and in particular to preserve insect population and cultural heritage services.

As it is well known, in agriculture biodiversity, loss is exacerbated due to two main trends: a) abandonment of marginal lands, and b) intensification activities in productive lands. Although biodiversity generates many benefits, including environmental externalities and economic benefits, the general public may not be fully aware of such benefits.

It is important that citizens fully understand the key role played by biodiversity, to properly assess values to its multiple functions and services[5].

This is most likely the case with **more intangible services, such as the pollination benefits that citizens are not willing to support**, probably due to the association with the existence of insects that have other negative externalities. Furthermore, preferences are also heterogeneous across countries. Thus, a common payment for ecosystem services (PES) may have to vary across countries to properly reflect such heterogeneous preferences. While in the Southern European countries, survey participants are willing to support the cultural heritage services linked to biodiversity preservation, such priority or concern does not strongly emerge in the UK.

[1] Techniques based on stated preferences aim at gathering information about people's preferences towards goods and services relying on their direct response to articulated questionnaires or other hypothetical valuation mechanisms. These techniques are widely used when valuing intangible goods or services (such as biodiversity services) that do not have an associated market price. In the current application, we employed choice experiments and various payment mechanisms.
[2] Protection of cultural heritage was described as a supporting service provided by biodiversity conservation that aimed at "additional protection of local rural sites of interest for traditionally and locally produced foods".
[3] Mosquito reduction, renaturalisation of part of cultivated area, and bird protection.
[4] The attributes valued in this online survey are: landscape enhancement, protection of pollinating insects, and protection cultural landscapes.
[5] Scientific assessment may be used to provide accurate information in terms of biodiversity benefits, which may be used to later generate more informed preferences and citizens views.

Key findings from EXIOPOL Bottom-up estimates

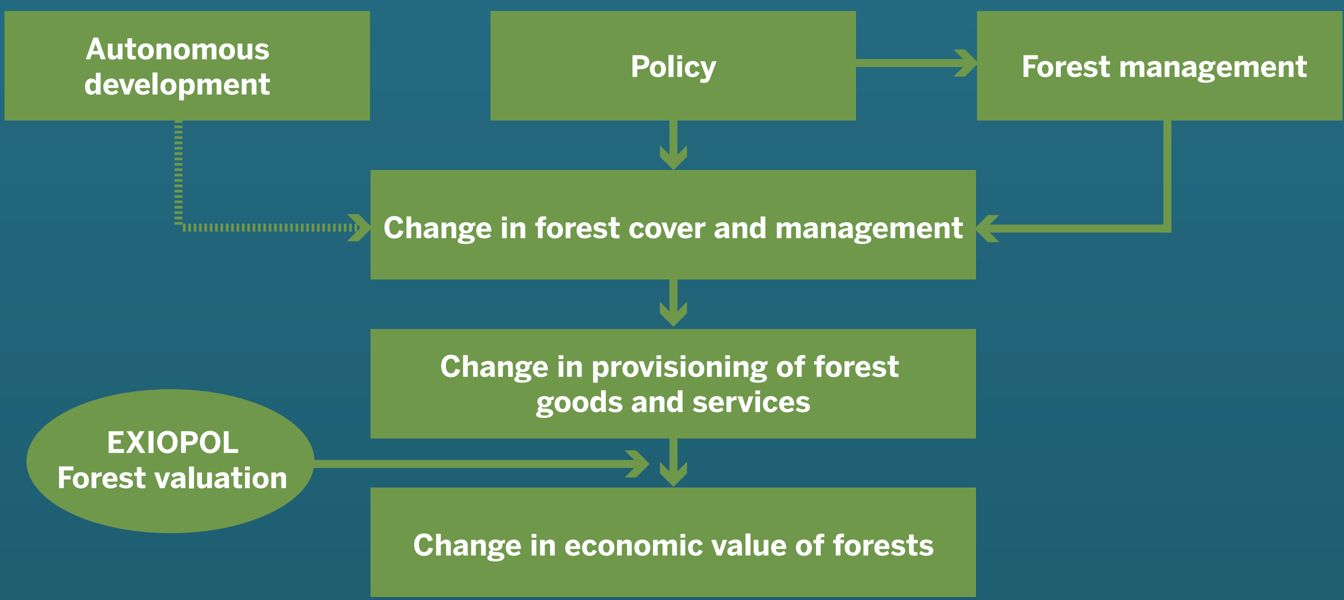
Forestry (CTFC and EFI)

Forests provide a broad range of goods and services that are important to human society. Traditionally, forests were mainly providing wood (e.g., construction, heating), non-wood products (e.g., food, fabrics, medicinal plants, fodder), and were of spiritual and religious importance to humans.Nowadays, forests are acknowledged to provide a much broader range of goods and services[1]. Thus, policy changes or management actions often simultaneously affect, in different ways, the provisioning of different forest goods and services[2].

Methodology

EXIOPOL focused first on the **identification and screening of main forest goods and services in the European Union.** In total over 200 forest goods and services were listed[3]. Wood and fuel wood, climate regulation (carbon sequestration), biodiversity protection (existence value), and recreation were identified as the most important forest goods at the EU level.

Further, more than **200 valuation studies** have been reviewed and **almost 700 value estimates for different types of forest externalities** have been documented in a database[4] for the following countries : UK (36), Italy (33), Finland (18), Germany (17), Spain, Sweden (14), Norway (10), Switzerland (7), Denmark (6), Austria (4), Czech Republic, France (3), Ireland, Poland (2), Belgium, Hungary, Netherlands (1). The vast majority of the reviewed studies focused on the valuation of recreation activities (110), while other types of studies represent a minority: forest conservation (23), biodiversity (19), Total Economic Value (6), carbon (5), aesthetics, afforestation, forest amenities (4), erosion, landscape (3), forest fire risk (2), forest wetland, health benefits, Use values, water (1).



In the final step, EXIOPOL linked the monetary values of forests (goods and services[5]) with their physical characteristics.

[1] (MEA 2005): Ecosystems and human well-being: current state & trends assessment, volume 1. In. Millennium Ecosystem Assessment.
[2] Verkerk P.J., Lindner M., Zanchi G. & Zudin S. (2011). Assessing impacts of intensified biomass removal on deadwood in European forests. Ecological Indicators, 11, 27-35.
[3] It should be noted that the established list is not complete, because of the constantly changing uses and importance the society ascribes to different forest goods and services: new goods and services are appearing and existing goods and services are used in new ways. Thus the lists should be taken as orientation points for an easier understanding of the issues tackled in EXIOPOL as well as a reminder about the vast number of different benefits forests are providing to the society.
[4] www.feem-project.net/exiopol/scheda.php?ids=62
[5] Considering the identified importance of forest goods and services in Europe, and the availability of valuation data, it was decided to consider recreation, carbon sequestration, biodiversity protection (passive values) as well as wood and non-wood forest goods and services.

Results

Considering the annual increment, forest area and market price, the profit adjusted value of **wood and non-wood forest products products ranges between 1.6 €/ha per year in Greece and almost 44€/ha per year in Denmark**. Further, based on the carbon sequestration capacity of the forest and the damage avoidance costs, the annual value of the carbon sequestration was calculated to be between **9€/ha in Estonia and 130 €/ha in Italy**.

The annual value of recreation was estimated by applying a benefit transfer procedure: the estimated values for unprotected forests ranged between **1.5 €/ha in Finland and 31.5 €/ha in the Netherlands**. Note that the recreational value of forests that were protected for biodiversity was estimated to be 1.86 times larger than the recreational value of unprotected forests.

Estimated mean values for wood and non-wood forest products, carbon and recreation (separately for unprotected forests and for forests protected for biodiversity) in € per hectare and year for European countries.

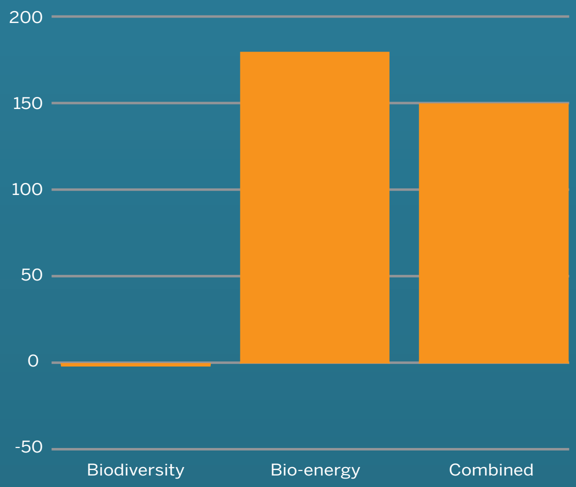
€ per hectare and year	Carbon	Wood and non-wood forest products	Recreation (unprotected forest)	Recreation (protected forest)
Austria	77.02	17.96	8.56	15.89
Belgium	64.20	21.57	25.58	47.48
Bulgaria	40.45	5.33	6.81	12.64
Czech Republic	32.56	20.7	11.50	21.34
Denmark	94.75	43.88	13.61	25.26
Estonia	9.98	6.58	2.71	5.03
Finland	21.78	8.31	1.53	2.84
Germany	92.48	20.28	17.24	32.00
Greece	14.86	1.63	7.01	13.01
Hungary	30.20	9.34	11.59	21.51
Ireland	15.10	29.01	10.68	19.82
Italy	130.78	11.92	14.92	27.69
Latvia	66.49	10.86	3.34	6.20
Lithuania	62.32	8.34	5.18	9.61
Luxembourg	0	8.78	13.48	25.02
Netherlands	108.87	13.62	31.47	58.41
Norway	63.93	4.97	2.16	4.01
Poland	69.995	10.88	10.77	19.99
Portugal	31.08	40.97	9.45	17.54
Romania	105.02	11.87	9.56	17.74
Slovakia	30.18	12.04	7.87	14.61
Slovenia	59.61	11.18	8.79	16.31
Sweden	11.94	12.46	1.94	3.60
Switzerland	19.48	18.76	16.64	30.88
United Kingdom	82.66	20.61	28.47	52.84

EXIOPOL provides decision-makers with examples of **monetary** values for a set of forest goods and services, and shows how they can serve for the **estimation of the economic consequences of changes in policy** and/or forest management strategies.

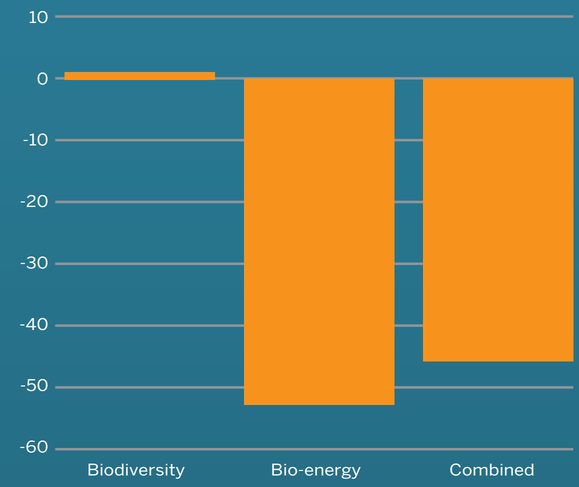
Example of policy application

In Europe, the intensified use of forest biomass for renewable energy production and forest biodiversity protection are two important topics related to forest land-use. However, the combination of policies related to biodiversity and to bio-energy could create a dilemma between wood production and forest biodiversity, but also with other important goods and services including carbon storage and recreation.
In the following months, a case study will focus on the analysis of these trade-offs by combining physical and economic impacts of policy alternatives: the impacts of four scenarios (a baseline scenario[6], a biodiversity protection scenario[7], a bio-energy scenario[8], and a combination of the last two) will be analysed using the large-scale EFISCEN model in 24 European Union countries as well as Norway and Switzerland until 2050.

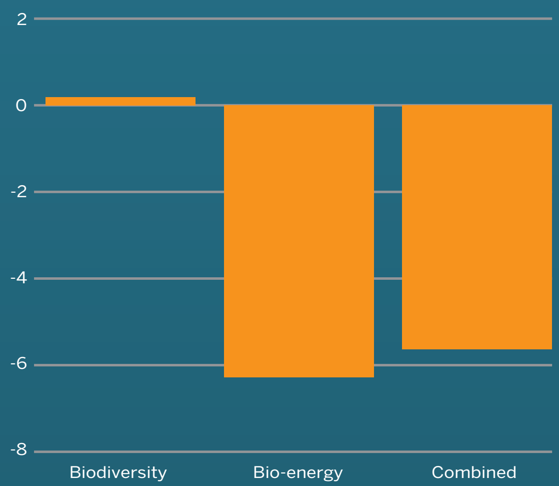
Deviation in wood removals (million m³ / yr)



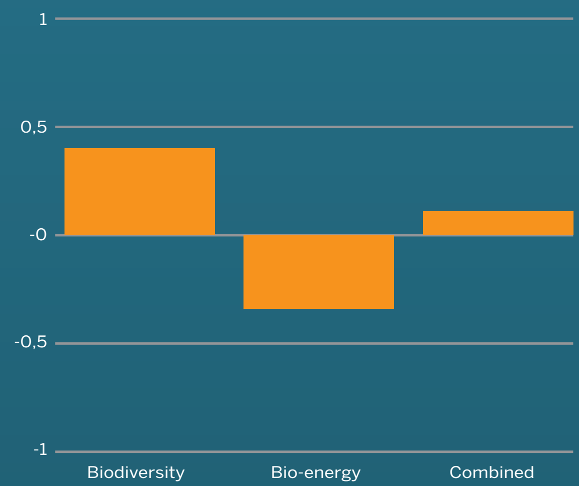
Deviation in carbon storage (Mt / yr)



Deviation in deadwood (ton/ha)



Deviation in recreational index (-)



The analysis will focus on the physical impacts affecting on a number of market (wood and residue production, forest carbon storage) and non-market (forest biodiversity and recreation) goods and services with the help of an economic valuation, using the values from the table aside.

Preliminary results[9] indicate that according to the biodiversity scenario, setting aside 10% of the forest area for biodiversity protection could have minor impacts on most forest goods and services. It could also result in an economic benefit of 2.1 €/ha in 2050 compared to the baseline scenario. In contrast, whereas the harvesting intensity can be significantly increased according to the bio-energy scenario compared to the baseline scenario, this could have strong negative impacts on forest carbon storage, biodiversity, and recreation. It could also result in an economic cost of 21.6 €/ha in 2050.

Linking European forest resource projections under alternative policy scenarios with the externality data collected in the EXIOPOL database offers valuable decision support to find suitable strategies combining renewable energy and biodiversity objectives.

[6] No policy changes, a moderate increase in wood extraction and no extraction of residues.
[7] Set aside 10% of forest area, with strong restrictions on harvesting in the protected areas.
[8] Wood and residue removal intensified to the potential maximum.
[9] Verkerk, H., Giergiczny, M., Mavsar, R., Wenchao, Z., Lindner, M., 2009. Economic valuation of the impacts of intensified biomass production and biodiversity protection on forest land-use in Europe. Poster presented at the EFORWOOD open science conference 'Shape your sustainability tools – and let your tools shape you. 23.-24.9.2009, Uppsala, Sweden.

Key findings from EXIOPOL Bottom-up estimates

Steel industry (IER)

The impacts on **ecosystem quality, human health, and climate change** from the steel industry were evaluated for all **European countries** while a second, more detailed study was performed for **Germany**.

General methodology

First, **data on the production of goods** from the manufacturing industry from Eurostat[1] were combined with emission factors for the corresponding production processes from the Ecoinvent 2.0[2] life cycle inventory. Second, the damage potentials of the estimated overall emissions were estimated and applied[3] for **ecosystem quality, human health and climate change**. This resulted in a list of **400 different pollutants** to be analysed[4]. These were **transformed into monetary values**[5] to identify the most relevant pollutants in an assessment of the industrial sector. A threshold of € 1 million[6] was chosen to eliminate those with minor impacts, leading to the identification of **55 different relevant pollutants** within the Industrial sector.

Relevant pollutants for impact assessment include classical airborne pollutants, heavy metals, and greenhouse gases.
This list of the 55 airborne pollutants is relevant when assessing impacts on human health, ecosystem quality, and climate change: policy measures addressing air quality improvements should, therefore, include at least these relevant substances.

European steel industry

Methodology

Emission data[7] considered for the steel industry in Europe include[8]: classical air pollutants, heavy metals, persistent organic pollutants (POPs) and particulate matter emissions. They are quantified over a grid of approximately 50x50km[9]. Greenhouse gas emissions are provided by the UNFCC[10].

The monetary valuation of these emissions was performed by the application of monetary damage factors[11] to estimate the damages to human health, the loss of biodiversity, and damages to crops and the ozone from nitrate deposition. The monetary estimation of climate change was carried out using the range of monetary values provided by UNFCCC.

1 PRODCOM statistics are available at epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database
2 The combination of emission factors and production statistics covers 25% of the entries in the life cycle inventory. It was assumed that the most important processes with respect to the emission of pollutants were covered in the study. For details see: www.ecoinvent.org.
3 Databases of IMPACT2002+ (Jolliet, O., Margni, M. D., Charles, R., Humbert, S., Payet, J., Rebitzer, G. and Rosenbaum, R. K. (2003); IMPACT 2002+: A New Life Cycle Impact Assessment Methodology; International Journal of Life Cycle Assessment 8(6): 324-330) and EcoIndicator99 (Goedkoop, M. and Spriensma, R. (2001). The Eco-indicator 99 - A damage oriented method for Life Cycle Impact Assessment; 3rd Edition. Amersfoort, Pré Consultants B.V.: 144.)
4 This list is available in the EXIOPOL Deliverable PD.II.5.2-a2.
5 The monetary values applied in the study resulted from the EU-project NEEDS (New Energy Externality Development for Sustainability). For details see: www.needs-project.org
6 This figure represents a value of less than one-tenth of a percent of the highest external cost values estimated: only pollutants reaching monetised damage potentials above the threshold for the application of both LCA databases (IMPACT2002+ and ReCiPe) were defined as being relevant for the further assessment by the industrial sector.
7 The emission data do not include all of the 55 relevant pollutants due to the lack of available data. Therefore, to provide a more complete picture of the external costs of the metal industry, the existing data sets need to be extended for these pollutants in future work.
8 EMEP: Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air pollutants in Europe: www.emep.int
9 So-called EMEP50 grid for the estimation of deposition of air pollutants.
10 To define the metal industry within the database, the nomenclature for reporting (NFR) corresponds to the United Nations Framework Convention on Climate Change (UNFCCC). Common reporting format (CRF) for the emission category 'NFR02 (level2)' was chosen. Data for the emissions of greenhouse gases were provided by the United Nations Framework Convention on Climate Change (UNFCC).
11 Derived by using the EcoSenseWeb model in the EU-funded NEEDS project: Preiss, P.; Friedrich, R. and Klotz, V. (2008); Report on the procedure and data to generate average/aggregated data; NEEDS integrated project of the 6th Framework Programme of the European Commission; Deliverable n° 1.1_v1 – RS 3a; University of Stuttgart - Institute of Energy Economics and the Rational Use of Energy.

Results

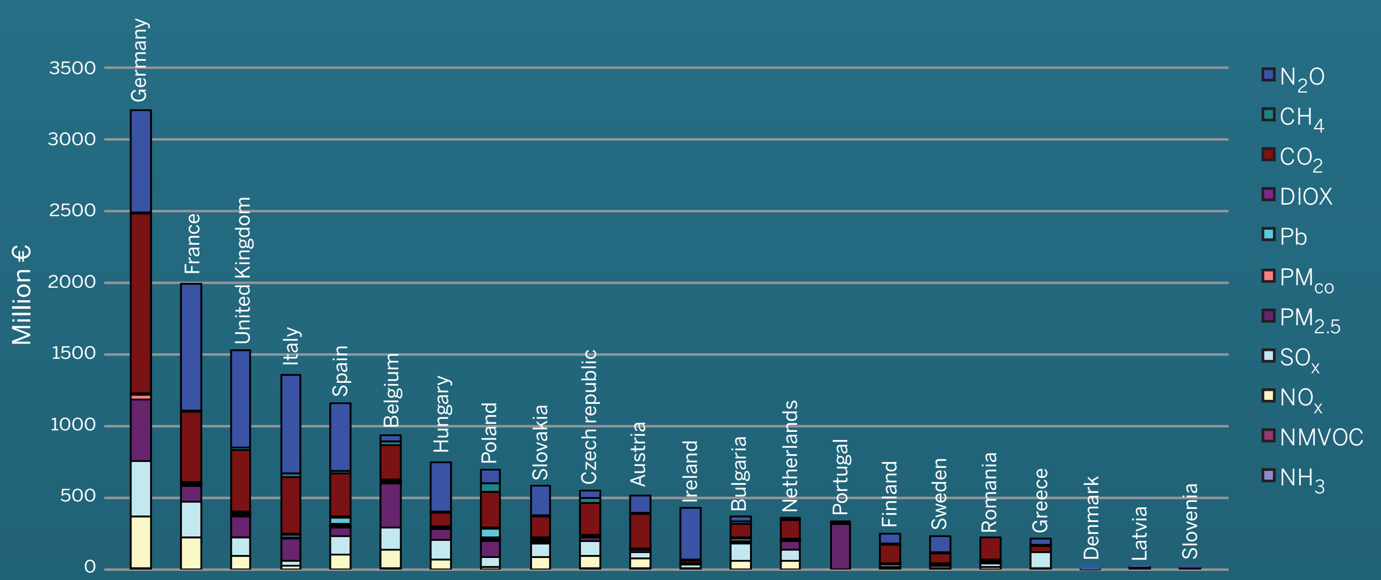
The calculated total amount of external costs for the metal industry in the EU-27 member states amounts to more than € 15.6 billion for 2005[12]. If compared to the estimated values of production for the EU-27 countries (€ 550 billion for 2005), the total external costs account for a little more than 2.8% of the total value of production. The highest share – (more than 95%) of the € 15.6 billion are caused by the GHG CO_2, N_2O, and by classical airborne pollutants NO_x, SO_2 and $PM_{2.5}$. Almost € 5 billion are accumulated for both CO_2 and N_2O, and nearly €2 billion for both $PM_{2.5}$ and SO_2 at the EU-27 level.

These costs result from the high level of monetary damages to human health and climate. $PM_{2.5}$ only has an impact on human health and NO_x. SO_2 also has minor and in some cases even positive impacts on biodiversity and crops.

Comparing the countries of the EU-27, **Germany is responsible for the largest share** of the total external costs with more than 20% of the total calculated for Europe. This is because Germany is leading the statistics on the value of produced output and emissions. It also has one of the highest densities of population in Europe.

European steel industry causes substantial external costs in western Germany and its neighbours
The amount of external costs for the steel industry in Germany ranges **between € 1.1 and € 1.3 billion**: most of these impacts are caused by emissions of primary particles, NO_X and SO_2. The highest impacts occur in western Germany as well as its western neighbours.

Sum of external costs generated by the EU-27 steel industry



[12] All values are expressed in $Euro_{2000}$

German steel industry

Methodology

The EcoSenseWeb model provides a detailed assessment of externalities as well as the calculation of external costs within different countries based on the impact pathway approach developed in the ExternE project series.

EcosenseWeb can perform an analysis of the endpoints of the **impacts on human health** with a differentiation of the cause of the impacts made by distinguishing between PM_{10} and SIA_{10} for cases of infant mortality, or for $PM_{2.5}$ and $SIA_{2.5}$ for 'chronic' YOLLs which can be compared to DALYs: these endpoints are then valued in monetary terms to obtain the external costs.

To compare the results, **two different chemical transport models** have been applied in the study of the steel industry in Germany. The aforementioned **EMEP model** is based on a 50x50km grid[13] and the **Polyphemus model**[14], and spatial emission data was provided by the German Federal Environment Agency[15].

Results

According to EMEP simulations, the steel industry in Germany results in external costs across all European countries, in damages to materials, crops, and human health, for a **total estimated at € 1.2 billion**, 60% of which are only in Germany (see table below).

External costs generated by the German steel industry																													
Country	Germany	Netherlands	France	Poland	Belgium	United Kingdom	Czech Republic	Italy	Austria	Hungary	Denmark	Romania	Sweden	Slovakia	Spain	Slovenia	Bulgaria	Luxembourg	Greece	Lithuania	Finland	Latvia	Ireland	Portugal	Estonia	Malta	Cyprus	EU-27	other countries
M €	744.74	75.67	62.12	52.64	41.29	29.14	27.15	26.51	15.77	9.46	9.05	8.70	5.52	5.35	3.34	2.87	2.00	1.88	1.69	1.67	0.94	0.88	0.70	0.45	0.36	0.05	0.04	1129.98	67.56

At the German regional level, the west of the country faces the worst impacts. The Ruhr area, for instance, is where most of the mining and metal processing industries are located and has the highest population density. In all of the four sub-regions analysed in Germany, more than 95% of the external costs result from damages to human health, the greatest share of which can be attributed to SO_2 and NO_X emissions.

At the European level, the disaggregated approach shows the highest value of external costs in the Netherlands, followed by France, Poland, and Belgium. Poland is contiguous to Saxony where there are important metal industries, while the other countries are close to the Ruhr area.

The external costs for all countries calculated with the **Polyphemus model** amount to more than € 1.1 billion. Damages to human health clearly represent the major source of the external costs. For Germany alone damages were estimated to be about € 844 million because of damages to the health of the German population as well as acidification and eutrofication.

The influence of the metal industry on the quality of the air regarding $PM_{2.5}$ is the highest in the region where the metal industry has the greatest presence. The region with most of the activities of that sector benefits the most of an emission reduction of that sector regarding the quality of the air.

Comparing the numbers calculated with the two different models, there is a difference of € 126 million. This can be attributed to the different data behaviours of the models, to the different data sets, and to the more diluted impact estimated from the source-receptor-matrices of the EMEP model. At the same time, around 10% of total damages should be considered a relatively minor difference, given other uncertainties. The external costs within Germany are higher for the estimations with Polyphemus by almost € 62 million. This difference is most likely due to a number of reasons such as the weaker dilution effect and the higher level of precision provided by Polyphemus in the mapping of $PM_{2.5}$, SOMO35 and SIA concentrations.

[13] Further information on the EMEP model, the design and the use of EcoSenseWeb is provided by Preiss, P. and Klotz, V. (2007); EcoSenseWeb V1.3: User's Manual & Description of updated and extended draft tools for the detailed site-dependent assessment of external costs; NEEDS integrated project of the 6th Framework Programme of the European Commission; Technical Paper n° 7.4 – RS 1b; University of Stuttgart - Institute of Energy Economics and the Rational Use of Energy. Further reports can be found on the EcoSenseWeb website. The link to the online tool EcoSenseWeb is: EcoSenseWeb.ier.uni-stuttgart.de/

[14] The model developed by ENPC is based on Eulerian dispersion and chemical transportation functions: detailed information on the Polyphemus model is provided by Mallet, V., Quélo, D., Sportisse, B., Ahmed de Biasi, M., Debry, E., Korsakissok, I., Wu, L., and Roustan, Y., Sartelet, K., Tombette, M. and Foudhil, H. (2007); Technical Note: The air quality modelling system Polyphemus; Atmospheric Chemistry and Physics, Vol. 7(2007), 5479-5487

[15] Data gas been provided by the Central System for Emissions (ZSE) of the German Federal Environment Agency (www.epa.gov/ttn/chief/conference/ei11/poster/doring.pdf)

Key findings from EXIOPOL Bottom-up estimates

Chemical industry (CUEC)

The chemical industry produces emissions, which not only come from the incineration of fossil fuels, but also directly from the industrial chemical processes.

Methodology

The analysis started with the Impact Pathway approach for standard pollutants. The analysis also began with the marginal social costs approach for the pollutants that disturb the climatic system of the Earth. It then proceeded with the identification of the environmental burden of the chemical industry throughout Europe. This process presented relevant pollutants and processes thanks to the EMEP[1] database for standard and micro pollutants emissions (SOx, NOx, particulates, POPs, NMVOC, heavy metals). The UNFCCC[2] web database was used to identify greenhouse gas emissions, which come from the chemical industry.

Due to the sector's specificity, it was also necessary to separately analyse the burdens from energy processes and the burdens directly associated with the chemical processes in the chemical industry. Specific damage factors developed in the NEEDS[3] project for particular pollutants. Countries were then used to obtain aggregated data for all of Europe. The impact of greenhouse gasses were then valued thanks to the FUND[4] model results, with 3 distinctive valuation scenarios using different normative assumptions regarding t discount rates and world equity impacts.

Results

The **energy consumption** of the chemical sector follow similar patterns to all fossil energy based industries: external costs are mainly caused by the incineration of coal and heavy fuel oils, with the associated emissions of SO_X, NO_X, and particulate matter. These external costs, alone, generate about **€ 1.6 Billion**, excluding GHGs.

If we only look at **chemical processes**, disregarding GHG contributions, about **€ 2.1 Billion of external costs in 2005** were produced, 60% accounting for standard air pollutants SO_2, NO_X and particulate matter, while heavy metals and persistent organic pollutants account for about 10% of these costs. More surprisingly, **30% of total external costs from chemical processes are associated with NH_3**.

Total external costs associated with **GHGs range between € 1 Billion and € 4 Billion**, depending on the valuation scheme used for GHGs. Nevertheless, 90% of the externalities affecting climate due to the energy use of the sector are caused by carbon dioxide, while 60% of the externalities of the chemical processes are caused by N_2O.

The Chemical industry and climate change

While most of European and international measures addressing climate change focus on the energy sector and energy related emissions, the chemical industry and its considerable emissions from chemical processes is a good example of a sector with for more focused sectoral policies.

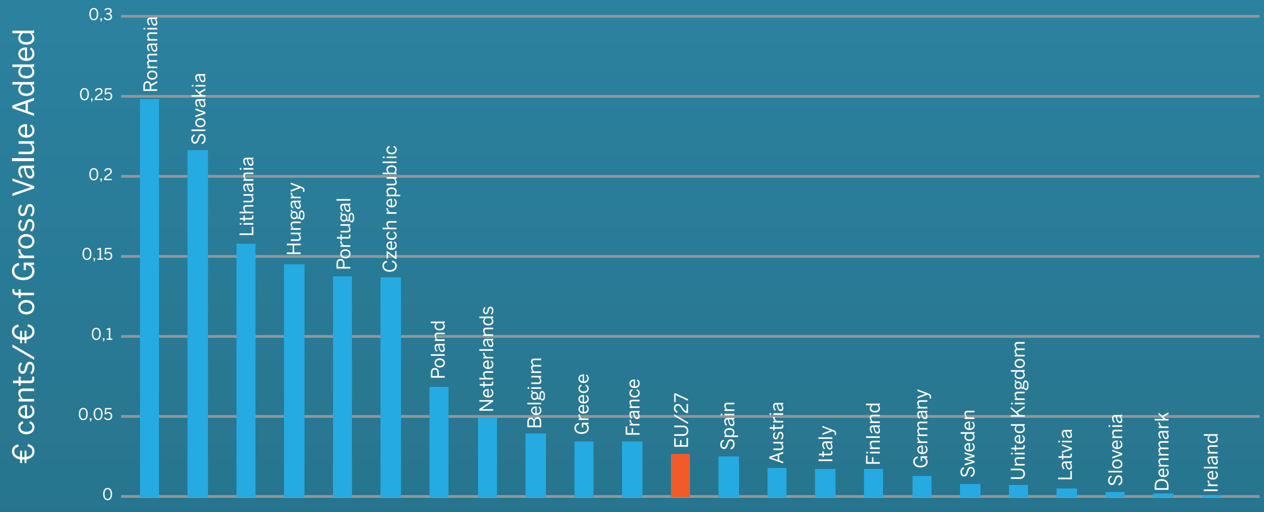
Within the summary of the results, it is interesting to compare the external costs generated by the chemical industry across different member states. The figure below reports the externalities per € of Gross Value Added, ranging between 0.1 €c/€ of GVA for Ireland, to as much as 82 €c/€ of GVA for Bulgaria. In newly acceded countries, there are normally lower environmental standards and low gross value added of chemical sectors.

Chemical industry results differ between east and west

The great discrepancy between environmental performances of different chemical industries in particular member states suggests that EU-wide policy should provide subventions from structural and cohesion funds for the modernisation of technologies, and a better governance in CEEC countries to help narrow the gap between west and east Europe.

[1] EMEP, European Monitoring and Evaluation Programme: www.emep.int
[2] UNFCCC, United Nation Framework Convention on Climate Change: online emission database on unfccc.int
[3] NEEDS project: www.needs-project.org
[4] FUND model: www.fund-model.org

Comparison of external costs associated with chemical industry in the EU (2005)



Key findings from EXIOPOL Bottom-up estimates

Wastes (CUEC)

The proper management of waste is the key responsibility of both the local and national government for a number of reasons, the most important one being that externalities can directly harm the environment or cause discomfort to residents.

Methodology

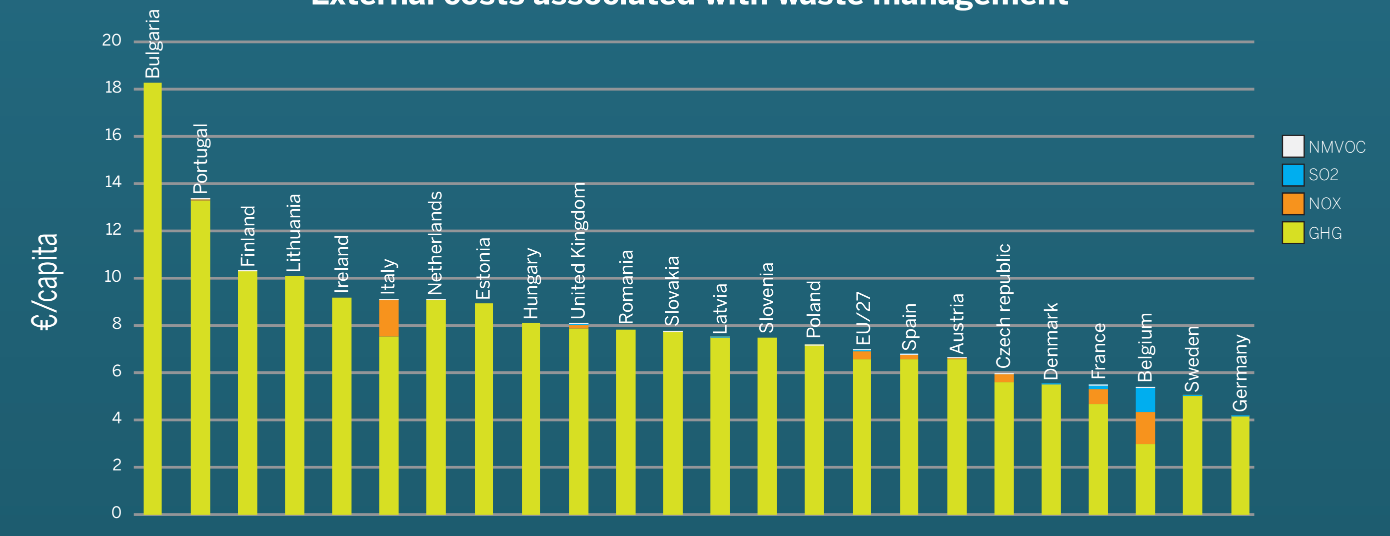
The analysis of a range of waste management technologies was performed thanks to the significant advances in the **impact pathway approaches and choice experiments** to evaluate the environmental impact of waste management in Europe[1].

Data relating to environmental burdens from waste management were identified in international databases[2]. These data mainly present greenhouse gases for landfill and standard air pollutants in the case of waste incineration. Existing regionalised damage factors for EU countries were updated and used to estimate damages from both standard air pollutants[3] and GHGs[4]. The aggregation of costs per pollutant categories and per countries was performed to enable a comparison of burdens across the EU.

Results

Waste management in Europe is a source of significant environmental damage. Our estimates show that the entire **EU annually produces about € 2.7 billion of external costs** associated with waste, which is comparable to the externalities produced by other industrial sectors, such as the entire chemical industry[5].

External costs associated with waste management



The damage cost of **incineration ranges from about 4 to 21 €/t waste**, depending on the assumptions regarding energy recovery. The **damage cost of landfilling is around 10 to 13 €/t waste**, which is mostly due to greenhouse gases[6].

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1 EXIOPOL Deliverable PDII.5.b
2 UNFCCC, United Nation Framework Convention on Climate Change; online emission database on unfccc.int: EMEP, European Monitoring and Evaluation Programme: www.emep.int
3 NEEDS project: www.needs-project.org
4 FUND model: www.fund-model.org
5 EXIOPOL Deliverable PDII.5.a-2.
6 Evaluated here with a unit cost of 19 €/tCO_2 according to ExternE [2004].

	Type of energy recovey				
	Heat		Electricity		
Type of disposal	Oil	Gas	Oil	Coal	Costs in €/t of wastes
Incinerator	X	-	-	-	4.5
	X	X	-	-	8.7
Landfill	X	-	-	-	10.1
	X	X	-	-	10.8
	-	-	X	X	10.9
	-	-	-	-	12.8
Incinerator[p*]	X	X	X	X	13.1
	X	-	-	-	15.7
*partload	-	-	X	X	15.9
Incinerator	-	-	-	-	21.2

Based on the comparison of external costs, **waste incineration** appears to be the preferable option and should receive policy support and attention. Assuming that the incinerated waste replaces other fossil fuels, the best option is to **incinerate pre-treated waste by supplying base load heat and/or electricity** in a public grid. Contrarily, waste that goes into landfills produces great quantities of methane, which adds to the external costs due to human induced climate change. Although in most cases incineration appears to be the better option, there are still locations where this might not be the case. Therefore, a careful local assessment should be carried out before deciding on the appropriate action.

Energy capture should be seen as a priority
The use of waste as a source of energy is shown to have significant influences on reducing external costs associated to the disposal of wastes, provided that they do not substitute existing zero-emissions technologies, such as nuclear or renewables.

The best option for landfills is a capped landfill with a gas capturing system, where the wastes are pre-treated to ensure a low amount of organic carbon. The captured landfill gas is then used for base load heat and electricity production. In addition there may be amenity costs amounting to **1 €/t waste** (highly variable with site and only imposed on the local population, thus to be internalised differently from air pollution).

Appropriate siting of incineration can minimise disamenity
Much of the work on the valuation of disamenity from incineration facilities suggests there is a strong habituation effect; in fact, the people's dissatisfaction lowers with time. Further analysis of disamenity of waste technologies is warranted, but our results suggest that the disamenity of incineration is far below that of landfills.

The use of **mechanical-biological treatment** techniques permits valuable reductions in direct emissions by controlling the methane emissions the case of 'methanisation' and by avoiding emissions from burning fossil carbon.

Depending on the technology, the benefits can amount to almost 6 €/t waste in the case of methanisation with energy recovery replacing gas and oil for heat and coal and oil for electricity.

When composting, with energy consumption produced by gas and oil for heat and coal and oil for electricity, the external costs are around **3 €/t waste**.

Expansion of the use of Mechanical Biological Treatments and composting
Mechanical-biological treatment and composting significantly reduce the externalities associated with waste management. Further construction and support of such facilities should be carefully considered in the development of waste management strategies.