Ex-post quantification of the effects and costs of policies and measures

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Executive Summary

Background and objective of the study

As climate change policies of international, European and national scale have been actively implemented for a number of years by now, the ability to assess the effectiveness of such policies and measures on greenhouse gas emissions has become increasingly important. Previous studies have recognized a significant variability in the implementation of policies and measures among the Member States (MS) as well as in actual emissions trends for different sectors in MS. They have also shown the difficulty to thoroughly assess the quantitative impacts of individual polices and measures to mitigate greenhouse gas emissions both at EU and Member States levels. These constraints make it difficult to identify the most effective policy instruments in order to reduce greenhouse gas (GHG) emissions in a particular sector and the most efficient distribution of efforts among sectors, in order for the EU to reach its targets.

At present the ex-post assessment of policies and measure remains subject to a number of shortcomings. For example, reported information on policies and measures is often limited to qualitative appraisals and lacks the assessment of quantitative impacts. Furthermore, ex-post evaluations are currently not conducted and reported in a consistent way by Member States. Moreover, a more thorough ex-post evaluation of policies and measures at the Member State level is necessary for the improved analysis of the opportunities for further development and refinement of EU and national climate change policies. Another current shortcoming is that the indirect effects of other policies, overlapping and rebound effects are often neither recognized nor quantified in the assessment of climate change policies and measures. Another area where significantly more work is needed is the development of methodologies to quantify the social costs and benefits of specific climate change policies and measures. Also, the variation of experiences and responsibilities with respect to monitoring, evaluation, statistical data among different MS is large and needs to be addressed.

The current study builds upon these insights as well as upon an initial study commissioned by the EU to develop methodologies for the ex-post evaluation of mitigation policies[1]. This study aims at

- Further refining and improving the methodologies developed for the ex-post quantification of policies and measures.
- Providing a critical overview of existing methodologies and recommendations to assess ex-post the effects, socio-economic costs and efficiency of policies and measures.

[1] AEA, Ecofys, Fraunhofer ISI (2009) 'Quantification of the effects on greenhouse gas emissions of policies and measures'", study prepared for the European Commission (http://ec.europa.eu/clima/policies/g-gas/studies_en.htm).

- Testing the refined and improved methodologies for selected Member States and selected policies in each MS
- Improving monitoring and reporting of the effects and efficiency of policies and measures ex-post.

The study aims to support Member States and the European Commission in assessing ex-post the efficiency and effectiveness of individual policies and measures. As such the study aims to provide guidelines and recommendations to assess the environmental impacts and socio-economic effects of policies and measures. It is set up around seven tasks.

- Task 1 *Critical overview of existing methodologies to quantify ex-post the direct and indirect socio-economic costs of climate change policies and measures* aims at providing recommendations for performing ex-post assessments of direct and indirect socio-economic costs and efficiency at the EU and Member State level.
- Task 2 *Review and assessment of the results and methodologies developed under the project 'Quantification of the effects on greenhouse gas emissions of policies and measures'* aims at providing revised and improved methodologies for the ex-post quantification of the effects of specific policies and measures".
- Task 3 *Testing of methodologies* focuses on testing of the improved and refined methodologies for the assessment of environmental and economic impacts, in an iterative way for 2-5 Member States and policies and measures.
- Task 4 *Proposal of indicators* aims to identify suitable indicators that allow monitoring of progress in the implementation of policies besides the direct quantified ex-post effects of policies and measures.
- Task 5 *Quality assurance and quality control (QA/QC) checks* elaborates concrete proposal of QA/QC checks to be performed by MS as well as at the Commission level.
- Task 6 *Recommendations for the enhancement of reporting requirements under the Monitoring Mechanism Decision* tackles proposal for specific legal requirements to be integrated in the revision of decisions 280/2004/EC and its implementing provisions (Decision 2005/166) that are currently elaborated by the Commission.
- Task 7 *Monitoring and data collection strategies* derives proposals of monitoring and data collection strategies.

In terms of methodological approach, the study builds upon the integrated, tiered approach developed within the AEA et al. (2009) study. It borrows from the principles in the IPCC Guidelines for National GHG inventories[2] and provides three tier levels that differ in detail and complexity with increasing data intensity, resolution of analysis in terms of depth and breadth, accuracy of estimates and resource requirements from Tier 1 to Tier 3.

Overview of methodologies to quantify the socio-economic costs of climate change policies and measures

Background

This task provides a critical overview of existing methodologies and applications to quantify ex-post the direct and indirect socio-economic costs of climate change policies and measures at MS and the EU level. In order to relate these socio-economic costs to the efficiency of policies and measures in terms of emissions reductions, a combination of the methodologies to quantify costs and those that quantify emission reductions is required. This can be achieved within the same modelling approach for some methodologies and through a combination of results from different models for other methodologies. The critical overview in this Task also takes into account experience and examples that were gained with the methodologies and applications of such methodologies for previous ex-post or ex-ante analyses. The overview ultimately aims to provide practical guidance on the necessary steps and procedures to assess ex-post the efficiency of policies and measures. This includes guidance on whether a cost component is relevant for a given policy, selecting the appropriate assessment methodology to tackle a particular cost type, the data needs, good practices for such estimation, as well as potential gaps or caveats that could prevent a detailed and comprehensive analysis.

Findings

The overview reveals that it is advisable to start with the following questions when conducting an assessment:

- What types of costs are covered?
- What is the policy area?
- Desired degree of accuracy in results
- Level of sectoral detail (and possibly geographical detail)

These questions must in turn be matched against the available resources. Moreover, often there are substantial trade-offs. For example, an assessment approach that provides the greatest level of detail in a single sector is more likely to neglect other sectors. These trade-offs can essentially be reduced to three types:

- Depth of analysis (detail and complexity)

[2] IPCC guidelines for National GHG Inventories, (2006), http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.

- Breadth of analysis (coverage of sectors and regions)
- Resources required (data, time, know-how, ease of interpretation of results)

It can be concluded that as the breadth increases, the depth of the analysis tends to decrease, as the assessment approach applies a 'lowest common denominator' approach, so that it can apply the same methodology to all regions/sectors. The level of resources required tends to increase in line with both the depth and the breadth of the analysis. Linking different assessment methodologies would be an approach that aims to maximise both depth and breadth, but comes with substantial resource requirements attached.

It is a challenge to include all these dimensions and their trade-offs into a practical guidebook or recommendation. There is no "one size fits all" solution. However, the following steps can help taking the necessary decision on the appropriate cost type and methodology in light of available data, resources and trade-offs to conduct an ex-post quantification of socio-economic costs.

Step 1 - Determine the level at which the costs are to be assessed.

Step 2 - Determine the type of cost to be assessed.

Step 3 - Determine the suitable methodologies for the cost type or cost component to be assessed taking into account the desired level of depth, breadth.

Step 4 – Assess data needs, data availability and quality.

Step 5 – Check resource requirements and availability to pursue assessment methodology.

Step 6 – Proceed with assessment - or in case of data or resource constraints - reconsider assessment methodology compromising on breadth or depth.

Identifying suitable methodology for each cost type or cost component reveals a fairly wide range of options for some cost types while a more limited portfolio seems relevant for other cost types (see Table 1.1). In light of the previous steps a decision may be taken on which methodological approach to pursue.

Table 1.1 Suitable methodologies for each cost type

Type of Cost	Suitable Methodologies	Depth	Breadth	Resources
Regulated Entities:				
Operating and investment costs	Basic assessment Econometric assessment System of equations Partial model	Tier 1 Tier 2 Tier 2 Tier 3	Tier 1 Tier 1 Tier 1/2 Tier 2	Low Medium Medium High
Administrative costs	Basic assessment	Tier 1	Tier 1	Low
Regulators:				
Administrative costs	Basic assessment	Tier 1	Tier 1	Low
Whole economy:				
All costs	Input-output analysis General model	Tier 1 Tier 2	Tier 3 Tier 3	Medium High

Summary of findings for selected European policies and measures

EU ETS, RES-E and CHP Directives

Introduction

The first trading period of the EU ETS lasted from 2005 to 2007; the second trading period continues from 2008 to 2012 when the Kyoto Protocol will expire; and the third period will begin in 2013 and end in 2020. The power sector is by far the largest user of ETS allowances and subject to the RES-E Directive and the CHP Directive as well. Furthermore and according to Article 11a of Directive 2009/29/EC and Directive 2004/101/EC (Linking Directive) CER and ERU certificates from CDM and JI projects can be transferred to the EU ETS. This mechanism links international carbon markets with the EU ETS. We therefore developed a methodology to cover the linkage of EU ETS with international carbon markets. To cover the complexity and cross-sectoral interactions of the EU ETS as well as to increase the understanding of different policies impacts, a model-based Tier 3 approach is essential.

Methodologies proposed

Within this project, the Tier 2 and Tier 3 evaluation methodologies for EU ETS, RES-E and CHP Directives have been revised and tested for selected Member States and with focus on the EU ETS. Relevant issues, which have been taking into account, are price elasticity of electricity demand and the overall socio-economic effects.

To ensure a step by step implementation of the different Tier methodologies, the revised Tier 2 approach is held independent from Tier 3 model results and mainly consists of publicly available input data. For the power sector the calculation procedure of this static approach consists of two steps:

- Step 1: Calculation of the increase in electricity demand due to price elasticity
- Step 2: Calculation of the corresponding CO_2 emissions to cover the surplus in electricity demand using the typical marginal power plant type of the national power plant fleet

This Tier 2 methodology of the electricity sector can be adapted to other industrial sectors under the EU ETS with similar data requirements.

Two power sector models (dispatch and investment model) and one macro-econometric model are combined in the dynamic Tier 3 approach. The calculation procedure consists of three steps:

- Step 1: Calculation of power plant dispatch with the dispatch model PowerFlex
- Step 2: Development of the power plants fleet derived with the investment model ELIAS
- Step 3: Calculation of the overall socio-economic effects with the macro-econometric model E3ME

For the counterfactual scenario without the EU ETS, a pre-step to derive the electricity demand depending on the electricity price (price elasticity) is included in step 1.

Testing

The criteria to select Member States for testing the revised methodology included diversity in terms of fossil fuel use for electricity generation as well as differences in CHP and RES-E. Denmark, the Czech Republic and Germany were selected for testing the revised Tier 2 and Tier 3 approaches.

For the Tier 3 approach, the main data challenges include demand and feed-in profiles in hourly resolution as well as techno-economic parameters of the power plant fleet. Crucial parts are confidential data, like electrical efficiency or fuel prices, as well as unknown profiles. Different strategies to deal with these data gaps have been derived, like a Tier 3 basic approach e.g., which consist of a simplified merit order of the power plant fleet.

Challenges/recommendations

The new Tier 2 approach is easy to implement in common spread-sheet software. For the power sector it includes price elasticity effects as well as fuel type specific merit order effects, but detailed fuel switching effects are not covered. The main advantage of the new Tier 2 approach is its independency from Tier 3 model results. It can therefore be implemented by a step by step process after having successfully established the Tier 1 approach. Concerning non-power ETS sectors, the Tier 2 approach for the power sector can be partly adapted, but indirect and cross-sectoral effects are not covered by this approach and there remains quite a large range of uncertainty around the results.

Indirect and cross-sectoral effects as well as overall socio-economic effects can be assessed via the revised Tier 3 approach which presents a major advantage of this revised approach. Another advantage of the integrated Tier 3 methodology is the detailed evaluation of the electricity sector, including detailed fuel switching effects, demand responses to price and the possibility of evaluating policy interaction effects with the RES-E and CHP Directive, and further related policies coming into force in the future (e.g. e-mobility, storage, energy efficiency, etc.). However, the trade-off in the Tier 3 approach is the high costs associated with developing and maintaining the models involved. The data costs can be partly reduced by using the Tier 3 basic approach (smaller data effort due to simplified power plant fleet).

Testing

The case studies for 2005 and 2010 for Denmark, the Czech Republic and Germany show that the price elasticity of demand is a relevant issue and has a significant impact on the results, especially for Member States with fossil fuel-fired power plants as the typical marginal power plant type to cover the surplus of electricity demand. Without the EU ETS, the CO_2 emissions of the power sector would have been 5 % to 15 % higher than in the policy scenario. The Tier 3 approach also shows that there was an impact on CO_2 emissions in the industrial sectors in the region of 5 %, and a very minor economic impact on GDP.

Possible indicators

Proposed indicators for reporting are CO_2 intensity of electricity generation and industrial production, energy intensity of industrial production, electricity generation mix and renewables share.

CO_2 Regulation for new cars

Introduction

The EU is very active in creating the CO_2 regulations aiming at decreasing the CO_2 emissions from road transport since these emissions continue to increase since 1990. However, in the last decade CO_2 emissions of new passenger cars have decreased significantly and at the same time vehicle prices have not increased (Smokers et al., 2006)[3]. The aim of this analysis is to develop a methodology of the ex-post evaluation of the effects and costs of the CO_2 regulations.

[3] http://ec.europa.eu/enterprise/sectors/automotive/files/projects/report_co2_reduction_en.pdf

Key points in the CO_2 regulations for passenger cars (ACEA)

A reduction in average CO_2 emissions from new cars limited to 120 g/km by 2012. Average new car CO_2 emissions should fall to 95 g/km in 2020. A staggered approach to implementation is as follows: 65% of new cars will comply with requirements in 2012; 75% in 2013; 80% in 2014 and 100% in 2015. Greater penetration of biofuels as complementary measure and super-credits for vehicles emitting less than 50 gCO_2/km.

Penalties will be imposed on a sliding scale; manufacturers exceeding their target by more than 3 g/km will pay €95 per excess gramme. Smaller charges between €5 and €25 for excesses of 1 – 3 g/km[4]

Methodologies proposed

For environmental effects we propose to calculate:

- Actual development of averaged CO_2 emission factor by mass, power or engine capacity class for each Member State and fuel type by multiplying the number of cars sold with their averaged mileage (from TREMOVE[5]) and the mass, power and engine capacity dependent emission factors
- Hypothetical development of averaged CO_2 emission factor by mass, power or engine capacity class for each Member State and fuel type for different assumptions: assuming that either of the three properties (mass, power, engine capacity) did not change since 2000, by assuming that the distribution over the classes didn't change since 2000 while the mobility (in terms of kilometers travelled) follows the historic development.

We expect that this type of analyses reflects the impact of the major parameters (fuels, engine capacity, mass, power) and as such can provide a quantitative range of the possible impact of the measure on the development of CO_2 emissions from new cars. Data will probably not allow to have these three effects combined in one analyses. Moreover, the three parameters (mass, power, engine capacity) are not fully independent.

Cost effectiveness needs also be assessed. We propose to include the additional manufacturing costs for applying more efficient vehicle technologies, vehicle prices and fuel costs. Since costs from the ex-post analysis cannot be transparent, we proposed to use ex-ante costs. We suggest to use already existing cost curves, describing the **additional manufacturer costs** for achieving increasing levels of CO_2 reduction in different vehicle segments. Smokers, et al. (2011)[6] developed cost curves per two fuels (petrol and diesel) and three autos' size categories (small, medium, large).

4 http://www.acea.be/news/news_detail/key_points_in_the_co2_regulation_for_passenger_cars/

5 http://www.tremove.org/model/index.htm

6 http://ec.europa.eu/clima/policies/transport/vehicles/cars/docs/study_car_2011_en.pdf

From the CO_2 emissions fuel consumption could be calculated for all different hypothetical and for the actual developments of the emission factors for new cars using fuel consumption data from TREMOVE. Then these can be converted into differences in **fuel costs**, using averaged fuel prices for each Member State.

Required data

Stock of new cars (number), distribution over classes: mass, power, engine capacity (number), share of petrol and diesel cars (%), new registrations (number/yr), emission rate of new cars (g CO_2/km) CO_2 from new cars, average distance driven by cars (km) from TREMOVE, fuel costs (EUR), production costs (Euro/vehicle), additional manufacturing costs (EUR).

Possible Indicators

Indicator 1: CO_2 emission reduced (%) expressed as actual emissions minus baseline emissions from new cars (GgCO_2) divided by baseline emissions from new cars (Gg).

Indicator 2: Fraction of biofuels in road transport (%) expressed as biofuels used in road transport (PJ) divided by total fuels used in road transport (PJ).

F-Gas Regulation

Introduction

Regulation No 842/2006 on certain fluorinated greenhouse gases (the F-Gas Regulation) is directed to fluorinated greenhouse gases (F-gases) such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and SF6, which have high global warming potentials and are controlled under the Kyoto Protocol. The F-Gas regulation addresses i.a.

- containment, use, recovery and destruction of F-gases as well as control of use for specified applications;
- labelling and disposal of products and equipment containing F-gases as well as placing on the market prohibitions;
- training and certification of maintenance personnel and companies handling F-gases.

Regarding the quantification of emission reductions affected and costs incurred by the F-Gas Regulation, the European Commission (DG CLIMA) published a technical study in 2011 (Schwarz et al. 2011)[7]. In the context of that study the bottom-up ‘AnaFGas’ model was developed for DG CLIMA featuring 21 F-gases and 29 F-gas using sectors

[7] Schwarz et al. 2011: Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases; Final Report & Annexes to the Final Report. Prepared for the European Commission in the context of Service Contract No 070307/2009/548866/SER/C4

differentiated by Member States. EU-wide implementation costs were estimated for seven cost categories, partially differentiating between sectors and EU regions. Thus, a highly complex Tier 2/3 method for assessing the F-gas regulation is available and data has been compiled.

Methodology proposed

In order to facilitate an ex-post evaluation of the F-Gas Regulation by Member States, a simplified Tier 2/3 approach for assessing emission reduction and cost estimates was developed in the present study based on an analysis and assessment of the above mentioned AnaFGas emission model and cost estimates. The concept of the simplification was to identify the quantitatively most relevant F-gas using sectors and cost categories which would primarily need to be assessed. F-gas sectors and cost categories of minor relevance would be neglected without an unjustified distortion of the results.

The assessment of emission reductions for the identified key sectors builds on sector-specific data/estimates on stocks of F-gas using equipment, specific F-gas charges and compositions, equipment lifetimes, leakage rates during operation, emission rates during disposal and some specific sales and consumption statistics. Data could be available from Tier 3 models like AnaFGas, national studies or emission inventories and/or sales statistics. Cost estimates are proposed in particular for personnel certification, containment and recovery and could be based on the specific findings of the above mentioned Schwarz et al. 2011 study or on comparable national studies.

Challenges

Despite considerably reducing the complexity of the F-gas using sectors, the developed simplified approach still demands rather high efforts in terms of technical expertise and modelling capacity to be employed and specific technical data to be collected or estimated.

F-gases account for 2% of the EU27 overall greenhouse gas emissions in 2009, however, with a rising trend. Given that limited relevance of EU F-gases emissions, however, it might be more time- and cost-efficient from a central EU perspective to concentrate on updates of the available centralised assessment tools and methodologies which might be undertaken by the European Commission in co-operation with some of the larger Member States. A considerable improvement of EU-wide ex-post evaluation results by means of reporting from smaller Member States is not to be expected.

For Member States wishing to improve their own assessment capacities on the F-gas Regulation, however, the proposed methodology would help focussing limited efforts on the most relevant sectors and cost-categories.

IPPC Directive

Introduction

The IPPC Directive sets out the legal framework for preventing and controlling pollution arising from a range of industrial activities. The Directive requires the industrial installations concerned to obtain an environmental permit from the competent authorities in the Member States. The conditions in these permits are largely influenced by related sectoral policies (for example, the Large Combustion Plant Directive) and guidance documents (Best Available Techniques Reference Documents, BREFs).

The IPPC requirements were applicable to new installations from October 1999 and for existing installations from October 2007. In the EU27, it is estimated that the IPPC Directive covers approximately 52,000 installations.

It is important to note that IPPC does not cover CO_2 directly, however, it promotes the implementation of a range of measures some of which might affect GHG emissions e.g. fuel switching.

Methodologies proposed

The authors of the 2009 study only developed a Tier 1 assessment methodology. This was a high level assessment of the policy impacts based upon existing EU wide statistics allowing for easy replication. It involved using:

- GHG emissions from manufacturing sectors over time extracted from UNFCCC;
- Industrial Production Index used as a measure of industrial activity;
- Average GHG emissions intensity calculated for the years preceding implementation of IPPC to estimate counterfactual GHG emissions and then these were compared with actual reported emissions.

However, the authors recognised that this approach was extremely simplified and consequently the methodology was considered insufficiently robust. Some proposals were suggested for Tier 2 and 3 methods.

As part of this study, we have refined the Tier 1 methodology and developed Tier 2 and 3 methodologies focusing on a selected activity (LCPs). The tier 3 approach is focussed at a plant-by-plant level with significant resource needs. Due to the diverse nature of activities covered by the IPPC Directive, the methodologies proposed for LCPs will not be directly transferable to all other activities. However, similar approaches could be taken for other large point source emitters.

To review the feasibility of such approaches, we have undertaken a review of key datasets that are available and could be of use for undertaking ex-post evaluation. This included data on emissions, activity rates, numbers of installations in each sector, uptake of techniques for compliance and associated costs. This identified a number of key data gaps and limitations.

Challenges

In addition to data availability concerns, other key issues with conducting an ex-post evaluation of the IPPC Directive from a GHG perspective is that the Directive is not specifically targeted at GHG emission reductions. Furthermore, the Directive overlaps in terms of sectors and potential impacts with a range of other directives including: EU ETS, Waste Incineration Directive (WID), Large Combustion Plant Directive (LCPD), Combined Heat and Power Directive and various national policies. It is extremely difficult, therefore, to isolate the impact of IPPC. Some of these interactions are perhaps simplified for future evaluations by the fact that the IPPC Directive has now been combined with various sectoral Directives (including WID and LCPD) to form the Industrial Emissions Directive (2010/75/EU).

The proposed methodologies were not tested or further refined as impacts on GHG emissions are likely to be low, complications due to interactions with other policies and gaps in the available data. Furthermore the resource requirements to undertake a Tier 3 assessment are expected to be significant.

Waste Incineration Directive

Introduction

The Waste Incineration Directive (WID) regulates the incineration of waste to prevent excessive pollution to air, water and soil. Incineration and co-incineration plants must be authorised, comply with emission limit values for releases to air and water, implement measurement and monitoring systems and recover any heat generated. WID imposes:

1. Emission limit values for air pollutants such as: Dust (PM), HCl, HF, SO_2, NOx, heavy metals and dioxins.
2. Recovery of heat generated by the incineration process, the heat must then be put to good use as far as practicable.

WID has been applied to existing plants since December 2005 and to new plants since December 2002. Note that this Directive is now part of the Industrial Emissions Directive (IED) as discussed in the IPPC section above.

Methodologies proposed

WID has large areas of overlap with IPPC and other PAMs which makes separating the impacts difficult and increases the uncertainty of results. Furthermore, the policy is not directly aimed at reducing GHG emissions and the impact is therefore likely to be less than for other policies.

The previous study developed Tier 1 and Tier 2 assessment methodologies and made some suggestions for a Tier 3 approach. The proposed approach was based on energy recovery per unit mass of waste incinerated from waste incineration. It was found that the analysis of WID is not fully suited to a Tier 1 and Tier 2 indicator based approach, because of the variability of the energy recovered from Municipal Solid Waste (MSW) incineration. Negative savings (increases of emissions) were calculated due to an anomalous fall in energy recovery from MSW incineration in 2006 in the EU27.

As part of this study, we have developed Tier 2 and 3 methodologies building upon more detailed national level data. The approaches proposed take a similar approach to those developed for the IPPC Directive utilising sector and/or site specific assumptions about operator response to the Directive e.g. abatement uptake rates. The key types of information required for an assessment are:

- Energy recovered from waste incineration.
- Activity data (quantity of waste treated).
- Exogenous variables e.g. moisture content of MSW. .
- Unit costs of abatement measures. .
- Emissions.
- Number of plants.
- Abatement technique uptake.

The operator surveys and installation-specific Tier 3 methodology outlined would require a significant amount of resources to undertake and the additional benefits would potentially be limited given the relatively small impact of WID on GHGs.

Challenges

The proposed methodologies were not tested or further refined as impacts on GHG emissions are likely to be low, complications due to interactions with other policies and gaps in the available data. Furthermore the resource requirements to undertake a Tier 3 assessment are expected to be significant.

Nitrates Directive

Introduction

The Nitrates Directive aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices. The Directive requires Member States to identify polluted or threatened waters, designate “vulnerable zones” (NVZs), establish Code(s) of good agricultural practice, to be implemented by farmers on a voluntary basis, establish Action Programmes, to be implemented by farmers within NVZs on a compulsory basis and undertake monitoring and reporting.

Methodologies proposed

The previous study proposed Tier 1 and 2 methodologies based on EU wide statistics, aggregated data reported by Member States to the UNFCCC and associated emissions factors. For Tier 1, emissions reductions were assessed in terms of the change in emissions of N2O from soil per unit of agricultural land, relative to 1996- the date by which Members States were required to implement the main components of the Directive. The Tier 2 approach was similar to the Tier 1 method but emission reductions were based on policy impacts from the actual implementation date rather than start date of the policy. Furthermore, instead of a single year being used as the ‘frozen efficiency’ for the application rate (as with Tier 1), the average application rate in the 3 years prior to the implementation of the Directive was used (to avoid the sensitivity of using a single year). The previous study concluded that the Nitrates Directive has a large variation in effectiveness between MS. Furthermore, it is difficult to isolate the effects of the Directive from other policies. As a result it concluded that the benefits are likely to be overestimated.

A number of possible improvements have been identified in this study including:

- Correcting for autonomous development by factoring in changes in technology that has led to the reduction in the quantity of N fertiliser required.
- Correcting for structural changes in activity data – conduct surveys to understand if and how farm management practices have changed as a result of the Nitrates Directive.
- Correcting for market forces – e.g. understand how use (and type) of fertiliser has changed as a result of changes in fertiliser prices. This should then be used to update the counterfactual scenario.
- Correction to reductions in emissions due to other policies – e.g. to split out potential impacts of other policies such as CAP.
- Correct for coverage of the NVZ designation – the 2009 estimates are based on a whole territory approach however this is not correct for all MSs.

No ex-post evaluation of costs has been undertaken to date, nor has a methodology been developed for doing so.

Challenges

Current data availability and quality only allows for a high level analysis. The quality of activity data could be improved through surveying several regions/MSs who have different types of soil, climate and land use to understand if farm management practices changed as a results of the Nitrates Directive (or if it would have occurred in the counterfactual). Emissions data is also based on national emissions inventories derived using an IPCC tier 1 methodology which is very simplistic.

Tier 3 would require econometric analysis, calibration of bottom-up data, climatic variation correction factors, correction for crop and fertilizer type changes. Currently there are major and prohibitive gaps in the data, including detailed MS emission inventories which factor in regional variations, actual (adopted) farm management practices for different types of soil and climate, MS specific time series data on changes in fertiliser use and the location and coverage of NVZs amongst others.

It should be noted that a detailed modelling study has recently been completed for the EC looking at the impacts of the Nitrates Directive on EU27 gaseous nitrogen emissions including NOx, NH_3 and N_2O[8]. This provides an alternative approach for evaluating the impacts of the Directive using the MITERRA-EUROPE model.

[8] Alterra, AEA Technology, ITP, NEIKER (2011): The impact of the Nitrates Directive on gaseous N emissions - Effects of measures in nitrates action programme on gaseous N emissions, Available from: http://ec.europa.eu/environment/water/water-nitrates/studies.html

2003 CAP reform

Introduction

The Common Agricultural Policy (CAP) is focused mainly on the European agriculture market but since 2007 a stronger focus on environmental protection has been developed. In recent years (notably in 2003 and during the CAP Health check in 2008) the main objects of the Directive changed to a more market oriented policy without coupling (decoupling) premium for the farmers (CAP reform). More environmental aspects and animal healthcare are considered in the next steps of the reform package. The key legislative instrument is the 2003 CAP Reform (COUNCIL REGULATION (EC) No 1782/2003) for the period of 2005 to 2013. It is based on regulatory instruments: decoupling subsidies, cross-compliance, financial modulation and development of rural areas.

Methodology proposed

The quantification of emission reductions and costs incurred by the CAP is challenging as direct linkages (e.g. commodity market, GDP consumer behaviour) or linkages on a sub-level (technology improvement per farm unit) are difficult to estimate. Several bottom-up models (e.g. CAPRI, MEACAP-Modelfarm, AGNEMOD and GAINS) linked economic indicators, costs and results of emission inventories to study these interactions and with these developing future scenarios.

In the present study based on an analysis and assessment a simplified concept was developed which identified the most relevant sectors (enteric fermentation, manure management) and cost categories which would primarily need to be assessed. The assessment of emission reductions for the identified key sectors builds on sector-specific data/estimates on national statistics (see e.g. EUROSTAT, animal numbers, farm numbers, amount of minerals fertilizers) or emission inventories (e.g. emissions and background data of average gross energy intake) and/or sales statistics. Different Tier levels for the assessment are proposed as follows:

Tier 1 level:

Using modelled information (mitigation costs, reduction potential, emissions per ha or farm) of a German standard farm. As the information may not be representative of, or comparable with, other Member State (MS) farm types surveys should be conducted on MS level for specific costs or technologies for farm management. With more information on MS level about the technology used, the reduction potential evaluated in the study could be applied to obtain an advanced view of the effect on emissions.

Tier 2 level:

For a Tier 2 approach regional circumstances – e.g. climate conditions (temperature, humidity) – which influence enteric fermentation (methane conversion factor) and the N-cycle have to be considered. It would therefore be necessary to conduct a study for at least one MS with climate conditions that differ from those in Germany, such as a Mediterranean country (e.g. France, Spain). This would enable conclusions for different farm types and would allow for a more differentiated analysis.

Tier 3 level:

For a Tier 3 approach, model runs should be conducted on individual MS level. This entails that MS should have detailed information available to use these for a model run. If no information is available a country specific survey could be conducted. The main emitters of agricultural emissions in Europe are Germany, France and Italy, Spain and Poland. Therefore, it is recommended that a detailed model analysis of those countries should be evaluated in a Tier 3 setting.

Cost can be assessed in particular for milk yield and production. The price of fertilizer and investment costs could be based on the specific findings of the above mentioned models and studies or on comparable national surveys (e.g. here stable cost per animal).

Challenges

Despite considerably reducing the complexity of the agriculture sectors, the developed simplified approach still demands rather high efforts in terms of technical expertise and modelling capacity and specific technical data to be collected or estimated.

Therefore, it might be more time- and cost-efficient from a central EU perspective to concentrate on updates of the available centralised assessment tools and methodologies which might be undertaken by the European Commission in co-operation with some of the larger Member States. A considerable improvement of EU-wide ex-post evaluation results by means of reporting from smaller Member States is not to be expected.

Landfill Directive

Introduction

There are three main impacts on GHG emissions resulting from the Landfill Directive:

1. The first effect of the Landfill Directive on GHG emissions results from the reduction of the amounts of biodegradable waste disposed to landfills, which leads to a reduction of activity rates used in the emission calculation. This effect is the main effect that the methodologies proposed in the previous project address.
2. The second effect of the Landfill Directive on GHG emissions is the obligatory implementation of landfill gas collection systems for landfill gas and the subsequent treatment (flaring) or energy use of the collected landfill gas.
3. The conversion of unmanaged and illegal waste disposal sites to managed waste disposal sites that comply with the requirements of the Directive led to the closure of old and illegal disposal sites and the establishment of new sites that are properly managed and fulfil requirements with regard to water control and appropriate location of sites, leachate management, protection of soil and water, gas control or stability. Unmanaged SWDS (Solid waste disposal sites)

produce less CH_4 from a given amount of waste than anaerobic managed SWDS. Thus, the implementation of the Landfill Directive resulted in a change in the methane correction factor (MCF) in estimation of CH_4 emissions which is not taken into account in any of the methodologies proposed in the previous project.

Methodology proposed

The methodological approach is generally based on equations and data as used for the First Order Decay Method (FOD) for the estimation of CH_4 emissions from solid waste disposal sites as performed for the GHG inventory reporting which is implemented in all EU MS and for which reviewed country-specific and default parameters are available. The methodological approach proposed in the previous project could be further refined. At a general level, the ex-post methodology should:

1. Take into account the effects of the closure of unmanaged landfills and the establishment of managed landfills in the emission estimation via the MCF (methane correction factor) in all methodological tiers;
2. Take into account the effects on landfill gas recovery on managed landfills resulting from the implementation of the directive in all methodological tiers;

Respective improvements in the methodological approaches are proposed.

Tier 1 level

Several improvements were identified for the Tier 1 method proposed in the previous project, in particular

- A refined, but still simple approach for the development of a counterfactual scenario categorizing MS in three landfilling types;
- The including of the effects on landfill gas recovery in the tier 1 level as data is easily available;

Tier 2 level

Several improvements were identified for the Tier 2 method proposed in the previous project, in particular

- A separation of three types of biological treatment to achieve consistency with the IPCC inventory estimation methods;
- A correction related to the accounting of emissions from recycling;
- Some simplification of the Tier 2 method proposed:

Tier 3 level

A new approach for a Tier 3 method that mainly improves the assumptions in the counterfactual scenario as the emission reduction methods of the Tier 2 method seems sufficiently precise and does not require further refinement.

Challenges

The estimation of emission reductions effects is relatively straightforward due to the fact that similar data requirements exist for the preparation of GHG inventories. Whereas cost estimates for the implementation of the Landfill Directive have been assessed in previous studies, the cost estimation of a counterfactual scenario presents a huge challenge related to the development because the Landfill Directive effectively stopped the illegal and unmanaged landfilling of biodegradable and hazardous waste. Thus, a counterfactual cost scenario would need to estimate the environmental damage caused by a continued illegal dumping of MSW and hazardous waste on human health and ecosystems and the costs for dealing with such damage. Whereas it is rather obvious that such long-term costs would be much higher than the costs for the implementation of the Landfill Directive, it is rather speculative to provide a detailed counterfactual cost estimation.

Energy Performance in Buildings Directive (EPBD)

Introduction

The EPBD was initially adopted in 2002 (2002/91/EC)[9], with the aim of promoting "…*the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness."* [Article 1]

The Directive set out a number of requirements including:

(a) a general framework for a methodology for calculating the integrated energy performance of buildings taking into account all aspects which determine energy efficiency;

(b) minimum standards to be set by MSs for the energy performance of new buildings and large existing buildings that are subject to major renovation, to be calculated on the basis of the above methodology;

(c) systems for the energy certification of new and existing buildings; and

(d) regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old.

A recast of the Directive was adopted in 2010 (Directive 2010/31/EU)[10]. The recast strengthens the building codes and energy performance requirements for buildings

[9] Directive 2002/91/EC of the European Parliament and the Council of 16 December 2002 on the energy performance of buildings

[10] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)

across the EU and requires all new buildings to be nearly zero energy buildings by 2020.

Methodologies proposed

Tier 1 is a top-down approach which assumes a linear relationship between number of buildings and the level of GHG emissions. In MS where existing energy policies are in place, it attributes all climate-corrected savings beyond 0.5% autonomous efficiency improvement per year to the EPBD. It assumes that the share of energy use for space heating is unchanged over the years, uses default values per country, and an EC average emission factor. Tier 2 adopts the same approach, with m^2 flooring instead of number of buildings as activity indicator, and MS specific emission factors and space heating shares. Tier 3 method is a detailed bottom-up model, using a simulation model (e.g. MURE), which relies on detailed data of building stock characteristics in the EU27.

The methodologies proposed focus primarily on assessing impacts of the Directive in relation to space heating due to the significance of associated emissions. However, the Directive can also impact on other functions such as space cooling and water heating. The methodologies can be adapted to consider impacts on these items through substitution of data for space heating with equivlant data for these functions although there are some issues rlated to availability of suitable data (e.g. degree cooling days) and overlap with other policies (e.g. Energy Labelling Directive).

An indicative top-down approach to costs assumes a % of total investment in buildings and subtracts the cost savings of energy reductions. A bottom-up approach uses technology specific costs.

Testing

We tested whether recommended improvements for Tier 1 and 2 can be implemented at the MS level with country specific data, and whether they deliver any useful results. This was tested for the UK and NL, although we also investigated the availability of relevant data sources for all MSs. The testing demonstrated the value in using the actual policy implementation date, and MS space heating shares where known (if possible, broken down according to fuel). We also surveyed all MS Competent Authorities to see which countries have detailed models for the building sectors and if these models are geared towards ex-post evaluation, which revealed no suitable examples and a good deal of variation in MS data availability.

Challenges

The main issues for ex-post evaluation of the EPBD relate to the difficulty in establishing the counterfactual, autonomous improvement, the impacts of overlapping PAMs, other exogenous factors (e.g. energy prices) and non-compliance. The main data challenges for a top-down assessment are MS specific space heating (or other functions such as cooling) shares and m^2 flooring (primarily in non-residential buildings). There is a more significant lack of data to enable bottom-up assessment.

Possible indicators

Proposed indicators for considering the impacts of the PAM include:

- Final temperature corrected energy consumed for space heating, cooling or water heating in the residential and non-residential buildings sector (GJ/m^2 residential or GJ/household; GJ/m^2 non-residential or GJ/employee)
- CO_2 intensity of final temperature corrected energy consumed for space heating, cooling or water heating in the residential and non-residential buildings sector (kt CO_2/household or ktCO_2/m^2 residential; kt CO_2/employee or kt CO_2/m^2 non-residential)
- Cost effectiveness (€/kt CO_2 abated)

Energy Labelling Directive

Introduction

The Labelling Directive was adopted in 1992 and is aimed at harmonising national measures to enable consumers to choose the most energy efficient appliances. A large number of Implementing Directives have been adopted which regulate the labelling specifications for each product type. Some Directives have been updated since their first adoption.

A revised Energy Labelling Directive was adopted in May 2010. It extends the energy label to energy-related products in the commercial and industrial sectors, for example cold storage rooms and vending machines. New energy labelling classes have also been introduced. The extension of the scope from energy-using to energy-related products (including construction products) means that the Directive covers any good having an impact on energy consumption during use.

Methodologies proposed

The methodologies in the 2009 study were well developed and analysis was carried out for all three tiers. Assessment of the policy impact at Tier 1 level was based on EU-level Eurostat data. Key indicators used were number of households and total electricity consumption by household. The approach does not separate out individual appliances nor does it split out other electricity uses not covered in the scope of the Labelling Directive (e.g. electric heating, electric water heating and small electric appliances). Tier 2 is based on national data collected in the Odyssee Database under framework of the Intelligent Energy for Europe (IEE) Programme. This approach calculates the impact of the Directive using appliance ownership data and unit consumption (kWh/appliance/year). It separates the main large appliances but does not make use of sales data or labelling classes. Tier 3 is a bottom-up approach using the MURE appliance stock model which includes sales on different appliances by label type by country.

The main issues identified related to correcting for autonomous progress and data availability.

Testing

As the methodologies were well advanced in the previous study, efforts for the testing were focused on whether recommended improvements to the Tier 1 and Tier 2 methods could be implemented (mainly related to the type of data used). We surveyed a selection of Member States to assess data availability at the Member State level revealing significant disparity in data availability.

Challenges

The main data challenges are: historical time series data on autonomous development at appliance level often not available at MS level (or not long enough) and data access issues of private data-sets, e.g. Odyssee database, MURE, GfK (including compliance data).

Possible Indicators

Proposed indicators for considering the impacts of the PAM include:

- CO_2 emissions of electricity consumption for lighting and electrical appliances in the residential sector ($ktCO_2$/dwelling)
- Electricity consumption for appliances in the residential sector (kWh / dwelling)
- Proportion of sales of top energy labels (A++/A+/A) in new sales (%)

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1 Background and Objectives

Previous work has shown the difficulty to assess the impacts of individual polices and measures to mitigate greenhouse gas emissions in a thorough manner. However, the ability to assess the effectiveness of policies and measures on greenhouse gas emissions has become increasingly important both at EU and Member States (MS) levels. At the EU level, the achievement of the 20% domestic emission reduction target will require close monitoring of the policies and measures at the MS level, in particular in the non-ETS sectors under the Effort Sharing Decision (Decision 406/2009/EC). At the international level in the context of the Cancún Decisions, developing countries are required to monitor, report, and verify mitigation actions, while developed countries are required to enhance the monitoring and reporting of the progress made in achieving quantified economy-wide emissions reductions.

At present the ex-post assessment of policies and measure remains subject to a number of shortcomings. First, the reported information on policies and measures is often limited to qualitative appraisals and lacks the assessment of quantitative impacts. Furthermore, ex-post evaluations are currently not conducted and reported in a consistent way by Member States. Moreover, a more thorough ex-post evaluation of policies and measures at the Member State level is necessary for the improved analysis of the opportunities for further development and refinement of EU and national climate change policies. Another current shortcoming is that the indirect effects of other policies, overlapping and rebound effects are often neither recognized nor quantified in the assessment of climate change policies and measures. Another area where significantly more work is needed is the development of methodologies to quantify the social costs and benefits of specific climate change policies and measures. Also, the variation of experiences and responsibilities with respect to monitoring, evaluation, statistical data among different MS is large and needs to be addressed.

The EU already commissioned an initial study to develop methodologies for the ex-post evaluation of mitigation policies which was released in 2009[11]. Whilst substantial progress has been made in a number of research areas, a number of gaps and areas for further development remain. The current study fully reviews and builds on the results of this study and aims at:

- Further refining and improving the methodologies developed for the ex-post quantification of policies and measures.
- Providing a critical overview of existing methodologies and recommendations to assess ex-post the effects, socio-economic costs and efficiency of policies and measures.

[11] AEA, Ecofys, Fraunhofer ISI (2009) 'Quantification of the effects on greenhouse gas emissions of policies and measures'", study prepared for the European Commission (http://ec.europa.eu/clima/policies/g-gas/studies_en.htm).

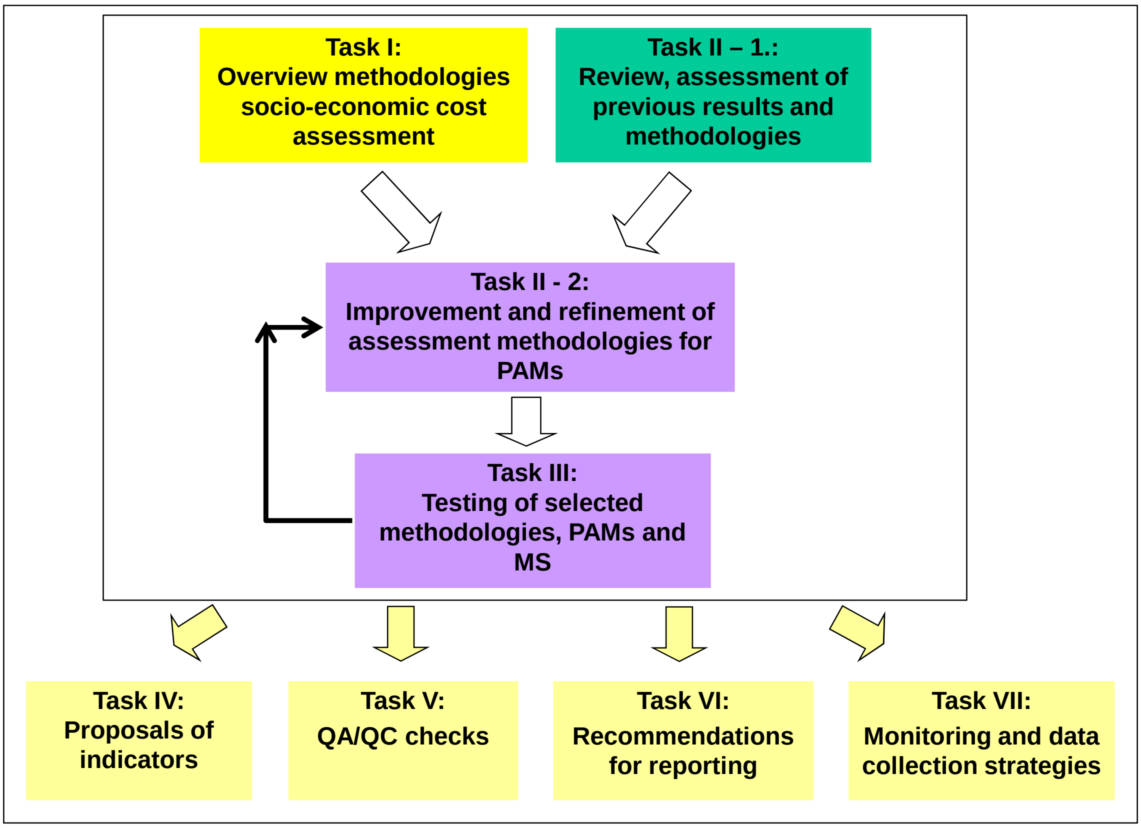
- Testing the refined and improved methodologies for 2-5 Member States and 2-5 policies in each MS
- Improving monitoring and reporting of the effects and efficiency of policies and measures ex-post.

The study aims to **support Member States and the European Commission** in assessing ex-post the efficiency and effectiveness of individual policies and measures. As such the study aims to provide guidelines and recommendations to assess the environmental impacts and socio-economic effects (including effects on sectoral and overall economic growth, welfare, employment, marginal abatement costs, structure and distribution) of policies and measures. The Commission and the Member States may benefit from the structured guidelines on methodologies and indicators in their monitoring, reporting and verification processes.

2 Report structure

The study is set up around seven tasks that were tackled in the project to address the above mentioned objectives. An overview of the individual tasks, corresponding to the subsections in this report, is given in Figure 2.1. The tasks are briefly described in the following:

Figure 2.1 Project structure and task overview



- Task 1 “Critical overview of existing methodologies to quantify ex-post the direct and indirect socio-economic costs of climate change policies and measures” aims at providing recommendations for performing ex-post assessments of direct and indirect socio-economic costs and efficiency at the EU and Member State level.
- Task 2 “Review and assessment of the results and methodologies developed under the project ‘Quantification of the effects on greenhouse gas emissions of policies and measures’" aims at providing revised and improved methodologies for the ex-post quantification of the effects of policies and measures”.
- Task 3 “Testing of methodologies” focuses on testing of the improved and refined methodologies for the assessment of environmental and economic impacts, in an iterative way for 2-5 Member States and policies and measures. The selection of Member States and Policies and Measures was based on the indicators of practicability, applicability and data availability. A set of refined and improved methodological tiers for the ex-post assessment of effects, socio-economic costs and efficiency for the policies and measures resulted from the testing phase.
- Task 4 “Proposal of indicators” aims to identify suitable indicators that allow monitoring of progress in the implementation of policies besides the direct quantified ex-post effects of policies and measures. This results in concrete proposal of indicators for reporting on ex-post assessments on the effectiveness of the EU level policies with appropriate definitions and data sources.
- Task 5 “QA/QC checks” elaborates concrete proposal of QA/QC checks to be performed by MS as well as at the Commission level.
- Task 6 “Recommendations for the enhancement of reporting requirements under the Monitoring Mechanism Decision” tackles proposal for specific legal requirements to be integrated in the revision of decisions 280/2004/EC and its implementing provisions (Decision 2005/166) that are currently elaborated by the Commission.
- Task 7 “Monitoring and data collection strategies” derives proposals of monitoring and data collection strategies.

The report is structured around these seven tasks. At first in Section 3 a critical overview of socio-economic costs assessment is elaborated in detail. This is followed by the review, assessment and refinement of the results and methodologies developed under a previous study by AEA et al. (2009)[12] and accompanied by proposals for improved methodologies in Section 4 (Task 2). Section 5 describes approaches and pro-

[12] AEA, Ecofys, Fraunhofer ISI (2009) ‘Quantification of the effects on greenhouse gas emissions of policies and measures’", study prepared for the European Commission (http://ec.europa.eu/clima/policies/g-gas/studies_en.htm).

cedures as well as the results of the testing phase (Task 3) which aimed to further improve and refine the methodologies and to implement the recommendations from the previous tasks (Task 1 and 2). The remaining sections are devoted to the proposals for indicators (Section 6), quality assurance and quality control (Section 7), monitoring and reporting (Section 8) as well as data collection strategies (Section 9).

3 Task 1 Critical overview of existing methodologies to quantify ex-post the direct and indirect socio-economic costs of climate change policies and measures

Task 1 provides a critical overview of existing methodologies and applications to quantify ex-post the direct and indirect socio-economic costs of climate change policies and measures at MS and the EU level. In order to relate these socio-economic costs to the efficiency of policies and measures in terms of emissions reductions, a combination of the methodologies to quantify costs and those that quantify emission reductions is required. This can be achieved within the same modelling approach for some methodologies and through a combination of results from different models for other methodologies. The critical overview in this Task also takes into account experience and examples that were gained with the methodologies and applications of such methodologies for previous ex-post or ex-ante analyses. Task 1 ultimately aims to provide practical guidance to the necessary steps and procedures to assess ex-post the efficiency of policies and measures.

3.1 Definition of the different types of costs

The ex-post economic efficiency of climate change policies or measures is assessed by relating the net cost of the mitigation activity to the mitigated emissions. The economic analysis takes into account costs and financial offsets that occur in the context of implementation of the policy or measure. The net costs are derived as the difference of total costs of the policy and measure and benefits, such as reduced expenditure on energy, that occur as a result of the implementation of the policy or measure.

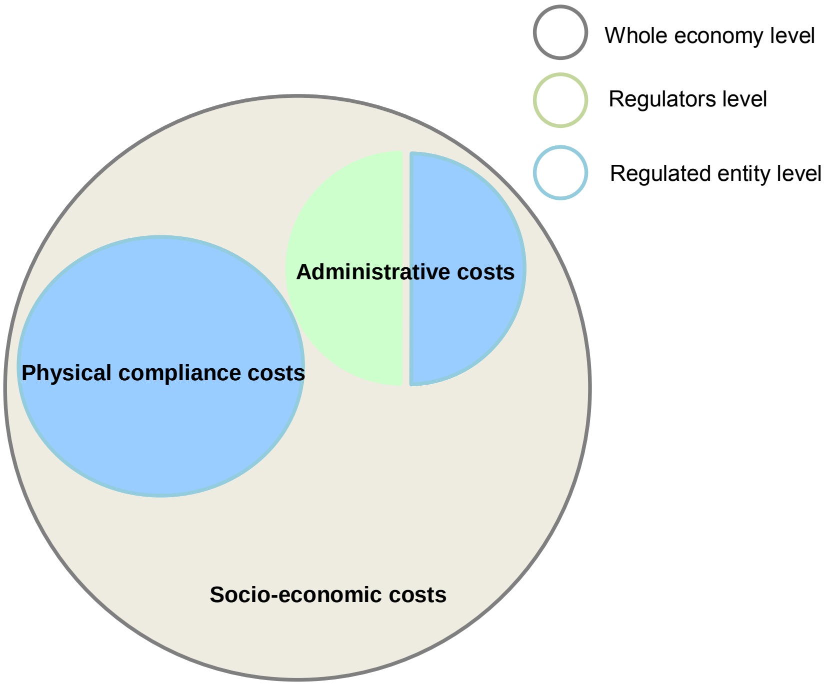
In general different types of socio-economic costs can be distinguished that arise at different stages of policy development and implementation and affect different economic agents. The levels of economic agents are defined as follows.

- *Regulated entities level (private decision*-makers): households and private companies that face costs related to the implementation of a mitigation measure, i.e. physical compliance costs as well as administrative and transaction costs.
- *Regulator level (Regulating authorities at EU and MS level):* policy making institutions that face costs related to the implementation and monitoring of a mitigation measure.

- *Whole economy level*: the level at which direct and indirect socio-economic costs occur, such as welfare losses, distributional and employment effects, as a result of the implementation of the mitigation measure.

The association of different costs types to these levels of economic agents is illustrated in Figure 3.1 and will be discussed in detail in the following sections.

Figure 3.1 Costs at different levels of economic agents



3.1.1 Compliance costs at the level of regulated entities

Compliance costs are the net costs that regulated entities face when complying with specific pieces of environmental legislation (IVM, 2006)[13]. According to a definition mentioned in IVM (2006) environmental compliance costs present a response to a regulation whose primary objective is to protect or improve the environment. Moreover, environmental compliance costs present additional costs to the regulated entities. The latter is usually the case when investment in new technologies, plants or equipment is needed to comply with the regulation and the investment does not lead to required returns to offset the costs. These compliance costs will depend on the particular technological alternatives available to the regulated entity. Net additional costs may not arise, however, when policies or measures address areas in which entities or consumers do not behave in economic rational ways or face (non-market price) transaction costs (such as information costs, adjustment costs etc.). In these cases, the policy or measure may help overcome barriers or market failures and may result in net cost savings.

[13] IVM (2006). Ex-post estimates of costs to business of EU environmental legislation (p. 55). Amsterdam.

Investment and operating costs

Investment costs refer to the capital costs needed to purchase, refurbish or retrofit plants and equipment to ensure compliance with the policy or measure. These costs usually originate upfront while induced cost savings occur over the lifetime of the investment. In order to account for these time issues, capital investment costs are usually annualised using assumptions on the interest rate and depreciation period or lifetime of the investment. These annual capital costs are then supplemented by annual operational costs that may occur to maintain compliance (such as energy, labour, material costs). To yield annual net costs, these costs are reduced by annual costs savings that result from the investment in equipment or plants, e.g. the savings in energy costs resulting from efficiency improvements, The annual net costs can then be compared to the mitigated emissions and provide a measure of abatement costs.

Box 3.1 Operator's versus economic (societal) perspective

For the assessment of abatement costs it is important to distinguish two perspectives, i) the operator perspective, and ii) the economic or societal perspective. The two perspectives differ mainly with respect to the interest rate, the lifetime or depreciation period of the investment and the consideration of social transfers. Individual operators analyse the economic efficiency of an investment by applying individual rates of returns that are based on their current situation and position in the market. Similarly, assumptions on the lifetime of the plant or equipment which from an economic point of view would simply refer to the technical lifetime of the investment may be different from an operator perspective based on their expectations on the pay-back period. Moreover, individual operators need to take tax requirements and subsidy payments into account as these immediately affect their (business) calculation. From an economic point of view, such social transfers do not play a role as they do not present actual economic costs or revenues.

An overview of the two perspectives and their differences is shown in Table 3.1. In both cases investment and energy related costs are treated the same. The treatment of the CO_2 price created by the regulation, however, deserves a closer consideration. Additional costs due to CO_2 pricing can be differentiated into direct CO_2 related cost increases that result from a policy regulation and are directly emitted by the regulated entity and indirect CO_2 related cost increases which refer to the additional costs that are passed on from regulated entities further up the production chain, such as the electricity industry. Private operators will always take both of these effects into account and adjust their economic calculation accordingly. From an economic perspective, however, these CO_2 pricing related additional costs whether direct or indirect present social transfers and should not be accounted for.

Table 3.1 Abatement costs from an operator vs. economic (societal) perspective

	Economic perspective	Operator perspective
Investment cost	full	full
Fuel cost	full	full
CO2-price	no	maybe
Discount rate	long-run capital market interest rate (ca. 4%)	individual rate of return (industry, electricity >12%; other 6-8%, private consumers 4%)
Time horizon	lifetime of investment	payback period (differs by investor and usage)
Taxes	no	yes
Subsidies	no	yes

The treatment of indirect CO_2-emissions - whether from the operator's or economic perspective - is highly relevant (and sensitive) in the case of abatement costs. As explained above, abatement costs present the net costs in relation to the mitigated emissions. As indirect CO_2 emissions, however, are mitigated further up at the electricity industry and not necessarily in immediate response to the considered policy or measure, a discrepancy will result for the cost savings induced by the policy or measure and the mitigated emissions in the "upstream" electricity sector. The "upstream" emissions reduction may lead to a change in the CO_2 cost share in the electricity price. Thus, ideally, electricity prices should be reduced by the share of indirect CO_2 price effects to avoid such bias. Alternatively, direct and indirect emissions and cost effects should be analysed simultaneously. In reality, however, this is difficult to apply.

For the current study, we therefore propose to refrain from this distinction and to use the market or contracted electricity price instead. For the purpose of analysing investment and operating costs in this study we recommend using assumptions closer to the operator's perspective, unless of course a general economic modelling approach as outlined in section 3.3.4 is pursued. This way, decision processes will be reflected in a way as they apply in other decision making situations. This implies that taxes and subsidies enter the net cost calculations. For the time horizon of an investment calculation, we recommend to use the asset depreciation range as used in accounting.

Of particular importance is the discount rate (or interest rate) used in the calculations. In a regular market case, the discount rate is equivalent to the rate of return of alternative investment opportunities, such as long-term capital market investment reflected in the long-term market interest rate. However, in reality we often observe investment behaviour of private operators as a result of their rational decision making which reflect different (higher) discount rates. In the area of private households, for example, observed purchase behaviour of energy efficient appliances compared to regular appliances reveal implicit discount rates of up to 20%. With their individual expectations on capital and energy markets private operators call for different rates of return. Higher discount rates imply that future monetary streams costs and savings (such as induced energy savings) receive a lower weight than in the case of low discount rates. In many cases, high implicit discount rates reflect the existence of barriers and market failures. Within this study we recommend to follow a two-group approach. Discount rates of 4% are to be applied for the assessment of policies and measures in the household sector or private transportation. Discount rates of 8% are to be applied for measures in the area of industrial, transformation and other business activity.

Investment and operating costs

Costs for research and development activities may help to establish advanced and more efficient technologies or techniques and thus bring down abatement costs in the medium to long run. These costs are sometimes (partly) covered by government funding or co-activities with universities and public units. R&D costs may range from small size and easily recoverable costs (by increased net returns to production) to large scale, possibly sunk-costs that cannot be recovered by increased net returns to production (e.g. the set-up of research and demonstration plants which purely serve research & development and will not go into large scale production).

Administrative costs

In addition to the investment and operating as well as maintenance costs, compliance costs include **administrative costs** for the regulated entity, e.g. to meet monitoring and reporting requirements. Administrative costs are defined as in the EU standard cost model[14] as “cost incurred by regulated entities in meeting legal obligations to provide information on their action or production”. They include one-time and recurring costs relating to labelling, reporting, registration, monitoring and assessment needed to provide this information. Only those costs are to be included that are in addition to the costs that the entity would have been exposed to anyway in the absence of the policy or measure. Such administrative occur not only on the level of regulated entities but also on the regulatory level. The latter are described in Section 3.1.2. A detailed description of the definition and method to assess administrative costs can be found in the Annex to the Impact Assessment Guidelines of the European Commission.[15]

Other costs

Costs to private entities other than investment and operating or administrative costs (**other costs)** may play a role when complying at the regulated entity level. In the nature of indirect costs include costs relating to *production, sales or revenue losses* due to changes in consumer demand arising in the same industry or in industries further down the value chain or otherwise complementary industries (e.g. loss in sales of

[14] European Commission (2009) ‚Impact Assessment Guidelines’, SEC (2009) 92, 15 January 2009.

[15] European Commission (2009) ‘Part III: Annexes to Impact Assessment Guidelines’, SEC (2009) 92, 15 January 2009

greenfield shopping centres due to decreased use of short distance automobile transportation as a result of a policy or measure). Similarly, changes in prices or costs of input factors resulting from a policy or measure immediately affect those industries that make use of these input factors but also all those industries that are further down the production chain or complementary to the affected industry. It provides a challenge to draw a system boundary for these effects as they may range from impacts on only some entities to impacts on the whole economy. For impacts on the whole economy, see Section 3.1.3 below.

Relevance of compliance costs for a given policy

The sections above give a definition and understanding of different costs types and cost components that may be affected by a policy or measure at the level of the regulated entity. While all these cost types or cost components are likely to be affected by a regulation, not all of them are equally relevant when analysing socio-economic cost effects. In this section, we therefore aim to provide further insights into the relevance of these cost types or components to help decision-makers or analysts take a decision on which cost types or cost components to assess in detail.

The assessment of **investment and operating costs** at the level of the regulated entity is deemed highly relevant for all policies and measures that induce substantial investment (capital-intensive sectors or products), e.g. in new low carbon technology or refurbishment of technology, buildings, and consequently lead to a shift in operating and maintenance costs. An assessment of investment and operating costs is less relevant, however, for policies that induce changes in behaviour (e.g. labelling) or that do not require substantial investment in low carbon technology in order to achieve the policy goal (CAP reform). The relevance of investment and operating costs is uncertain in areas where investment costs cannot be singled out (e.g. CO_2-regulation) or cannot fully be attributed to CO_2-mitigation (landfill directive).

Investment and operating costs provide the main input to marginal abatement cost curves that are commonly used to assess, compare and rank the mitigation costs of different mitigation option. They are a helpful indicator for decision making with respect to which mitigation option to tackle with a policy and how to design the policy in order to efficiently achieve the desired mitigation. For example, a mitigation option with low or negative abatement costs may be more efficiently tackled with a standard or information policy rather than a subsidy or investment scheme. On the other hand, mitigation options that are high up the marginal abatement cost curve may need a stimulation of investment in terms of support schemes or financial incentives.

In the context of ex-post analysis, the comparison of investment and operating costs with and without the policy reveal information on the changes in abatement costs due to the policy. Investment and operating costs may be higher in the policy case because of increased demand for specific technologies or equipment and subsequent price spikes or they may be lower because of scale or learning effects in applying a new technology or equipment. Understanding these reactions helps to assess the efficiency (and desired effects) of the policy. Moreover, information on investment and operating costs serve as an essential input to partial or whole economy modelling approaches that are used to assess the indirect effects of policies and measures.

The assessment of **administrative costs** at the regulated entity level is deemed most relevant for policies that require substantial additional administrative work, such as additional monitoring and reporting requirements or active participation in policy mechanism (e.g. EU ETS). Such additional costs will likely affect small and medium sized enterprises the most which have low or no internal capacity or resource to implement the policy requirements. In the case of the EU ETS, for example, the installation and know-how in handling of a trading account, plus the additional monitoring and reporting requirements impose substantial costs particularly on small business that have never been involved in similar requirement or activities, such as asset or electricity trading, before. Administrative costs, on the other hand, may be less relevant for policies that address barriers or reinforce or accelerate existing changes in behaviour or investment.

3.1.2 Regulatory costs

Costs on the regulators level occur on two levels: On a first level they are administrative costs which occur during the design and set-up phase of the policy or measure, during its implementation and during the monitoring process which includes reporting and verification. On a second, more abstract, level regulators face transaction costs.

1. Administrative costs, listed in chronological order of occurrence:
    - Design and set-up costs: costs that arise during the design and start-up phase of the given measure. These costs include costs for personnel, material costs and expenditures for research and development in order to ensure that the given policy and measure can be and is put in place. Moreover, it may also include costs relating to actual government support schemes, such as investment subsidies, grants etc.
    - Implementation costs: costs that arise to put a given policy in place. These costs include efforts to change rules and regulation, capacity building efforts and other institutional efforts (IPCC, 2007[16]). The costs that arise here are the same as in design and set-up costs.
    - Monitoring, reporting, verification costs: resources spend on enforcement and monitoring (Pizer & Kopp, 2003)[17]. The costs that arise here are the same as in design and set-up costs
2. Transaction costs: Transaction costs in general are costs that have no market price and as such are not physically paid but are incurred when trading goods

[16] IPCC. (2007). Costs and benefit concepts, including private and social cost perspectives and relationships to other decision-making frameworks. Climate Change 2007: Working Group III: Mitigation of Climate Change. Retrieved May 17, 2011, from http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch2s2-4.html.

[17] Pizer, W. A., & Kopp, R. (2003). Calculating the Cost of Environmental Regulation (p. 61).

or services (e.g. information costs, adjustment costs, idle costs etc.). In the given context they can be defined as the costs of implementing a climate mitigation policy under the prerequisite that appropriate implementation efforts have been (or are in the process of being) put in place (IPCC, 2007)[18]. Transaction costs on regulators level occur for example for research and information, for enactment or litigation on the legislature side, during the design and implementation (e.g. regulatory delay). Agencies incur several other transaction costs relating to design and implementation, monitoring and detection. A typology of transaction costs including these examples is proposed in McCann et al., 2005[19].

While administrative costs on the regulator side can be described (and further assessed ex-post) as defined and laid out in Section 10 of the Part III – Annex to the Impact Assessment Guidelines[20], the quantification of transaction costs is out of the scope of this study because identification of their complete magnitude does neither seem feasible nor beneficial. One reason for this is the uncertainty about who actually bears these costs (McCann et al., 2005)[21].

Relevance of regulatory costs at regulators level

Regulatory costs at the regulator level are relevant for all policies and measures with respect to conducting the required impact assessments as well as monitoring, reporting and verification activities. They may be considered most relevant for large and genuinely new policy programs that require high upfront administrative and transaction costs in its design, set-up and first implementation phase. Moreover, the will be more relevant for policies that are based on large R&D activities which are often subcontracted than for programs and are differentiated by actors than for policies of the command style which put out regulatory standards and bans and apply uniformly for all covered goods, products or activities.

3.1.3 Macroeconomic effects (economy-wide level)

Macroeconomic effects are important indicators of the impact a policy has on a societal level. They can be assessed as effects on costs, employment, welfare, trade, structure, allocation and distribution of resources and more. As whole-economy level effects, they account for direct effects for an industry, firms, household or sector due to the policy or

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[18] See above.

[19] Mccann, L., Colby, B., Easter, K., Kasterine, A., & Kuperan, K. (2005). Transaction cost measurement for evaluating environmental policies. Ecological Economics, 52(4), 527-542. doi: 10.1016/j.ecolecon.2004.08.002.

[20] European Commission (2009) 'Part III: Annexes to Impact Assessment Guidelines', SEC (2009) 92, 15 January 2009

[21] Mccann, L., Colby, B., Easter, K., Kasterine, A., & Kuperan, K. (2005). Transaction cost measurement for evaluating environmental policies. Ecological Economics, 52(4), 527-542. doi: 10.1016/j.ecolecon.2004.08.002.

measure **and** indirect effects relating to simultaneous adjustments and feedback within the economy and corresponding indirect costs in other industries, firms, households or sectors. They can show varying levels of detail with respect to sectoral disaggregation (whole economy, sector level according to a 2, 3 or 4 digit level of economic production (e.g. NACE)) and may be expressed in different ways. The relevance of each of these effects is discussed further below.

- Gross domestic product (GDP) effects: GDP is a measure of total national economic production. Environmental policies can lead to an increase or decrease in production, both in the sectors directly affected and in other sectors. A change in GDP captures the net (production) effect of all these simultaneous sector adjustments. A loss of GDP is a cost to the economy.
- Employment and unemployment effects: A policy or measure may lead to changes in employment in both the regulated entities and the regulators. For example additional staff may be required to exercise tasks relating to the design, set-up, implementation, monitoring or evaluation of a policy. If this policy leads to a reduction in economic output, jobs may be lost as a result and this may have further knock-on effects in other sectors. The resulting net employment effect (direct and indirect) is often an important indicator for the assessment of policies and measure, in particular in countries with high unemployment rates and unemployment support schemes.
- Structural change (winners and losers in business): Structural effects on businesses are often displayed as changes in value added (roughly GDP by sector). They refer to changes in production in sectors that are affected by the policy, either directly (e.g. complying with a new standard or regulation, investment support) or indirectly (e.g. through supply chain effects).
- Distributional effects (winners and losers in society): The distributional effects identify how different groups in society are affected. It is often measured in terms of real incomes or spending power. For example, if a policy leads to a loss of jobs in low-paid sectors, or increases fuel prices to low-income households, it could be the most vulnerable groups that are worst affected.
- Environmental effects: Climate policy may have other costs/benefits. For example, lower coal combustion reduces CO_2 emissions, but also local air pollution. It is possible to estimate the value of these effects in monetary terms, taking into account the effects on human health, and damages to buildings and crops. In Europe the ExternE series of projects[22] provides estimates of the benefits of reducing air pollution. Other environmental effects that could be covered in similar ways include damage to the local and rural environments (e.g. from power lines or renewables) and noise pollution from vehicles. However, as the

[22] See http://www.externe.info/ for details of methodologies used, including definitions and assumptions used.

costs/benefits are often particular to a local area, they are likely to require a specific economic assessment. They are not included in most standard assessment approaches but can be calculated separately.

- Other economic impacts: Other economic indicators that could be affected by climate policies include investment, government balances and international trade flows. These are included in GDP results but may be of interest to particular focus groups.
- Welfare: Measures of welfare are sometimes used to summarise some or all of the above indicators; they typically combine detailed versions of the individual elements to give a single output that can be used by policy makers.

Box 3.2 Informational Box: Welfare Measures

Welfare gains or losses can be measured as the sum of producer and consumer surplus gained or lost triggered by an environmental policy implementation: If an environmental policy for example triggers a price increase, consumer surplus is lost due to the higher price that consumers will now need to pay for an unchanged amount of a given commodity. In turn, producer surplus is lost as a consequence of consumers reducing their demand for the given good in view of the higher price.

Another way of approximating welfare changes are the concepts of compensating variation (CV) or equivalent variation (EV). The former (CV) determines the amount of money that would be necessary to make the consumers of an economy as well off after a change than before the change (e.g. before and after the implementation of an environmental policy). The latter (EV) is the amount of money that needs to be taken away at the original price to reduce the individual's welfare by the same amount as the price rise. CV and EV thus provide measures of the welfare effect for consumers in monetary terms. In general, they are similar in size and comparable to the measure of consumer surplus.

Relevance of macroeconomic effects for a given policy

In a policy analysis, the macroeconomic effects can be much more difficult to quantify than the compliance and regulatory costs described above; while those are able to focus on single entities, an evaluation of macroeconomic effects must take into account impacts on every sector in the national economy. It is therefore important to determine at an early stage in the analysis whether it is necessary to include macroeconomic effects.

GDP effects

It is easier to answer the question of when not to include GDP impacts in a policy analysis. This is usually when either economic impacts are very small (i.e. there is no impact on GDP), or when the impacts are limited to a single sector (i.e. the absolute change in output in that sector equals the absolute change in GDP). However, it should be noted that in the modern economy with integrated supply chains, it is rare to be able to view a sector in isolation. For example the nitrates directive may only apply to agriculture directly, but will also impact on chemicals firms through changes in demand, and households through changes in food prices.

GDP effects will tend to be larger when sectors that contribute a large share of economic output (i.e. services in much of Europe) are affected by the policies.

Employment and unemployment effects

The level of economic output is a key determinant of employment levels, so if a policy is expected to lead to a large change in economic output (either at the sectoral or macroeconomic level) then there is likely to be an impact on the number of jobs. However, when considering employment effects it is not just the number of jobs that are important; the types of jobs and their skills requirements are also important.

Employment effects are likely to be larger when labour-intensive sectors are affected by policy. If policies are simply diverting jobs from one activity towards another with no net impact (if workers with the right skills are available) then employment effects may be less relevant.

Climate policy is unlikely to have much impact on the supply of labour, so it can be assumed that any reduction in employment is matched by an increase in unemployment.

Structural change

All policies will lead to structural change to a certain extent, as that is their aim. In general, any policy analysis that considers GDP should be able to include an assessment of any sectoral impacts, because GDP is the sum of these impacts.

Important questions include which sectors stand to gain or lose the most and how the negative impacts could be offset. The issue of employment is also linked, for example if it is found that the jobs in the growing sectors have very different requirements to those in the declining sectors.

Distributional impacts

It may be important to consider social and distributional impacts if:

- There are large changes in employment or wages (see above)
- There are changes in the prices that households pay for products

Distributional impacts are probably less relevant if it is only businesses that are affected and there are no major employment effects.

Environmental impacts

The assessment of non-climate environmental impacts may be relevant to all policies, but particularly those that reduce fuel consumption in built-up areas.

Other economic impacts

These will be included in GDP impacts and, in general will be relevant to an analysis in the same cases that GDP impacts are.

Welfare impacts

All of the above feature as components of welfare; the advantage of the welfare indicators is that they combine this into a single number. Therefore this would be appropriate if the policy has many different impacts across a wide range of actors.

3.1.4 Summary and overview

Various measures of costs can be used to assess ex-post the efficiency of policies and measures. These costs occur on different levels of economic activity and may be quantified using different approaches (see Section 3.3 for methodologies of ex-post quantification of socio-economic costs). This chapter aimed to cluster different cost types, provide measures for their quantification, and illustrate the level of economic activity they occur on. An overview of this is shown in Table 3.2.

Table 3.2 Overview of levels where mitigation costs occur, what kind of specific costs they face and which general cost types the specific costs can be related to

Level	**Specific cost type (defined below)**	**General cost type**
Regulated entities	Investment and operating costs • Investment • Variable inputs (fuels, transport etc.) • Operation and maintenance costs • R&D costs Administrative costs • Costs for reducing barriers to implementation and information • Transaction costs • Other direct costs	direct costs
	• Production losses • Losses in revenue • Changes in prices/costs of input factors and output	indirect costs
Regulators	Administrative costs • Design, set-up • Monitoring, reporting, verification • Transaction costs • R&D costs	direct costs

Whole economy level (socio-economic costs)	• GDP effects • Employment effects • Marginal abatement costs • Structural change • Distributional impacts • Environmental impacts • Other economic impacts • Welfare losses	direct and indirect costs

While all these cost types or cost components are likely to be affected by a regulation, not all of them are equally relevant when analysing socio-economic cost effects. The decision on which cost types to analyse in more detail was discussed in detail above. It will depend on a number of factors:

- The level of economic agents that are to be considered.
- The specific policy or measure under consideration as some policies or measure may not induce a large effect on a specific cost type or component, e.g. small programs or policies only affecting a single sector or a low share of overall emissions may not result in large GDP effects, such as the F-Gas regulation.
- The resources available for the assessment, as in general the assessment of indirect effects requires information on all sectors in the economy with their respective data and more elaborated assessment tools.

Generalized and highly simplified, it can be concluded that investment and operating costs are highly relevant for all polices and measures that induce large investment activities into new equipment or retrofit of equipment. Administrative costs at the regulated entity level are deemed most relevant for small and medium sized enterprises. Regulatory costs at the regulators level seem most relevant for programs that require substantial administrative efforts both on the Commission as well as the Member States level while macroeconomic effects may be considered most relevant for policies that affect a large range of sectors or affect a sector or activity which is highly integrated in vertical supply chains. It should be noted though that these conclusions are highly simplified and need to be seen in context of the actual policy and its mechanisms that is to be assessed.

3.2 Recommendations for performing ex-post assessment of direct and indirect socio-economic costs of climate policies and measures

3.2.1 Introduction

In this section we introduce the different assessment methodologies and bring them together with the different levels of economic agents and cost types to give recommendations of preferred means of assessment and practical guidance to applying the recommendations.

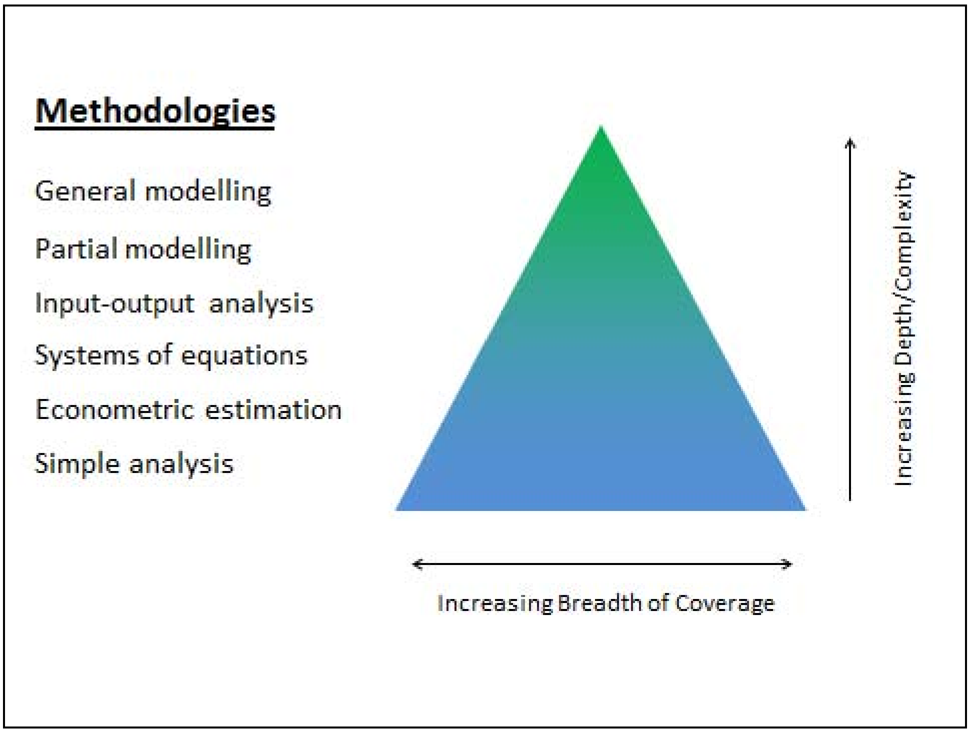
We start out with a brief introduction to the assessment approaches (a detailed overview and discussion of the assessment methodologies can be found in Section 3.3.). We then focus on linking the cost types introduced in Section 3.1 to these assessment methodologies. We give guidance with respect to the question how to estimate costs (or cost components) in practice. This includes guidance on selecting the appropriate assessment methodology to tackle a particular cost type and the data needs as well as potential gaps that could prevent a detailed and comprehensive analysis. We conclude our recommendations with a set of important tips and caveats for conducting a socio-economic cost assessment of policies and measures.

Further down, in Section 3.4, we additionally attempt to illustrate how to bring the cost types, assessment methodologies together with specific policies and measures that are considered within the scope of this project. This aims to provide illustrative practical guidance for assessing the socio-economic costs of current energy and climate policies in the European Union.

3.2.2 Brief overview of assessment approaches

There are a number of different assessment methodologies available that could be applied to estimating costs. These are characterised below:

Figure 3.2 Methodologies for cost assessment



The above illustration highlights the fact that there are often trade-offs between the breadth of coverage (across different parts of the economy) and the depth of coverage (in terms of level of detail within directly-affected parts). This is discussed further in

Section 3.2.4. The modelling options are also usually much less flexible in the way they can be applied.

It should not be assumed that a complex methodology should be preferred to alternative approaches. There are some factors that reduce substantially the attractiveness of using such an approach:

- The level of resources required to apply the methodology makes a quick (and rough) assessment impossible.
- Data requirements tend to increase in line with level of complexity (e.g. qualitative analysis does not require any hard data but models require large and complete data sets).
- If complex models are not backed up by theoretical foundations or if data is not sufficiently tested for its fit, they may appear to give false robustness to results.
- Simpler approaches are easier to understand and present to policy makers.

The different assessment methodologies are described in detail in Section 3.3, with the characteristics of different methodologies summarised in the table below.

Table 3.3 Characteristics of methodologies

	Methodology				
	Basic assessment	**Intermediate assessment**			**Modelling**
	Simple analysis	**Econometric estimation**	**Systems of equations**	**Input-output analysis**	**Partial / General modelling**
Gives direct costs	Yes	Yes	Yes	Yes	Yes
Gives indirect costs	No	No	Partially	Yes	Maybe
Degree of complexity	Low	Medium	Low to Medium	Medium	High
Data requirements	Low	Medium	Medium	Low	High
Software required	Spreadsheet or less	Econometrics package	Depends on application	Spreadsheet	Specialised
Suitable for ex-post analysis	Yes	Yes	Yes	Yes	Usually
Main advantages	Flexible, easy, low-cost	Flexible, can estimate unobservable factors	Flexible, gives some indirect costs	Gives indirect impacts	High level of detail
Main disadvantages	Information yielded is limited	Needs careful interpretation	Scope limited by the equations included	Quite rigid assumptions	High cost, limited to existing tools

3.2.3 Practical guidance for linking the cost types and components to the assessment methodologies

This section aims to provide guidance on the necessary steps and decisions to conduct an ex-post assessment of socio-economic costs of policies or measures. It provides a step by step approach including the identification of relevant cost types, selecting the appropriate assessment methodology and pointing out the data and resource needs. We conclude our recommendations with a set of important trade-offs, tips and caveats for conducting a socio-economic cost assessment of policies and measures.

In order to link the costs to the assessment methodology, the following steps should be addressed.

Table 3.4 Step by step approach for socio-economic cost assessment

Step 1 -	Determine the level at which the costs are to be assessed (see Section 3.1)
Step 2 -	Determine the type of cost to be assessed (see Section 3.1)
Step 3 -	Determine the suitable methodologies for the cost type or cost component to be assessed (see below)
Step 4 –	Assess data needs, data availability and quality (see below)
Step 5 –	Check resource requirements and availability to pursue assessment methodology
Step 6 –	Proceed with assessment - or in case of data or resource constraints - reconsider assessment methodology compromising on breadth or depth

Step 3 - Determine the suitable methodologies for the cost type or cost components to be assessed

Step 3 aims to identify the suitable methodology for each cost type or cost component. There is a fairly wide range of options available for some cost types while a more limited portfolio seems relevant for other cost types.

Table 3.5 suggests the methodological options for quantifying the different types of costs. Providing an assessment of physical compliance costs is possible with a wide range of approaches that differ – as described above – in their ability to reflect depth and breadth of results; for administrative costs only a basic approach is available (although the results of this could be fed into a model), and the linkages required for a whole-economy analysis limit the options for this type of assessment..

Table 3.5 Suitable methodologies for each cost type

Type of Cost	**Suitable Methodologies**
Regulated Entities:	
Operating and investment costs	Basic assessment Econometric assessment System of equations Partial model
Administrative costs	Basic assessment
Regulators:	
Administrative costs	Basic assessment
Whole economy:	
All costs	Input-output analysis General model

In the following sections more detailed guidance will be given on how to select a suitable methodology for assessment of a specific cost type and how in principle to proceed to estimate the cost effects for the respective methodology.

3.2.3.1 Regulated entity level:

Many policies and measures immediately induce costs for companies or business as well as households relating to the implementation of the required mitigation measures. These include investment and operating costs as well as administrative costs for compliance.

Investment and operating costs (regulated entity level)

Investment and operating costs can be assessed on various levels of detail with respect to the depth and breadth of analysis.

Qualitative assessment (Tier 1): The simplest approach is a qualitative assessment which involves a qualitative description of the potential (expected) effects on investment or operating costs due to the policy or measure including. It does not involve actual cost estimates based on data, however, it is designed to provide an estimate of the direction of change (positive, negative) and its relative size (small, medium, large). It can also give an indication on which area of technology or input factors may be affected the most and whether effects further up the supply chain may be expected.

Usually, such qualitative assessment is done by expert judgement either on a single basis or through surveys (e.g. Delphi survey). Such an assessment does not require substantial amounts of resources, but may be time-intensive if done via multi-person surveys. The interpretation of results is usually limited.

Basic assessment (Tier 1): A basic assessment approach is a simple quantitative analysis usually in "spreadsheet-modelling" style. It is based on simple relationships of variables (equations) and requires limited details of data. It can be applied to assess direct abatement costs and benefits (e.g. basic (direct) employment effects) at the operator level. Costs are estimated on the basis of a simple function, such as unit costs * quantity (e.g. ETS price * quantity purchased) or abatement costs that give the net costs in relation to the mitigated emissions. Sometimes costs per unit of reduction are considered at a particular stage of abatement, these are referred to as marginal abatement costs. They ignore the fact that costs at an earlier stage of abatement may have been lower. A basic assessment approach can only be used to quantify direct effects. There are no feedback mechanisms that allow to include the effects of induced changes in other parts of the economy or of rebound effects (e.g. a policy leading to an increase in energy efficiency results in decreased operational (energy) costs for households and with a higher available budget to be spent additional energy consuming goods may be purchased and again increase energy demand, possibly to levels higher than the original one).

The *procedure* of using a basic assessment approach is to set up a simple equation to assess the costs relating to changes in investment or operation, such as net costs = additional/reduced investment costs + additional operating costs – reduced operating costs. Data will need to be collected for both the reference scenario (without the policy or measure) and the policy scenario and the results for the two scenarios will be compared. In order to assess how a development without the policy would have looked like, an average pre-policy (growth) trend for investment or operating costs can be used. This implies that the exact starting date of the policy is known. As lag effects may be relevant, sensitivity analyses for trends with varying pre-policy time periods may support the analysis and provide a range of possible cost effects.

Collecting *data* on investment, operation and maintenance (capital investment, energy labour, spare parts, retrofits, new build etc.) costs can sometimes be difficult as these data concern company data and are often confidential. Annual company reports may provide some of the required information. Moreover, surveys and interviews may be conducted to reveal investment and operating costs (before and after the introduction of the PAM). In a more aggregate (sector based) scheme the data may also be published in official statistics or sector association publications. Changes in energy costs which are part of the operating costs may be derived based on physical energy consumption data and energy prices; a change in energy consumption can be multiplied with the respective energy price to estimate the effect on energy costs. Data on physical energy input may be obtained as suggested above, while data on energy prices may be available from the International Energy Agency (IEA) or from national utility publications (electricity) as well as national statistics.

A basic assessment approach can always be used to get a first idea of the potential cost effect of a policy or measure. It does not require much time or resources and can be done without sophisticated computational or modelling skills.

Intermediate assessment (Tier 1 to 2): An intermediate assessment approach would go beyond the basic simple assessment in allowing for multiple simultaneous relationships of variables and/or in allowing to conclude on unobservable relationships based on the information from past data. The former can be addressed by setting up a system of equations rather than a simple equation to assess the effect of changes in demand and output due to the policy or measure. A more detailed description along with an illustrative example for this approach is provided in Section 3.3.3.

A **system of equations** allows for substantially more depth (level of detail within directly-affected parts) as it accounts for interaction within input and output variables and can to a limited extent provide information on indirect costs. Naturally, such a system of equations will always depend on the actual activity/sector/policy and measure under consideration. As such, it requires careful specification of equations (functional relationships of major inputs to the activity as well as on outputs (including by-products) from the activity) and thus needs expert knowledge on the input and output processes at least in the sector directly covered by the policy or measure. The *procedure* for the approach is similar to the basic assessment approach with the exception that a more complex system of equations needs to be elaborated. Depending on the complexity, a simple spreadsheet tool may be sufficient or more sophisticated numerical software packages may be needed. In terms of *data* requirements, the same as in the basic assessment approach applies. Furthermore, additional data is needed for the variables that are considered to enter the equations. This could, for example, include information on energy prices for alternative fuels or prices for alternative products or inputs to analyse their influence on the investment and operating costs of the affected activity. Again, the data needs highly depend on the actual activity and its respective characteristics induced by the policy and measure. In terms of Tier classification this approach can be considered a Tier 2 approach in terms of depth and a Tier 1 to 2 approach in terms of breadth.

Example of a linked set of equations

An analysis of ETS costs, in terms of lost economic output, was carried out at European level for a selection of energy-intensive sectors at the NACE 4-digit level. The first stage in the process was to estimate the absolute carbon costs faced by each sector (including a proxy to take into account higher electricity costs); this was divided by turnover to get a relative cost increase which was assumed to be passed on to users. These figures were then combined with a set of price elasticities, which were estimated using econometric panel-data methods, to give an estimate of loss of output in domestic and foreign markets. Summing the two gave a total loss of output.

Apart from the econometric estimation, all the calculations were carried out in a spreadsheet and, although the calculations involved several assumptions, they provided an indication of potential loss of real economic output for each sector.

Econometric analysis: Econometric (or regression) analysis provides a similar approach which is also based on single or multiple equations but with a focus of using historical data to estimate behavioural (and unobservable) relationships that cannot be directly measured. A more detailed description along with illustrative examples can be found in Section 3.3.3. The exact specification of the regression equations varies highly by activity and sector affected by the policy or measure. In terms of *procedure*, expert knowledge and judgement is needed to set-up such a specification, conduct the estimation and interpret the results. The actual estimation and interpretation requires expertise in econometric and statistical analysis (theory and practice) including the testing of statistical parameters to assure quality and robustness of the results. Software packages are available for purchase to support the econometric analysis. *Data* requirements for econometric analysis go far beyond the requirements described for the basic assessment approach as time series data of sufficient lengths for each variable is needed in order to conduct the analysis and ensure quality. In terms of Tier classification, this approach can be considered a Tier 2 approach in terms of depth and a Tier 1 approach in terms of breadth.

Modelling approach: The most appropriate modelling approach to assess direct investment and operation costs to the regulated entity is a **partial model**. As discussed in detail in Section 3.3.4, partial models are able to include and analyse detailed information on a particular sector both in terms of monetary and physical units, thus reflecting engineering relationships and constraints. They provide a well suited approach for the assessment of direct compliance costs to the regulated entity (agents, business and sectors). However, they do not take into account potential feedback or indirect effects on or from other sectors. In cases where impacts on other sectors are likely, linking of individual models may present a suitable complement[23].

Procedure: In order to conduct an assessment using a partial model access to an appropriate model as well as in-depth expertise with the particular models is required. In some cases models are open access and can be adjusted to the question under consideration (e.g. GEMIS, http://www.gemis.de/). In most cases, however, such models would need to be purchased and individually applied. Alternatively, specific model runs, and the analysis thereof, can be contracted out to respective organizations.

Data requirements are usually very high because detailed information on specific sectors and technologies is needed, sometimes reflecting several hundred different technology options. Generally, though, most of these data are stored within the model framework and only need to be supplemented by data relating to the policy or counterfactual scenario under consideration.

In summary, partial models present a well suited Tier 3 level approach in terms of depths and a lower Tier level in terms of breadth, though for the assessment of direct

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[23] Such an approach has successfully been applied in Task 3, testing of the EU ETS, by linking an electricity sector model (PowerFlex) with a macroeconometric model (E3ME).

compliance costs to the regulated entity a broad range of breadth does not seem essential.

Examples and good practices

A number of examples exist for the ex-post estimation of compliance costs at the regulated entity level. The presentation of compliance costs generally differs by the policy and measure scrutinized, for example policies relating to Nitrates or Agriculture report costs in € per hectare, per Nitrogen or per litre of milk produced. This reflects the fact that some policies do not primarily aim at reducing greenhouse gases and are thus difficult to compare in terms of cost-effectiveness or efficiency. For polices and measures primarily aiming at reducing specific energy demand or non-energy greenhouse gases, compliance costs are usually reported in terms of € per t of CO_2eq mitigated.

Numerous examples for analyses of (marginal) abatement costs can be found in the literature (e.g. McKinsey (2007)[24]; or as an online tool for Austria http://www.co2-vermeidung.at/?page_id=204). These studies usually take a forward looking approach and analyse and rank abatement costs by implementation measures. A similar approach can be used in ex-post assessments by looking back at which measures were actually implemented in the context of a specific policy and assessing the additional costs of the implemented measures in comparison to the counterfactual scenario[25]. In case studies, IVM (2006, ibid.) quantify the costs to business for six policies including the Nitrates Directive and the IPPC Directive. They focus on comparing the results to ex-ante studies and find that the costs tend to be overestimated in ex-ante settings. However, they point out that a comparison suffers from significant methodological barriers. The ex-post estimates were derived for two countries (Denmark, Netherlands) for the Nitrates Directive depending on data and resources availability.

A good example of how a partial modelling approach can be applied for an ex-post assessment is provided in the previous study (AEA, 2009)[26]. The PRIMES model that is primarily used for ex-ante assessment was modified and recalibrated for an ex-post assessment of selected EU policies and measures (including the ACEA agreement, the Biofuels Directive and the RES-E Directive). In the context of the previous study, the model was not used to arrive at cost estimates though.

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[24] Here for Germany, http://www.mckinsey.de/downloads/presse/2007/070925_Kosten_und_Potenziale_der_Vermeidung_von_Treibhausgasemissionen_in_Deutschland.pdf

[25] For a discussion of the counterfactual scenario, please see Section 3.3.1, IVM (2006) Ex-post estimates of costs to business of EU environmental legislation, Report under ENV.G.1/FRA/2004/0081, AEA et al. (2007) Assessing how the costs and benefits of environmental policy change over time,

[26] See AEA et al. (2009): Summary of the results of the decomposition analysis performed using the PRIMES model, http://ec.europa.eu/clima/policies/g-gas/studies_en.htm

3.2.3.2 Regulator level: Administrative costs

The European Commission provides a standardized method for estimating administrative costs called the EU Standard Cost Model. The approach is summarized on the Commission website[27] and is described in Annex 10 of the Impact Assessment guidelines[28].

In brief the EU Standard Cost Model is a basic calculation that consists of multiplying the expected time commitment of the administrative burden, by the average labour costs of those involved, and then summing across the affected entities. The Impact Assessment guidelines stress the proportionality of following this approach; i.e. if the administrative costs are small then a simple calculation is sufficient.

3.2.3.3 Whole economy level: Macroeconomic effects

If the policy is likely to have a macroeconomic impact (i.e. effects on sectors beyond those directly affected) then a comprehensive assessment will need to cover whole-economy effects.

As the methodologies that estimate macroeconomic effects require a set of data that covers the whole economy, they are rather limited in number and are quite formal in approach. The two main options, described below, are input-output analysis and general modelling. The choice of approach in part depends on the context but also the level of resources available; the Tier 3 modelling approach is likely to be much more intensive than a less complex input-output analysis.

Input-Output analysis (Tier 2)

Input-output (IO) analysis is described in more detail in Section 3.3.3, including a simple example. It is closely linked to the calculation of multiplier effects and essentially translates impacts in one sector into impacts at the macroeconomic level. IO analysis can be carried out relatively easily in a spreadsheet package with little specific expertise required.

The main data input is an input-output table, which provides a statistical interpretation of supply chains and inter-industry linkages. IO tables are now available for nearly all Member States, either published by Eurostat[29] or national statistical offices. It is preferable to use an IO table for as recent a year as possible to ensure that the figures used are up to date.

Before carrying out an IO analysis, it is necessary to determine the loss of output in the *sector th*at is directly affected (see above), and IO analysis can be applied to any policy

[27] http://ec.europa.eu/governance/better_regulation/admin_costs_en.htm

[28] http://ec.europa.eu/governance/impact/commission_guidelines/commission_guidelines_en.htm

[29] http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/introduction

type for which this direct loss of output may be estimated. After this the calculation is relatively straight forward.

The limitations of the approach are also described in Section 3.3.3 and relate to the fixed structure and level of sectoral detail (NACE 2-digit level). The first of these limitations can be addressed by applying a modelling approach (see below) but there is no standard approach to deal with the latter, given available data. There are also limitations to the costs that input-output analysis can cover; a standard IO analysis will give impacts for GDP and structural effects (and could be extended to cover employment), but it is not able to cover the other cost types in Section 3.1.3.

General modelling (Tier 3)

General modelling is a term that is used to describe modelling approaches that cover the whole economy (as opposed to partial models that cover a specific sector). This group of models includes CGE (Computable General Equilibrium) and macro-econometric approaches.

Typically these models are based around an input-output table, as described above, but also capture more complex and behavioural relationships (for example, models include measures of and responses to price, which are not present in input-output analysis).

The main drawback to the approach is the high level of resources available, in terms of time required, costs and data. Model-based analyses will in most cases require external contracting to organisations that have specific capacity. Before undertaking a model-based analysis it is thus important to ensure that there will be noticeable impacts at the macroeconomic level.

The most common types of models are described in Section 3.3.4. The IA Tools website[30] also provides information about model-based approaches and how they can be applied in policy analysis. Although less specialised than partial models, even general models can have different specialist areas, such as energy or transport, which may be of relevance to a particular policy area.

Although the modelling approach as a whole can cover all of the cost types outlined in Section 3.1.3, specific models may only include subsets of these costs so it is important to be clear about requirements.

Combining methodologies

Combining methodologies gives an option for providing a simultaneous assessment of these different types of costs. For example, if a quantitative assessment of administrative costs was used to provide inputs to a combined partial/general modelling system, it would be possible to address all the cost types.

[30] http://iatools.jrc.ec.europa.eu/bin/view/IQTool/WebHome.html

There are therefore quite strong potential benefits of combining different approaches. However, there are also costs involved in this, as the resource requirements are roughly the sum of the two or more individual approaches, plus extra costs for forming the linkages. Particularly when linking models these costs may be considerable.

Example and good practices

Assessment of the CHP Directive: The assessment of the economic costs/benefits of CHP combined a Tier 2 level analysis of direct costs with a Tier 3 macroeconomic model-based assessment of whole-economy costs/benefits.

The first stage of the analysis was to estimate the potential capacity (in energy terms) for CHP in each Member State based on available literature, and the costs associated with installing this capacity. These two factors were then put into the macro-econometric E3ME model with an additional assumption that the available CHP replaced the same amount of heating fuels in houses and a second assumption about how the investment is funded (e.g. through public subsidy or by energy companies). The modelling determines the macroeconomic impacts of the extra investment and reductions in fuel consumption, so the combined outputs of the analysis give both a detailed assessment of direct CHP effects and an indication of the wider economic impacts (Impact Assessment on the Energy Efficiency Directive, http://ec.europa.eu/energy/efficiency/eed/eed_en.htm).

Assessment of EU ETS Directive: Within the current study, we modify a bottom-up partial model for an ex-post application and link it to a macro-econometric model to assess the environmental and socio-economic effects of the EU ETS Directive. The modified and linked versions were tested for several Member States, details on the methodology and results are presented in Section 5.1

3.2.4 Conclusions

Overview

When conducting an assessment it is advisable to start with the following questions:

- What types of costs are covered?
- What is the policy area?

Then there is the issue of level of detail required:

- Degree of accuracy in results
- Level of sectoral detail (and possibly geographical detail)

This must in turn be matched against the available resources.

A step by step approach for socio-economic cost assessment was laid out in Section 3.2.3. Following these steps can help taking the necessary decision on the appropriate cost type and methodology in light of available data and resources to conduct an ex-post quantification of socio-economic costs.

It is a difficult task to summarise this into a general "one size fits all" approach to carrying out an assessment and it must be stressed that even setting up such an assessment could be a major task. The issue of data availability is key but will vary between each of the policy areas (and possibly by country as well) and must be considered on a case-by-case basis.

Trade-offs and the tiers of methodologies

The situation is further complicated by the fact that there are often trade-offs between the factors above. For example, an assessment approach that provides the greatest level of detail in a single sector is more likely to neglect other sectors. It is not possible to categorise methodologies into the simple Tier 1, 2 or 3 groups as has been done previously[31].

These trade-offs can essentially be reduced to three types[32]:

- Depth of analysis
- Breadth of analysis
- Resources required

The depth of analysis refers to the level of detail and complexity of the direct costs within a single sector. The breadth refers to the coverage of different sectors and geographical regions (which could mean more countries or a greater level of spatial detail).

It can be concluded that as the breadth increases, the depth of the analysis tends to decrease, as the assessment approach applies a 'lowest common denominator' approach, so that it can apply the same methodology to all regions/sectors.

The resources required include data and the time to carry out (and document) the assessment, but also the ease with which results can be interpreted. The level of resources required tends to increase in line with both the depth and the breadth of the analysis. Linking different assessment methodologies would be an approach that aims to maximise both depth and breadth, but comes with substantial resource requirements attached (see Section 3.3.5).

We thus propose to define the assessment methodologies in terms of these three categories. Within these three categories there are three different tier levels, as previously. However, as all the methodologies can be applied at Member State level (if the data are available) this is not considered when allocating a tier level to a methodology.

Table 3.6 summarises the assessment methodologies, according to this classification. Clearly an element of judgment is involved in applying the classification and it is of

[31] AEA, Ecofys and Fraunhofer ISI (2009): Quantification of the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019)

[32] The detailed review of approaches in Section 3.3 highlights some more of the trade-offs between these dimensions.

course dependent on the specific application or model involved, but this summary is intended to provide a general guide.

Table 3.6 How the methodologies fit into the tiers

	Depth	Breadth	Resources
Basic assessment	Tier 1	Tier 1	Low
Econometric analysis	Tier 2	Tier 1	Medium
System of equations	Tier 2	Tier 1/2	Medium
Input-output analysis	Tier 1	Tier 3	Medium
Partial model	Tier 3	Tier 2	High
General model	Tier 2	Tier 3	High
Linked model	Tier 3	Tier 3	Very high

Conclusions drawn in the literature

These conclusions close with a set of findings and recommendations from previous ex-post evaluations or meta-studies analysing such ex-post evaluations for various policies, including climate change policies. Within the ADAM project[33], a meta-analysis of evaluation studies within Europe (focus on Finland, Germany, Poland, Portugal, the UK and the EU) revealed that evaluations most often address the energy, business, industry and transport sectors. According to the analysis within the ADAM project, the evaluation community in the UK is most sophisticated. The UK has developed a 'standardised' system for climate policy evaluation, based on common guidance documents produced by an 'inter-departmental analysts group' (IAG). "*These guidance documents served as a template to structure the policy analysis that informed the 2006 Climate Change Programme Review (DEFRA 2006)[34]. An important objective of this guidance was to allow for consistent ranking of policies according to their cost-effectiveness, and the guidance is particularly specific about which impacts should be monetised. A system of peer review is designed to ensure that the guidance is observed*."

On the EU level, the ex-post evaluation of environmental policy performance in general remains a relatively recent and limited phenomenon (Görlach et al., 2005; AEA et al., 2009)[35]. While several environmental Directives require the regular evaluation of per-

[33] IVM (2008). Adaptation and Mitigation Strategies: Supporting European Climate Policy. D-P2.4 An appraisal of EU climate policies, 3 Paper: Climate change policy evaluation across Europe.

[34] DEFRA (2006) Greenhouse Gas Policy Evaluation and Appraisal in Government Departments, for Environment, Food and Rural Affairs, London.

[35] Görlach et al. (2005). Cost-effectiveness of environmental policies - an inventory of applied ex-post evaluation studies with a focus on methodologies, guidelines and good practice

formance, few of these explicitly require an assessment of their cost-effectiveness. At the time of their study, only four environmental Directives explicitly mandated that cost-effectiveness be assessed ex-post, two of which are directly related to climate change (Directives 2001/77 on renewable energy, 2003/30 on biofuels and 2004/8 on cogeneration)

Continuous and consistent monitoring from the outset of a new policy on is considered key to ex-post evaluation both in terms of tracking actual implementation patterns and data. At best, ex-ante impact assessments would already provide research questions for an ex-post assessment and identify the data required for it.

More attention has been paid to such monitoring and evaluation practices, as for example in the project "Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services (EMEEES)" within the Intelligent Energy for Europe Programme (see http://www.evaluate-energy-savings.eu/) and the predecessor of the current study.

3.3 Overview of different approaches to quantitative analysis

3.3.1 Introduction

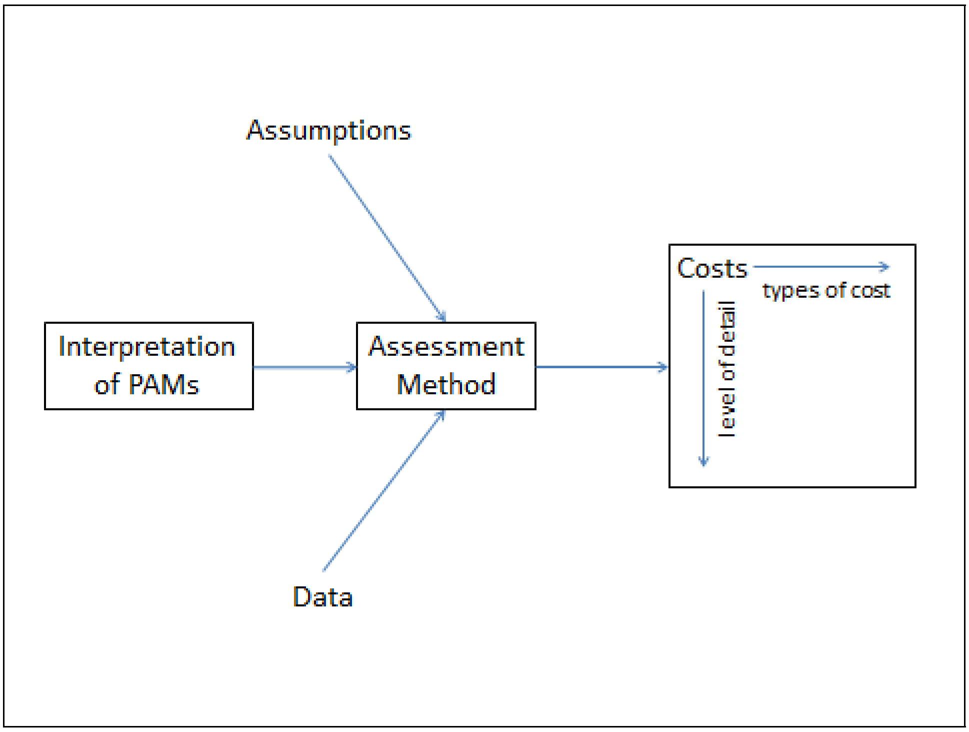
In this section we will give an overview of the possible methods used for quantitative assessment of the costs of the various policies and measures. In conducting this review, there are a number of dimensions that must be considered, for example:

- Policy area
- Type of cost assessed
- Methodological complexity of the approach
- Level of sectoral detail in the approach
- Level of geographical coverage
- Appropriate timeframe of use (e.g. long or short-term)

Figure 3.3 provides a very broad overview of the inputs and outputs from the assessment process.

Specific Agreement No 3475/B2004.EEA. http://ecologic.eu/projekte/3ea/panacea/inc/downloads/1731_Cost-effectiveness_conclusions.pdf; AEA, Ecofys and Fraunhofer ISI (2009): Quantification of the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019)

Figure 3.3 Overview of the assessment process



This review will aim to cover all of the main methodologies available, from the very simple to the highly complex. The sources that we draw upon for the intermediate and advanced methodologies include the IA Tools model inventory[36], the UNFCCC's inventory[37] and specific publications by the EU and operators of computer models. In addition Pollitt et al (2010)[38] provides a description of the main limitations of existing economic models in assessing environmental costs. Although, due to their nature, more of the available space is devoted to describing the more complex approaches, this is not on its own intended to be interpreted as a clear recommendation.

Although the aim of this review is to be as broad as possible, the large number of dimensions means that it is not possible to cover every single methodology; the aim is to cover the ones that are most commonly applied (or could be applied) and are most relevant to the project as a whole.

In this section we also depart from the standard Tier 1/2/3 definitions that have previously been used. Although this is a useful approach for categorising assessment methodologies, it is recognised that the different dimensions, and the likely trade-offs be-

[36] See http://iatools.jrc.ec.europa.eu/

[37] See http://unfccc.int/cooperation_support/response_measures/items/5112.php

[38] 'A scoping study on the macroeconomic view of sustainability', see http://ec.europa.eu/environment/enveco/studies_modelling/pdf/sustainability_macroeconomic.pdf

tween the levels of detail in these dimensions, means that a more flexible approach must be adopted.

The review also aims to be as broad as possible in its coverage of the types of costs outlined in Section 3.1. However, it should be noted that costs which either cannot be defined or cannot be measured are generally excluded, as by definition they cannot be incorporated into either ad-hoc assessment or formal modelling techniques. This is not intended to give the impression that these costs are not important or should be ignored from a comprehensive (i.e. qualitative and quantitative) assessment.

In addition to the methodological aspects, the review will consider the data required for the assessment of policies and measures, as this is clearly a key constraint on the application of methodologies. This will cover the availability of data in the policy areas, its quality and usability as well as the gaps that remain to be filled to conduct a thorough assessment.

A simple way of measuring costs would be to compare differences over time, i.e. before and after the introduction of a policy. However, the changes in costs may be due to other factors. For example, energy costs for ETS sectors increased after the introduction of the ETS but this was only partly due to the ETS. The approach to do this is usually to set up and compare a baseline and scenarios, as described in Box 3.3.

Box 3.3 Baseline and Scenarios

Baseline and Scenarios

One common feature of all the assessment methodologies is the way in which the estimates of costs are derived. In each case a baseline (what actually happened) and counterfactual scenario (what would have happened had the policy not been implemented) are set up. The costs are then estimated as the relative or absolute difference between these two outcomes. This approach attempts to isolate the costs that result from policy implementation from any other costs, for example those due to changes in global energy prices or other policy.

Determining the counterfactual can be difficult in some cases, in particular if other policy measures target the same sectors or entities or if policies interact or interdepend. Moreover, the implementation of policies and measures may differ by Member States. All the approaches described below aim to identify the costs and benefits of climate policy and fully separate these costs from other economic costs and allow for Member State specific implementation.

In some cases it may help to compare the counterfactual of the ex-post assessment to the business-as-usual scenario from ex-ante analyses that are part of the impact assessment before a policy or measures comes into place. Though a number of reasons exist why ex-ante and ex-post cost assessments differ (e.g. uncertainty with respect to overall economic development and other key parameters, innovation of new and unanticipated technology or methods, more detailed information ex-post on costs and prices, differences in planned, adopted and implemented policies, time lags in implementing the policy)[39], it may give an indication of the possible development without the policy.

3.3.2 Basic assessment approaches

The basic assessment approaches described in this section are in general on a par with the Tier 1 and possibly Tier 2 methodologies used previously. They should not require computer software more advanced than a spreadsheet. They may be appropriate for estimating direct compliance or administration costs (where it is difficult to apply more sophisticated approaches) but are unlikely to give an insight into indirect costs. For example, in assessing the costs of the EU ETS, they may be able to give the costs of compliance to a particular industry, but not to national or European GDP.

The essential inputs required for carrying out such an assessment are measures of unit costs and the quantities involved. Following the example above, the cost of ETS compliance at any given time could be estimated as:

*Cost of ETS allowances = Number of ETS allowances purchased * ETS price*

The EU standard cost model[40] for administrative costs follows a similar approach.

The example in the equation highlights some of the key advantages of using such an approach:

- It is easy to make the calculation
- It is easy to interpret the results
- It is very flexible, e.g. it could be applied at firm level, sectoral level or national level[41]
- The data requirements are limited
- The method is suitable for ex-post analysis

The example above could easily be extended, e.g. to take into account allocated allowances; it could be extended almost indefinitely to meet the user's requirements (see the description of systems of equations in the next section).

However, some caution must be required when using simplistic approaches for detailed analysis as key feedback mechanisms are missing. While the example above may provide the cost of ETS allowances, this should not be interpreted as the loss in firms'

[39] For a more detailed discussion on the differences of ex-ante and ex-post assessments, please see: IVM (2006). Ex-post estimates of costs to business of EU environmental legislation, Amsterdam or AEA (2007). Assessing how costs and benefits of environmental policy change over time, report to the European Commission Ref. ENV.G.1/ETU/2006/0107r.

[40] European Commission (2009) 'Impact Assessment Guidelines', SEC(2009) 92, 15 January 2009.

[41] In economic terms described as the micro, meso and macro levels.

profits because other factors in this calculation will also change (e.g. if the firm passes on costs its sales may fall).

The flexibility of these types of assessment makes them suitable for carrying out preliminary scoping analyses. If a simple analysis indicates very low costs it is unlikely that a more complex approach will yield different results and may not be necessary.

Box 3.4 Marginal abatement cost curves

MAC curves

Another well-known example of this type of analysis is provided by Marginal Abatement Cost (MAC) Curves, as produced by McKinsey & Company among others. These exemplify the benefits of such an approach very well; although complex analysis underlies the findings, the results for each policy are simplified to include only a cost and a potential reduction in emissions. Ease of interpretation has been the major factor in the widespread adoption of the curves as a tool to aid policy makers, despite their obvious limitations. Although a misunderstanding of these limitations and the underlying assumptions means that false conclusions are often drawn from MAC curves, the methodology itself provides a powerful tool for policy makers in assessing short-term policy costs.

Top-down MAC curves

Top-downMAC curves exemplify the relationship between mitigation costs to the actual mitigation (e.g. Euro/ton CO_2 mitigated). Top-down MAC curves are produced by macroeconomic models with the results presented in a simplified form (as for the curves described above). The difference in top-down MAC curves is that they measure costs at the whole economy level rather than individual users. They indicate the social costs of the last unit of mitigation (see for example (Klepper & Peterson, 2004)). They correspond to the shadow price of implementing a policy measure and are often referred to as the implicit environmental tax associated with the policy.

Klepper, G., & Peterson, S. (2004). Marginal Abatement Cost Curves in General Equilibrium: The Influence of World Energy Prices.

In summary, it is important not to neglect the role that this basic type of assessment may play; it is not necessary to always apply a complex macroeconomic model to estimate cost impacts. Key advantages of this type of approach include its flexibility and its ease of use and interpretation. However, at the same time it is important to recognise the limitations of these approaches, both when carrying out an assessment and when drawing inference from the results.

The characteristics of this type of assessment make it suitable for carrying out preliminary analyses to see if it is worthwhile committing the resources for applying a more complex methodology.

Summary of key characteristics: Basic assessment methodologies

Gives direct costs: Yes

Gives indirect costs: No

Degree of complexity: Low

Data requirements: Low

Software required: Spreadsheet or less

Suitable for ex-post analysis: Yes

Main advantages: Flexible, easy, low-cost

Main disadvantages: Information yielded is limited

3.3.3 Intermediate assessment approaches

The category of intermediate assessment approaches also covers a broad range of approaches; the definition we use is somewhat arbitrary but the methodologies fall into two broad groups:

- Those that use the available data to interpret unobservable relationships
- Those that consider more than one relationship simultaneously

The data requirements for these approaches are more onerous than those in the previous section but still much less than the modelling approaches discussed in Sections 3.3.3. These methodologies are thus also generally quite flexible and, although they are probably beyond the scope of spreadsheet analysis, do not require huge amounts of software expertise.

The following paragraphs describe three examples of methodologies that can be used to estimate policy costs.

3.3.3.1 Econometric analysis

Econometric (or regression) analysis is a statistical method for using historical data to estimate behavioural (and unobservable) relationships that cannot be directly measured. It has a strong empirical basis. The techniques involved themselves form the parameters for many of the more complex modelling methodologies (see next section) but can also be applied on their own.

Building on the example in the previous section, this approach could be used to estimate the increase in price for a particular product, as a result of the ETS. It could also be used to estimate the reduction in sales that result from this increase in prices.

Econometric equations are used to estimate elasticities (in the examples the increase in price from an increase in costs, or the reduction in demand from an increase in price), usually in percentage terms. The inputs are data sets which combine cases with and without the changes, so that the differences can be analysed. These differences can be either over time (e.g. before and after introduction of the ETS), over sector (e.g.

those inside and outside ETS coverage), or in different geographical areas (e.g. inside and outside Europe).

Basic econometric estimation can be carried out using a number of software packages, although some expertise is required in defining the equations used (to prevent bias in the results). The approach is subject to criticism and it is important to recognise some of the limitations of the approach; these include dependence on the accuracy of input data and the assumption that historical relationships can be used to estimate policy changes (see Box). Although there are some alternative approaches available to estimate unobservable relationships, including surveys and interviews, or real-life experiments (see Swann (2007)[42] for some further examples), these have their own limitations and are required to generate their own data, requiring quite a large investment. Econometric analysis thus can be used to draw its own conclusions but would ideally fit inside a more comprehensive cost assessment.

Box 3.5 Lucas Critique

Lucas Critique

The Lucas Critique was published by economist Robert Lucas (1976) in response to the growing use of econometric methods in policy assessment. His argument was that it is not appropriate to use estimates of behaviour in one policy situation to assess impacts in another (the famous example is that since no one has ever escaped from Fort Knox there is no need to guard it). This argument has subsequently been broadened to suggest that estimates of behaviour based on past data should not be used for analysis in a different time period.

Although the extension of the argument is not so relevant for ex-post analysis, the basic critique could apply if the equation is unable to isolate policy effects. This should be considered in econometric assessment, particularly of large-scale change, but the lack of an alternative approach to quantifying estimates remains an issue.

Source: Lucas, R (1976), "Econometric Policy Evaluation: A Critique", in Brunner, K.; Meltzer, A., The Phillips Curve and Labor Markets, Carnegie-Rochester Conference Series on Public Policy, 1, New York: American Elsevier, pp. 19–46, ISBN 0444110070

Summary of key characteristics: Econometric estimation

Gives direct costs: Yes

Gives indirect costs: No

[42] Swann (2006) 'Putting Econometrics in its Place: A new direction in applied economics', Edward Elgar, Cheltenham.

Degree of complexity: Medium

Data requirements: Medium

Software required: Econometrics package

Suitable for ex-post analysis: Yes

Main advantages: Flexible, can estimate unobservable factors

Main disadvantages: Needs careful interpretation

3.3.3.2 Systems of equations

Another way of building on the basic assessment approaches described in the previous section is to combine two or more equations. We describe this as a 'system', although this can be used to describe approaches ranging from the relatively simplistic (e.g. combining two basic relationships) to something resembling a fully-specified modelling approach (as described in the following section). The approach has two defining characteristics:

- By combining two or more relationships it can estimate indirect costs
- It is flexible and can be designed and applied on an ad-hoc basis rather than providing the fixed structure of a formal model.

The software requirements are dependent on the type of methodology used. Two examples of systems with varying degrees of complexity are given below.

Following the previous example of the ETS, it would be possible to estimate the costs to energy suppliers of including a manufacturing sector in the trading scheme (e.g. steel). This could include the following equations:

- Energy demand by steel sector = Output of steel sector * Energy used per unit of production
- Output of steel sector = F (Price of steel)
- Energy used per unit of production = F (Price of energy)

The inputs to this system would be the prices of energy and steel, with and without the direct costs of ETS compliance. The relationships between prices and quantities used are not explicitly defined here but could be estimated using econometric equations (as described above). The output is the costs to the energy sector, which is the reduction in energy demand multiplied by the cost of energy (without ETS costs).

The second example considers the factors of production other than energy. The final equation above (with the same left-hand side variable) could be extended to show:

- EUPUoP = F (Price of capital, Price of labour, Price of energy, Prices of materials)

Three similar equations could be set up for capital, labour and material inputs per unit of production; these can then be solved simultaneously.

This representation of production is in fact a standard one, usually with fixed substitution effects between the factors of production (so that parameters can be estimated). It is referred to as the CES (constant elasticity of supply) production function and is included in many of the models described in the following section. However, it could also be applied in a separate analysis, independent of a large-scale model.

Summary of key characteristics: Systems of equations

Gives direct costs: Yes

Gives indirect costs: Partially

Degree of complexity: Low to Medium

Data requirements: Medium

Software required: Depends on application

Suitable for ex-post analysis: Yes

Main advantages: Flexible, gives some indirect costs

Main disadvantages: Scope limited by the equations included

3.3.3.3 Input-output analysis

A specific example of a system of equations is input-output analysis. This is based on an input-output table which shows the purchases between different sectors of the economy, often referred to as the 'structure' of the economy. An example is given in Table 3.7.

Table 3.7 Simplified example of input-output table

Purchases, billions of euros

	Agriculture	Manu.	Services
Agricultural goods	20	40	10
Manufactured goods	10	80	20
Services	10	20	30
Value Added	60	60	40
Output	100	200	100

Coefficients, inputs per unit of output

	Agriculture	Manu.	Services
Agricultural goods	0.2	0.2	0.1
Manufactured goods	0.1	0.4	0.2
Services	0.1	0.1	0.3

In this example three sectors are defined, and the two tables show the flows of money between sectors (from the input products in the row to the industry outputs in the column, e.g. manufacturing buys 40 units of agricultural goods) and the same information converted to coefficients (obtained by dividing by industry output). The coefficients show the units of input required to produce one unit of outputs (e.g. manufacturing uses 0.2 units of agricultural goods to produce one unit of output).

Input-output tables are available at NACE 2-digit levels (i.e. around 60 sectors) for most EU Member States from Eurostat, although usually only for a single year (often 2005). Almost all of the models referred to in the next section incorporate input-output tables

The main benefit of using input-output analysis is that it gives an assessment of indirect costs. For example, following the linkages in Table 3.7., if production in the manufacturing sector falls by 100 units, then its suppliers will also see production fall, by 20 in the case of agriculture and 10 in the case of services, plus a further 40 in the manufacturing sector itself. These sectors will in turn require less inputs so their suppliers will also lose out, and so on, creating a multiplier effect. The total value of lost output, the sum of direct and indirect impacts, can be derived quite easily by performing a relatively simple matrix calculation.

The simplicity of the approach also provides its key constraints; the structure is quite inflexible beyond its basic application. Fixed production functions are implicitly assumed with no economies of scale or substitution effects[43]; this assumes, for example, that the share of energy in total production is fixed. It is also assumed that input prices remain unchanged, which often contradicts the assumptions for looking at cost impacts. In summary, input-output analysis is a tool for understanding linkages between different parts of the economy, rather than a methodology that should be readily applied for scenario analysis. As with the basic approaches described in the previous section, it could be used as the first stage of a more comprehensive assessment.

Summary of key characteristics: Input-output analysis

Gives direct costs: Yes

Gives indirect costs: Yes

Degree of complexity: Medium

Data requirements: Low

Software required: Spreadsheet

Suitable for ex-post analysis: Yes

[43] This could be considered a specific example of CES production function with the rates of substitution fixed at zero.

Main advantages: Gives indirect impacts

Main disadvantages: Quite rigid assumptions

3.3.4 Modelling approaches

3.3.4.1 Introduction

This section provides an overview of the modelling approaches that are available to estimate costs. The various approaches are split into three sets of groups:

- Partial and general models
- Top-down (economic) and bottom-up (engineering) models
- Equilibrium and non-equilibrium models

These distinctions are discussed below. However, first we discuss some characteristics that are common to all the modelling approaches.

A model provides a fixed framework in which to carry out an assessment of costs. Constructing such a framework is a highly resource-intensive exercise, usually measured in months rather than weeks. The framework is likely to be pre-existing rather than constructed for a specific assessment.

Some of the main advantages and disadvantages stem from this. If a model has been applied previously the structure will have been verified and the assumptions will be better understood. The input data may also have been previously verified as accurate. The repeated use of the same model may allow for a comparison between sets of results.

However, the fixed structure of a model also underlies a lack of flexibility in the approaches. For example, it is often difficult to change the sectors defined in a model, leading to a ‘take it or leave it’ situation. The same is true of geographical coverage, as not all models define all 27 EU Member States individually.

Although models do not necessarily need to be complex, most of the ones that are relevant to estimating the costs of climate policy are. This means that quantitative modelling is usually intensive in its use of resources and the data requirements are also high. Models typically use either a specialised software platform, such as GAMS, or are written in a native programming language. In either case a degree of programming expertise is required. Finally, it should be noted, that despite the high level of detail involved, most models represent agglomerations of the basic and intermediate methodologies described in previous sections, and in many cases are subject to the same limitations.

Finally it should be noted that models are usually used for ex-ante analysis, assessing the future impacts of changes in policy. Although there is no theoretical reason why the modelling approaches described below should not be used for ex-post assessment, specific tools may not be set up to do this.

Summary of key characteristics: Modelling

Gives direct costs: Yes

Gives indirect costs: Maybe

Degree of complexity: High

Data requirements: High

Software required: Specialised

Suitable for ex-post analysis: Usually

Main advantages: High level of detail

Main disadvantages: High cost, limited to existing tools

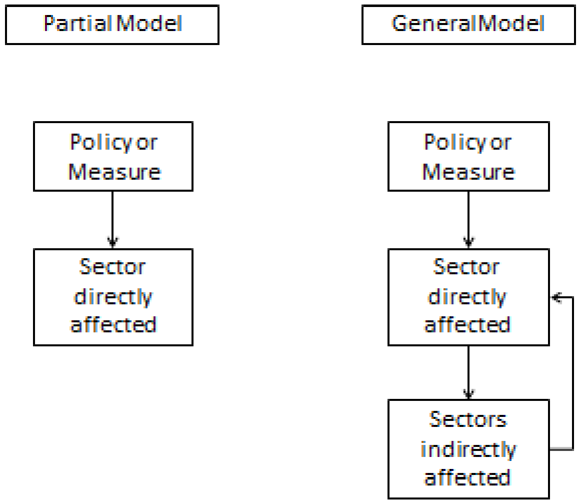
3.3.4.2 Partial and general models

The difference between partial[44] and general models is in their coverage of the economy; partial models focus on a particular sector, while general models include all the sectors in the economy (as defined by the National Accounts, see Eurostat, 1996[45]). This distinction is particularly important when considering indirect costs, as partial models will usually not be able to assess these. Furthermore, these feedbacks can also affect the original sector (see Figure 3.4). For example, if the automotive sector sells less vehicles, it will require less metal, but then the metals sector will also have less demand for vehicles; a partial model of the automotive sector would miss this feedback, while a general model would automatically capture it.

[44] Partial models are also often referred to as 'partial equilibrium' models, although they do not necessarily need to be equilibrium models. In IA Tools they are referred to as 'sectoral' models.

[45] Eurostat (1996) 'European System of Accounts, ESA 1995', Eurostat, Luxembourg.

Figure 3.4 Partial and general models



It is, however, important to note the considerable advantages offered by partial models. General models usually have to offer the same level of detail for all the sectors they include but partial models are able to use more detailed data relevant to a particular sector, including data measured in physical, rather than monetary, units. For example, passenger kilometres travelled is a good way of measuring the demand for transport, but is not relevant to the retail sector.

The relationships built into a partial model are also able to incorporate factors specific to that sector, including physical engineering relationships, as described below. Finally the model operator often has specialised expertise in this area, rather than standard economic training.

The most common sectors in which partial models exist are transport, energy and agriculture. Some examples of such models are shown below; they are described further in IA Tools:

Agriculture: CAPRI

Energy: PRIMES, POLES

Transport: TRANS-TOOLS, TREMOVE

In summary, partial models are appropriate tools to use when making a very detailed assessment of an individual sector where there is unlikely to be much impact on other sectors (or when only considering direct compliance costs to the regulated sector). General models are more appropriate when a lower level of detail within an individual sector is required. There is thus a trade-off between the direct and indirect level of detail, although this in some cases this can be addressed by linking individual models, as discussed in Section 3.3.5.

3.3.4.3 Bottom-up engineering models

Bottom-up engineering models are specific examples of partial models that are able to take into account the characteristics and technologies of a particular sector. They place an emphasis on physical data and this must be available for an ex-post assessment to be carried out.

Like other partial models they usually take demand as an exogenous input and then consider the different ways in which this demand can be met.

A good example is the electricity sector, where the models take the demand for electricity as a largely exogenous input and then find ways in which this demand can be met using renewable and conventional power sources under different conditions. The strong focus on technology means the models are able to take into account factors such as the lifetimes of power plants and the intermittency and geographical requirements of wind, solar and hydro power. Each different generation method has a cost attached to it (which could be separated into investment and operating costs) and the total cost can be estimated from the final share.

One of the key examples of using such an approach is that it is much better equipped to take into account threshold effects and non-linear relationships. Consider an example that introduced carbon pricing to the steel sector. A bottom-up model would be able to estimate that once the carbon price reached a certain level, it would become economic to switch to a new kind of furnace and emissions would be reduced. The equivalent representation in a top-down (i.e. CGE or econometric) model would be a linear representation of this, usually of the form X% increase in price leads to b*X% reduction in demand, where the value of b does not change.

The benefits of this approach from a presentational and educational perspective should also be noted. In the example above the bottom-up model is able to say how the increase in costs is linked to a reduction in emissions, while the top-down model does not offer an explanation of the mechanism involved.

The main drawback of the approach is that it involves the construction of a complex model that can then only be applied to one sector.

3.3.4.4 Equilibrium models

Computable General Equilibrium (CGE) models are the most commonly applied type of economic tool. They are top-down in nature and are generally considered to be appropriate for long-run cost assessments covering the whole economy, usually going to NACE 2-digit level of detail. Examples of models include GEM-E3, GTAP and Worldscan.

CGE models are strongly grounded in neoclassical economic theory and work on the assumption that individuals act optimally in their own self-interest. The model is solved so that the whole economy is in ‘equilibrium’ (e.g. supply = demand), implying that resources are allocated efficiently. The behavioural relationships in a CGE model are typically 'calibrated', meaning that a mathematical approach is used to fit the model to a single base year of data. This means that, compared to some other modelling approaches, the data requirements for the model are not so high, even if there is a high degree of sectoral disaggregation (the GTAP database is designed for this purpose).

One of the key strengths of CGE models is their internal consistency; they allow for comparative analysis of policy scenarios by ensuring that in all scenarios the economic system remains in general equilibrium. This is often expanded to include the energy system and implied environmental emissions, although this treatment is much less detailed than that offered by bottom-up approaches.

The main weakness of CGE models is that the key assumptions of rational and optimal behaviour do not always hold in the real world, particularly in the short term. This has been increasingly questioned post-crisis and means that some observed phenomena, such as involuntary unemployment, are missing from the models' assessment. These assumptions can heavily influence model outcomes, in extreme cases pre-determining the direction of results. For example, as CGE models assume that all the best available technologies have already been adopted and resources are being used efficiently, the costs of reducing CO2 emissions may appear higher than results from other modelling approaches.

As with all modelling approaches, care must thus be taken when interpreting results from CGE models.

3.3.4.5 Econometric models

Econometric models are empirical in nature with model relationships determined by statistical estimates based on historical (usually time-series) data sets, rather than pure economic theory. They are also top-down in nature but can be applied for short-term assessments as well longer-term outcomes. Like with CGE models, NACE 2-digit level of disaggregation is the standard level of detail. The most well-known econometric models also incorporate energy demand and GHG emissions, although not to the same degree as bottom-up models.

The main advantage of econometric models is their empirical basis, meaning that they are much less dependent on theoretical assumptions. They do not assume optimisation, they allow imbalances to occur in any given year, and they do not assume that prices automatically adjust so that supply is equal to demand.

However, this empirical basis means that they are much more dependent on large and accurate data sets with which to form their parameters; this can limit their use in some types of analysis, for example if only one year of data is available. Unlike CGE models there is no standard database available.

Another disadvantage of using this approach (and econometrics in general) is that the statistical approach does not attempt to offer any explanation of why the results occur (e.g. linking to a particular technology), just that they are based on relationships derived from observed data.

Increasingly it is recognised that CGE and econometric modelling approaches are based on different branches of economic theory and in some cases will produce different results. Sometimes a CGE model and an econometric model are applied to the same policy question so that results are not dependent on a single set of assumptions.

Examples of econometric models include E3ME/E3MG, GINFORS and NEMESIS.

3.3.4.6 Agent-based models

Finally, it is worth mentioning one other type of model that does not fit into the categories above but is gaining recognition in the research community. Agent-based models are bottom-up in design and are used to simulate the interactions between individual groups (the agents). They are strongly linked to the concept of complexity, as described in Beinhocker (2007)[46].

The development of agent-based models has been relatively recent, as increasing computer power has made this type of simulation more feasible. As yet there is no agent-based representation of the macro-economy so current agent-based models are likely to be appropriate tools to use for cost assessments in very few cases. This is, however, an area of ongoing research so applications may be possible in the future. The Matisse project provides an example, where an agent-based model was designed to test transition pathways.[47]

3.3.5 Linking different approaches

The idea of linking different methodological approaches has obvious advantages; it allows an approach that can combine the benefits of each component part, possibly giving a Tier 3 assessment to both the depth and breadth of the analysis. Some of the linkages have been alluded to already in this review, for example an intermediate approach can be formed by combining two items of basic analysis.

Basic assessment measures are often used to form the inputs for model scenarios, for example to estimate the costs of complying with a particular regulation:

- The direct cost is estimated by multiplying hours spent and cost per hour
- This is put into an economic model to estimate indirect costs

Less complex calculations are also sometimes used to provide a check on modelling results. For example, although a model usually provides a much higher level of detail, its outputs should not be an order of magnitude different from a simpler approach.

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[46] Beinhocker, E (2007) 'The Origin of Wealth', Random House, ISBN 0-7126-76589

[47] http://www.matisse-project.net/projectcomm/uploads/tx_article/Working_Paper_3_02.pdf

It is also becoming more common to link modelling tools together. Again, the attractions are fairly clear, by combining a bottom-up partial model with a top-down general one, it is possible to form a tool with both considerable depth and breadth.

These linkages generally take one of two forms, either through the transfer of data (referred to as a ‘soft linkage’ or through the amalgamation of computer code (a ‘hard linkage’). Several European research projects have aimed to link existing models, with varying degrees of success. Examples include:

- IP-SENSOR (land use and agriculture)
- SEAMLESS (environment and agriculture)
- iTREN (transport, economy and environment)

The main disadvantage of combining models is the high cost involved. This reflects a mix of theoretical and practical difficulties. Some examples are:

- Consistency in model definitions and dimensions – This includes sectoral definitions, but also the scope and level of detail in geographical coverage, and the time steps (e.g. monthly, annual, five-yearly) that different models use.
- Consistency in assumptions – For example, if an equilibrium model is combined with a disequilibrium model, what are the properties of the combined model?
- Developing a common understanding between model operators from different backgrounds.

For hard linkages, much of this cost is in up-front investment in developing consistent computer code using a common language. For soft linkages the cost is in implementation as passing data between models (and often institutions) is a time-consuming process, especially when the linkages are two-way, requiring an iterative process.

3.3.6 Treatment of uncertainty

So far this review has concentrated on how quantitative assessment methods can be used to estimate various types of costs of climate policy. Previous sections have made some reference to reasons why these estimates may be inaccurate, including limitations with data and approximations of non-linear relationships. There are, however, numerous other possible sources of uncertainty that tend to increase in line with the degree of complexity in the assessment methodology; these are discussed in Pollitt et al (2010). For ex-post analysis it should be noted that two of the main sources of uncertainty, a baseline forecast and predictions of future technology, are much less relevant than for ex-ante assessments.

Two examples of different complexity are given below.

In the basic example in which the direct costs of ETS compliance are estimated from the number of allowances purchased and the ETS price, the structure itself is fixed and so the uncertainty lies in the inputs used. The number of allowances used is given by data and so the only uncertainty is the accuracy of the data. The same applies to the price input, although it is noted that the data show the average of a value that is constantly changing. Given this, however, we can be reasonably sure that the costs estimated are close to the actual direct costs.

If a top-down modelling approach was used to answer the more difficult question of costs to the whole economy, the degrees of uncertainty increase substantially. All the data inputs are subject to error and the (unobservable) modelled relationships, including non-linearities, are also approximations of the true position. Thus the more complicated question leads to a higher degree of uncertainty in cost estimates.

3.4 Annex to Task 1: Overview of recommended methodologies for PAMs considered in this study

In this Section the methodologies introduced and discussed above, are cross-referenced against the policy areas to provide suggestions of the most appropriate tools available in each case. This is illustrated where possible with examples, and it is noted that there may be cases where it is appropriate to use more than one approach to look at the same policy area.

Table 3.8 provides an overview of the different PAMs. The focus of the table is on economic costs, excluding administrative costs, although the more complex methodologies also give results for environmental impacts.

In most cases administrative costs can be added by making a separate estimate (e.g. using the EU Standard Cost Model) and adding this to the total.

The column for estimating whole-economy costs largely refers only to Tier 3 approaches in terms of breadth, noting that on its own, this will in most cases not give the same level of depth as a specialised sectoral approach. In some cases input-output analysis would be feasible (although unusual); this is where the policies affect sectors that are defined at the NACE 2-digit level, which is usually the highest level of accuracy that is available in input-output tables.

Table 3.8 Overview of recommended methodologies

	Within Sector		Whole Economy
Policy	Tier 1 or 2	Tier 3	
EU ETS	A basic calculation with actual allowance price multiplied by CO2 emissions. By taking change in total energy price and an estimated price elasticity this could be expanded to provide impact on total energy costs.	For any given sector (but particularly the electricity sector) the application of a detailed bottom-up model with a defined set of technologies and implementation costs.	The application of a general economic model, preferably linked to a bottom-up sectoral model can give a comprehensive coverage of both sectoral and whole-economy costs.
RES-E Directive	An estimate of the costs of building new renewable capacity using an average unit cost. This could be offset against the costs of building and running conventional plants. A more accurate calculation could make use of cost curves[48] that estimate rising costs for various technologies once the most favourable locations have been	The application of a bottom-up model of the energy sector, incorporating a wide range of different electricity generation technologies and their associated costs.	The application of a general economic model that can incorporate both costs to the electricity sector and demands on equipment suppliers, then estimating the wider costs/benefits to the whole economy.

[48] For an example see Hoogwijk, M (2004) 'On the global and regional potential of renewable energy sources', Utrecht University.

	Within Sector		Whole Economy
Policy	Tier 1 or 2	Tier 3	
	used. Generation based subsidies: feed-in tariffs, quota or bonus systems: feed-in tariff / certificate price / bonus minus electricity price multiplied with RES-E electricity generation. Installation based subsidies: investment grant /tax reduction multiplied with installed RES-E capacity. Costs for power connection of the plant to the grid.		
CHP Directive	An estimate of the costs of building new CHP capacity using an average unit cost.	Similarly to the RES-E Directive the use of a bottom-up energy model that includes a detailed treatment of CHP and the associated costs and benefits.	To estimate whole-economy costs, a general model must be able to cover the sectors that produce and use the heat and offset these against the costs of using other fuels.
Biofuels Directive	A basic calculation will be based on total biofuel sales and the cost difference between petrol/diesel and biofuels per	To determine total costs to the transport sector it is best to apply a specialised transport model, which takes account of char-	As all sectors (and households) use road transport to some extent, most general economic models will be able

	Within Sector		Whole Economy
Policy	Tier 1 or 2	Tier 3	
	unit of energy. Costs of imported biofuels are based on market prices. For domestic production an assessment of production costs is necessary.	acteristics of vehicle fleets as well as users' response to changes in motor fuel prices.	to estimate indirect and whole-economy costs from an increase in transport costs, but this needs to be estimated first.
ACEA agreement	It is considered not feasible to extract a meaningful indication of ex-post vehicle costs due to the ACEA agreement from monitored vehicle price developments over time. Ex post cost assessment therefore needs to be based on a combination of ex-post fuel costs and ex-ante vehicle cost estimates. Benefits of lower fuel consumption are to be estimated on the basis of the difference between observed fuel consumption figures and assumed autonomous developments in the baseline scenario. As with the CO_2 impact assessment the basic calculation for the Tier 1	Again a dedicated transport model that includes the characteristics of the vehicle fleet and users' responses to changes in both vehicle prices and fuel efficiencies. Such a model should be able to incorporate rebound effects in its results. Attributable vehicle cost developments need to be based on ex-ante assessments also for the Tier 3 approach.	A general economic model would be able to provide an estimate of whole-economy costs and benefits if it takes the average cost of vehicles and the average fuel efficiency of vehicles as an input.

	Within Sector		Whole Economy
Policy	Tier 1 or 2	Tier 3	
	and 2 approaches will not include rebound effects.		
F-gas Regulation	There is a wide range of different responses that is difficult to summarise in a basic calculation. However, data on costs have been published by DG CLIMA, so it may be possible to provide an estimate based on average costs.	The use of a model that specifically considers this type of emissions and the costs of reducing these emissions, based on the detailed data that could be used in a Tier 1 or 2 assessment.	It is likely that the effects of the regulation are too localised to be used in either a general economic modelling approach, or using input-output analysis.
Landfill Directive	In most countries this led to an increase in landfill costs[49]. Although there is large variation in costs an average by MS and for the EU would give an indication of direct costs. These could be allocated to sector according to waste produced, but again these figures should	We are not aware of any modelling methodology that goes into the necessary level of detail. The most suitable approach is an econometric analysis, which would probably be classified as Tier 2, but even this would be highly reliant on uncertain data.	If it is possible to produce an estimate of costs to each sector, a general economic model could be applied to estimate the total costs to the economy. However, the analysis will only be as accurate as the assumptions about costs that are used.

[49] AEA, Ecofys and Fraunhofer ISI (2009): Quantification of the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019), pp73.

	Within Sector		Whole Economy
Policy	Tier 1 or 2	Tier 3	
	be viewed as approximate.		
2003 CAP reform	An assessment of changes in support payments to different types of farms as a result of the reforms (i.e. before and after). If the data allow an econometric assessment of behavioural responses could be carried out.	Although agricultural and combined land-use/agricultural models, such as CAPRI, exist, it is not clear how suitable they are for producing an estimate of the economic costs of CAP reform.	If it is possible to estimate an impact on food prices, a general model with detail in the agricultural sector (e.g. GTAP) could be applied to determine costs to the whole economy. This approach would not be suitable without this prior assessment, however.
IPPC Directive	There are major problems in providing an estimate of costs of compliance with the IPPC Directive, as reflected in previous attempts to quantify emissions savings[50]. The key constraints lie in the broad nature of the measures involved and the available data which are	The same constraints apply to using a Tier 3 methodology; The methodology proposed Task 2 would require resource intensive data collection from operators.	The tier 3 methodology proposed in Task 2 may be sufficient to estimate whole-economy costs. Outputs from the tier 1 and 2 methodologies could be used to estimate whole-economy costs, but the results of such analysis should

[50] AEA, Ecofys and Fraunhofer ISI (2009): Quantification of the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019), pp55-58.

	Within Sector		Whole Economy
Policy	Tier 1 or 2	Tier 3	
	generally disaggregated by sector rather than installation. However, a methodology which overcomes this data constraint to produce compliance cost estimates is included in Task 2.		be treated with caution.
Waste Incineration Directive	It is difficult to estimate costs to the waste industry as different sites will need to take different actions to comply with the regulation. There is likely to be strong variation between MS. Nevertheless, a bottom-up approach which utilises relevant reports may yield an approximation of costs if assumptions are made about the share of sites that must take action.	A Tier 3 approach would need to expand on this to take into account factors such as switching to landfill, relocation of sites or the effects of passed on costs. It should also cover the possible benefits of selling energy to other sectors.	As well as including costs to the waste industry, which may be passed on to waste producers, an assessment of whole-economy costs must take into account the use of captured energy which will lead to savings elsewhere.
Energy Performance of Buildings Directive	Estimates of costs must be formed using a bottom-up approach based on the available data for particular technologies (e.g. from the MURE database). These can then be offset	A Tier 3 approach needs to take this assessment further with a more rigorous assessment, including rebound effects and non-compliance, and produce more detailed estimates of the	An estimate of whole-economy costs would require data on investment in buildings that fall under EPBD. Total investment in buildings is available for some countries, but this would

	Within Sector		Whole Economy
Policy	Tier 1 or 2	Tier 3	
	against the expected savings in energy consumption.	fuel (cost) savings from each part of the directive.	give an over-estimate of the costs (and benefits for construction firms).
Labelling of Electric Appliances	The direct costs of labelling are likely to be small and dominated by the administrative element. A basic estimate of cost per unit * number of units is therefore recommended.	A Tier 3 approach is much more complex as it needs to take into account purchasers' responses and the costs of producing more efficient equipment. The best possible approach is to apply an econometric assessment of customers' choices using data from periods before and after the directive[51]. This could be enhanced by the use of survey data.	To estimate whole-economy effects it is necessary to combine the results from the Tier 3 sectoral assessment with an estimate of energy savings, taking into account rebound effects. Again the direct cost of producing the labels is likely negligible so could be excluded from the assessment.
Nitrates Directive	Any estimate of costs is likely to have a large range of uncertainty as the link between use of fertiliser and agricultural pro-	A Tier 3 analysis would need to take into account the direct costs, plus a consideration of changes to crops grown and	Similarly to the recommendations for CAP reform, impacts on food prices could be used in a general model to estimate

[51] Standard economic theory offers no help here as it assumes that customers have perfect information and therefore do not require labels; the policy is therefore viewed as a correction for 'market failure'.

	Within Sector		Whole Economy
Policy	Tier 1 or 2	Tier 3	
	duction is complicated by many other factors. An econometric assessment that takes into account these other factors may yield estimates of costs but the data requirements are considerable.	impacts on the total demand for food. As far as we are aware this goes beyond the capabilities of existing tools and available data.	whole-economy costs, but these are largely dependent on the initial estimates.

4 Task 2: Review and assessment of the results and methodologies developed under the project "Quantification of the effects on greenhouse gas emissions of policies and measures"

This section provides a review and critical assessment of the results and methodologies developed under the study by AEA et al. (2009)[52] and is devoted to further improving and refining these methodologies.

The previous study by AEA et al. provides recommendations for the further development of the methodological approach and the next steps to take for all policies and measures investigated in a consistent way. The current study critically assesses these recommendations and takes them into account in the improvement and refinement of the methodologies. The assessment includes all EU policies and measures evaluated in the previous study. In terms of methodological approach, the current study builds upon the integrated, tiered approach developed within the AEA et al. (2009) study. It borrows from the principles in the IPCC Guidelines for National GHG inventories[53] and provides three tier levels that differ in detail and complexity with increasing data intensity, resolution of analysis in terms of depth and breadth, accuracy of estimates and resource requirements from Tier 1 to Tier 3.

In the previous study, the ex-post quantification methods for some policies and measures were constrained due to limited modelling capacities of the previous consortium, e.g. for the ex-post assessment of the EU ETS, for the IPPC Directive, for the Directive on Renewables, the CHP Directive, for F-Gases or in the agricultural sectors. The following subsections provide an overview of the recommended next steps from the first project describing the models and statistical tools that would be necessary for specific policies and explains how the project team deals with the less advanced areas identified in the previous project.

The focus of the critical review of all policies and measures evaluated in the previous project is to:

- identify those areas and policies where the previous project achieved advanced results and methodologies (e.g. related to the ACEA agreement). These areas needed less improvement, but were included in the testing of methodologies under Task 3 (e.g. Labelling Directive);
- identify areas and policies in which significant problems have been indicated due to shortcomings in the modelling approaches and statistical tools available to the pre-

[52] AEA, Ecofys, Fraunhofer ISI (2009) 'Quantification of the effects on greenhouse gas emissions of policies and measures'", study prepared for the European Commission (http://ec.europa.eu/clima/policies/g-gas/studies_en.htm).

[53] IPCC guidelines for National GHG Inventories, (2006), http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.

vious project. In these areas Tier 3 approach are developed or existing methodologies further improved;

- refine the draft methodologies to better address of changes in policy, socio-economic and technological factors;
- refine the draft methodologies to better address interactions with relevant EU level policy measures, paying particular attention to the interactions of the EU ETS with other policy instruments and exogenous factors, and to the impact of the EU ETS on the development of the international carbon market (JI/CDM).

Based on the review and assessment of the results and methodologies of the previous study and the improvement and refinement of the methodologies, a number of policies and measures were proposed for an in-depth investigation and testing within this project. They comprise the following

- EU-ETS Directive
- RES-E Directive
- CHP Directives
- Biofuels Directive
- CO_2-regulation
- F-Gas regulation & MAC Directive
- IPPC Directive
- Waste Incineration Directive
- Nitrates Directive
- 2003 CAP reform
- Landfill Directive
- Energy Performance of Buildings Directive (EPBD)
- Energy Labelling Directive

4.1 EU ETS

4.1.1 Review and critical assessment of existing methodology

The existing Tier 1 and Tier 2 methodology for the impact assessment of the EU Emissions Trading Scheme is based on emission intensity trends, which are derived from emission inventories and energy and industrial statistics within a five year period before the implementation of the Directive. The first trading period lasted from 2005 to 2007; the second trading period continues from 2008 to 2012 when the Kyoto Protocol will expire; and the third period will begin in 2013 and end in 2020.

In the Tier 1 approach the historic emission trend from 2000 to 2005 is assumed to continue. In the Tier 2 approach this baseline is adapted with the development of energy prices and renewable energy sources. Finally the verified emissions under the EU ETS and the hosted Emission Reduction Units from Joint Implementation will be compared to the estimated baseline (AEA et al. 2009, p. 67).

The previous project describes the existing Tier 1 and Tier 2 methodology as insufficient and the calculated results as not realistic[54]. Although the forward projection of emission intensity trends seems to be a pragmatic methodology for a Tier 1 approach, it should be carried out on a more detailed level to improve the quality of the results.

Against this background and to ensure a step by step implementation of the different Tier methodologies, the revised Tier 2 approach should be held independent from Tier 3 model results and mainly consist of publicly available input data. The proposed improvements for Tier 2 are described in subsection 4.1.2.

To cover the complexity and cross-sectoral interactions of the EU ETS, a model-based Tier 3 approach is essential. In the previous project, a combination of a detailed bottom-up model for the power sector and an econometric model for industrial sectors is put forward. The costs and emissions determined for the policy scenario are thereby compared with a counterfactual scenario without the policy. A relevant gap in the methodology is thereby seen in the implementation of price elasticity and demand-induced emission reduction effects[55]. Moreover, the existing Tier 3 approach has been exemplified for two sectors (the power sector and the cement sector) in Germany to date. We therefore included price elasticity in the Tier 3 approach by linking a bottom-up power sector model with a macro-econometric model, which covers all industrial sectors as well. The proposed improvements for Tier 3 are described in subsection 4.1.3.

Furthermore a methodology to cover the linkage of EU ETS with international carbon markets is developed and described in subsection 4.1.4.

4.1.2 Proposed improvements and refinement methodology for Tier 2

We developed a revised Tier 2 approach for the electricity sector, which is independent of the Tier 3 model results and mainly consists of publicly available input data. This approach can be adapted to other industrial sectors, which is described at the end of this subsection.

[54] Quantification on the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019), Final Report Appendix I, p. 82 and 85, 2009.

[55] Quantification on the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019), Final Report Appendix I, p. 68 to 70, 2009.

The calculation procedure is based on two main steps: calculation of the increase in electricity demand due to price elasticity and calculation of the corresponding CO_2 emissions to cover the surplus in electricity demand with a typical marginal power plant.

Step 1: Calculation of the increase in electricity demand due to price elasticity

The calculation of the increase in electricity demand consists of the following input parameters:

- Total net electricity generation per year (data source: e.g. Eurostat)
- Total CO_2 emissions from electricity generation per year (data source: e.g. CITL, Eurostat or EEA)
- Average annual CO_2 price (data source: e.g. point carbon)
- Average annual electricity spot market price (data source: e.g. national electricity market)
- Assumed price elasticity (data source: e.g. Cambridge Econometrics[56])

The calculation derives the relative change in the electricity spot market price due to missing CO_2-costs in the counterfactual scenario compared with the policy scenario and multiplies it with the assumed price elasticity (**Equation 1**).

Equation 1

$$Change\ demand = \frac{CO_2\ emissions \cdot CO_2\ price}{electricity\ generation \cdot electricity\ price} \cdot price\ elasticity$$

Step 2: Calculation of the corresponding CO_2 emissions to cover the surplus in electricity demand

For the calculation of the corresponding CO_2 emissions to cover the surplus in electricity demand, the typical marginal power plant type, which will operate additionally, has to be derived using the following input parameters:

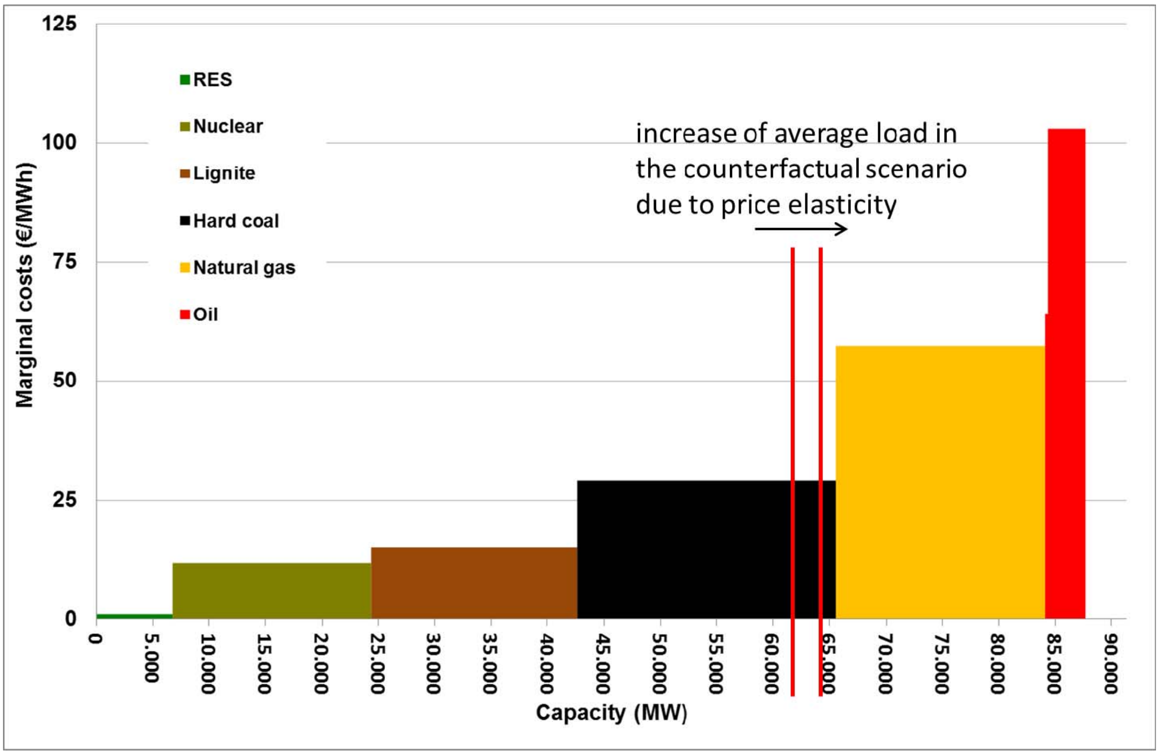
- Fuel costs and other variable costs as well as electrical efficiency to derive specific marginal generation costs per power plant type (data source: e.g. technical literature and statistics, fuel prices could be unpublished or confidential)

[56] Elasticities are commonly available. See, for example, Cambridge Econometrics (2010), http://www.scotland.gov.uk/Resource/Doc/1035/0103829.pdf. It should be noted that it is also assumed here that all cost increases are passed on in the form of higher prices. For electricity, which is not usually subject to international competition, this assumption seems reasonable (and is also common in the Tier 3 modelling approach).

- Installed capacity and average availability per power plant type to derive a simplified merit order (data source: e.g. IEA Electricity Information, technical literature or statistics)
- Average residual load, which has to be covered by the power plant fleet (data source: entsoe)

From the intersection of the average residual load and the simplified merit order of the power plant fleet, the typical marginal power plant type can be derived. As illustrated in Figure 4.1, the typical marginal power plant type in Germany 2005 is a hard coal fired power plant. Taking the specific emission factor of this plant type into account, the corresponding generation costs and CO_2 emissions to match the surplus in electricity demand can be calculated.

Figure 4.1 Simplified merit order of the German power plant fleet and the average residual load in 2005



Source: PowerFlex model results

This Tier 2 methodology of the electricity sector can be adapted to other industrial sectors under the EU ETS. The data requirements are similar as for the electricity sector, and an overview of the procedure is given in Figure 4.2.

The European Commission (DG CLIMA) publishes estimates of the share of carbon costs in each NACE 4-digit sector (i.e. at quite a detailed level) at EU level, including the direct costs of CO_2 emissions, and the indirect effect from higher electricity prices[57]. The estimates are provided for an ETS price of €30/t CO_2, but the costs (given as a percentage of GVA) can be scaled up linearly for different carbon prices.

When a firm is faced with higher costs it can either increase prices, leading to a potential loss of output, or reduce profit margins. Firms in different sectors will react in different ways, depending on the degree of competition within that sector. For example, companies that sell commoditised goods tend to be forced to match global market prices regardless of their production costs, while local monopolies may be free to set their own prices.

It is difficult to estimate actual cost pass-through rates for most sectors, with most available methodologies dependent on advanced econometric techniques[58]. We recommend that when carrying out an estimate the user:

- Either refers back to the results from previous studies;
- Or uses pass-through rates of zero (all costs result in lower profits) and one (all costs lead to higher product prices) to provide a range of outcomes.

The loss of profits can be estimated by multiplying the change in margins by total output (turnover).

If prices increase, this will have impacts on real output and potentially employment. Again, the size of the impact (the price elasticity) can vary greatly between firms in different sectors and depends on the degree of competition within that sector. Estimating the scale of the impacts requires the use of econometric methods[59].

If there are no results from previous studies it is recommended that a range of possible elasticities are used, for example taking a range of zero to -2. In these cases a 5 % increase in prices would lead to a 0 % change in output (sales) or a 10 % loss of output.

Although the employment effects vary between sector and country, macroeconomic models such as E3ME often estimate that every 1% fall in output leads to a 0.5% fall in employment, so this ratio could be used for a very rough calculation

An example calculation is provided in Section 5.1.1.

[57] http://ec.europa.eu/clima/policies/ets/leakage/docs/20090701_list_sectors_en.pdf

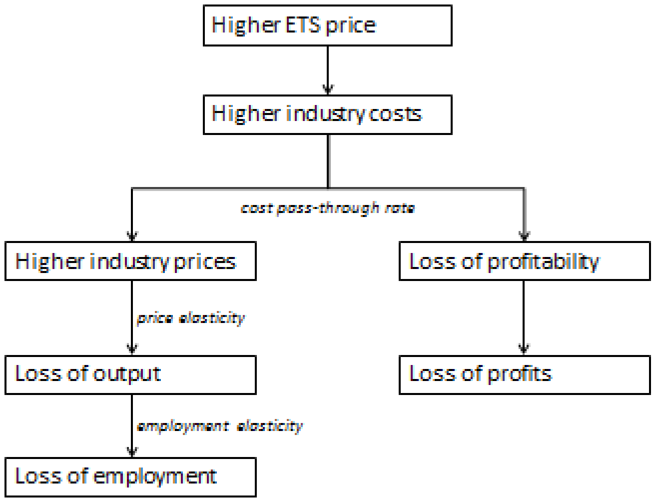
[58] For examples see:

http://ec.europa.eu/enterprise/policies/sustainable-business/climate-change/energy-intensive-industries/carbon-leakage/files/cl_executive_summary_en.pdf

http://ec.europa.eu/enterprise/policies/sustainable-business/climate-change/energy-intensive-industries/carbon-leakage/files/cl_literature_review_en.pdf

[59] See previous footnote.

Figure 4.2 Tier 2 calculation procedure for industrial sectors (excl. power sector) under EU ETS



4.1.3 Proposed improvements and refinement methodology for Tier 3

The main improvements since the previous project have been made within the Tier 3 methodology for the development of a model interface to link bottom-up partial models for the electricity sector with a general econometric model. This approach combines two distinct modelling tools that provide an in-depth analysis of the power generation sector as well as coverage of all ETS sectors and the wider economy. Especially price elasticity and demand-induced emission reduction effects are thereby taken into account (Figure 4.3).

Within a scenario analysis, the economic and ecological effects of a policy scenario and a counterfactual scenario without policy induced impacts will be determined. While for the EU ETS policy scenario historic CO_2 prices are taken into account, the counterfactual scenario consists of a CO_2 price of zero. The price for one European Allowance Unit (EAU) is therefore defined as CO_2 price within the scenario analysis. These data are available on a daily base for spot prices based on over-the-counter (OTC) brokered prices. While in the beginning of the first trading period of the EU ETS the EAU spot price was in the range of 20 €/EAU to 30 €/EAU, it decreased to nearly 0 €/EAU in 2007. In the second period of the EU ETS the EAU spot price started 2008 in the range of 20 €/EAU and 25 €/EAU and reached a level of about 15 €/EAU from 2009 onwards. In 2012 the EAU spot price has currently decreased to below 10 €/EAU[60].

The revised Tier 3 methodology consists of the three main steps for the policy and the counterfactual (Figure 4.3). For the counterfactual scenario a pre-step is included to derive the change of electricity demand from price elasticity (step 0):

Step 0: Calculation of electricity demand depending on electricity price (price elasticity).

Iteration loop between the PowerFlex model (see step 1) and the E3ME model (see step 3).

Data exchange and model linkage:

- Change of annual average electricity spot market price calculated with the PowerFlex model as data input for the E3ME model.
- Change of electricity demand calculated with the E3ME model as data input for the PowerFlex model.

Step 1: Calculation of power plant dispatch with the PowerFlex model.

Input data and parameters needed:

- Power plant fleet with installed capacity (MW), availability (%), electrical efficiency (%), CO_2 emission factor (t CO_2/MWh fuel), fuel price (€/MWh fuel), variable costs (€/MWh electricity), CO_2 price (€/t CO2) and CHP plant[61] (yes/no) (historic or counterfactual data)
- Electricity demand, RES feed-in[62] and must-run generation in hourly resolution (historic data)
- CHP profile in hourly resolution (generic data)
- Storage power plants with installed capacity for pumping and generation (MW), efficiency of pumping and generation (%), storage capacity (MWh) and variable costs (€/MWh electricity) (historic data)

Model calculation:

- Linear optimization problem to minimize the overall costs of electricity supply

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[60] Source: PointCarbon.

[61] The policy scenario includes effects from the CHP Directive. It is possible to evaluate policy interaction with further counterfactual scenario configuration and parameter variation.

[62] The policy scenario includes effects from the RES-E Directive. It is possible to evaluate policy interaction with further counterfactual scenarios configuration and parameter variation

- Day ahead optimization (365 optimization periods with 24 h each)
- Linkage of the optimization periods (plant capacity and other variables in hour 1 of the current optimization period depend on the values in hour 24 of the previous optimization period)
- Model software GAMS[63] with Cplex solver

Output data and results:

- Calculated generation mix, electricity prices (marginal costs) and operation of power and storage plants in hourly resolution
- Aggregation of hourly values to annual values (e.g. average electricity price, annual CO_2 emissions)

Model linkage:

- Transfer of the calculated average annual spot market electricity price to the E3ME model
- Transfer of the calculated operation hours of the power plant fleet to the ELIAS model.

Step 2: Determination of investment effects in the power sector with the ELIAS model.

Input data needed for ELIAS model:

- Power plant fleet of starting year 2005 (historic data) including vintages
- Operating hours of the power plant fleet calculated with the PowerFlex model
- Projection of electricity demand, fuel and CO_2 prices up to 2050
- Specific investment costs and technical lifetime for different power plant technologies

Model calculation:

- Simulation of investment decisions to cover electricity demand

Output data and results:

- Calculated power plant fleet (incumbent power plants and new investments)

Model linkage:

- Transfer of the calculated power plant fleet to the PowerFlex model, if needed
- Transfer of calculated investments to the E3ME model, if needed

[63] General Algebraic Modelling System

Step 3: Calculation of the overall socio-economic effects with the E3ME model.

Input data needed for E3ME model:

- Full set of National Accounts Economic data (historic data)
- Full set of energy balances and prices, emissions (historic data)
- Estimated econometric elasticities based on historical data
- ETS allowance price (historic data)
- Electricity price calculated with the PowerFlex model
- Investments for new power plants calculated with the ELIAS model, if applicable

Model calculation:

- Simulation of demand for electricity and fuels, and the subsequent economic impacts

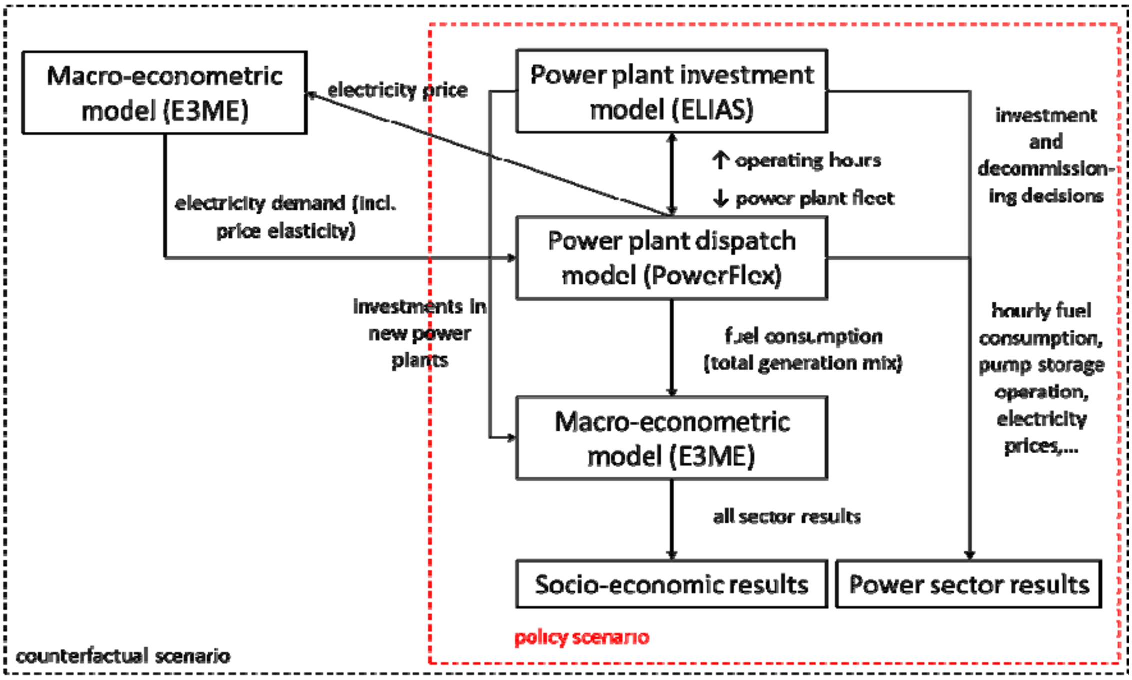
Output data and results:

- Energy demand and emissions (all sectors)
- Sectoral economic output, summing to GDP
- Employment impacts

Model linkage:

- Transfer of the electricity demand to the ELIAS and PowerFlex mode

Figure 4.3 Linkage of the detailed power sector models PowerFlex and ELIAS with the general econometric model E3ME



Source: Authors' own illustration

The detailed evaluation of the power sector, which is by far the largest user of ETS allowances and subject to the RES-E Directive and the CHP Directive as well, will increase the understanding of different policies impacts. For the power sector, the improved model-based approach includes the short-term dispatch of power plants (PowerFlex model) and the long-term investment effects in the power sector (ELIAS model). These two models are described below. The wider economic framework and coverage of the other ETS sectors is provided by the E3ME macroeconomic model. E3ME is an econometric model with parameters derived on a fully empirical basis, reflecting real-world behaviour at the Member State level. The model provides an estimate of direct and indirect economic costs and is described further below after the power sector models.

The sectoral/geographical coverage is thus:

- For the power sector in the selected Member States a very detailed treatment is provided based on the PowerFlex model. This is described below.
- For the power sector in other Member States a less detailed treatment is provided based on E3ME's Energy Technology Model[64]. This explicitly includes a

[64] See Barker, Lofsnaes and Pollitt (2007) 'The ETM in E3ME43', Cambridge Econometrics working paper: http://www.camecon.com/Libraries/Downloadable_Files/ETM.sflb.ashx.

range of generation technologies, but at a much lower level of detail than PowerFlex.

- For the industrial sectors that are included in the ETS, a simpler 'top-down' method is used, based on econometric parameters. Individual technologies are not explicitly defined.

Ideally, it would be possible to include a more detailed treatment of the industrial sectors as well, taking into account their production methods and available technologies. Such bottom-up models are being developed for some of the sectors and, over time, will become better linked to the macroeconomic framework (as described in Chapter 2). However, it should be noted that the level of resources required to carry out such an exercise is considerable, as a separate model is used for each sector.

Nevertheless, by combining a detailed treatment of the power sector with an econometric approach to cover wider costs and indirect impacts the weakness of the existing Tier 3 methodology can be eliminated. Another strength of this approach is its use of a consistent data base. This comprehensive Tier 3 methodology refinement can also be used for the impact assessment of the RES-E Directive and the CHP Directive (see chapter 4.2 and 4.3).

At the same time, the Tier 3 approach also shows some limitations. Due to the technical detail of the dispatch model, the geographical broadness is limited to individual Member States or a group of neighbouring Member States. The reason for this limitation is linked with the complexity of the optimization problem, which has to be solved by a common computer system and within an acceptable time frame. The complexity of the optimization problem corresponds directly with the amount of power plants considered in the model and the geographical area. Another limitation is the availability of the required data and models. While data concerning grid load or fuel consumption are freely available at ENTSOE or from the EUROSTAT database, technical data concerning the power plant fleet are mainly based on the commercial UDI World Electric Power Plants Database (WEPP). Furthermore, the required models are also not freely available, so that similar models have to be developed by Member States themselves or research institutions with model capacities have to be involved in the evaluation process via service contracts.

There are also some limitations in the econometric modelling and measurement of costs. As described in Chapter 2, these often reflect the level of data that are available. For example, the analysis is carried out at sectoral rather than installation level and the highest degree of disaggregation that is available is NACE 2-digit level. The econometric model is also subject to the Lucas Critique (i.e. it is assumed that behavioural responses do not change, see Chapter 2) although this is less of an issue for ex-post analysis.

4.1.3.1 Description of the power plant dispatch model PowerFlex

The power plant dispatch model PowerFlex developed by Öko-Institut is a fundamental model which dispatches thermal power plants, feed-in from renewable energy sources, pumped storage hydro power plants and flexible power consumption at minimal costs to meet the electricity demand and the necessary reserve capacity. The PowerFlex model has been designed as both a linear and a mixed-integer optimisation model and is currently used for ex-post evaluation of policy measures and for ex-ante scenario analysis of paths geared to increasing the use of renewable energy sources, electric mobility and smart grids[65].

Thermal power plants are modelled in detail with the help of technical and economic parameters. Power plants with an installed electrical capacity exceeding 100 MW are distinguished individually and by specific efficiency. Furthermore three different operating conditions are differentiated in the mixed-integer option of the model: start-up and shutdown, partial load and full load. Alongside technology-specific ramp rates, efficiencies are also distinguished in the different operating conditions.

Smaller thermal power plants are grouped together according to technology and construction year and ascribed characteristics with the help of type-specific parameters. For these power plants ramp rates are not taken into account. The same is true of pumped storage hydro power plants, which are grouped together according to comparable relations of storage capacity to installed electrical capacity. For Germany for example, the overall thermal power plant fleet is composed of approx. 250 individual power plants and 150 technology aggregates.

Biomass power plants using biogas, wood or plant oil can be modelled in two ways: first of all as predefined continuously feed-in and secondly as technology aggregates for the flexible use of biomass plants within the thermal power plant fleet. CO_2 emissions from the thermal power plant fleet, which are induced by fuel combustion, are calculated based on fuel-specific CO_2 emission factors. Other gaseous emissions, like SO_x or NO_x for example, could generally be included in the PowerFlex model as well. The emission factors of other gases than CO_2 depend on the combustion technology as well as flue gas cleaning technology. The detail of modelling other gaseous emissions is therefore limited by the technologies distinguished in the PowerFlex model.

The electricity which can be produced from run-of-river, offshore wind, onshore wind and photovoltaic is predefined using generic feed-in patterns in hourly resolution. The actual quantity of feed-in is determined endogenously, with the result that the available yield of fluctuating electricity can also be curtailed (e.g. in the case of negative residual load and insufficient storage capacity).

The production pattern for electricity from combined heat and power is based on a typical pattern for district heating and assumed uniform distribution in the case of industrial

[65] For example, the eTelligence E-energy project or the OPTUM e-mobility project.

CHP plants. This produces a specific CHP pattern for each major energy source. For must-run power plants like blast furnace gas or waste incineration plants, a uniformly distributed feed-in of electricity is assumed.

Electricity demand is predefined in hourly resolution analogously to fluctuating feed-in from renewable energy sources. The demand pattern is composed of the system load for the considered year[66] and an assumed uniform distribution of the electricity production from industrial power plants, which is not included into the transmission grid load. In order to meet the demand for primary reserve capacity, taking into account the minimum partial load and maximum ramp rates of the power plants, a year-round minimum capacity of thermal power plants is predefined, derived from pre-qualification conditions for primary regulation and technology-specific minimum capacity of typical plants.

Based on perfect foresight, the minimal cost dispatch of thermal power plants, feed-in from renewable energy sources and pumped storage hydro power plants is then calculated within the scope of linear or mixed-integer optimisation, taking into account technical and energy-economic constraints. The optimisation problem is implemented in GAMS[67] and solved using the simplex algorithm[68]. While the linear option consists of a year-long optimisation horizon (8,760 time steps and several millions variables), the mixed-integer option is due to its exponential rising complexity based on a day-ahead optimisation (365 optimisation horizons, each with 24 time steps and several thousands of variables).

As a result electricity prices, fuel mix and CO_2 emissions are determined in hourly resolution. These data and other detailed information (e.g. operating hours and marginal income of individual power plants) can be linked to the investment model ELIAS and the general econometric model E3ME (see Figure 4.3 and Figure 4.4).

The geographical scope, which has to be equal for the two power sector models, depends mainly on the available hardware resources. On a server with four common central processing units (approx. 8-12 GHz) and approx. 12 GB RAM, the geographical scope is limited to individual Member States or to a group of smaller and neighbouring Member States. The geographical scope could be increased of course, if the considered technical details of the power plant fleet are reduced and the complexity of the optimisation problem, which has to be solved, decreases accordingly.

4.1.3.2 Description of the power plant investment model ELIAS

ELIAS (Electricity Investment Analysis) is a bottom-up simulation model for investments in power plants. Based on the decommissioning of power plants as well as on the development of electricity demand over time, the need for investment in new power

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[66] https://www.entsoe.eu/db-query/consumption/mhlv-a-specific-country-for-a-specific-month/

[67] General Algebraic Modelling System.

[68] CPLEX solver from Ilog.

capacity is determined. New electricity generation capacity is added assuming perfect foresight of an ideal-typical investor, knowing all costs over the depreciation period of the investment. The investment in new power plants is cost-driven, i.e. the lower the unit generation costs, the higher corresponding capacity additions of the technology. A bandwidth of technologies is added as a function of their distance from the cheapest technology.

ELIAS may incorporate results of the merit order model PowerFlex in its decommissioning rationale and investment decision. Similarly, capacity additions estimated by ELIAS may serve as an input for PowerFlex.

The investment modeling is based on expectations about future policy and energy-economic framework conditions (fuel and CO_2 prices, allocation rules, etc.). From 2005 to 2011, parameters correspond to materialised values. From 2012 onwards, price and policy projections are used. LCOE are determined by capital expenditures for investment as well as fixed and variable operating costs. LCOE are influenced by the policy scenario by an additional cost stream (CO_2 allowance costs) as well as by resulting changing operating hours (PowerFlex). The additional cost stream for CO_2 allowances depends on the fuel type (CO_2 intensity), the allocation rule (auctioning, benchmarking, etc.) and the CO_2 price. Operating hours are influenced by the fuel type and the CO_2 allowance price (the higher the CO_2 intensity and the higher the CO_2 price, the fewer hours the power plant is dispatched).

LCOE are estimated based on the net present value of all costs over the depreciation period as well as the evolution of full load hours during the same period. In consequence, cost accruals in the first years of the depreciation period have a higher impact than costs occurring in later years. Therefore, allocation rules and the corresponding necessity to purchase CO_2 emission allowances have a higher impact in the first years after power plant construction. This has two implications: firstly, for the effectiveness of climate policy it is important that stringency of allocation rules is ensured already at the beginning. Secondly, for the purpose of ex-post evaluation, data quality must be highest for the first years after introduction of the policy (from when on the ex-post assessment is carried out) in order to have an assessment of the effects of climate policy.

It also has to be mentioned that real decisions on power plant investment at the beginning of the EU ETS were based on the *expectation* of future climate policy as well as other energy-economic framework conditions, whereas the modeling for the ex-post assessment uses *materialised* values and *projections* from today's perspective subsequently (see above). That means that the basis for investment decision may have been different in 2005 from what are considered the investment conditions from an ex-post perspective.

Allocation rules in the first two trading periods were to a large extent determined by national governments. Therefore, differences exist between member states. The allocation may be reflected in the modeling in three ways:

- Assumption of 100% auctioning: this option is easy to implement; however, it does not reflect the actual circumstances in the first two trading periods.

- (Detailed) allocation rules for each member state: this corresponds to the most accurate reflection of the policy (consideration of benchmarks, compliance factors[69], transfer rules[70], etc.). However, the complexity and diversity of rules make it difficult to implement.
- Auctioning shares for each member states: this method allows for a differentiation of auctioning rules for different technologies and member states based on the amount of allowances that have to be purchased. This is a good compromise between accuracy and easiness of implementation.

For the testing case for Germany, calculations were carried out using auctioning shares for different technologies.

4.1.3.3 Iteration between power plant dispatch (PowerFlex) and investment (ELIAS)

Power plant dispatch and power plant investment are calculated by an iterative application of the investment model ELIAS and the dispatch model PowerFlex (Figure 4.4). Investment decisions in new power plants are taken from the perspective of an ideal-typical investor based on the levelised costs of electricity (LCOE) as the most important decision variable (ELIAS)[71]. Power plant dispatch is determined by minimising overall electricity generation costs (PowerFlex). The demand for new power plant investment is determined by the decommissioning of power plants as well as the development of the electricity demand (ELIAS). Decommissioning of power plants takes place at the end of the technical lifetime. Electricity demand is influenced by the policy (price elasticity of the counterfactual scenario) and is modelled in the E3ME model (section 4.1.3.4). The power plant structure serves as an input to the dispatch model PowerFlex, which in turn determines the dispatch of power plants and corresponding operating hours. Operating hours are fed back to ELIAS as an essential input for the investment decision.

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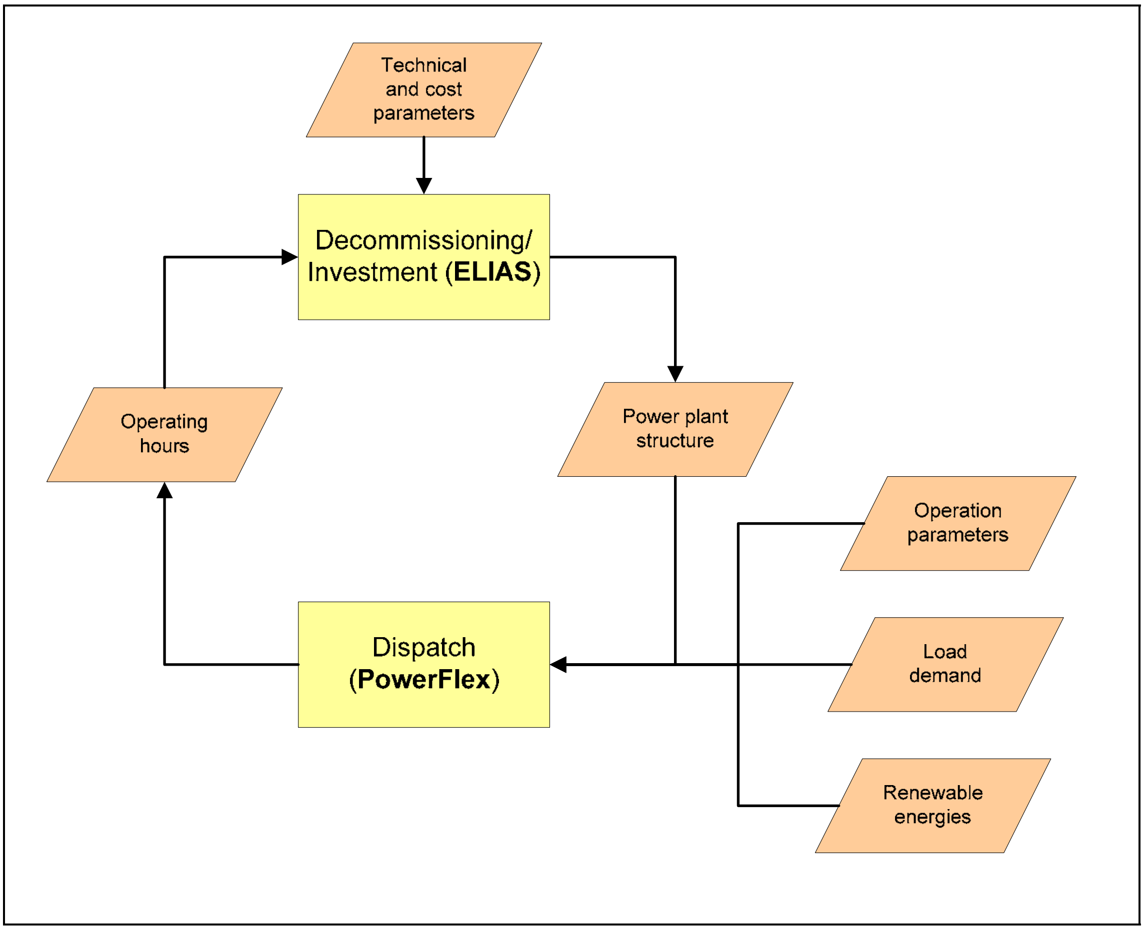
[69] Compliance factors stipulate the amount of emission allowances effectively allocated based on the corresponding allocation rule. For instance, if emission allowances according to a benchmark are 100 t for power plant and the compliance factor is 95%, then 95 EUA are allocated to that power plant.

[70] Transfer rule allow for a (temporal) carry-over of allowances of an (old, inefficient) power plant to a new power plant if the former is decommissioned. Since the new power plant requires fewer allowances, the transfer rule leads to a net income for the new power plant and thus for an additional incentive for investing in new power plants.

[71] The electricity price is not directly considered in the ELIAS as input data, rather the electricity price is a result of the dispatch of power plants in the PowerFlex model, which in turn depends on the power plant fleet calculated in ELIAS. In turn, operating hours of individual power plants are related to the electricity price. Operating hours are considered in ELIAS for determining the overall amount of electricity generation going offline and the type of new technologies built. In this regard, there is an indirect link between power plant investment and the electricity price.

Figure 4.4 Iteration between power plant decommissioning and investment (ELIAS) and power plant dispatch (PowerFlex)



Source: own illustration

Iterations between ELIAS and PowerFlex are carried out until results regarding power plant investment and power plant dispatch become stable in both models. In this regard, there are two fundamental feedbacks between power plant decommissioning and investment on the one hand and power plant dispatch on the other hand:

- Decommissioning/investment demand (electricity gap): Market results (operating hours) influence the overall electricity generation of decommissioned power plants[72] and thus the need for new generation capacity. The overall capacity of new power plants added, in turn, affects power plant operation. In this regard, there is an interaction between power plant operation and the magnitude of new capacity additions.
- Investment decision: The types of power plant technologies invested in depend on the full costs of electricity generation (LCOE). An important influence pa-

[72] In this project, power plants are decommissioned at the end of their technical lifetime.

rameter for determining the LCOE is the number of operating hours, on the basis of which the investment analysis is carried out. The power plant types built in turn influence the merit order of the power plants and thus power plant dispatch. In this regard, there is an interaction between the power plant technologies built and power plant dispatch.

4.1.3.4 Description of the econometric model E3ME

E3ME is a computer-based model of Europe's economic and energy systems and the environment. It was originally developed under the European Commission's research framework programmes and is now widely used in Europe for policy assessment, for forecasting and for research purposes.

The economic structure of E3ME is based on the system of national accounts, as defined by ESA95 (European Commission, 1996), with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, with estimated sets of equations for labour demand, supply, wages and working hours. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2009 and the model projects forward annually to 2050. The main data sources are Eurostat, DG Ecfin's AMECO database and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. Gaps in the data are estimated using customised software algorithms.

The main dimensions of the model are:

- 33 countries (the EU27 member states, large candidate countries plus Norway and Switzerland)
- 42 economic sectors, including disaggregation of the energy sectors and 16 service sectors
- 43 categories of household expenditure
- 19 different users of 12 different fuel types
- 14 types of air-borne emission (where data are available) including the six greenhouse gases monitored under the Kyoto protocol.
- 13 types of household, including income quintiles and socio-economic groups such as the unemployed, inactive and retired, plus an urban/rural split

Typical outputs from the model include GDP and sectoral output, household expenditure, investment, international trade, inflation, employment and unemployment, energy demand and CO_2 emissions. Each of these is available at national and EU level, and most are also defined by economic sector.

The econometric specification of E3ME gives the model a strong empirical grounding and means it is not reliant on the assumptions common to Computable General Equilibrium (CGE) models, such as perfect competition or rational expectations. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (eg up to 2020) and rebound effects, which are included as standard in the model's results.

In summary the key strengths of E3ME lie in three different areas:

- the close integration of the economy, energy systems and the environment, with two-way linkages between each component
- the detailed sectoral disaggregation in the model's classifications, allowing for the analysis of similarly detailed scenarios
- the econometric specification of the model, making it suitable for short and medium-term assessment, as well as longer-term trends

For further details, the reader is referred to the model manual available online from www.e3me.com.

Assessment of environmental impacts and socio-economic costs

As direct environmental impact of the EU ETS in the electricity sector the CO_2 emissions related to the fuel consumption of the plant dispatch in hourly resolution are determined. For the other sectors the CO_2 emissions related to energy and electricity price variation are determined with the E3ME model. This is a three-step process:

- Aggregate energy demand is determined as a function of economic activity, energy prices and current technology.
- Energy demand is shared between 12 different fuel types, with econometric equations for the main types (hard coal, fuel oil, natural gas and electricity) and fixed shares for the others.
- CO_2 emissions are estimated using fixed coefficients to fuel consumption.

The results from E3ME include other air-borne pollutants, such as SO_2, NO_x and particulates, at more aggregate level, so could be used to estimate co-benefits, for example from reduced coal combustion. These have been linked to damage coefficients from the ExternE projects to provide a monetary value of marginal costs (e.g. to health and to buildings). However, this is not the focus of this exercise.

Box: Energy Prices

E3ME treats international energy prices (excluding taxes) as exogenous, matching the actual outcome over the assessment period (and matching the projections used with PRIMES for ex-ante assessment). Traditionally this has been a standard modelling assumption; that developments in Europe do not affect global markets. However, feedbacks may be important; Sinn (2009) noted that if it was supply rather than prices that were fixed, 100% of the emission reductions would be offset by increased consumption elsewhere (a form of carbon leakage).

The reality is likely to lie somewhere in between, with reductions in demand leading to both reductions in supply and some reduction in prices. Some models, including POLES, have attempted to capture this relationship using global supply curves. However, it must be noted that even these relatively sophisticated treatments cannot accurately account for political factors, such as changes in OPEC quotas.

In addition, price reactions vary by fuel type and an endogenous approach would need to take this into account. While oil is largely traded globally, gas contracts are increasingly becoming separated from oil prices. Coal prices are determined at a regional level, but are to some extent still dependent on oil prices due to the high transport cost of coal.

For electricity, prices in E3ME are set to include a measure of 'levelised' costs, so that wholesale prices include the costs of fuel, ETS compliance and investment in new plant.

Reference: Sinn, H.W. 2009. The Green Paradox, CESIfo Forum 2009 Volume 10 Issue 3, downloadable at http://ideas.repec.org/s/ces/ifofor.html

The electricity generation costs and the investment costs for new plant capacities are part of the physical compliance costs of the regulated entities in the electricity sector. Plant-specific electricity generation costs and the resulting electricity price from plant dispatching are a result of the PowerFlex model. Investment costs for new plant capacities can be calculated with the ELIAS model in the counterfactual scenario. For the policy scenario empirical research is taken into account and supplemented with economic data of the ELIAS model data base if necessary.

The overall economic effects (for example in terms of GDP, employment and structural change, see Section 2.1.3) in all sectors are determined with the E3ME model. There are two main feedback mechanisms:

- The first relates to the energy production and extraction sectors. If physical business and household fuel demand fall, this is reflected in lower intermediate and final economic demand for the outputs of the fuel sectors. However, in economic terms, these sectors are small in European countries.

- The second relates to the increase in costs of industries that use energy. Depending on market structure, these costs may be absorbed (resulting in lower profits) or passed through (resulting in lower product demand).

The advantage of using a general macroeconomic model is that these economic impacts are held within a single framework. For example higher energy and industrial prices will lead to competitiveness effects at the sectoral (2-digit) level but also on an aggregate level to give a measure of domestic inflation and the effects on households' incomes[73]. Ultimately this leads to an estimate of loss of production across the entire economy and a reduction in GDP.

Administrative costs of the regulated entities as well as the regulator are not part of the models and have to be derived based on a literature survey.

4.1.4 Linkage of EU ETS and international carbon markets

According to Article 11a[74] of Directive 2009/29/EC and Directive 2004/101/EC (Linking Directive) CER and ERU certificates from CDM and JI projects can be transferred to the EU ETS. This mechanism links international carbon markets with the EU ETS. Between 2008 and 2010 about 2,100 million emission units including EUA, CER and ERU have been surrendered per year, whereas in 2008 and 2009 about 82 million emissions units and in 2010 about 137 million emissions units are from ERU and CER (about 4 % of total surrendered certificates in 2008 and 2009; about 8 % of total surrendered certificates in 2010)[75]. Incumbents who commenced operation prior to 2008 as well as new entrants in the second trading period are allowed to use CDM/JI credits at a specific maximum depending on their allocation in the second trading period. For Germany for example, this figure is set to 22 %[76].

In the first phase of the EU ETS the price for EUA certificates started with 30 €/EUA and declined to nearly zero in 2007. In the second phase of EU ETS the EAU spot price started 2008 in the range of 20 €/EAU to 25 €/EAU and reached from 2009 onwards a level of about 15 €/EAU. In 2012 the EAU spot price declined to currently less

[73] Using Eurostat household expenditure survey data, it is possible to estimate the impacts on incomes of a range of different types of households, including income quintiles and vulnerable socio-economic groups (e.g. retired, unemployed, economically inactive), plus an urban and rural split.

[74] Use of CERs and ERUs from project activities in the Community scheme before the entry into force of an international agreement on climate change

[75] Cames et al, Functioning of the ETS and the Flexible Mechanisms, European Parliament, 2011, p. 12.

[76] Hermann et al., Free allocation of emission allowances and CDM/JI credits within the EU ETS, Öko-Institut Berlin, 2010, p. 36.

than 10 €/EAU[77]. The CO_2 price is influence by different factors. On the supply side, additional surrendered CER and ERU emission units increase the total amount of available EUA and may lead to a decreasing EUA price. On the demand side, an increasing consumption of CO_2-intensive goods produced by companies under the EU ETS, may lead to an increasing EUA price. The EUA price is therefore also influenced by the development of the economy in general. Marginal CO_2 abatement costs, which are influenced by other economic and technological parameters, like the price spread from coal to gas or an increasing efficiency ratio of electricity generation for example, influence the EUA price as well.

The prices for surrendered CER have been lower than for surrendered EUA in the second phase so far (by about 2 €/t to 5 €/t)[78]. Therefore it can be assumed, that without the possibility of using CER and ERU, the price for EUA would be higher. To estimate this price effect with a basic methodological approach on Tier 1 level, the price spread from EUA to CER certificates as well as the surrendered emission units could be taken into account. Under the restriction of a linear correlation between EUA price and surrendered CER certificates, the adjusted EUA price can be estimated via weighted combination of surrendered CER, ERU and EUA.

In a recent study from Öko-Institut (Hermann and Matthes, 2012)[79], it is estimated that the use of CERs between 2008 and 2020 amounts to 1.6 billion t in the EU ETS. Based on the estimation of future EUA prices and the effects of the set-aside and the linear reduction factor[80], the average price increase in 2013 is 3.5 €/EUA in 2013 and 9.5 €/EUA in 2020. Compared to prices in 2013, this constitutes a price increase of 44 %; compared to prices in 2020, a price increase of 66 %. It can therefore be concluded that without the CDM (with a similar volumes as the set-aside and linear reduction factor), EUA prices would have been 50 % higher than in the current case (including CERs).

E3ME includes an exogenous treatment of CDM/JI. A more sophisticated methodology may be possible, but it is difficult for an economic model to explain why low-cost CDM options are not taken up (partly because the models do not include administrative costs). Nevertheless, it is important to be aware of the implications of including CDM/JI in the targets; these are reflected in the modelling results:

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[77] Ibid., p. 13.

[78] Ibid., p. 14.

[79] Hermann, H.; Matthes, F. (2012): Strengthening the European Emissions Trading Scheme and Raising Climate Ambition. Facts, Measures and Implications. Report by Öko-Institut for WWF and Greenpeace. http://www.oeko.de/oekodoc/1484/2012-056-en.pdf.

[80] EUA futures are estimated at 7.9 €/EUA in 2013 and 14.3 €/EUA in 2020. Price effects in 2013 of a set aside (1.4 billion EUA) are estimated at 2.5 €/EUA in 2013 and 4 €/EUA in 2020. Price effects in 2013 of a set aside and linear reduction factor of 2.25% (1.7 billion EUA) are estimated at 4.5 € / EUA in 2013 and 15 €/EUA in 2020.

- The domestic target becomes less ambitious as emission reductions are partly achieved in third-party countries.
- The EUA price will be lower, meaning that the direct compliance costs are less. However, the value of allocated allowances will also be lower.
- A lower EUA price may mean lower economy-wide costs (e.g. to GDP, employment), but it is also important to note the flow of money out of the EU to third-party countries.
- Administrative costs for CDM/JI are higher than for purchasing ETS allowances.

4.1.5 Summary and conclusions

Due to the major improvements made for the Tier 2 and the Tier 3 methodology approach the EU ETS policy is proposed to be further investigated within the course of this project in the testing of methodologies phase (see section 5.1).

4.2 RES-E Directive

4.2.1 Review and critical assessment of existing methodology

The existing Tier 1 and Tier 2 methodology for ex-post evaluation of the RES-E Directive developed in the previous project takes the electricity produced by renewable energy sources as activity data in association with an emission factor for electricity generation substituted by them. The amount of electricity produced by renewable energy sources is therefore assumed to be an output of the RES-E Directive in general. Other options, which take the existing policy trend or autonomous RES-E development into account, are described but not chosen for calculations in the previous project.

The emission factor for the Tier 1 approach represents the electricity mix from coal, natural gas and oil power plants on European level[81] and for the Tier 2 approach on national level respectively. In the Tier 3 approach the average emission factor is derived from the national marginal power plants in terms of short term or long term marginal costs[82].

The relevant data needed for the Tier 1 and Tier 2 approach are available within the EUROSTAT data base, both on European as well as on national level[83]. The applica-

[81] Nuclear power plants are excluded because their operation was not influenced in the past.

[82] Quantification on the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019), Final Report Appendix I, p. 34 to 36, 2009.

[83] Main tables “Electricity generated from renewable sources” and “Total gross electricity generation”, data base entries “Imports (by country of origin) - electricity - annual data”, “Exports (by country of destination) - electricity - annual data” and “Supply, transformation, consumption – fuel type - annual data”

tion of the current Tier 1 and Tier 2 approach is therefore feasible for all Member States. The Tier 3 approach needs a partial model of the electricity sector to determine the emission factor for the marginal power plants. The previous project calculates the impact assessment for Germany exemplarily with the PowerACE model[84].

The definition of the policy induced development of RES-E needs further refinement and clarification for all Tier levels considering autonomous development of RES-E. Another important task is further understanding of the interaction of the RES-E Directive and the EU ETS and CHP policies, which highly influence the power sector as well.

4.2.2 Proposed improvements and refinement methodology

For all Tier levels, the definition and derivation of the policy induced development of RES-E has to be clarified further. This means the derivation of autonomous development of already cost-effective plants as well as the interaction with national RES-E policies which have been implemented independently of the RES-E Directive.

One approach to define autonomous RES-E development is to consider RES-E with marginal costs less than the average electricity price as not induced by the RES-E Directive. In general this affects mainly large hydro power plants. However, the RES-E Directive targets also non-cost barriers for renewable electricity. Therefore the overall RES-E development could also be defined as policy induced in total. Against that, electricity generation from biological waste treatment should be excluded, due to electricity generation is generally a secondary product of waste treatment only.

As opposed to this task the definition of the Tier 1 and Tier 2 emission factor on European respectively national level is seen to be an adequate methodology. On Tier 3 level the emission factor of the marginal power plants has to be derived with a partial model of the electricity sector.

For Tier 1, the following improvements are suggested:

- Definition of autonomous RES-E only for electricity generation from biological waste treatment. All other RES-E generation is defined to be policy induced by the RES-E Directive.
- The emission factor to calculate the environmental impact is derived from the European energy mix in the electricity sector including all energy sources not covered by the RES-E Directive. Corresponding to the methodology in the upcoming reporting under the Renewable Energy Directive (2009/28) and to the suggestions of the previous project, nuclear power plants should be excluded from the calculation of the emission factor.
- For the calculation of the economic impact, generation based and installation based subsidies can be distinguished. For RES-E policy based on feed-in tariffs, quota-

[84] Quantification on the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019), Methodologies Report Appendix II, p. 167, 2009.

based tradable certificates or bonus systems, the economic impact can be derived as product of RES-E electricity generation and feed-in tariff, certificate price or bonus minus average electricity price. For RES-E policy based on investment subsidies or tax reduction, the economic impact can be derived as product of installed RES-E capacity with investment subsidy or tax reduction. Another cost proportion arises from connecting the power plant to the grid. These costs maybe included into electricity grid charges of the network operator.

For Tier 2, the following improvements are suggested:

- Definition of autonomous RES-E development and calculation of the additional electricity generation from renewable energy sources as described for Tier 1.
- The emission factor to calculate the environmental impact is derived from the national energy mix in the electricity sector including all energy sources not covered by the RES-E Directive. Corresponding to the methodology in the upcoming reporting under the Renewable Energy Directive (2009/28) and to the suggestions of the previous project, nuclear power plants should be excluded from the calculation of the emission factor.
- Improvements for the calculation of the economic impact are the same as for Tier 1 approach.

For Tier 3, the following improvements are suggested:

- The partial model of the electricity sector should include plant dispatching as well as investment decisions to cover short term and long term effects. Therefore the dispatching model PowerFlex and the power plant investment model ELIAS can be taken into account. The models and their linkage and interaction are described in section 4.1.2.
- The development of RES-E in the counterfactual scenario should also consider the effect of autonomous RES-E development as described for the Tier 1 and Tier 2 approaches.
- The environmental impact is calculated with the dispatching and investment models of the electricity sector as described in section 4.1.2. The scenario analysis takes the empirical power plant fleet for the baseline scenario and a model-based determined power plant fleet for the counterfactual scenario into account.
- The cost assessment described for Tier 1 and Tier 2 can be refined with electricity prices and RES-E feed-in on hourly resolution.

<u>Data assessment and consistent data base</u>

The relevant data input for the impact assessment of the power sector is described in section 4.1.2.

4.2.3 Summary and conclusions

The methodology to determine the environmental impact on Tier 1 and Tier 2 does not consist of major improvements and consists of good data availability. It is therefore seen not to be a candidate for methodology testing. Opposed to this the improved methodology for the assessment of the economic impact is suggested for further testing on Tier 3 level.

The suggested improvements on Tier 3 level should be tested in combination with the EU ETS policy for selected Member States to improve the understanding of policy interactions. The evaluation of policy interaction is based on a scenario analysis with 4 scenarios (counterfactual without EU ETS and without RES-E Directive, counterfactual without EU ETS but with RES-E Directive, counterfactual without RES-E Directive but with EU ETS and the policy scenario with EU ETS and with RES-E Directive). For the power sector it will show differences concerning electricity mix, electricity prices and CO2 emissions for example, In combination with the macroeconomic model E3ME, it shows interactions concerning electricity prices and investment, providing many of the macroeconomic costs described in Chapter 2 (GDP, employment, structural and distributional impacts). Impacts on air quality can be assessed in a limited manner using the same approach described for the EU ETS.

4.3 CHP Directive

4.3.1 Review and critical assessment of existing methodology

The current Tier 1 methodology does not constitute a policy impact assessment, but an analysis of what contribution CHP has provided to GHG reduction since the introduction of the CHP Directive, regardless of whether this contribution is policy-induced or corresponds to the autonomous development of CHP[85]. In this regard, Tier 1 does not distinguish between the baseline (policy scenario considering the CHP Directive) and the counterfactual scenario (without considering the CHP Directive).

CO_2 reduction due to CHP is estimated by calculating CO_2 emissions from fuel use in CHP plants and comparing CHP electricity and heat production to CO_2 emissions from European average electricity generation and from heat generation in gas-fired heat-only boilers[86].

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[85] Quantification on the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019), Methodologies Report, p. 50, 2009.

[86] Quantification on the effects on greenhouse gas emissions of policies and measures (ENV.C.1/SER/2007/0019), Final Report Appendix I, p. 47, 2009.

One major gap concerning the ex-post evaluation of the CHP Directive have been significant data problems identified in the previous project concerning the fuel type specific disaggregation of CHP EUROSTAT data. Therefore assumptions had to be made for the Tier 1 approach.

EUROSTAT data are now available on a more detailed base which allows for disaggregating input and output data related to CHP plants in further categories. This relates to fuel input as well as to heat and electricity generation (both in gross and net values). Generally, CHP and heat-only or electricity-only power plants are separated in EUROSTAT which allows using data relevant for CHP only. Furthermore, data is differentiated with regard to whether CHP heat is produced by autoproducers or as a main activity. Furthermore, data are differentiated with regard to fuel types. This allows calculating CO_2 emissions from fuel combustion in CHP plants in a rather accurate manner.

The now generally available CHP data are the major improvement concerning the conclusions of the previous project. The explicit split of inputs and outputs in CHP and non-CHP data therefore renders unnecessary the assumptions with regard to the efficiency of CHP plants made in the report of the previous project. Furthermore, since fuel types are available in a disaggregated manner, fuel-specific CO_2 emission factors (instead of generally using the CO_2 emission factor of natural gas as proposed in the previous project) can be used for estimating CO_2 emissions of CHP plants.

In addition, EUROSTAT contains fuel-specific fuel consumption of overall electricity generation for member states. This allows estimating the EU average CO_2 emission factor for electricity generation as needed for the proposed Tier 1 methodology. CO_2 emission reductions related to the displacement of heat is based on the assumption of a natural gas-fired heat-only boiler and an assumed thermal efficiency of 85%.

Furthermore, since autoproducers are separated from main activity CHP producers, the assumption by the methodology that the increase of CHP production by autoproducers is autonomous (i.e. not policy-induced) can be implemented with the data available by EUROSTAT.

According to the report of the previous project, Tier 2 allows for a first order policy impact assessment enabling a simple differentiation between the baseline (policy scenario) and the counterfactual scenario. It aims at increasing the level of detail using sectoral data on heat demand. Furthermore, CHP technologies are to be differentiated on a sectoral level and the number of CHP installations and the installed capacity at a sectoral level need to be identified. New CHP technologies should be identified. With regard to the average emission factor for electricity generation, average Member State values are to be used.

As regards sectoral disaggregation of data, EUROSTAT provides final energy consumption in different sectors. However, there is no information available with respect to the CHP data at a sectoral level. Furthermore, heat production as well as installed capacity is available for CHP in a technology- and fuel-specific disaggregation. However, there is no information available on sectoral CHP capacity or sectoral heat demand. In this regards, a first order policy impact assessment as suggested by the report of the previous project is not feasible with the data available in EUROSTAT. Furthermore, there is no further methodological information available on how this sectoral analysis would need to be performed[87]. As regards the CO_2 emission factor for electricity generation on a member state level as suggested by the previous project, the corresponding data is available (cf. Tier 1 above). National CO_2 emission factors can therefore be calculated. Generally, due to the lack of data on a European level and the lack of further methodological guidance, the Tier 2 methodology can therefore be applied only in a very limited manner. National data may be used instead (as suggested by the previous report for the case of the Netherlands).

As regards Tier 3, the previous report does not explicitly provide a methodological procedure. However, the methodological discussion describes the need for analysing the economics of CHP and for discerning the policy impact of national CHP legislation from the CHP Directive as well as the impact of the CHP from other ECCP policies. In this regard, there is a differentiation between the baseline scenario and the counterfactual scenario. However, this kind of information is not available in EUROSTAT and therefore requires a deeper analysis based on national data.

In the previous report, there is no methodological approach for the estimation of socio-economic costs related to the CHP Directive.

4.3.2 Proposed improvements and refinement of methodology

Assessment of environmental impacts and socio-economic costs

The methodologies for estimating CHP reduction effects as proposed by the previous study can be further improved based on the findings of the review above as well as on further considerations.

For Tier 1, the following improvements are suggested:

- It is proposed that the reference value for heat production be based on a boiler efficiency of 100% (formerly 85%). An efficiency of 100% corresponds to the best available technology regarding heat-only boilers (condensing boilers). An upward adjustment of the efficiency would also result in more conservative emission reduction estimates.
- The estimation of CO_2 emissions of CHP plants should be based on the fuel-specific fuel consumption available in EUROSTAT and corresponding CO_2 emission factors by IPCC.
- The assumption that the development of CHP production by autoproducers can be considered as autonomous improvement is not a plausible general assumption (and therefore requires more specific analyses in Tier 3). For this reason, CHP pro-

[87] A discussion on the application of Tier 2 to the case of the Netherlands is available as a case study, though.

duction should be equally considered (as CHP production from main activity producers) for the evaluation of effects of the CHP Directive.

- A comparison of the CHP reductions effects in a specific year against the levels in 2004 (as suggested in the previous report) is certainly a valid assumption for Tier 1. All emission reductions achieved since 2004 would then be attributed to the CHP Directive.
- Socio-economic costs can be estimated on two levels. Firstly, compliance costs by operators can be estimated based on unit costs of CHP production (as described in Table 3.8 in comparison to unit costs of electricity production of alternative technologies. Secondly, policy (administrative) costs can be estimated by multiplying the additional CHP generation induced by the Directive with a unit cost of CHP support (e.g. CHP bonus per kilowatt hour of CHP electricity). Corresponding data should relate to European average values.

As regards Tier 2, the following improvements are suggested:

- As outlined above, a combined sectoral and technology-specific disaggregation of CHP is not feasible with EUROSTAT. For this reason, a first order policy assessment cannot be performed in Tier 2. A more in-depth analysis should be carried out in Tier 3.
- Other suggestions for Tier 1 related to fuel-specific fuel consumption, to the reference value of boiler efficiency as well the distinction between autoproducers and main activity CHP producers are also applicable for Tier 2.
- Socio-economic costs can be estimated in analogy to Tier 1. Corresponding data should relate to national values.

Regarding the Tier 3 approach, an in-depth analysis regarding the impact of the CHP Directive in comparison to a scenario without the directive should be performed allowing for a detailed differentiation between the baseline (policy scenario) and the counterfactual scenario. Since national CHP legislation is usually linked to the CHP Directive, its impact should be considered equal to the impact of the CHP Directive (i.e. part of the baseline scenario). The following approach could be chosen. Based on typical operating hours of CHP plants (and other power plants) provided by the PowerFlex model, the investment in new power plants is estimated for the counterfactual scenario (without CHP Directive)[88] and for the case with the CHP Directive (baseline scenario) using the power plant investment model ELIAS. CHP promotion by the directive can ideally be reflected in the model by incorporating related grants, feed-in tariffs, etc. which affect the profitability and thus the investment in different plant types. The difference in investment in new CHP plants between both scenarios corresponds to the investment effect of the CHP Directive. Similarly, investment effects induced by other

[88] Another option of defining the baseline scenario would be to consider empirical data on CHP construction as outlined in Section 4.1.2.

measures (e.g. EU ETS) can be estimated and roughly separated from the effects of the CHP Directive based on a scenario analysis considering different combinations of EU ETS, RES-E Directive and CHP Directive (see section 4.1.2).

The actual CO_2 reduction effect by the CHP Directive can be calculated by using the PowerFlex model for both scenarios (power plant fleet with and without the implementation of the CHP Directive) and by estimating corresponding CO_2 emissions. Furthermore, reference values for heat production as proposed for Tier 1 and 2 should be used to estimate the CO_2 reduction effect related to the additional CHP heat production.

Socio-economic costs can be estimated on several levels. Firstly, compliance costs for investment in CHP technology is estimated by considering the difference in the power plant structure between the baseline and counterfactual scenario and corresponding investment costs. Secondly, policy costs can be estimated by considering additional CHP generation (or additional CHP capacity installed) and the corresponding governmental support (grants, feed-in tariffs, bonuses, etc.). Finally, costs related to the overall economy can be estimating overall costs for the supply of electricity in the counterfactual and the baseline scenarios using the PowerFlex model. Furthermore, additional cost or benefits due to fuel savings and changing heat prices (e.g. district heating in comparison to heat-only boilers) can be estimated based on PowerFlex model results.

Data assessment and consistent data base

- For Tier 1 and 2, data related to GHG reduction effects correspond to the data described in the previous report (EUROSTAT and IPCC). These are now available and can be used for the estimation.
- For estimating socio-economic costs in Tier 1 and 2, unit costs of CHP production (in comparison to unit costs of electricity generation of other technologies) as well as policy costs (CHP support) need to be collected on a EU level (Tier 1) and a national level (Tier 2).
- For the estimation of GHG reduction effects as well as socio-economic costs, data on investment costs as well as energy-economic framework conditions (fuel prices, CO_2 prices, CHP subsidies, heat prices, etc.) as well as other power sector-related data (such as load curves or feed-in curves of renewables) need to be collected.

4.3.3 Summary and conclusions

The improved availability of CHP data in EUROSTAT allows for estimating CO_2 emissions from fuel consumption of CHP plants as well as the CO_2 emission factor of electricity generation on a more disaggregated level (fuel-specific fuel consumption, separation of CHP from non-CHP generation as well as separation of CHP production from autoproducers from main activity CHP generation) which enables the estimation of CO_2 reduction effects based on Tier 1. Assumptions regarding the electric efficiency of boilers as well as regarding the consideration of CHP generation from autoproducers as autonomous development should be further improved. Socio-economic costs can be estimated by collecting EU average values for unit costs of CHP production (in comparison to electricity generation from other technologies) and CHP support data (grants, bonuses, etc.).

As regards Tier 2, a first order policy assessment cannot be performed due to a lack of data. More disaggregated data of CHP production as well as improved assumptions regarding boiler efficiency should be used in analogy to Tier 1. Socio-economic costs should be estimated in analogy to Tier 1, but based on national data.

Regarding Tier 3, a methodology for estimating CO_2 reduction effects induced by the CHP Directive is proposed. Firstly, additional power plant investment due to the promotion of CHP (by feed-in tariffs, grants, etc.) is estimated in the power plant investment model ELIAS. The difference in corresponding CO_2 emissions related to electricity generation is estimated with the PowerFlex model. CO_2 reductions due to the displacement of heat from heat-only boilers are calculated in analogy to Tier 1 and 2. Socio-economic costs can furthermore be estimated by using data on CHP investment costs, on CHP support schemes and corresponding modelling results of the PowerFlex model (electricity price).

The testing of the improved Tier 1 and 2 methodologies should be performed for representative Member States corresponding to the share of CHP. For the testing of the improved Tier 3 methodologies, the estimation of the non-policy induced CHP scenario (counterfactual scenario) is a crucial task.

4.4 Biofuels (Directive 2003/30/EC)

Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport required the Member States to introduce legislation and take the necessary measures to promote biofuels (liquid or gaseous fuels used for transport and produced from biomass) account for a minimum proportion of the fuel sold on their territory. The reference value for these targets was set at 5.75 %, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2010.

4.4.1 Review and critical assessment of existing methodology

The methodology of the ex-post evaluation for the EU biofuels policy done by the former consortium has been reviewed and the most important factors which can influence the outcomes of the ex-post analysis are written down in this paragraph. The following paragraphs describe and motivate which of the improvements are proposed in this project.

Summary of Tier 1, 2 and 3 approach for biofuels

In the previous project the methodology had three levels of complexity (Tier 1, Tier 2, Tier 3) which are distinguished in the following manner:

> **Tier 1 approach:** calculates impacts based on the total biodiesel and bioethanol consumption in EU-27, and uses EU average default emission factors for each of the two main groups.

> **Tier 2 approach:** calculates total impacts based on the total biodiesel and bioethanol consumption per MS combined with MS specific average default emission factors for each of the two main groups.

> **Tier 3 approach:** calculates impacts based on streams of specific feedstock/type of biofuel combinations at MS level, combined with MS specific emission factors for these individual streams. However, due to a lack of data on specific feedstocks for most of the MS (except for Germany) the refined calculation could not be carried out for a larger number of countries.

These methods are applicable to the EU biofuel policy in the 2003-2008 period as well as to the current policy based on the FQD and RED.

In the Renewable Energy Directive (2009/28/EC) and the Fuel Quality Directive (2009/30/EC) typical emission well-to-wheel GHG emission factors are listed for a wide range of biofuel type / feedstock type combinations. These typical values can be used as inputs for determining the EU average emission factors in the Tier 1 approach and the MS specific emission factors in the Tier 2 and 3 approach. Our interpretation of the terminology "EU / MS specific emission factors" is that these are to be derived by weighting the typical emission factors for different fuel / feedstock combinations, as listed in the FQD and RED, over the EU or MS specific distribution of biofuel / feedstock streams. This exercise already mimics a large part of the tier 3 approach, so that amendment of the Tier 1 and 2 approach to base them on the recent emission factors from the RED / FQD diminishes the methodological distinction between the three approaches.

Gaps identified in the previous project's approach

For Tier 1 methodology

The Tier 1 approach adopted in the previous project was simple in its nature, but perfectly adequate for the level of complexity. Apart from including default emission factors based on the RED / FQD there is no need for adjustments of the tier 1 methodology.

For Tier 2 methodology

Member State specific average default emission factors for bio-diesel and bio-ethanol are to be used. The emission factors, however, are intended to be taken from the data published in the renewable energy and fuel quality directives, which are EU average typical emission factors for different biofuels from a range of feedstocks. This seems to imply that MS specific emission factors for specific biofuels, as used in the Tier 2 approach, are only MS specific in as far as they are determined based on weighting of the emission factors for production of that biofuel from different feedstocks over the MS specific distribution of feedstocks. However, it is not clear from the report how this is done and what the MS specific feedstock distributions are.

Member State specific emission factors per feedstock, depending on details of the production chains from which a MS obtains its biofuels, could be a further detailing of the analysis, provided that such detailed, production chain specific emission factors are available. At some point in time this might be based on information from certificates of origin. For the moment, however, such further detailing does not appear feasible and is not considered as part of the proposed methodology for Tier 2. .

For Tier 3 methodology

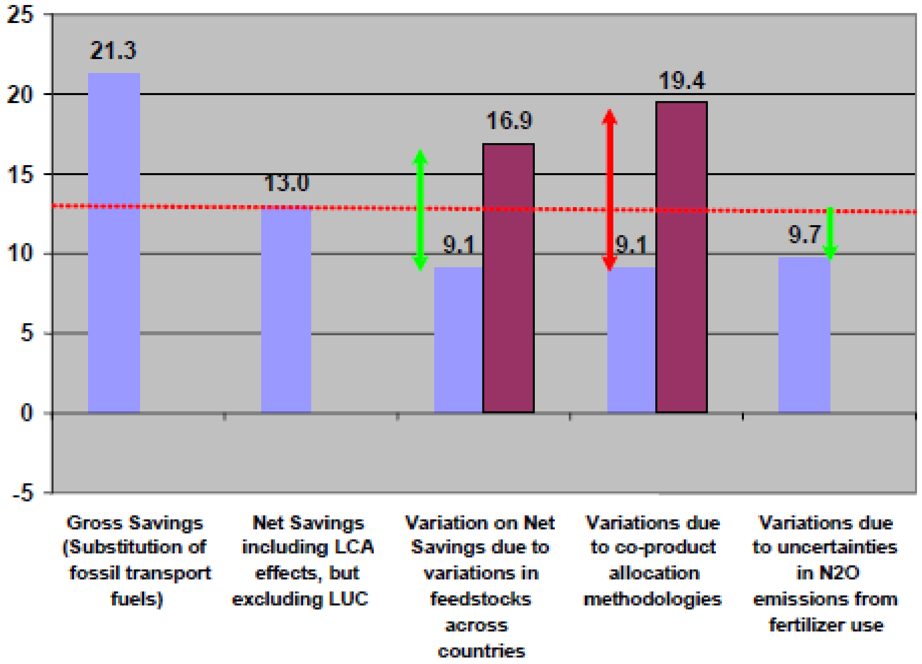
In the tier 3 approach the omission of effects of Land Use Change (LUC), as well as the relative lack of Member State specific feedstock streams, give clear directions for future improvements. It needs to be found out to which extent information on MS specific feedstock streams can be obtained from MS reporting or other monitoring work.

Emission factors for biofuels from MS specific feedstock / production chains

The inclusion of MS specific feedstock data would be a clear improvement. The previous report only reports the findings for Germany. There is however a Tier 3 result for the EU15 too in the report. It is unclear what these results are based on. It may be that aggregated data at EU level are available, but a split between the Member States was not available or found. Clearly, inclusion of such feedstock stream data would improve the level of detailed insight and realism.

Figure 4.5 Figure 4-5 from the final report of the previous project.

Figure 4-5 Biofuels Directive: sensitivity analysis for the different factors affecting the CO_2 savings (Mt CO2 equ. in 2007 for the EU27)



Note: The dotted red line represents the result derived using EU average conditions. Variations due to methodological choices are shown as red arrows. Variations due to data issues are shown as green arrows.

As a further comment to the above graph the previous report mentions that: "The difference between gross and net savings is changing rapidly (the red dashed line). The data on variations in feedstocks across countries (green arrows) as well as methodological issues (red arrows) could be improved along the lines presented in the present report."

It is expected that the methodological issues with respect to allocation of GHG emissions to co-products can be resolved on the basis of the calculation methodology used for deriving the typical emission factors as listed in the RED and FQD.

With respect to the assessment of feedstock streams it should be noted that the Commission is preparing for the monitoring of Directive 2009/28. Consultants contracted by DG Energy are working on a baseline report for this which should include methodologies in these areas.

A remarkable outcome of the previous project, however, is the surprisingly small difference between the results for the Tier 2 and Tier 3 methodology. This could be the results of the fact that for most countries both are underpinned by the same emission factors.

Land use change

The report elaborates on direct and indirect land-use change. When the production of biofuels results in direct land use change, producers need to calculate these emissions according to the methodology included in the Renewable Energy and Fuel Quality Directives. This could also be considered at some point in time based on information from certificates of origin. For the moment, however, such further detailing does not appear feasible and is not considered as part of the proposed methodology for Tier 2.

With regards to indirect land use change, the available knowledge is reviewed and based on this. The previous project decided that the effects of iLUC could not yet be included in the methodology. The impact of iLUC, however, could be large.

The Commission recognises that iLUC can reduce the contribution of biofuels to GHG emission reduction and discussions are currently looking at whether/how this should be addressed. Depending on the outcome of on-going work, the inclusion of default emission factors for indirect land-use change as soon they become available could therefore be another clear recommendation.

Recommendations from the previous project

The previous project recommended the following further research to improve the evaluation methodology for GHG emission reduction due to bio-fuel use:

1. The well to tank GHG emissions of the bio-fuel (this is currently part of the emission factors and is widely accepted, although individual parts of the LCA such as N_2O release from fertilisers are subject to a high variation)
2. Emissions arising from land-use change. Direct land use change emissions could be reported in detail in future if reported information could be based on certificates of origin. With regards to indirect land use change, should a methodology be proposed by the Commission in the frame of the Renewable Energy and Fuel Quality Directives, these default emission factors for indirect land-use change could be included in the ex post assessment methodology as soon as they emerge.
3. As developments in this sector move very quickly, default emission factors for the tier 1 approach need to be updated on a regular basis.
4. Rising energy prices. If in future years the price of oil will further increase, biofuels will benefit from this as they will become more competitive.
5. Technological development. Innovations and further increase in production scale will probably reduce cost of bio-fuel and making them more competitive.

Regarding the evaluation and development of possible improvements of the ex-post CO_2 impact assessment methodology this project will focus on improvements at the tier 2 and 3 level with respect to the issue nr. 2, as well as on exploring options for improving emission factors for Member State specific feedstocks and types of bio-fuels.

Issue 1 is considered relevant but requires detailed study beyond the scope of the current project. Issue 3 is relevant but should be treated in the context of the periodic review of the Renewable Energy and Fuel Quality Directives. Issues 4 and 5 are not considered a methodological issue, but rather to relate to the periodic generation of input data for the assessment of CO_2 impacts and cost effectiveness.

4.4.2 Proposed improvements and refinement of methodology

Improvement of the methodology for assessment of CO_2 impacts

Given the limitations of available data on the share of individual bio-fuel streams in the total bio-fuel consumption at the national level as well as on the life cycle emissions associated with specific bio-fuel feed stocks and production chains, the Tier 3 approach can currently still not be tested. The data needed to perform such an analysis are at least not readily available. Therefore a methodology should be developed and at the same time the availability of mentioned data should be investigated. These actions do not fit within the scope and budget of the present project. Indications that mentioned data are in principle available would be welcome, because without these data, the approach will for sure not be feasible. The project will therefore focus on identifying approaches for resolving the data availability issues associated with the Tier 3 approach. An assessment of what has changed with respect to the availability of data in the last two years will be done. Furthermore obstacles for a more refined calculation will be identified, e.g. related to the need for labelling the various feedstocks.

Making use of the publication of the Renewable Energy and Fuel Quality Directives and the resulting availability of detailed typical well-to-wheel emission factors, the Tier 2 approach will be updated and improved.

Recently a number of studies on (indirect) land use change in relation to biofuels have been carried out for the European Commission:

- the JRC AGLINK modelling[89]
- the first IFPRI modelling[90]
- the JRC model comparison exercise[91]
- the JRC spatial Allocation Model[92].

There is also a further refinement of the IFPRI study with Monte Carlo analysis of the (indirect) LUC values, which has now been published[93]. In addition to this also a recent review of the various modelling analyses[94], requested by the EP, and a recent review carried out by CE Delft are available. In light of these developments and the complexity

[89] http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=3439

[90] http://trade.ec.europa.eu/doclib/docs/2010/march/tradoc_145954.pdf

[91] http://re.jrc.ec.europa.eu/bf-tp/download/ILUC_modelling_comparison.pdf

[92] http://re.jrc.ec.europa.eu/bf-tp/download/EU_report_24483_Final.pdf

[93] http://trade.ec.europa.eu/doclib/docs/2011/october/tradoc_148289.pdf

[94] http://www.mvo.nl/Portals/0/duurzaamheid/biobrandstoffen/nieuws/2011/03/EP%20rapport.pdf

of the issue it considered that further study into (indirect) LUC emissions factors within this project is neither feasible nor adding value.

Since all the studies referred to as well as the Commission's work are forward-looking it may however be useful assess how relevant such work is for ex-post evaluation (and how factors such as the use of set-aside land during the implementation of Directive 2003/30 can be taken into account).

Development of a methodology for assessment of costs

In addition to assessing CO_2 impacts, options for ex post assessment of costs and economic impacts will be explored. Identifying appropriate sources for information on biofuel costs and prices is an important element of this work.

As the previous study did not address this in detail, a first step in developing a method for ex post cost assessment should be to better define what the purpose and approaches will be.

Market prices are relatively well-known but actual production costs are more difficult to assess and thus require more attention. Whether prices or costs need to be used in an assessment of societal costs of biofuels policies, depends on the origin of the biofuels:

Imported biofuels can be considered a commodity so that the international market price (exclusive of taxes) can be used as proxy for the societal costs. In that case the feedstock and production chain for a given biofuel do not influence the cost assessment and can be used for the Tier 1, 2 and 3 approaches.

For biofuels produced within the country in which they are used (or within the European Union when assessing cost effectiveness from an EU perspective) the production costs are the required input for calculating cost effectiveness from a societal perspective. In this case costs do depend on the specific origin and production chain of the biofuel. Actual production cost data are not generally available in the public domain, however. Nevertheless, for the Tier 1 and 2 approaches estimating such costs incidentally is expected to be possible with sufficient accuracy on the basis of literature, market surveys and expert information. For the Tier 3 approach the required detail is at the level of individual biofuel producers, so that cost information will be difficult to obtain. Monitoring development of these costs over time in a detailed way (e.g. on an annual basis) will very likely not be possible.

Provided that sufficient information can be found to monitor cost trends, TREMOVE or another model may be used to identify second order impacts of biofuel costs on transport performance (kilometres driven), and to separate the impact of the Biofuels Directive from the impact of other policy measures and trends.

The main improvements to be developed are:

Tier 1

- A method to regularly update the default LCA emission factors for various bio-fuels.
- An appropriate method to assess costs at Tier 1 level.

Tier 2

- Default emission factors for indirect land use change impacts to be incorporated into the tier 2 approach.
- An appropriate method to assess costs at Tier 1 level.

Tier 3

- An EU monitoring system should be developed and put in place that is aimed at detailed monitoring of the various feedstock streams and associated costs / prices. Such a system will enable detailed consideration of contributions by specific feedstock or type of bio-fuel, including any reported direct land use change emissions, at the member state level as well.
- Also for the Tier 3 approach default emission factors for indirect land use change impacts should be incorporated.

Assessment of environmental impacts (focus on GHG)

PAMs addressing GHGs and other air pollutants should focus on GHGs but may analyze other air pollutants to the extent they have an impact on costs and benefits. For the impact of bio-fuels three topics of the total bio-fuels consumption are of major importance:

1. The domestically produced amount of bio-fuels as part of the total consumption
2. The imported amount of bio-fuels as part of the total consumption
3. The exported amount of domestically produced bio-fuels (if applicable).

The total bio-fuel consumption (on an aggregated level) can be derived from the national energy supply balance, as reported to EUROSTAT. This provides data on the national primary production of bio-fuels and the amounts imported and exported. The balance of this constitutes the gross national consumption.

The environmental impacts from the first mentioned topic can ideally[95] be derived from the national GHG inventory (energy transformation and –use, LUC). This also holds for topic 3. The environmental impacts from imported bio-fuels can partly be derived from the GHG inventory (energy transformation and -use) but the iLUC aspects should be assessed separately.

[95] In historic inventories, the bio-fuels emissions may not be included in detail.

For the Tier 1 approach the default emission factors for the various bio-fuels should be up to date. With the rapidly developing technology in this field, LCA GHG impacts may change quickly. For that reason some system of regularly updating the default emission factors must be installed.

With the Tier 2 approach the impacts of direct and indirect land use change are important to assess. This is possible only if default emission factors for (in)direct land use change are agreed upon. At present the impact of LUC on the emissions can most suitably be addressed in a Tier 3 approach where specific feedstock streams are considered at a MS level. Development of methods to include these effects in the ex-post assessment methodology, however, has to wait until ongoing work at the EU level has reached agreement on the size of these effects and general methodologies to assess them.

Furthermore the previous report mentions that effects of cultivation of the soil, including exhalation of N_2O (from fertilizers) should be incorporated. N_2O emissions, however, are already included in the typical emission factors for different biofuels as listed in the FQD and RED.

For a Tier 3 approach the individual specific feedstock streams that are used for biofuel production, and any reported direct land use change emissions, must be assessed. This most detailed form of assessment requires many, detailed data. Most of these data are not easily accessible and getting them would require a great effort. It will probably not be easy to conduct a full Tier 3 assessment in the near future.

Assessment of socio-economic costs

The implicit assumption in the previous report was that bio-fuels are –for the time being- not an economically competitive alternative for conventional fuels. This leads to a problem that the 'normal' costs of a certain feedstock or bio-fuel in a market not influenced by incentives and/or legal obligations, are no longer available. In an artificially stimulated market, the price is no longer an appropriate indicator for costs. Thus, societal costs should therefore be calculated bottom up with an agricultural scientifically sound model. Such bottom-up calculations do not fit within the present projects budget nor scope, but should form an integral part of the proposed approach.

To complicate matters further, the methods of promoting use of biofuels differs per Member State. There are MS that use tax exemptions on Biodiesel or Bioethanol, others using blending targets only for both or one of the prominent biofuels. This was specifically the case for the 2003-2008 period in relation to Directive 2003/30/EC. In response to the RED and FQD most Member States appear to implement the legislation through mandatory targets.

In practise there is a vast array of combinations of the possible policies among the MS. This implies, however that a socio-economic cost assessment must be based on a Member State specific approach. The additional costs for substitution of conventional fuels by biofuels will depend on local availability (of biofuel or feedstock to produce it from) and the global market for that product, which is influenced by the increased demand in the European Union[96]. If this approach of analysing per MS (including EU trade measures for imported goods) is adopted, though, it should be possible to arrive at a realistic estimate of societal cost for the biofuel stimulating measures. This may seem a quite complicated task, but fortunately there is no need to split between the effects of national (MS specific) and European regulation. The national measures are all implementations of policies to meet obligations set by the European Union.

The societal costs for importing and/or domestically producing biofuels is another matter though. Here a feedstock stream specific analysis should be made. A fundamental difficulty with this approach will remain getting reliable feedstock specific cost data for the locally produced biofuels. The cost of the feedstock itself should be deductable from available EU and FAO production and cost data. The production costs for the fuel may be harder to obtain, but could be estimated from available data. A bottom-up approach from studies in this or related process industry may give enough detail to arrive at reliable production costs estimates for the various biofuel streams.

Data requirements

Tier 1

Accessible and reliable cost and volume data for imported streams of bio-fuels or raw feedstock / intermediates. For internally produced bio-fuels, the production costs for specific types of bio-fuel (if needed, split over feedstock and production process used) must be available.

For a societal cost estimate of the policy measures, an aggregated EU 27 level of costs should be available as well. In principle, this is the same as the weighted average of the various member state specific costs.

Further the base price of fossil fuels must be available as well.

Tier 2

Again, reliable cost and volume data for imported streams of bio-fuels or raw feedstock / intermediates must be available. However, here a greater level of detail is required, so that individual bio-fuels and/or raw feedstock streams can be assessed. For internally produced bio-fuels, the production costs for specific types of bio-fuel must be available.

For a societal cost estimate of the policy measures, an aggregated EU 27 level of costs should become available as well. This level could be deduced from historic world and EU market cost prices (split per biofuel or major raw feedstock type). For domestically

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[96] Pelkmans, L., Govaerts, L. and Kessels, K. (2008). Inventory of biofuel policy measures and their impact on the market. Report of ELOBIO subtasks 2.1-2.2.

< http://www.elobio.eu/fileadmin/elobio/user/docs/Elobio_D2_1_PolicyInventory.pdf >

produced biofuels (from foreign and domestic feedstock alike), it may be difficult to obtain reliable cost data, because of producer specific processes and rapidly advancing / changing technology in this field

Tier 3

For the more detailed assessment, reliable cost and volume data must be available for streams of individual types of bio-fuel and raw feedstock species split out per member country as well as well as at aggregated EU27 level.

For a societal cost estimate of the policy measures, a MS specific level of costs should be available as well. This level could be deduced from historic world and EU market cost prices (split per biofuel or major raw feedstock type). For domestically produced biofuels (from foreign and domestic feedstock alike), it may be near impossible to obtain reliable cost data, as these will be producer specific in the tier 3 approach.

4.4.3 Summary and conclusions

For further improving the methodology of assessing effectiveness of GHG policy measures in the field of biofuels, the previous project presented a useful framework for assessing effectiveness. The approach was split in three levels of detail: tier 1 addressing impacts of biofuel use with EU average emission factors, tier 2 doing the same with more detailed, MS specific emission factors, and tier 3 incorporating feedstock and production process specific data. The basic approach was worked out quite well already, the two more advanced tiers can be improved upon. Improvements with respect to the assessment of impacts on CO_2 emissions, as brought forward in this project, include:

- For Tier 1: regular update of emission factors (necessary due to rapidly changing biofuel technology)
- For Tier 2: determination of default emission factors that incorporate indirect land use change.
- For Tier 3: A monitoring system to be developed and put in place that is aimed at detailed monitoring of the various feedstock streams, including reporting their direct land use change emissions.

In addition a method will need to be developed for collecting cost information and for assessing costs and cost effectiveness of the biofuels policy. Monitoring costs may be difficult as a large part of this information is generally not available in the public domain. It is, however, assumed likely that such data can be approximated with satisfactory quality based on literature data and expert knowledge for the purpose of periodic surveys of ex-post costs and impacts.

4.5 CO_2 regulation for new cars

4.5.1 Introduction

The emissions from road transport have continually increased since 1990 while emissions in many other sectors are decreasing. Because of this, the EU is very active in creating regulations aiming at decreasing the CO_2 emissions from road transport. The aim of this section is to develop a methodology of the ex-post evaluation of the effects and costs of the CO_2 regulations for new cars.

4.5.2 CO_2 regulations for passenger cars

To control greenhouse gas emissions from the transportation sector, the European Commission signed voluntary agreements with the automotive industry to reduce the emissions of carbon dioxide. Three agreements were signed in 1998-1999, with the following associations:

- ACEA—European Automobile Manufacturers Association (Association des Constructeurs Européens d'Automobiles): BMW, DaimlerChrysler, Fiat, Ford, GM, Porsche, PSA Peugeot Citroën, Renault, VW Group.
- JAMA—Japanese Automobile Manufacturers Association: Daihatsu, Honda, Isuzu, Mazda, Mitsubishi, Nissan, Subaru, Suzuki, Toyota.
- KAMA—Korean Automobile Manufacturers Association: Daewoo, Hyundai, Kia, Ssangyong.

Cars sold by the members of the above mentioned associations represented about 90% of the total EU vehicle sales.

The agreements define a fleet-average CO_2 emission target for new cars sold in the European Union, to be reached collectively by the members of each association.

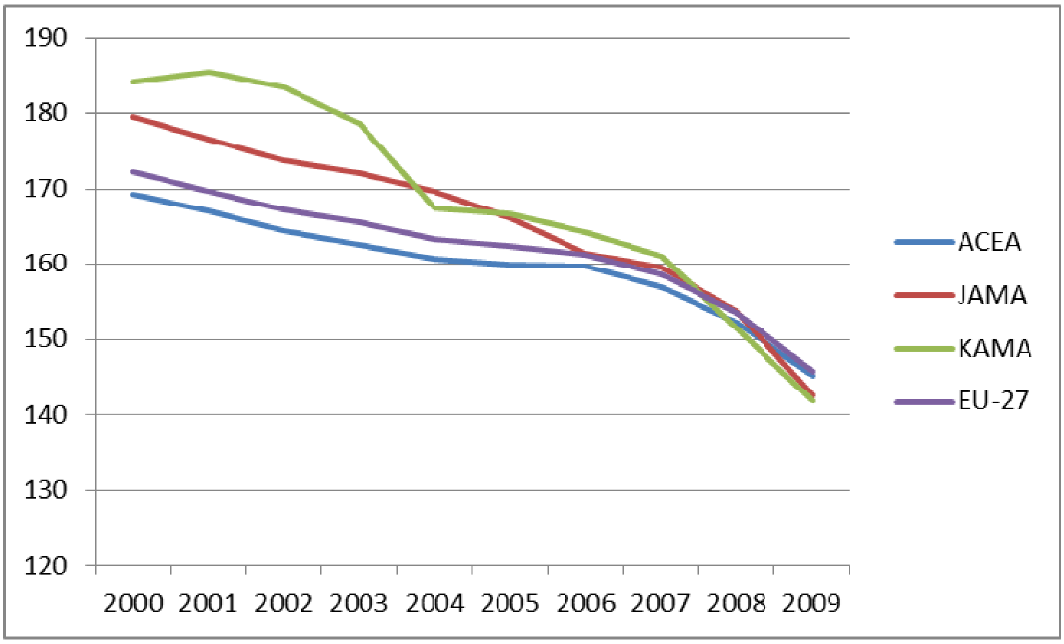
The ACEA Agreement, signed in March 1998, included the following major provisions:

- An averaged CO_2 emission target of 140 g/km to be reached by 2008 (this target represented a 25% reduction from the 1995 level of 186 g/km)
- An intermediate target range of 165-170 g CO_2/km by 2003
- The possibility to extend the agreement to 120 g CO_2/km by 2012
- Individual ACEA members to introduce models of 120 g CO_2/km or less by 2000

Japanese and Korean manufacturers (JAMA and KAMA) signed similar commitments to that of ACEA, target of 140 gCO_2/km to be reached by 2009.

Progress toward the CO_2 emission targets was monitored jointly by the European Commission and by ACEA. Average CO_2 emissions from new light-duty vehicles for the period of 2000-2009 have decreased as shown in Figure 4.6.

Figure 4.6 Average CO_2 emissions (2000-2009), g/km



Note: CO_2 figures for ACEA, JAMA and KAMA have been adjusted for the change in the test procedure (a 0.7% downward adjustment from the New European Driving Cycle measurement (NEDC[97]), while the EU-27 figures are non-adjusted measurements (ECE+EUDC[98] cycle according to Directive 93/116/EC).

In spite of the significant CO_2 emission reductions achieved in the initial years and a 5% drop recorded in 2009 (in part due to economic recession and in part by the advent of the regulation and national tax incentives for low CO_2 cars), none of the three associations was able to reach the 140 g/km target by 2008/2009. Therefore, the voluntary agreements were replaced by mandatory CO_2 emission regulations from new light-duty vehicles in 2009.

With this, the Commission developed a mandatory CO_2 emission reduction program. Two separate regulations cover CO_2 emissions from passenger cars and light commercial vehicles

- CO_2 emission targets for new passenger cars were adopted on 23 April 2009 *(Regulation 443/2009/EC)*[99]. The regulation established a fleet-average

[97] Technical Guidelines for the preparation of applications for the approval of innovative technologies pursuant to Regulation (EC) No 443/2009 of the European Parliament and of the Council,
URL: http://ec.europa.eu/clima/policies/transport/vehicles/cars/docs/guidelines_en.pdf

[98] See URL http://www.dieselnet.com/standards/cycles/ece_eudc.php

[99] REGULATION (EC) No 443/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles

CO_2 emission target of 130 g/km to be reached by 2015. The regulation also defines a long-term target of 95 g CO_2/km to be reached from 2020.

- CO_2 emission targets for light commercial vehicles were proposed in May 2011 *(Regulation 510/2011/EU)*[100]. The regulation sets the average CO_2 emissions for new light commercial vehicles at 175 gCO_2/km and from 2020 sets a target of 147 gCO_2/km.

The regulations cover only CO_2 emissions, other greenhouse gases are not regulated.

Passenger Cars

A fleet-average CO_2 emission target of 130 g CO_2/km must be reached by 2015. This fleet averaged target is translated into manufacturer specific targets, that must be met by these individual manufacturers using vehicle technology. To meet the EU CO_2 emission target of 120 g CO_2/km, a further emission reduction of 10 g CO_2/km is to be provided by additional measures, such as the use of biofuels. A blending of transport fuels with an average 10% biofuel would be necessary to do so.

The specific emissions target for each manufacturer in a calendar year is based on the vehicle mass. It is calculated as the average of the *Specific Emissions of* CO_2 (g/km) of each new passenger car registered in that calendar year, where:

$$\textit{Specific Emissions of } CO_2 = 130 + 0.0457 \times (M - M_0)$$

In the above formula, M is the mass of the vehicle (kg), and M_0 is 1372 kg for calendar years 2012-2015. From the end of 2014, the value of M_0 will be adjusted every three years to reflect the average mass of passenger cars in the previous three calendar years. Thus, the target of 130 g/km is directly applicable to vehicles of an average mass, while lighter cars have lower CO_2 targets and heavier vehicles have higher CO_2 targets.

The regulation is phased-in over the period from 2012 to 2015. Manufacturers must meet their average CO_2 emission targets in 65% of their sales in 2012, 75% in 2013, 80% in 2014 and 100% from 2015.

[100] REGULATIONS REGULATION (EU) No 510/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 May 2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO2 emissions from light-duty vehicles

4.5.3 Proposed methodology

In a previous project "Quantification of the effects on greenhouse gas emissions of policies and measures" an advanced methodology related to the ACEA agreement was developed. This methodology was critically reviewed in this study.

As the ACEA agreement has been superseded by the current CO_2 legislation (Regulation 443/2009 and Regulation 510/2011), improvements to the 3 tiered methodology were developed in view of application of the methodology to the current CO_2 legislation.

The earlier project defined three tiers for the ex-post evaluation of the ACEA agreement in relation to GHG emission impact. There was no methodology developed for assessing the costs. The definition of the tier levels as worked out in the former project is recapitulated in the next table (Table 4.1).

Table 4.1 3-tiered methodology proposed by the former project.

Tier 1 – EU level

The assessment of the policy impact over the period since the voluntary agreement was implemented is made on the following basis:

The upper bound of the policy impact is estimated from the time series of:

- emission rates of new cars;
- number of new registrations; and,
- average distance travelled per passenger car.

No corrections are made for dieselisation or autonomous progress (the performance of new cars is evaluated as compared to the base year 1995), i.e. frozen efficiency at 1995 levels is assumed.

Tier 2 – MS level

In the Tier 2 methodology, national data for the emission rate of new vehicles (g CO_2/km) substitutes EU averages. The assessment of the policy impact over the period since the voluntary agreement was implemented is divided into two components:

1. First, the upper bound of the policy impact is estimated from the time series of:
   - emission rates of new cars;
   - number of new registrations; and,
   - average distance travelled per passenger car.

This is similar to Tier1 but using national emission rates.

2. Then, the impact of the shift from petrol to diesel fuel is calculated and its effects removed from the upper bound. The methodology assumes that the shift to diesel was not influenced by the voluntary agreement and so cannot be attributed to it. (The correction due to dieselisation is 12% for the EU 15.)

No correction is made for autonomous progress.

Tier 3 – Detailed calculations using an appropriate transport model

In summary, the methodology for a Tier 3 ex-post analysis is:

1. Reproduce the historical data, given the bottom-up calculation methodology in an appropriate transport model.
2. Assess the importance of specific factors. These are:
   - Firstly, what is the rate of autonomous technological progress? This can be identified from the historical trend of gCO_2/km per vehicle in the period before the ACEA agreement, e.g. in the period 1990-1996.
   - Mix of Petrol and Diesel cars, given their different time trajectories in emissions performance.
   - Then, there is a comfort factor increasing the indicator g/km: the change in the composition of the vehicle stock by size class, reflecting the development of manufacturers' marketing policies, consumer preferences and wealth.
   - Fiscal policies such as the car taxation according to CO_2 impact.
   - Fuel price
   - Use of low emission fuels.
3. The 'unexplained' change in emissions factor can then be taken as the impact of the ACEA agreement (which assumes, of course, that all other major factors have been identified and their impact accurately assessed).

According to the previous project, the Tier 1 and 2 levels seem to overestimate the CO_2 reduction of the ACEA agreement. As a result this project focused on (an improved) Tier 2 approach. It can be done since more detailed data on new registered cars in the EU became available. The added value of this project was to make an attempt to assess the costs of the implementation of the CO_2 regulations. The available cost data are very limited but some information about the effect of emission reduction on the production costs of new cars became available from recent studies. In this project, an indicative exploration is proposed to assess the cost effectiveness of the EU regulations for new cars.

Environmental effects of the CO_2 regulation

All regulations concerning new cars are aimed at reduction of the carbon emission factor. Therefore the effect of the regulations can be estimated based on a comparison of actual and the hypothetical (without regulation) emissions. The actual and hypothetical development of CO_2 emissions can be estimated using available data.

The hypothetical CO_2 emissions scenario assumes a constant CO_2 emission factor for the years following 2000. The actual emission scenario uses as much as possible detailed data on reported/projected energy use and emission data. Comparison of both scenarios reflects the impact of different parameters (such as changes in fuels, engine capacity, mass, power) and as such will provide a quantitative range of the possible impact of the measure on the development of CO_2 emissions from new cars.

The Regulation 443/2009/EC requires Member States to record information for each new passenger car registered in its territory. Every year, each Member State shall submit to the Commission all the information related to their new registration. In particular, the following details are required for each new passenger car registered: manufacturer name, type, variant, version, make and commercial name, specific emissions of CO_2, mass in running order, wheel base and track width. Additional information, such as fuel type, fuel mode and engine capacity were also submitted. The somewhat aggregated, database is publicly available at the EEA website.[101]

Vehicle stock data used for the evaulation were derived from the TREMOVE[102] datasets. TREMOVE is a policy assessment model, designed to study the effects of different transport and environment policies on the transport sector. The model estimates for technical and non-technical measures and policies such as road pricing, public transport pricing, emission standards, subsidies for cleaner cars etc., the transport demand, modal shifts, vehicle stock renewal and scrap page decisions as well as the emissions of GHG, air pollutants and the welfare level. TREMOVE models both passenger and freight transport. The model covers all inland urban and interurban transport modes - road, rail, water and air transportation. It covers the period 1995-2030. At the moment, input databases are calibrated to feed the model for 31 countries (EU-27 plus Croatia, Norway, Switzerland and Turkey).

The following data were used in the environmental analysis.

1) For each manufacturer in each MS:

a) Total number of new cars registered by fuel type for each year between 2000 and 2009 (number)
b) Distribution of these cars over engine capacity classes (number) to aggregate the new cars into size classes (small, medium, large) [103]
c) Averaged CO_2 emission factor by engine capacity classes[103] (gCO_2/vkm)[104]
d) Averaged respectively mass, power and engine capacity by class[103]

2) Averaged mileage for new cars (vkm from TREMOVE)

Please note that the above classification method introduces a flaw in the calculation method. No correction is made for the impacts of autonomous trends in mass and power-to-weight ratio. What is observed is that cars of the same model gain weight over time (for instance the current VW Golf is 400 kg heavier than the first model). Also performance of cars has increased due to increased kW/tonne ratios. Both trends

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[101] http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-1

[102] http://www.tremove.org/

[103] As these classes form the aggregation level in the publicly available database. The underlying more detailed data will also be available for use by the EU and it's Member States.

[104] Specific emission factor from EEA database (type approval emissions)

would lead to increased CO_2 emissions if no measures were taken to improve the efficiency of vehicles. The current available data sources do not provide enough detail to address and quantify these effects.

With the available data two trends of the development of the CO_2 emissions, actual and hypothetical were calculated. The following formula was applied:

$$E_{CO_2}(y) = \sum_{classes} N_{class}(y) * Mileage_{class}(y) * EF_{CO_2,class}(y)$$

In actual CO_2 emission scenario $EF_{CO_2,class}(y)$ reflects the CO_2 emission factors in year y while in the hypothetical scenario it was assumed that within each class the averaged CO_2 emission factor did not change since the year 2000[105]. Table 4.2 presents the actual and hypothetical CO_2 emissions from new cars (diesel and petrol) in 2009. The emission reductions achieved for petrol are larger than those for diesel cars. As the emission reduction from new cars last over the total lifetime of the vehicle and the replacement of the current fleet progresses the total impact of the regulation will increase.

Table 4.2 CO_2 actual and hypothetical emissions [Gg] from new cars for the year 2009

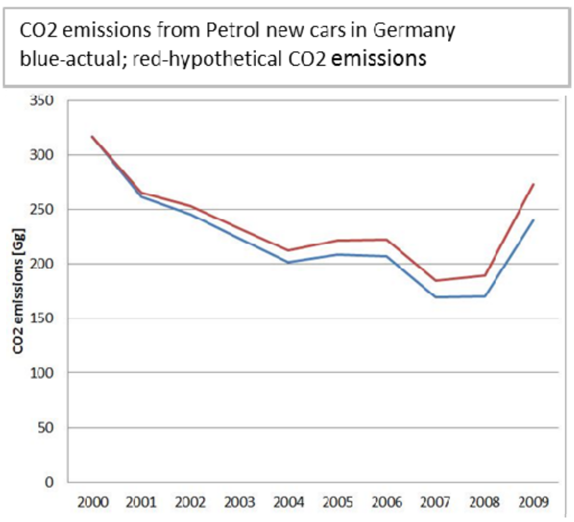
Member State	Diesel			Petrol			Emissions from road transport [Gg]	share of emissions from new cars
	Actual Emissions [Gg]	Hypo-thetical Emissions [Gg]	Δ	Actual Emissions [Gg]	Hypo-thetical Emissions [Gg]	Δ		
Austria	32.10	32.88	2%	13.53	15.09	11%	20893.74	0.22%
Belgium	83.30	88.71	6%	7.49	8.66	16%	25914.06	0.35%
Bulgaria	2.85	2.89	1%	0.46	0.47	1%	7618.90	0.04%
Cyprus	0.25	0.27	7%	0.41	0.44	9%	2251.09	0.03%
Czech Republic	16.12	17.13	6%	6.31	6.79	8%	17289.93	0.13%
Germany	256.85	268.90	5%	239.74	273.01	14%	144134.20	0.34%
Denmark	18.54	19.25	4%	8.76	10.31	18%	12159.77	0.22%
Estonia	0.42	0.44	4%	0.37	0.40	8%	1995.51	0.04%
Spain	140.53	140.89	0%	21.05	23.84	13%	86114.04	0.19%
Finland	16.26	16.34	0%	6.32	6.96	10%	11277.71	0.20%
France	280.98	290.22	3%	57.41	67.58	18%	122270.41	0.28%

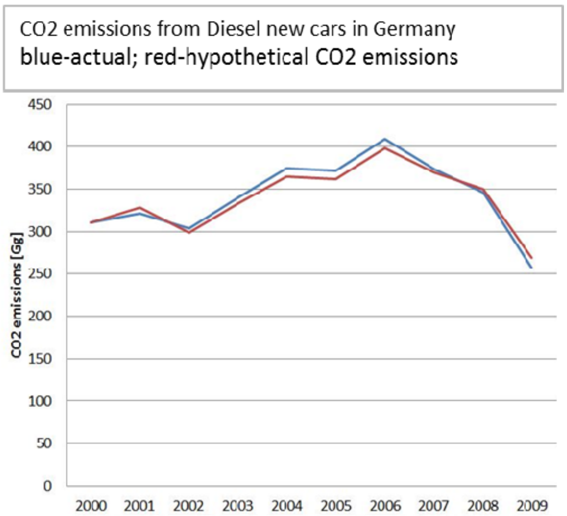
[105] Sometimes there was no data for the year 2000 (specific class of cars were not existing/sold) then the oldest available data was used.

Member State	Diesel			Petrol			Emissions from road transport [Gg]	share of emissions from new cars
	Actual Emissions [Gg]	Hypo-thetical Emissions [Gg]	Δ	Actual Emissions [Gg]	Hypo-thetical Emissions [Gg]	Δ		
Greece	4.72	4.84	3%	14.58	16.76	15%	20964.32	0.09%
Hungary	4.74	4.88	3%	3.05	3.33	9%	11992.22	0.07%
Ireland	8.88	9.64	8%	3.03	3.30	9%	11859.79	0.10%
Italy	112.99	116.46	3%	41.20	46.44	13%	109905.73	0.14%
Lithuania	0.52	0.53	2%	0.13	0.14	11%	3965.41	0.02%
Luxembourg	9.61	10.14	6%	1.06	1.23	16%	5822.93	0.18%
Latvia	0.41	0.43	6%	0.24	0.25	7%	2848.76	0.02%
Malta	0.07	0.07	4%	0.08	0.09	9%	496.27	0.03%
Netherlands	35.69	37.54	5%	35.98	42.68	19%	33343.93	0.21%
Poland	12.78	12.53	-2%	7.30	7.85	8%	43879.90	0.05%
Portugal	22.86	24.64	8%	4.70	5.29	13%	18262.65	0.15%
Romania	5.54	5.67	2%	4.15	4.22	2%	14389.72	0.07%
Sweden	47.99	60.29	26%	13.08	14.35	10%	18752.39	0.33%
Slovenia	5.02	4.99	-1%	2.41	2.56	6%	5204.23	0.14%
UK	183.15	196.07	7%	134.33	154.96	15%	110811.97	0.29%

Figure 4.7 below presents the trend of the actual and hypothetical CO_2 emissions from new cars [Gg] for Germany (petrol and diesel). The increasing emissions from new petrol cars are due to the increase in sales. The CO_2 emissions decreased but the observed effect is very small.

Figure 4.7 CO_2 emissions [Gg] from new cars in Germany





As described the CO_2 emission factors for EU new cars are decreasing as a result of the environmental policies which were introduced. However, this effect is very small compared to the overall emissions from road transport up till now, as the new cars constitute only a small fraction of the total passenger car fleet. (CO_2 emissions from new cars had a share <0.35% in total emissions from road transport, Table 4.2). The impact of the regulation will increase as new cars (with lower emissions) will replace the current fleet.

Cost effectiveness of CO_2 regulation

A cost assessment of the CO_2 regulations should be made mainly on the basis of the additional manufacturing costs due to the application of more efficient vehicle technologies and the associated fuel cost savings. Those manufacturing costs could (partly) be translated into higher purchase prices (and some-times higher maintenance costs). This together with the reduced running (fuel)costs, will influence the consumer behaviour.

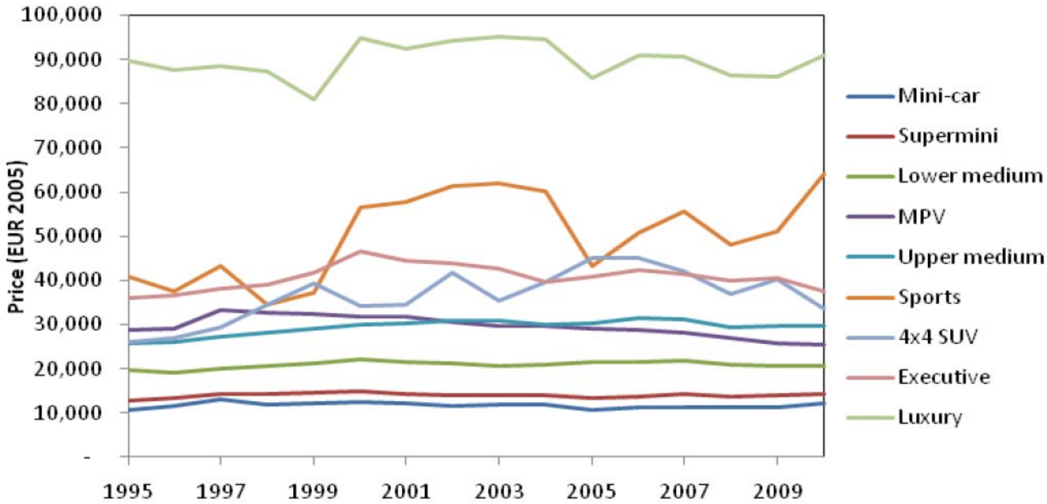
There is no database available which can provide the specific costs and savings needed for an in-depth analysis. Information on sales prices could become available, however, due to strategic pricing strategies, the actual sales price of vehicles will not always reflect the costs for technological development. Because the costs cannot be made transparent in an ex-post analysis, it is proposed to use ex-ante costs to calculate the cost effectiveness, which are available from ex-ante studies. We note that that this will be a conservative estimate and the overall cost based on the ex-post cost curves would most likely be lower, due to technical developments.

Detailed data on vehicle prices is not available in the public domain. However, there is some information available. For example the AEA report (2011)[106] presents the average vehicle list price (indexed for inflation and exchange rates) for each of the size categories within the dataset bought from JATO[107] (Figure 4.8).

[106] AEA, 2011. Effects of regulations and standards on vehicle prices

[107] JATO Dynamics Ltd, provide a suitable dataset. The dataset covers list price and selected feature data for the top ten selling models in 2010 for six Member States, plus twenty other models that are representative of each particular nation's vehicle choices in 2010. The terms and conditions of accessing the data does not allow it to be reproduced in its original form http://www.jato.com/USA/Pages/Default.aspx

Figure 4.8 Evolution in the average prices of passenger cars in each size category over the period 1995-2010 in EUR 2005



Source: JATO Dataset

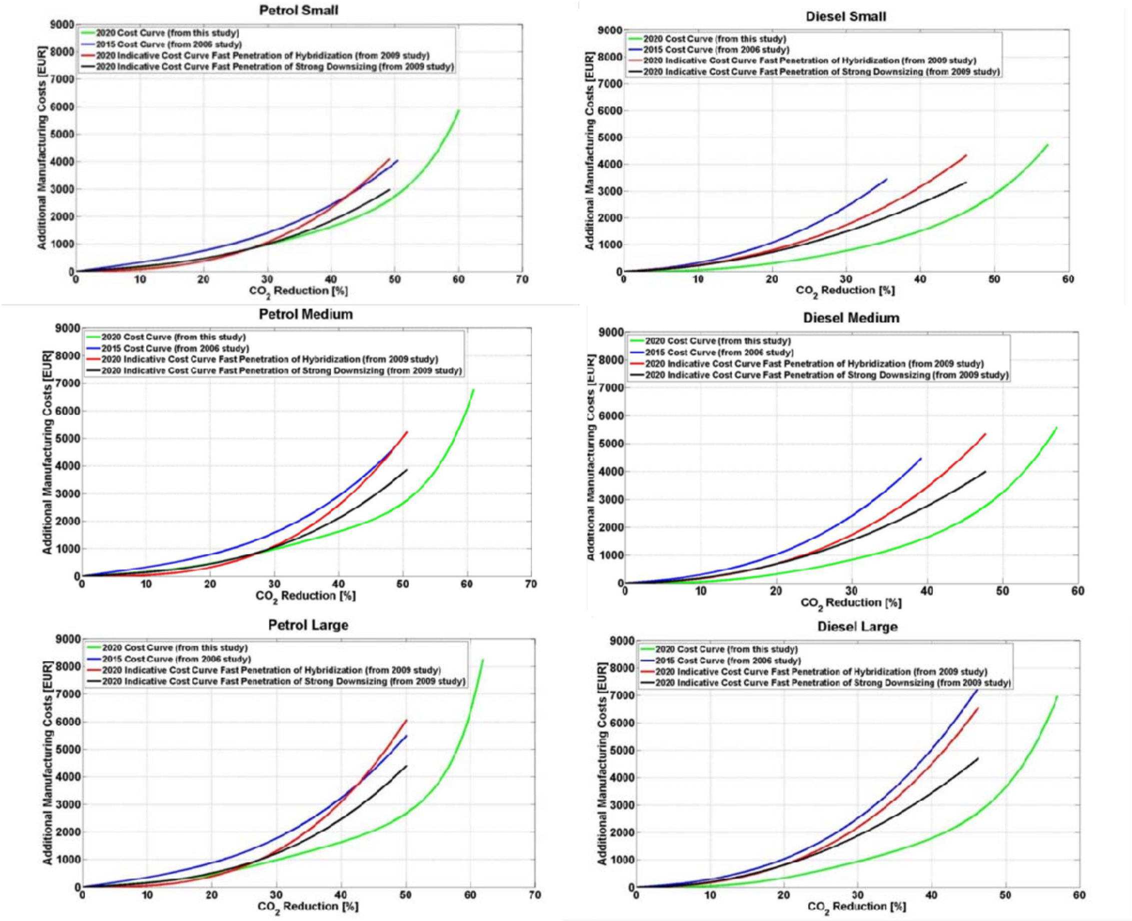
As Figure 4.8 shows, no big change in price of passenger cars (with exception of sport cars) were observed. This was confirmed by the conclusions of the AEA, 2011 study, that the evidence from the JATO dataset does not provide any definite relationship between policy regulations (Euro standards) and car prices. Moreover, it was concluded that direct costs (manufacturing costs) are managed by new technologies such as platform sharing, quality control systems and statistical process control techniques (e.g. six sigma). Growth in environmental, safety and product regulation has led to a wide range of strategies and practices by manufacturers to balance production costs and regulatory compliance. However the fact that prices do not change, or even that net production costs do not change, does not mean that measures, taken on cars to meet environmental demands, do not have a net economic cost. Without those measures cars would have been cheaper. So also for costs there is a baseline issue which cannot be quantified on the basis of available data.

Based on the literature review the most appropriate cost curves, presented in the latest study[108] were selected (Figure 4.9). The cost curves for 2020 from this study were originally used to assess the 95 g/km target for 2020. In the longer term the reduction potential is higher and the costs for a given reduction are lower. The differences are

[108] Support for the revision of Regulation (EC) No 443/2009 on CO2 emission from cars. Framework Contract No ENV.C.3./FRA/2009/0043
http://ec.europa.eu/clima/policies/transport/vehicles/cars/docs/study_car_2011_en.pdf

caused by additional technologies that become available in the longer term, by learning effects, but also by improved insights in costs of various options.

Figure 4.9 Cost curves for petrol and diesel cars in 2020 compared to cost curves presented in other studies (Smokers, 2006; Sharpe and Smokers, 2009).



The cost curves are for three size segments (small, medium, large) of petrol and diesel vehicles. All of the cost curves (Figure 4.9) present a relatively small increase of additional manufacturing costs for the first 20% of CO_2 reduction. For additional manufacturing cost of CO_2 reductions by 20% the 2020 cost curve shows max 500 EUR and the 2015 cost curve 1000 EUR per vehicle.

To estimate the cost effectiveness it is necessary to know the number of registered new cars, the emission effects and the additional manufacturing costs[109]. Since the

[109] The impact of mass change and possibly kW/tonne change in new cars is not included in this analysis. The costs for technologies applied to compensate those trends may not need to be attributed to the regulation, but the fact that some additional technology is already needed to

cost curves are available per 3 car classes and 2 fuel types, the number of new cars and emission effects in EU27 are calculated for these classes (Table 4.3). The CO_2 emission effect was calculated as a relative difference between CO_2 EF in 2009 and the CO_2 EF as it was in 2000. In some cases data for the year 2000 were not available and in such cases the oldest available EFs were applied.

Table 4.3 Average environmental effect of decreased type approval CO_2 emission factors. (Based on number of registered new cars in 2009 in EU27)

	Diesel						
	Small		Medium		Large		Not defined diesel
	cars nr	Effect	cars nr	Effect	cars nr	Effect	
EU27	2860999	-1.2%	2423709	-3.6%	940490	-2.3%	5684
	Petrol						
	Small		Medium		Large		Not defined petrol
	cars nr	Effect	cars nr	Effect	cars nr	Effect	
EU27	4744052	-14.3%	2068144	-11.4%	248259	-12.0%	17493

At EU27 level, the achieved CO_2 reductions were 2.4% for new diesel cars (between -1.2% and -3.6%) and 12.6% for new petrol cars (between -11.4% and -14.3%).

A rough estimation was done using the 2015 cost curve. However, it has to be stressed that to assess the costs of already implemented policies ex-post cost curves should preferably be used. The additional manufacturing costs for new cars were estimated as 4200 mln € (200 mln for diesel cars and 4000 mln € for petrol cars).

The cost analysis presented in this report uses a very simplistic approach.

A reliable detailed cost effectiveness of the CO_2 regulation for new cars could not be calculated as several (partly counteracting) effects cannot be quantified on the basis of currently available data. Especially the definition of a good baseline for the costs is not possible as the autonomous developments (without CO_2 regulation) in car mass, power to mass ratio and fuel efficiency (and the attributable costs) are not known/quantifiable. Furthermore fuel savings have to be accounted for in a cost effectiveness assessment and this should also include either total costs of the vehicle over its lifetime related to lifetime GHG emission reductions, or that annual emission savings are somehow re-

maintain the CO_2 emission level, combined with the non-linearity of the cost curves, leads to higher costs for the observed net reductions.

lated to amortised costs. The fact that the annual mileage tends to reduce with vehicle age should also be incorporated in a detailed cost effectiveness analysis.

At the moment the required data to quantify above mentioned aspects is not available or insufficient to develop a generic EU method for an ex-post cost effectiveness assessment of the CO_2 regulation.

Ex-ante cost curves could be used to make a rough estimate but this approach does not account for the above mentioned relevant aspects.

Indicators

The proposed indicator for quantifying the effects of policy on CO_2 emissions from new cars is: CO_2 emission reduced (%). It is expressed as actual emissions minus baseline emissions from new cars ($GgCO_2$) divided by baseline emissions from new cars (Gg).

4.5.4 Summary and conclusions

The CO_2 emission factors for EU new cars are decreasing as a result of the environmental policies which were introduced. However, new cars at present constitute only a very small fraction of the total passenger car fleet. The impact of the regulation will increase as new cars (with lower emissions) will replace the current fleet.

A detailed EU method for ex-post cost effectiveness assessment of the CO_2 regulation could not be developed as the required data are not available or insufficient.

The following aspects determining the emission and cost development of new cars (without CO_2 regulation) cannot be distinguished in the required detail:

- autonomous trends (increasing) in mass and power-to-weight ratio;
- autonomous trends in sales and price;
- running costs (fuel efficiency and amortization);
- annual mileage as function of the age of the vehicles.

4.6 F-gas Regulation & MAC Directive

4.6.1 Legislative Instruments

The key legislative instruments on European level directed to fluorinated gases are

- Regulation No 842/2006 on certain fluorinated greenhouse gases (F-gas Regulation) and
- Directive 2006/40/EC relating to emissions from air-conditioning systems in motor vehicles (MAC Directive)

Both legislative acts address emissions of fluorinated greenhouse gases (F-gases) such as HFCs, PFCs and SF6, which have high global warming potentials and are controlled under the Kyoto Protocol. The F-gas Regulation applies since 4 July 2007 with the exception of Article 9 and Annex II, which apply since 4 July 2006. Measures of the MAC Directive are expected to reduce F-gas emissions from 2011 onwards.

The F-Gas regulation addresses

- the containment, use, recovery and destruction of those gases;
- the labelling and disposal of products and equipment containing F-gases;
- the reporting of information on those gases;
- the control of use;
- the placing on the market prohibitions of some products and equipment;
- the training and certification of maintenance personnel and companies handling F-gases.

The MAC Directive requires gradual phase-out of F-gases with GWP >150 (in fact: HFC-134a) in new systems in the period 2011-2017 in EU-27.

As no reliable cost estimates for the additional cost incurred by the MAC Directive are available yet, this study focusses on the F-gas regulation.

Early national policy measures on Member State level addressing F-gases were based on existing ODS (ozone depleting substances) legislation, which was extended to F-gases or applied to sectors relying on both ODS and F-gases. For example, in France, recovery of CFCs, HCFCs and HFCs was mandatory from 1992 onwards. Since 1992, the Danish KMO system and the Dutch STEK system have been working on the prevention of emissions of all types of halogenated refrigerants and on training and certification of personnel and companies. After the European commitments for reduction goals of GHG emissions under the Kyoto Protocol, some Member States have individually implemented their measures gas addressing GHG emissions in addition to European legislation. Early legislation on F-gas emissions entered into force in e.g. in Denmark (March 2001) and Austria (December 2002).

Certain provisions of the F-gas Regulation have been transposed into national legislation by most Member States, some even decided to establish provisions of national legislation which are stricter than the requirements of the F-gas Regulation with regard to scope and mechanisms of different measures.

4.6.2 Review and critical assessment of existing methodology

In the previous project it was recommended that a Tier 3 approach, applied at subcategory level, would be the most appropriate to capture the interactions between the policy and F-Gas emissions. It was concluded that undertaking such assessment, would require a significant amount of data that are currently not available. Therefore no adequate results were calculated in the initial study.

Meanwhile, however, the European Commission (DG CLIMA) published a technical study in 2011 (Schwarz et al. 2011)[110] which covers, among others, the quantification of emission reductions affected and costs incurred by the F-Gas Regulation. In the context of that study the bottom-up 'AnaFGas' model was developed for DG CLIMA featuring 21 F-gases and 29 F-gas using sectors differentiated by Member States. EU-wide implementation costs were estimated for seven cost categories, partially differentiating between sectors and EU regions. Thus, a highly complex Tier 2/3 method for assessing the F-gas regulation is available and data has been compiled.

For the present study, we base the environmental analysis on the AnaFgas model. AnaFgas (Analysis of Fluorinated greenhouse gases in the EU-27) is a bottom-up stock model to derive consumption and emission scenarios for F-gases from the relevant sectors and sub-sectors for the EU-27 Member States. A short overview of AnaFgas is given in Box 6.

[110] Schwarz et al. 2011: Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases; Final Report & Annexes to the Final Report. Prepared for the European Commission in the context of Service Contract No 070307/2009/548866/SER/C4

Box 6 Summary characterisation of AnaFgas model

AnaFgas

- models consumption and emissions of HFCs, PFCs and SF6 for the period 1995 to 2050 based on market data
- estimates of the quantity of equipment or products sold each year containing these substances (F-gases),
- estimates the amount of substances required to manufacture and/or maintain equipment and products over time.
- in total features 21 different F-gases (12 HFCs, 7 PFCs, SF6 and NF3)
- separately represents seven sectors with a total of 29 sub sectors (cf. Figure 4.10)

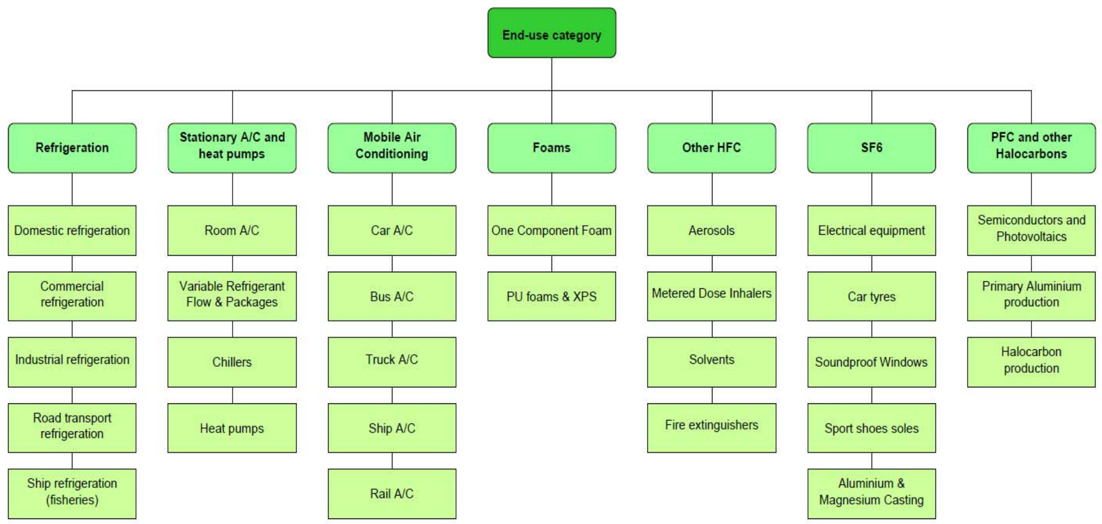


Figure 4.10 Sectoral structure of the AnaFgas model

The AnaFgas model's sectoral and computational structure is based on the IPCC 2006 guidelines for emission reporting under the UNFCCC. AnaFgas is based on a counter-factual "without measures (WOM)" consumption and emission scenario for the EU-27 which reflects for each MS the situation that would must like have occurred since 1995 (baseline year for F-gases under the Kyoto Protocol) without the 2006 EU policy intervention (F-gas Regulation, MAC directive). However, national mitigation measures which existed prior to the F-gas regulation are accounted for in the WOM. The counter-factual consumption and emission scenarios are based on sub-sector specific growth assumptions. In comparison to a "with measures (WM)" reference scenario, the effects of the F-Gas regulation can be modelled on a Tier 3 basis.

Thus, a Tier 3 method for assessing the F-gas regulation is available and data has been compiled. The methodological approach is described in detail in the above mentioned Schwarz et al. 2011 study. Estimates for both F-gas emissions and abatement cost[111] at MS and EU level are calculated within that study. Specific insight to the F-Gas consuming and emitting subsectors presented onwards in this chapter on F-gases generally draws from that study.

4.6.3 Proposed improvements and refinement methodology

4.6.3.1 Overview

Within the present study, we develop a simplified approach for assessing emission reduction and cost estimates based on the highly complex AnaFgas model. This simplified Tier 2 approach is evaluated and tested with Tier 3 model and is proposed for future use by Member States in the assessment of their PAMs directed to F-gases is to be developed.

At present, all MS have developed F-gas inventories and report their activity data. In the IPCC 2006 guidelines for emission reporting Tier 2 and Tier 3 approaches are proposed which rely on the same sectoral structures and computational paths. However, Tier 2 and Tier3 approaches are differentiated along the use of default (Tier 2) vs. country-specific (Tier 3) emission factors.

For the simplified approach, we concentrate on those few source sub-categories that account for the major part of the F-gas emissions and/or of the emission reduction potential as assessed with the AnaFgas model. For those “key” categories we undertake the deduction of generalised parameters in order to come up with simplified assessment methodologies for Member States’ F-gas directed PAMs. The results for the analysed key categories can finally be scaled to estimate full emission reduction and abatement costs.

The environmental (GHG-reduction) and economic (direct costs to industry and regulators, both one-off and recurring costs) assessment takes place against a counterfactual “without measures” (WOM) scenario reflecting the situation that would likely have occurred since 1995 (baseline year for F-gases under the Kyoto Protocol) without the 2006 EU policy intervention (F-gas Regulation, MAC Directive). However, Member States’ mitigation measures which existed prior to the F-gas regulation should also be accounted for in the WOM. In parallel, the environmental and cost effects of any implementation of the F-gas Regulation or the MAC Directive exceeding the respective minimum requirements are not to be taken into account.

As we suggest a set of default values for key parameters derived from the AnaFgas which in application by the Member States may be replaced by country specific values, the proposed methodology might be labelled as a simplified Tier 2 / Tier 3 approach

[111] GHG reductions incurred by the MAC Directive are included in the AnaFgas model. However, abatement cost estimates in that study do not include the costs to comply with the MAC Directive.

4.6.3.2 Choice of key F-gas emitting subsectors for the simplified assessment approach

Using the IPCC's CRF sectoral split, the major share of F-gas emitting sources as well as of estimated effects of EU F-gas legislation are grouped together within CRF category 2F1 (Refrigeration and Air Conditioning Equipment), cf. Table 4.4.

Table 4.4 Sectoral (CRF) shares of EU27 emissions and emission reductions

Sectoral (CRF) shares of EU 27 Emissions (reference - with measures)					
	2015			2030	
2F1	Refrigeration and A/C Equipment	78%	2F1	Refrigeration and A/C Equipment	78%
2F4	Aerosols/ Metered Dose Inhalers	8%	2F4	Aerosols/ Metered Dose Inhalers	10%
2F9	Other	3%	2F8	Electrical Equipment	3%
2F8	Electrical Equipment	3%	2F2	Foam Blowing	3%
2F2	Foam Blowing	2%	2E	Prod. of Halocarbons and SF6	2%
2E	Prod. of Halocarbons and SF6	2%	2F7	Semiconductor Manufacture	2%
2F7	Semiconductor Manufacture	1%	2C3	Aluminium Prod.	1%
2C3	Aluminium Prod.	1%	2C4	SF6 used in Al & Mg Foundries	1%
2C4	SF6 used in Al & Mg Foundries	1%	2F9	Other	1%
2F5	Solvents	0%	2F5	Solvents	0%
2F3	Fire Extinguishers	- %	2F3	Fire Extinguishers	- %
2F6	Other appl. using ODS substitutes	- %	2F6	Other appl. using ODS substitutes	- %
Sectoral shares of EU 27 Emission reductions in comparison to counterfactual scenario					
	2015			2030	
2F1	Refrigeration and A/C Equipment	88%	2F1	Refrigeration and A/C Equipment	94%
2F2	Foam Blowing	6%	2F2	Foam Blowing	3%
2C4	SF6 used in Al & Mg Foundries	3%	2C4	SF6 used in Al & Mg Foundries	1%
2F4	Aerosols/ Metered Dose Inhalers	2%	2F4	Aerosols/ Metered Dose Inhalers	1%
2F9	Other	1%	2F9	Other	1%
2F8	Electrical Equipment	0%	2F8	Electrical Equipment	0%
2C3	Aluminium Prod.	- %	2C3	Aluminium Prod.	- %
2E	Prod. of Halocarbons and SF6	- %	2E	Prod. of Halocarbons and SF6	- %
2F3	Fire Extinguishers	- %	2F3	Fire Extinguishers	- %
2F5	Solvents	- %	2F5	Solvents	- %
2F6	Other appl. using ODS substitutes	- %	2F6	Other appl. using ODS substitutes	- %
2F7	Semiconductor Manufacture	- %	2F7	Semiconductor Manufacture	- %

Source: AnaFgas model v. 3.25, using GWPs of the 2nd Assessment Report, as obligatory for Kyoto Reporting.

For an adequate modelling of emissions, emission reductions and abatement costs, the AnaFgas model uses a more detailed sectoral structure than CRF. Table 4.5 gives a synopsis of both systems and indicates the application of the EU level regulatory instruments.

Table 4.5 Sectoral structure of AnaFgas vs. IPCC/CRF & EU legislation

Sectoral structure in AnaFgas model		**Regulatory approach on EU level**	**IPPC category CRF**
Sector	**Sub-Sector**		
Refrigeration	Domestic Refrigeration	F-Gas-Regulation	2F1 - Refrigeration and Air Conditioning Equipment
	Commercial Refrigeration	F-Gas-Regulation	
	Industrial Refrigeration	F-Gas-Regulation	
	Road Transport Refrigeration	none	
	Shipping Refrigeration (fisheries)	none	
Stationary A/C and Heat Pumps	Room A/C	F-Gas-Regulation	
	Variable Refrigerant Flow & Packaged type (Rooftop)	F-Gas-Regulation	
	Chillers	F-Gas-Regulation	
	Heat Pumps	F-Gas-Regulation	
Mobile A/C	Car A/C	MAC Directive	
	Bus A/C	(F-Gas-Regulation) [a]	
	Truck A/C	(F-Gas-Regulation) [a]	
	Ship A/C	(F-Gas-Regulation) [a]	
	Rail A/C	(F-Gas-Regulation) [a]	
Foams	One Component Foam	F-Gas-Regulation	2F2 - Foam Blowing
	PU foam	none	
	XPS	none	
Other HFCs	Aerosols	F-Gas-Regulation	2F4 - Aerosols/ Metered Dose Inhalers
	Metered dose inhalers	F-Gas-Regulation	
	Solvents	F-Gas-Regulation	2F5 - Solvents
	Fires extinguishers	F-Gas-Regulation	2F3 - Fire extinguishers
SF6	Electrical equipment	F-Gas-Regulation	2F8 - Electrical Equipment
	Car tyres	F-Gas-Regulation	2F9 - Other
	Soundproof windows	F-Gas-Regulation	
	Sport shoe soles	F-Gas-Regulation	
	Aluminium & Magnesium Foundries	F-Gas-Regulation	2C4 - SF6 Used in Aluminium and Magnesium Foundries [b]
PFC and other Halocarbons	Semiconductor and Photovoltaics	none	2F7 - Semiconductor Manufacture
	Primary Aluminium production	none	2C3 - Aluminium Production
	Halocarbon production	none	2E - Production of Halocarbons and SF6

[a] Only the general recovery provision of Art. 4(3) of the F-gas Regulation applies to the mobile air conditioning sectors. Thus, for the AnaFgas model, no emission reduction effect was estimated for these subsectors.
[b] HFC emissions as SF_6 replacement in magnesium casting to be reported in 2C5 (Other Metal Production)

As the same sectoral imbalance holds for emission reporting, many Member States use sectoral definitions for sub-categories similar to the AnaFgas approach.

Table 4.6 presents the same AnaFgas model data as Table 4.4, however, in the more detailed AnaFgas sectoral structure. It becomes apparent that

a) the shares and the according order of the subsectors in both overall projected F-gas emissions and emission reductions vary significantly over time, and

b) the shares and the according orders vary significantly between projected emissions and projected emission reductions (defined in comparison to the counterfactual "without measures" scenario).

Table 4.6 Sectoral (AnaFgas) shares of EU27 emissions and emission reductions

Sectoral shares of EU 27 Emissions (reference - with measures)				Sectoral shares of EU 27 Emission reductions in comparison to counterfactual scenario			
2015		2030		2015		2030	
Car A/C	27%	Room A/C	26%	Commercial Refr.	37%	Car A/C	53%
Commercial Refr.	15%	Commercial Refr.	20%	Industrial Refr.	18%	Commercial Refr.	16%
Room A/C	13%	Industrial Refr.	9%	Room A/C	12%	Room A/C	12%
Industrial Refr.	8%	Truck A/C	5%	Car A/C	12%	Industrial Refr.	7%
Aerosols	4%	Aerosols	4%	One Component Foam	6%	One Component Foam	3%
Truck A/C	3%	Road transport Refr.	4%	Chillers	4%	Chillers	2%
Soundproof windows	3%	Metered dose inhalers	4%	VRF & Rooftop	3%	VRF & Rooftop	2%
Metered dose inhalers	3%	VRF & Rooftop	3%	Alu & Mag Foundries	3%	Alu & Mag Foundries	1%
Electrical equipment	3%	Chillers	3%	Aerosols	1%	Heat Pumps	1%
Road transport Refr.	3%	Electrical equipment	3%	Fire extinguishers	1%	Aerosols	0%
Halocarbon Prod.	2%	Heat Pumps	3%	Soundproof windows	1%	Soundproof windows	0%
XPS	2%	XPS	2%	Domestic Refr.	1%	Fire extinguishers	0%
Fire extinguishers	2%	Fire extinguishers	2%	Electrical equipment	0%	Electrical equipment	0%
Chillers	2%	Halocarbon Prod.	2%	Car tyres	0%	Car tyres	0%
VRF & Rooftop	2%	Bus A/C	2%	Heat Pumps	0%	Domestic Refr.	0%
Bus A/C	2%	Ship A/C	2%	Road transport Refr.	- %	Road transport Refr.	- %
Ship A/C	2%	Semiconductor and PV	2%	Shipping Refr. (fisheries)	- %	Shipping Refr. (fisheries)	- %
Semiconductor and PV	1%	Primary Aluminium Prod.	1%	Bus A/C	- %	Bus A/C	- %
Primary Aluminium Prod.	1%	Shipping Refr. (fisheries)	1%	Truck A/C	- %	Truck A/C	- %
Shipping Refr. (fisheries)	1%	Alu & Mag Foundries	1%	Ship A/C	- %	Ship A/C	- %
Heat Pumps	1%	Soundproof windows	1%	Rail A/C	- %	Rail A/C	- %
Alu & Mag Foundries	1%	Domestic Refr.	0%	PU foam	- %	PU foam	- %
Domestic Refr.	1%	Solvents	0%	XPS	- %	XPS	- %
Solvents	0%	Car A/C	0%	Metered dose inhalers	- %	Metered dose inhalers	- %
Rail A/C	0%	Rail A/C	0%	Solvents	- %	Solvents	- %
PU foam	0%	PU foam	0%	Sport shoe soles	- %	Sport shoe soles	- %
One Component Foam	0%	One Component Foam	0%	Semiconductor and PV	- %	Semiconductor and PV	- %
Car tyres	- %	Car tyres	- %	Primary Aluminium Prod.	- %	Primary Aluminium Prod.	- %
Sport shoe soles	- %	Sport shoe soles	- %	Halocarbon Prod.	- %	Halocarbon Prod.	- %

Source: AnaFgas model v. 3.25, using GWPs of the 2nd Assessment Report, as obligatory for Kyoto Reporting.

As a general principle, we suggest defining the same set of subsectors to be subject to the simplified Tier 2/ Tier 3 emission reduction assessment approach for all Member States. However, in depth analysis of the AnaFgas model results reveals that the shares and orders as shown in Table 4.6 for EU 27 are not transferable to all Member States across the board. In contrast, it appears to be useful to fully grasp all subsectors which are key to the emission reduction in single Member States.

Setting the minimum threshold for each Member State's estimated 2015 emission reductions to be covered by the subsectors defined as "key" to 80 %, the minimum list of subsectors to be treated in the simplified assessment approach per Member States results as shown in Table 4.7.

Table 4.7 Key subsectors for emission reduction in 2015 per MS, 75% threshold

Order of key subsectors for emission reduction in 2015 in comparison to the counterfactual "without measures" scenario up to the cumulated threshold of 80 %								
	Commercial Refrigeration	Industrial Refrigeration	Room A/C	Car A/C	One Compo-nent Foam	Chillers	VRF& Multisplit	Al & Mg Foundries
EU-27	1	2	3	4	5			
EU-15	1	2	4	3	5			
EU-12	1	2	3	4				
Austria	1	2		3		4		
Belgium	1	2	4	3	5			
Bulgaria	1	3	2					
Cyprus	2		1	3			4	
Czech Rep.	1	2		3	4			
Denmark	1		3	2				
Estonia	2	3			1			
Finland	1	3		4	2			
France	1	2	4	3		5		
Germany	1	2		3	5			4
Greece	2	3	1	4				
Hungary	1	2	3					
Ireland	1	2		3				
Italy	1	4	2	3				
Latvia	1		4	3	2			
Lithuania	1	3		4	2			
Luxembourg	1	3	4	2				
Malta	1		2	3				
Netherlands	2	1	4	3				
Poland	1	2		3				
Portugal	1	4	3	2				
Romania	1	3	2					
Slovakia	1	4	2		3			
Slovenia	3	4	2		1			
Spain	1	3	2	4			5	
Sweden	1			2	5	4		3
UK	1	2	4	3				
legend:		red cells: appears in key category list for 2030 grey cells: vanishes in key category list for 2030						

Source: AnaFgas model v. 3.25, using GWPs of the 2nd Assessment Report, as obligatory for Kyoto Reporting.

For the final list of subsectors to be included we thus propose all subsectors that are contained in Table 4.7. Using this approach we also make sure, that sub-sectors of rising relevance for emission reductions compared to a counterfactual "without measures" scenario are taken on-board (i.e. the red cells in Table 4.7, the additional 2030 key subsectors). The resulting final list of key subsectors to be considered for the simplified Tier 2 / Tier 3 assessment approach is shown in Table 4.8.

Table 4.8 Key subsectors to be covered in simplified Tier 2 / Tier 3 assessment and their shares in projected 2015 F-gas emission reductions

Key subsectors' shares of projected 2015 emission reduction in comparison to the counterfactual "without measures" scenario									
	Commercial Refrigeration	Industrial Refrigeration	Room A/C	Car A/C	One Component Foam	Chillers	VRF& Multisplit	Al & Mg Foundries	SUM
EU-27	37%	18%	12%	12%	6%	4%	3%	3%	96%
EU-15	36%	18%	12%	12%	5%	5%	3%	3%	95%
EU-12	44%	17%	14%	11%	9%	1%	1%	1%	99%
Austria	39%	21%	3%	19%	- %	12%	3%	- %	96%
Belgium	35%	26%	7%	10%	7%	3%	2%	- %	91%
Bulgaria	42%	12%	29%	9%	4%	- %	2%	- %	98%
Cyprus	29%	8%	39%	9%	5%	- %	9%	- %	100%
Czech Rep.	34%	29%	3%	14%	11%	3%	2%	- %	96%
Denmark	60%	7%	12%	14%	- %	- %	0%	- %	93%
Estonia	33%	13%	8%	9%	35%	- %	1%	- %	100%
Finland	40%	15%	4%	12%	21%	5%	0%	- %	98%
France	38%	20%	8%	13%	3%	5%	3%	3%	93%
Germany	28%	24%	2%	14%	10%	4%	1%	12%	95%
Greece	32%	9%	36%	8%	6%	3%	5%	- %	98%
Hungary	51%	19%	11%	11%	7%	- %	1%	- %	100%
Ireland	41%	36%	4%	10%	6%	- %	1%	- %	98%
Italy	35%	11%	23%	13%	3%	8%	4%	2%	98%
Latvia	41%	10%	11%	12%	26%	- %	1%	- %	100%
Lithuania	41%	17%	9%	14%	18%	- %	0%	- %	100%
Luxembourg	49%	12%	10%	19%	8%	- %	- %	- %	97%
Malta	39%	7%	25%	17%	3%	- %	8%	- %	99%
Netherlands	29%	43%	6%	8%	5%	3%	1%	- %	95%
Poland	50%	19%	1%	14%	11%	2%	1%	- %	99%
Portugal	46%	10%	11%	16%	9%	1%	5%	- %	98%
Romania	43%	16%	29%	5%	1%	- %	0%	4%	99%
Slovakia	38%	12%	25%	7%	15%	- %	1%	- %	99%
Slovenia	23%	16%	23%	12%	25%	- %	- %	- %	99%
Spain	35%	10%	21%	10%	4%	5%	8%	- %	94%
Sweden	42%	6%	4%	12%	9%	10%	0%	11%	94%
UK	45%	20%	6%	12%	3%	3%	4%	- %	95%

Source: AnaFgas model v. 3.25, using GWPs of the 2nd Assessment Report, as obligatory for Kyoto Reporting.

Thus, the described procedure of choosing the key subsectors to be included in the simplified assessment approach results in coverage of 96% of projected emission reductions for the EU 27. This share varies among MS between 91 % and 100 %.

The corresponding picture for projected 2030 emission reductions is shown in Table 4.9, highlighting the rising share of passenger car air-conditioning. The EU 27 coverage of projected emission reductions is 97 %, varying between MS from 94 % to 100 %.

Table 4.9 Key subsectors to be covered in simplified Tier 2 / Tier 3 assessment and their shares in projected 2030 F-gas emission reductions

Key subsectors' shares of projected 2030 emission reduction in comparison to the counterfactual "without measures" scenario									
	Commercial Refrigeration	Industrial Refrigeration	Room A/C	Car A/C	One Compo-nent Foam	Chillers	VRF& Multisplit	Al & Mg Foundries	SUM
EU-27	16%	7%	12%	53%	3%	2%	2%	1%	97%
EU-15	16%	7%	12%	53%	3%	3%	2%	1%	97%
EU-12	19%	7%	13%	53%	5%	1%	1%	0%	99%
Austria	14%	7%	3%	66%	- %	5%	2%	- %	97%
Belgium	17%	13%	10%	48%	4%	2%	2%	- %	94%
Bulgaria	18%	5%	27%	45%	2%	- %	2%	- %	99%
Cyprus	15%	4%	28%	42%	2%	- %	8%	- %	100%
Czech Rep.	13%	10%	3%	62%	5%	2%	1%	- %	96%
Denmark	25%	1%	15%	59%	- %	- %	0%	- %	99%
Estonia	15%	5%	10%	49%	20%	- %	1%	-0%	100%
Finland	17%	6%	6%	55%	11%	3%	0%	- %	98%
France	14%	7%	10%	57%	2%	3%	2%	1%	96%
Germany	12%	9%	2%	60%	5%	2%	1%	5%	97%
Greece	15%	4%	28%	42%	3%	3%	4%	- %	99%
Hungary	22%	8%	12%	52%	4%	- %	1%	- %	98%
Ireland	22%	16%	6%	48%	3%	- %	1%	- %	97%
Italy	14%	4%	23%	49%	2%	4%	2%	1%	98%
Latvia	15%	4%	13%	54%	13%	- %	1%	- %	99%
Lithuania	15%	6%	11%	58%	8%	- %	0%	- %	98%
Luxembourg	18%	4%	10%	64%	3%	- %	- %	- %	99%
Malta	15%	3%	18%	57%	1%	- %	6%	- %	100%
Netherlands	15%	21%	9%	45%	3%	2%	1%	- %	97%
Poland	19%	7%	1%	65%	5%	1%	0%	- %	99%
Portugal	17%	4%	8%	62%	4%	1%	3%	- %	99%
Romania	22%	8%	32%	33%	1%	- %	0%	2%	99%
Slovakia	19%	6%	26%	39%	9%	- %	1%	- %	99%
Slovenia	10%	6%	20%	52%	12%	- %	- %	- %	99%
Spain	16%	4%	22%	45%	2%	3%	4%	- %	97%
Sweden	20%	3%	6%	54%	5%	5%	0%	5%	97%
UK	20%	8%	8%	55%	2%	2%	2%	- %	97%

Source: AnaFgas model v. 3.25, using GWPs of the 2nd Assessment Report, as obligatory for Kyoto Reporting.

4.6.3.3 Assessment of environmental impacts

The assessment of environmental impacts focussed on reduction in direct greenhouse gas (GHG) emissions. For the PAM analysed here (F-Gas-regulation & MAC Directive) GHG refer solely to F-gas emissions. In order to calculate CO_2-equivalent GHG gas emissions based on metric tons of emissions of the large variety of F-gases three different sets of global warming potential (GWP) factors are available as published in the 2nd, the 3rd and the 4th IPCC Assessment Report Climate Change (AR) respectively. While both the F-gas regulation and the MAC directive refer to the GWPs of the 3rd AR, international GHG emission reporting under the Kyoto protocol is based on the GWPs as published in the 2nd AR. Thus, for the time being we propose basing the environmental ex-post assessment primarily on the GWP of the 2nd AR, while the GWP sets of the 3rd and 4th AR should additionally be incorporated in the calculation schemes for information only.

As a general issue for F-gases, emissions in most subsectors cannot satisfactorily be estimated by the “simple” use or modelling of F-gas consumption data, as F-gases in most cases are used as cooling agents in more or less closed applications, and actual emissions take place during lifetime through leakages and at the end of the applications’ life time. Depending on the recovery (recycling or destruction) rate and the end of the life time, a substantial part of original consumption is not at all released into the atmosphere. The amount of F-gas stored in the applications, and thus potentially yet to be emitted or recovered, is usually referred to as the bank. However, a rather conventional emission calculation approach without banks can be followed for subsectors with open applications, e.g. if F-gases are used as propellant in one component foams or as protective cover in magnesium casting.

Table 4.10 structures the identified “key” sub-sectors in parallel to the full picture of Table 4.5:

Table 4.10 Overview on sub-sectors identified as key for simplified assessment approach

<table>
<tr><th colspan="2">Sectoral structure in AnaFgas model</th><th rowspan="2">Regulatory approach on EU level</th><th rowspan="2">IPPC category CRF</th></tr>
<tr><th>Sector</th><th>Sub-Sector</th></tr>
<tr><td rowspan="2">Refrigeration</td><td>Commercial Refrigeration</td><td>F-Gas-Regulation</td><td rowspan="6">2F1 - Refrigeration and Air Conditioning Equipment</td></tr>
<tr><td>Industrial Refrigeration</td><td>F-Gas-Regulation</td></tr>
<tr><td rowspan="3">Stationary A/C and Heat Pumps</td><td>Room A/C</td><td>F-Gas-Regulation</td></tr>
<tr><td>Variable Refrigerant Flow & Packaged type (Rooftop)</td><td>F-Gas-Regulation</td></tr>
<tr><td>Chillers</td><td>F-Gas-Regulation</td></tr>
<tr><td>Mobile A/C</td><td>Car A/C</td><td>MAC Directive</td></tr>
<tr><td>Foams</td><td>One Component Foam</td><td>F-Gas-Regulation</td><td>2F2 - Foam Blowing</td></tr>
<tr><td>SF6</td><td>Aluminium & Magnesium Foundries</td><td>F-Gas-Regulation</td><td>2C4 - SF6 Used in Aluminium and Magnesium Foundries</td></tr>
</table>

In the following sub-chapters, the chosen key sub-sectors will be defined, and the environmental assessment approaches will be laid out, one by one.

Commercial Refrigeration

Commercial refrigeration is divided in two sectors.

(1) Supermarket refrigeration for which large on-site erected centralised systems are typical.

(2) Small commercial applications for which prefabricated condensing units are typical together with hermetically operating stand-alone-systems and vending equipment.

In commercial refrigeration natural fluids like NH_3 or CO_2 so far play a marginal role. In this context, we consider only R-404A (a blend consisting of 44% HFC-125, 4% HFC-134a and 52% HFC-143a) being the only HFC refrigerant in Europe outside Germany, Austria, Czech Republic and Slovenia. In these countries usually R-404A is used only for low and HFC-134a for medium temperatures. Next to these HFCs, in the commercial refrigeration sector only the ozone depleting substances (ODS) R12 and R22 are still contained in banks, however these ODS are not relevant for the greenhouse gas effect.

For the emission calculation, an estimate of size and composition (shares of refrigerants / F-gases) of the bank is crucial. In case MS don’t have their own detailed, bottom-up bank model available, we propose using default figures for specific banks derived from the AnaFgas model (i.e. bank size per capita of population, split up for different refrigerants and changing over time along with the phase-out of ODS and market introduction of HFCs).

Box 7 Emissions equations for commercial refrigeration

$$Bank_{Country,n} = Population_{Country,n} * Default\_spec.\_Bank_n$$

$$for\ n \leq 1995 + 2 * Lifetime:\ Disposal_n = Bank_{n-Lifetime} - Bank_{n-Lifetime-1}$$

$$for\ n > 1995 + 2 * Lifetime:\ Disposal_n = \frac{Bank_{n-Lifetime}}{Lifetime}$$

$$EM_{Lifetime,n} = Bank_n * EF_{Lifetime,n}$$

$$EM_{Disposal,n} = Disposal_n * EF_{Disposal,n}$$

$$EM_n = EM_{Disposal,n} + EM_{Lifetime,n}$$

$$\Delta EM_n = EM_{n,WOM} - EM_{n,WM}$$

Default emission factors (EF) and lifetimes are proposed to be based on the AnaFgas model, with EF varying between the reference (with EU measures, WM) and the counterfactual (without EU measures, WOM) scenarios. Emission reductions for the ex-post assessment can finally be calculated for each year by subtracting lifetime and disposal emissions in the reference (WM) scenario from lifetime and disposal emissions in the counterfactual (WOM) scenario.

Industrial Refrigeration

About 75% of industrial refrigeration is required for food production, with the sector of basic chemicals constituting most of the demand for the remaining 25% refrigerants in other industrial sectors. The use of chillers[112] for cooling of liquids in industrial processes, however, is accounted for in the “Chillers” subsector under stationary air conditioning for reasons of being technically identical.

The subsectors proposed for consideration are:

- Beer production
- Wine production
- Meat production.
- Dairy industry / Milk production.
- Frozen food.
- Fruit juice/sparkling water.
- Chocolate production

And beyond food industry:

- Cold storage
- Ice rinks.
- chemical industry / basic chemicals

HFC Refrigerants considered industrial refrigeration are HFC-134a and the blends R-404a (44% HFC-125, 4% HFC-134a and 52% HFC-143a) and R-407c (23% HFC-32, 25% HFC-125 and 52% HFC-134a). Next to these HFCs, the ODS R12 and R22 as well as the natural fluid NH_3 are to be considered in the refrigerant banks.

For the emission calculation, an estimate of the sizes and compositions (shares of refrigerants / F-gases) of the banks is crucial. In case MS don’t have their own detailed, bottom-up bank model available, we propose using default figures for specific cooling demand per industry sector covered, for specific charges (kg of refrigerant per cooling capacity) and for representative shares of refrigerants in the bank (changing over time), all defaults being derived from the AnaFgas model.

[112] Chillers are mostly centrally positioned systems for the air-conditioning of whole buildings (department stores, factories, hotels) or large halls (cinemas, sports complexes, computer centres) which work indirectly. The refrigeration circuit cools a liquid (mostly water) down to +5 or +6°C, which is pipelined through the building as a coolant.

Box 8 Emissions equations for industrial refrigeration

$$Installed\_Cooling\_Capacities_n = Production\_data_n * Specific\_cooling\_demand$$
$$Bank_n = Installed\_Cooling\_Capacities_n * Specific\_Charge * Percentage\_of\_gas_n$$
$$Disposal_n = \frac{Bank_{n-Lifetime}}{Lifetime}$$
$$EM_{Lifetime,n} = Bank_n * EF_{Lifetime,n}$$
$$EM_{Disposal,n} = Disposal_n * EF_{Disposal,n}$$
$$EM_n = EM_{Disposal,n} + EM_{Lifetime,n}$$
$$\Delta EM_n = EM_{n,WOM} - EM_{n,WM}$$

Default emission factors (EF) and lifetimes are proposed to be based on the AnaFgas model, with EF varying between the reference (with EU measures, WM) and the counterfactual (without EU measures, WOM) scenarios. Emission reductions for the ex-post assessment can finally be calculated for each year by subtracting lifetime and disposal emissions in the reference (WM) scenario from lifetime and disposal emissions in the counterfactual (WOM) scenario.

Room Air Conditioners

In line with a recent Ecodesign study[113], we define room air conditioners as split[114] and factory-sealed moveable air conditioning devices. The usually available stock data involve all systems with cooling capacity <12 kW, thus also including most part of so-called multi split devices[115]. Room air conditioners include systems of the reversible type to be used also for heating (air-to-air heat pumps). Variable refrigerant flow (VRF) systems (which are multi split as well) and rooftop packages are covered in a separate subsector.

Since 2000, the former standard refrigerant R-22 ODS) has been replaced continuously in the stock of room air conditioners by R-407C (an HFC blend consisting of 23% HFC-32, 25% HFC-125 and 52% HFC-134a) and, increasingly, R-410A (an HFC blend consisting of 50% HFC-32 and 50% HFC-125).

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[113] ECODESIGN Lot 10 Draft of Chapter 2, Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation) Contract TREN/D1/40-2005/LOT10/S07.56606, Draft report of Task 2, July 2008, Economic and Market analysis. Co-ordinator: Philippe Riviere, Armines, France.

[114] "Split" air conditioning systems are split up into an outdoor unit, housing important components of the air conditioner like the compressor, condenser coil etc. and an Indoor unit that produces the cooling effect inside the room.

[115] Multi Split Air Conditioning Systems are not like traditional split system which are also known as a 'one to one split system', meaning one external unit (condenser) supplying one internal unit (evaporator). In a multi split air conditioning system, one external unit is connected several internal units and thus suited to serve a multitude of rooms.

For the emission calculation, an estimate of size and composition (shares of refrigerants / F-gases) of the bank is crucial. In case MS don't have their own detailed, bottom-up bank model available, we propose using interpolated stock figures from the above mentioned Ecodesign study[113] and default charges per item and representative shares of refrigerants in the bank (changing over time), all defaults being derived from the AnaFgas model

Box 9 Emissions equations for room air conditioners

$$Bank_n = Stock_n * Charge * Percentage\_of\_gases_{Stock,n}$$

$$Disposal_n = \frac{Stock_{n-Lifetime}}{Lifetime} * Charge$$

$$EM_{Lifetime,n} = Bank_n * EF_{Lifetime,n}$$

$$EM_{Disposal,n} = Disposal_n * EF_{Disposal,n}$$

$$EM_n = EM_{Disposal,n} + EM_{Lifetime,n}$$

$$\Delta EM_n = EM_{n,WOM} - EM_{n,WM}$$

Default emission factors (EF) and lifetimes are proposed to be based on the AnaFgas model, with EF varying between the reference (with EU measures, WM) and the counterfactual (without EU measures, WOM) scenarios. Emission reductions for the ex-post assessment can finally be calculated for each year by subtracting lifetime and disposal emissions in the reference (WM) scenario from lifetime and disposal emissions in the counterfactual (WOM) scenario.

Variable Refrigerant Flow Systems and Rooftop Packages

Variable refrigerant flow (VRF) systems are a special type of multi split systems and consist of a number of air handling units connected to a single external condensing unit, and allow refrigerant flow to be varied in response to changes in the cooling or heating requirements within the air conditioned space. VRF show significantly higher refrigerant charges than split and moveable devices, exceeding the threshold value of 3 kg for application of leak checks and record maintenance provided in Art 3 of the F-gas Regulation. Therefore it makes sense to consider them separately in an assessment of the F-gas regulation, the more so as in the model bank and emissions calculation VRF devices differ from other stationary air conditioning systems. VRF systems came in relevant quantities onto the EU market in 2003; the only relevant refrigerant is R-410A, an HFC blend consisting of 50% HFC-32 and 50% HFC-125.

Packaged air conditioning systems means units with combined compressor, condenser, and evaporator, mounted outdoor, mostly on **rooftops**. Not in design, but in refrigerant charge, packaged systems are similar to VRF systems and thus considered separately from split devices. The spread of packaged systems over Europe widely differs by countries. There are only few markets of relevance, with Spain accounting for 60% of the total market, followed by UK, Italy and France. Two HFC refrigerants are in use for new systems: Starting in 2001, R-407C (an HFC blend consisting of 23% HFC-

32, 25% HFC-125 and 52% HFC-134a) was used exclusively, but was replaced soon by 410A (an HFC blend consisting of 50% HFC-32 and 50% HFC-125), which is the only refrigerant in new systems as of 2006.

For the emission calculation, an estimate of size and composition (shares of refrigerants / F-gases) of the bank is crucial as well as sales figures. In case MS don't have their own detailed, bottom-up bank model available, we propose using sales figures collected for the AnaFgas model and default charges per item and representative shares of refrigerants in the bank (changing over time), all defaults being derived from the AnaFgas model.

Box 10 Emissions equations for Variable Refrigerant Flow Systems and Rooftop Packages

$$Disposal_n = Sales\_of\_units_{n-Lifetime} * Charge$$
$$Bank_n = Bank_{n-1} + Sales\_of\_units_n * Charge - Disposal_n$$
$$EM_{Lifetime,n} = Bank_n * EF_{Lifetime,n}$$
$$EM_{Disposal,n} = Disposal_n * EF_{Disposal,n}$$
$$EM_n = EM_{Disposal,n} + EM_{Lifetime,n}$$
$$\Delta EM_n = EM_{n,WOM} - EM_{n,WM}$$

Default emission factors (EF) and lifetimes are proposed to be based on the AnaFgas model, with EF varying between the reference (with EU measures, WM) and the counterfactual (without EU measures, WOM) scenarios. Emission reductions for the ex-post assessment can finally be calculated for each year by subtracting lifetime and disposal emissions in the reference (WM) scenario from lifetime and disposal emissions in the counterfactual (WOM) scenario.

Chillers

For air-conditioning of whole buildings (department stores, factories, hotels) or large halls (cinemas, sports complexes, computer centres) mostly centrally positioned systems are used which work indirectly. The refrigeration circuit cools a liquid (mostly water) down to +5 or +6°C, which is pipelined through the building as a coolant. Such systems are called chillers. Chillers are not only used for air conditioning but also for cooling of liquids for industrial processes. To avoid double counting, we propose industrial chillers not to be considered under industrial refrigeration but together with the technically identical air conditioning systems under stationary air conditioning. Most chillers are used for cooling capacities higher than those which are provided by directly evaporating systems. Their refrigeration capacities range from 15 kW to over 3,000 kW.

Chillers can be divided according to their compressors in reciprocating/scroll chillers, screw chillers, and centrifugal chillers. They show large differences in refrigerant charges and in lifetime. They also differ by the refrigerants, i.e. HFC blend R-407C, HFC blend R-410A, or HFC-134a. Standard refrigerant for piston, scroll, and screw chillers before 2000 was R-22. Centrifugal chillers had used R-11 or R-12 before 1995, when fully halogenated ODS were replaced by HFC-134a. In addition to the common chillers, in a few countries (France, Italy) so-called mini-chillers are used.

As for VRF systems and rooftop packages, we suggest basing the emissions calculation on sales figures. In case MS don't have their own detailed, bottom-up bank model available, we propose using sales figures collected and estimated for the AnaFgas model and default charges per item and representative shares of refrigerants in the bank (changing over time), all defaults being derived from the AnaFgas model.

Box 11 Emissions equations for Chillers

$$Disposal_n = Sales\_of\_units_{n-Lifetime} * Charge$$
$$Bank_n = Bank_{n-1} + Sales\_of\_units_n * Charge - Disposal_n$$
$$EM_{Lifetime,n} = Bank_n * EF_{Lifetime,n}$$
$$EM_{Disposal,n} = Disposal_n * EF_{Disposal,n}$$
$$EM_n = EM_{Disposal,n} + EM_{Lifetime,n}$$
$$\Delta EM_n = EM_{n,WOM} - EM_{n,WM}$$

Default emission factors (EF) and lifetimes are proposed to be based on the AnaFgas model, with EF varying between the reference (with EU measures, WM) and the counterfactual (without EU measures, WOM) scenarios. Emission reductions for the ex-post assessment can finally be calculated for each year by subtracting lifetime and disposal emissions in the reference (WM) scenario from lifetime and disposal emissions in the counterfactual (WOM) scenario.

Mobile air conditioning of passenger cars

Emission reductions due to EU legislation in mobile air condition (MAC) are proposed to be assessed only for passenger cars as this is the only subsector the MAC Directive applies to. Mobile air conditioning in buses, trucks, ships and rail cars is only subject to the general recovery provision of Art. 4(3) of the F-gas Regulation which was not considered to induce emission reduction effects in the AnaFgas model.

A survey of Öko-Recherche on new registrations in Germany has revealed that the share of vehicles equipped with MAC systems has significantly increased from 1993 to 2008. In contrast, the refrigerant charge decreased in the same time.

The usual refrigerant used in mobile air conditioning since the phase-out of the ODS R-12 is HFC-134a with a GWP of 1,300 (2^{nd} & 3^{rd} AR). As a consequence of the MAC Directive, HFC-134a might be expected to be gradually replaced by low-GWP refrigerants, e.g. HFC-1234yf ("HFO-1234yf", "HFO") with a GWP of 4 or R-744 (i.e. CO_2) with a GWP of 1.

The emission calculation to determine refrigerant bank and disposals is based on passenger car[116] stock data, quotas of vehicles equipped with MAC, average charges and lifetimes. In case MS don't have their own detailed, bottom-up stock & bank model available, we propose using stock figures estimated for the AnaFgas model and default MAC quotas and charges per car and (for the reference "with measures" scenario) default shares of low-GWP refrigerants in the bank (changing over time), all defaults being derived from the AnaFgas model.

Box 12 Emissions equations for Car A/C

$$Bank_n = Stock\_of\_cars_n * MAC\_Quota_{Stock} * Average\_Charge_{Stock}$$

$$Disposal_n = \frac{Stock\_of\_cars_{n-Lifetime}}{Lifetime} * MAC\_Quota_{new,n-Lifetime} * Charge_{new,n-Lifetime}$$

$$EM_{Lifetime,n} = Bank_n * EF_{Lifetime,n}$$

$$EM_{Disposal,n} = Disposal_n * EF_{Disposal,n}$$

$$EM_n = EM_{Disposal,n} + EM_{Lifetime,n}$$

$$\Delta EM_n = EM_{n,WOM} - EM_{n,WM}$$

Default emission factors (EF) and lifetimes are proposed to be based on the AnaFgas model, with EF varying between the reference (with EU measures, WM) and the counterfactual (without EU measures, WOM) scenarios. Emission reductions for the ex-post assessment can finally be calculated for each year by subtracting lifetime and disposal emissions in the reference (WM) scenario from lifetime and disposal emissions in the counterfactual (WOM) scenario.

One Component Foams

The propellant gas in canned one-component polyurethane (PU) foam can contain HFCs which have replaced HCFC-22 from 2002 at the latest. The gas expels the foam from the aerosol cans; on application, it is completely released to the atmosphere. Thus, one component foam (OCF) is an example for an open HFC application, where no banks have to considered, once the product is in use. OCF is subject to placing on the market prohibitions in accordance with Article 9 of the F-gas Regulation.

The majority of cans contain hydrocarbon gases as propellant; approximately 10-13% contain HFCs (EU27, 2006). According to manufacturers, the formulation of several special foam types (fire safe foam, winter foam, mega foam) still relies on high shares

[116] The MAC Directive applies to the following vehicle categories:

- Category M1: Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat.
- Category N1: Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3,5 tonnes; among those only: Class I, Reference mass≤ 1305 kg.

of HFC-134a in the gas mixture (up to 110 g per can). HFC-152a was used with quantitative importance only for a short time.

The emission calculation to determine HFC emissions is based sold OCF cans as well as average shares and charges of HFC-containing cans. In case MS don’t have their own detailed data available, we propose using sales figures collected and estimated for the AnaFgas model and default HFC shares and charges per can, all defaults being derived from the AnaFgas model.

Box 13 Emissions equations for One Component Foam

$$Consumption_n = Cans\_sold_n * Percentage\_of\_cans_{HFC} * Charge_{can}$$
$$EM_{Lifetime,n} = Consumption_n$$
$$EM_n = EM_{Lifetime,n}$$
$$\Delta EM_n = EM_{n,WOM} - EM_{n,WM}$$

HFC shares and charges per can vary between the reference (with EU measures, WM) and the counterfactual (without EU measures, WOM) scenarios. Emission reductions for the ex-post assessment can finally be calculated for each year by subtracting emissions in the reference (WM) scenario from emissions in the counterfactual (WOM) scenario.

Aluminium and Magnesium Foundries

SF_6 is in use for cleaning aluminium melt in secondary aluminium production, and in magnesium casting SF_6 is used as a cover gas to prevent the hot molten metal from burning.

Aluminium Cleaning

SF_6 is currently used for cleaning aluminium melt in Austria and Germany only. Data is available for Germany 1999 (begin of use) until 2009 and for Austria 2006 (begin of use) until 2008. The German operator has decided to phase-out SF_6 by 2015 at the latest. As aluminium cleaning is not directly addressed by the F-gas Regulation, we do not consider the according emission reductions to EU F-gas legislation, although the company's decision might be substantially be influenced by the EU F-gas legislation.

Thus, we propose limiting the assessment of emission reductions in the Aluminium Cleaning and Magnesium Foundries subsector to magnesium casting:

Magnesium Casting

In magnesium casting SF_6 cover gas applied is considered to be released to the atmosphere. Three magnesium casting technologies are applied in Europe: Die casting (large scale production), sand casting (prototypes and small scale production), and recycling. Magnesium casting is another example of an open F-gas application; magnesium die casting is subject to the restriction of use according to Article 8 of the F-gas Regulation.

In 2006, magnesium production with SF_6 took place in Germany, France, Italy, Romania, Spain, Sweden and the UK. Earlier, magnesium casting with SF_6 took place also in Austria and in Denmark.

The F-gas Regulation prohibited the use of SF_6 for die casting plants with annual SF_6 consumption of more than 850 kg, as of 2008. This measure almost halved the SF_6 consumption in the European magnesium industry and limits SF_6 use to smaller die casters, to sand casters and to recycling plants. Nine of the ten big die casting plants, affected by the F-gas Regulation, have replaced SF_6 by HFCs (HFC-134a, HFC 125) as the new cover gas. One has changed to SO_2. The GWP of HFC-134a is ~5% of the GWP of SF_6, for HFC-125 this figure amounts to ~12 % a (using the GWP values of the IPPC's 2nd AR).

The emission estimates for the reference "with measures" (WM) scenario are based on 100 % emission of consumed F-gases. Here, the MS can draw on the information the information they usually collect for their GHG reporting. For the counterfactual WOM scenario, we suggest using 2006 SF_6 emissions and scaling them with the development of the production of the respective magnesium casting facilities. These data would need to be gathered from national statistics or ideally collected from the foundry operators on a plant-by-plant basis, as specific SF_6-consumptions per ton of cast are known to have huge variations (cf. e.g. IPCC Good Practice Guidance).

Emission equation Magnesium casting

$$EM_{n,WM} = Consumption\_Fgas_n$$

$$EM_{n,WÓM} = Consumption\_SF6_{2006} * \frac{Production\_Mg-cast_n}{Production\_Mg-cast_{2006}}$$

$$\Delta EM_n = EM_{n,WOM} - EM_{n,WM}$$

Emission reductions for the ex-post assessment can finally be calculated for each year by subtracting emissions in the reference (WM) scenario from emissions in the counterfactual (WOM) scenario.

4.6.3.4 Assessment of costs

The cost assessment approach presented here builds heavily on the cost-assessment performed in current study[117] for DG CLIMA on a review of the F-gas Regulation. There, direct costs of the implementation and application of the F-gas regulation (including implementing Commission regulations 303/2008 through 307/2008) to the regulated industry are estimated, distinguishing one-off costs and annual recurring costs.

[117] Öko-Recherche, Öko-Institut, HEAT International & Partners: "Service contract to provide technical support for conducting a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases"; Service Contract for the European Commission, DG CLIMA, No 070307/2009/548866/SER/C4

As well, public set-up costs, both one-off and recurring, are estimated addressing public expenses which are not covered by certification or other fees.

As mentioned above, at present no reliable cost estimates for the additional cost incurred by the MAC Directive are available.

Prior to the F-gas Regulation, certain measures were in place in some sectors, e.g. leak checks, recovery of F-gases and certification measures in some Member States and industries. The assessment of the costs of implementation and application of the F-gas Regulation refers to **additional** costs which were caused by provisions of the F-gas Regulation or MAC Directive. In the Member States the costs for implementation of the F-gas Regulation differ largely for various reasons not only related to the levels of labour costs and public fees and charges. In some Member States, the infrastructure for application of the provisions including relevant bodies, training programmes, certification requirements etc. has been available prior to the F-gas Regulation, in other Member States this is not the case.

Costs which result from national rules exceeding the minimum requirements of the F-gas Regulation and related Commission Regulations No 303-307/2008 should not be taken into account in this assessment. Examples include costs for company certification in the mobile AC sector as required in Hungary, France and Finland.

The direct costs to the industry are estimated separately for the different types of requirements set out in the EU, i.e.

- Costs for certification of personnel and companies
- Costs of containment provisions
- Costs of recovery
- Costs of Reporting
- Costs for labelling & manuals

In the cost analysis performed in the above mentioned study for the review of the F-gas regulation[117], costs to meet the bans according to Articles 8 and 9 of the F-gas regulation are deemed to be negligible in comparison to the other cost categories.

For each type of requirement the affected subsectors and one-off and recurring costs are estimated:

Costs for certification of personnel and companies

The calculation of certification/ attestation costs according to the requirements set out in (EC) 303-307/2008 is based on the number of personnel and companies subject to these requirements. Costs occur only once in most cases (one-off costs). Certification costs generally include the fees which need to be paid for company and personnel certification.

The costs for full certification of personnel include

- Fees for theoretical and practical exams (do not occur for mobile AC sector)
- Fees for training (which is generally necessary)
- Fees for the issuance of the certification documents.

In case personnel certificates can be issued based on existing qualifications, costs for trainings and exams do not apply. As for personnel certification/attestation, costs for the non-productive time, travel costs and other expenses which need to be covered by companies are to be accounted.

The costs for full company certification include

- the verification of company information by authorities and
- fees for the issuance of the company certificate.

Costs of containment provisions

Since 4 July 2007 containment provisions according to Article 3 of the F-gas Regulation apply to stationary refrigeration, air conditioning and heat pump equipment, as well as to fire protection installations. Equipment with F-gas charges <3 kg is not subject to these provisions. Standard leakage check requirements are defined in (EC) 1516/2007 and (EC) 1497/2007.

Long before entry into force of the F-gas Regulation containment measures (including leak checks and leak detection systems) have been carried out in most F-gas sectors, however to a smaller extent and mostly more reactive than proactive. The application of containment provisions according to Article 3 involves additional costs for upgrading of systems ≥300 kg with leak detection systems, as well as for leak checking by frequencies defined in Art 3(2) and for repair and record keeping.

Costs of recovery

One of the objectives of the F-gas Regulation (Article 4) is to increase the recovery efficiency through the use of certified personnel. This mainly targets to recovery at end-of-life of stationary equipment. Additional costs to the operators of stationary refrigeration, air conditioning and heat pump (SRAC) systems, resulting from extra recovery activities and from the use of certified personnel, can be attributed to the F-gas Regulation.

Costs of reporting

The reporting provisions of Article 6(1) of the F-gas Regulation apply to the importer, exporter and/or producer of >1 tonne of F-gases per year. In a recent F-gas study for DG CLIMA[118], annual reporting costs per company were estimated as at most. €10.000 per year (including personnel costs) based on a communication by the European Fluorocarbon Technical Committee (EFCTC). Considering an estimate of 80 affected companies, we propose neglecting reporting costs in the simplified ex-post assessment approach.

[118] Öko-Recherche, Öko-Institut, HEAT International & Partners: “Service contract to provide technical support for conducting a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases”; Service Contract for the European Commission, DG CLIMA, No 070307/2009/548866/SER/C4

Costs for labelling & manuals

Article 7 and (EC) 1494/2007 set out requirements for labelling of new equipment containing HFCs or PFCs placed on the market after 1 April 2008. Information on F-gases shall be included in the instruction manuals provided for products and equipment covered by Article 7 (chapter 4.2.8). One-off costs emerge from (re)design of the label and additions in the instruction manuals. These one-off costs apply to the original equipment manufacturers (OEM) and to the contractors which are assembling customized components on site, and to fillers of F-gas containers.

Public set-up costs

Public set-up costs include public expenses which are not covered by certification fees or other fee, for design/set-up of certification systems, and related central data systems, for public awareness rising and other information activities as well as for control and inspections. Public costs can be partly considered one-off costs but partly occur regularly and hence relate to recurring costs.

Public set-up cost can hardly be related to the different subsectors where emission reductions are supposed to take place. In a recent F-gas study for DG CLIMA[119], average public set-up costs are estimated at ca. 50,000 Euros per 1 million inhabitants. However, specific costs can be differ depending on whether a Member State has to set-up completely the initial infrastructure or can at least partially rely on existing information systems. Average recurring costs are estimated at ca. 23,000 Euros per 1 million inhabitants

Sectoral share of costs

As major shares of estimated costs are incurred due to training and certification of personnel, the sectoral breakdown of the cost assessment is not as differentiated as for the environmental assessment. Thus in the above mentioned study[119] for most cost categories, a sectoral breakdown of the costs incurred by the F-gas Regulation in:

- the stationary refrigeration, air conditioning and heat pump (SRAC) sector,
- mobile air-conditioning (MAC) sector,
- the fire protection systems (FPS) sector,
- the high voltage switchgear (HVS) sector and
- the solvents subsector.

For containment and recovery provisions only, costs in the SRAC sector are further differentiated for subsectors as used in the AnaFgas model and thus directly in line to

[119] Öko-Recherche, Öko-Institut, HEAT International & Partners: "Service contract to provide technical support for conducting a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases"; Service Contract for the European Commission, DG CLIMA, No 070307/2009/548866/SER/C4

the set of “key subsectors” proposed for the simplified ex-post assessment methodology.

Preliminary[120] results indicate that in both one-off and recurring costs above 95% are to borne in the stationary refrigeration and air conditioning (SRAC) and mobile air conditioning (MAC) sectors. These sectors strongly coincide with the subsectors above identified as key from an environmental assessment point of view. Despite the fact that environmental and cost assessment do therefore not match at 100% in the subsectoral differentiation, we are thus highly confident that the proposed key subsectors do very well represent the total cost incurred by EU F-gas legislation, as well.

In the following sub-chapters the cost assessment approaches will be laid out in more detail, as applied to the different sectors.

Stationary refrigeration, air conditioning and heat pumps (SRAC)

Personnel certification

The cost calculation for personnel certification is based on the number of personnel trained and the training demand according to the categories 1-4 laid out in Commission regulation (EC) No 303/2008, and specific cost per training (incl. an issue fee for personnel which does not require additional training. In addition companies have to compensate for non-productive time and travel expenses etc. which we propose estimating based on training costs using a specific factor.

Box 14 Cost calculation for one-off costs personnel certification in the stationary refrigeration, air conditioning and heat pump (SRAC) sector.

$$Cost_{Training,n} = Personnel\_certified_n * share\_training\_demand_{Cat1-4,n} * spec.\_\cos t_{Cat1-4}$$

$$Cost_{Lost\_prod.\_time,n} = Cost_{Training,n} * Factor_{Cat1-4}$$

$$Cost_{certification,n} = Cost_{Training,n} + Cost_{Lost\_prod.\_time,n}$$

For MS without own data available, estimates of total personnel per MS when the F-gas entered into force, estimates of new personnel to be trained and default factors could be based on the abovementioned F-gas study for DG CLIMA.

Company certification

Company certification is required in the stationary refrigeration, air conditioning and heat pump sector according to Regulation (EC) 842/2006, Art 5(1).

Information on company certification was available for the above mentioned F-gas study[119] from 15 Member States. Costs for company certification vary largely within and between Member States. The major influencing factor appears to be the size of com-

[120] Cost data collected and estimated in the aforementioned F-gas study for DG CLIMA4 is at present subject to industry review and hence preliminary. Validation is expected by July 2011.

panies, in different regions and Member States the intensity of the company check and fees of authorities' impact costs. Large cost differences occur between Western Europe and Eastern/South-Eastern Europe.

Box 15 Cost calculation for one-off costs for company certification in the stationary refrigeration, air conditioning and heat pump (SRAC) sector.

$$Cost_{certification,Country,n} = Companies\_certified_n * spec.\_\cos t_{Country}$$

For MS without own data available, estimates of total companies per MS when the F-gas entered into force, estimates of new companies to be certified and geographically differentiated default factors could be based on the abovementioned F-gas study for DG CLIMA can be provided.

Containment

Additional costs that arise to the operators from application of Art 3 of the F-gas Regulation can be allocated to regular leak checking, quick repair, record keeping and, for installations with an F-gas charge above 300 kg, a detection system.

The calculation is based on estimated working hours needed for leakage checks, repair, and record keeping, shares of checks performed before the F-gas Regulation, cost per working hours (incl. travel), annual cost of detection systems, shares of installation with an F-gas charge above 300 kg (thus requiring an detection system), and operated installations. All figures to be used specific per subsector and country, where appropriate.

Box 16 Cost calculation for recurring costs for additional containment in the stationary refrigeration, air conditioning and heat pump (SRAC) sector.

$$hours_{leakchek,installation,subsector,n} = hours\_per\_check_{subsector,n} * frequency\_of\_checks_{installation,subsector,n}$$

$$Working\_hours_{installation,subsector,n} = hours_{leakchec,inst.,subsector,n} + hours_{repai,inst.,subsector,n} + hours_{recor,inst.,subsector,n}$$

$$Working\_hours_{additional,inst.,subsector,n} = Working\_hours_{inst.,subsector,n} * (1 - share_{regular\_check\_before\_F-gas\_Regulation})$$

$$Cost_{add\_hours,installation,subsector,country,n} = Working\_hours_{additiona,inst.,subsector,n} * Cost\_per\_hour_{incl.travel,country,n}$$

$$Cost_{add\_hours,subsector,country,n} = Cost_{add\_hour,installation,subsector,country,n} * No\_of\_installations_{subsector,country,n}$$

$$Cost_{detection\_system,subsector,country,n} = share\_Fgas-charge > 300kg_{subsector} * Cost\_per\_detection\_system_n$$

$$Cost_{subsector,n} = Cost_{add\_hours,subsector,n} + Cost_{detection\_system,subsector,n}$$

For MS without own data available, default factors could be based on the abovementioned F-gas study for DG CLIMA and from the AnaFgas model respectively.

Recovery

It is estimate that the recovery activities in the SRAC sector needs to increase significantly compared to the situation prior the F-gas Regulation, for equipment with F-gas charges over 3 kg (percentage increase similar to leak checking). In the sub sectors of equipment <3 kg the increase in recovery activities must be even very much higher to meet the requirements of Art 4 of the F-gas Regulation, because in many SRAC sub sectors end-of-life was hardly common prior to the F-gas Regulation.

The cost calculation is based on estimated working hours needed for a recovery and cost per working hours (incl. travel), and number of installations due for disposal. All figures to be used specific per subsector and country, where appropriate.

Box 17 Cost calculation for recurring costs for recovery in the stationary refrigeration, air conditioning and heat pump (SRAC) sector.

$$\mathrm{cost\_per\_recovery}_{subsector,n} = hours\_per\_recovery_{subsector,n} * Cost\_per\_hour_{incl.travel,country,n}$$
$$Cost_{country,n} = \mathrm{cost\_per\_recovery}_{subsector,n} * No\_of\_disposals_{subsector,country,n}$$

For MS without own data available, default factors could be based on the abovementioned F-gas study for DG CLIMA and from the AnaFgas model respectively.

Labelling & manuals

The cost calculation is based on estimations of the number of affected companies / model series in each sector and country and the average costs for redesign of labels and additional text in instruction manuals.

Box 18 Cost calculation for one-off costs for labelling and manuals the stationary refrigeration, air conditioning and heat pump (SRAC) sector.

$$Cost_{country,n} = \mathrm{cost\_per\_company/model\_series} * No\_of\_companies/model\_series_n$$

For MS without own data available, default factors could be based on the abovementioned F-gas study for DG CLIMA.

Mobile air-conditioning (MAC)

As mentioned above, no evidence-based cost estimates for the implementation and application of the MAC directive are available. Thus this chapter only refers to the requirements to the MAC sector as laid out in the F-gas Regulation in combination with Commission Regulation (EC) No 307/2008.

Personnel attestation

The cost calculation for personnel certification is based on the number of personnel trained and specific cost per training. In addition companies have to compensate for non-productive time and travel expenses etc. which we propose estimating based on training costs using a specific factor.

Box 19 Cost calculation for personnel attestation in the mobile air conditioning (MAC) sector.

$$Cost_{Training,n} = Personnel\_certified_n * spec.\_\mathrm{cost}_{Country}$$
$$Cost_{Lost\_prod.\_time,n} = Cost_{Training,n} * Factor_{country}$$
$$Cost_{certification,n} = Cost_{Training,n} + Cost_{Lost\_prod.\_time,n}$$

For MS without own data available, estimates of total personnel per MS when the F-gas entered into force, estimates of new personnel to be trained and default factors could be based on the abovementioned F-gas study for DG CLIMA.

Company certification

Additional national requirements in some Member States (company certification also in the mobile AC sector) are not considered in this assessment since additional costs induced by such national further reaching legislation do not relate to the F-gas Regulation.

4.6.3.5 Data assessment

The simplified ex-post assessment approaches for both environmental and cost presented here are intensively based on recent study for DG CLIMA reviewing the F-gas regulation[121]. That study takes a model-based approach an aims at a comprehensive assessment of environmental and cost impact of the F-gas Regulation. This setting allows to offer country/region and subsector specific default values for nearly all parameters used in the calculation schemes as empirically based or experts' guess data were collected and calculated for the cost modelling and AnaFgas.

Thus, in applying the proposed assessment approach, Member States in possession of detailed environmental and cost data on F-gas abatement would have the option to use their own, country specific input data in order to calculate banks, emissions, emission reductions and costs for the proposed set of key subsectors (Tier 3 approach). Else, MS can choose to use default values based on the mentioned F-gas study[121] and the AnaFgas model. Depending on how country specific the adopted (default) model values are, this would represent a Tier 2 or Tier 3 approach.

The single exemption concerning the availability of default data refers to the counterfactual emission scenario for SF_6 emissions from magnesium casting which we suggest to base on country or installation specific time series of production figures. With the limited number of targeted installations across Europe such figures might be prone to confidentiality concerns. However this aspect would need to bested.

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[121] Öko-Recherche, Öko-Institut, HEAT International & Partners: "Service contract to provide technical support for conducting a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases"; Service Contract for the European Commission, DG CLIMA, No 070307/2009/548866/SER/C4

4.6.4 Summary and conclusions

The F-gas Regulation[122] and the MAC Directive[123] address emissions of fluorinated greenhouse gases (F-gases) such as HFCs, PFCs and SF6, which have high global warming potentials and are controlled under the Kyoto Protocol. The F-gas Regulation applies since 4 July 2007 with the exception of Article 9 and Annex II, which apply since 4 July 2006. Measures of the MAC Directive are expected to reduce F-gas emissions from 2011 onwards.

F-Gas regulation addresses i.a.

- containment, use, recovery and destruction of F-gases as well as control of use for specified applications;
- labelling and disposal of products and equipment containing F-gases as well as placing on the market prohibitions;
- training and certification of maintenance personnel and companies handling F-gases.

The MAC Directive requires gradual phase-out of F-gases with GWP >150 (in fact: HFC-134a) in new systems in the period 2011-2017 in EU-27.

Some Member States have had in place national policies and measures addressing F-gases since the early 1990s, mostly connected to ODS (ozone depleting substances) related measures. After the European commitments for reduction goals of GHG emissions under the Kyoto Protocol, some Member States have individually implemented their measures gas addressing GHG emissions in addition and prior to European legislation. Certain provisions of the F-gas Regulation have been transposed into national legislation by most Member States, some even decided to establish provisions of national legislation which are stricter than the requirements of the F-gas Regulation with regard to scope and mechanisms of different measures.

IPPC emission categories affected are by F-Gas Regulation and MAC Directive

2C4 SF_6 used in Aluminium and Magnesium Foundries (SF_6),
2C5 Other Metal Production (HFC) and
2F Consumption of Halocarbons and SF_6.

Further F-gas emissions which are not affected by the EU legislation in question are reported under IPPC emission categories

2C3 Aluminium Production (PFC) and
2E Production of Halocarbons and SF_6.

[122] Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases

[123] Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC

We suggest a simplified Tier 2 / Tier3 ex-post assessment approaches for both environmental and cost which is based on recent study for DG CLIMA reviewing the F-gas Regulation (Schwarz et al. 2011[124]) and the Tier 3 F-gas consumption and emission model AnaFgas which was developed in connection to that study. “Simplified” means that we reduce the complexity of the diverse F-gas emitting sectors and concentrate on a limited number of subsectors in order to determine emission reductions and costs in comparison to the counterfactual “without measures” scenario. Nevertheless we estimate that more than 95 % both of emission reductions and of costs incurred by the F-gas regulations are covered by the proposed approach for each Member State[125]. Table 4.11 and Table 4.12 summarize the proposed key subsectors for the simplified approach.

Table 4.11 Key sectors for environmental assessment

Key sectors for environmental assessment	
Sector	**Sub-Sector**
Stationary Refrigeration	Commercial Refrigeration
	Industrial Refrigeration
Stationary Air-Conditioning and Heat Pumps	Room A/C
	Variable Refrigerant Flow & Packaged type (Rooftop)
	Chillers
Mobile Air-Conditioning	Car A/C
Foams	One Component Foam
Non-Ferrous Metals	Magnesium Casting

Table 4.12 Key sectors for cost assessment

Key sectors for cost assessment	
Sector	**Cost categories**
Stationary Refrigeration, Air-Conditioning and Heat Pumps	certification of personnel
	certification of companies
	containment: leakage checks & repair
	recovery of F-gases at disposal
	labelling and manuals
Mobile Air-Conditioning	attestation of personnel
Cross-cutting	Public set-up costs on information system etc.

The assessment of emission reductions for the identified key sectors builds on sector-specific data/estimates on stocks of F-gas using equipment, specific F-gas charges and compositions, equipment lifetimes, leakage rates during operation, emission rates

124 Schwarz et al. 2011: Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases; Final Report & Annexes to the Final Report. Prepared for the European Commission in the context of Service Contract No 070307/2009/548866/SER/C4

125 100 % being defined as the full scale model results for cost and emission reductions.

during disposal and some specific sales and consumption statistics. Data could be available from Tier 3 models like AnaFGas, national studies or emission inventories and/or sales statistics.

Cost estimates are proposed in particular for personnel certification, containment and recovery and could be based on the specific findings of the above mentioned Schwarz et al. 2011 study or on comparable national studies. However, a gap yet to be filled for a complete assessment of EU F-gas legislation is a sound assessment approach for the costs incurred to industry by the MAC Directive. Available cost estimation methodologies are restricted to the F-gas Regulation. Emission reductions initiated by the MAC Directive can be assessed with the present approach though.

Despite considerably reducing the complexity of the F-gas using sectors, the developed simplified approach still demands rather high efforts in terms of technical expertise and modelling capacity to be employed and specific technical data to be collected or estimated.

F-gases account for 2% of the EU27 overall greenhouse gas emissions in 2009, however, with a rising trend. Given that limited relevance of EU F-gases emissions, however, it might be more time- and cost-efficient from a central EU perspective to concentrate on updates of the available centralised assessment tools and methodologies which might be undertaken by the European Commission in co-operation with some of the larger Member States. A considerable improvement of EU-wide ex-post evaluation results by means of reporting from smaller Member States is not to be expected.

For Member States wishing to improve their own assessment capacities on the F-gas Regulation, however, the proposed methodology would help focussing limited efforts on the most relevant sectors and cost-categories.

4.7 IPPC Directive

4.7.1 Overview of the Directive

The IPPC Directive aims to prevent and control pollution arising from certain industrial activities, including energy and mineral industries, production and processing of metals, chemical industries and waste management. The Directive sets out measures to prevent or reduce emissions into the air, water and land and defines the legal framework and environmental conditions for issuing permits to carry out the activities abovementioned. The Directive requires industrial installations concerned to obtain an environmental permit from the competent authorities in the Member States. It should be noted that the conditions of the permits are largely influenced by related sectoral polices (for example, the Large Combustion Plant Directive) and related guidance documents (BREFs); this interlinking of policies makes it extremely difficult to isolate the impact of IPPC.

The IPPC requirements are applicable to new installations since the 30th October 1999 and for existing installations since the 30th October 2007. In the EU27, it is estimated that the IPPC Directive covers approximately 52,000 installations[126].

The Commission published its proposal and an impact assessment for a Directive on industrial emissions on 21st December 2007[127], which consolidated seven existing Directives related to industrial emissions into a single clear and coherent legislative instrument. The now repealed Directives included the titanium dioxide industry related directives (78/176/EEC, 82/883/EEC, 92/112/EEC), the IPPC Directive (2008/1/EC), the Solvent Emission Directive (1999/13/EC), the Waste Incineration Directive (2000/76/EC) and the LCP Directive (2001/80/EC). Following agreement between Council and Parliament on 7 July 2010, the Directive (2010/75/EU) was formally adopted on 24 November 2010 and published in the Official Journal on 17th December 2010; coming into force on 6th January 2011.

It is important to note that IPPC does not cover CO_2 directly, however, it promotes the implementation of a range of measures some of which might affect GHG emissions. For example, fuel switching from coal/oil to natural gas to reduce SO_2 emissions also means reduction of CO_2 emissions because of the higher efficiency of natural gas. However, the installation of wet scrubbers, another measure to reduce SO_2 emissions, can have the opposite effect and increase CO_2 emissions as a result of a fuel penalty.

4.7.2 Links with other EU Directives

The IPPC Directive overlaps with a range of other directives, in particular the:

- EU ETS: For installations that are covered both by the EU ETS and by the IPPC, there is no requirement that CO_2 emission limit values be set in the IPPC permit. Member States can decide whether IPPC measures relating to energy efficiency are included for EU ETS participants.
- Waste Incineration Directive: Many of the plants regulated by the WID are also subject to IPPC controls (either as waste incineration activities or as energy, mineral or other activities co-incinerating waste). Distinguishing between the relative effects of each Directive at these plants is difficult. It should be noted that the WID and IPPC Directive are now regulated under a single Directive as described in the previous section.
- Large Combustion Plant Directive (LCPD): The main GHG impact of the LCPD is through changes in efficiency of combustion plant. This may arise from additional abatement measures required to meet Emission Limit Values (ELVs),

[126] European Commission, (2008), website on the IPPC Directive:
http://ec.europa.eu/environment/air/pollutants/stationary/ippc/ippc_ms_implementation.htm

[127] Proposal for a Directive of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control) (recast)". European Commission, Brussels, 21st December 2007. Available from: http://ec.europa.eu/environment/ippc/proposal.htm

generally an efficiency penalty arising from a need to process exhaust gases, or, from indirect improvement through replacement of a plant with a more efficient plant more capable of meeting LCPD emission limit values. However, other factors (e.g. fuel and technology costs and efficiency) are very important when operators are considering replacement of an LCP. Energy efficiency gains or penalties under LCPD are hard to differentiate from those resulting from other EU regulation influencing the efficiency of combustion. It should be noted that the LCPD and IPPC Directive are now regulated under a single Directive as described in the previous section.

- Combined Heat and Power Directive (CHPD): The impacts of the CHPD have a direct effect on GHG emissions due to the implementation of energy efficiency measures. Due to the current national implementation levels the effects are considered marginal for now but will become more prominent in the future, and it will be difficult to identify the regulatory driver behind the efficiency improvements.
- National Policies: Entec (2010) found that approximately half of Member States had an integrated permitting procedure in place before the implementation of the IPPC Directive. Most of this legislation required integrated permits and at least partially satisfied the requirements of IPPC. However, some Member States' legislation did not cover all aspects such as BAT, cross media effects, energy use, odour and noise control. Those Member States with an integrated permitting procedure pre-IPPC include Austria, Belgium, Denmark, France, Germany, Hungary, Ireland, Luxembourg, the Netherlands, Sweden and the UK.

  Additionally, there is diversity in transposition of the IPPC Directive into national legislation. For example, Member States can choose to allow case-by-case permitting or use of General Binding Rules covering whole industry sectors. It is therefore difficult to separate the effect of IPPC from pre-existing legislation and the Tier 1 analysis assesses the combined effect of national and EU level policies.

4.7.3 Review and critical assessment of existing methodology

The previous study developed a Tier 1 assessment methodology which attempted to assess the impact of IPPC on the GHG intensity of certain industrial sectors[128] included within the scope of the IPPC Directive aggregated together. The methodology can be summarised as follows:

- GHG emissions from manufacturing sectors over time were extracted from UNFCC;

[128] 1A1 - Fuel combustion by energy industries, 1A2 - Fuel combustion by manufacturing industries and construction, 2. Industrial processes.

- The Industrial Production Index (IPI) (Eurostat) was used as a measure of industrial activity;
- The GHG emissions intensity of industry was calculated for each year from the variables above;
- The average GHG emissions intensity was calculated for the years before implementation of the IPPC (assumed to be the period prior to 1996). On the assumption that the average GHG emissions intensity would not vary in the counterfactual scenario, this figure was used in conjunction with the IPI to estimate the total counterfactual GHG emissions;
- The reduction (or increase) in GHG emissions due to implementation of IPPC was then calculated from the difference between actual GHG emissions and the estimates of GHG emissions in the baseline scenario.

This approach and the approaches proposed in the previous study for Tier 2 and 3 methodologies are summarised in Table 4.13.

Table 4.13 Overview of approaches in the previous study

Approach	Tier 1	Tier 2	Tier 3
Activity indicator	Industrial production index	Industrial production index	Installation or industry specific activity data.
Emission factor (g CO_2eq/unit of activity)	EU Average	EU Average	MS specific
Policy interaction	No	No	Yes
Autonomous development	No	Yes	Yes
Structural effects	No	No	Yes
Geographic factors	No	No	No
Timing issues / delay or announcement effects	No	Consideration of MS implementation date and new vs. existing installation effects.	
Source data	Eurostat / UNFCC	Eurostat / UNFCC	Installation or industry specific

The Tier 1 methodology was not considered sufficiently robust by the authors of the previous study. The elements which were identified as being insufficiently robust, the recommendations for methodological improvements from the previous study and the main areas which could be explored in this study are described below:

- **Emissions data used –** the Tier 1 methodology developed in the previous study used data on GHG emissions, aggregated for all sectors[128];
    - Aggregating the data for all sectors obscures changes in emissions in the counterfactual from particular sectors due to exogenous variables (activity rate, fuel prices);
    - The data source used (UNFCC) includes emissions from installations not included in the scope of IPPC thus masking changes in emissions from IPPC installations. For certain sectors, where the majority of installations are included in the scope of IPPC, Eurostat or UNFCC could be suitable data sources for high level analysis;
    - The previous report recommended that alternative data sources, such as E-PRTR, CITL and GAINS should be investigated. The suitability of these data sources and others for use in policy assessments are investigated in this study. The resource and cost efficiency of extensive data collection, which is necessary for detailed assessment of IPPC is also discussed, considering that IPPC does not regulate GHG emissions directly; recommendations on the sectors and activities which we consider may be feasible to evaluate are also presented;
    - A methodology for assessing the impact of the policy on other air pollutants is explored in this study, as action taken to reduce one set of pollutants may have impacts on others (see below).
- **Activity Indicator -** The activity indicator (IPI) used in the Tier 1 methodology is not sufficiently precise to accurately estimate the counterfactual;
    - The IPI aggregates the activity levels of all sectors together. The GHG intensity of specific sectors varies widely and will have a significant impact on emissions; therefore changes in the activity level of the major emitting sectors should be accounted for separately when establishing the counterfactual, ideally for all Tiers of assessment. In addition, the IPI is not available for all MSs and includes activity data for installations which are not included within the scope of the IPPC(D);
    - The previous study recommended that alternative data sources which have indicators of production at a lower level of sector disaggregation should be investigated. Data sources which could provide more detailed activity data have been investigated in this study and are discussed later in this section.
- **Policy Implementation –** the Tier 1 methodology in the previous study assumed that the Directive will be implemented in a consistent manner across all MS; however, this is not necessarily the case;
    - The previous study recommended that more detailed methodologies should investigate and account for differences in the timing of implementation and stringency of permit requirements between MSs;

    - In this study, data sources (e.g. previous Entec studies, Industrial emissions Reporting Information Systems (IRIS) reports) which would enable this assessment have been reviewed.

- **Policy Interaction –** The Tier 1 methodology developed in the previous study did not account for the interaction of other policies which address similar emissions sources, such as the LCPD, WID, EU ETS, the CHP Directive and national policies. The impacts of such policies should be assessed in order to isolate the impact of IPPC, although as noted above this is difficult given the interlinking nature of the policies included in the IED. The previous study recommended that reviewing the implementation of overlapping policies at a MS level and the use of more disaggregated source (installation-level) data would help to disentangle the impacts of these overlapping policies albeit with significantly greater data requirements.

- **Accounting for other exogenous variables –** The Tier 1 methodology developed in the previous study did not account for exogenous variables which can have a significant impact on emissions, such as technology changes which occur in the counterfactual and fuel prices;
    - The previous study recommended that these factors should be investigated in greater detail in future work, as accounting for these factors would reduce the level of uncertainty in the results of any assessment;
    - In this study, possible data sources (e.g. GAINS, PRIMES, Eurostat) are assessed to determine whether they can be used to account for exogenous variables in the counterfactual.

- **Cost estimation** – The previous study did not propose an approach for estimating compliance costs for IPPC, as it was not part of the scope of the study;
    - A methodology for compliance cost assessment is investigated in this study, including data sources for the uptake and cost estimates of possible abatement options.

4.7.4 Proposed improvements and refinement of the methodology

The IPPC Directive may affect GHG emissions through requirements to improve energy efficiency and measures taken to abate emissions of polluting substances to air and water, which may influence GHG emissions indirectly e.g. fuel penalties. However, the impact of measures taken to reduce emissions to water on GHG emissions will be small compared to the impact due to energy efficiency and air quality measures; therefore it is recommended that the impact of water abatement measures is excluded from further analysis (the impact of water treatment was not explicitly covered in the previous study).

A large number of sectors and activities are included within the scope of the IPPC Directive, including energy industries, production and processing of metals, the mineral industry, chemical industry, waste management and other activities (including pulp &

paper). It is recommended that all Tiers of assessment methodology should account for changes in activity levels at a sector level, as the GHG intensity of specific sectors varies widely and will have a significant impact on emissions in the counterfactual. However to do this for all sectors within the scope of IPPC would not be cost-efficient. Therefore it is recommended that any assessment should be focussed on sectors which are responsible for the majority of GHG and air pollutant emissions.

Criteria could be developed to identify the sectors which should be included in the analysis. Such an assessment, based on average emissions per installations and contribution to total emissions in E-PRTR was undertaken for, ‘An assessment of the Possible Development of an EU-wide NO_x and SO_2 Trading Scheme for IPPC Installations’[129]. This study found that the activities and sectors which contribute the majority of emissions of air pollutants (NO_x, SO_x and particulate matter) are: large combustion plants >50MW (LCPs), refining of mineral oil & gas, coke production, integrated steelworks, cement manufacture, glass manufacture and pulp & paper. For the purposes of this study it is assumed that future assessments will focus on assessing the impact of IPPC on the same set of sectors and activities.

The methodology and data sources for assessing each of these sectors will differ slightly, but for simplicity the approaches set out below focus on LCPs (>50MW) as an illustrative example; the relevant data sources for other sectors are discussed in the data assessment section. It should also be noted that there are interactions between the IPPC Directive and the ELVs in the LCPD. In some MSs IPPC permit conditions are based almost entirely on the ELVs from the LCPD; isolating the impact of IPPC from that of the LCPD is therefore not possible.

Assessment of environmental impacts

‘Tier 1’ methodology

A high-level assessment of the impact of IPPC on LCPs at an EU-wide level could be conducted using the following steps:

- The LCP emissions inventory, which MSs have been required to report on data from 2004, includes details of the total emissions of SO_2, NO_x and dust for each LCP and the total annual amount of energy input broken down into five categories of fuel: biomass, other solid fuels, liquid fuels, natural gas and other gases;
    - Fuel consumption data, when multiplied by EU or MS specific emission factors could provide an estimate of total CO_2 emissions from LCPs for each MS. This method includes some uncertainty, as emission factors for certain types of fuel (for example, ‘other solid fuels’) can vary considerably (e.g. from hard coal to lignite);

[129] Entec on behalf of the European Commission, (2010), ‘An assessment of the Possible Development of an EU-wide NOx and SO_2 Trading Scheme for IPPC Installations’.

  - Fuel consumption data, when multiplied by an assumed efficiency factors (fuel type-specific) will provide an estimate of the total heat/electricity generated by LCPs for each MS; this figure can be used as the activity indicator. This method includes significant uncertainty, as the efficiency of boilers can vary considerably;
  - Totals of emissions of SO_2, NO_x and dust particles from LCPs can be used in the analysis directly, without adjustment;
- By dividing the emissions estimates by the activity estimates described above, estimates of the emissions intensity (CO_2, SO_2, NO_x and dust) of LCPs can be derived for:
  - The counterfactual – using the average of data from 2004-2006;
  - Each year after the full implementation of IPPC for LCPs (2007 onwards);
- Estimates of emissions of all pollutants for the counterfactual can then be produced for the years 2007 onwards, by multiplying the counterfactual emissions intensities by the estimates of activity;
- Emissions reductions can then be estimated by subtracting the counterfactual emissions estimates from the actual emissions for the years 2007 onwards;
- Estimates of the benefits due to emissions reductions can be estimated by multiplying the emissions reductions estimates by EU-wide damage cost functions;
- The main limitations of this approach are that it does not consider:
  - the impact of installations which install abatement equipment prior to the data of full-IPPC compliance;
  - changes in activity due to closures, or new plants;
  - flexibilities in the LCP Directive;
  - changes in exogenous variables.

‘Tier 2’ methodology

The Tier 1 methodology could be improved upon by taking the following steps:

- Uncertainty around the estimation of CO_2 emissions from LCPs can be reduced by reviewing data sources (for example, the IEA coal centre) on the type and GHG emission factor of fuels consumed by MS in order to produce MS-specific CO_2 emission factors; this is particularly relevant for the ‘other solid fuels’ category;
- Uncertainty around the estimation of the activity rate of LCPs can be reduced by consulting sector studies, or contacting sector experts in competent authorities to develop MS-specific assumptions on the efficiency of LCPs for each fuel type;

- The counterfactual could be refined by:
  - Consulting sector studies to identify exogenous variables (such as changes in alternative fuel-price differentials and business-as-usual efficiency improvements) and then updating the counterfactual estimates of emissions intensity to reflect these changes;
  - Conducting a literature review of EC and MS policies which may overlap with IPPC; the impact of EU ETS on GHG emissions and fuel choice is particularly relevant;
- Estimates of the benefits due to emissions reductions could be refined by applying MS-specific damage cost functions;
- The main limitations of this approach are that it does not consider:
  - the impact of installations which install abatement equipment prior to the data of full-IPPC compliance;
  - changes in activity due to closures, or new plants;
  - flexibilities in the LCP Directive.

'Tier 3' methodology

In order to complete a detailed assessment of the impacts of the IPPC Directive on LCPs, a bottom-up approach, which accounts for changes in the counterfactual at a plant level, could be considered. Such an approach could be conducted using the following steps:

- The LCP emissions inventory, with data available from 2004 up to 2009, includes details of the total emissions of SO_2, NO_x and dust, the thermal capacity and annual quantity of energy input broken down into five categories of fuel (biomass, other solid fuels, liquid fuels, natural gas and other gases) at an installation level;
- The competent authority, or LCP operators could be contacted to establish: the GHG emission factors for fuel at each installation and the efficiency of the LCPs;
- The load factor for each installation can be calculated by dividing the annual energy consumption by the maximum energy input possible (thermal capacity * number of hours in a year). The activity rate for each installation can be estimated by multiplying this load factor by the efficiency of the LCP;
- The initial counterfactual emissions intensity of each installation can then be estimated by dividing the installation's emissions by the activity rate. If the emissions intensity of an installation shows a step reduction in the years prior to full IPPC implementation, this may be due to early installation of abatement equipment for IPPC compliance; where this occurs and it can be established that the change is not due to exogenous variables, the counterfactual emissions intensity should be calculated excluding that year;

- MS and EC policies, and sector reports should be reviewed and sector experts in the competent authorities should be contacted to establish if policies or other exogenous variables (technological improvements, changes in fuel-price differentials) would have had an impact on the emissions intensity of different types (fuel, or technology type) of LCP; the impact of EU ETS on GHG emissions and fuel choice is particularly relevant. Where it is established that policies or other exogenous variables will have a significant impact on the emissions intensity of LCPs an adjustment factor (fuel, or technology specific) could be used to recalibrate the counterfactual emissions intensity for each affected installation;
- The counterfactual emissions for each installation can then be estimated by multiplying the activity rate by the updated counterfactual emissions intensity of each installation;
- An estimate of the emissions reductions due to the full implementation of IPPC can then be made at an installation level by subtracting actual emissions from the counterfactual emissions. It should be noted that this will include the impacts of the LCPD due to interactions between the two Directives. For future assessments this should not be a concern as the two Directives have now been combined under the IED;
- The benefits of these emissions reductions can then be estimated by either:
    - Applying MS-specific damage cost functions to the total emission reductions estimates; or
    - Entering the installation-level emissions reductions estimates along with geographic and stack data into an air quality model and modelling population exposure (very resource/data intensive).

It should be noted that the Tier 3 approach proposed above will be extremely resource intensive, due to: the quantity of data required at an installation-level and the work required to properly assess the impact of other policies and exogenous variables on the counterfactual. As IPPC only has an indirect impact on GHG emissions, the efficiency of conducting detailed assessments of this policy should be considered carefully.

Assessment of socio-economic costs

'Tier 1' methodology

A high-level assessment of the cost impact of IPPC on LCPs at an EU-wide level could be conducted using the following steps:

- Using the emissions reductions estimates from the Tier 1 environmental impacts assessment, the average emissions intensity reduction can be estimated for each pollutant (as a %);
- Identify abatement measures with similar emission reductions potential (% reduction) as the average emissions intensity reduction (above); the cross-media impacts of the measures and their penetration prior to IPPC should be considered in this selection process. The average cost of these abatement measures

can then be estimated to produce unit abatement costs for each pollutant. It should be noted that it may be necessary to produce two (or more) estimates of this figure as the range of abatement measures implemented in 2007 when BAT requirements first came into force and in 2008 and 2016 when ELVs from the LCPD are enforced may be different;

- By multiplying the emissions reductions estimates (from the environmental impacts assessment) by the cost per tonne of emissions reduced figure (above) an estimate of the total costs of compliance can be produced;
- It should be noted that this methodology has a high level of uncertainty, as:
    - o It does not account for national policies already in place, or attempt to isolate the impact of IPPC from other policies;
    - o Differences in fuel type, technology and existing uptake of abatement measures between MS and installations are not accounted for;
- Given the high level of uncertainty, it would be inappropriate to use these cost estimates as inputs to economic models for the estimation of wider socio-economic impacts.

'Tier 2' methodology

The Tier 1 methodology can be improved upon by taking the following steps:

- The estimates of unit abatement costs can be constructed and refined at a MS level by:
    - o Reviewing publicly available IPPC/LCPD implementation studies, BREF documents and MS reports to identify abatement measures which have been installed to comply with IPPC/LCPD;
    - o Reviewing MS policies and National Action Plans to identify where emissions reductions were required in the counterfactual for compliance with non-IPPC policies;
    - o This improvement in estimation of the unit abatement costs, along with improvements in the estimates of emissions reductions relative to the counterfactual will reduce uncertainty in cost estimation.

'Tier 3' methodology

In order to complete a detailed assessment of the impacts of the IPPC on LCPs, a bottom-up approach, which accounts for changes in the counterfactual is required. Such an approach could be conducted using the following steps:

- A more detailed assessment of the abatement measures implemented to comply with IPPC at an installation level can be achieved through a combination of different methods:
    - o LCP operators could be surveyed to ascertain directly which abatement options have been implemented for IPPC compliance; this could take in-

to account abatement measures which were taken up under the counterfactual scenario;

- Sector experts in the competent authorities could be contacted to develop assumptions on the type of abatement option which is required for specific fuel and technology types; this could take into account abatement measures which were taken up under the counterfactual scenario;
- Changes in the emissions intensity of an installation from the counterfactual (estimated in the environmental assessment) can be used to identify the type of abatement option which has been implemented; for example, if the SO_2 emissions intensity of an installation has reduced by 90% in the first year of full IPPC implementation it can be assumed that FGD was installed;
- The result of using a combination of these methodologies is that the abatement option taken up for IPPC compliance at each installation is known with a higher level of certainty;

- Unit-costs (capital and operating) for each type of abatement option which has been installed for IPPC compliance can be established from a number of data sources (BREFs, EGTEI reports, sector studies, abatement equipment manufacturers, GAINS);
- The costs associated with installing and operating abatement equipment for IPPC compliance can then be estimated for each installation using the load factor and thermal capacity data derived from the LCP emissions inventory, and the unit costs. A present value for the cost of compliance can then be derived by discounting these costs over time. It should be noted that the cost of compliance for plants which chose the LLD route will be related to the revenue lost and cost of replacing existing LCPs;
- An assessment of the administrative costs of compliance can be made for a typical installation by:
    - Estimating the man-hours required for operator and competent authority employees to process the permits and multiplying these figures by MS-specific hourly wage rates; and
    - Investigating the MSs permit application and renewal charges;
- The total costs of compliance can then be determined at a sector level by summing the abatement and administrative costs for each sector for each year; this information can then be used as an input to economic models to assess the impacts of the policy on wider socio-economic impacts;
- If required, sensitivity analysis can be conducted by using high and low estimates of abatement unit costs and hourly wage rates.

Data assessment

The previous section set-out a methodology for assessing the impact of IPPC on LCPs and gave examples of data sources which could be used. Assessment of the impact on other sectors can be conducted using a similar methodology, but using different data sources. The key types of data required to perform an ex-post assessment of the IPPC Directive for each sector are:

- Emissions from installations;
- Activity data (units produced);
- Number of installations;
- Abatement measures implemented (specifically for IPPC);
- Estimates of unit costs for abatement measures;
- Reports on changes in exogenous variables which affect the counterfactual.

Table 4.14 (below) summarises some of the available data sources, the type of information they contain, the sectors for which this is applicable and additional comments on the quality and usefulness of the data.

Table 4.14 Data sources applicable to assessment of IPPC

Data Source	Type of Information	Sectors / MS / Time	Additional Comments
PRIMES	• Assumptions on energy use under a number of scenarios, including a 'baseline'; • Earlier versions of PRIMES could be used to identify a baseline scenario which represents the counterfactual.	• All applicable sectors, years and MS are included within the PRIMES model.	• Sector categorisation in PRIMES does not match with activities listed in Annex 1 IPPC.
GAINS	• Contains emissions scenarios for a number of scenarios; the scenarios which best represent the counterfactual and IPPC implementation scenarios could be used to estimate emissions reductions; • Unit-cost information is available for specific abatement options, although sometimes several measures are bundled together; • Information on the capacity of sectors and the typical size of installations is included, but this information appears patchy, or incomplete; • MS information on wage rates, fuel and electricity costs is available; • Estimates of energy savings and costs are available for a limited number of sectors and abatement options; • Estimates of different types of fuel use are available.	• Good disaggregation of emissions data by sector; • Good disaggregation of costs by sector; • Fuel consumption assumptions insufficiently disaggregated by sector; • All data is disaggregated by MS; • Information is only available for the years 2000, 2005, 2010, 2015, 2020.	• It may not be possible to select GAINS scenarios which reflect the counterfactual scenarios and situation post IPPC implementation; the impact of other policies may be included in the analysis. In addition, alterations to account for exogenous variables would be required; • Unit-cost information is useful; • Fuel-use / activity data is not sufficiently detailed.
EPER / E-PRTR	• Includes data on the release of pollutants to air and water at an installation level; for installations which meet the capacity	• All applicable IPPC sectors are included;	• Although not all emissions from IPPC installations are included

Data Source	Type of Information	Sectors / MS / Time	Additional Comments
	and emission thresholds.	• Data is available for all MSs; • Data is only available for the years 2001, 2004, 2007 and 2009.	due to the capacity thresholds, for sectors which are large emitters, the majority of emissions will be included. This is a key source of information for non-LCP sectors; • Emissions from LCPs and other parts of the installation (e.g. for an iron and steel plant) cannot always be differentiated.
Eurostat	• Environmental expenditure data is available for 'protection of ambient air and climate'; only available at an aggregated sectoral level; • Detailed statistics on the units of production is available in detail (not differentiated by firm size); • Totals of GHG and other air pollutants is available, but not sufficiently disaggregated by sector and acidic pollutants are included together as 'Total acidifying potential'; • Information which is useful for simple assessments of the impact on competitiveness and socio-economic impacts is available (total expenditure, imports, exports, gross operating surplus, number of employees); • Information on the consumption of different types of fuel for certain sectors and processes (e.g. coke ovens, blast furnaces).	• Data disaggregated by MS; • Data available for years 1997-2007; • Varying level of disaggregation by sector, depending on information type.	• Includes information on all installations, not only those included within the scope of IPPC; • Some data is disaggregated by firm size (number of employees); this could be used to approximate which data is relevant to IPPC installations; • Energy consumption for specific sectors and activities is potentially very useful; • Useful information for broader socio-economic analysis; • Production data is extremely useful for establishing the activity rate.

Data Source	Type of Information	Sectors / MS / Time	Additional Comments
CITL	• CO_2 emissions at an installation level	• Only applicable to installations which are included within the scope of the ETS; • Data available for all years;	• CITL data would be useful for assessing the contribution of ETS installations to the total GHG emissions reductions.
IRIS	• Data on the number of 'new' and 'existing' IPPC permits and the permitting status of the installations; • Detailed sector reports on IPPC implementation is available for the Iron & Steel and Cement sectors; these include information on ELVs and abatement techniques taken up; similar reports for other sectors will be available in the future.	• Permit numbers disaggregated by sector and MS; • Detailed data for I&S and cement sectors.	• Useful for establishing numbers of installations; • Sector reports very useful for establishing policy implementation and abatement measure uptake.
Entec MBIs database and model	• Installation-specific data on the emissions of SO_2, NO_x, PM extracted from E-PRTR; • Installation-specific data on the emissions of GHG estimated from data included in E-PRTR; • Assumptions on abatement measures installed, fuel type, production volume; developed through consultation with MS and industry sector experts, and analysis of E-PRTR data.	• Emissions data for 2007 only; • Sectors included: LCPs (all sectors), refineries, glass, cement, iron & steel. • All MS.	• Although the database is not publicly available, a similar database could be developed from E-PRTR data using the methodologies described above; • Assumptions on abatement uptake in 2007 and for compliance with IED in 2016 are available at MS level in the appendices to the report.

4.7.5 Summary and conclusions

Our main conclusions are:

- As IPPC has large areas of overlap with, and is linked to a framework of, related Directives (as demonstrated by its integration with a number of sectoral Directives under the IED), it is recommended that any future assessments should consider the impact of these Directives in combination e.g. IPPC and LCPD;
- As IPPC only has an indirect impact on GHG emissions, the efficiency of conducting detailed assessments of this policy (in particular, the framework for a Tier 3 approach described above), should be considered carefully;

If assessment of the impact of IPPC on GHG emissions is required, it is recommended that the study should focus on a limited numbers of sectors, which contribute the majority of emissions of GHGs and other air pollutants. Assessing each of these sectors will require slightly different tailored methodologies and specific data, which could be available from sources such as databases and emissions inventories (e.g. Eurostat, LCP, E-PRTR or CITL), models (GAINS, PRIMES), sector studies or by contacting sector experts and operators directly, depending of the level of detail needed.

If a thorough assessment of the impacts of the IPPC Directive is required, a Tier 3 bottom-up approach is considered most appropriate, which accounts for changes in the counterfactual at an installation level. Such an approach permits an assessment of the impacts of overlapping policies and other exogenous variables on the counterfactual. However it is important to note that this installation-level approach will be extremely resource intensive.

Besides, the total costs of compliance can be determined at a sector level by summing the abatement and administrative costs for each sector for each year; this information can then be used as an input to economic models to assess the impacts of the policy on wider socio-economic impacts.

As a result, it was agreed with the Commission that this Directive would not be subject to testing under Task 3.

4.8 Waste Incineration Directive

4.8.1 Policy overview

The Waste Incineration Directive (WID) regulates the incineration of waste to prevent excessive pollution to air, water and soil. Incineration and co-incineration plants must be authorised, comply with emission limit values for releases to air and water, implement measurement and monitoring systems and recover any heat generated. The WID imposes:

1. Emission limit values for air pollutants such as: Dust (PM), HCl, HF, SO_2, NOx, heavy metals and dioxins.
2. Recovery of heat generated by the incineration process, the heat must then be put to good use as far as practicable.

The Waste Incineration Directive has been applied to existing plants since December 2005 and to new plants since December 2002. Note that this Directive is now part of the Industrial Emissions Directive (IED) as discussed in the IPPC section above.

4.8.2 Links with other EU Directives

The IPPC also covers waste incineration plants provided they meet specific capacity thresholds[130]:

- The WID sets more explicit requirements for the recovery of energy than the IPPC Directive;
- The WID only sets minimum obligations for emissions to air, land and water; meeting these requirements is not necessarily sufficient to comply with IPPC.

The previous study assumes that the direct effect of IPPC on GHG emissions is marginal as it does not directly regulate GHG emissions and that the more explicit requirements for the recovery of energy in WID will be the major factor impacting on GHG emissions. However, for more detailed assessments, the impact of the IPPC Directive's requirements for emissions to land, air and water on an installation's energy demand for abatement equipment should be considered. In addition, the WID and IPPC Directive are now combined together with other policies into the more comprehensive Industrial Emissions Directive (IED). The merits of separating the effects of the WID from IPPC will be qualitatively discussed in this study.

There are a number of other policies and measures which may influence the recovery of energy from waste in addition to WID:

- The Framework Directive on Waste (75/442/EEC) requires national competent authorities to draw up waste management plans, which encourage the recovery of waste for its use as a source of energy; this Directive will indirectly affect the implementation of WID by increasing the activity rate;

[130] The minimum capacity thresholds for inclusions within the scope of IPPC are 3 tonnes / hour for the incineration of municipal waste and 10 tonnes per day for the incineration of hazardous waste. WID does not have a minimum capacity threshold, but does exclude installations where the capacity is less than 50 tonnes per year and the primary purpose is research, development and testing to improve the incineration process.

- The Combined Heat and Power (CHP) Directive (2004/8/EC) aims to indirectly support the advancement of CHP which is commonly used to capture the energy generated through the incineration of MSW;
- National policies on waste collection, recovery, disposal and incineration will also interact with WID.

The previous study concluded that in the absence of WID these policies would have delivered GHG emissions savings by encouraging the disposal of waste through incineration and increased energy recovery at incineration plants.

4.8.3 Review and critical assessment of existing methodology

The previous study developed Tier 1 and Tier 2 assessment methodologies and made some suggestions for a Tier 3 approach. These are summarised in the table and text below.

Table 4.15 Key methodological choices from AEA (2009) study

Approach	Tier 1	Tier 2	Tier 3
Source Data	EU-27 values for: • Mass of MSW disposed through incineration (Eurostat); • Energy from incineration available for final energy consumption (Eurostat); • Energy from waste as heat and electricity (CEWEP country reports); • Large scale electricity and production (Eurostat); • Primary fuel consumed in electricity production (Eurostat); • Emission factors for combustion of fossil fuels (IPCC).	As Tier 1, except MS-specific values where available.	Includes detailed bottom up statistics.
Autonomous development + structural change	Does NOT consider autonomous development or structural change. The energy available per unit mass of MSW incinerated is assumed to remain at 2005 values in the absence of the Directive.	Autonomous change is considered by extrapolating the linear trend (from 1995 to 2004) in energy available for final consumption per unit mass MSW incinerated forward to the present as a counterfactual.	Correction(s) of autonomous development and structural change.
Policy start date	Calculates policy impacts from same start date, no adjustment for implementation delays or announcement effect	As for Tier 1	

Approach	Tier 1	Tier 2	Tier 3
Policy Interaction	Combined effect of national and EU policies. Combined effect of closely related national and EU policies.	Some effect of pre-existing policies removed from the estimation.	Estimates effect of specific EU policy.
Exogenous factors	No adjustment for exogenous factors.	No adjustment for exogenous factors.	Adjustments for impacts of profitability of waste incineration.

The tier 1 approach can be summarised as follows:

- It is assumed that if WID had not come into force in 2005 for all incineration plant, the energy recovered per unit mass of waste incinerated would have remained 'frozen' at 2005 levels;
- The year 2005 was taken as the reference year for energy recovery per unit mass of waste incinerated;
- The energy recovered from waste incineration subsequent to 2005 is assumed to displace heat and electricity from other sources. The ratio of heat energy to electrical energy output from MSW incineration is based on the country reports of CEWEP (Confederation of European Waste-to-Energy Plants).

The tier 2 approach can be summarised as follows:

- The methodology attempts to take into account autonomous development in the recovery rate for specific MS and some of the policy interactions that were not included in the Tier 1 approach by extrapolating trends in energy available for final consumptions per unit of MSW incinerated;
- MS specific data (where available) was used for calculating energy recovery rate, emission factors for heat and electricity.

A Tier 3 methodology was not developed as part of the previous study. It was found that the analysis of WID is not fully suited to a Tier 1 and Tier 2 indicator based approach, because of the variability of the energy recovered from Municipal Solid Waste (MSW) incineration. Negative savings (increases of emissions) have been calculated due to an anomalous fall in energy recovery from MSW incineration in 2006 in the EU 27. The main recommendations from the previous study were to:

- Improve MS representation by using national data;
- Develop the national emissions counterfactuals by treating 2006 carefully (considering the assumptions of energy recovery rates for each Member State);
- Consider overlaps with IPPC measures; particularly the impact of NO_x abatement techniques (SNCR) on emissions of N_2O which is a powerful GHG;

- Consider any possible "early-mover" policy effects i.e. where waste incinerators may have implemented abatement techniques and energy recovery practices prior to the policy start date.

In addition to these improvements, this study could investigate:

- The feasibility of improving the counter-factual in a Tier 2/3 approach by:
    - o Investigating sector reports to identify what abatement measures were already implemented before WID came into force and to determine where this was in preparation for WID, or to comply with other policies;
    - o Investigating exogenous variables which will impact on the counterfactual; for example the moisture content of MSW which is incinerated;
- Review existing databases to identify national trends, such as E-PRTR and other reporting documents (e.g. IPPC reports);
- Assess the potential to use models such as GAINS and PRIMES to develop MS-specific counterfactuals;
- Assess the costs of measures via a literature and database review;
- Consider the feasibility, costs and benefits of isolating the impact of WID from the impact of IPPC, considering the consolidation of the WID and IPPC directive into the IED.

4.8.4 Proposed improvements and refinement methodology

The main conclusion of the previous study was that Tier 1 and Tier 2 methodologies may not be suitable for accurately assessing the impact of WID on emissions of GHGs and other air pollutants. However, Tier 2 & 3 methodologies which use the same principles as described in the IPPC section could be developed provided that they accounted for the following:

- Activity rates:
    - o Tier 2 - Eurostat data and CEWEP reports could again be used to determine the quantity of MSW treated by waste incineration plants;
    - o Tier 3 - An operator survey would be required to accurately determine the quantity of waste treated at an installation level; alternatively MS may collect this information at a national level;
- Policy implementation and interaction with other policies:
    - o Tier 2 & 3 - Okopol (2007) includes a summary at a MS level of where stricter ELVs than those required for WID are included in permits; where this occurs, it will be a challenge to disentangle the effect of multiple policies (IPPC, WID, national policies). CEWEP reports also include information on policies in place for each MS;

  - Tier 3 - An operator survey may be required to accurately identify the measures implemented for specific policies; alternatively MS may collect this information at a national level;
- Changes in exogenous variables over time:
  - Moisture content of MSW treated:
    - Tier 2 – GAINS data on the proportion of food / paper / other waste incinerated could be used to approximate the change in moisture content over time at a MS level;
    - Tier 3 – An operator survey may be required to assess this; alternatively MS may collect this information at a national level;
  - Identifying abatement measures taken up in plants in advance of WID and determining whether this uptake was in preparation for WID or to comply with other policies;
    - Tier 2 – Sector experts at competent authorities could be consulted to determine this at a MS level;
    - Tier 3 – An operator survey may be required to assess this;
  - Changes in energy prices and subsidy levels which may affect the level of waste incinerated and the financial benefits to operators from energy recovery:
    - Tier 2 and 3 – changes in prices and subsidies included in CEWEP reports over time could be used to inform analysis of how energy recovery rates would have changed in the counterfactual;
- Cost estimation:
  - Tier 2 & 3 – Okopol (2007) includes case studies for a number of types of installations which includes cost estimates for a range of abatement measures; this information can be used to determine unit costs;
  - Tier 2 – summaries of abatement measure uptake, disaggregated by MS, plant and technology type are available in Okopol (2007);
  - Tier 3 - An operator survey may be required to assess abatement uptake at an installation level. Alternatively, MSs may have already conducted an Impact Assessment for WID, which can include useful cost

data; for example AMEC recently completed an ex-post assessment of the implementation of WID in the UK[131].

It should be noted that the operator surveys and installation-specific Tier 3 methodology outlined above would require a significant amount of resources to undertake and the additional benefits of such a study should be carefully considered in relation to the relatively small impact of WID on GHGs.

Data assessment

The data sources which were reviewed for this study are summarised in Table 4.16 (below);

Table 4.16 Review of data sources applicable to WID

Data Source	Scope of data source	Key information
CEWEP Reports	• Available for most MS; • Available for 2004, 2006, 2008 & 2010.	Information available at MS level (not installation-level) on: • Total arisings of waste; • Quantity of waste treated by disposal route (including waste-to-energy plants); • Numbers of plants & plans for future plants; • Electricity and heat produced & exported from waste-to-energy plants; • Includes details of MS policies, prices and subsidies which is useful for determining the counterfactual; • Does not contain information on emissions to air or water, or the abatement techniques applied.
PRIMES	• Available for all MS & all years.	• Projections are not available for waste incineration plants specifically; of limited use for this study.
GAINS	• Available for all MS & all years.	• See general comments on available data in IPPC section; • Does not include waste incineration with heat recovery as a separate category for emissions and

131 AMEC on behalf of Defra, (2011), 'Evaluation of effectiveness and cost efficiency of air quality policies 2001-2010'.

		costs under the scenarios; • Does include information on the proportion of paper, food and other wastes included in MSW; • Includes data on the total availability of MSW (Mt).
EPER / E-PRTR	• Available for most MS; • Available for 2001, 2004, 2007 & 2009.	• Includes data on the release of pollutants to air and water at an installation level; for installations which meet the capacity thresholds (3 tonnes per hour for waste incineration); • Also includes information on waste transfers between installations.
Eurostat	• Available for all MS & all years.	• See general comments on available data in IPPC section; • Statistics on the quantities of hazardous and non-hazardous processed by disposal route, including 'energy recovery'.
CITL	• Available for all MS & all years.	• Installation level data on GHG emissions for those plants which are included within the scope of the EU ETS.
IRIS	• Available for all MS & all years.	• Data on the number of 'new' and 'existing' IPPC permits and the permitting status of the installations; • Detailed sector reports are not available for waste incineration.
Okopol (2007)[132]	• Snapshot in 2007 for all MS	• Interpretation of the Directive by MS including details of where derogations have been applied and where stricter BAT-AELs than required in WID have been applied; • Information on the frequency of emissions measurement required by MS and the number of plants which comply with ELVs for different types of pollutants by MS; • MS summaries of the number of plants and their

[132] Okopol on behalf of the European Commission, (2007), 'Assessment of the application and possible development of community legislation for the control of waste incineration and co-incineration'.

		capacity by plant and technology type and the number of plants with specific abatement techniques installed; • Case studies for a number of different types of plant, including information on the uptake of abatement measures, the performance and costs of this equipment.
MS WID fact sheets[133]	• Snapshot in 2008 for all MS	• Interpretation of the Directive by MS including details of where derogations have been applied and where stricter BAT-AELs than required in WID have been applied; • Summary of the number of plants included within the scope of the Directive and the permit requirements; • Includes links to MS sector Impact Assessments where available.

4.8.5 Summary and conclusions

Our main conclusions are:

As WID has large areas of overlap with IPPC (as demonstrated by its integration with a number of sectoral Directives under the IED), it is recommended that any future assessments should consider the impact of these Directives in combination, as isolating the impacts will be extremely difficult; As WID only has an indirect impact on GHG emissions, the efficiency of conducting detailed assessments of this policy should be considered carefully. In particular the framework for a Tier 3 approach described above requires significant resources and survey work (i.e. to determine activity rates, assess the changes in exogenous variables, identify the measures implemented for specific policies and assess technology abatement uptake and related costs). As a result, it was agreed with the Commission that this Directive would not be subject to testing under Task 3.

[133] AEA, Association Aspen and Vito on behalf of the Commission, (2010), Analysis of the reports submitted by Member States on the implementation of directive 2008/1/EC, Directive 2000/76/EC, Directive 1999/13/EC and further development of the web platform to publish information – Draft report on subtask 3: Analysis of Member States implementation of IPPC and WI Directives – Annex A: Member States IPPC factsheets'. Available from: http://circa.europa.eu/Public/irc/env/ippc_rev/library?l=/implementation_2006-2008/ms_factsheets&vm=detailed&sb=Title

4.9 Nitrates Directive

4.9.1 Policy overview

The main objective of the Nitrates Directive (Council Directive 91/676/EEC) adopted in 1991, is to protect waters against the pollution caused or induced by nitrates from agricultural sources. To achieve this, Codes of Good Agricultural Practices have been published and MS are required to establish Action Programmes containing a set of measures within designated nitrate vulnerable zones (NVZ) in their territories.

The Nitrates Directive is an important supporting instrument for other EU policies concerning water, air, climate change and agriculture, and its implementation yields benefits in all these areas. In this sense it is closely linked with the Water Framework Directive, the Common Agricultural Policy (CAP), the Industrial Emissions Directive and the NEC Directive.

4.9.2 Review and critical assessment of existing methodology

The first European Climate Change Programme (ECCP) quantified the potential (ex-ante) savings from N_2O emissions from soils in the EU-15 at 10 $MtCO_2$ eq, by 2010. These savings however were not allocated to a particular policy (i.e. just for the nitrates directive). The 2009 study provides an ex-post estimate of the annual benefits in 2005 at 10.7 $MtCO_2$ eq. (Tier 1 approach) and 8.2 $MtCO_2$ eq. (Tier 2 approach). The method and limitations of these Tiers are set out below in Table 4.17.

Note, the 2009 study did not estimate the ex-post costs of the Nitrates Directive nor develop a method to do so.

Table 4.17 Nitrates Directive – Ex-post method and estimates of N_2O reductions from soil (EU-15)

Tier	Methodology	Limitations applicable to Tier 1 & 2	Ex-post estimates (annual)	Confidence
1	Data was based on EU wide statistics. Emissions were calculated based on aggregated data reported by Members States to UNFCCC, and associated emission factors. A single year was used as the 'frozen efficiency' for the application rate (i.e. pre-directive efficiency). Emissions reductions are assessed in terms of the change in emissions of N_2O from soil per unit of agricultural land, relative to 1996- the date by which Members States were required to implement the main components of the Directive. No adjustment for delays in implementing action plan measures (e.g. Ireland introduced action plan in 2006).	• Assumes there is no autonomous development (e.g. improvements in technology). • No adjustments for structural changes in activity data (e.g. changes in agricultural use of the land over time) • Does not make any adjustments/deductions for reductions in emissions due to other policies (national or EU). In particular the CAP but also relevant is IPPC (now consolidated within the Industrial emissions Directive - IED) and the NEC Directive. • No adjustment is made for geographical climate conditions (e.g. rainfall, soil type), type of livestock and/or crop used on land or market forces (e.g. demand for organic produce, changes in N fertiliser prices). • No adjustment is made for the coverage of the NVZ (i.e. assumes whole territory when estimating emissions).	10.7 Mt CO_2 eq. (in 2005)	Low – It was not considered to be an accurate representation of the impacts of the Directive
2	Similar method to Tier 1 but calculates emissions reduced based on policy impacts from the actual implementation date rather than start date of policy (when MSs were required to implement the main components of the Directive). Instead of a single year being used as the 'frozen efficiency' for the application rate, the average application rate in the 3 years prior to the implementation of the Directive was used (to avoid the sensitivity of using a single year).		8.2 Mt CO_2 eq. (in 2005)	Low – It was not considered to be an accurate representation of the impacts of the Directive
3	A Tier 3 assessment was not undertaken nor was a method suggested as to how this might be done.	-	-	-

Note: savings relate to EU-15. An EU-27 estimate was not undertaken.

Recommendations from the previous study included the following:

- Further develop the database of disaggregated statistics by Member State, using DG Agriculture Farm Structural Survey if relevant.
- Expand the scope of Tier 3 to include, if cost effective:
    - Integration of econometric analysis of input and commodity prices on Nitrogen fertiliser application rates;
    - Calibration of bottom up data on farm management measures implemented within Action Programmes;
    - Correction for impacts on climatic variation on fertiliser application rates; and
    - Correction for changes in crop type and fertiliser type on fertiliser application rates.

4.9.3 Proposed improvements and refinement methodology

Table 4.18 sets out some possible areas that could improve the benefits estimated. It also sets out how this could be done and how difficult/resource intensive this might be and the overall effect on the Tier 2 estimate. In most instances, any refinements are likely to reduce the estimated benefits associated with the Nitrates Directive, which the 2009 study recognises is likely to be an overestimate.

Table 4.18 Tier 2/3 options – Refining benefits estimated

Area for improvement	Possible approach	Feasibility	Effect on Tier 2 estimate (8.2Mt CO_2 eq)
Emissions inventory data	MS emissions inventories provide the best way to determine N_2O emission from soil. Currently MS inventories are based on a single method for all types of fertiliser and soils (IPCC – Tier 1 approach). The 2009 study only considered direct soil emissions. It may be possible to consider additional sources of emissions that are linked to the ND implementation, including: pasture, range and paddock manure; indirect soil emissions such as nitrogen leaching and run off; manure processing and manure storage. There is a recognition of the simplicity of the IPCC Tier 1 approach but no agreed results have been developed for Tiers 2 (factors location specific values) and 3 (Tier 3 being based on actual measurements and models).	It is not feasible as part of this study to develop a revised emissions inventory using an IPPC Tier 2 or 3 approach.	Unknown – The effect may be to increase or decrease the benefits of the Nitrates Directive
Corrections for autonomous development	The counterfactual baseline used in the 2009 study would need to be updated to factor in changes in technology that has lead to the reduction in the quantity of N fertiliser required. A list of new technologies would need to be drawn up and screened to determine	This will depend on the availability of underlying data used to determine the counterfactual as part of the 2009 study. It would then require a literature review and	Likely to lead to a decrease in the 8.2Mt CO_2 eq estimate. However this was not deemed a priority issue in the 2009 study.

Area for improvement	Possible approach	Feasibility	Effect on Tier 2 estimate (8.2Mt CO_2 eq)
	those that are likely to have been developed in the absence of the Nitrates Directive.	stakeholder surveys to understand if the technology may have been introduced in the absence of the Nitrates Directive.	
Corrections for structural changes in activity data	It may be possible to conduct surveys for several regions/MSs who have different types of soil, climate (e.g. rainfall) and land use to understand if farm management practices changed as a results of the Nitrates Directive (or if it was due to other factors). It may then be possible to see how this varies to the 2009 emissions factors used to pro-rate the Tier 2 estimate.	Pro-rating (scaling) the Tier 2 estimate is considered the most feasible option, as it is unlikely that a bottom up approach could be developed as part of this study (for data collection and resource issues).	Likely to lead to a decrease in the 8.2 Mt CO_2 eq estimate.
Correction to reductions in emissions due to other policies	It would be necessary to assign a proportion of the Tier 2 estimate or any subsequent estimate developed, to the Nitrates Directive and those attributable to the CAP (and to a lesser extent IPPC and the NEC Directive). In November 2010, the European Commission launched "*The impact of the Nitrates Directive on gaseous N emissions – effects of measures in nitrates action programmes on gaseous N emissions*"[134]. The aims of this study are to explore further the effects on air emissions of some specific measures in nitrates action programmes. The results of this study will provide a useful additional source of information – see below	This would need to be conducted in collaboration with any further assessment of the CAP in particular. It would require a literature review and stakeholder survey to understand the driving force behind key farm management changes.	Likely to lead to a decrease in the 8.2 Mt CO_2 eq estimate.
Corrections for market forces	It would be necessary to understand how use (and type) of fertiliser has changed as a result of changes in fertiliser prices. The Commission has expressed specific interest in understanding this relationship. Additionally other market factors should be considered such as changes in demand for organic produce which will have had an effect on the use of N fertiliser regardless of the Nitrates Directive. This should then be used to update the counterfactual scenario.	It would require a literature review and stakeholder survey to understand the effect market forces have had on fertiliser application rates.	Likely to lead to a decrease in the 8.2 Mt CO_2 eq estimate.
Correction for the coverage of the nitrate vulnerable zones (NVZ) designation	The 2009 Tier 1 and 2 estimates are both based on a whole territory approach (i.e. 100% NVZ designation). However not all MSs have adopted a whole territory approach, with the EU average at 42%[135]. The Commission has made available 2009 data on % NVZ designation by MS. Unless the NVZ designation is 100%, it is unlikely to be sufficient to simply apply	If it is possible to assign emissions reduced by policy, all emissions attributable to the Nitrates Directive will need to factor in NVZ coverage. This means any literature review and stakeholder survey should already	Likely to lead to a decrease in the 8.2 Mt CO_2 eq estimate.

[134] http://ec.europa.eu/environment/funding/pdf/calls2010/specifications_en_10009.pdf
[135] http://www.ialibrary.bis.gov.uk/uploaded/09.%20Nitrate%20Vulnerable%20Zones.doc

Area for improvement	Possible approach	Feasibility	Effect on Tier 2 estimate (8.2Mt CO_2 eq)
	NVZs designations percentages as a proportion of MS estimates (note: a MS breakdown was not included in the 2009 study). This is because NVZs will be designated in areas that have a higher risk of leakage to water and therefore are likely to account for a higher proportion of reduced N_2O from soil.	consider NVZ designations.	

A valuable source of information to support the development of a Tier 2/3 approach as outlined in Table 4.18 is the Alterra (2010) study entitled "*The impact of the Nitrates Directive on gaseous N emissions – effects of measures in nitrates action programmes on gaseous N emissions*"[136]. The aims of this study were to explore further the effects on air emissions of some specific measures in nitrates action programmes implemented under the Nitrates Directive.

For this purpose, a comparison of two scenarios "with and without implementation of the Nitrates Directive" was performed using the MITERRA-EUROPE model[137] for the calculation of the gaseous nitrogen (N) emissions from agriculture sources: ammonia (NH3), nitrous oxide (N_2O), and nitrogen oxides (NOx). This model is based on the existing GAINS and CAPRI models, supplemented with a nitrogen-cycle and leaching module, databases (i.e. FAO, Eurostat, Joint Research Centre), soil data, literature review and expert opinion.

The methodology assesses at a NUTS 2 level the nitrogen emissions resulting from the use of the most common agricultural practices in each Member State (without obligations deriving from the Nitrates Directive). It uses for its calculations designated NVZ, based on the assumption that the Nitrates Directive only had a significant impact in these areas through the implementation of several measures affecting the use of nitrogen fertilizer (i.e. balanced nitrogen fertilization, limit of 170 kg N/ha/year from animal manure, closed periods, prohibition of application of nitrogen fertilizer during winter/wet periods and on sloping soils, buffer strips). It also notes that the calculated baseline scenario includes a fully implemented IPPC Directive.

Results show that all N emissions decrease for both scenarios in the period 2000-2008, but that the emissions of the scenario with implementation of the Nitrates Directive are smaller than without the Nitrates Directive. In particular, the total calculated EU-27 N_2O

[136] http://ec.europa.eu/environment/water/water-nitrates/pdf/Final__report_impact_Nitrates_Directive_def.pdf

[137] MITERRA-EUROPE was developed in the project "Integrated measures in agriculture to reduce ammonia emissions" for the Directorate-General Environment of European Commission (Contract number 070501/2005/422822/MAR/C1). The model MITERRA-EUROPE assesses the effects and interactions of policies and measures in agriculture on N losses and P balances at a regional level in EU-27.

emission in 2008 was 6.3% higher without the Nitrates Directive (326.57 kt nitrogen) than with the Nitrates Directive (307.15 kt nitrogen).

Specifically, N_2O emission factors were derived using an approach associated to application of fertilizers that depend on environmental, crop and management factors. The approach used has been developed by Lesschen et al. (2011) as part of the NitroEurope IP[138] project, which focuses on the nitrogen cycle and its influence on the European greenhouse gas balance.

It is important to note that within the NitroEurope framework the model INTEGRATOR139 has been developed to assess nitrogen and GHG (N_2O, CH_4 and CO_2) emissions from all major terrestrial ecosystems in response to changes in land use, land management and climate at a high spatial resolution for the EU27. This tool includes a modified and updated version of the MITERRA-EUROPE model and should also be taken into account if conducting a detailed assessment.

Regarding policy costs, as noted earlier, the 2009 study does not estimate the costs of the Nitrates Directive. It notes that ex-ante costs differ by MS ranging from €6 to €236 per hectare affected and from €0.4 to €3.5 per kg nitrogen reduced.

The 2009 study states "for two Member States (Denmark and Netherlands) where it was possible to compare ex ante and ex post estimates, the authors found that the ex-ante estimate is at least as large as the ex-post estimate and usually larger. When expressed as cost-per-kg nitrogen reduced, the ex-ante estimates were found to be between 1.2 and 1.9 times as large as the ex-post estimate (Kuik, 2006)".

It is evident that estimating costs will be a time and resource intensive activity. For example a Tier 2/3 assessment will need to factor in at a region level (given variations in climate, crop and livestock reared) the impacts of the action plan:

- How farmers complied with the nitrogen limit – e.g. spread on additional land (or availability of spreading on nearby land), reduced stocking rates;
- Costs savings from reduced use of manufactured fertilisers and increased availability of organic manure;
- Costs of storage requirements and greater costs from increased demand for labour during autumn and spring peaks (e.g. end of the closed period);

  Note: the amount of storage required with all varies depending on volumes of water to store, availability of field heaps;
- Any loss in yield from reduced fertiliser use;
- Increased administrative and farm management complexity (e.g. field inspections, risk assessments, record keeping requirements);

[138] http://www.nitroeurope.eu/about

[139] http://www.biogeosciences-discuss.net/9/6051/2012/bgd-9-6051-2012-print.pdf

- Any capital costs of replacing or modifying inappropriate equipment for spreading and applying fertiliser;
- Any cost of additional cover crops; and
- Any lost revenue from reduced livestock.

4.9.4 Summary and conclusions

The greatest value added is likely to be on estimating the ex-costs of the Nitrates Directive, given that the ex-post benefits have been estimated, albeit likely to be overestimated. Significant resources and survey work will be required to produce more robust ex-post estimates of both costs and benefits. For example, stakeholder surveys will be needed to understand the effect of market forces on fertiliser application rates and the driving forces behind key farm management changes and technology uptake (if they occur as a result of the Nitrates Directive).

Future work could assess the applicability of modelling approaches, such as the Alterra (2010) modelling study and the NitroEurope IP project, to support a more detailed assessment.

4.10 2003 CAP reform

4.10.1 Overview of the Regulation

Common Agricultural Policy (CAP), which encompasses agricultural subsidies and programmes, is a key policy area of the European Union. Up to now it has represented more than 40% (the European Agricultural Guarantee Fund, EAGF) of the total EU's financial budget and is expected to fall to 36% upon the post 2013-reform[140]. The focus of the CAP is mainly orientated to the European agriculture market but has since also developed a stronger focus on environmental protection.

In the past, the reduction of greenhouse gas emissions was not the direct goal of the CAP but the latter nevertheless led to reduced emissions in the agriculture sector as an indirect effect resulting from reduced mineral fertilizer application, improved manure management, a contribution to the production of biofuels and an increase in soil carbon sinks. The CAP promotes the agricultural sector and farm incomes as well as other objectives, mainly through providing economic incentives. Therefore, a direct link between implementation costs of CAP (subsidies to farmers) and emission reduction costs cannot be established or has only limited application in this case due to different types of indicators (commodity market and consumer behaviour). In contrast, with the

[140] In the year 2011 the Commision presented a proposal which indicates to make the CAP more efficient as a legal instrument and to consider sustainable agriculture and support rural areas. “The CAP towards 2020”. http://ec.europa.eu/agriculture/cap-post-2013/communication/com2010-672_en.pdf

implementation of the IPPC Directive and the associated improvement of plant technology cost calculations can be carried out.

The key legislative instrument is the 2003 CAP Reform (COUNCIL REGULATION (EC) No 1782/2003) for the period of 2005 to 2013. It is based on two pillars.

Pillar 1 (income support) addresses three main topics:

1. **Decoupling subsidies** describe the shift from commodity support to support of farmers (single farm payment, SFP) through direct payments based on average historical commodity-based payments from 2000-2002. Member States (MS) can divide their countries into regions and apply different methods for calculating a single farm payment. The amount of the decoupled payments made to farmers is linked to a) the amount of payments received in the past (the standard method) or b) a flat rate area payment (the regional method with a single payment per ha of agricultural land). Opting payments MS could introduce a hybrid system consisting of both methods. Farmers are not required to produce any crops, in contrast to previous reforms. Decoupled payments allow EU farmers to be more responsive to domestic market signals than to policy interventions because they would not compromise the amount of payment received when producing less in response to market conditions. However, MS could retain coupled payments equal to 25 percent of the area for arable crops, 50 percent of the sheep and goat premiums, 40 percent of supplemental durum wheat aid, and from 40 percent to 100 percent of various beef premiums[82]. In the new MS which entered into the EU in 2004 (for 10 countries) support for farmers is provided in the form of a Single Area Payment (SAP). Those payments are fully decoupled from production but still attached to land. Farmers can also receive coupled (to crop and livestock) payments from the national budget, the so-called top-ups. The support provided through SAP is lower than the payments received by farmers in the EU-15, but level increases progressively.

   The milk market is still regulated by a quota system. Every MS has a national production quota which it distributes to farmers. Whenever a MS exceeds its quota, a super-levy has to be paid to the EU which is collected beforehand from the overproducing milk producers. In spite of decreasing dairy cattle numbers the efficiency of milk production raised and still over production of milk occurred in recent years and “super-levy" for milk quota violations was paid by different MS of the EU. Farmers receive direct payments from 2004 until 2013. Therefore, first impacts of the CAP reform could be seen from 2005 onwards.

2. **Cross-compliance**. Farmers must comply with food safety, animal welfare, and environmental standards stemming from EU legislation to receive the single farm payment (SFP). In addition, it is obligatory for farmland to be kept in good agricultural and environmental (GAEC) condition. The system establishes a link between the granting of income support to the farmers and the compliance by

beneficiary with specified requirements of public interest. The individual MS is given no scope for national variations as regards the tying of direct payments to compliance with already existing EU regulations and directives, but have more flexibility to set the management requirements under GAEC.

3. **Financial modulation**, implemented in two parts means reallocating subsidies from the direct payments in Pillar 1 to rural development measures in Pillar 2: The CAP budget for Pillar 1 is fixed from 2004 to 2006 and is then limited to a one percent increase from 2007 to 2013 141. Member States were obliged to cut direct payments beginning in 2005 (2005: 3%, 2006: 4%, as from 2007: 5%) in favour of the development of rural areas (shift of funding from Pillar 1 to 2, compulsory modulation). For Pillar 1 measures reduction of direct payments are not considered to have had significant impacts on production and greenhouse gas (GHG) emissions. The majority (over 70%) of subsidies of the CAP budget goes to direct payments for farmers. As an effect reduction of incentives towards intensive production (e.g. extensification, livestock, reduced fertiliser use) will be expected. All support under Pillar 1 is fully financed from EU resources through the Guarantee Section of the European Agricultural Guarantee and Guidance Fund (EAGGF).

Pillar 2 is dedicated to the development of rural areas and also funds environmental management schemes. In the beginning of the CAP reform the minority of subsidies of the CAP budget (based on an agreement between MS of the EU) was spent on rural development measures[142]. But since 2006 an increase of funds for agri-environmental measures became much more important in terms of environmental impacts. A stimulation of adoption of environmentally friendly production techniques (e.g. reduced tillage, efficient slurry application techniques, investment in animal housing and organic farming) could be expected.

4.10.2 Links with other EU Directives

The CAP overlaps in particular with the Nitrates Directive due to the prevention of nitrogen loads in soils stemming from the application of agriculture waste (more efficient application) and the reduced use of mineral fertilisers and the groundwater directive.

4.10.3 Review and critical assessment of existing methodology

The previous study evaluated and analysed elements of the coupled Common Agricultural Policy: the sheep and goat meat regime and the beef sector premium, animal numbers (activity rates) and emissions in total (as an environmental indicator) using

[141] David Kelch, Mary Ann Normile, 2004, The CAP Reform 2003-2004, Electronic Outlook Report from the Economic Research Service, www.ers.usda.gov, p. 8

[142] http://www.euractiv.com/cap/cap-reform-2014-2020-linksdossier-508393.

only a Tier 1 and Tier 2 approach. The methodology and approach was according to the IPCC guidelines (1996, 2000 and 2006)[143]. In both cases, the availability of data and the complexity of the policy have limited the extent of the analysis (see Table 3.10). Furthermore, since the outcome of the 2003 reform will only be reflected within emissions data from 2005 at the earliest, the extent to which the policy has been evaluated to date is limited in previous research. However, sheep and goats are not among the main emitters of GHGs in the agriculture sector, a differentiation of greenhouse gases was not considered at all and the complexity of the different impacts on emission factors for CH_4 and N_2O emissions (e.g. manure management, improved technology of stables and direct soils) from Pillar 2 measures was not taken into account.

Table 4.19 Methodology in the previous study: 2003 CAP reform – Ex-post method (EU-15)

Approach	Tier 1I	Tier 2	Tier 3 *
Activity indicator	**Number of animals (sheep, goats, beef cattle)**	**Number of animals (sheep, goats, beef cattle)**	**Number of animals (sheep, goats, beef cattle)**
Emissions (gCO_2eq/unit of activity)	**EU15 and MS emissions**	**EU15 and MS emissions**	**EU15 and MS emissions**
Policy interaction	**No**	**No**	**Yes, combined national and EU policy**
Autonomous development	**No**	**No**	**Yes**
Structural effects	**No**	**No**	**Yes (where data available)**
Geographic factors	**No**	**No**	**No**
Timing issues / delay or announcement effects	**Same start date**	**Single year being used as the “frozen efficiency” for the application rate, the average application rate in the 3 years prior the implementation of the regulation**	
Other exogenous factors	**No**	**No**	**Yes**
Source data	**Eurostat, UNFCCC**	**Eurostat, UNFCCC**	**Eurostat, UNFCCC**

*The Tier 3 approach could not be further elaborated in the course of the previous study.

143 http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf.

Furthermore, the transition period (from 2007 onwards) for the implementation of CAP 2003 measures and direct payments for the 12 new EU member states were not taken into consideration in the previous study.

Recommendations for further improvement included the following:

- The feasibility of using existing economic models e.g. CAPRI[144] (Common Agricultural Policy Regional Impact) to perform a Tier 3 approach on an EU-27-wide basis needs to be assessed. The outputs from this analysis can be used to assess the robustness of the Tier 1 / Tier 2 approach and identify suitable correction factors to improve the reliability of this approach.

- The priority should be an assessment of the impacts of the reforms on livestock numbers or nutrient applications.

4.10.4 Proposed improvements and refinement methodology

1. Identifying GHG emission reductions, reduction potentials and mitigation costs driven by the CAP 2003 reform is difficult because of the indirect linkages (e.g. commodity market, GDP consumer behaviour) or linkages on a sub-level (technology improvement per farm unit). Some studies (S.H. Gay, et al. 2005[145]; L. Höglund-Isaksson et al. 2006[146]) and projects (see CAPRI, MEACAP[147]) focused their work on this issue and for some agri-environment measures a direct effect on mitigation of GHG emissions could be defined: For Pillar 1: Decoupling of support would lead to decreasing animal numbers (animal density), mainly as a consequence of declining cattle numbers due to productivity increases in milk production. (decoupling of support for dairy took place in Belgium, France, Italy and Spain from 2006 onwards, in Austria, , Netherlands, Portugal, Sweden from 2007 onwards). However, the impact of declining animal numbers will affect a decrease in GHG emissions.
2. For Pillar 2 measures GHG emissions could decrease due to support for reduced tillage, efficient manure and fertilizer application techniques, investments in animal housing and organic farming. New stable installations include improved techniques to reduce ammonia emissions and a shift from grazing to

[144] http://www.capri-model.org/dokuwiki/doku.php?id=capri:capri_pub.

[145] S.H: Gay, B. Osterburg, D. Baldock, A. Zdanowicz, 2005, Recent evolution on the EU Common Agriculture Policy (CAP): state of play and environmental potential. MEACAP, EU Project SSPE-CT-503604. http://ec.europa.eu/research/fp6/ssp/meacap_en.htm.

[146] L. Höglund-Isaksson, W. Winiwarter, Z. Klimont, I. Bertok, 2006, Emission scenarios for methane and nitrous oxide from the agricultural sector in the EU-25. IIASA Interim Report IR-06-019.

[147] http://ec.europa.eu/research/fp6/ssp/meacap_en.htm.

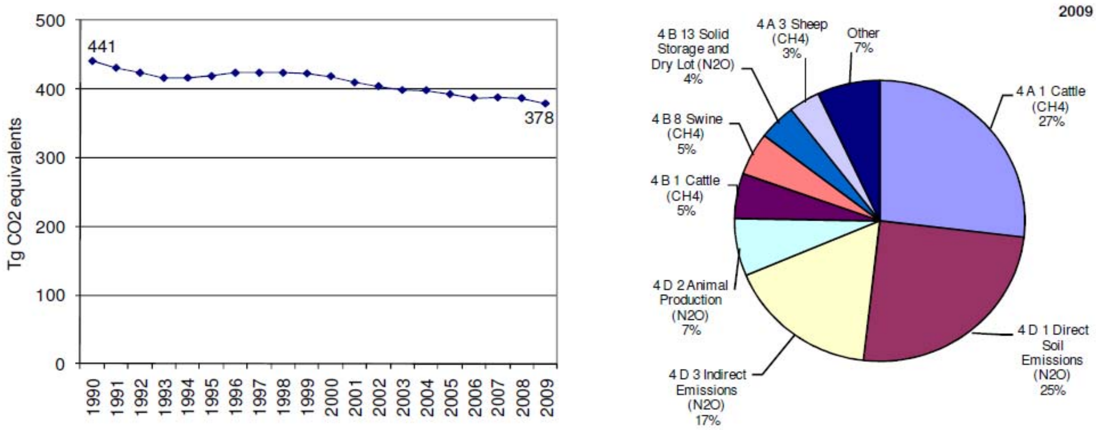
slatted floor permanent housing system could support emission reductions as well[86].

3. Land-use changes are more controlled due to cross-compliance from 2005 onwards. Permanent grassland registered in the Integrated Administration and Control System (IACS) could move to other uses e.g. arable, built up area etc. but on a limited share by MS (cross compliance). Nevertheless, as reported in the NIR (2011) of the EU the most important land use changes in the EU-15 were the conversions from grassland to cropland, the conversions from grassland to forestland, and the conversion of forestland to settlements (built up area). The share of emissions becomes important for conversions from grassland to cropland. (see EU NIR p. 595, 2011). This could lead to an increase of CO_2 emissions from soils.

4. The aid of energy crops of 45 €/ha up to a maximum guaranteed area of 1.5 million ha in the EU could lead to a more intensive production of energy crops grown on non-set-aside land which is eligible for the Energy Aid Payments Scheme. This premium has been abolished by the Health Check of the CAP (2008) as for 2010.

Within the present study, we recommend an approach for assessing emission reductions and cost estimates based on a more detailed analysis by taking into account the differentiated sectors and GHGs of the agriculture emissions inventories (submission 2011, time period 1990 – 2009) that are influenced by the subsidies of both pillars and the increase of extensive production in rural areas. This study will focus on the few source sub-categories (see Figure 4.11) that account for the major part of GHGs and emission reduction.

Figure 4.11 EU-15[148] GHG emissions for 1990- 2009 from CRF "Agriculture" in CO_2 equivalents (Tg) and share of largest key source categories in 2009



Source: EU National inventory report (NIR), 2011, p.423

These include 4A enteric fermentation from cattle which account for a substantial share of CH_4 emissions (27% of EU-15 agriculture GHG emissions in 2009); 4B cattle (5% of the GHG emissions), 4D 1 direct soil and 4 D3 indirect soil emissions which account for a substantial share of N_2O emissions (42% GHG emissions in 2009) and where an overlap with the Nitrates Directive exists (see proposed methodology in the 1st interim report of this project). The main reasons for the high amount of emissions are the use of fertiliser and manure and cattle numbers still being high in most Member States. Therefore, reduction potentials could be expected because of the implementation of Pillar 1 and 2. In addition:

– Emission reductions (between the years 2000 and 2009) in CH_4 emissions (enteric fermentation and manure management, reporting Format 4A & 4B) were due to
  – improved energy use of CH_4 from manure (biogas)
  – more extensive agriculture (grazing)
  – improvements in manure management systems (housing and storage)
  – .
– Reductions in N_2O emissions (Common reporting Format 4B & 4D) were due to
  – a reduced input of nitrogen (manure and synthetic fertilizers)
  – improvements in manure management.

[148] Here only EU 15 is considered because Germany and France are the main emitters and the EU-27 does not have a common target under the Kyoto Protocol in the same way as EU-15.

We will look at those areas for which impacts have already been assessed in projects (e.g. see http://www.ieep.eu/topics/climate-change-and-energy/?page=7, project MEACAP, Impact of Environmental Agreements of the CAP) and in which way cost models (e.g. costs of places per cow or milk quota related to external factors e.g. milk yield, GDP etc.) could be combined for the calculation. Cost calculations of the counter-factual scenario (scenario without measure, here mentioned without implementation of CAP) will be improved by considering Tier 2 and Tier 3 methodologies using specialised models developed for DG AGR (currently updated or developed models e.g. CAPRI, Common Agricultural Policy Regionalised Impact Modelling System and AGNEMOD, AGricultural MEmber states MODelling), and the model GAINS[149] (considering policy scenarios). Additional activity indicators could be linked with the other GHG emissions and could take the form of:

- external factors (e.g. GDP, population growth) relating to global supply and demand for dairy products;
- CH_4 conversion rates (methane conversion factor, MCF, percentage of feed energy converted to methane).

In the following chapters, the different sectors are divided into two parts, first the methodology considering animal numbers (Pillar 1 contribution to 4A and 4B) and second the environmental impacts of Pillar 2 (4D).

4.10.4.1 Income support (Pillar 1), contribution to 4A and 4B

At present, all MS have developed their agriculture inventories. In the IPCC Guidelines for emission reporting, Tier 2 and Tier 3[150] approaches are proposed which rely on the same sectoral structures and computational paths. However, Tier 2 and Tier 3 approaches are differentiated along the use of default (Tier 2) vs. country-specific (Tier 3) emission factors. An overview of the different proposed methodologies for the sectors 4A and 4B is given in Table 4.20.

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[149] Lena Höglund-Isaksson, Wilfried Winiwarter, Zbigniew Klimont, Imrich Bertok, 2006, Emission scenarios for methane and nitrous oxides from the agricultural sector in the EU-25, IIASA Interim Report IR-06-019.

[150] Tier1: For estimating emissions from animal husbandry, collecting animal numbers per livestock characteristic. Tier 2: emissions estimates require feed intakes for a representative animal in each subcategory; Tier 3: This approach could employ the development of sophisticated models that consider diet composition in detail, concentration of products arising from ruminant fermentation, seasonal variation in animal population or feed quality and availability, and possible mitigation strategies.

Table 4.20 Methodology in this study: 2003 CAP reform – Ex-post method (EU-15 and EU-27) for CRF 4A and B

Approach	Tier 1	Tier 2	Tier 3
Activity indicator	Number of animals (only dairy cattle necessary)	As Tier 1	Number of animals (dairy cattle), model AGNEMOD of the IPTS (JRC), CAPRI as additional activity indicators
Emissions	EU15/27 and MS emissions (UNFCCC), until 2013 reporting IPCC Guideline 2006 will be used. At the moment the used emission factors are drivers.	As Tier 1	EU15/27 and MS emissions (UNFCCC)
Policy interaction	Yes, combined national and EU policy	As Tier 1	Yes, combined national and EU policy and scenarios
Autonomous development	No	No	Yes (milk quotas, milk yields, commodities prices)
Structural effects	No	No	Yes (where data available)
Geographic factors	No	No	Yes
Timing issues / delay or announcement effects	Same start date	Consideration of MS implementation date, instead of a single year being used as the "frozen efficiency" for the application rate, the average application rate in the 3 years prior the implementation of the regulation	
Other exogenous factors	No	No	Yes
Source data	Eurostat, UNFCCC etc.	As Tier 1	Eurostat, UNFCCC, different studies

Assessment of environmental impacts

The **Tier 2** approach can be improved by considering the respective sectors (4A, 4B) referring to point 1 (decoupling of support of animal production, Pillar 1) as follows, also taking emission factors into account:

CRF 4A (enteric fermentation):
For CRF 4A: Milk quota, which gradually increases until their abolition in 2015, was an important driver of reductions of methane emissions from agriculture[151] by keeping sta-

[151] Compensation payments to milk producers are fixed as follows: EUR 11.81/tonnes in 2004, EUR 23.65 in 2005 and EUR 35.5 from 2006 onwards. OECD, 2004, Analysis of the 2003 CAP Reform, p. 9.

ble EU milk production and contributing to a decrease in dairy herd. The main objective of the regime, in combination with price support measures to the dairy sector, is to regulate milk production below a specified reference quantity. Therefore, the milk sector (specifically dairy cattle numbers, average gross energy intake, milk yield), for the main MS emitters (France and Germany as the main emitters, and Spain, Portugal, Greece where methane emissions increased in the latest years) could be checked. Although animal numbers of dairy cattle constantly decreased in recent years, quantifiable factors such as average gross energy intake and milk yields increased to attain a higher efficiency of milk production per cow. Those factors can counterbalance each other.

For CRF 4B (manure management): Furthermore, the storage and management of manure could be evaluated. CH_4 emissions occur in particular when large numbers of animals are managed in, for example, dairy farms, beef feedlots, and swine and poultry farms and where manure is disposed of in liquid-based systems. In most of the European countries liquid management systems are used and emissions increased over the last five years. The methane conversion factor (MCF) default value for liquid storage provided in IPCC (1996), IPCC (2000a) and IPCC (2006) varies by a factor of almost 4 for the European countries. But the two most important factors influencing the amount of CH_4 emitted from manure management systems are the climate region and whether solid or liquid systems predominate (see NIR, 2011, p. 516, Table 6.32). In Dämmgen et al. (2011)[152] a reassessment of the calculation procedure for methane producing capacity and a methane conversion factor is given. The methodology is improved in this study by examining the CRF sectors separately based on their implied emission factors which reflect the measures, introduction of technology or changes of the feeding situation. The development of changes in animal waste management systems and the N-management can be estimated in the same way as for CRF 4 A and is described below (the same methodology applies in the case of CH_4 and N_2O emissions).

The equation (using dairy cattle as an example) for the calculation follows and can be applied for other animal groups, which are negligible as mentioned above:

EM_{GHG} = activity rates $_{\text{(number of dairy cattle)}}$ * implied emission factor $_{\text{[GHG kg/head /year]}}$

- Emissions inventories, in which MS have been required to report on data, include details of the total emissions of methane and N_2O and the total annual numbers of dairy cattle on the Tier 2 level (EM_{GHG});
  - Activity rates, such as the number of animals (dairy cattle are used here), could provide an estimate of methane and N_2O emissions for each MS when multiplied by EU or MS specific emission factors.

[152] U. Dämmgen, B. Amon, S. Gyldenkaerne, N.J. Hutchings, H. Kleine Klausing, H.-D. Haenel, C. Rösemann, Reassessment of the calculation procedure for the volatile solids excretion rates of cattle and pigs in the Austrian, Danish and German agricultural emission inventories. Landbauforschung – vTI Agriculture and Forestry Research 2, 2011, (61) 105-116.

- By dividing the emissions estimates by the activity number described above, estimates of the emissions intensity (or implied emission factors, IEF) of dairy cattle can be derived per MS for:
    - o The counterfactual scenario – using the mean data (animal numbers as an indicator) of 2004-2006;
    - o Each year after the full implementation of the CAP (2007 onwards);
    - o Each year after the full implementation of the CAP also for the new MS (2007 onwards). It has been evaluated that for some countries of the EU-15 MS the implementation of the policy impact occurred at a later point (e.g. Denmark, Greece and Portugal). Transitional period for EU-15 to EU-27: The reforms entered into force in 2004–2005. New Member States applied for a transitional period delaying the reform in their countries to 2007 and phasing in reforms up to 2012 (countries such as Poland, Hungary and the Czech Republic joined the EU in May 2004, with Bulgaria and Romania following in 2007).
- Estimates of emissions of GHG for the counterfactual scenario can then be produced for 2007 onwards by multiplying the counterfactual emissions intensities by the activity rates[153];
- Emissions reductions can then be estimated by subtracting the counterfactual emissions estimates from the actual emissions for 2007 onwards;
    - o Estimates of the benefits due to emissions reductions can be estimated by multiplying the emission reduction estimates by EU-wide damage cost functions (e.g. cheese production, Non-Fat Dried Milk (NFDM) production, and butter manufacturing)[154];
    - o A more complex approach that requires detailed country-specific data on gross energy intake and methane conversion factors[155] (depending on temperature) for specific livestock categories can also be taken into

[153] Constant productivity increases also play a role and can be characterized by quantifiable factors such as average gross energy intake and milk yields. Since 2005 a higher efficiency of milk production per cow could be attained. However, emissions estimates are mainly characterized by the numbers of animals.

[154] Global Agricultural Information Network, EU 27, Dairy and Product Semi-Annual 2011, GAIN report number: PL0111.

[155] The extent to which feed energy is converted to CH4 depends on several interacting feed and animal factors. When good feed is available (i.e., high digestibility and high energy value) the lower bounds should be used. When poorer feed is available, the higher bounds are more appropriate. In some cases, there may be reasons to modify methane conversion factors over time. These changes may be due to the implementation of explicit greenhouse gas (GHG) mitigation measures, or may be due to changing agricultural practices such as feed conditions or other management factors without regard to GHGs. Regardless of the driver of change, the data and methane conversion factors used to estimate emissions must reflect the change in farm practices. (Citation, IPCC Guidelines 2006, Vol.4, p 10.30).

account. In this case animal numbers per MS from 2004 onwards are multiplied with a constant implied emission factor (IEF) from the year 2005.

  - o A counterbalancing approach could be developed in particular for 4B, so that by focusing on animal numbers as an indicator the reduction of animals has a higher influence on GHG emissions in the sector and differences of manure management lead to a compensation effect and minor emissions.

- o By multiplying the emissions reductions from the number of dairy cattle (per head) estimates for GHGs with their specific GWP, the amount of CO_2 equivalent can be estimated and linked with costs for milk production per animal.

A possible **Tier 3** approach can be summarised as follows:

The improvement in comparison to the previous study is the use of agriculture models which consider not only detailed country-specific data, but also regionalized and geo-referenced data which take into account the exact areas on which fertilizers are applied or a very disaggregated breakdown of animal populations (in particular dairy cattle). For DG AGR several commodity models considering the CAP reform were developed by the JRC, IPTS (http://agrilife.jrc.ec.europa.eu/index.html) and funded by the European Commission.

- The study "Modelling and Analysis of the European Milk and Dairy Market" was carried out from October 2007 until July 2008 by the AGMEMOD (AGricultural MEmber states MODelling) Consortium under the management of the Agricultural Economics Research Institute (LEI, the Netherlands), in cooperation with the European Commission's Joint Research Centre - Institute for Prospective Technological Studies (JRC-IPTS, Spain)[156]. The improvement here is that the AGMEMOD model is an econometric, dynamic, partial equilibrium, multi-country, multi-market model for EU agriculture at MS level. Based on a set of commodity-specific model templates, country-specific models were developed to reflect the details of agriculture at MS level and at the same time allow for their combination in an EU model. Indicators such as milk yields or growth factors (e.g. population or real GDP) for the years 2000 – 2020 and 2005 – 2020 of different scenarios per regions can be applied as scaling factors by multiplying with emission rates for further emission estimates.

[156] BARTOVA, L., T. FELLMANN AND R. M'BAREK (Eds.) (2009): Modelling and Analysis of the European Milk and Dairy Market. AGMEMOD Consortium. JRC Scientific and Technical Reports, European Commission, Joint Research Centre, Institute for Prospective Technological Studies, Seville, http://ipts.jrc.ec.europa.eu/publications

- Previous analysis by Öko-Institut of EU models such as CAPRI showed large discrepancies of emission results for recent years compared to GHG inventories due to a lack of disaggregated bottom-up and regionalized data in the EU model. But it could give an indication of the regions that will be more vulnerable in terms of a nitrogen surplus[157] (this considers the sectors 4A, B and D), in particular in soils. Meanwhile, the model was updated in several sectors, especially the dairy market sector. The model development that is funded by the European Commission builds on an open network approach. The activities are managed by W. Britz at the Institute for Food and Resource Economics, University of Bonn. The results are available as publications on the webpage http://www.capri-model.org/dokuwiki/doku.php?id=capri:capri_pub.

Assessment of socio-economic costs

The previous study did not propose an approach for estimating compliance costs because of its complexity. In the case of the CAP reform the actual target is not the reduction of GHG emissions and abatement costs are not known. Only a few prices (e.g. milk prices) are easily available. In order to complete a detailed assessment of the impacts of the CAP reform on GHG emission reductions, a bottom-up approach which accounts for changes in the counterfactual scenario is required. Such an approach could be conducted using the following steps to obtain abatement costs:

For 4A and 4B the estimates of unit abatement costs can be constructed and refined at a MS level by:

- Using the emissions estimates per head from the Tier 2 environmental impacts assessment (as described above) and the milk yield per head (source: "Agricultural trade statistics 1999-2009", http://ec.europa.eu/agriculture/agrista/) a correlation between emissions and milk yield per MS could be calculated. Based on the milk price per MS and the correlation of methane emissions per amount of milk produced, the cost for emission reductions could be calculated.
    - Tier 1: By multiplying the emissions reductions estimates (from the environmental impacts assessment) with the cost per tonne of avoided emissions an estimate of the total mitigation costs could be made;
    - Tier 2 & 3 – The AGNEMOD model includes case studies for a number of types of regions which includes cost estimates for a range of abatement measures. This information can be used to determine unit costs, specific regions or MS can be evaluated with this information;

[157] EUROPEAN COMMISSION, JOINT RESEARCH CENTRE, Institute for Prospective Technological Studies Agriculture and Life Science in the Economy, Economic Impact of the Abolition, of the Milk Quota Regime, – Regional Analysis of the Milk Production in the EU – , Febr. 2009

- o Tier 3: Estimation of the unit abatement costs (e.g. International Farm Comparison Network[158], dairy farm numbers and farm sizes, dairy farm structure and its development, milk and feed price developments, trends in land, beef and quota prices) along with improvements of the estimates of emissions reductions relative to the counterfactual scenario will reduce uncertainty in cost estimation. The counterfactual scenario could be refined by updating the counterfactual estimates of emissions intensity to reflect these changes. For example livestock densities on the mode of dairy farms range between 1.69 and 1.98 LU ha^{-1} (LU, Livestock units). Farm milk production was between 266,356 and 436,735 kg milk $farm^{-1}$ a^{-1} caused by the respective number of dairy cows and the average milk yield of 6,026 up to 7,267 kg milk cow^{-1} a^{-1}[198].
- o It should be noted that this methodology only has a low level of uncertainty. For the statistical animal numbers the amount of uncertainty around 1-5 % is assumed. Furthermore, the methodology which is described by IPCC Guidelines and used by the MS is on Tier 2/3 level. A higher uncertainty can be expected if only emission factors (30 – 50 %) are analysed.

Data assessment

The previous section set out a methodology for assessing the impact of CAP on the enteric fermentation and manure management sectors and gave examples of data sources which could be used. An assessment of the impact on other sectors can be conducted using a similar methodology, but using different data sources. The key types of data required to perform an ex-post assessment of the CAP reform for each sector are:

- Emissions from animals by MS;
- Activity data (animal numbers);
- Abatement measures implemented (specifically for CAP and the new 12 MS);
- Estimates of unit costs for abatement measures;
- Reports on changes in exogenous variables (improvement of technology, GDP, milk yields etc.) which affect the counterfactual.

Table 4.21 summarises some of the available data sources, the type of information they contain, the sectors for which this is applicable and additional comments on the quality and usefulness of the data.

[158] http://www.ifcnnetwork.org/en/output/dairyreport/.

Table 4.21 Data sources applicable to assessment of CAP

Data Source	Type of information	Sectors / MS / Time	Additional comments
CAPRI	• Contains balances for N,P,K, emissions of ammonia, methane and N_2O, GHG inventories according to international standards • Production quotas for milk; A and B selling quotas for sugar beet in conjunction with A,B,C, prices; set-aside; the different premiums of the Common Agricultural Policy. Recently, major programs from Pillar II of the CAP (Less Favoured Area support, Natura 2000 payments to agriculture, Agri-Environmental Measures) had been roughly integrated.	• EU27 (EU25 plus Bulgaria and Romania), Norway, Turkey and Western Balkans broken down to about 280 administrative regions (NUTS II). • Base year is 2004 (average of 2003-2005), all years onwards are based on projections, in cooperation with DG AGRI a baseline for the year 2020 will be estimated, the years in between are interpolated.	• Open source and freely available, but handling the data is not easy.
AGNEMOD	Contains emissions scenarios for a number of scenarios; the scenarios which best represent the counterfactual and CAP implementation scenarios could be used to estimate emissions reductions; Unit-cost information is available for specific abatement options, although sometimes several measures are bundled together.	• Good disaggregation of emissions data by sector; • Good disaggregation of costs by sector; • All data is disaggregated by MS and region; • Annual information of milk quota is available for the years 2004 – 2009; • Different scenario projections can be used up to 2010, 2015 or 2020.	• Unit-cost information is useful.
FAO	Activity data	• Activity data on MS level, commodity costs.	
GAINS	Animal numbers and IEF on MS level or uniform.	• Scenarios for the respective policies and MS, 1990, 1995, 2000, 2005, 2010, 2020.	

Data Source	Type of information	Sectors / MS / Time	Additional comments
UNFCCC reports	Emissions per sector and activity data on MS level.	• Activity data, emissions, and emission factors.	• Best background information, annual availability
EUROSTAT	Costs per milk and milk production, dairy cattle numbers.	• Activity data and exogenous factors	• Time series show some inconsistencies in comparison with MS data
International Farm Comparison Network	All information and data of the dairy market sector on MS level.	• Exogenous factors and background information	• The report is not available for free
"Agricultural trade statistics 1999-2009", http://ec.europa.eu/agriculture/agrista/	Milk yields on MS level, animal numbers.	• Exogenous factors	• Time series show some inconsistencies.

4.10.4.2 Rural development (Pillar 2), contribution to 4B and 4D

Referring to the points 2 – 4 (improvement of manure techniques, increasing grazing, energy crops) under the chapter about proposed improvements results could be obtained from a detailed literature search about these issues and which considers a Tier 1, Tier 2 or Tier 3 approach.

Reductions of nitrogen emissions (N_2O, NH_3) can be achieved by improvement of the nutrient cycle and N efficiency. The mitigation measures addressing the N-cycle were modelled by A. Weiske and J. Michel (2007)[159] for their impact on N_2O, NH_3 as well as CH_4 and CO_2 emissions within the project MEACAP[160]. Based on the report of A. Weiske and J. Michel (2007), the pointed issues which are mentioned above (2. improvement of agricultural technique, 3. land use changes, 4. cultivation of energy crops) could be described in detail. The report demonstrates an example of a farm survey in Germany for the year 2004, mitigation scenarios and the impact on GHG emission reductions and abatement costs. Some management-based mitigation measures with a focus on manure handling were modelled for a set of dairy, bull fattening and pig

[159] A. Weiske, J. Michel, 2007, Greenhouse gas emissions and mitigation costs of selected mitigation measures in agricultural production, MEACAP WP3 D15a, RESEARCH PROJECT n°SSPE-CT-2004-503604.
[160] MEACAP, Impact of Environmental Agreements on the CAP.

fattening model farms with respect to their potential to reduce GHG emissions. The model 'ModelFarm' (Michel et al., 2006)[161] took into account the upstream production chain as well as farm operations; additionally, a cost-benefit analysis was carried out for each of the modelled options to calculate the respective mitigation costs. Taking into account the farm area the reduction potential of GHG emissions was calculated per hectare and year to compare the effect of mitigation measures for the different sized farms and production types. An overview of modelled reference GHG emissions (the mean of the test results) caused by different farm compartments of plants and live-stock production of the respective farming for the year 2004 (here it has to be taken into account that EF which were used, stem from the IPCC Guideline 1996, therefore the value should be updated with new information, e.g. EF, GWP) is given in Table 4.22. It has to be considered that in the study the MCF (Methane conversion factor) value used is not state-of-the-art because it depends on climate (temperature) and the feeding situation (which changed significantly in the latest years).

Table 4.22 Global warming potential (mean) calculated with the model "ModelFarm" for different farm types and size in Germany.

Type	Unit	Dairy cattle	Bull fattening	Pig fattening
Farm area	[ha]	70.1	60.7	65
Total emissions plant production	[t CO_2-eq. a^{-1}]	179-1	173.1	225.1
Total emissions live-stock farming	[t CO_2-eq. a^{-1}]	391.5	264.4	453.9
Total emissions per farm	[t CO_2-eq. a^{-1}]	570.6	437.5	679
Total emissions per hectare	[t CO_2-eq. a^{-1}]	8.2	7.3	11.1

To improve the estimation of abatement costs the following analysis and results of the MEACAP study given below can be used for mitigation actions supported by rural development.

a. Feeding situation:

[161] Michel, J, Weiske, A., Kaltschmitt, M. (2006): Ökologische und ökonomische Analyse. In: K. Möller, G. Leithold, J. Michel, S. Schnell, W. Stinner, A. Weiske (Hrsg.): Auswirkung der Fermentation biogener Rückstände in Biogasanlagen auf Flächenproduktivität und Umweltverträglichkeit im Ökologischen Landbau - Pflanzenbauliche, ökonomische und ökologische Gesamtbewertung im Rahmen typischer Fruchtfolgen viehhaltender und viehloser ökologisch wirtschaftender Betriebe. DBU-Endbericht AZ15074.

An adjustment of the feed composition could decrease the amount of nitrogen excretion which leads to a reduction of GHG emissions.

Dairy cattle: For fattening cattle a protein surplus is often inevitable due to an imbalance between energy and protein in the feed. The protein surplus can be reduced by adding components with lower protein content to the ration (e.g. maize silage). However, a change in the feeding strategy had a respectable potential to reduce GHG emissions without causing additional costs. A successful feeding strategy a 50 % reduction of the rotational grass-clover area for maize silage production resulted in a total farm GHG emission reduction of 2.6 % (–15.4 t CO_2-eq. farm^{-1} a^{-1} or –0.23 t CO_2-eq. ha^{-1} a^{-1}). Higher farm income was caused by lower costs for plant production (–4,100 € a^{-1}) and livestock farming (–400 € a^{-1}), the mitigation costs were negative and increased the income by € 296 relative to one tonne reduced CO_2 equivalents[97]. With the knowledge of the numbers of dairy farms (considering the amount of herd size and grassland, see EUROSTAT) the respective emissions per farm (or per ha) and mitigation costs could be estimated (Tier 1 approach) for the year 2004 and multiplied by the annual reduction potential for the year 2009 onwards. The result could be compared with the reported GHG emissions of dairy cattle to attain the counterfactual scenario.

Fattening pigs: A three phase feeding system for fattening pigs in comparison to the other livestock appeared to have the highest reduction potential. Mitigation costs seemed to be negative because of the greater efficiency of nutrient use and increased the income by € 334 relative to one tonne of reduced CO_2 equivalents[97]. With knowledge of the numbers of farms for fattening pigs (considering the amount of herd size and grassland, see EUROSTAT) it was possible to estimate the respective emissions per farm (or per ha) and abatement costs. The methodology follows the procedure described above for dairy cattle. In Table 4.23 an overview of the needed indicators and information is given.

Table 4.23 Background Information for calculation of counterbalance scenario

Environmental indicators	Socio-economic costs	Data assessment
Emissions per ha or farm Emission reduction potential for different scenarios	Mitigation costs	Model ‘ModelFarm’; Eurostat number of farms or ha size

b. Comparison of straw- and slurry-based livestock housing systems:

The impact on GHG emissions of straw- and slurry-based housing systems differ considerably due to the different predominating aerobic or anaerobic storage conditions. In the MEACAP model it could be demonstrated that for the straw- and slurry-based housing systems the value of an uncertain emission factor could determine whether a measure is assumed to increase or decrease the total farm GHG balance. Depending on the used methane conversion factor (MCF) of 39 % (IPCC, 2001 and 2006) for emissions from manure storage, the farm GHG emissions were reduced when tied and straw-based systems were introduced whereas an emission factor of 10 % (IPCC, 1997) increased the GHG potential of these animal housing systems. Furthermore, the study showed that changing from slurry- to straw-based systems is not recommended. Using a default MCF of 39 % (IPCC, 2001) for modelling the study presented that GHG emissions of the deep litter systems were reduced by 8.4 % for dairy cattle and by 5.9 % for fattening pigs, causing mitigation costs of around 330 € t^{-1} CO_2-eq. The straw-based tied system reduces GHG emissions by 13.6 % with lowest mitigation costs of 132 € t^{-1} CO_2-eq. The tied stalls as slurry-based system show a little GHG reduction (–0.6 %) for the use of both methane conversion factors. However, this system results in the highest mitigation costs of 1800 € t^{-1} CO_2-eq.

The effect of different housing systems could be evaluated with estimating a counter-balancing approach as developed in particular for 4B by applying the mean of implied emission factor (from 2004 to 2006) as an indicator for the CAP reform differences of manure management would lead to a compensation effect and minor emissions. In Table 4.24 an overview of the needed indicators and information is given.

Table 4.24 Background Information for calculation of counterbalance scenario

Environmental indicators	Socio-economic costs	Data assessment
N_2O emissions per MS and subsector of 4B Emission reduction potential for different scenarios	Mitigation costs	UNFCCC reports per MS; Model 'ModelFarm'; Eurostat number of farms or ha size

c. Frequency of manure removal from animal housing

With the livestock feeding system regime the amount of ingested nitrogen is excreted by animals in urine and manure. CH_4 emissions can be emitted by these excrements which are not removed directly from fouled animal housing surfaces and manure pits through the exhaust air. The MEACAP study found that the use of scraping systems combined with frequent removal of manure from animal housing into a covered storage facility resulted in a considerable GHG reduction for pig fattening farms (even though high mitigation costs) whereas the mitigation effect for cattle farms was completely counterbalanced by losses within subsequent steps of manure management. However, the study estimated very high mitigation costs of around 480 €t^{-1} CO_2-eq. for measures due to the additional investment for the scraping system and the electricity expenses. In comparison to studies that only include the reduction of emissions in animal housing, the results of the study showed that mitigation options with an apparent emission reduction potential resulted in emission increases in other parts of the system, so that the overall effect would be an increase in GHG emissions. Therefore, it should be relevant to evaluate the mitigation measures at the system level, which could not be conducted in this study without a better information base.

d. Manure storage techniques

GHG emissions from stored slurry could be reduced by covering slurry tanks by natural (e.g. straw, peat, bark) materials, plastic covers or permanent rigid covers. Furthermore, methane emissions could be decreased by aerobic conditions of the manure surface. The MEACAP study investigated that various manure storage cover techniques for cattle manure with an existing natural surface crust and for pig manure without a surface crust model results of mitigation costs and emission reductions were different. For cattle farms the GHG mitigation potential (- 0.2 %) was negative or low but with high mitigation costs (for rigid covers 580 € $t^{-1}CO_2$-eq.) whereas for pig fattening farms a higher mitigation potential (around -0.8%) with negative or low mitigation costs was suggested by the MEACAP model. The environmental impact is, however, marginal and livestock density and farm size are more relevant. Due to the high uncertainty (e.g. in terms of emission factors and even low availability) for the applied technique, no further analysis will be conducted in this study.

e. Improvement of manure application techniques

With the correct application of manure management as a final step, nitrogen losses as a plant nutrition can be avoided. Therefore, the use of mineral fertilisers can be reduced which leads to a reduction of N_2O emissions from agricultural soils (4D).The reduction of the surface area of slurry exposed to the air leads to an increasing rate of infiltration into the soil so that ammonium-N adsorbs to clay particles. Normally, broadcasting techniques is applied in the EU. In the MEACAP model several manure application techniques (e.g. trail hose, trail shoe, and injection) of dairy cattle farms were modelled; as a result, the trailing hose system appeared to be the best approach in terms of GHG mitigation (-1.5 % GHG mitigation potential) and lowest mitigation costs (95 € t^{-1} CO_2-eq.). In the MEACAP study total emissions per farm (around 590 t CO_2-eq.a^{-1}) and total emissions per hectare (approximately 8.2 t CO_2-eq. ha^{-1} a^{-1}) were evaluated. This information could be used for a Tier 1 approach (bottom-up) to calculate the emissions for all MS farms (data available in EUROSTAT). The counterfactual could be estimated using the estimated emissions from 2005 onwards from the UNFCCC reporting for direct soils with subtracting the estimated emissions on EU-15 or EU-27 or on MS level. Furthermore, the reduction potential (-1.5 %) could be applied to the reported GHG emissions per MS as well. Table 4.24 gives an overview of the information needed.

f. Use of mineral fertilisers (controlled-release fertilisers, urease or nitrification inhibitors)

As mentioned in the MEACAP study the use of fertilisers with nitrification inhibitors (NI) was selected as a GHG mitigation measure for modelling. These types of specific fertilisers are already used in agriculture. The calculation of N_2O emissions in MEACAP based on the emission factor 1.25 % of the N-emitted as N_2O (IPCC 1996, 2000) with a reduction of N_2O emissions by 51% after NI and was applied to the model farm for dairy cattle, bull fattening and pig fattening. The use of improved mineral fertilisers with nitrification inhibitors to increase the N efficiency in crop production represented a successful GHG mitigation measure, in particular for pig fattening farms where GHG emissions (around 2.5% reduction of GHG emissions) are reduced at low or negative mitigation costs (8 - 9 € $t^{-1}CO_2$ eq.). As stated in the study, the GHG reduction potential was directly correlated to the extent of mineral fertiliser use. Reported emissions to the UNFCCC 4D 1 (direct soils, mineral fertilisers) based on a Tier 1 approach of the IPCC Guidelines and reflect the declining emission trend since the implementation year (2005) of the CAP 2003 reform. By dividing the reported emissions by the activity number (nitrogen input from application of synthetic fertilizers), estimates of the emissions intensity (or implied emission factors, IEF) can be derived per MS for:

- The counterfactual scenario – using the mean of data (amount of kg N a^{-1} mineral fertilizer as an indicator) from 2004 to 2006;
- Each year after the full implementation of the CAP (2007 onwards);
- Each year after the full implementation of the CAP also for the new MS (2007 onwards). It has been evaluated that for some countries of the EU-15 MS the implementation of the policy impact occurred at a later point (e.g. Denmark, Greece and Portugal). Transitional period for EU-15 to EU-27: The reforms entered into force in 2004–2005. New Member States applied for a transitional period delaying the reform in their countries to 2007 and phasing in reforms up to 2012 (countries such as Poland, Hungary and the Czech Republic joined the EU in May 2004, with Bulgaria and Romania following in 2007).
- Estimates of GHG emissions for the counterfactual scenario can then be produced for 2007 onwards, by multiplying the counterfactual emissions intensities by the estimates of activity;
- Emissions reductions can then be estimated by subtracting the counterfactual emissions estimates from the actual emissions for 2007 onwards;
    - Estimates of the benefits due to emissions reductions can be estimated by multiplying the emissions reductions estimates by the mitigation costs of the model "ModelFarm" (8 - 9 € $t^{-1}CO_2$ eq.).

Table 4.25 gives an overview of the information is needed.

Table 4.25 Background Information for calculation of counterbalance scenario

Environmental indicators	Socio-economic costs	Data assessment
N_2O emissions per MS and subsector of 4D-1 Emission reduction potential for different scenarios	Mitigation costs	UNFCCC reports per MS; Model 'ModelFarm'; Eurostat number of farms or ha size

g. Comparison of livestock grazing and permanent housing

The choice of livestock management has a clear impact on GHG emission reduction. On the one hand if more extended grazing is implemented, fewer field operation e.g. grass cutting, silage baling, manure management would take place and reduce emissions. On the other hand additional maintenance costs (fence construction for dairy cattle) would occur. But farm emissions are strongly influenced by the different N fertilization regimes chosen on arable land and by animal excreta on pastures. Intensive grazing leads to unevenly distributed dung, urine patches and soil compaction which could be a significant source of N_2O emissions, but on the other hand urine infiltrates into the soil before oxidation of NH_3 emissions would occur. However, animal housing systems cause a higher rate of CH_4 emissions from the storage. The model calculations for the implementation of a half-day cattle grazing system for dairy cattle in comparison to a completely house system show a considerable GHG mitigation potential if manure application, application of mineral fertilizers and diesel use are also considered in the emissions reduction balance (for N_2O: -14.3 % emissions, and CH_4: -7.3 %). For the implementation of a summer half day grazing system the total GHG emissions reduction potential of plant production and livestock farming was estimated at approx. -2.6 % of farm GHG emissions. In Table 4.26 an overview of the GHG emissions reduction potential per substance is given. Less energy-intensive operations associated with the grazing system also reduced farm production costs so that mitigation costs per hectare were negative (around -271 € t^{-1} CO_2-eq. ha).

Table 4.26 GHG emissions reduction potential (in percentage) of plant production and livestock farming

Plant production	[%]
CH_4 emissions	0
N_2O emissions	22,2
Diesel use	-24,1
N fertilizer use	-20,1
Livestock farming	
CH_4 emissions	-7,3
N_2O emissions	-14,3
Farm greenhouse gas emissions in total	-2,6

Note: Data for the implementation of a summer half day grazing system (mean value of the results from the model 'ModelFarm'). For the emissions reduction potential in total, NH_3 emissions were not considered and presented here.

The reduction potential (see Table 4.26) for CH_4 or N_2O can be applied as a scaling factor on the reporting GHG emissions per MS from the year 2005 onwards to estimate the counterfactual scenario. Table 4.27 gives an overview of the information needed.

Table 4.27 Background information for calculation of the counterbalance scenario

Environmental indicators	Socio-economic costs	Data assessment
N_2O emissions per MS and subsector of 4D-2, and of 4B Emission reduction potential for different scenarios	Mitigation costs	UNFCCC reports per MS; Model 'ModelFarm'; Eurostat number of farms or ha size

h. Biogas production (anaerobic digestion)

Animal manure, mixtures of residues and energy crops can be used for biogas production. The model 'ModelFarm' found that technical but also management-based measures influencing the entire production chain of the farm have the highest GHG mitigation potential of the mitigation measures. In the model dairy cattle and bull fattening farms were considered as a cluster and it was assumed that a group of farms operated one collective biogas plant. Furthermore, different scenarios (production of thermal energy only used on the farm or for total use applied, usage of different type of engines, feedstock supply) were analysed, which calculated mitigation costs on farm level with and without subsidies. The results of the study presented that biogas production of this order of magnitude (approximately 300 kW) was more efficient for the use in an Otto gas engine (OG) than for a pilot injection engine (PI). The use of the Otto gas engine is more cost-efficient, with the effect that the mitigation costs are clearly lower (122 € t-1 CO_2-eq.) than for the pilot injection engine (193 € t^{-1} CO_2-eq.). Furthermore, the costs of the additional maize silage supply (maize silage production and transport costs) have to be considered in the cost calculation. In the study by Weiske and Michel (2007) a detailed overview is given of the mitigation costs and the GHG emission reductions (see Table 38). Table A 28 (see below for a cost overview using the example of a dairy cattle farm, DF3) also provides an overview of the different scenarios used in the study.

Table A 28: Biogas production characteristics and costs for farm-scale and total use of thermal energy and without any subsidies of model farm DF3.

DF3		S-PI-F	SR-PI-F	SRI-OG-F	S-PI-T	SR-PI-T	SRI-OG-T
Biogas production	[$m^3\ a^{-1}$]	317.738	448.575	1.191.818	317.738	448.575	1.191.818
CH_4 production	[$m^3\ a^{-1}$]	177.420	258.567	704.512	177.420	258.567	704.512
Electric power	[kW]	77	116	291	77	116	291
Produced energy (el.)	[$MWh\ a^{-1}$]	678	1.018	2.549	678	1.018	2.549
Max. usuable heat energy	[$MWh\ a^{-1}$]	183	675	2.199	183	675	2.199
Supplementary energy	[$MWh\ a^{-1}$]	112	104	255	112	104	255
Pilot fuel	[$kg\ a^{-1}$]	15.158	22.090	0	15.158	22.090	0
Investment biogas plant	[€]	312.700	325.100	694.600	312.700	325.100	694.600
Investment heat use	[€]	14.500	14.500	14.500	14.500	14.500	14.500
Specific investment	[$€\ kW^{-1}$]	4.061	2.803	2.387	4.061	2.803	2.387
Annual investment	[$€\ a^{-1}$]	52.127	57.237	95.980	52.127	57.237	95.980
Annual operating costs	[$€\ a^{-1}$]	45.943	54.120	88.886	45.943	54.120	88.886
Annual personnel costs	[$€\ a^{-1}$]	12.660	15.825	25.320	12.660	15.825	25.320
Annual substrate costs	[$€\ a^{-1}$]	0	0	157.819	0	0	157.819
Annual costs for heat use	[$€\ a^{-1}$]	1.290	1.290	1.290	1.290	1.290	1.290
Total costs	[$€\ a^{-1}$]	112.020	128.472	369.295	112.020	128.472	369.295
Revenues electricity	[$€\ a^{-1}$]	40.680	61.080	152.940	40.680	61.080	152.940
Revenues heat	[$€\ a^{-1}$]	1.400	1.400	1.400	5.124	18.900	61.572
Total gain	[$€\ a^{-1}$]	-69.940	-65.992	-214.955	-66.216	-48.492	-154.783

Table 38: GHG emissions and mitigation costs without subsidies for the implementation of a biogas plant (BG) and a farm-scale (F) or total use of produced heat (T) on dairy farm DF3 (S = digestion of manure and energy plants from set-aside land, SR = digestion of manure, energy plants from set-aside land and surplus cropland available due to reduction of livestock density, SRI = digestion of manure, energy plants from set-aside land and surplus cropland available due to a reduction in livestock density and additional imported maize silage, PI = pilot injection gas engine CHP, OG = Otto gas engine CHP).

		DF3 BG		S-PI-F	SR-PI-F	SRI-OG-F	S-PI-T	SR-PI-T	SRI-OG-T
Farm area	[ha]	75.4	300	300	300	300	300	300	300
Operating income	[$€\ ha^{-1}$]	22	22	-256	-354	-843	-243	-296	-642
Resources plant production	[$t\ CO_2$-eq. a^{-1}]	57	228	193	218	147	193	218	147
Direct emissions plant production	[$t\ CO_2$-eq. a^{-1}]	133	529	515	511	563	515	511	563
Total emissions plant production	[$t\ CO_2$-eq. a^{-1}]	190	756	709	729	710	709	729	710
Resources livestock farming	[$t\ CO_2$-eq. a^{-1}]	42	167	167	131	131	167	131	131
Direct emissions livestock farming	[$t\ CO_2$-eq. a^{-1}]	368	1,464	708	566	566	708	566	566
Total emissions livestock farming	[$t\ CO_2$-eq. a^{-1}]	410	1,630	875	698	698	875	698	698
Emissions construction and disposal of biogas plant	[$t\ CO_2$-eq. a^{-1}]	0	0	48	48	52	48	48	52
Emissions operation of biogas plant	[$t\ CO_2$-eq. a^{-1}]	0	0	217	273	619	217	273	619
Emission credits	[$t\ CO_2$-eq. a^{-1}]	0	0	-452	-673	-1,668	-482	-813	-2,148
Total emissions biogas production	[$t\ CO_2$-eq. a^{-1}]	0	0	-187	-352	-998	-217	-491	-1,478
Total emissions per farm	[$t\ CO_2$-eq. a^{-1}]	600	2,387	1,396	1,075	410	1,367	935	-70
Total emissions per hectare	[$t\ CO_2$-eq. $ha^{-1}\ a^{-1}$]	7.96	7.96	4.65	3.58	1.37	4.56	3.12	-0.23
Mitigation costs	[$€\ t^{-1}\ CO_2$-eq.]			84.0	85.9	131.2	77.9	65.6	81.1

Source: Tables were taken from the study by Weiske and Michel (2007), chapter 4.8.1, p. 44 and Appendix, (at farm-scale (F) or total use of produced heat (T), S = digestion of manure and energy plants from set-aside land, SR = digestion of manure, energy plants from setaside land and surplus cropland available due to a reduction in livestock density, SRI = digestion of manure, energy plants from set-aside land and surplus cropland available due to reduction of livestock density and additional imported maize silage, PI = pilot injection gas engine, OG = Otto gas engine, DF3= Dairy cattle Farm scenario 3)

The biogas production was estimated as a very efficient and cost-effective mitigation measure to reduce on-farm GHG emissions whilst also substituting the use of fossil fuels. However, it is has to be concluded that this study cannot draw a firm conclusion on the GHG emission reduction that can be achieved on MS level. There is less information available on the number of plants in operation in the agricultural sector from 2004 onwards (no time series available), how much power they have and how much energy is distributed in local network or used on-farm. Therefore, this study cannot consider the sector energy consumption of biogas for calculation but gives a suggestion of how the information could be considered (see Table 4.28).

Table 4.28 Background information for calculation of the counterbalance scenario

Environmental indicators	Socio-economic costs	Data assessment
CH_4 emissions per biogas plant Emission reduction potential for different scenarios	Mitigation costs, investment costs per engine, per plant (kW), operating & personal costs	Model 'ModelFarm'; Eurostat number of farms or ha size

i. Organic farming

Organic farming is typically characterised as an extensive agricultural system with low inputs of energy and agro-chemical technology, high labour input but also lower productivity per unit area. In contrast, intensive agricultural systems are characterised by high inputs of energy and agro-chemical technology, lower labour input but a high productivity per unit area. As a result of the study the sustained cost efficiency of organic production, however, depends on existing premiums under agri-environment programmes and the currently commercially available premium for products that originate from organic farming. The GHG reduction potential was modelled on the one hand on an area basis (t CO_2-eq. ha^{-1}) and on the other hand per unit of energy in the products leaving the farm (t CO_2-eq. GJ^{-1} ME) in order to treat the different agricultural products in one uniform reference value. In particular the study analysed dairy cattle farms as a standard unit and emission abatement was mainly caused by reductions in N_2O (–45 %) due to the reduced N input amounts because of less manure (reduced livestock density) and no mineral fertiliser use. In comparison with livestock and crop production (and considering all direct and indirect biogenic emissions and pre chain emissions) GHG emissions of crop production were reduced by approx. 82 t CO_2-eq. whereas GHG emissions of livestock production were reduced by approx. 180 t CO_2-eq. The higher revenues from products and lower expenses for feed imports etc. of organic farming led to an increase in farm income so that the mitigation costs are negative (around -72 € $t^{-1}CO_2$-eq.).

As a Tier 1 approach the following methodology could be used:

- For calculating emissions stemming from organic farming the number of farms of organic farming (dairy cattle, source EUROSTAT) could be used as an activity rate and multiplied with the estimated emissions of the study described above, depending on the size of the farm (see Table 45, p. 51 in Michel and Weiske, 2007). With the mean of the activity rate for 2004 to 2006 the total emissions can be estimated for the counterfactual scenario for this sector. Estimates of emissions of GHG for the counterfactual scenario can then be produced for 2007 onwards by multiplying the counterfactual emissions intensities by the estimates of activity;

- Emissions reductions can then be estimated by subtracting the counterfactual emissions estimates from the actual emissions for 2007 onwards;
- Estimates of the benefits due to emissions reductions can be estimated by multiplying the emissions reductions estimates by mitigation costs.

Table 4.29 Background Information for calculation of counterbalance scenario

Environmental indicators	Socio-economic costs	Data assessment
Emissions per farm Emission reduction potential for different scenarios	Mitigation costs	Model 'ModelFarm'; Eurostat number of farms or ha size

Table 4.29 above gives an overview of the information is needed.

4.10.5 Summary and Conclusions

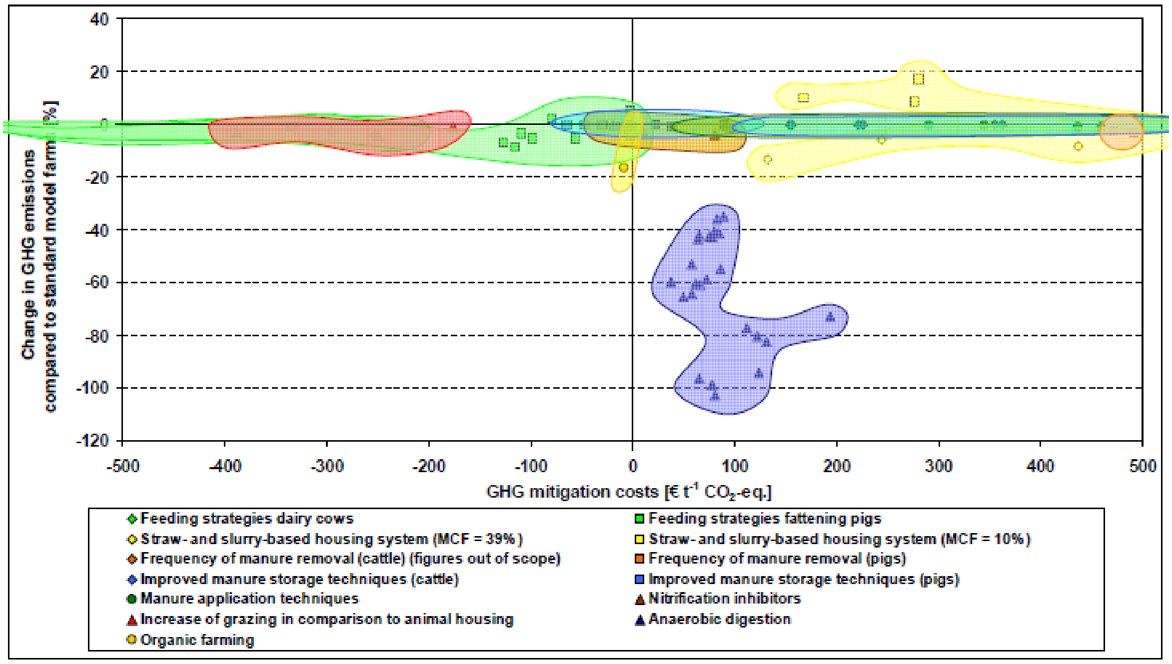
The Common Agricultural Policy (CAP) was implemented to support farmers, guarantee their income and food. For this reason products were coupled with subsidies which led to an overproduction of milk and other agricultural products in Europe. In recent years (notably in 2003 and during the CAP Health check in 2008) the main objects of the directive changed to a more market oriented policy without coupling (decoupling) premium for the farmers (CAP reform). More environmental aspects and animal healthcare are considered in the next steps of the reform package. Furthermore, the improvement of rural areas was a key focus of funding (financial shift from Pillar 1 to Pillar 2). As CAP only has an indirect impact on GHG emissions, the efficiency of conducting assessments should be considered carefully.

For the enteric fermentation (4A) sector which is mainly driven by the milk quota, a methodology is proposed which considers animal numbers of dairy cattle as a main driver for GHG emissions and calculated implied mission factors of GHG on Tier 2 level. Tier 2 considers furthermore the Tier 1 approach. For a Tier 3 approach the results could be linked with information from the AGNEMOD or CAPRI models. Both models were developed for the European Commission (DG AGR). They differ in resource requirements, in focus (AGNEMOD is more focused on milk production) and accessibility. For the 4A sector it seems advisable to use a Tier 2 approach.

For the manure management (4B) and emissions of soils (4D) sectors based on the model 'ModelFarm' which considers information of a German farm survey from 2004 the implementation of different technologies or changes of agricultural production chain could be used as a basis for evaluating a counterfactual scenario and emissions reduction potential. The enteric fermentation (4A) sector was not evaluated in the study. The sectors of organic farming, feeding situation, comparison of straw- and slurry based livestock, improvement of manure application techniques, use of mineral fertilizers and the comparison of livestock grazing and permanent housing were selected and could be transferred from the German standard model farm to MS level.

The different sectors and their GHG reduction potential in percentage and the respective mitigation costs are presented in Figure 4.12 which is a result of the MEACAP project. The figure shows that for most measures only small changes of GHG emissions can be achieved in Germany. The mitigation costs associated with these measures show a wide range, from very negative to highly positive. Straw- and slurry based housing systems, however, have a large potential to reduce emissions. But mitigation costs are estimated to be positive and range from 100 to 500 € t^{-1} CO_2-eq. depending on the applied methane conversion factor (MCF). However, anaerobic digestion (biogas production) seems to have the highest potential to reduce GHG emissions with smaller capital expenditure.

Figure 4.12 GHG reduction potential in percentage and the associated mitigation costs of nine technical and management-based mitigation measures.



Source: MEACAP project, Weiske and Michel, 2007, Fig. 1, p. 56

The 'ModelFarm' model was funded by the Deutsche Bundesstiftung Umwelt (DBU – AZ 15074) and developed by J. Michel at the Institute for Energetic and Environment GmbH, Leipzig (2006). In 2009, the division became the Leipziger Institute for Energy GmbH (www.ie-leipzig.com). The model was used in the MEACAP project by the EC (contract no.: 503604) and the first priority was to focus on the modernisation and sustainability of agriculture and forestry, including their multifunctional role, in order to ensure the sustainable development and promotion of rural areas. It was coordinated by the Institute for European Environmental Policy (http://www.ieep.org.uk/research/MEACAP/MEACAP_Home.htm). It is recommended for the model to be used for calculating mitigation costs and emission reduction potentials on MS level for the EU. The usage in the different Tier levels is proposed as follows:

Tier 1 level:

Using the modelled information (mitigation costs, reduction potential, emissions per ha or farm) of a German standard farm. If it is possible that the information is not comparable with other MS farm types a survey should be conducted on MS level for specific costs or technologies depending farm management. With more information on MS level about the technology used, the reduction potential evaluated in the study could be applied to obtain an advanced view of the effect on emissions.

Tier 2 level:

For a Tier 2 approach regional circumstances – e.g. climate conditions (temperature, humidity) – which influence enteric fermentation (methane conversion factor) and the N-cycle have to be considered. It would therefore be necessary to replicate the study with the 'ModelFarm' model for at least one MS with climate conditions that differ from those in Germany, such as a Mediterranean country (e.g. France, Spain). This would enable conclusions to be drawn for different farm types and would allow for a more differentiated analysis.

Tier 3 level:

For a Tier 3 approach, model runs should be conducted on individual MS level. This entails that MS should have detailed information available to use these for a model run. If no information is available a country specific survey could be conducted. The main emitters of agricultural emissions in Europe are Germany, France and Italy, Spain and Poland. Therefore, it is recommended that a detailed model analysis of those countries should be evaluated in a Tier 3 setting.

Due to the lack of information for some categories no methodology could be analysed for calculating the counterfactual scenario for the EU in this study:

- Biogas production
- Frequency of manure application
- Removal from animal housing
- Manure storage techniques.

4.11 Landfill Directive

4.11.1 Policy overview

The aim of the Landfill Directive (Council Directive 1999/31/EC) is to provide for measures, procedures and guidance to prevent or reduce as far as possible negative effects of waste disposal sites on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including the greenhouse effect. The Landfill Directive sets targets to reduce biodegradable waste disposed to landfill progressively by 25% (2006), 50% (2009), 65% (2016) compared to 1995 levels (amount of biodegradable waste produced in 1995 or the latest year before 1995 for which standardised Eurostat data is available. The deadline for implementation of the Landfill Directive (Directive 1999/31/EC) in the Member States was 16.07.2001 (some MS applied for exemptions and later implementation). MS that landfilled more than 80% of their municipal waste in 1995 may postpone each of the targets by a maximum of four years.

The Directive aims to achieve these objectives by encouraging a reduction in the amount of municipal solid waste being landfilled through diversion to alternative waste management practices and reducing GHG emissions by encouraging recovery of gases produced at landfill sites. MS were required to set up a national strategy for the implementation of the reduction of biodegradable waste going to landfills by not later than July 2003 and to report on the implementation of these national strategies every three years to the Commission.

Concerning the disposal of waste in landfills, the Directive 1999/31/EC on the landfill of waste and the Decision 2003/33/EC also set standards on acceptance criteria for the authorisation, design, operation, closure and aftercare of landfills. Part of these standards is the obligation to collect landfill gas from all landfills (Annex I General requirements for all classes of landfills of Directive 1999/31/EC).

The implementation of the Landfill Directive has yielded in large emission reductions in EU Member States. Member States were aiming on fulfilling the targets laid down in the Directive and worked on increasing the proportion of waste going to incineration, to recycling or reuse path and decreased the amounts of waste going to landfills.

4.11.2 Review and critical assessment of existing methodology

There are three main impacts on GHG emissions resulting from the Landfill Directive:

- The conversion of unmanaged and illegal waste disposal sites to managed waste disposal sites that comply with the requirements of the Directive led to the closure of old and illegal disposal sites and the establishment of new sites that are properly managed and fulfil requirements with regard to water control and appropriate location of sites, leachate management, protection of soil and water, gas control or stability. Unmanaged SWDS (Solid waste disposal sites) produce less methane (CH_4) from a given amount of waste than anaerobic managed SWDS. In unmanaged SWDS, a larger fraction of waste decomposes aerobically in the top layer. In unmanaged SWDS with deep disposal and/or with high water table, the fraction of waste that degrades aerobically should be smaller than in shallow SWDS. This effect is introduced in the monitoring methodology for CH_4 from waste disposal through the MCF, the methane correction factor. An MCF is assigned to each of five categories: managed –anaerobic, managed semi-aerobic, unmanaged- deep, unmanaged –shallow and uncategorized SWDS. The inventory methodology requires countries to provide data or estimates of the quantity of waste that is disposed to each of the four categories of solid waste disposal sites. Thus, the implementation of the Landfill Directive resulted in a change in the MCF in estimation of methane emissions which is not taken into account in any of the methodologies proposed in the previous project.[162]

- The second effect of the Landfill Directive on GHG emissions is the obligatory implementation of collection systems for landfill gas and the subsequent treatment (flaring) or energy use of the collected landfill gas. The CH_4 recovery is separately estimated in the inventory methodology and the captured CH_4 is subtracted from the estimated methane emissions from SWDS. This effect is only taken into account in the Tier 2 method proposed in the previous project[162], but not in the Tier 1 method and therefore does not account in the Tier 1 method for a very substantial part of the emission reduction due to the Landfill Directive.
- The third effect of the Landfill Directive on GHG emissions results from the reduction of the amounts of biodegradable waste disposed to landfills, which leads to a reduction of activity rates used in the emission calculation. This effect is the main effect that the methodologies proposed in the previous project address.

In the methodological description of the previous project it is stated that the analysis proposed does not rely on UNFCCC reported emission or activity data since there may be a discrepancy between the definition of solid waste disposed to landfill (emission sector 6.A) and that of Landfill Directive compliant sites.[162] It may be true that the definitions may slightly vary, however, the inventory estimation is based on the best available national waste statistics and there is no second set of better activity data in MS on waste disposal. Thus, slight differences in definitions may add to the uncertainties of the emission estimation, but should not prevent experts from using the estimation conducted for the GHG inventory for the ex-post quantification as this is the only way to ensure consistency with the national estimation of emissions from waste disposal on landfills and because it is unlikely that better activity data exist.

Thus at general level, the ex-post methodology should be refined in the following areas:

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- Take into account the effects on the methane correction factor (MCF) in all methodological tiers;
- Take into account the effects on landfill gas recovery on managed landfills in all methodological tiers;
- Be based on the first order decay (FOD) estimation of CH_4 from SWDS as performed for the GHG inventory reporting.

The following sections analyse more closely the specific Tier methods proposed:

Proposed Tier 1 method in the previous project

The Tier 1 assessment of the policy impact of the Landfill Directive developed in the previous project is based on the methodology proposed in the 2006 IPCC guidelines for national GHG inventories for calculating CH_4 emissions:

A FOD model is used to describe the decomposition of organic matter in municipal waste disposed to landfills. Default IPCC values are taken for the decay model, these include: waste composition; methane correction factor; degradable organic carbon fraction of waste; fraction of decomposable degradable organic matter (DDOC); fraction of CH_4 in landfill gas; decay rate constants.

The central assumption of the counterfactual for disposal of municipal solid waste (MSW) to landfill is that in the absence of the Landfill Directive the fraction of MSW disposed to landfill would have remained at 1999 levels. The difference in waste disposed to landfills between this counterfactual and the actual monitored and reported masses is assigned to the implementation of the Directive.

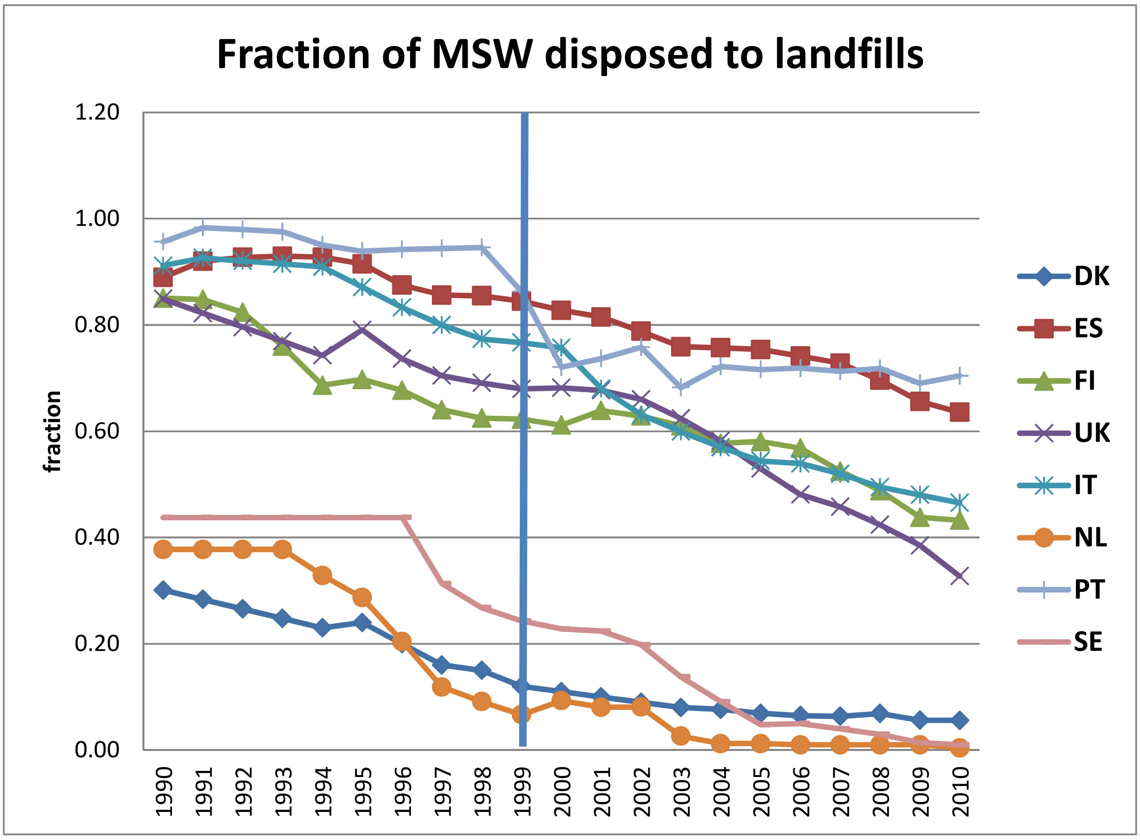
Critical review

1. The method proposed does not differentiate between MSW deposited to managed and to unmanaged landfills, however it was one of the important achievements of the Landfill Directive, that unmanaged, illegal landfills were replaced by managed landfills. Unmanaged landfills have lower methane correction factors (MCF) that correct for aerobic decomposition.
2. The Tier 1 method does not take into account the CH_4 recovery from landfills. However, the landfill Directive contributed to the diffusion of CH_4 capture systems via the acceptance standards for landfills. Only in properly managed landfills, it is possible to capture CH_4. This additional effect of the landfill Directive is therefore not monitored in the Tier 1 methodology. Therefore Tier 1 presents an incomplete assessment. As the estimation of this effect is rather simple with data available in greenhouse gas inventories, it is proposed that this effect should also be taken into account in the Tier 1 method.
3. The chosen counterfactual - the fraction of MSW disposed to landfill in one single year 1999 is not representative for all MS. Some MS already implemented early national legislation on standards for landfills and the deposition of biodegradable waste on landfills. These MS already had a downward trend for the fraction of MSW disposed to landfills. Countries acceding the EU later showed

that in countries without strong national legislation on landfills such as the Landfill Directive, the fraction of MSW disposed to landfills continued to increase after 1999. Thus, the extrapolation of the fraction of MSW disposed to landfill based on the year 1999 may either an under-or overestimation of the effects of the Landfill Directive. Figure 4.13 shows selected MS with downward trends for the fraction of MSW disposed to landfills already prior to 1999. If the year 1999 (blue line in graph) is taken as counterfactual, it is likely that the effects of the Landfill directive are overestimated given the existing downward trend for the years 1990-1999. Figure 4.14 depicts the trend of the fraction of MSW disposed to landfills for two new MS (Hungary and Estonia). In these MS, the fraction of MSW landfilled further increased after 1999, thus the 1999 counterfactual would provide a result that CH_4 emissions would have been lower without the Landfill Directive and the proposed method does not work for this category of MS.

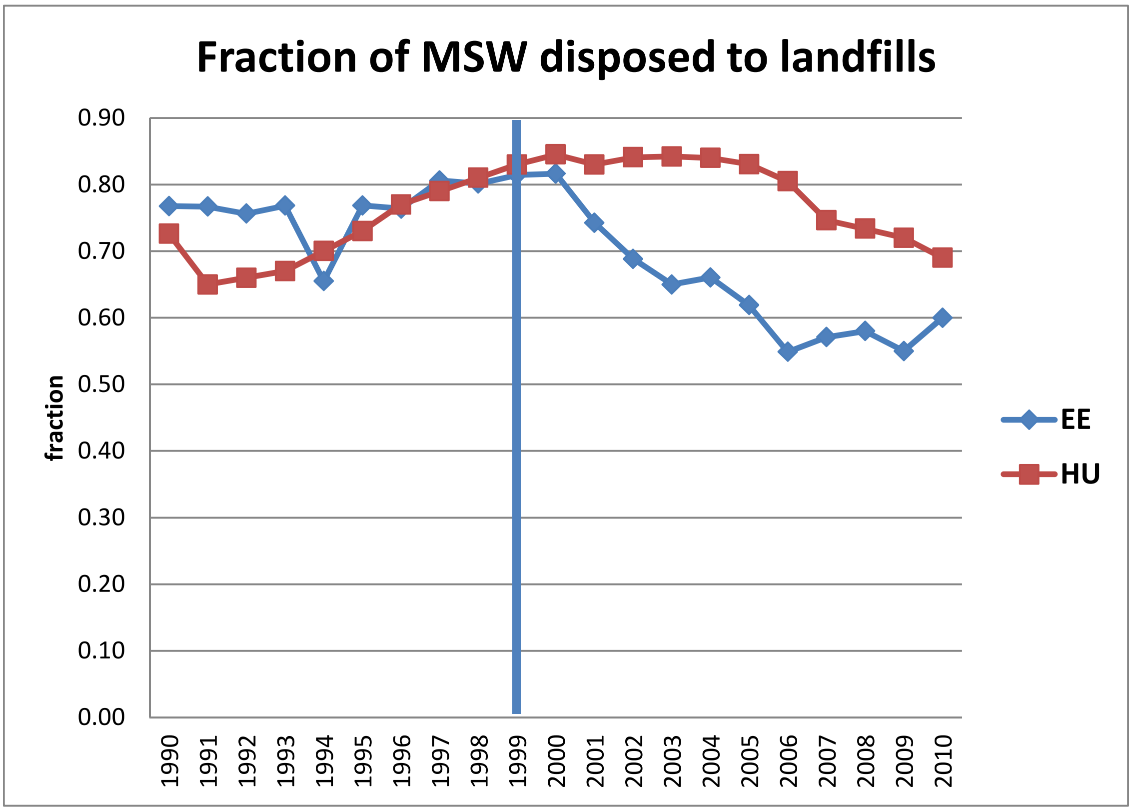
4. The Tier 1 method ignores the emissions from the treatment of MSW in alternative treatment methods that replace the landfilling. This simplification seems appropriate for a Tier 1 method.

Figure 4.13 Fraction of MSW disposed to landfills for selected MS with downward trend prior to 1999



Source: MS GHG inventory submissions 2012

Figure 4.14 Fraction of MSW disposed to landfills for selected MS with upward trend prior to 1999



Source: MS GHG inventory submissions 2012

Proposed Tier 2 method in previous project

The Tier 2 assessment of the policy impact of the Landfill Directive developed in the previous project is also based on the first order decay methodology of the 2006 IPCC Guidelines for national GHG inventories for calculating CH_4 emissions:

1. The mass of waste disposed to landfills is extrapolated based on the fraction of MSW amounts disposed in the period 1995 to 1998. A linear regression of the fraction of MSW disposed to landfill against time prior to the implementation of the Directive is carried out for the period 1995 to1998 and used to extrapolate the trend as a counterfactual for the absence of the Directive.
2. MS specific data is used for the composition of MSW.
3. The Tier 2 method attempts to include the effects of the increased rate of CH_4 recovery by assuming that in the absence of the directive, recovery rates would have remained at 1999 levels. The emissions associated with the difference in CH_4 recovery are assigned as a saving result from the implementation of the Directive.
4. Emissions associated with increased recycling and biological treatment are estimated as well as the emissions/ emission reductions due to diversion of waste

streams to waste incineration and energy use from incineration. It is assumed that the waste not disposed to landfills or incineration is split 50:50 between recycling and biological treatment.

5. A time horizon of 150 years is considered in the equation ad is explained with the fact that emissions will still occur from the landfill after the addition of waste is stopped.

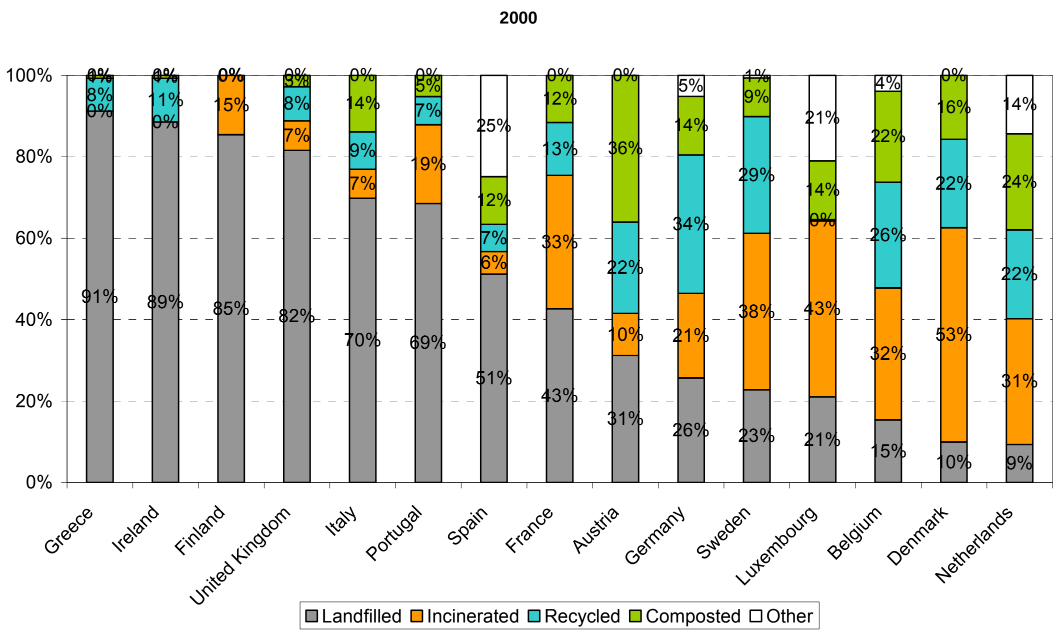
Critical review

- The trend extrapolation for the fraction of waste disposed to landfills corrects for the observations explained in the previous section.
- The waste composition is the key parameter where MS data should be used as in the method proposed whereas for other parameters, most MS use default values.
- The methodological description is not very clear related to the alternative waste treatment types. The equation accounts for emissions from recycling of different waste types. However, such emissions do not occur in the 2006 IPCC Guidelines for GHG inventories and it is unclear to what type of emission sources the methodology refers to and which EFs should be used. Recycling may be taken into account in the opposite way because recycling avoids emissions associated with producing materials (e.g. for glass and paper production) that are recovered from waste and used as resources. The accounting of emissions from recycling in the Tier 2 method seems therefore incorrect.
- The methodological description for the emissions from biological treatment could be improved by differentiating the types of biological treatment, which are composting, anaerobic digestion at biogas facilities and mechanical-biological treatment of waste. However, it is not necessary to differentiate different waste types in the calculation of emissions from biological treatment. This is not in accordance with IPCC methodologies and such differentiation is only necessary for the FOD method.
- The highest 2600 IPCC Guidelines half-life value for the decay of biodegradable materials in landfills is 35 years for wood. The IPCC FOD method goes back into the past over a default period of 50 years. Therefore the time horizon of 150 years assumed in the Tier 2 method seems exaggerated.
- The Tier 2 method is somewhat unclear with regard to the way how waste incineration with energy recovery is treated as alternative waste management practice: In accordance with the IPCC methodology, for biodegradable waste that is diverted from landfilling to incineration only CO_2 emissions resulting from oxidation, during incineration of carbon in waste of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil) are considered net emissions and should be included in the CO_2 emissions estimate. The CO_2 emissions from combustion of biomass materials (e.g., paper, food, and wood waste) contained in the waste are biogenic emissions and should not be in-

cluded in national total emission estimates. The biodegradable MSW mainly consists of such biomass materials for which no emissions need to be calculated from an inventory perspective. Therefore it seems essential to differentiate between the fossil fraction and the biogenic fraction in the estimation of emissions from incineration which is not addressed in the suggested methodology. The differentiation included in the previous study related to waste types is not necessary, as general EFs for biodegradable and fossil fractions exist.

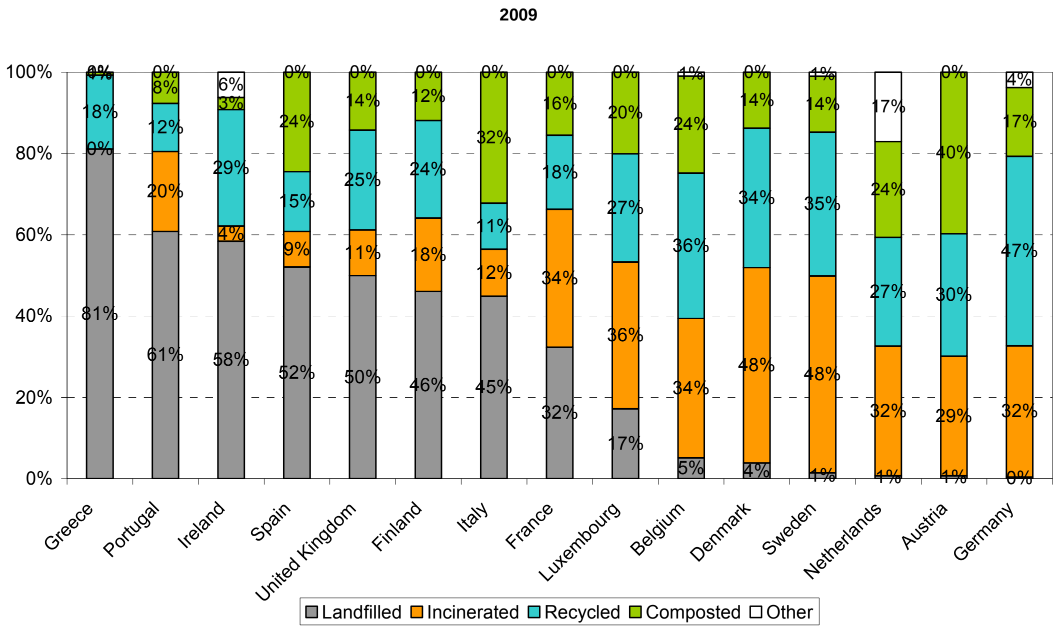
- The replacement of fossil fuels by waste fuels results in emission savings in the energy sector. In the suggested methodology, this is taken into account for waste incineration with energy use, but not for the landfill gas used for energy purposes.
- Emissions associated with increased recycling and biological treatment are estimated and it is assumed that the waste not disposed to landfills or incineration is split 50:50 between recycling and biological treatment. As Eurostat data is available on the exact fractions of different waste treatment methods for EU MS, it is recommended to use the actual shares from Eurostat statistics instead this rough assumption and to extrapolate a time series for each year based on the Eurostat data (available for every three years). Figure 4.15 and Figure 4.16 show that for some MS the 50:50 share would produce incorrect results, e.g. some MS do not use composting as general technologies beyond private households and in recent years composting accounts for less than 50% of the divertion except for Italy.

Figure 4.15 Waste management practices in EU-15 Member States in the year 2000



Source: Eurostat 2011

Figure 4.16 Waste management practices in EU-15 Member States in the year 2009



Source: Eurostat 2011

- Similar to the Tier 1 method, the conversion of unmanaged and illegal waste disposal sites to managed waste disposal sites that comply with the requirements of the Directive and that resulted in a change in the MCF in emissions estimation is not taken into account in any of the methodologies proposed in the previous project.

Proposed Tier 3 method in previous project

No specific Tier 3 method was developed. It was proposed in the previous project that the principal development of a Tier 3 analysis would include the refinement of the counterfactual for waste disposal through various waste management practices in the absence of the Directive. As such data is available from Eurostat statistics and because it is a relatively simple calculation without sophisticated modelling, it should already be taken into account in the Tier 2 method as proposed above.

4.11.3 Proposed improvements and refinement methodology

Almost all EU MS have implemented First-order-decay models to calculate CH_4 emissions from landfills, which have been repeatedly reviewed as part of the UNFCCC inventory review, therefore it is useful to base the ex-post methodology on this existing estimation approach.

Differentiation between managed and unmanaged landfills for Tier 1 and Tier 2 methods.

In the FOD method and the IPCC default model, the four different methane correction factors (MCF) (unmanaged - shallow, unmanaged – deep, managed and uncategorized) are taken into account and for each year of the estimation the fraction of waste disposed in each site type has to be entered in the estimation. For countries for which unmanaged landfills existed until 1999 or later (some MS eliminated unmanaged waste disposal prior to the Landfill Directive, for these countries, this addition in the method is not relevant), the counterfactual estimation should assume higher fractions of waste disposed to unmanaged or uncategorized sites in the FOD estimation for the counterfactual development. A linear regression of the fraction of MSW disposed to unmanaged and uncategorized landfills for the period 1995 to 1999 should be prepared and the trend should be extrapolated based on this result and used as counterfactual for the absence of the Directive.

Estimation period

The IPCC default period of 50 years should replace the 150 years currently assumed in the methodological description.

Improvements for Tier 1 method

Fraction of MSW disposed to landfills:

It is suggested to categorise MS into different groups to derive the counterfactual assumptions with regard to the fraction of MSW disposed to landfills:

1. MS with increasing and decreasing fractions of MSW disposed to landfills in the period 1990 to 1999: A linear regression of the fraction of MSW disposed to landfill against time prior to the implementation of the Directive should be carried out for the period 1995 to1998 and used to extrapolate the trend as a counterfactual for the absence of the Directive (same approach as for Tier 2)
2. MS with relative constant fractions of MSW disposed to landfills in the period 1990 to 1999: the fraction of the year 1999 can be used for the counterfactual estimation.

CH_4 recovery

It is proposed to include the effect of the Landfill Directive on the recovery of landfill gas in the Tier 1 method, because the Landfill Directive contributed significantly to the diffusion of CH_4 capture systems via the acceptance standards for landfills. This additional effect of the landfill Directive should therefore be monitored in all methodological approaches in the same way as in the Tier 2 method. The data is easily available from the GHG inventories, therefore this element can easily be incorporated in the Tier 1 method and strongly improves the result.

Improvements for Tier 2 method

Emissions from biological treatment

The methodological description for the emissions from biological treatment should be improved by differentiating the types of biological treatment, which are composting, anaerobic digestion of organic waste and mechanical-biological treatment of waste. The IPCC method however does not require consideration of different waste types as suggested in the previous project, because in particular composting and anaerobic digestion require relatively homogenous organic material and the IPCC method used organic waste treated as aggregate input data. Emissions from composting include CH_4 and N_2O emissions, this would also be a necessary improvement of the method suggested in the previous project.

The corrected equation would read:

$$CH_4\,BIO_i = M compost_i \; * EF\;CH4\,compost_i + M\;anaerob_i \; * EF\;CH4\,anaerob_i + M\;MBT_i \; * EF\;CH4\,MBT_i$$

$$N2O \quad BIO_i = M compost_i \; * EF\;N2O\;compost_i + M\;anaerob_i \; * EF\;N2O\;anaerob_i + M\;MBT_i \; * EF\;N2O\;MBT_i$$

Whereas:

BIO $_i$ = Emissions from biological treatment of waste diverted from landfills in year i

M compost $_i$ = Mass of organic waste composted in year i

EF compost $_i$ = EF for CH_4 and N_2O for composting in year i

M anaerob $_i$ = Mass of organic waste treated with anaerobic digestion in year i

EF anaerob $_i$ = EF for CH_4 and N_2O for anaerobic treatment in year i

M MBT$_i$ = Mass of organic waste treated with mechanical-biological treatment in year i

EF MBT $_i$ = EF for CH_4 and N_2O for mechanical-biological treatment in year i

Emissions from alternative waste treatment types

The methodological description suggested in the previous project accounts for emissions from recycling of different waste types. On the contrary, recycling could be taken into account in the opposite way in the estimation because recycling avoids emissions associated with producing materials (e.g. for glass and paper production) when recycled materials are used as resources. The accounting of emissions from recycling in the Tier 2 method should be done by adding avoided emissions from recycling in the counterfactual estimation:

Avoided emissions from recycling = Amount of material x (paper, glass) recycled * EF from production of material x

EFs from glass and paper production should be consistent with the EFs used in the GHG inventories for these source categories.

Emissions from waste incineration

For CH_4 and N_2O emissions in equation of the previous project can be used, but it is not necessary to differentiate into waste types.

For CO_2 emissions the suggested equation for incineration needs to be modified in the following way:

Emissions $_{incin}$ = Mass (wet) of biodegradable waste incinerated * dry matter content in the waste incinerated * C content in dry matter * fraction of fossil carbon in total carbon * EF $_{incin}$ *oxidation factor * 44/12

The replacement of fossil fuels by waste fuels results in emission savings in the energy sector. In the suggested methodology, this is taken into account for waste incineration with energy use, but not for the landfill gas used for energy purposes. The latter therefore should be added in the calculation of GHG emissions avoided as a result of energy recovery from incineration of waste diverted to incineration and from energy use of landfill gas.

Improvements for Tier 3 method

Instead of the approach proposed in the previous study (which is integrated in the improvements of the Tier 2 method suggested above), a Tier 3 method should develop country-specific counterfactual scenarios taking into account the specific national legislation and landfills and on waste management to improve the assignation of emission reduction effects and the timing and specific elements of the national implementation of the Landfill Directive. Several reports show that some MS implemented the Directive later than foreseen or implemented the Directive in an incomplete way[163],[164]. The extrapolation used in the Tier 2 method based on the years 1995-1999 does not take into account such differences in the implementation scope and schedule. Such analysis could be implemented in a Tier 3 approach as regular reports of the status of implementation of the Landfill Directive are available.

Cost estimation

Costs for landfills generally include investment costs (estate, exploitation, building technique, installation engineering, outside facilities), operation expenses (maintenance and repair, staff, administration, insurance and taxes, operation supplies, leach-

[163] Bipro 2009: Assessing legal compliance with and the implementation of the waste acceptance criteria and procedures by EU-15. Final report for the European Commission.

[164] COWI 2007: Follow-up study on the implementation of Directive 1999/31/EC on the landfill of waste in EU-25, Final report for the European Commission.

ate treatment) and abandonment costs (surface sealing, renaturation, deconstruction of outside facilities, collection of leachate and landfill gas) (UBA 2004)[165].

The previous project "Quantification of the effects on GHG emissions of policies and measures" quoted an ex-post assessment of the cost effectiveness if the EU Landfill Directive that was conducted by Golder Europe by using a questionnaire and an individual landfill site operator interview in EU- Member States. The authors found that the implementation of the Landfill Directive was generally followed by a cost increase.

Nevertheless the authors found several potential limitations to this result: costs have been only approximated as actual costs that depend on the different types of waste to be disposed and the location of the landfill.

Technology costs

In Germany, total costs for a landfill with a fill volume of 150.000 m^3 annually add up to 6.621 million €, or 44 €/m^3 respectively. Operation expenses are assumed to account for 61 % of total costs, whereas abandonment costs only account for 17 % (UBA, 2004). By closing landfills and processing the amount of waste from landfill by another technology (incineration, composting, MBT), the costs of treating waste will change. Incineration costs, depending on system throughput (200.000 t/year) and system type range from 100 – 120 €/t in Germany, whereas operation expenses for MBT with a throughput of 200.000 t/year account for 60 €/t (UBA 2004). Incineration costs could be reduced by using the generated energy in the form of district heating.

Gate fee approach

Another approach to quantify costs for the implementation of the Landfill Directive is the use of gate fees as suggested and determined in a study conducted by AEA Technology for the European Commission (2001)[166] as a proxy for economic costs. The concept of gate fees is explained as follows in this study: *"Gate fees are the fees charged by the operators of waste management facilities for disposal of received waste. They can be seen as representing the actual financial costs of waste management to the public more accurately than technology costs. Gate fees will be set at a level to recover all capital and operating costs, but will also include a profit element. In the case of recycling, sometimes a price is paid for receipt of recycled materials – this can be viewed as a negative gate fee. In a competitive market, gate fees tend to be set at the level which the market can bear, and are therefore strongly influenced by the cost of nearby methods of waste disposal. For example, the fee charged by a composting plant may be set just below the fee charged by nearby landfill*

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[165] UBA (2004): Rechtliche, ökonomische und organisatorische Ansätze zur Schließung von Siedlungsabfalldeponieraum. Forschungsbericht 299 34 301

[166] European Commission (2001): Waste management options and climate change. Final report for the European Commission, DG Environment, by AEA Technology (Authors: A. Smith, K. Brown, S. Ogilvie, K.Rushton and J.Bates)

sites or incineration plants." The costs of different waste treatment options compiled in this study are presented in Table 4.30.

Table 4.30 Overview of costs of different waste treatment types

Treatment type	Typical average cost [€ / tonne]	Cost range reported [€ / tonne]
Landfill	56	11-162
Incineration	64	31-148
Mechanical biological treatment	60-75	60-75
Composting		
Separate collection	10-40	0-75
Open systems	35	16-174
Closed systems	50	16-174
Home	0	0
Anaerobic digestion	65	41-153

Source: European Commission (2001)

Costs for counterfactual

For a quantification of costs resulting from the implementation of the Landfill Directive, a counterfactual would need to consider the costs without the Directive.

The Landfill Directive significantly reduced the costs of unmanaged and uncontrolled landfills that represented serious threats to environment and health, in particular the pollution of groundwater by leachate infiltration into the soil. The decontamination and restorage of damage caused by uncontrolled landfills results in very high costs, however it is very difficult to derive an exact cost estimate for the effect of the Landfill Directive.

An alternative, but incomplete approach would be to assume that without the Landfill Directive other waste treatment practices would have been implemented that reduce the environmental risks of uncontrolled landfills in the same way as the Landfill Directive. Table 4.30 indicates that compared to the other waste treatment types, managed landfills are the option with the lowest costs for the implementation. A full implementation of incineration of all MSW e.g. would have caused higher costs of 8 € per tonne of MSW according to these data.

4.11.4 Summary and conclusions

Based on easily available data and consistent with the inventory estimation the Tier 1 and Tier 2 methodologies for the effects of the landfill Directive could be further improved. The improved Tier 1 and Tier 2 methods are not significantly more data or labour intensive than the approaches suggested in the previous study.

An approach to quantify the costs of the implementation of the Landfill Directive would however be very resource demanding because data for the counterfactual development would be very difficult to gather. The Landfill Directive effectively stopped the illegal and unmanaged landfilling of biodegradable and hazardous waste. Thus, a counterfactual cost scenario would need to estimate the environmental damage caused by a continued dumping of MSW and hazardous waste outside appropriately managed landfills on human health and ecosystems and the costs for dealing with such damage. Whereas it is rather obvious that such long-term costs would be much higher than the costs for the implementation of the landfill Directive, it is rather speculative to provide a detailed cost estimation.

4.12 Energy performance of buildings

4.12.1 Policy overview

The EPBD was initially adopted in 2002 (2002/91/EC)[167], with the aim of promoting "…*the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness."* [Article 1]

The Directive sets out a number of requirements including:

(a) a general framework for a methodology for calculating the integrated energy performance of buildings taking into account all aspects which determine energy efficiency;

(b) minimum standards to be set by MSs for the energy performance of new buildings and large existing buildings that are subject to major renovation, to be calculated on the basis of the above methodology;

(c) systems for the energy certification of new and existing buildings; and

(d) regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old.

[167] Directive 2002/91/EC of the European Parliament and the Council of 16 December 2002 on the energy performance of buildings

A recast of the Directive was adopted in 2010 (Directive 2010/31/EU)[168]. The recast strengthens the building codes and energy performance requirements for buildings across the EU and requires all new buildings to be nearly zero energy buildings by 2020.

4.12.2 Review and critical assessment of existing methodology

Overview of methodologies

The methodologies developed in the previous study are summarised as follows:

- Tier 1 method:
    - Tier 1 assumes a simple linear relationship for the residential sector between the total number of residential buildings and the level of greenhouse gas emissions, and for the non-residential sector between the total number of employees and the level of greenhouse gas emissions.
    - Tier 1 assumes that where existing energy policies are in place, all savings that go beyond 0.5% autonomous efficiency improvement per year can be attributed to those policies.
    - Tier 1 approach assumes that renewable electricity production is replacing the average European fuel mix of public and auto producers.
    - Tier 1 approach assumes that the share of energy use for space heating is unchanged over the years, and uses default values per country.
    - Tier 1 approach corrects energy use for space heating to account for climate influences.
- Tier 2 method:
    - Same as Tier 1 but is based on m^2 in both the residential and non-residential sector buildings rather than the number of dwellings and assumes that saved electricity would have been produced by the average national fuel mix for the power production in a country.
- Tier 3 method:
    - Tier 3 method applies a detailed bottom-up model that includes amongst others information on energy savings measures per type of building, impact of energy prices and takes into account delay time of policies.
    - The Tier 3 method uses the MURE simulation model which relies on detailed data of: building stock characteristics in the EU27 (split/single, multi-family, split by age classes, split by fuels, distinction by countries and cli-

[168] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)

matic zones) and the technical characteristics of existing, new and refurbished buildings which penetrate the stock.

- o The main data sources provide trends in numbers of households, trends in square metres, structural data for buildings, building energy efficiency standards and penetration rates, diffusion of heating technologies.

The table below, replicated from the previous study, highlights the main differences between the methodologies in terms of impacts on the results.

Table 4.31 Overview of approaches in the previous study

Approach	Tier 1	Tier 2	Tier 3
Activity indicator	Number of households (Inventory sector 1.A.4.B.). Number of employees (Inventory sector 1.A.4.A.). Estimate of space heating shares.	Number of households and development of square metres. Estimate of space heating shares.	As Tier 2 but including data on building stocks and technical characteristics of existing, new and refurbished buildings. Use of the MURE simulation model
Emission factor	Fuel specific emission factors. Aggregate average EU emission factors for electric space heating	Fuel specific emission factors. Emissions for electric space heating based upon aggregate data reported by Member States to UNFCCC	Fuel specific emission factors. Short term marginal emission factor (hourly model or approximation by fossil fuel plants)
Autonomous development and previous policies	Correction for autonomous progress / previous policies included in a very approximate manner by assuming a fixed rate based on the stock renewal and the period 1990-2002 previous to the EPBD	Correction for autonomous progress / previous policies included in a very approximate manner by assuming a fixed rate based on the stock renewal and the period 1990-2002 previous to the EPBD	Autonomous progress / previous policies simulated by the penetration of the building regulation before the introduction of the EPBD.
Structural effects	No adjustment for structural changes in the activity data	Adjustment for the increase in household size.	Adjustment for the increase in household size, for the shift in multi / single family houses,

			change in age structure No adjustment for increase in internal temperatures and length of heating period.
Timing issues	Calculates policy impacts from implementation date at EU level, no adjustment for implementation delays or announcement effect.	Calculates policy impacts from implementation date within each MS, no adjustment for implementation delays or announcement effect.	Calculates policy impacts from implementation date within each MS. Adjustment for implementation delays or announcement effect.
Policy interaction	Combined effect of closely related national and EU policies.	Combined effect of closely related national and EU policies.	Separation of national promotion schemes by explicit simulation of potentially overlapping policies.
Geographic factors	Adjustment for climatic influence	Adjustment for climatic influence	Adjustment for climatic influence
Other exogenous factors	Non compliance with building regulation implicit in statistical data. No further adjustment for exogenous factors	Non compliance with building regulation implicit in statistical data. No further adjustment for exogenous factors	Non compliance with building regulation explicitly modeled. Adjustment for impacts of commodity prices for heating on the autonomous uptake of insulation measures.

Overview of main conclusions from the previous study

Tiers 1 and 2 do not take into account the time delay in compliance with the Directive. Much of the data available to carry out an assessment on all three tiers dated at most recent from 2006/07, which is the same year in which the policy was implemented in many countries. The conclusion from the previous study was that 'it has been objectively impossible to carry out a real ex-post evaluation…' Hence simulation exercises were used to illustrate the ex-post evaluation methods, and an ex-ante assessment was applied to illustrate the Tier 3 approach.

The results from modelling the impacts using Tiers 1, 2 and 3 differ substantially from one another. The differences can be explained by the following variations in methodological approaches:

- Assumptions on the start date of the policy impacts;
- Inclusion of comfort factors;
- Overlap in national support policies for buildings;
- Non-compliance issues;
- Assumptions on autonomous progress/previous policies;
- Imperfection of climatic correction;
- Differences in emission factors for electric heating.

The previous study concluded that 'the size of the possible CO_2 savings indicates that by 2020 the EPBD could be one of the largest impacts to ECCP policies if its implementation is enforced'.

Recommendations from the previous study

The key recommendations from the previous study can be summarised as follows:

- Resolve the decision as to whether 'comfort increasing factors', such as m2 per dwelling, should be included in the impact evaluation result (as in Tier 1) or excluded from the results (as in Tier 2 or 3). It was recommended to include them but explain them separately; currently difficult to separate factors due to data limitations.
- Assumed start date for implementation and impacts from the EPBD. Tiers 1 and 2 assumed an immediate impact, despite some MS not complying until 4-5 years later. Tier 3 modelled the observed delays. Both approaches have their merits.
- Consider how the availability of information regarding non-compliance could be improved e.g. at the time of the previous study there were a number of infringement procedures open for the EPBD against a number of MSs.

The study identified a number of key steps for improving the methodologies developed:

- Improvements in the data basis available for the service sector in the EU27 – particularly relevant for the Tier approach;

- Further investigations regarding the extent of non-compliance with the EPBD, and associated local Building Regulations/Standards for both residential and non-residential sectors across the EU27;
- Further investigations of the issue of data averaging (necessary for the imperfect climatic corrections) for the Tier 1 and 2 approaches.

4.12.3 Identified gaps in existing methodology and proposed refinements

i) The supposed start of the impacts due to the EPBD has a large influence on the final results. Tier 1 and 2 approaches suppose an immediate impact even if implementation of the Directive is formally delayed, as in many MS. Tier 3 assumes that the observed delays are important for the final impacts. Both approaches have arguments in their favour.

   Proposed solution: In theory, the analysis of longer time series for the Tier 1, 2 and 3 approaches should show when the EPBD really is starting to have an impact, because this should show an accelerated decrease of the specific energy use. Investigate whether sufficient data is available to enable a longer time series (see below).

ii) The methodologies proposed focus primarily on assessing impacts of the Directive in relation to space heating due to the significance of associated emissions. However, the Directive can also impact on other functions such as space cooling and water heating. The methodologies can theoretically be adapted to consider impacts on these items through substitution of data on space heating (e.g. share of energy use) with equivalent data for these functions although there are some issues related to availability of suitable data (e.g. degree cooling days) and overlap with other policies (e.g. Energy Labelling Directive).

iii) More recent data on the split of energy use in the residential sector into various functions, e.g. space heating, hot water production, cooling, lighting etc. could improve results for the Tier 1 and 2 methods. Proposed solution: to investigate if these data are readily available (see below)

iv) There is a big gap between the Tier 1 and 2 approaches and the Tier 3 approach regarding level of detail and required input data. The Tier 1 and 2 approaches can be rather easily applied using EU and national statistics, whereas the Tier 3 approach requires very detailed input data. It could be investigated if an approach can be developed that provides more insight on the actual impact of the various areas of interest of the EPBD but which do not require the detailed data input of the Tier 3 approach.

   Proposed solution: to investigate if it is possible to distinguish between the impact of new and existing buildings, residential and non residential buildings, energy use for space heating, hot water consumption, lighting and cooling, demand side and supply side measures, implementation of renewable energy measures (like solar hot water systems).

v) The impact of policies aimed at improving the efficiency of hot water production is not included in the analysis for Tiers 1 and 2. This means that policies aimed at improving the efficiency of hot water production are not covered such as more efficient boilers, solar water heaters etc. In Task 3 it is investigated how this can be included in these approaches. This also holds for the impact of more efficient lighting in the non-residential sector that is currently not covered in one of the approaches

vi) Because of lack of data (and timing) the presented Tier 3 approach was applied for an ex-ante assessment instead of an ex-post assessment.

Proposed solution: Testing if these type of models really can be applied in ex-post assessments because of the large number of empirical data that are required e.g. compliance, actual implementation of energy efficiency measures in the building stock, actual standards and energy use for new buildings. Within Task 3 testing for a number of Member States what data are available and if the Tier 3 approach applied to ex-post assessment is feasible. It should be noted that the model itself which was used in the previous study is not publicly available for use.

vii) The previous project states that “decisions have to be made as to whether comfort increasing factors such as m2 per dwelling are to be included in the impact evaluation result (as in Tier 1) or excluded from the results (as in Tier 2 or 3)”,

Proposed solution: we suggest that we exclude comfort increasing factors from the results because these structural changes are not targeted by policies under the EPBD.

viii) Data on non-compliance appears to be limited. Further investigations could be undertaken on what data are available and gathered on a regular basis.

Proposed solution: Non compliance with the Directive, and associated local Building Regulations/Standards, has a large impact on the evaluation results but is largely unknown for both the residential and the non-residential sector. We investigate this issue more carefully in Task.

ix) The data available for the evaluation of the Directive in the non-residential sector is poor in many of the EU27 countries. Approaches to improve this situation exist, mainly in the form of suitable surveys of buildings in this sector. We believe that this cannot be solved within the scope of this project.

Proposed solution: We investigate this more closely in Task 3 of the project:

a. what the data quality is for the non-residential sector in various MSs; and
b. what alternative approaches MS apply to monitor energy efficiency for this sector.

x) The issue of data averaging for the Tier 1 and 2 approaches, which is necessary due to imperfect corrections for climatic variations, is also considered difficult to address under the scope of this study. This is because almost no data are available on the share of energy use that is dependent on changes in outside temperature.

No available literature was found on ex-post evaluations of the EPBD at MS and EU level. In addition, we have investigated the availability of any new publications and refreshed literature sources/datasets from the reference list used in the 2009 study as well as those sources used in the MURE simulation model. Overall the results show very little additional or more updated data or publications.

Coverage of the proposed improvements listed above:

i) In theory the analysis of longer time series for the Tier 1, 2 and 3 approaches should show when the EPBD really is starting to have an impact, because this should show in an accelerated decrease of the specific energy use. It should, however, be noted that this will of course depend on the quality of the data. Results of assessment: As discussed above, there is very little refreshed data and therefore it is recommended that this forward projection exercise take place only after sufficient time has passed to enable more robust assessment of the impact of the EPBD, for example in future if a detailed assessment of the EPBD is carried out. The existing datasets do not allow for sufficient detailed (Tier 3) modelling of the impacts after implementation/compliance.

ii) More recent data on the split of energy use in the household sector into various functions: space heating, hot water production, cooling, lighting etc. could improve results for the Tier 1 and 2 methods.

Results of assessment: The previous ex-post evaluation study used existing data for Tiers 1 and 2 and 3 ranging to 2006/07. We have carried out a survey of the datasets used and the results are as follows:

- EU: Data to 2007 only: a) More recent data is available from the Odyssee MURE project (see http://www.odyssee-indicators.org/reports/household/households.pdf) with the data from 1990-2007.
- Trends in EE and household/service sector energy consumption before/after 2002 (to 2007) available in an Odyssee report (Nov 2009) (see http://www.odyssee-indicators.org/publications/PDF/brochures/buildings.pdf) but this only provides one extra year of refreshed data.

Conclusion: no refreshed data of this type is apparent on the EU level[169]. However, it is possible that more recent and complete data are available on the level

[169] Update (August 2012) – data has now been released for 2009 on the ODYSEE website (http://www.odyssee-indicators.org/).

of Member States. This is further investigated during the testing phase in Task 3.

iii) It could be investigated if an approach can be developed that provides more insight on the actual impact of the various areas of interest of the EPBD but which do not require the detailed data input of the Tier 3 approach.

Results of assessment: It was investigated if the ratio of new build to existing building stock can be used, Tiers 1 and 2 could assume that new build (since MS compliance) consumes proportionately less energy per unit than existing stock. So the ratios of new build to number of dwellings and employees in the service sector could be used to determine the impacts of the EPBD.

For the UK and the Netherlands there is published data available regarding new build in the residential sector and the compliance with the EPBD and level of building efficiency established in new build (residential) stock. This data may be available for other MSs.

iv) Testing if these type of models really can be applied in ex-post assessments because of the large number of empirical data that are required e.g. compliance, actual implementation of energy efficiency measures in the building stock, actual standards and energy use for new buildings. Within Task 3 testing for a number of Member States what data are available and if the Tier 3 approach applied to ex-post assessment is feasible.

Results of assessment: We have completed a widespread search for MS level ex-post evaluations of the EPBD and, to date, found limited relevant sources. Examples identified which appear to be promising for the purposes of supporting evaluation of the EPBD include a “European Prototype Tool” which could be used for the evaluation of building performance (national tools are also described)[170] as well as the BREEAM method[171] which is currently widely used for ex-ante assessment and has been adapted for a number of MSs. These – along with any other MS specific approaches – are investigated in Task 3 of the study.

4.12.4 Summary/ Conclusions

We have attempted to embellish the existing evaluation methodology and found that the data identified does not significantly enrich the methodologies or results from the existing ex-post evaluation carried out in 2009. Therefore it may be reasonable to not select this policy for a detailed assessment until a later date when sufficiently refreshed

[170] Available from: http://www.buildingeq-online.net/fileadmin/user_upload/Results/BEQ_report_WP5_090823.pdf

[171] http://www.breeam.org/podpage.jsp?id=54

data is available and adequate time has lapsed to enable a more comprehensive assessment of the impacts of the EPBD

However, because of the potentially significant impact of the Directive in terms of reductions in GHG emissions it was agreed to undertake the following investigations in Task 3 of the study:

1. To further test if our recommended improvements for the Tier 1 and 2 approaches can be implemented on the MS level (with country specific data) and test if they deliver any useful results.
2. To further investigate which countries have detailed models for the building sectors and if these models are geared towards ex-post evaluations.

4.13 Energy Labelling Directive

4.13.1 Policy overview

The labelling directive was adopted in 1992 (EC, 1992) and is aimed at harmonising national measures to enable consumers to choose the most energy efficient appliances. A large number of Implementing Directives have been adopted which regulate the labelling specifications for each product type. Some Directives have been updated since their first adoption. The Directive applies to the following type of products: i) Refrigerators, freezers and their combinations, ii) Washing machines, dryers and their combinations, iii) Dishwashers, iv) Ovens, v) Water heaters and hot water storage appliances, vi) Lighting sources, vii) Air conditioning appliances.

A revised Energy Labelling Directive was adopted in May 2010 (EC, 2010c). It extends the energy label to energy-related products in the commercial and industrial sectors, for example cold storage rooms and vending machines. New energy labelling classes have also been introduced. The extension of the scope from energy-using to energy-related products (including construction products) means that the Directive covers any good having an impact on energy consumption during use. These products do not consume energy but "have a significant direct or indirect impact" on energy savings. Examples are window glazing and outer doors

4.13.2 Review and critical assessment of existing methodology

The methodologies in the previous project were well developed and the analysis was carried out for all three tiers. A summary of these methodologies is provided below.

Table 4.32 Key methodological choices from AEA (2009) study

Approach	Tier 1	Tier 2	Tier 3
Activity indicator	Number of households	Number of households and appliance ownership	Number of appliances

Approach	Tier 1	Tier 2	Tier 3
Emission factor	EU average	MS average	MS average fossil park/hourly short-term marginal
Policy interaction (in particular synergy with national promotion schemes)	No	No	Yes
Autonomous development (i.e. improvement of appliances in the per-Directive period)	Yes (at aggregated level)	Yes (at appliance level)	Yes (at appliance level)
Structural effects (e.g. adjustment for structural changes due to changes in ownership)	No	Yes (if data allows for corrections)	Yes (if data allows for corrections)
Geographic factors (e.g. adjustment for climatic variation for electric heating)	No	Yes	Yes
Timing issues / delay or announcement effects	Same start date	MS specific	MS specific
Other exogenous factors: impacts of commodity prices (electricity prices) but impact small	No	No	Yes

Tier 1 – EU level

In the 2009 study, assessment of the policy impact at Tier 1 level was based on EU-level Eurostat data. Key indicators used were number of households and overall electricity consumption per household. The approach did not separate individual appliances nor did it split out other electricity uses not covered in the scope of the Labelling Directive (e.g. electric heating, electric water heating and small electric appliances).

The methodology extrapolated electricity consumption per residential dwelling from the period 1990-1995 up to 2006 and compared this baseline with actual observed electricity consumption over the period to calculate actual electricity consumption. No corrections are made for climate impacts on electric heating because data does not allow separation.

Emissions from electricity saved are evaluated with an average EU emission coefficient including nuclear power plants.

Tier 2 – MS level

This approach is based on national data collected in the Odyssee Database. This approach calculates the impact of the Directive using appliance ownership data and unit consumption (kWh/appliance/year). The approach did not make use of sales data or label classes. Tier 2 is limited by the number of countries in the Odyssee Database for which information on individual appliances is available.

No correction was made for autonomous progress[172]. The previous study remarked that whilst in principle this is possible by using data from the pre-Directive period, however, in reality for many countries the time series are not long enough.

Tier 3 – Detailed calculations using the MURE stock model

The methodological steps employed were as follows:

1. Evaluate the energy impact of the Directive using the MURE appliance stock model which includes sales on different appliances by label type by country.
2. Evaluate the impact of the Directive on energy consumption using energy data from the year 1990 up to 2004.
3. Convert electricity savings with emission factors based on marginal power plant in terms of Short Term Marginal Costs (STMC)
4. Assess the importance of broader influential factors including the impact of national support schemes and the impact of electricity prices.

The table below shows the key input data variables for the Tier 3 methodology approach suggested in the previous project.

Table 4.33 Main data inputs for Tier 3 methodology suggested in 2009 study

Input variables	**Sources**
Appliances lifetime	CECED study
Lifetime standard deviation	
Ownership rate	
Energy labelling shares of the yearly shares	GfK (CECED for the years before 1995)
Specific energy consumption by energy labelling category (only for refrigerators and freezers)	CECED databases
Household number	Census data

The 2009 study concluded that the tiered methodologies deliver results which are comparable. Proposed refinements to the methodology are suggested in the section below, but the main recommendations from the 2009 study are can be broadly summarised as:

- Correct for autonomous progression

[172] This is taken to mean the progress that would have been made in absence of the Labelling Directive

- Clarify the availability of private data sets
- Increase the number of appliances covered in the Tier 3 approach

4.13.3 Proposed improvements and refinement of the methodology

Tier 1 – EU level

The current approach uses the indicator *total electricity consumption by household* in Eurostat and divides this by the total number of households. This indicator aggregates all use of electricity for space and water heating and all electrical appliances. Eurostat does not split out residential electricity usage for different applications. This approach does not account for consumption changes due to changes in usage or ownership. Energy consumption at the household level is determined by a combination of ownership level (which is strongly related to income of households), technology and usage patterns, each of which varies between appliance sectors.[173] It might be more pertinent to use average private consumption (in euro) per household as an indicator to assess electricity consumption for appliance to construct the counter factual

The JRC (2009) has estimated breakdown of residential electricity consumption at EU level by appliance type (see Table 5.10). This split could be used to provide a more precise impact assessment of residential electricity consumption per dwelling for the relevant appliances included under the Directive. In this way, non-relevant appliances (e.g. lighting and space heating) can be excluded. However, it is not clear if this data is collected on an annual basis or if it was collected as a one-off survey. It is will be important to understand how this split may have changed over time. This is investigated further in Task 3.

Table 4.34 Breakdown of residential electricity consumption in EU-27 in 2007

EU-27 residential electricity consumption (2007)	TWh	% of total
Cold appliances (refrigerators & freezers)	*122*	*15.2%*
Washing machines	*51*	*6.4%*
Dishwashers	*21.5*	*2.7%*
Electric ovens & hobs	*60*	*7.5%*
Air-conditioning	*17*	*2.1%*
Ventilation	22	2.7%
Water heaters	68.8	8.6%
Heating systems/electric boilers	150	18.7%
Lighting	84	10.5%
Television	54	6.7%

173 ECI (2005) "40% House". Environmental Change Institute, University of Oxford

EU-27 residential electricity consumption (2007)	**TWh**	**% of total**
Set-top boxes	9.3	1.2%
Computers	22	2.7%
External power supplies	15.5	1.9%
Home appliances stand-by	43	5.4%
Others	60.6	7.6%
Total consumption of appliances covered under Labelling Directive	*271.5*	*34%*
Total residential electricity consumption	**800.72**	**100%**

Notes:

1) Those appliances that are italicised are covered by the Labelling Directive

Source: JRC

Corrections could potentially be made for climate impacts on electric heating. Crawley (2008) has developed a methodology to characterise the potential impact of climate on buildings.[174] This is investigated further in Task 3.

Tier 2 – MS level

The current Tier 2 approach relies on appliance ownership data and unit consumption from the Odyssee Database. The ODYSSEE database was updated in January 2011. However, the problem still remains that not all Member States are included in the coverage of the database[175]. The ODYSSEE database includes the stock of appliances but does not make use of sales data or labelling. It furthermore does not cover all products/appliances currently included under the Directive.

An alternative method would involve using MS-level consumption data by PRODCOM code in Eurostat (for instance, consumption of units of washing machine) which is publicly available. Whilst the PRODCOM database does not currently contain information on real energy use of appliances (or the label category), the CECED database provides information on the average energy consumption by appliance. To be investigated further following submission of this report.

A weak aspect of this methodology and also the current Tier 3 approach is that energy use per appliance is not based on the actual observed energy use per appliance per country but is based on the standardised usage for various appliances. The series "Preparatory Studies for Eco-design Requirements of EuPs"[176] provides a wealth of information on each of the appliances of concern (washing machines, dishwashers,

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[174] Crawley, D (2008) 'Estimating the impacts of climate change and urbanization on building performance', *Journal of Building Performance Simulation,* 1(2): 91-115

[175] Data is included from Austria, Bulgaria, Belgium, Croatia, Cyprus, Czech Republic, Spain, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxemburg, Netherlands, Poland, Romania, Slovakia, Slovenia, Sweden and the UK.

[176] http://ec.europa.eu/energy/efficiency/studies/ecodesign_en.htm

refrigeration, lighting, air conditioning, ovens etc.) including real consumer use patterns. For instance, Report 14 on Domestic Washing Machines and Dishwashers includes real consumer usage considerations such as choice of programme temperatures, partial loading and spinning speeds. These reports could be a useful source of information for more detailed data and are investigated further in Task 3.

Finally, the ODYSSEE database is not publicly available and therefore consideration should be given to how, on a regular basis, evaluations of the labelling scheme could be carried out.

Tier 3 – detailed calculation

Four proposed next steps were identified in the 2009 project:

- Increase the number of appliances covered in the Tier 3 approach, in particular labels for air conditioning and lighting
    - This partly depends on whether the MURE model has expanded coverage to include air conditioning and lighting. To be investigated further following submission of this report.
    - Alternatively, the "Preparatory Studies for Eco-design Requirements of EuPs" could be a useful source of sales data. The "Domestic Lighting" report provides sales data by energy classes for the period 2004-2007.[177] The "Airco and ventilation" report provides detailed sales data and estimates of existing stock. However, air conditioning sales data is not split by label type.[178] There is a 2009 study that has analysed sales of air conditioning unit by energy class in Italy and Spain over the period 2005 to 2008.[179]
- Discuss with GfK and manufacturers whether more detailed data sets may be obtained to improve the issue of *autonomous progress*, or try to clarify the issue through further expert consultations.
- Clarify the availability of private data sets for regular evaluations of the Labelling Directive. The MURE database is not currently publicly available nor is GfK data.
- Integrate the most recent study results to improve on the time period covered (Fraunhofer ISI/GfK/BSR Sustainability 2008).

Additional Tier 3 recommendations:

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[177] Van Tichelen et al., (2009) Preparatory Studies for Eco-design Requirements of EuPs, Lot 19: Domestic Lighting. Final Report http://www.eup4light.net/assets/pdffiles/Final_part1_2/EuP_Domestic_Part1en2_V11.pdf

[178] Riviere (2008) Preparatory study on the environmental performance of Lot 10: Residential Room Conditioning Appliances (airco and ventilation), Draft Report.

[179] Stöeckle (2009) Dynamics of the AC Markets Worldwide, Proceedings of EEDAL 2009 Conference, Berlin, Germany, June 2009.

The previous Tier 3 methodology also seeks to determine the impact of a broader set of socio-economic factors on consumers' behaviour (e.g. appliance prices, electricity prices, household size and national support schemes). Analysis from the previous study shows that information for many of these factors is limited. Here, we have investigated for which factor information can be found on a country-by-country basis:

Appliance prices – the "Preparatory Studies for Eco-design Requirements of EuPs" could be a useful source of current product prices data. For instance, Report 19 Domestic License has collated typical retail prices for domestically used lamps based on consultation with small and large retailers, advertising brochures etc. This data is aggregated at the EU-27 level.

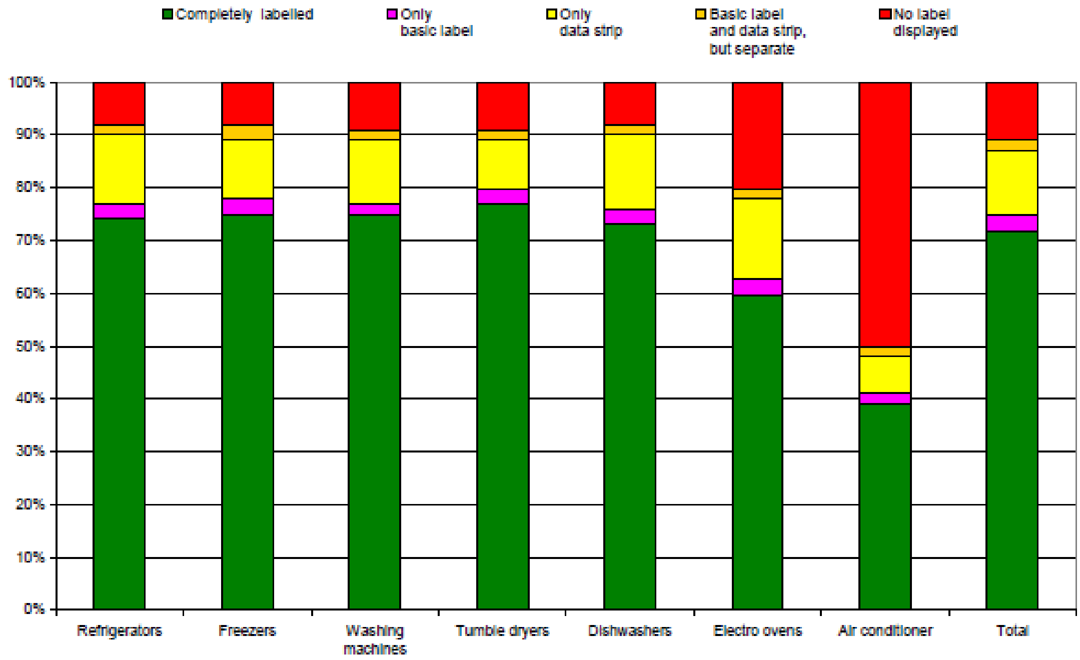
Electricity prices – Eurostat data is available at a MS level

Household size – Eurostat data is available at a MS level

National support schemes – Studies assessing the impact of national schemes are present, however, they tend to address one country and one appliance. For instance, Eckl (2008) assessed the impact of the Italian tax subsidy programme on the sales of cold appliances in Italy.

In addition to the broader socio-economic factors considered it might also be relevant to include the impact of compliance with the Directive. Fraunhofer ISI/GfK/BSR Sustainability (2008) surveyed retail trade in the all 27 EU Member States in order to ascertain compliance of appliance vendors with the Labelling Directive. The results indicated a significant difference in the degree of compliance labelling depending on type of appliance (see figure below). The results show a high level of compliance for white appliances which came into force more than 10 years ago (between 1994 and 1997). However, for electric ovens (59%) and air conditioners (39%), for which the Implementing Directives were adopted in 2—2 and had to be applied at national level from 2003, the degree of compliance is much lower.

Figure 4.17 Completeness of the labelling per type of appliance



Source: Fraunhofer/BSR/GfK (2008)

With regard to overall compliance per country, the highest share of correctly labelled appliances were found in Denmark, Hungary, the Netherlands, Norway and Portugal. On the other hand, the share of mislabelled appliances is very high in Bulgaria and Slovenia.

4.13.4 Summary and conclusions

Methodologies were well developed in the previous project. The major weak point, however, is data availability. It was agreed to:

1. Investigate and test if the suggested improvements for the Tier 1 approach (linking electricity use for products covered by the Directive to private consumption of households) delivers useful results (see Task 3).
2. Investigate which data are available on the member state level (select four to five member states) to improve testing of the Tier 2 methodology (this includes data on more products/appliances, actual energy use/patterns) (see Task 3)

Not to further refine and test the Tier 3 approach within this project because this approach is too data-intensive to apply on the level of Member State.

5 Task 3 Testing of methodologies

This section describes the approaches, procedures and results from the methodology testing of the study. The testing aimed to further improve and refine the methodologies and to implement the recommendations from the previous tasks (Task 1 and 2). The testing process was of an iterative nature. i.e. the methodologies developed in the previous project "Quantification of the effects of policies and measures" as well as recommendations from Task 1 and 2 are implemented to reveal any remaining gaps and challenges, if appropriate, and derive further recommendations for refining and improving the methodologies.

The testing phase highly benefits when Member States volunteer to provide data or information on data. Therefore, an inquiry for information was sent out to Working Group 2 Members to request data and information on data from Member States.

The testing focussed on three policies

1. **ETS Directive:** The previous project ascribed a high significance for further development and testing of the ETS Directive, e.g. the interaction between the electricity sector and other industrial sectors as well as taking price elasticity into account. The new approach considers these issues by linking the macro-econometric model E3ME with a dispatch and an investment model of the electricity sector.
2. **Energy Performance of Buildings Directive (EPBD):** The EPBD was selected for testing because of the potentially significant impact of the Directive in terms of reductions of GHG emissions. The testing was primarily focussed on the quality and availability of data for a given methodology.
3. **Energy Labelling Directive**: The Energy Labelling Directive was selected for testing as the methodologies to assess the Directive are relatively well developed but face some limitations in terms of restrictive data availability. The testing phase aimed to investigate and test if the suggested improvements for the least detailed approach deliver useful results.

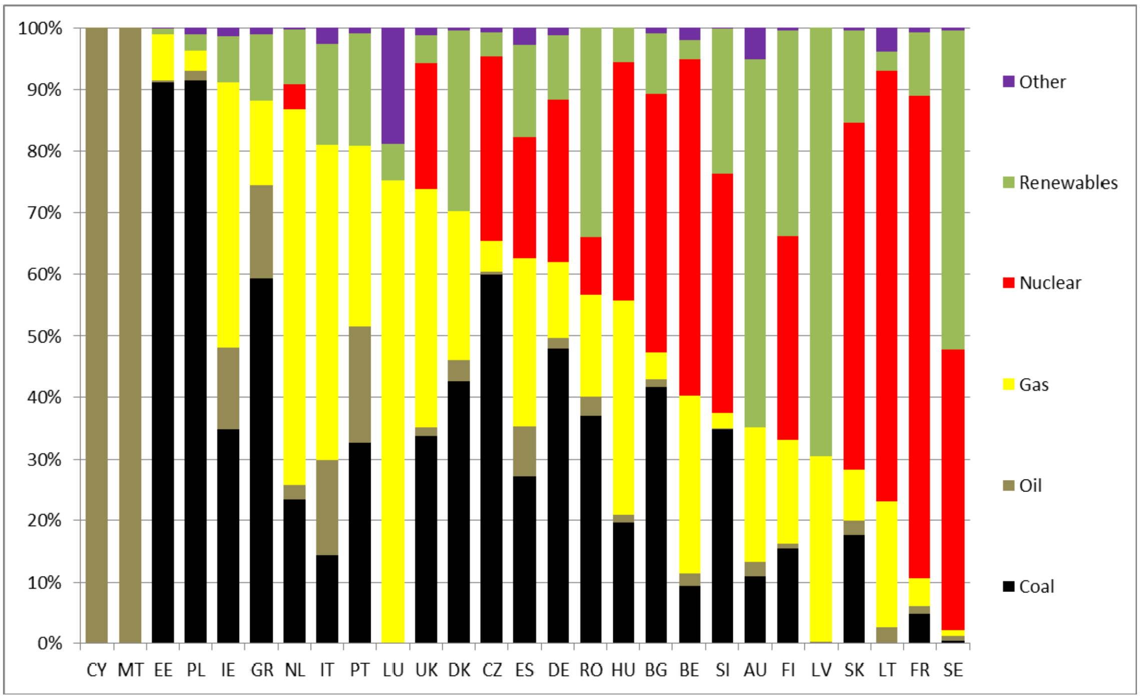
5.1 EU ETS Directive: Testing of methodologies

The testing of the revised Tier 2 and Tier 3 approach for the EU ETS Directive is recommended as it fills a methodological gap that currently exists. The testing isolates and quantifies the effects of the EU ETS Directive. For the Tier 3 approach the CHP Directive and RES-E Directive are taken into account for the policy scenario as they complement the set of policies affecting the power sector. Within the EU ETS sectors, the power sector is focussed upon within the high-detail level testing as it accounts for a large share of total ETS emissions.

Focussed testing is conducted for three Member States whose electricity generation mix is diverse in terms of fossil fuel use and differs in terms of the main fossil fuel types used and the share of electricity generation by CHP and RES power plants.

Figure 5.1 shows fuel mix of electricity generation in the year 2005 on Member State level. The Member States are ranked according to the share of fossil fuel within electricity generation, starting with Cyprus and Malta on the left (100 % fossil fuel use in 2005) and ending with France (11 % fossil fuel use in 2005) and Sweden (2 % fossil fuel use in 2005) on the right.

Figure 5.1 Fuel mix of gross electricity generation 2005 in European Member States (authors' own calculation)



Data source: EU Energy and Transport in figures 2010[180]

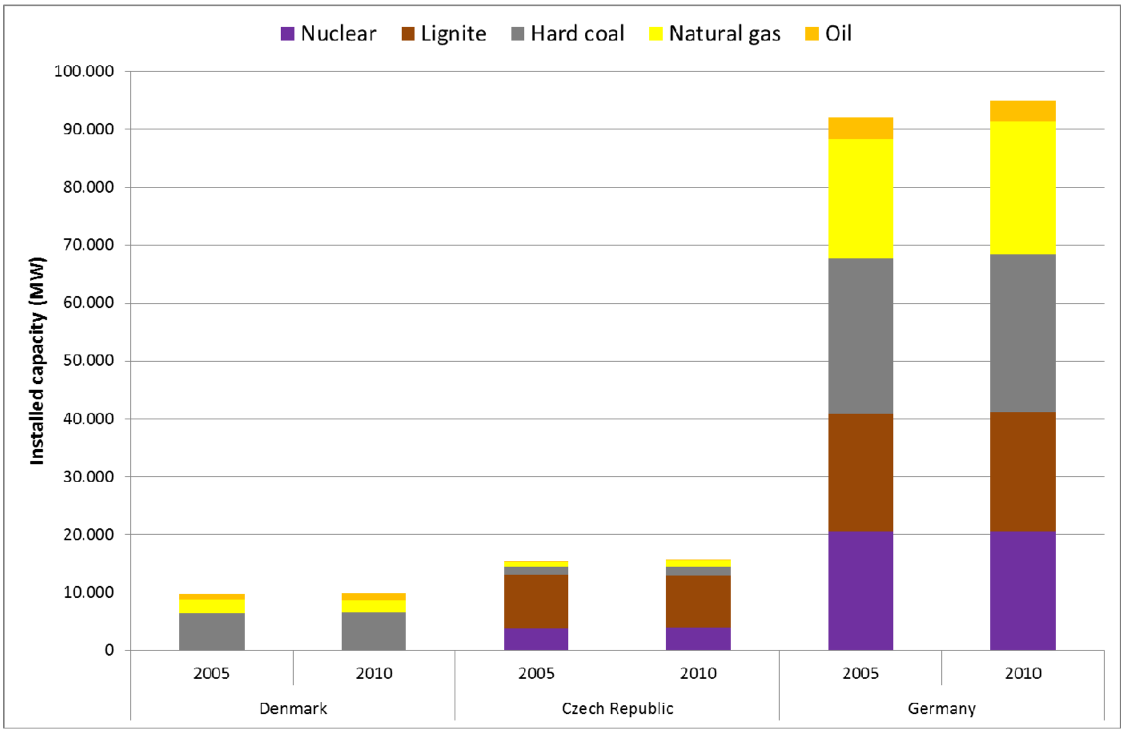
Selected Member States for testing the revised Tier 2 and Tier 3 methodologies are Denmark, the Czech Republic and Germany. Their different key parameters are shown in Table 5.1; the installed capacity of the thermal power plant fleet is shown in Figure 5.2.

[180] http://ec.europa.eu/energy/publications/doc/2010_energy_transport_figures.pdf.

Table 5.1 Key parameters of selected Member States for testing the revised Tier 2 and Tier 3 methodology (data source: Eurostat database[181])

	Denmark	Czech Republic	Germany
Share of fossil fuel used for electricity generation	65 % – 70 %	60 % – 65 %	60 %
CHP share of electricity generation	50 %	15 %	13 %
RES share of electricity generation	25 % – 35 %	5 % – 8 %	10 % – 17 %
Main fossil fuel types	hard coal, natural gas	lignite, hard coal	lignite, hard coal, natural gas

Figure 5.2 Installed capacity of the thermal power plant fleet in Denmark, Czech Republic and Germany 2005 and 2010



Source: IEA statistics Electricity Information 2011, authors' own calculations

[181] http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables.

For the revised Tier 2 approach adapted to industrial sectors (non-power sectors), the paper and paperboard sector at EU level is selected for testing (see subsection 5.1.1.2).

5.1.1 Testing of revised Tier 2 approach

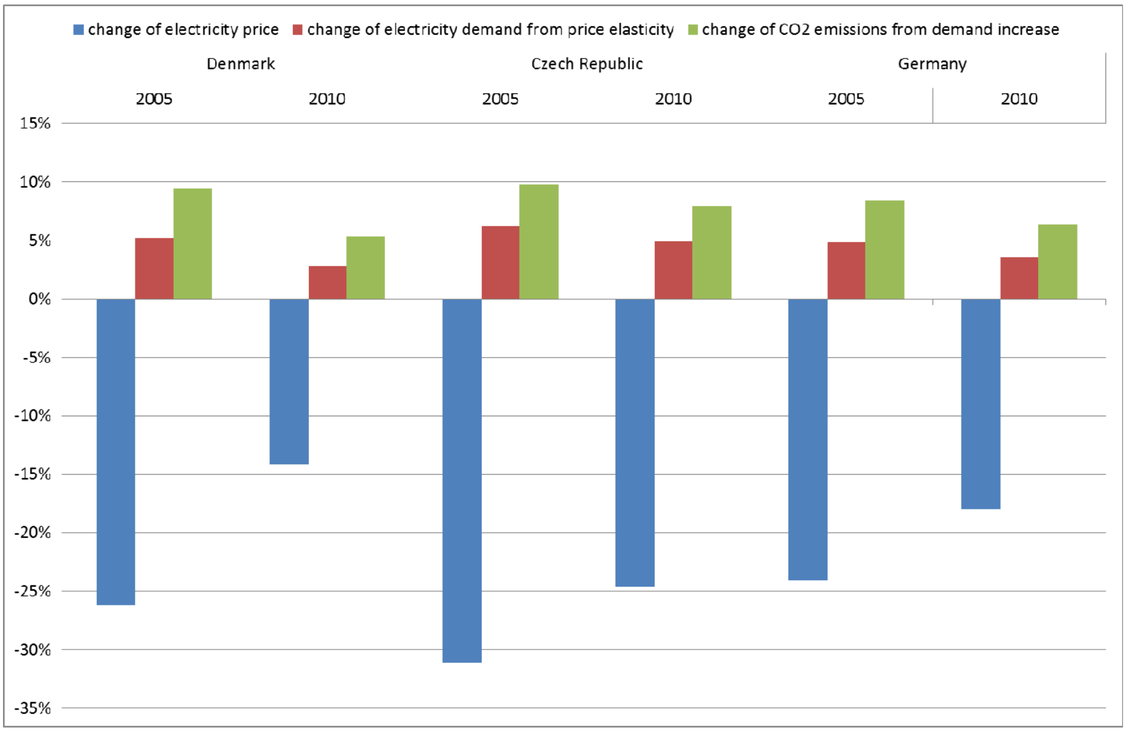
The revised Tier 2 approach for the power sector is tested for Denmark, the Czech Republic and Germany (subsection 5.1.1.1). The revised Tier 2 approach for non-power industrial sectors is tested for the paper and paperboard sector at EU level (subsection 5.1.1.2).

5.1.1.1 Power sector

The change of electricity price and electricity demand in the counterfactual scenario as a result of step 1 of the revised Tier 2 approach (see subsection 4.1.2) as well as the change of CO_2 emissions as a result of step 2 are shown in Figure 5.3. Depending on the annual average electricity price, the electricity price decreases in the range of 15 % and 0 %. With the assumed price elasticity of -0.2 the electricity demand increases in the range of 3 % and 6 % (output of step 1 of the revised Tier 2 approach).

The marginal power plant derived from the average residual load for the thermal power plant fleet is a hard coal fired power plant in Denmark and Germany and a lignite fired power plant in the Czech Republic. Due to these fossil fuel fired marginal power plants the CO_2 emissions increase in the counterfactual scenario in the range of 5 % and 10 % (output of step 2 of the revised Tier 2 approach).

Figure 5.3 Change of electricity price, electricity demand and CO_2 emissions in the counterfactual scenario for the power sector as results of the revised Tier 2 approach



Source: own calculation

The revised Tier 2 methodology shows several advantages compared to the Tier 2 approach of the previous project:

- No model results from Tier 3 are necessary. It is an independent approach and consists mainly of publicly available data.
- Price elasticities show a relevant impact on the electricity demand and the corresponding effects in the power sector and is therefore implemented in the Tier 2 approach.
- The methodological structure and the input data needed are comparable to the revised Tier 3 approach, but the calculation procedure is significantly simplified (average annual values compared to profiles in hourly resolution for example) (see subsection 5.1.2). The revised Tier 2 approach therefore reduces the gap between Tier 2 and Tier 3 with manageable effort.

5.1.1.2 Industrial sectors (non-power sectors)

It does not usually make sense to carry out an assessment for the EU ETS at purely national level because all countries within Europe are faced with the same cost increase.

Our example therefore considers a specific sector, paper and paperboard, at the EU level (it is defined as NACE 2112 (Rev.1.1) or NACE 171 (rev.2)) in 2008. According to the data published by DG CLIMA[182], if the carbon price is €30/t CO_2, direct carbon costs account for 7.1 % of GVA and another 4.8 % from indirect carbon costs (i.e. the higher prices passed on by the electricity sector).

In 2008, the average ETS price was around €23/t CO_2. This means that in a counter-factual case with no ETS, costs for the sector would fall by (7.1 % + 4.8 %) * 23 / 30 = 9.1 %.

Converting the percentage increase as a share of GVA to change in total costs is quite a complicated procedure. We suggest referring to the original data on production, for example from the Eurostat Structural Business Statistics (SBS; Industry, Trade and Services branch). For paper and paperboard (nearest billion) at EU level in 2008 the following applies:

- Total purchases of goods and services: €65bn
- Personnel costs: €10bn
- GVA at factor cost: €16bn
- Production: €77bn.

A decrease in costs of 11.9 % of GVA therefore equals €1.5bn, or 1.9 % of total costs for the sector (including costs of both other goods and services and personnel).

If the sector did not change its prices, the €1.5bn would mean an increase in profits for the sector, resulting from lower production costs.

If the domestic sector reduced its prices by 1.9 % in response it would see an increase in demand. According to a DG Enterprise study[183], the import substitution elasticity is 0.9, meaning that a 1.9% decrease in price would benefit the industry by 1.7 % (at the expense of importing companies). However, there would also be some increase in total demand (elasticity -0.5), which would lead to a small further gain of output.

In this example, the changes in output are quite small, which partly reflects the relatively small share of energy costs in total costs. A sector that was more carbon-intensive could see larger changes in output.

5.1.2 Testing of revised Tier 3 approach

The revised Tier 3 approach links the macro-econometric model E3ME, which covers all ETS and non-ETS sectors of all EU27 Member States, with a dispatch and an in-

[182] http://ec.europa.eu/clima/policies/ets/leakage/docs/20090701_list_sectors_en.pdf.

[183] http://ec.europa.eu/enterprise/policies/sustainable-business/climate-change/energy-intensive-industries/carbon-leakage/files/cl_executive_summary_en.pdf.

vestment model for the electricity sector for individual Member States (see subsection 4.1.3). The ex-post evaluation of policy interaction regarding EU ETS, RES-E Directive and CHP Directive is generally possible with the revised Tier 3 approach by parameter variation and further configurations of counterfactual scenarios. For this project, the focus is on testing the approach for the EU ETS only [184]. Alongside the revised Tier 3 approach, the Tier 3 basic approach using a simplified version of the thermal power plant fleet is also tested in this section for all selected Member States.

5.1.2.1 Data preparation

Relevant data for the power plant dispatch and investment models of the electricity sector are the residual load profile, derived from different load and feed-in profiles, and several techno-economic parameters of the power plant fleet. These model parameters need to be calculated or derived from different data sources, which are publicly or commercially available. However in some cases the data needed are confidential or do not exist at all. In such cases, this section provides different possibilities of how to assume model parameters for the missing data.

One main data source is the commercial statistic of the International Energy Agency (IEA), whose data can be obtained in different ways, for example in publications like “Electricity Information 2011” or in the online database (www.oecd-ilibrary.org).

The residual load profile can be described as the amount of electricity in every hour, which must be generated by the thermal power plant fleet of a Member State. The residual load is defined as the demand profile minus feed-in profiles of renewable energy sources with preferential feed-in and must-run power plants. The residual load profile includes grid losses and electricity consumption in the energy transformation sector[185] as well as import and export flows, but excludes the consumption used by pumped storage hydropower plants. The dispatch of pumped storage hydropower plants is a model result. The yearly net electricity production without pumped storage hydropower plants can be found in the commercial IEA online database for all European member states[186].

The main database for the derivation of the residual load profile in hourly resolution is the public announcements of the transmission grid load. It is available for all European Member States at the European Network of Transmission System Operators for Electricity (www.entsoe.eu) from 2006 to the present only. Due to the lack of data for the

[184] The RES-E Directive and CHP Directive were excluded from testing for the time being at the request of DG Clima due to evaluation projects for the RES-E Directive and CHP Directive which are currently being carried out on behalf of the Commission.

[185] Like the corresponding electricity demand of coal mining and refineries.

[186] IEA (2011) „Electricity Information 2011“ p. IV.323 (e.g. for Germany) or IEA Electricity Information Statistics (http://www.oecd-ilibrary.org/energy/data/iea-electricity-information-statistics_elect-data-en).

testing year of 2005, the grid load profile of the year 2006 is taken into account by approximation (scaled value). The annual sum of the ENTSOE-E grid load profile can amount to less than the total net electricity generation, e.g. due to industrial autoproducers of electricity. For the missing profile a uniform distribution is assumed.

Concerning feed-in profiles of electricity generation from must-run power plants and renewable energies, a uniform distribution is – except for wind and solar power – also assumed. Electricity generation in wind and solar power plants depends on weather conditions and show therefore a strong intermittency. If available, real feed-in data should be used as the feed-in profile. These feed-in profiles can be derived in Germany from, for example, national Transmission System Operators (TSO)[187] and in Denmark from the electricity exchange energinet.dk[188].

If only annual data for wind and solar power are available, the following default profiles can be used by approximation:

- Real feed-in data of another year;
- Real feed-in data of a neighbouring Member State with similar weather conditions;
- Generic feed-in profile for photovoltaic with a typical day/night and winter/summer profile.

The generic feed-in profile for solar power from the EnBW Transportnetze AG (Transmission system operator in the south-west of Germany) is used for Denmark, the Czech Republic and Germany. Feed-in profiles for wind power are available for Denmark and Germany. For the Czech Republic, in absence of country-specific profiles, the German feed-in profiles for wind power are selected.

The annual power generation of must-run power plants can be taken from the commercial IEA online database, which provides a detailed overview of each energy source and each European Member State. The same is true for annual import and export flows. By approximation a uniform distribution is assumed to derive hourly values in this case studies for Denmark, the Czech Republic and Germany. However, if hourly values exist, these data can be used instead.

The power plant fleet is described with a set of techno-economic parameters, which represents the level of detail of the approach (Tier 3 and Tier 3 basic). The installed capacity, the commissioning year and the technology type, like gas turbine or steam turbine, is taken for the revised Tier 3 approach from the commercial UDI Platts World Electric Power Plant Database[189] for all selected Member States. The availability of power plants and their specific electrical efficiency is not part of this database. These

[187] Tennet, 50 Hertz, Amprion and EnBW Transportnetze AG.

[188] http://www.energinet.dk/EN/El/Engrosmarked/Udtraek-af-markedsdata/Sider/default.aspx.

[189] http://www.platts.com/Products/worldelectricpowerplantsdatabase.

data are confidential in most cases and therefore have to be derived by a literature survey or cooperation with national authorities. If no data can be found, the availability and the electrical efficiency of similar power plants of other countries could be used. The last option is to estimate the missing data for availability and efficiency. In these case studies, individual electrical efficiencies are partly available for Germany. For the other German power plants, the electrical efficiency ratios are calculated depending on fuel type, plant type and year of starting operation. These formulas have been also used for the Danish power plants. For the Czech Republic these formulas have been slightly adapted to reflect the assumed level of electrical efficiencies.

For the Tier 3 basic approach, the fuel type specific total installed capacity is taken from the IEA publications “Electricity Information 2011” and “Coal Information 2011” to derive a simplified Merit Order for all selected Member States. The fuel type specific electrical efficiency ratio is derived as an average value from the Tier 3 power plant fleet, but could also be defined be assumptions. Instead of the revised Tier 3 approach, no commercial power plant database is needed as data input for the Tier 3 basic approach.

Further relevant parameters for the revised Tier 3 approach as well as the Tier 3 basic approach are fuel prices for the different types of fuel used for electricity generation. These data are only partly available and mainly confidential. For Germany fuel prices are taken from a national data source[190] and further adapted to the E3ME model. For Denmark and the Czech Republic, the data are taken from the E3ME model database.

5.1.2.2 Change of electricity demand due to price elasticity (pre-step of the counterfactual scenario)

The pre-step of the calculation procedure for the counterfactual scenario (step 0) derives the change of electricity demand due to price elasticity from an iteration process between the dispatch power sector model PowerFlex and the macro-econometric model E3ME. The change of the average electricity price in the counterfactual scenario calculated with the PowerFlex model serves as input for the E3ME model. The E3ME model derives the change of electricity demand due to the revised electricity price including cross-sector interactions and specific elasticity parameters. The revised electricity demand serves as input for the PowerFlex model and the iteration process starts again. The iteration process is completed, when the results are stable. With an abortion criterion of 1 % (allowed difference of the results), 5 iteration loops are needed for Germany and 3 iteration loops for Denmark and the Czech Republic.

Figure 5.4 shows the change of the annual average electricity spot market price in the counterfactual scenario calculated with the power plant dispatch model PowerFlex us-

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[190] Matthes 2010: Energiepreise für aktuelle Modellierungsarbeiten. Regressionsanalytisch basierte Projektionen. Teil 1: Preise für Importenergien und Kraftwerksbrennstoffe.

ing the revised Tier 3 and Tier 3 basic approach[191]. The calculated electricity spot market price decreases in the range of 25 % and 35 % for Denmark and 25 % and 30 % for Germany. This price reduction reflects a mixture of hard coal and natural gas fired power plants as typical marginal power plant type in the merit order of Denmark and Germany. For the Czech Republic the calculated price reduction is in between 55 % and 60 % due to lignite fired power plants being the typical marginal power plant type. The annual average price reduction effect corresponds with the CO_2 emission factor of the marginal power plants.

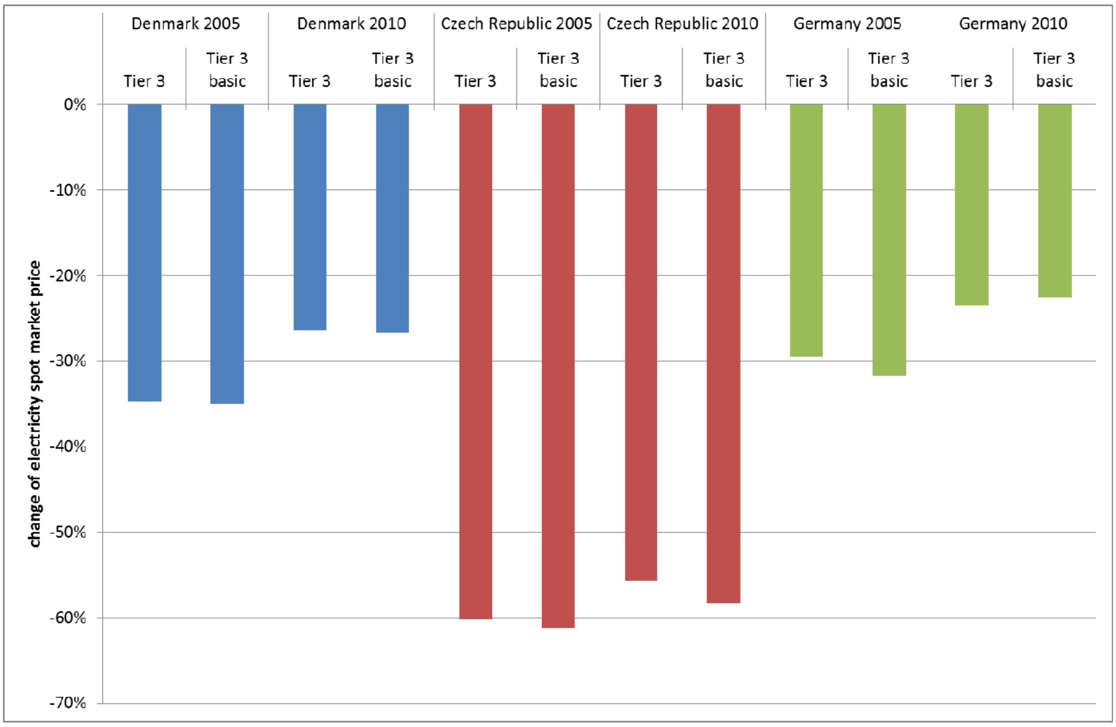
The calculated change of the annual average electricity spot market price serves as input for the E3ME model to derive the increase of electricity demand due to price elasticity (Figure 5.5). The more the electricity spot market price decreases, the more the electricity demand increases. For Denmark and Germany the electricity demand increase is approx. 2 % to 3 %, for the Czech Republic the electricity demand increase is approx. 8 % in the year 2005 and 4.5 % in the year 2010. The difference in the demand increase in the Czech Republic is based on two effects:

- Differences in real prices and developments in electricity prices: Electricity prices excluding ETS costs were higher in 2010 compared with 2005, so the relative impact of the ETS is stronger in 2005 than in 2010. This effect on its own would justify a value of 5.5% in 2010.
- Differences between short and long-term effects in the E3ME model: In 2005 a shock to electricity prices has been applied and the 2005 results represent the short-term impact of that shock. In 2010 there are only minor differences in the counterfactual electricity prices from the previous years, but the long-term effects of the price shock in 2005 is still visible.

The differences in the change of the electricity spot market price calculated with the Tier 3 approach and the Tier 3 basic approach are quite small, so that from this point of view (price elasticity) the Tier 3 basic approach is comparable to the Tier 3 approach and leads to sufficient results.

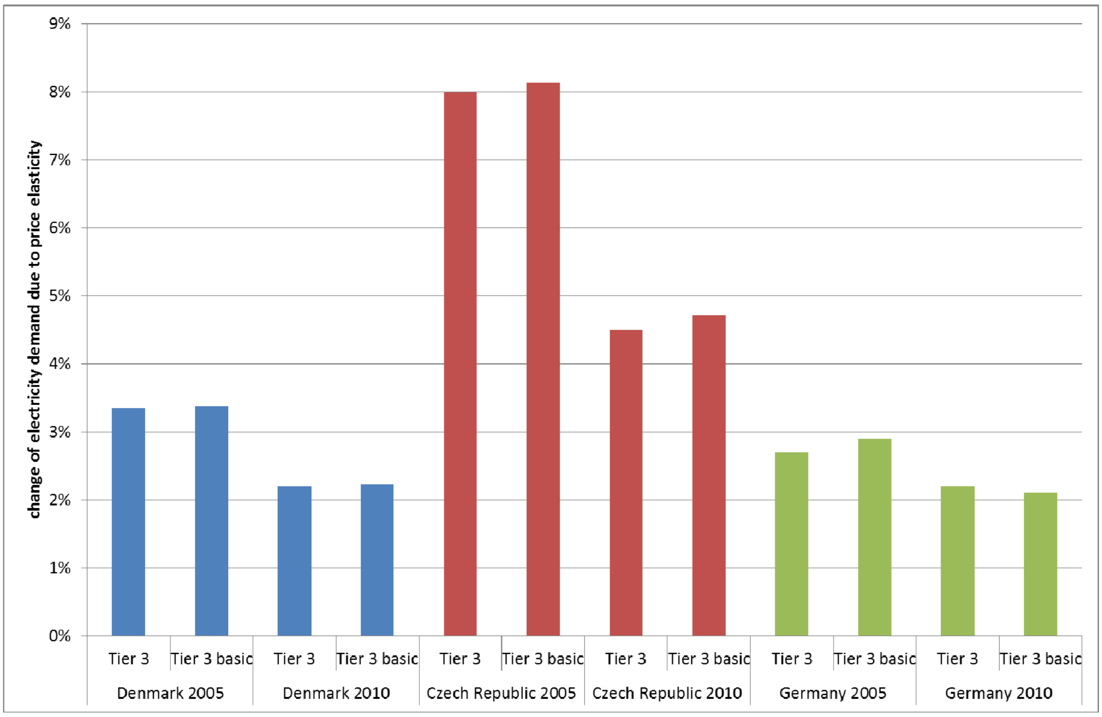
[191] The Tier 3 basic approach uses a simplified merit order of the thermal power plant fleet, which consist only of a typical fuel type specific power plant instead of individual power plants in the detailed Tier 3 approach (see section 4.1.3).

Figure 5.4 Change of electricity spot market price in the counterfactual scenario as result of the revised Tier 3 and Tier 3 basic approach (authors' own calculation)



Source: PowerFlex model results as part of the iteration with the E3ME model

Figure 5.5 Change of electricity demand in the counterfactual scenario as result of the revised Tier 3 and Tier 3 basic (authors' own calculation)



Source: E3ME model results as part of the iteration with the PowerFlex model

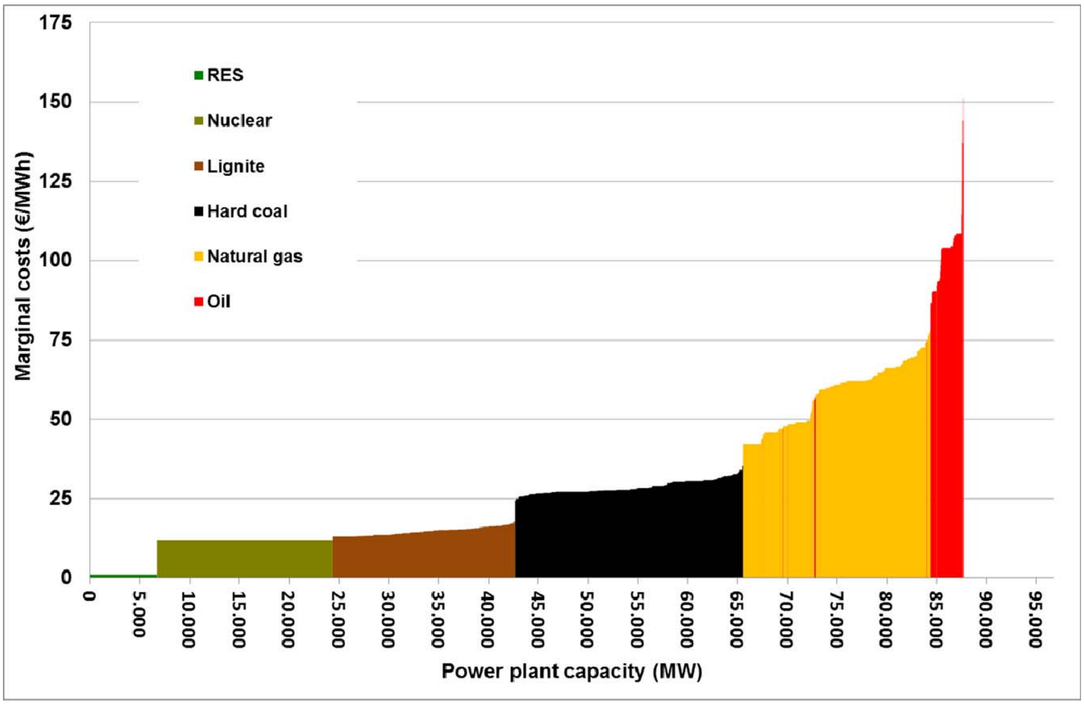
5.1.2.3 Change of power plant dispatch in the counterfactual scenario

The dispatch of the power plants is calculated based on the historic power plant fleet of Denmark, the Czech Republic and Germany in 2005 and 2010, both for the policy and the counterfactual scenario. The installed and available plant capacities are sufficient to generate the electricity demand in the policy scenario as well as the increased electricity demand in the counterfactual scenario (see also subsection 5.1.2.4).

Marginal costs of thermal power plants consist of fuel costs, CO_2 costs and other variable costs. The merit order of the power plant fleet is therefore affected by the EU ETS. In the counterfactual scenario excluding CO_2 costs, the merit order consists of different fuel types in the sequence of nuclear, lignite, hard coal, natural gas and oil fired power plants (Figure 5.6). The merit order of the revised Tier 3 approach is therefore comparable with the merit order of the simplified Tier 3 basic approach (Figure 5.7).

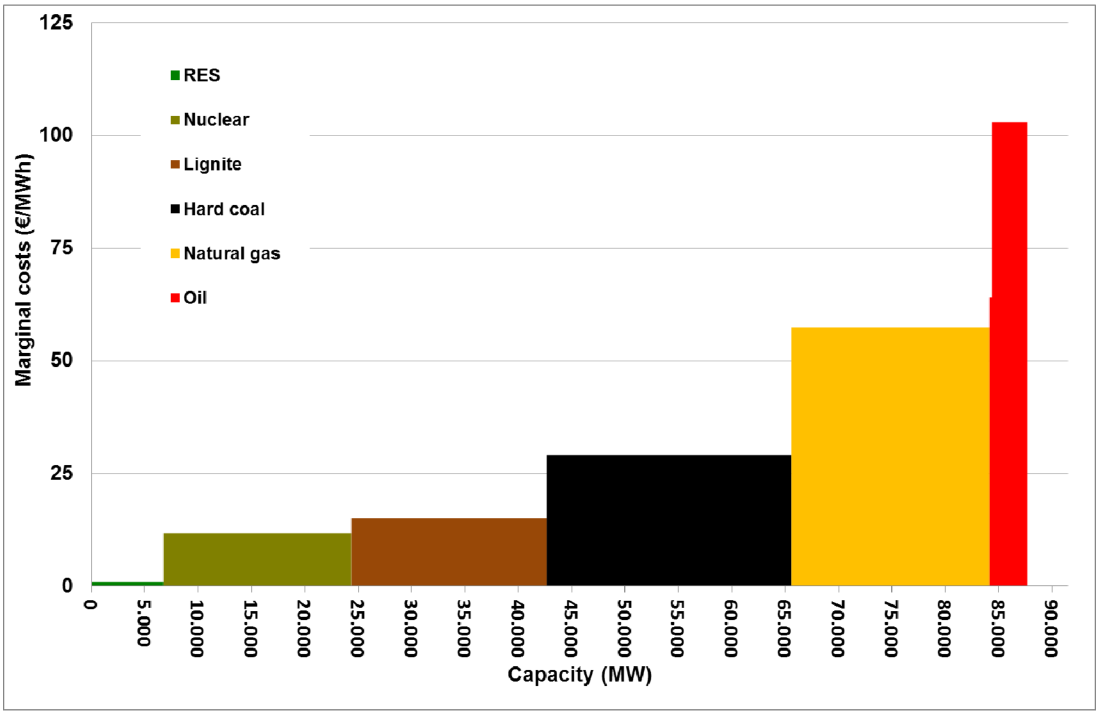
In the policy scenario the merit order changes using the revised Tier 3 approach. High-efficiency hard coal power plants (new plants) shift with low efficient lignite power plants (old plants) as well as high-efficiency natural gas power plants (new plants) shift with low efficient hard coal power plants (old plants) in the merit order (Figure 5.8). In terms of new power plants of both fuel types or power plants with the same year of starting operation, the merit order of these power plants is (mostly) unchanged (see also subsection 5.1.2.4). This fuel switching effect within a fuel type section of the merit order cannot be observed with the Tier 3 basic approach (Figure 5.9).

Figure 5.6 Merit order of the German power plant fleet in the counterfactual scenario 2005 using the Tier 3 approach (authors' own calculation)



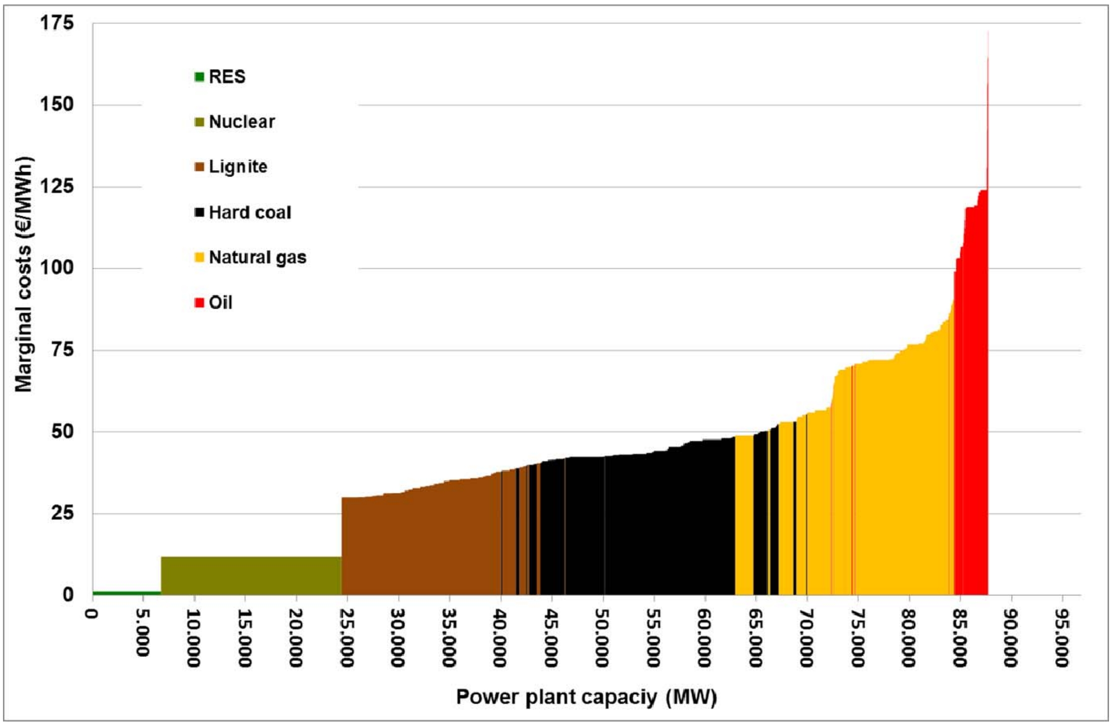
Source: PowerFlex model results

Figure 5.7 Merit order of the German power plant fleet in the counterfactual scenario 2005 using the Tier 3 basic approach (authors' own calculation)



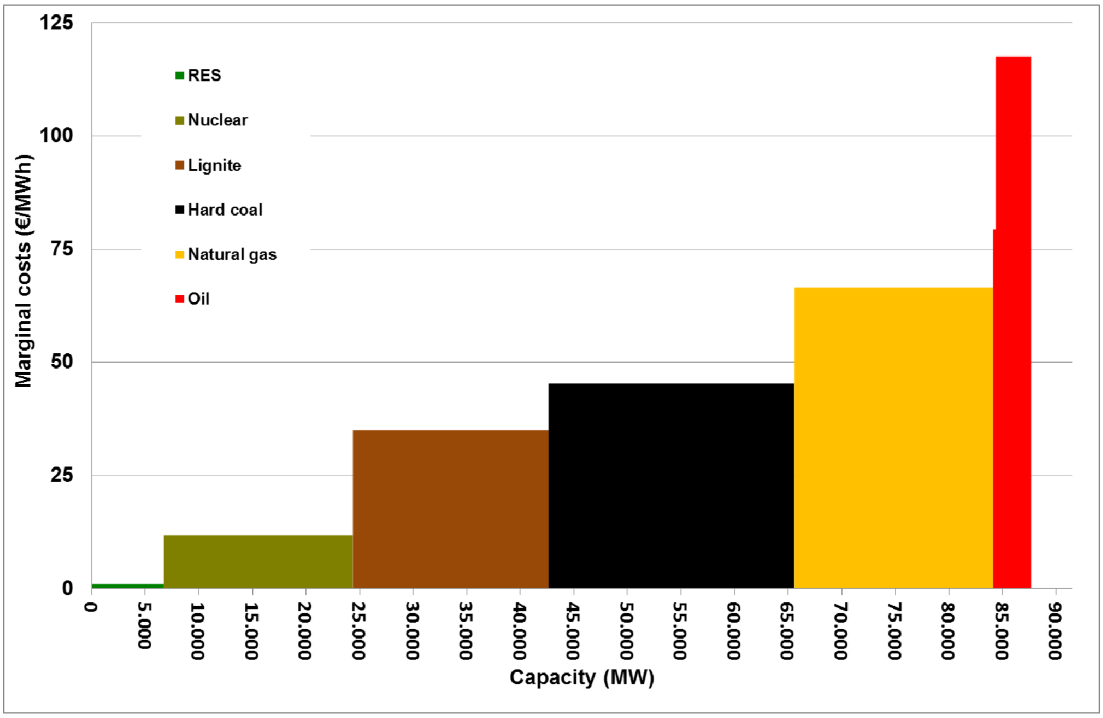
Source: PowerFlex model results

Figure 5.8 Merit order of the German power plant fleet in the policy scenario 2005 using the Tier 3 approach (authors' own calculation)



Source: PowerFlex model results

Figure 5.9 Merit order of the German power plant fleet in the policy scenario 2005 using the Tier 3 basic approach (authors' own calculation)

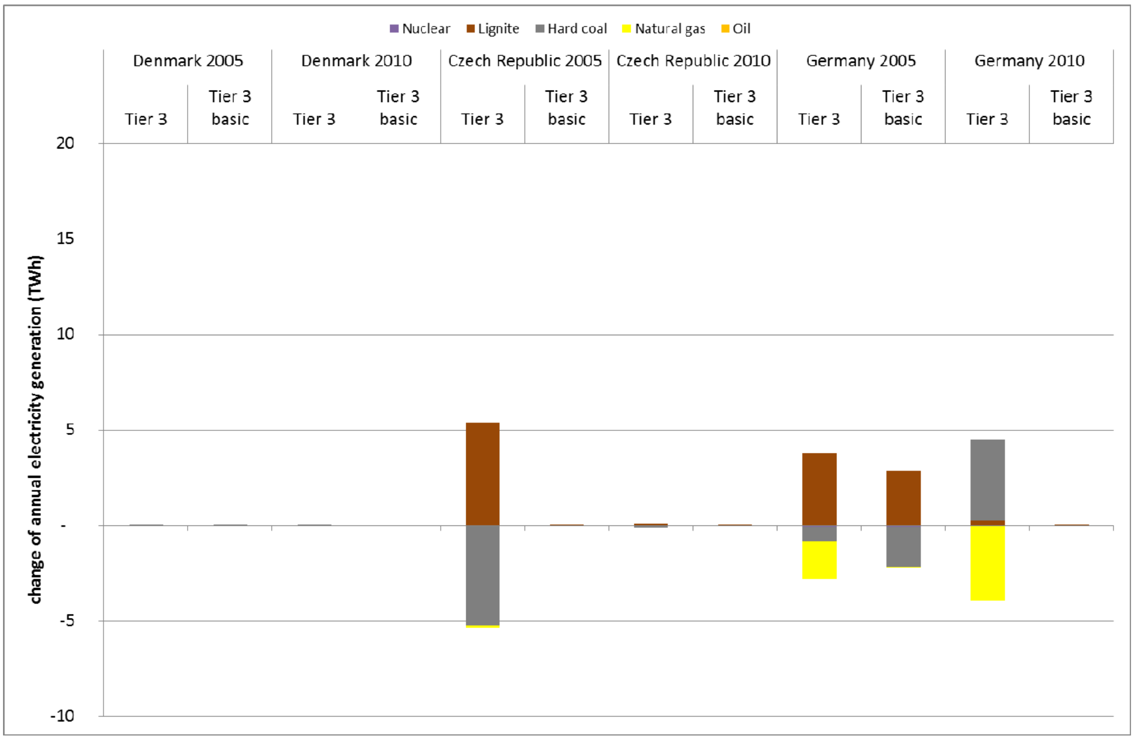


Source: PowerFlex model results

Sensitive input parameters for the fuel switching effect within the merit order are the fuel price spread between hard coal and lignite and between natural gas and hard coal as well as the corresponding spread of the electrical efficiency ratios.

The fuel switching effect can be shown separately in the counterfactual scenario excluding price elasticity (Figure 5.10). Electricity generation shifts for example from hard coal to lignite (Czech Republic 2005, Tier 3; Germany 2005, Tier 3 basic) and from natural gas to hard coal (Germany 2010, Tier 3). In Denmark nearly no fuel switching effect occurs due to the high share of CHP plants. The CHP constraint in the power plant dispatch model, which ensures covering the heat demand from hard coal and natural gas fired CHP power plants, restricts the fuel switching effect as well. In the scenario 2010 for the Czech Republic no fuel switching effect occurs due to increasing hard coal fuel prices compared with 2005. The revised Tier 3 approach shows this fuel switching effect in more detail and with a higher contribution than the Tier 3 basic approach.

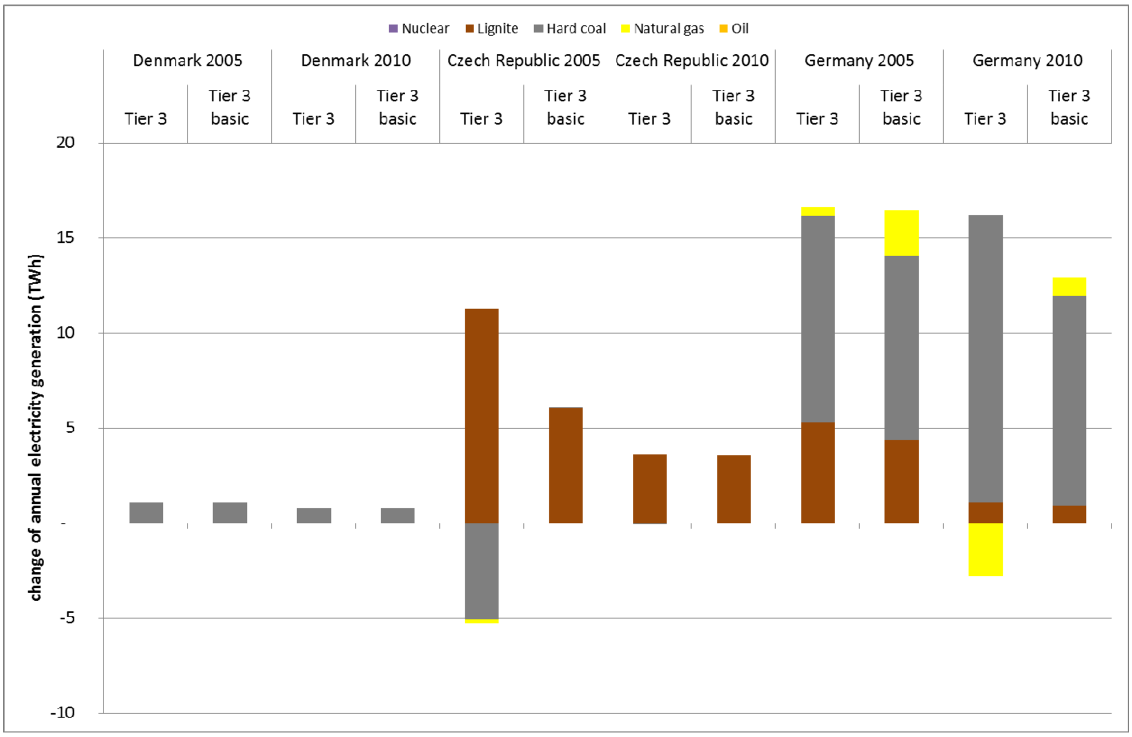
Figure 5.10 Change of annual electricity generation in the counterfactual scenario excluding price elasticity as a result of the revised Tier 3 and Tier 3 basic approach (authors' own calculation)



Source: PowerFlex model results

Including price elasticity in the counterfactual scenario, the fuel switching effect partly disappears in the annual electricity generation figures due to the higher electricity demand which has to be covered (Figure 5.11). Only in two scenarios using the Tier 3 approach does a generation shift from hard coal to lignite (Czech Republic 2005) and from natural gas to hard coal (Germany 2010) still appear. The increased electricity demand is covered by hard coal power plants in Denmark, by lignite power plants in the Czech Republic and by a mixture of lignite, hard coal and natural gas fired power plants in Germany. Compared with the fuel type specific annual change of electricity generation excluding price elasticity (Figure 5.10), the fuel type specific annual change of electricity generation including price elasticity is up to three times higher. It can therefore be concluded, that in terms of the change of annual electricity generation, the effect of price elasticity is more important than fuel switching.

Figure 5.11 Change of annual electricity generation in the counterfactual scenario including price elasticity as result of the revised Tier 3 and Tier 3 basic approach (authors' own calculation)

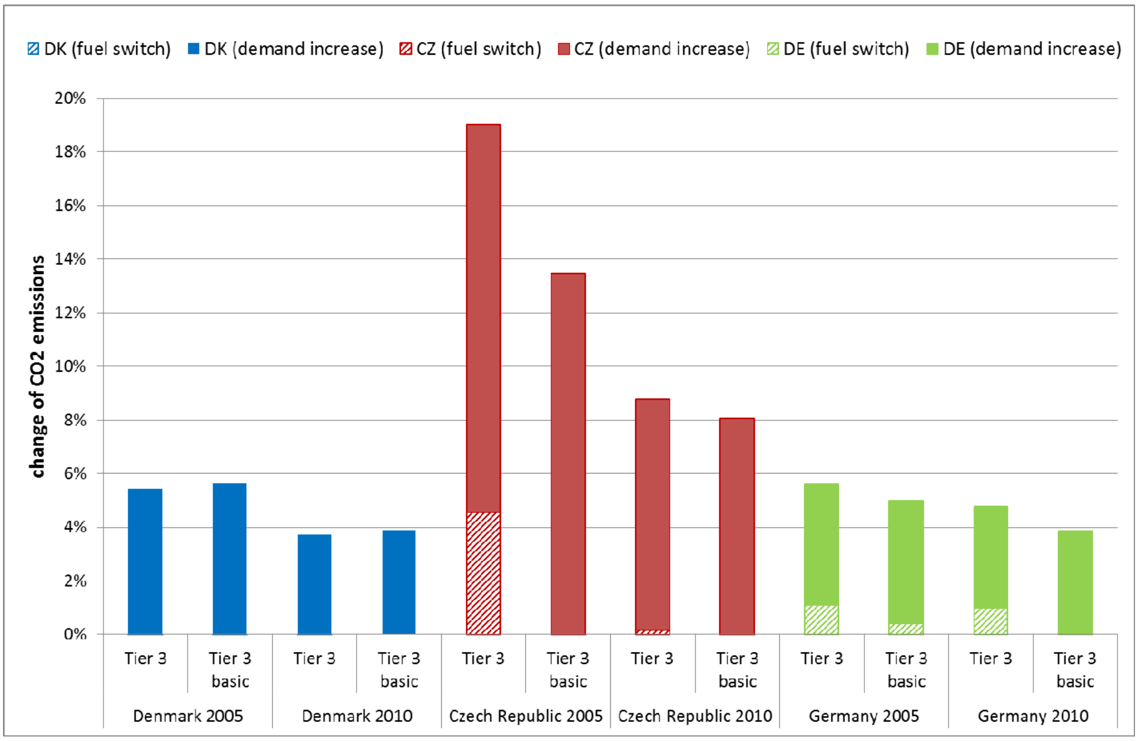


Source: PowerFlex model results

Concerning the change of CO_2 emissions in the counterfactual scenario, the effect of price elasticity is becoming even more important than the effect of fuel switching (Figure 5.12). This is due to the fact, that the demand increase is covered by fossil fuel power plants in all three Member States selected for testing (Figure 5.11). Furthermore, the CO_2 effect of switching electricity generation from hard coal to lignite and from natural gas to hard coal is smaller than from additional electricity generation from fossil fuel power plants. The CO_2 effect of fuel switching would be the highest if electricity generation shifts from lignite (highest CO_2 emission factor) to nuclear (no CO_2 emissions) as could occur for the Czech Republic, for example, depending of the spread of marginal costs between these two types of power plants.

The differences between the Tier 3 and the Tier 3 basic approach a quite small for Denmark and Germany, but significant for the Czech Republic in the year 2005 due to the fact that fuel switching occurs in the Tier 3 approach (new hard coal power plants shift ahead of old lignite power plants in the merit order) but does not occur in the Tier 3 basic approach.

Figure 5.12 Change of CO_2 emissions in the counterfactual scenario as result of the revised Tier 3 and Tier 3 basic (authors' own calculation)



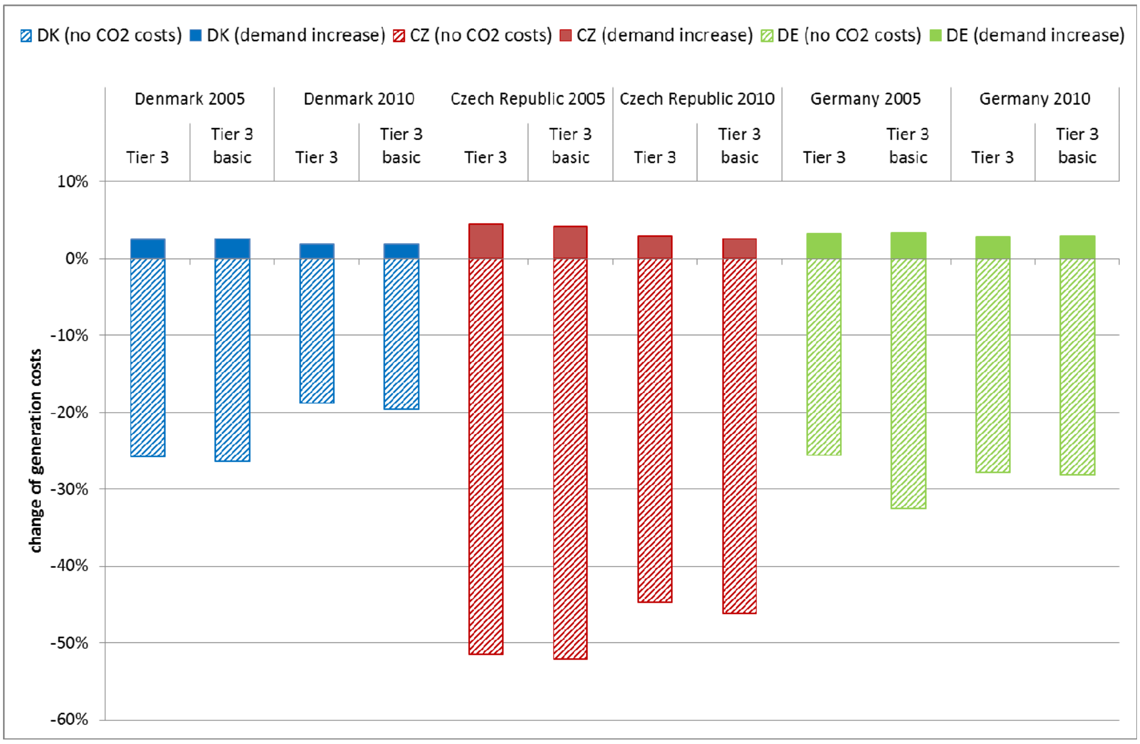
Source: PowerFlex model results

The overall effect concerning the annual electricity generation costs in the counterfactual scenario consist of two opposed sub-effects:

- Missing CO_2 costs in the counterfactual scenario lead to decreasing electricity generation costs compared with the policy scenario.
- Electricity demand increase in the counterfactual scenario lead to increasing electricity generation costs compared with the policy scenario.

The effect from missing CO_2 costs is about ten times higher than the effect from demand increase, so that the overall annual electricity generation costs decrease in total by 15 % to 25 % in Denmark, 40 % to 50 % in the Czech Republic and 25 % to 30 % in Germany. The calculated overall effect in terms of the change of annual electricity generation costs is quite comparable between the Tier 3 and the Tier 3 basic approach.

Figure 5.13 Change of electricity generation costs in the counterfactual scenario as result of the revised Tier 3 and Tier 3 basic approach (authors' own calculation)

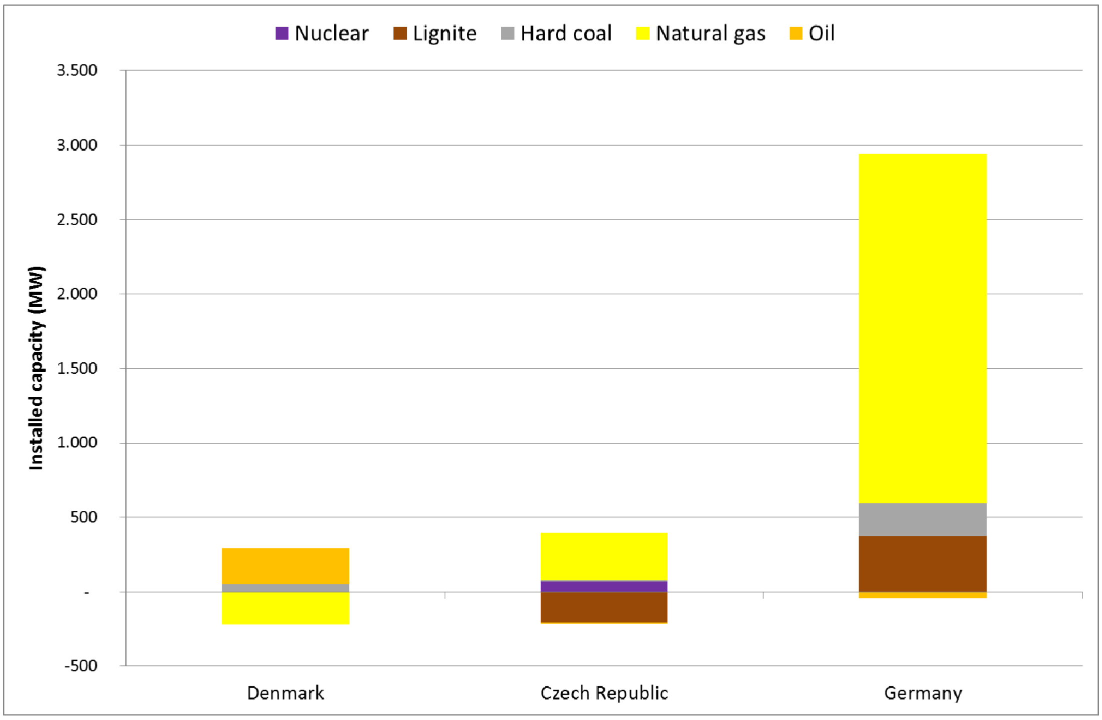


Source: PowerFlex model results

5.1.2.4 *Development of the power plant fleet and investment decisions*

From 2005 to 2010 the installed capacity of the thermal power plant fleet in Denmark, the Czech Republic and Germany remained quite stable (Figure 5.2). The change of the installed capacity for nuclear, hard coal, lignite and oil fired power plants is less than 500 MW within the national power plant fleet of the selected Member States. Only for natural gas fired power plants in Germany, the installed capacity increased by about 2,000 MW, mainly from the installation of combined-cycle plants (Figure 5.14).

Figure 5.14 Development of the power plant fleet from 2005 to 2010



Source: IEA statistics Electricity Information 2011, own calculations

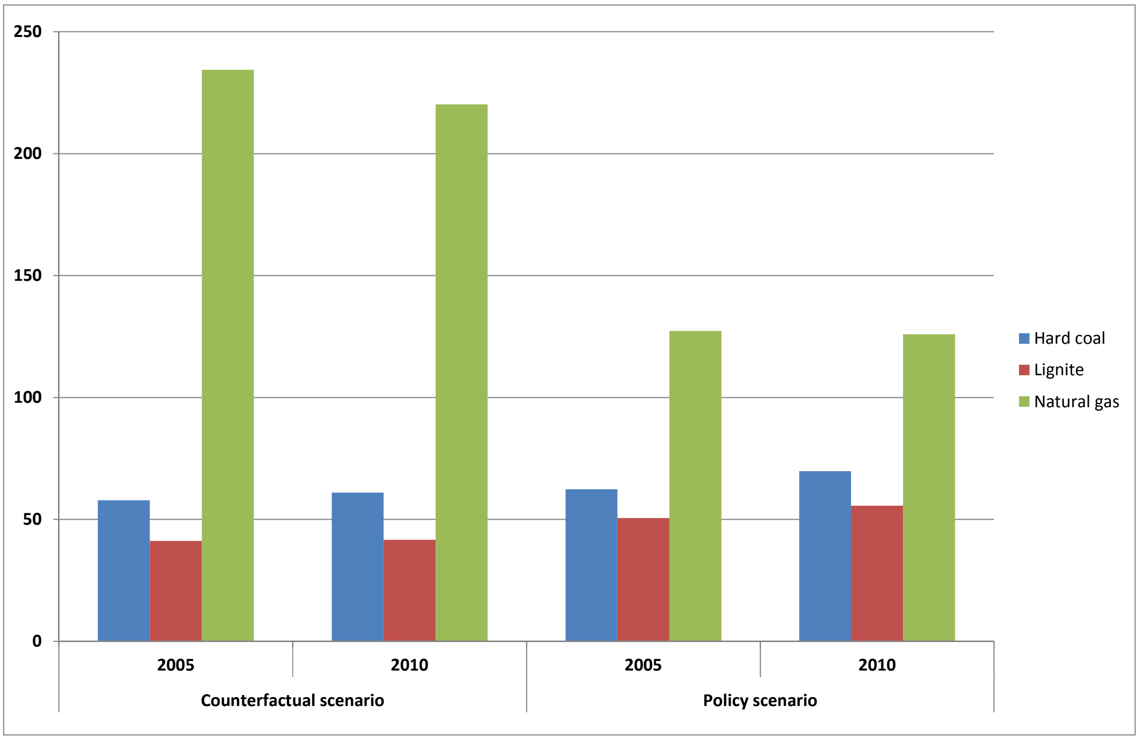
It can therefore be concluded that investments in new power plants were very limited between 2005 and 2010. Due to this limited investment, it is not practical to reproduce the investment using the investment model ELIAS. Notwithstanding, it should be evaluated whether the ETS (policy scenario) had influence on the overall (although limited) investment in comparison to the counterfactual scenario and what the nature of this influence was related to the overall magnitude of the investment and the investment in specific power plant types. Therefore, a simplified iteration between PowerFlex and ELIAS is carried out.

According to the results of the power plant dispatch model (PowerFlex), the installed plant capacities of the policy scenario are also sufficient to generate the increased electricity demand in the counterfactual scenario (see also subsection 5.1.2.3). Therefore, it can be concluded that no investment in new power plants is triggered in both scenarios. This is consistent with the very limited investment observed in the years 2005 and 2010 (above). In this regard, overall investment demand was generally small between 2005 and 2010 and the ETS did not have a significant influence on the *magnitude* of investment demand.

However, the ETS may have had an influence on the *type of power plants* built. The comparison of levelised costs of electricity (LCOE) provides an indicator of changes in the profitability of investment for different power plant types. The LCOE is calculated in ELIAS based on all costs related to power plant construction and operation over the depreciation period, i.e. investment costs, fixed and variable operating costs, fuel costs as well as policy costs (CO_2 costs, other applicable subsidies or taxes, etc.).

In this regard, there are two major effects on power plant profitability due to CO_2 costs. As a direct effect, CO_2 costs are considered in the investment decision. The higher the specific CO_2 emissions, the higher the corresponding CO_2 costs in the investment decision. CO_2 costs are highest for lignite-fired power plants followed by hard coal- and natural gas-fired power plants. As indirect effect, the CO_2 price changes the dispatch of power plants and therefore operating hours. Changed operating hours in turn affect the profitability of investment in new power plants since they are the basis for calculation of the LCOE (Figure 5.15).

Figure 5.15 Levelised costs of electricity for different power plants in the counterfactual and policy scenarios, 2005, 2010



Source: ELIAS model results

ELIAS model results show that the ETS (policy scenario) significantly improves the profitability of natural gas-fired power plants (lower LCOE than in the counterfactual scenario) due to increasing operating hours (at the expense of hard coal- and lignite-fired power plants). However, the LCOE of hard coal- and lignite-fired power plants are only affected to a limited extent by the CO_2 price since there is only little change of the merit order (fuel switch) at the considered level of the CO_2 price. Hence, although the profitability of power plants is affected differently depending on the technology, the ranking of profitability (lignite > hard coal > natural gas) is not affected. This is consistent with the (mostly) unchanged merit order of power plants as a result of the CO_2 price (see also section 5.1.2.3). The ETS therefore did not have a significant impact on the *type of power plants* built.

In conclusion, the ETS generally affects the profitability and therefore investment in new power plants. However, the impact on demand for new power plant capacity and on the ranking of profitability is limited in the time frame considered (2005 - 2010).

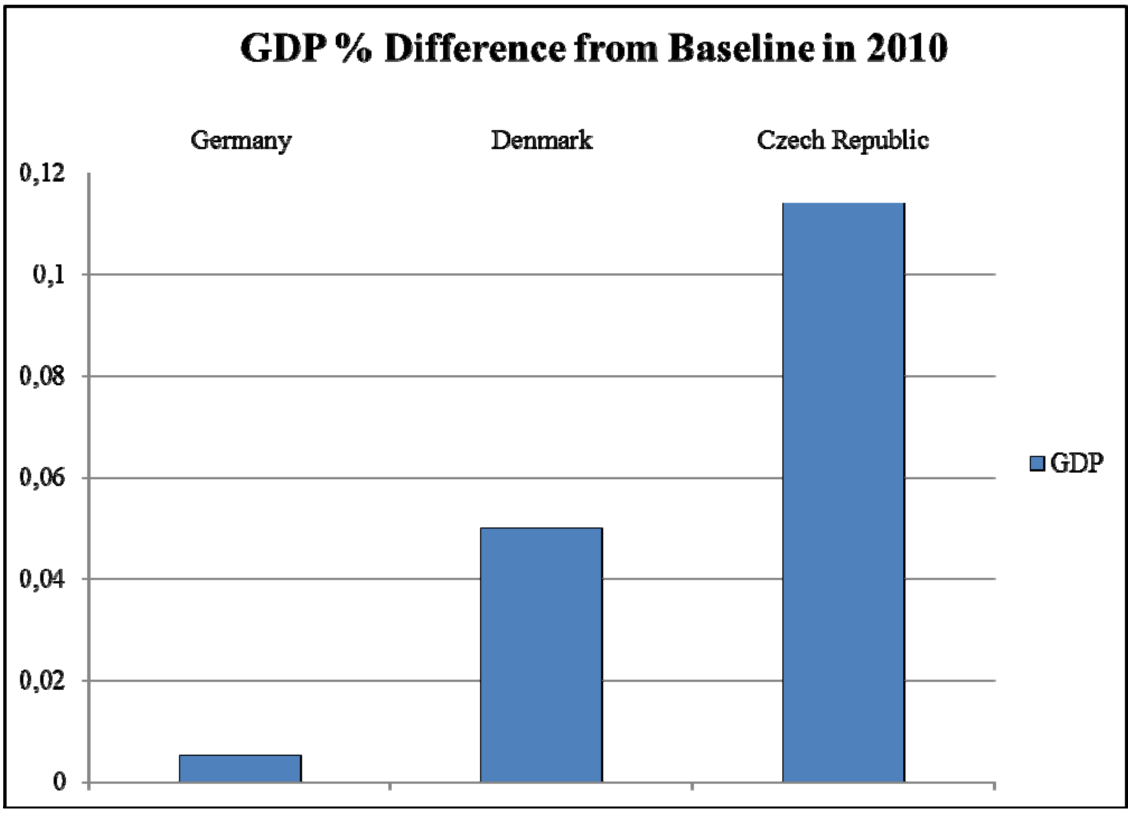
5.1.2.5 Overall socio-economic effects

In a counterfactual scenario with no ETS, energy costs are reduced for European industry. This leads to increases in energy consumption and emissions, but lower production costs will also have economic benefits.

The E3ME model covers sectors at the NACE 2-digit level, which is the maximum possible for a macroeconomic model (due to available input-output data) but is still relatively limited. For example, non-metallic mineral products includes the cement and lime sectors, but also glass and other ceramics, which are much less carbon-intensive in production. The benefit of the modelling approach is that it can provide macroeconomic impacts for the whole economy, including GDP and total employment/unemployment.

The following two charts therefore show the net impacts on GDP and total economy-wide emissions in the counterfactual case with no ETS for the three Member States selected for testing. The third chart provides an example of sectoral results in Germany, showing impact on emissions and sectoral output.

Figure 5.16 GDP % difference from baseline in 2010



Source: E3ME model results

The model results show that GDP increases slightly in the counterfactual case with no ETS (Figure 5.16). The changes are larger in countries that are more carbon intensive, partly because the cost reduction is larger for domestic markets and partly because their competitiveness against other European countries improves.

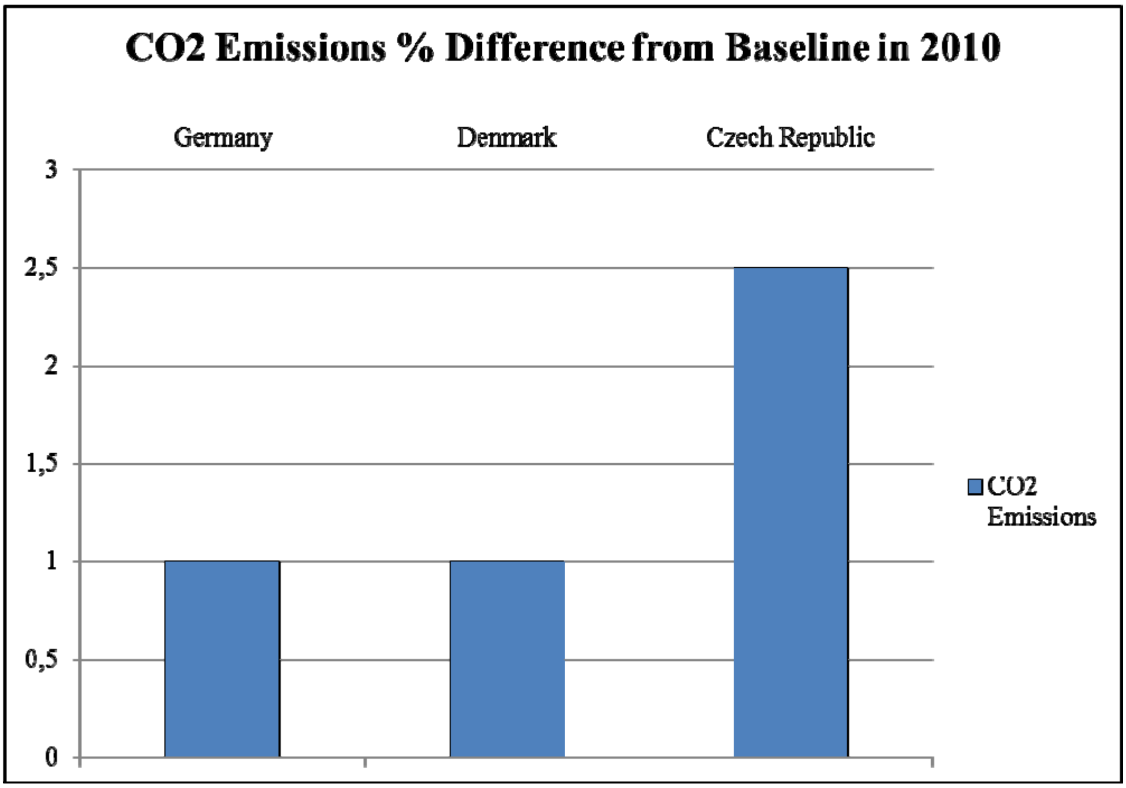
However, the scale of the impacts should be noted. At most, the total impact is 0.1 % of GDP and it is much lower in other countries, for example close to zero in Germany. This is due to the impacts in the sectors directly involved being quite small (see example below), and these sectors making up a relatively small share of GDP.

Employment effects are even smaller. The ETS does not really have a direct impact on employment, but there are potential indirect impacts through loss of production. However, given the scale of the GDP impacts, aggregate employment does not change by much.

Figure 5.17 shows CO_2 energy emissions in the counterfactual case with no ETS. Emissions from power generation are excluded from the chart as they are assessed separately in PowerFlex. However, domestic and transport emissions, which are not covered by the ETS, are included in the denominator.

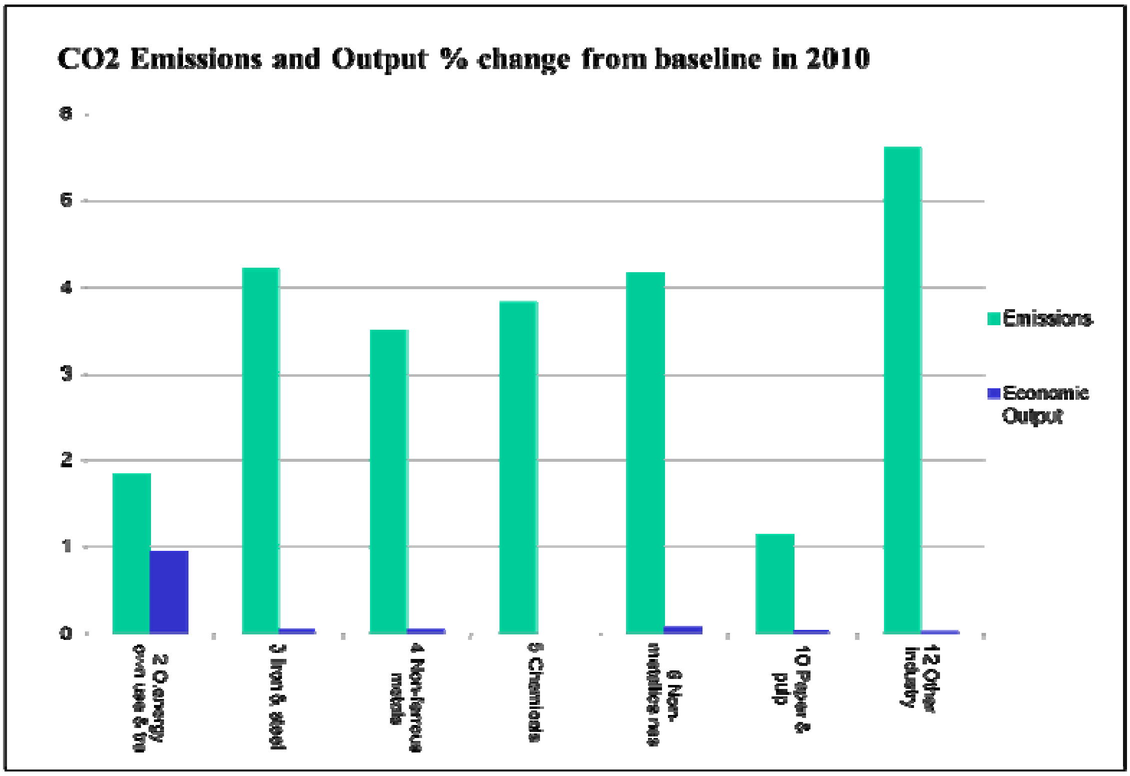
The model results show a modest reduction in emissions between 1 % and 3 %, with a higher reduction in the Czech Republic than in other countries (suggesting that Czech industry was able to make more low-cost emission reductions).

Figure 5.17 CO_2 emissions % difference from baseline in 2010



Source: E3ME model results

Figure 5.18 CO_2 emissions and Output % change from baseline 2010 in Germany



Source: E3ME model results

Figure 5.18 provides an example of sectoral output. In Germany, most sectors would have had emissions around 4 % higher in 2010 if there had been no ETS, as represented by the green bars in the chart. The biggest impacts are from sectors that use coal in their production.

The results show that, although these sectors would have benefitted from lower production costs, at the NACE 2-digit level the effects would have been modest. Output could have been up to 1 % higher in the energy sectors (excluding power generation), which includes gas distribution, but the effects are much more marginal in the industry sectors. There are two main reasons for this:

- At NACE 2-digit level, energy does not make up a large share of production costs, even in the energy-intensive sectors.
- Competitiveness effects are limited, as all European countries face the same increases in production costs.

It should be stressed that this does not mean that all impacts are marginal; within these sectors there are specific sub-sectors and firms which have very high energy intensities and are exposed to international trade. However, this lies beyond the scope of the macroeconomic model and must be assessed separately, for example using an advanced version of the Tier 2 approach described previously.

5.1.3 Discussion and recommendations

The new Tier 2 approach for the power sector is easy to implement in common spreadsheet software and consists of publicly available data. It includes price elasticity effects as well as merit order effects concerning the marginal power plant derived from a simplified fuel type specific merit order of the power plant fleet. Fuel switching effects are not covered by the new Tier 2 approach. The main advantage of the new Tier 2 approach is its independency from Tier 3 model results as suggested in the previous project (e.g. derived correction factors). This Tier 2 approach can therefore be implemented by a step by step process after having established the Tier 1 approach successfully. Concerning non-power ETS sectors, the Tier 2 approach for the power sector can be partly adapted, but indirect and cross-sectoral effects are not covered by this approach and there is quite a large range of uncertainty around results.

Indirect and cross-sectoral effects as well as overall socio-economic effects are only part of the revised Tier 3 approach and are calculated with the macro-econometric E3ME model. A further surplus of detail in the Tier 3 approach is covered by the dynamic dispatch of power plants as well as the development of the power plant fleet using the power sector models PowerFlex and ELIAS. One advantage of the integrated and revised Tier 3 methodology is the detailed evaluation of the electricity sector, including fuel switching effects, demand responses to price and the possibility of evaluating policy interaction effects with the RES-E and CHP Directive, and further related policies coming into force in the future (e.g. e-mobility, storage, energy efficiency, etc.). Further advantages are the macro-econometric evaluation of other ETS sectors, including indirect and cross-sectoral effects. However, the trade-off in the Tier 3 approach is the high costs associated with developing and maintaining the models involved; they are therefore commercial and typically available on a consultancy basis. Developing new tools is an expensive exercise.

The data costs can be partly reduced by using the Tier 3 basic approach (smaller data effort due to simplified power plant fleet).

The case studies for 2005 and 2010 for Denmark, the Czech Republic and Germany show that the price elasticity of demand is a relevant issue and has a significant impact on the results, especially for Member States with fossil fuel-fired power plants as the typical marginal power plant type to cover the surplus of electricity demand. With the Tier 2 approach, the policy induced demand decrease due to higher prices is the only driver for the effects on CO_2 emissions and electricity spot market prices. In the counterfactual scenario without the EU ETS, the CO_2 emissions of the power sector would have been 5 % to 10 % higher than in the policy scenario calculated with the Tier 2 approach. Using the Tier 3 or the Tier 3 basic approach respectively, the calculated CO_2 emission effect is slightly smaller for Denmark and Germany but higher for the Czech Republic. These differences are based on different demand increases and fuel switching effects. The Tier 3 approach also shows that there was an impact on CO2 emissions in the industrial sectors in the region of 5%, and a very minor economic impact on GDP.

We recommend the implementation of the revised Tier 2 approach for the power sector. Including a price elasticity and demand responses is a major improvement compared with the Tier 1 approach. For national or European authorities, who are interested in indirect and cross-sectoral effects, overall socio-economic effects as well as effects from policy interaction, we recommend to implement the revised Tier 3 approach, although recognizing the costs associated with this.

5.2 Energy Performance of Buildings Directive (EPBD): Testing of methodologies

The testing for the EPBD was more related to the quality and availability of data for a given methodology. It is further tested if the recommended improvements for the less-detailed approaches (Tier 1 and 2) can be implemented at the MS level (with country specific data) and whether they deliver any useful results. This was tested for the UK and NL although we also investigated the availability of relevant data sources for all MSs. In addition, it was further investigated which countries have detailed models for the building sectors and if these models are geared towards ex-post evaluations. This was investigated for all MSs.

5.2.1 Methodological approach

5.2.2 Recommendations from Task 2

In Task 2 we identified the most important gaps in the existing Tier 1, 2 and 3 approaches from the previous study. An initial assessment had showed that the data identified does not significantly enrich the methodologies or results from the existing ex-post evaluation carried out in 2009. However, because of the potentially significant impact of the Directive in terms of reductions of GHG emissions we recommended undertaking further investigations including the following:

- To further test if our recommended improvements for the Tier 1 and 2 approaches can be implemented on the MS level (with country specific data) and test if they deliver any useful results.
- To further investigate which countries have detailed models for the building sectors and if these models are geared towards ex-post evaluations (via a questionnaire of MS Competent Authorities).

The recommended improvements for Tier 1 and 2 from Task 2 included:

1. *Analyse the availability of more recent and detailed data on the split of energy use in the residential sector into various functions which could improve the results of the Tier 1 and 2 methods* e.g. space heating, hot water production, cooling, lighting etc.
2. *Analyse a longer time series to improve assessment of time delay on the impact of the EPBD*. The assumed start of the impacts due to the EPBD has a large influence on the final results. Tier 1 and 2 approaches assume an immediate impact even if implementation of the Directive is formally delayed, as in many MS. In theory, the analysis of a longer time series for the Tier 1 and 2 approaches should show when the EPBD is really starting to have an impact, because this should show an accelerated decrease of the specific energy use.

3. *Investigate possibilities to analyse the impacts of specific areas of interest for the EPBD in more detail without having to rely on the detailed Tier 3 approach.* Investigate if it is possible to distinguish between the impact of new and existing buildings, residential and non-residential buildings, energy use for space heating, hot water consumption, lighting and cooling, demand side and supply side measures, implementation of renewable energy measures (like solar hot water systems).
4. *Investigate if results should be corrected for comfort increasing factors*. The previous project states that “decisions have to be made as to whether comfort increasing factors such as m^2 per dwelling are to be included in the impact evaluation result (as in Tier 1) or excluded from the results (as in Tier 2 or 3)”

Testing approach

Following research undertaken for Task 2, we concluded that results should be corrected for comfort increasing factors where the data is available (i.e. to exclude comfort factors), but to report on the impact of the comfort increasing factors separately where possible. In practice, this means that if m^2 per dwelling data is available, the results should also include the difference if number of dwellings is substituted in as activity indicator (as in Tier 1) which is a quick and simple substitution. If the data is not available, then this issue does not arise.

This testing chapter examines closely whether the split of energy use in the residential sector into various functions (e.g. space heating, hot water production, cooling, lighting etc) improve the results of the Tier 1 and 2 in the case of the UK and NL. We also consider the issue of implementation date.

Regarding existing Tier 3 models, a proforma was sent out to all MS Competent Authorities, although it received a low response rate. The survey was supplemented by a literature review.

The question of whether there are possibilities to analyse the impacts of specific areas of interest for the EPBD in more detail without having to rely on the detailed Tier 3 approach is considered in the context of existing Tier 3 models, and other mixed bottom up and top down approaches currently being undertaken by Member States.

*Table 5.2 Summary of current approaches for Tier 1 and 2 with the issues investigated in the testing phase highlighted in **bold***

Approach	Tier I	Tier II
Activity indicator	Number of households (Inventory sector 1.A.4.B.). Number of employees (Inventory sector 1.A.4.A.).	Number of households and development of square metres. **Estimate of space heating shares.**

	Estimate of space heating shares.	
Emission factor	Fuel specific emission factors. **Aggregate average EU emission factors for electric space heating**	Fuel specific emission factors. **Emissions for electric space heating based upon aggregate data reported by Member States to UNFCCC**
Autonomous development and previous policies	Correction for autonomous progress/previous policies included in a very approximate manner by assuming a fixed rate based on the stock renewal and the period 1990-2002 previous to the EPBD	Correction for autonomous progress/previous policies included in a very approximate manner by assuming a fixed rate based on the stock renewal and the period 1990-2002 previous to the EPBD
Structural effects	No adjustment for structural changes in the activity data	Adjustment for the increase in household size.
Timing issues	**Calculates policy impacts from implementation date at EU level, no adjustment for implementation delays or announcement effect.**	**Calculates policy impacts from implementation date within each MS, no adjustment for implementation delays or announcement effect.**
Policy interaction	Combined effect of closely related national and EU policies.	Combined effect of closely related national and EU policies.
Geographic factors	Adjustment for climatic influence	Adjustment for climatic influence
Other exogenous factors	Non-compliance with building regulation implicit in statistical data. No further adjustment for exogenous factors	Non-compliance with building regulation implicit in statistical data. No further adjustment for exogenous factors

5.2.3 Data

Split of energy use into various end-use functions

<u>Residential data</u>

UK Data:

The department for Energy and Climate Change publishes data on energy consumption split according to fuel and end use (i.e. space heating, hot water production) (DECC, 2011). The latest information available is up to 2009.

NL Data:

The Dutch statistical bureau[192] publishes data on energy consumption annually for the residential sector, with a split according to type of fuels (including electricity) used. Data on the split of energy use by different functions (space heating, hot water production, cooking) is collected on an annual basis and is published by the Dutch energy agency. Data are collected through the "Home study" which carries out surveys on energy use and type of energy efficiency measures implemented among a representative sample of households in the Netherlands[193].

Current reporting in the EU-27: split of energy use into various end-use functions

The Odyssee database provides free access to key indicators for 2009 (2007 or 2008 for some indicators and/or Member States); these are summarised in the table below.

Table 5.3 ODYSSEE indicators for "households" and the "buildings" and "services" sectors[194]

Category	**Indicators**
For households:	
Energy consumption / CO_2 pattern and drivers	• Energy consumption by end-use in the EU 27 • Real energy prices for households in the EU 27 • Importance of the climatic corrections for households
Unit consumption per dwelling	• Specific consumption per dwelling: actual value vs climatic corrected (EU) • Average consumption per dwelling in EU countries • Variation of the average consumption per dwelling before the crisis • Variation of the average energy consumption per dwelling in 2009 and 2010 • Consumption per dwelling, energy price and income in the EU 27 • Influence of income on the consumption per dwelling • Unit consumption per dwelling (adjusted to EU climate)
Space and water heating	• Heating consumption per dwelling in the EU 27 • Drivers of the variation in heating consumption per dwelling in the EU 27 • Drivers of the changes in total household consumption (1990-2009) • Heating consumption per m2

[192] http://statline.cbs.nl/statweb/?LA=en
[193] http://senternovem.databank.nl/
[194] http://www.odyssee-indicators.org/publications/ee_trend_by_sectors.php

Category	Indicators
	• Benchmarking of household space heating • Influence of dwelling size on the unit consumption for space heating • Effects of buildings standards • Diffusion of solar water heaters • Solar water heaters and solar rate
Electricity consumption per dwelling	• Electricity consumption by end use and per dwelling • Electricity consumption per dwelling: thermal uses vs electrical appliances • Electricity consumption per dwelling for electrical appliances and lighting (EU): actual level • Electricity consumption per dwelling: annual growth and actual level • Electricity consumption per dwelling for electrical appliances and lighting (EU): annual growth • Electricity consumption per dwelling for lighting • Electricity consumption per dwelling for lighting: with respect to the number of lighting point • Unit consumption per dwelling for air conditioning • Trends in unit consumption of air cooling per dwelling
Electricity consumption by type of appliances	• Breakdown of consumption between large and small electrical appliances and lighting (EU) • Household electricity consumption by type of appliance • Electricity consumption for 6 type of appliances • Electricity consumption of electrical appliances per dwelling and private consumption per households • Electricity consumption of electrical appliances per dwelling and electricity prices • Variation of the consumption per dwelling for large appliances (EU) • Energy efficiency trends for large appliances (ODEX)
Market share of label A, CFL lamps, water heaters and insulation materials	• Market share of label A for cold appliances and washing machines (EU) • Market share of label A for refrigerators • Efficiency of new air conditioners in the EU (EER) • Diffusion of CFL lamps (average number of lamps per dwelling) • Diffusion of CFL lamps (% of CFL in total number of lamps) • Target for large electrical appliances • Penetration of low emission glazing • Use of insulation materials
Energy efficiency trends	• Energy efficiency progress by end-use for households (EU-27)

Category	Indicators
	• Energy efficiency improvements by country in the household sector • Energy savings in households (EU)
Decomposition of household energy consumption and CO2 emissions	• Trends in electricity consumption per country • Elasticity of total household electricity consumption to GDP • Drivers of the changes in households consumption per dwelling • Decomposition of the energy consumption of households (EU) • Decomposition of the CO2 emissions variations (EU)
For the building sector:	
Energy Consumption	• Final energy consumption for all sector • Share of buildings in final energy consumption • Energy consumption trends in residential & non residential buildings (EU) • Split of energy consumption of buildings between residential and tertiary • Electricity consumption in residential and non residential buildings
Floor area	• Total floor area of buildings by type • Floor area by type of building by country
Buildings permits	• Buildings permits indices
Unit consumption per m2	• Energy consumption of buildings per m2 • Electricity consumption of buildings per m2
For the services sector:	
Energy efficiency trends	• Final consumption in the service sector (EU) • Energy consumption and economic growth in services (EU) • Value added, employment and floor area in services (EU) • Energy consumption by sub-sectors in services • Electricity consumption by sub-sectors in services • Energy intensity • Electricity intensity in the service sector • Electricity consumption per employee • Electricity consumption by end uses • Electricity consumption per employee: thermal and air conditioning • Electricity consumption in services by branch • Share of electricity in final energy consumption in the service sector • Electricity consumption per employee • Share of space heating in final energy consumption in the service sector • Energy consumption in hotel/restaurant sector per m² and per em-

Category	Indicators
	ployee • Energy consumption in health sector per m² and per employee • Energy consumption in education sector per m² and per employee • Energy consumption in office sector per m² and per employee • Energy consumption in trade sector per m² and per employee • Decomposition of the energy consumption in the EU • Decomposition of the energy consumption in case of France and Denmark • Decomposition of the CO_2 variations for tertiary

If the reporting continues on this basis annually, the indicator on consumption per m² for heating could be used for a Tier 2 assessment. Whilst no equivalent indicator is available for other functions such as space cooling, data is available on consumption per dwelling and total household consumption broken down by different functions and Member State. However, the Odyssee database relies on expert judgement in addition to national statistics, and therefore may not be the most accurate data source.

A report from the Building Performance Institute Europe (BPIE) entitled Europe's Buildings under the Microscope (BPIE, 2011) presents survey data for 2009 on the share of heating consumption in terms of final energy use in residential mix with corresponding energy mix for three given regions (selecting Spain, Poland and France as examples of these).

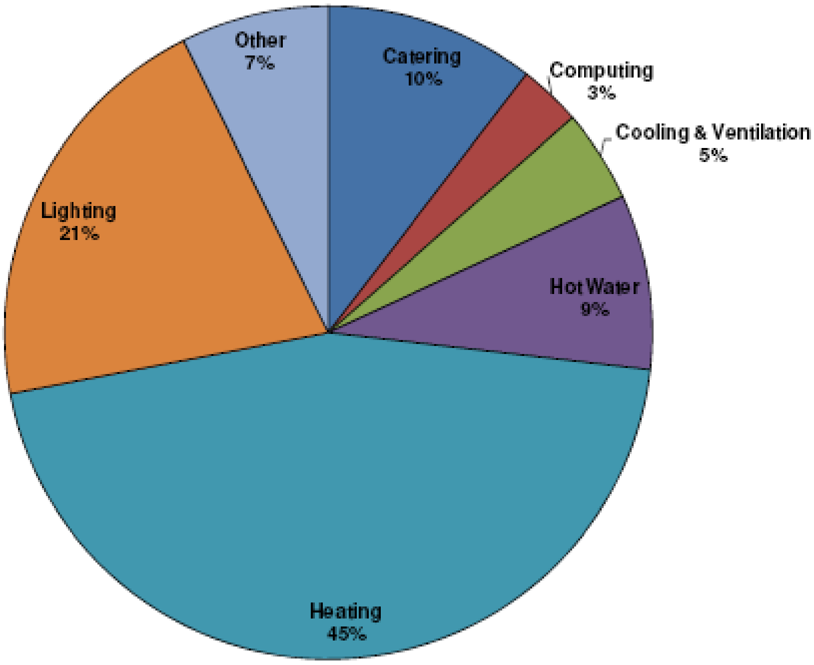
Eurostat does not give a split of energy according to end uses.

Non-residential sector

UK Data

The split according to end use is given in the *Energy Consumption in the UK 2011* report (DECC, 2011) although without the relative split into electricity and other fuels.

Figure 5.19 Service sector energy consumption by end use, UK, 2009



Source: DECC, 2011, ECUK Table 5.5

NL Data

Data on the relative split according to fuel and end use in the service sector are not systematically monitored on an annual basis. Most recent data available currently are for 2008.

Current reporting in the EU-27: split of energy use into various end-use functions

This data is not available from Eurostat or other European data sources (e.g. see summary of ODYSSEE indicators presented above).

The 2009 BPIE study collates and summarises data on:

- Breakdown of non-residential floor space in selected countries (billion m^2)
- Share of non-residential buildings by size and function type in each country
- Specific energy use ($kWh/m^2/a$) in non-residential buildings (data for six countries presented)

If this survey is repeated annually, and data made available, it could prove a useful source of data. It does not currently provide refreshed data on split of energy use into various functions for non-residential buildings.

5.2.4 Analysis and results

In this section we analyse for the UK and NL the impact on the results for calculated savings and CO_2 reductions of an adjusted Tier I approach by applying:

- Different shares and longer time series for the share of space heating in the residential sector instead of a fixed share;
- The time delay of implementation between adoption of the EPBD (2002) and actual transposition into law (2006 in the case of the UK and NL);
- Country specific CO_2 emission factors for electricity usage instead of the EU average.

To understand the implications of each of these changes we analysed the following cases:

	Assumptions
Case 1A: Current Tier 1 approach (without delay, EU grid factor)	Default space heating shares taken from the 2009 report Policy impact EPDB starting in 2002 EU average emission factor for electricity consumption
Case 1B: Current Tier 1 approach (with delay UK grid factor)	Default space heating shares taken from the 2009 report Policy impact EPDB starting in 2006 EU average emission factor for electricity consumption
Case 1C: Current Tier 1 approach (with delay, UK grid factor)	Default space heating shares taken from the 2009 report Policy impact EPDB starting in 2006 MS average emission factor for electricity consumption
Case 2: DECC space heating shares	Applying MS space heating shares for fuel (average) and electricity Policy impact EPDB starting in 2006 MS specific emission factor for electricity consumption
Case 3: Fuel specific space heating share	Applying MS space heating shares, broken down according to different types of fuel and electricity Policy impact EPDB starting in 2006 MS specific emission factor for electricity consumption

On the whole, the tested approach adopted is consistent with the Tier 1 methodology set out in the 2009 methodologies report, with some Tier 2 level improvements where the data was readily available. Box 1 provides an overview of the proposed Tier 1 methodology from the 2009 report.

Box 5.1 Tier 1 methodology for ex-post EPBD assessment, 2009 report

In the existing Tier 1 approach, policy impact in year t since the introduction of policies (year i) for the residential sector is given by:

$PI_{i,t} = (((1\text{-}0.5\%)^{\wedge\,(t-i)}\, E_i) – E_t) * F_t * A_t$

Whereby:

- Policy impact $PI_{i,t}$ of energy efficiency policies in the residential sector (ktonnes of CO_2eq) in year t compared to the year policies were introduced year i
- A_t number of households in year t
- E_i final temperature corrected energy consumption for space heating per household in the year policies were introduced (year i)
- E_t final temperature corrected energy consumption for space heating per household in year t
- F_t carbon intensity for the energy consumption in the household sector in year t

For E_i calculation of final temperature corrected energy consumption for space heating per household in year i:

- Take the default factor on the share of energy use for space heating for your country for fuel use in the residential sector (Sf) and for electricity (Se)
- Determine the fuel consumption for the household sector in year i (FCi): Coal consumption in year i + Natural gas consumption in year i + Oil consumption in year i (TJ) + renewables consumption in year i.
- Determine the electricity consumption for the household sector in year t (ECi).
- Determine the number of households in year Ai
- Determine the correction factor for temperature fluctuations by taking the long term average heating degree days (Tl) and the actual heating degree days (Ta_i) in year i.

$E_i = [(FC_i * Sf + EC_i * Se) * (Tl/Ta_i)]/A_i$

E_t calculation of final temperature corrected energy consumption for space heating per household in year t (GJ/household) uses the same calculation procedure as for E_i.

For F_t calculation of the carbon intensity for the energy consumption in the household sector in year t:

- [Coal consumption in year t* CO2 emission factor for coal + Natural gas consumption in year t * CO2 emission factor for natural gas + Oil consumption in

[195] This formula has subsequently been amended so as to calculate the carbon intensity F for energy consumed for space heating in the household sector. The revised formula should be used for further calculations.

year t * CO2 emission factor for oil + electricity consumption in year t * EU27 average emission factor for electricity production] divided by FC_t+EC_t[195]

The following amendments were made to the methodology:

1. The formula for carbon intensity F_t was amended so as to calculate the carbon intensity for energy consumed for space heating, rather than the carbon intensity of all energy consumed in households.
2. The policy impact is calculated using the carbon intensity from year i, at the start of policy impact, rather than year t. This is so as to separate out impacts from fuel switching from energy efficiency impacts[196].

Box 5.2 Revised Tier 1 methodology for ex-post EPBD assessment, amendments in red

In the existing Tier 1 approach, policy impact in year t since the introduction of policies (year i) for the residential sector is given by:

$PI_{i,t} = (((1\text{-}0.5\%)^{\wedge\,(t\text{-}i)} E_i) – E_t) * F_i * A_t$

Whereby:

- Policy impact $PI_{i,t}$ of energy efficiency policies in the residential sector (ktonnes of CO_2eq) in year t compared to the year policies were introduced year i
- A_t number of households in year t
- E_i final temperature corrected energy consumption for space heating per household in the year policies were introduced (year i)
- E_t final temperature corrected energy consumption for space heating per household in year t
- F_i carbon intensity for the energy consumption in the household sector in year i

For E_i calculation of final temperature corrected energy consumption for space heating per household in year i:

- Take the default factor on the share of energy use for space heating for your country for fuel use in the residential sector (Sf) and for electricity (Se)
- Determine the fuel consumption for the household sector in year i (FCi): Coal

[196] It is not possible to completely remove all impacts from fuel switching, as this will affect the amount of energy consumed in year t as opposed to year i, although the impacts of this are considered to be minimal.

consumption in year i + Natural gas consumption in year i + Oil consumption in year i (TJ) + renewables consumption in year i.

- Determine the electricity consumption for the household sector in year t (ECi).
- Determine the number of households in year Ai
- Determine the correction factor for temperature fluctuations by taking the long term average heating degree days (Tl) and the actual heating degree days (Ta_i) in year i.

$E_i = [(FC_i * Sf + EC_i * Se) * (Tl/Ta_i)]/A_i$

E_t calculation of final temperature corrected energy consumption for space heating per household in year t (GJ/household) uses the same calculation procedure as for E_i.

For F_i calculation of the carbon intensity for the energy consumption in the household sector in year i calculate:

- [Coal consumption in households in year i * S_{coal} *CO2 emission factor for coal + Natural gas consumption in households in year i * S_{gas}* CO2 emission factor for natural gas + Oil consumption in households in year i * S_{oil} * CO2 emission factor for oil + electricity consumption in households in year i * S_e* EU27 average emission factor for electricity production] divided by FC_t * S_f +EC_t * S_e [197]

5.2.4.1 UK Testing

The default shares for energy use for space heating are given in the 2009 Methodologies report, taken from the Ecofys MERLIN project, and reproduced in Table 5.4. This was produced during the Sectoral Emission Reduction Objectives for Climate Change project[198] and is around ten years old. No refreshed data is available from the more recent Ecofys SERPEC[199] project.

Table 5.4 Share of Energy use for space heating

	Residential sector		Service sector	
	% fuel demand	% electricity demand	% fuel demand	% electricity demand

[197] This formula has subsequently been amended so as to calculate the carbon intensity F for energy consumed for space heating in the household sector. The revised formula should be used for further calculations.

[198] Blok, K. et al, Sectoral Emission Reduction Objectives for Climate Change, Summary Report for Policy Makers, Updated March 2001, Ecofys, AEA Technology and the National Technical University of Athens

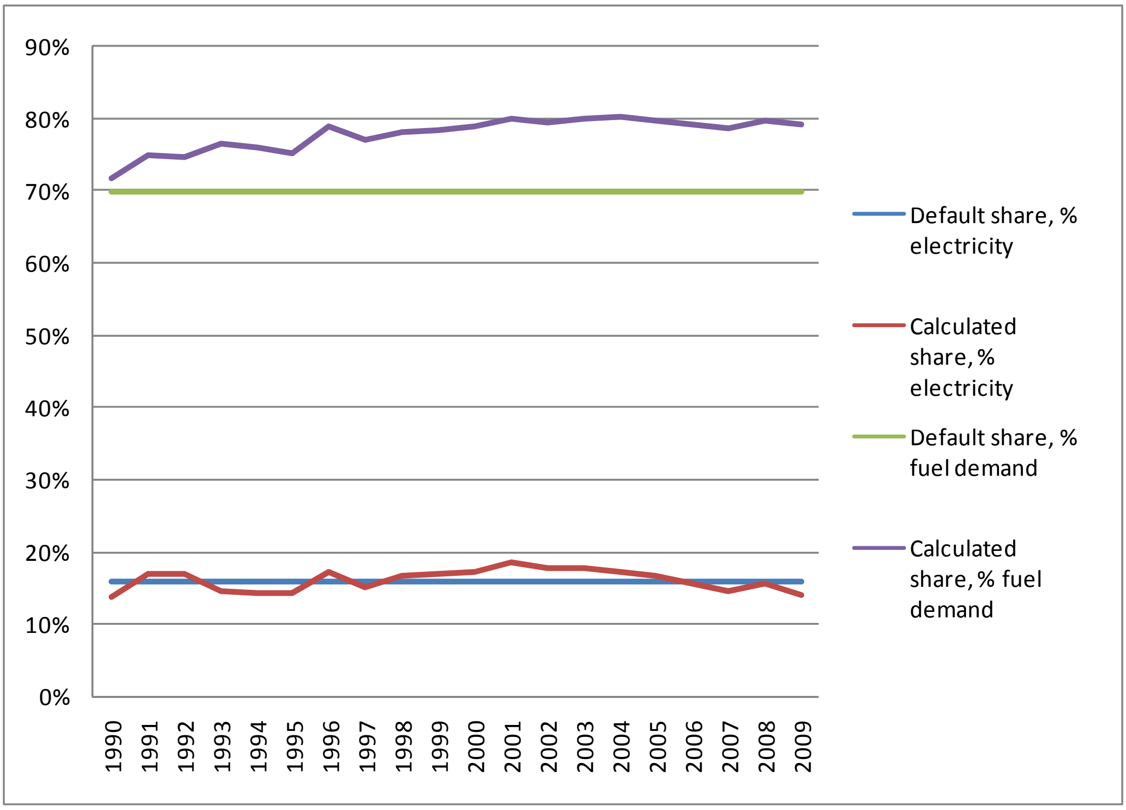
[199] Ecofys et al, Sectoral Emission Reduction Potentials and Economic Costs for Climate Change (SERPEC-CC), Summary report, 2009

	Residential sector		Service sector	
	% fuel demand	% electricity demand	% fuel demand	% electricity demand
UK	70%	16%	86%	11%

Source: Eurostat and Joint Research Centre

The shares in the residential sector were recalculated for the UK, using data published in the *Energy Consumption in the UK 2011* report from the UK Department for Energy and Climate Change. A comparison of the default and calculated shares is given in Figure 5.20, and shows that in the case of fuel demand, the UK default value is an underestimate.

Figure 5.20 Share of energy used for space heating in the residential sector, UK



Source: Calculated based on DECC, 2011

The impact on results was tested using a comparison of three different approaches to calculating space heating shares. The first uses the default shares of 70% of residential fuel demand and 16% of residential electricity demand. The second uses the calculated values for percentage fuel demand used for space heating and percentage of electricity demand used for space heating, based on the new MS data. This represents (independently) the portion of fossil fuels consumed in the residential sector for space heating, and the portion of total electricity consumed in the residential sector which is used for space heating[200].

These are set out in Table 5.5.

Table 5.5 Share of Energy use for space heating

	Residential sector	
	% total fuel demand used for space heating	% total electricity demand used for space heating.
2002	79%	18%
2006	79%	16%
2009	79%	14%

Source: Calculated based on DECC, 2011

In the third approach, the figure of average share of fuel demand for space heating (as above, in terms of the % of total fuel consumed) is broken down according to solid fuels, gas and oil, as shown in Table 5.6.

Table 5.6 Space heating shares according to fuel type, residential, UK

Year	solid fuels	gas	electricity	oil	Total	total excluding electricity
2002	86%	79%	18%	83%	66%	79%
2003	86%	79%	18%	84%	66%	80%
2004	86%	80%	17%	84%	66%	80%
2005	86%	79%	17%	84%	65%	80%
2006	85%	79%	16%	83%	64%	79%
2007	85%	78%	14%	83%	63%	79%
2008	86%	79%	16%	84%	65%	80%

200 This is not to be confused with the percentage of total energy consumed for space heating broken down by fuel type, in which case the percentages would add up to 100%.

2009	93%	76%	14%	82%	62%	79%

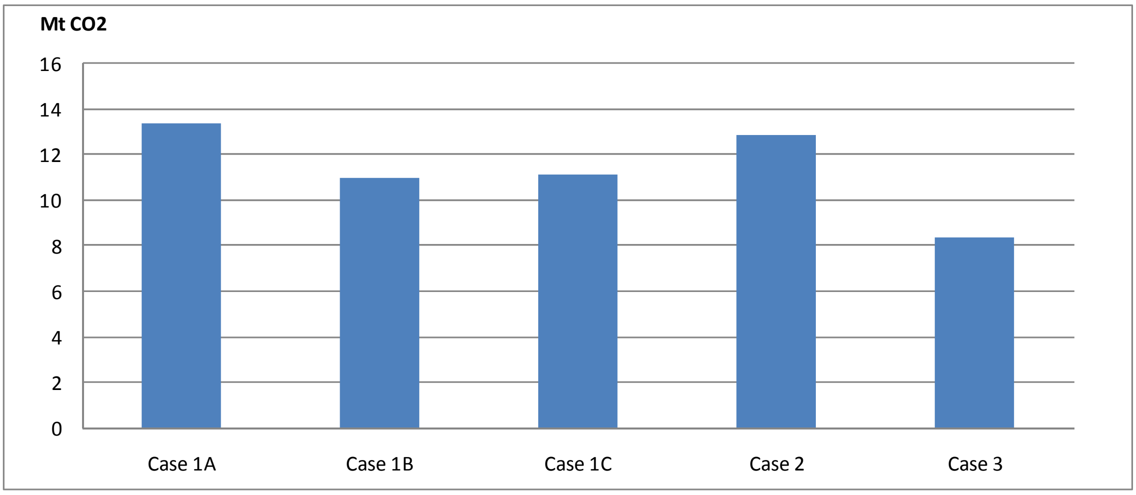
Source: Calculated based on DECC, 2011

The overall share of energy is given for the services sector, although this is not broken down per fuel type, and so has not been considered further.

UK results

The following results are given for the UK, shown in Figure 5.21.

Figure 5.21 Results from UK testing, policy impact of EPBD (Mt CO_2 saving)



The higher result in Case 1A reflects the longer time period under consideration (7 years as opposed to 3 years). The difference between cases 1A and 1B reveals efficiency gains in the 2002-2006 period before the EPBD was transposed, and may indicate impacts of other overlapping UK policy, a higher rate of autonomous improvement, or a combination of the two. A comparison of cases 1B and 1C shows that substituting a UK specific electricity emission factor does not have a big impact on results in this case (0.1Mt), which is not surprising as there is not much difference between the calculated emission factors (120,448 kg CO_2/TJ for the UK, against 118,688 kg CO_2/TJ for the EU in 2002).

The results using the DECC data on fuel split by end use are the result of updated values which affect both energy consumed and the carbon intensity. The result in Case 2 is due to improved data, and reflects a 2% decrease in the share of electricity used for space heating between 2006-2009, over and above the 6% overall decrease in electricity used in the same period. The Case 3 results using the fuel specific space heating shares give a lower estimated savings, partly due to the effects of fuel switching and partly due to more accuracy in estimating the temperature corrected energy consumption for space heating, due to data averaging issues in the previous two approaches (i.e. because of the dominance of gas over other fuels, which is not reflected in the overall average).

Netherlands testing and results

For the Netherlands a similar testing was performed, using consumption data from the Dutch Statistical Bureau. This included the following cases:

	Assumptions
Case 1A: Current Tier 1 approach (without delay, EU grid factor)	Default space heating shares taken from the 2009 report Policy impact EPDB starting in 2002 EU average emission factor for electricity consumption
Case 1B: Current Tier 1 approach (with delay, EU grid factor)	Default space heating shares taken from the 2009 report Policy impact EPDB starting in 2006 EU average emission factor for electricity consumption
Case 1C: Current Tier 1 approach (with delay, NL grid factor)	Default space heating shares taken from the 2009 report Policy impact EPDB starting in 2006 NL average emission factor for electricity consumption
Case 2: Current Tier 1 approach (with delay, NL grid factor and NL space heating shares)	Applying NL space heating shares for fuel (average) and electricity Policy impact EPDB starting in 2006 NL specific emission factor for electricity consumption
(Case 3)	Case 3 is not calculated for the Netherlands, as the emissions for fuel are calculated purely on a basis of gas consumed, so no further breakdown according to fuel is possible.

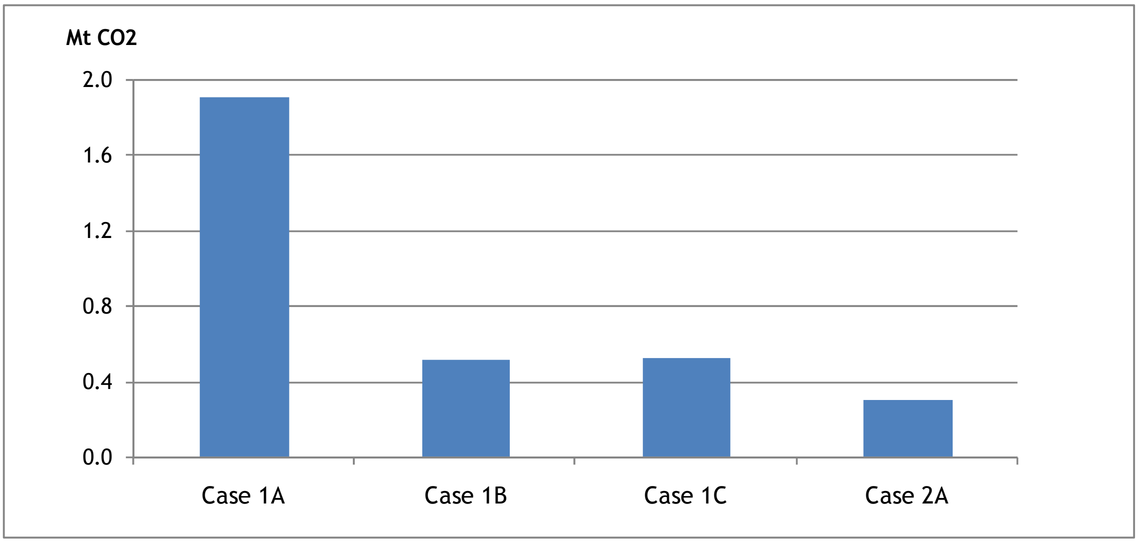
In the case of the Netherlands, Case 3 is not calculated, as the emissions for fuel are calculated purely on a basis of gas consumed, so no further breakdown according to fuel is possible. The results for the Netherlands are given in Figure 5.22.

The table below provides the most important parameters that are used in the calculations.

Grid factor	EU: 2002: 119kg CO2/GJ electricity 2006: 157 kg CO2/GJ electricity	NL 2002: 114 kg CO2/GJ electricity 2006: 141 kg CO2/GJ electricity

Share space heating	Default for NL Fuel: 87% Electricity: 7%	NL space heating shares Fuel: 2002: 76% (Homes database) Fuel: 2006: 74% (Homes database) Electricity: 7% (Calculated using Homes database)

Figure 5.22 Results for NL, impact of EPBD (Mt CO_2 saving)



The results show the comparatively high impact of assuming an immediate implementation date (Case 1A; start date 2002) compared to the case in which it is assumed that policy impacts start to materialize from 2006 onwards (Case 1B). This large difference is caused by the fact that the annual decrease in natural gas consumption per household in the period 2002-2006 was about twice as high (33 m^3 per household per year) as the savings in the period 2006-2009 (16 m^3 per household per year). Figure 5.23 provides an overview on the decrease in natural gas consumption for households.

This difference in annual efficiency improvements can probably partly be explained by the fact that in the period 2002-2006, national policies have been more effective in triggering investments in energy savings then in the period 2006-2009. However, more detailed analysis is needed to draw firm conclusions because of other factors such as autonomous changes in energy prices, the increasing in single person households, and the number of new build homes to come on the market.

As in the case of the UK, the difference according to EU average or MS grid factors is very small. Finally, Case 2 gives a lower result, and illustrates the value in using refreshed data where available for space heating shares[201].

Figure 5.23 Decrease in total natural gas consumption and natural gas consumption for space heating in the Netherlands (temperature corrected and for comparison with data from the Dutch statistical bureau and from the Homes database).

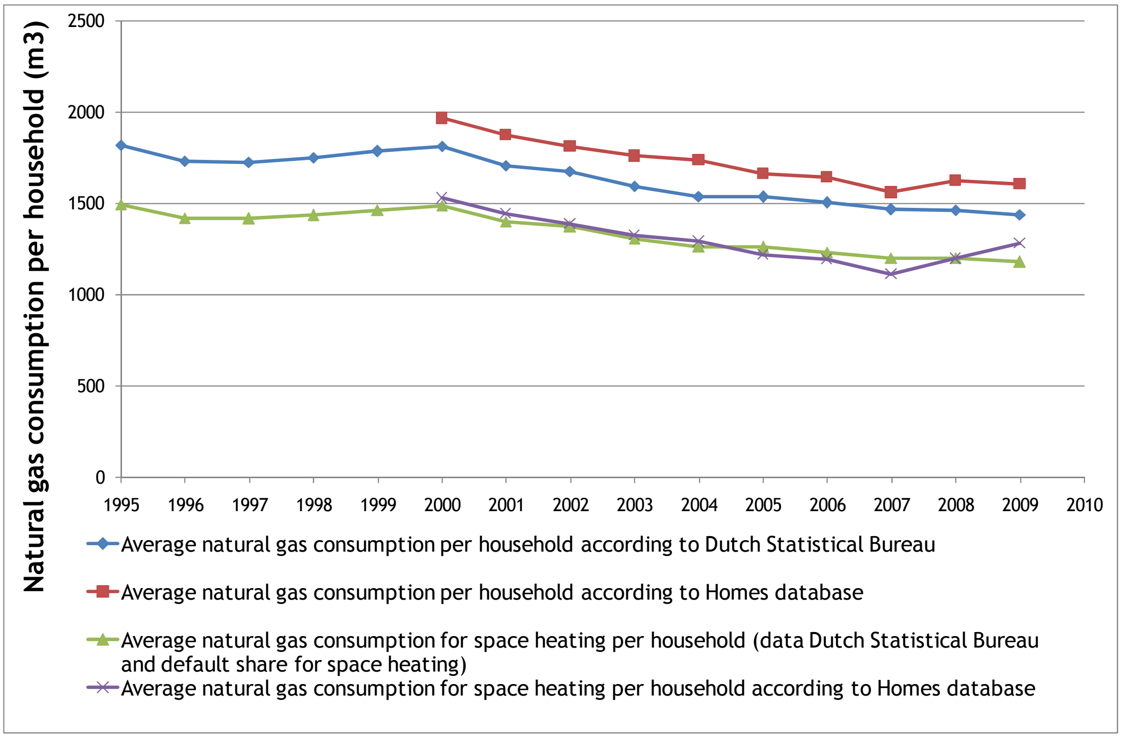


Figure 5.23 shows the anomalous data points for 2008 and 2009 in the HOMES database, displaying an upward trend for these years, unlike the data from the statistical bureau which shows a downward trend. The average natural gas consumption in the HOMES database is derived from research conducted under a fixed group of respondents consisting in a panel of over 3,500 households, which aims to be representative of the population of households in the Netherlands. The discrepancy in trends for 2008 and 2009 illustrates the need to be careful with using data from a relatively small sample to extrapolate trends for a whole country.

[201] We have used the 2008 value from the Homes data for Case 2, as the 2009 value shows anomalous variation compared to the rest of the time series, and is commented on as such in the data source. We have therefore assumed that the 2009 value is incorrect pending further investigation following submission of this report.

5.2.5 Conclusions from Tier 1 & 2 testing

The following conclusions can be drawn:

- If there is data available at MS level on the fuel split according to end usage, this allows for a more accurate assessment of impact. This could be suggested as an option for an improved Tier 1 or 2, where data is available at MS level.
- There is value in using data giving fuel specific space heating shares where available, as this captures impacts from fuel switching and avoids data averaging issues.
- The implementation date assumed can have a big impact on results. It would be fairly straightforward to present implementation dates alongside the methodology, and to use these to derive more accurate results for both Tiers 1 & 2. The longer time series leading up to implementation could then be used as an indicator of trend before implementation of the directive.
- Energy data is available on Eurostat for calculating MS level grid factors, and can be accessed in the same location as the EU level data. This equally applies to emissions data from the EEA databank. Although the results from the testing do not show a large difference using MS data due to the relative proximity of the UK and NL grid emissions to the EU average, there is a fairly large variation across the EU, ranging from countries mainly reliant on nuclear and hydro to carbon intensive grids in Eastern Europe. There is therefore a good case for only using MS level grid factors (i.e. in Tier 1 as well as Tier 2).
- When not using Eurostat data on energy consumed in the residential and services sector, it is recommended to use energy consumed rather than energy produced, so as to not include transmission losses.

Further suggested improvements to Tiers 1 and 2

The 2009 methodology notes that the next stage of the analysis would be to adopt the same approach next for cooling (and possibly other functions such as water heating). However, there are a number of issues with this:

1. Data on the relative split for energy used for cooling is not readily available (although some data is included in the ODYSSEE database).
2. Degree cooling days are not currently commonly available, and are not reported in Eurostat.
3. If adopting a top-down approach for the Energy Labelling Directive, there is a high risk of double-counting savings from air-conditioning and fans (as the methodology currently does not differentiate between reduced demand and increased appliance efficiency).

Similarly, although energy consumption shares for lighting and appliances are more commonly available at MS level, the same issue of double-counting arises if also undertaking a top-down assessment for the Energy Labelling Directive.

Regarding exogenous factors, the UK Department for Energy and Climate Change publishes time series data on degree comfort factors in Energy consumption in the UK 2011, giving internal and external temperatures from 1970 to 2009. This means that the impact of the increase in 'comfort temperatures' can be considered separately.

The current EPBD methodologies do not cover cost assessment. A basic assessment using a top down approach would entail looking at data on sectoral investment in buildings and making an assumption on the proportion which is used on energy efficiency measures and measures which improve the efficiency of buildings. This is then summed with the cost savings from reduced demand for energy. An intermediary approach would refine this by considering additional costs such as certification costs and training costs. A full scale assessment would use bottom-up cost data to derive a more accurate estimation of the costs and cost savings arising from the implementation of the directive.

5.2.6 Tier 3 data assessment

Member States currently report under the End-use energy efficiency and Energy Services Directive (ESD) of progress on National Energy Efficiency Action Plans (NEEAP), available on the MURE-2 website[202]. A survey of current evaluation of the EPBD and minimum thermal insulation standards shows that some ex-post evaluation is currently being undertaken, as detailed in Table 5.7.

Table 5.7 MS ex-post evaluation reported under the ESD, MURE-2 website

	PAM	**Ex-post?**	**Estimates**	**Comments**
Austria	Min thermal insulation standards	yes	14.85 PJ deemed estimate unit reduced energy consumption	
Italy	EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy Performance of Buildings		578,169 PJ space heating and electricity	Own calculation on the basis of the Italian NEEAP 2011

[202] http://www.isisrome.com/mure/index.htm

Luxembourg	Space heating (+electricity): min thermal standards	yes	0.16PJ/13MT CO2 in 2010	Integrated bottom up/top down methods
Spain	Thermal standards - Action Plan 2005-2007: Renovation of the thermal envelope of existing buildings	yes		

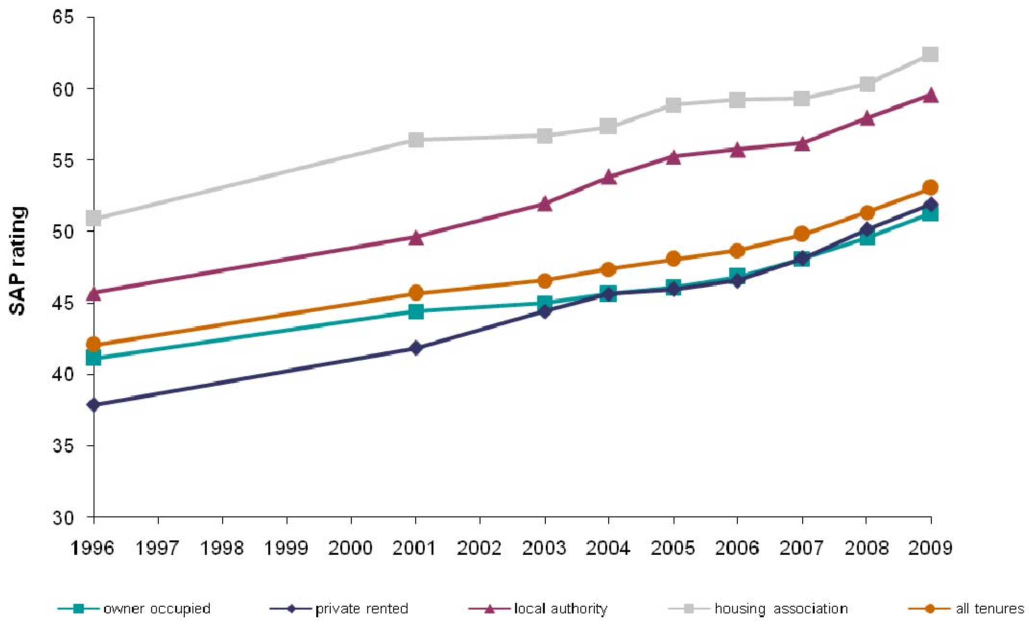
At a pan-European level, Europe's Buildings under the Microscope (BPIE, 2011) presents detailed survey data for 2009, including:

- Average heating consumptions levels in terms of final energy use (kwh/m^2) by construction year
- U values for external walls in different countries for different construction periods
- Air tightness levels for of single house built over last century, MS breakdown
- Specific energy use in non-residential buildings (kwh/m^2 a)
- Age categorisation of housing stock by region and residential floor space standards by region.

In the UK, the Department for Communities and Local Government undertakes the English Housing Survey every few years. This includes detailed data on housing stock and uptake rates of energy efficiency measures (wall and loft insulation, boiler types, double glazing, heating controls, etc.) in residential housing. It also includes overall energy efficiency and emissions calculations for Buildings included in the survey.

The Standard Assessment Procedure (SAP), an integrated methodology developed for energy assessment of buildings in the UK, shows an increase in energy efficiency across residential housing. The SAP rating is based on the energy costs associated with space heating, water heating, ventilation and lighting, less cost savings from energy generation technologies. It is adjusted for floor area so that it is essentially independent of dwelling size for a given built form. The SAP rating is expressed on a scale of 1 to 100, the higher the number the lower the running costs (BRE, 2011).

Figure 5.24 UK average SAP rating per dwelling, 1996-2009



Base: all dwellings

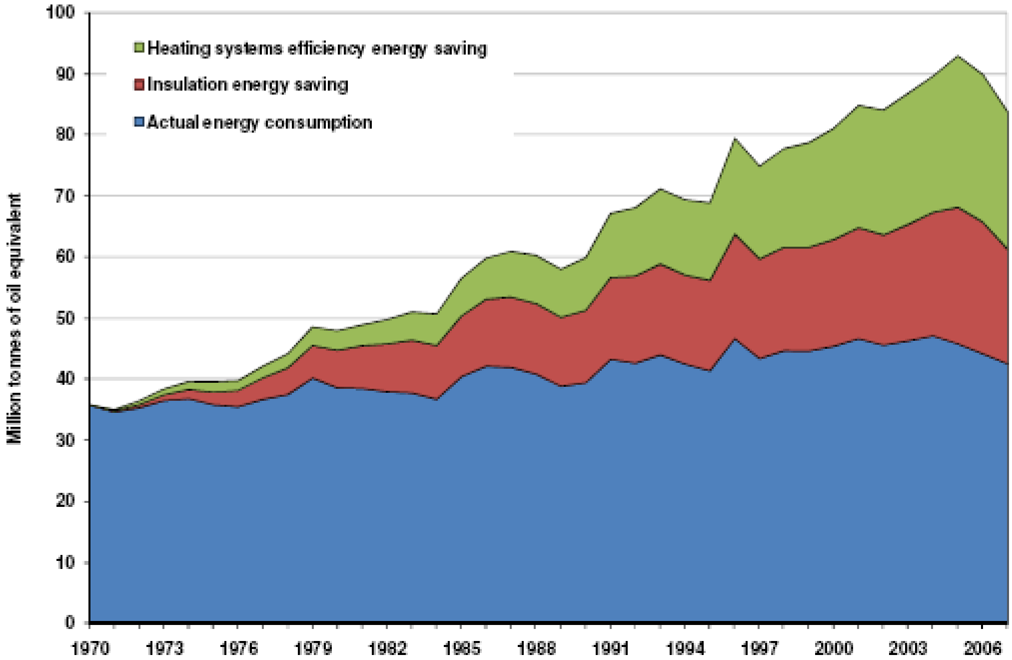
Source: English House Condition Survey 1996 - 2007, English Housing Survey 2008 onwards, dwelling sample

The following analysis is also undertaken, and results presented, in Energy Consumption in the UK 2011:

- Domestic energy consumption by end use and fuel 1990 to 2009
- Boiler types by tenure (England only) 1996 to 2009
- Energy savings due to insulation and heating efficiency improvements in Great Britain 1970 to 2007

Figure 5.25 below presents energy savings (insulating saving and heating efficiency saving) based on how much additional energy would have been required if insulation and heating efficiencies had remained at 1970 levels. The savings due to heating modelled data using the BREhomes and BRE Domestic Energy Model (BREdem) tools, with variation in property type and tenure accounted for.

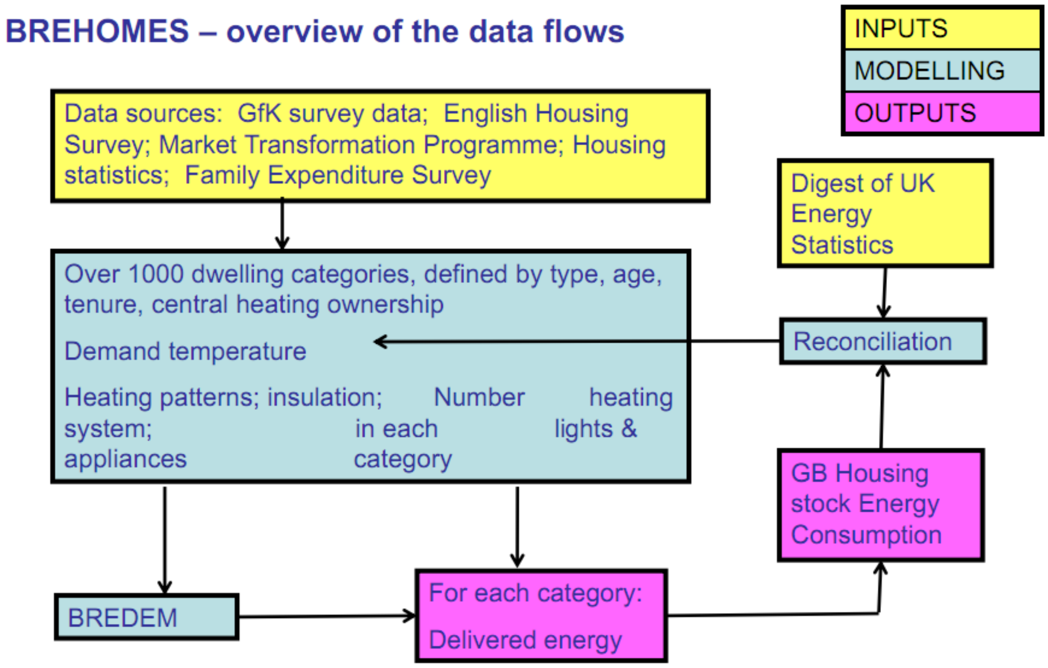
Figure 5.25 Savings due to better insulation and heating efficiency, UK, 1970 to 200



Source: DECC, ECUK Table 3.18

BREDEM is a model of the energy use of individual dwellings which calculates annual energy required for space heating, water heating, cooking and lights and electric appliances. The first version of BREDEM was developed in the 1980s, with continuous development since. BREHOMES is a bottom-up model of the energy use of the UK housing stock which uses BREDEM to do its energy calculations. The principal sources are the English Housing Survey, the annual GfK survey since (sample size about 18,000 households) and top down estimates of household energy consumption from energy balances (Prime, 2009). A data flow chart is given below.

Figure 5.26 Data flow chart for BREHomes model



Source: Prime, 2009

Further data sources used for UK modelling and energy consumption indicator development are given in the Joint Working Group on Energy and the Environment (JWGEE): progress on the development of indicators July 2005, as shown in the table below.

Table 5.8 Data Sources for Joint Working Group on Energy and the Environment indicator development, 2005

Technology / End use	Source	Comment
Boiler acquisitions	SBGI sales data by SEDBUK efficiency band	Good market coverage post 2000
Efficiency of boiler stock	BREHOMES model	From GB energy balance
Heating demand	BREHOMES model	Derived temperature trend
Insulation acquisitions	GfK surveys, + manufacturers, EEC & Warm Front returns	GfK sample size small; other data used for cross checking
Insulation ownership	English House Conditions Survey & GfK	Now annual, but small samples; needs scaling
Insulation performance	Various studies, mainly linked to SoP and EEC	Pilot studies need wider follow-up

Source: Defra 2005.

Every 3 to 4 years in the Netherlands, the Ministry of Infrastructure and the Environments undertakes the WoON survey[203]. In this survey 40.000 respondents fill out an extensive questionnaire related to their housing that also includes questions on their energy use, implementation of energy efficiency measures (wall and loft insulation, boiler types, double glazing, heating controls, etc.) and their energy behaviour.

Using the data from this survey, ECN and partners developed the energy model Sawec[204] (Simulation and analysis for residential energy consumption and related CO_2 emissions).This model is used to make predictions about home related energy consumption in the Netherlands.

Results of the survey of Member States are given in Table 5.9 below.

[203] http://www.rijksoverheid.nl/onderwerpen/woningmarkt/woononderzoek/woononderzoek-nederland-won

[204] http://www.ecn.nl/nl/units/ps/modelinstrumentarium/sawec/

Table 5.9 Survey results on current data availability and bottom up ex-post evaluation models in EU-27, MS level

Member State	Data available	Tier 3 model?	Comments
NL	Split new build/existing stock Compliance levels in new build Split of energy use (gas and electricity only), residential and service sectors. Space heating shares for gas available. Costs of compliance (EPC and certification costs)	No	There is a model available that focuses on the price of residential buildings in relation to the label. Cost of Energy Performance Certificate: Residential sector: typically between €100 and €250, depending on size of dwelling, non-residential sector: typically € 0.50 – 1 per m^2. <u>Certification costs:</u> Education/training: €750 (residential) ; €1500 (non-residential) Exam training (voluntary): typically €400 -500 Exam: €410 (residential); €660 (non-residential) BRL publication: €70, ISSO publication: €40, Digital copy of ISSO documentation: €46 Software: €350 (annual licence fees may apply) Subscription costs: Certification Institute: no data available Member of dispute committee: €400 annual
DE	Split new build/existing stock Split of energy use in residential and	Yes	The model is "STE-Gebäude-Simulationsmodell", bottom-up approach, run by Forschungszentrum Jülich, Institut für Energie- und Klimaforschung, Contact: Mr. Patrick Hansen (Email:

	service sectors Costs of compliance (single building level) Total investment in buildings – residential and service sectors		p.hansen@fz-juelich.de) Energy split data from Working group "Nutzenergiebilanzen" at the AGEB Costs of compliance data may be available from the Bundesinstitut für Bau-, Stadt- und Raumforschung Other data available at the Federal Office for Statistics.
SL	New build/existing split Energy use split in the residential sector is modelled. Services sector split for 2008 only. Some costs of compliance data	Yes	It is a bottom up model. Inputs are: useful floor area divided by type of building (single or multi family house) and by period of construction; renovation degree; useful floor area of new build houses.
SK	Data is patchy: • Data on housing (number of flats and buildings) in 2001 and 1991. Data on public existing buildings is available, data on new buildings is scattered or missing. • Split according to end use/fuel for res sector, but not electricity consumption.	No	Ex-post evaluation in terms of energy savings and investment costs for renovation of certain types of buildings is conducted within the national energy efficiency action plans by Ministry of Economy of the SR. In future, this should be automatized within the monitoring system of energy efficiency. Data on electricity consumption is not monitored, thus, we cannot quantify the split among the main end uses.

5.2.7 Overall discussion and recommendations

The testing on Tier 1 and 2 improvements shows that data averaging issues for space heating shares are an issue, and supports a case for using more accurate data on this where available.

The testing of improvements for Tiers 1 and 2 shows the value in using more accurate data generally if this available at Member State level rather than strict adherence to a Tier 1 or 2 methodology, including:

- Data on energy consumption with split according to both fuel and end usage
- Data on exogenous factors such as increase in mean heating temperatures over a given time period

We have also identified some improvements to the actual methodology itself.

The survey of Member States and literature review indicate that a bottom up assessment (i.e. Tier 3) is currently possible in some Member States. Others may opt for a mixed bottom up/top-down approach.

5.2.8 Annex to EPBD testing – revised Tier 1 & 2 methodologies

The main proposed changes to the Tier 1 EPBD methodology include the following:

- Calculating an emission factor for the energy consumed for space heating in buildings, as opposed to overall energy consumption.
- Calculating the emission factor for year i as opposed to year t (i.e. year policy is introduced rather than the last year in the time period under consideration). This is so as to separate out impacts from fuel switching from energy efficiency impacts.
- Calculating a MS grid emission factor using published EEA emissions data, rather than using an EU27 average emission factor.
- Using the year that the policy was implemented at MS level, as opposed to a default implementation year of 2002, as this information is readily available.

The changes to the methodology are set out in the box below.

Box 5.3 Revised Tier 1 methodology for ex-post EPBD assessment, amendments in red

In the existing Tier 1 approach, policy impact in year t since the introduction of policies (year i) for the residential sector is given by:

$PI_{i,t} = (((1-0.5\%)^{\wedge\,(t-i)} E_i) - E_t) * F_i * A_t$

Whereby:

- Policy impact $PI_{i,t}$ of energy efficiency policies in the residential sector (ktonnes of CO_2 eq) in year t compared to the year policies were introduced year i

- A_t number of households in year t
- E_i final temperature corrected energy consumption for space heating per household in the year policies were introduced (year i)
- E_t final temperature corrected energy consumption for space heating per household in year t
- F_i carbon intensity for the energy consumption in the household sector in year i

For E_i calculation of final temperature corrected energy consumption for space heating per household in year i (GJ/household):

- Take the factor on the share of energy use for space heating for your country for fuel use in the residential sector (Sf) and for electricity (Se)
- Determine the fuel consumption for the household sector in year i (FCi): Coal consumption in year i + Natural gas consumption in year i + Oil consumption in year I (TJ) + renewables consumption in year i.
- Determine the electricity consumption for the household sector in year t (ECi).
- Determine the number of households in year Ai
- Determine the correction factor for temperature fluctuations by taking the long term average heating degree days (Tl) and the actual heating degree days (Ta_i) in year i.

$E_i = [(FC_i * Sf + EC_i * Se) * (Tl/Ta_i)]/A_i$

E_t calculation of final temperature corrected energy consumption for space heating per household in year t uses the same calculation procedure as for E_i.

For F_i calculation of the carbon intensity for the energy consumption in the household sector in year t, calculate:

- [Coal consumption in households in year i * S_{coal} * CO2 emission factor for coal + Natural gas consumption in households in year i * S_{gas}* CO2 emission factor for natural gas + Oil consumption in households in year i * S_{oil}* CO2 emission factor for oil + electricity consumption in households in year i * S_e* MS grid emission factor]; divided by FC_t*S_f +EC_t*S_e
- With S_i share of energy use for space heating in each country in the residential sector by individual fuel use (S_{coal}, S_{gas}, S_{oil}), for average fuel use (S_f) and for electricity (Se). If S_i share of energy use for space heating in each country in the residential sector by individual fuel use (S_{coal}, S_{gas}, S_{oil}) data are not available, use S_f. Default values for S_f and S_e are provided for each MS in the case where refreshed data is not available.

Policy impact in year t since the introduction of policies (year i) for the ***service*** sector is calculated using the same calculation rules as for the residential sector. For the service sector:

- Activity indictor is number of employees
- Shares of energy use for space heating differs from the residential sector
- Assumption with respect to autonomous efficiency improvement of 0.5% per year in the residential sector and 0% per year for the service sector.

Uncertainty analysis

- Uncertainty in the numbers on the share of energy used for space heating in the residential and service sector. These numbers are not regularly updated.
- Uncertainty is related to the uncertainty in the energy statistics used, and the use of default emission factors
- Energy statistics on the service sector are usually not of a very high quality and includes relatively large uncertainties
- Assumption with respect to autonomous efficiency improvement of 0.5% per year in the residential sector and 0% per year for the service sector. This is derived from the period 1990 - 2002 and needs to be revised or quantitative evidence provided to support the assumption.

Data sources

- Actual heating degree days: Eurostat
- Electricity and energy statistics: Eurostat
- Household statistics: Eurostat
- Employment statistics: Eurostat
- Emissions data: EEA
- Default emission factors for fossil fuel: http://www.ipccnggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (Table2.2)
- Default shares for space heating are reproduced from the 2009 report below.

	Residential sector		Service sector	
	% fuel demand	% electricity demand	% fuel demand	% electricity demand
AUT	90%	23%	86%	8%
BEL	70%	21%	86%	2%
DEU	89%	16%	86%	7%
DNK	77%	23%	86%	2%
ESP	57%	15%	75%	3%
FIN	85%	36%	88%	4%
FRA	88%	35%	83%	14%
GBR	70%	16%	86%	11%
GRC	86%	15%	77%	21%
IRL	83%	11%	85%	10%
ITA	81%	3%	83%	2%
LUX	82%	40%		10%
NLD	82%	7%	54%	11%
NOR	92%	33%	85%	10%
PRT	59%	48%	74%	5%
SWE	69%	40%	83%	6%
SWI	80%	10%	85%	10%
LAT	73%	1%	85%	10%
EST	73%	15%	85%	10%
LIT	74%	12%	85%	10%
POL	60%	7%	85%	10%
HUN	79%	6%	85%	10%
CHZ	79%	10%	85%	10%
SLO	77%	16%	85%	10%
ROM	61%	10%	85%	10%
BUL	61%	31%	85%	10%
SLK	61%	10%	85%	10%

Souce: Ecofys MERLIN project

The revised Tier 2 methodology is the same as the revised Tier 1 methodology, except that:

- The activity indicator A is m^2 of floor space in the residential sector and in the service sector calculations. The results should also be calculated substituting the Tier 1 activity indicators in order to illustrate the impact of ‘comfort factors’.
- Refreshed MS level data should be used on shares of energy use for space heating in both the residential and service sector, where possible broke down according to fuel.

5.2.9 References

BPIE, 2011. Europe's Buildings under the Microscope. Available online at http://www.bpie.eu/eu_buildings_under_microscope.html [Accessed 23/01/11]

BRE, 2011. The Government's Standard Assessment Procedure for Energy Rating of Dwellings, 2009 edition incorporating RdSAP 2009. Published on behalf of DECC by BRE, Watford

Prime, J. 2009. Producing household energy consumption data – the modelling approach used in the UK. A presentation to the Expert Round Table on Energy Efficiency Indicators in the Residential Sector, Moscow, 28-29 September 2009 http://www.iea.org/work/2009/moscow/prime.pdf

UK Department for Energy and Climate Change, 2011. Energy Consumption in the UK 2011. Available online at: http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx

UK Defra, 2005. Joint Working Group on Energy and the Environment. Progress on the development of indicators – July 2005. Available online at: http://www.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=Statistics/publications/ecuk/file19842.pdf&minwidth=true

5.3 Energy Labelling Directive: Testing of methodologies

As the methodologies to assess the Energy Labelling Directive are relatively well developed but face some data availability limitations the testing phase aims to investigate and test if the suggested improvements for the least detailed approach (Tier 1: linking electricity use for products covered by the Directive to private consumption of households) delivers useful results. On a more detailed level (Tier 2) data availability at the MS level is investigated to improve the understanding of the potential to apply the Tier 2 methodology (this includes data on more products/appliances, actual energy use/patterns). This is investigated for all MS Competent Authorities.

5.3.1 Tier 1: Methodological approach

5.3.1.1 Overview of existing methodology (Tier 1)

In the 2009 study, assessment of the policy impact using a Tier 1 approach was based primarily on EU-level Eurostat data. Key indicators used were number of households and overall electricity consumption per household. The approach did not separate individual appliances nor did it split out other electricity uses not covered in the scope of the Labelling Directive (e.g. electric heating, electric water heating and small electric appliances).

The previous study, for a Tier 1 approach, calculated the impact of the Directive as follows:

Step 1. It established the electricity consumption per household from Eurostat data. This also contains electricity uses not covered by the Labelling Directive e.g. electric heating.

Step 2. It projected the baseline development from the pre-Directive period (1990-1995) to the evaluation period up to 2006.

Step 3. The difference of this baseline with the real development for a country provides the impact in terms of electricity savings.

Step 4. Electricity savings are converted to CO_2 savings with average EU emission factors for electricity.

5.3.1.2 Proposed improvements and refinement of the methodology (Tier 1)

The 2009 approach uses the indicator total electricity consumption by household in Eurostat and divides this by the total number of households. This indicator aggregates all use of electricity for space and water heating and all electrical appliances. Eurostat does not split out residential electricity usage for different applications. This approach does not account for consumption changes due to changes in usage or ownership. Energy consumption at the household level is determined by a combination of ownership level (which is strongly related to income of households), technology and usage patterns, each of which varies between appliance sectors.

Two potential improvements were identified in Task 2:

- It might be more pertinent to use average private consumption (in euro) per household as an indicator to assess electricity consumption for appliances to construct the counter factual.
- The JRC (2009) estimated breakdown of residential electricity consumption at EU level by appliance type (see Table 5.10). This split could be used to provide a more precise impact assessment of residential electricity consumption per dwelling for the relevant appliances included under the Directive. In this way, non-relevant appliances (e.g. lighting and space heating) can be excluded. This study was conducted a one-off survey in 2009 and is in the process of being updated[205], it is not clear if this data is collected on an annual basis or if it was collected as a one-off survey. It will be important to understand how this split may have changed over time.

Table 5.10 Breakdown of residential electricity consumption in EU-27 in 2007

EU-27 residential electricity consumption (2007)	**TWh**	**% of total**
Cold appliances (refrigerators & freezers)	122	15.2%
Lighting	84	10.5%
Washing machines	51	6.4%
Dishwashers	21.5	2.7%
Electric ovens & hobs	60	7.5%
Air-conditioning	17	2.1%
Ventilation	22	2.7%
Water heaters	68.8	8.6%
Heating systems/electric boilers	150	18.7%
Television	54	6.7%
Set-top boxes	9.3	1.2%
Computers	22	2.7%
External power supplies	15.5	1.9%
Home appliances stand-by	43	5.4%
Others	60.6	7.6%
Total consumption of appliances covered under Label-	271.5	34%
Total residential electricity consumption	**800.72**	**100%**

Notes:

1) Those appliances that are italicised are covered by the Labelling Directive

Source: JRC (2009) Electricity Consumption and Efficiency Trends in European Union: Status Report

205 Personal communication with JRC, January 2011

5.3.2 Tier 1: Analysis and results

The JRC (2009) report estimated breakdown of residential electricity consumption at EU level by appliance type. Consultation with the JRC has ascertained that this is not an annual survey and therefore cannot be used as an improvement for the Tier 1 methodology.

However, the Odyssee database provides free access to key indicators up to 2009, including:

- Consumption per dwelling (toe/dwelling);
- Consumption per dwelling for electrical appliances (kWh/dwelling);
- Consumption per dwelling for heating (toe/dwelling);
- Consumption per m² for heating (koe/m2); and
- Consumption per dwelling scaled to EU average climate (toe/dwelling).

Consumption per dwelling for lighting and electrical appliances is provided at the EU-level and by individual Member States. This information could be used to improve Tier 1. This information is available publicly and is reproduced in Table 5.11

Table 5.11 Consumption for electrical appliances and lighting per permanently occupied dwelling (excluding space heating, water heating and cooking) (kWh per dwelling)

Member State	**1990**	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Austria	1771	1959	2122	2237	2261	2367	2419	2485	2521	2511	2588	2652
Belgium	2055	2560	2766	2816	2674	2689	2715	2607	2751	2698	2750	2789
Bulgaria	2244	2327	2116	1975	1902	1930	1651	1518	1490	1441	1460	1514
Cyprus	1688	2320	2858	2745	3014	3425	3319	3594	3694	3659	3587	3501
Czech Rep.	996	1450	1615	1646	1652	1675	1701	1710	1769	1815	1855	1847
Denmark	2806	2941	3044	3024	3064	3040	3090	3109	3139	3100	3021	2902
Estonia			903	963	964	964	978	974	1005	1048	1089	1088
Finland		3695	4064	4148	4161	4284	4212	4304	4237	4285	4144	4237
France	1920	2122	2412	2493	2547	2618	2651	2700	2744	2744	2824	2793
Germany	1687	1914	2049	2077	2198	2227	2185	2203	2229	2255	2237	2258
Greece	1230	1607	2318	2363	2613	2688	2771	2792	2926	2960	2991	2990
Hungary	1290	1391	1449	1499	1576	1702	1681	1642	1733	1696	1764	1693
Ireland	1345	1976	2436	2696	2476	2609	2733	2704	2916	2798	2956	2626
Italy	1971	2074	2140	2126	2165	2254	2254	2229	2230	2193	2195	2184
Latvia				1020	1086	1145	1145	1186	1322	1352	1592	1489
Lithuania		1012	1065	1146	1144	1196	1298	1343	1476	1543		
Luxembourg	No data											

Member State	**1990**	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Malta	No data											
Netherlands	2111	2515	2651	2665	2739	2791	2797	2877	2855	2834	2877	2752
Poland	No data											
Portugal	1477	1916	2334	2304	2408	2438	2487	2504	2463	2750	2561	2557
Romania		961	1018	1002	1005	1062	1034	1184	1277	1332	1316	
Slovakia	2143	2424	2715	2681	2487	2459	2432	2359	2281	2278	2237	2178
Slovenia			2343	2488	2519	2669	2580	2722	2766	2807	2699	
Spain	1750	1891	2073	2099	2126	2138	2184	2195	2315	2240	2232	
Sweden	3505	3566	3329	3741	3784	3842	3858	3800	3744	3692	3697	3738
United Kingdom	3102	3248	3271	3343	3353	3369	3400	3407	3396	3414	3371	3232
EU average	**2019**	**2123**	**2295**	**2330**	**2380**	**2441**	**2448**	**2509**	**2565**	**2555**	**2565**	**2607**

Step 1 of the Tier 1 methodology (as summarised in the section above) can be improved with the Odyssee data on electricity consumption for electrical appliances and lighting per household. The results are shown in Table 5.12.

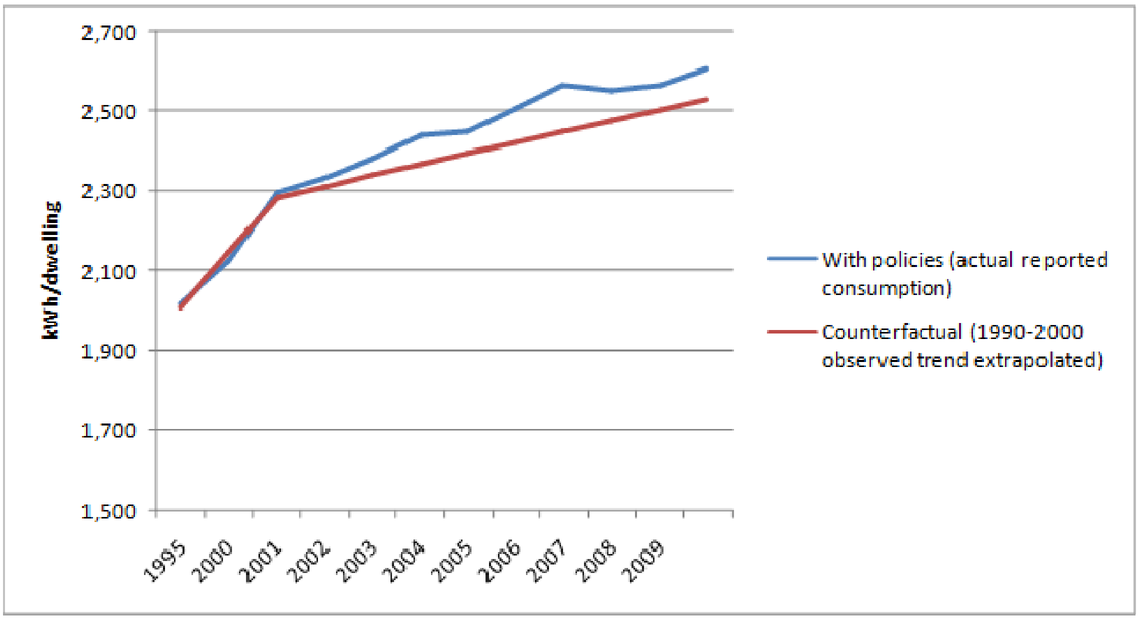
Table 5.12 Testing of Tier 1 with Odyssee data (electricity consumption for electrical appliances and lighting)

	Observed development	**Counter-factual scenario (1990-2000)[1]**
Total no of dwelling (2001 census)	187,232,539	187,232,539
kWh/dwelling (2009)	2,607	2,532
Total consumption of electricity (kWh)	488,115,229,173	474,147,681,764
EU emission factor electricity households (kgCO2e/kWh)	0.41228	0.41228
$MtCO_2e$	201	195
$MtCO_2e$ savings in the year 2009	**- 5.76**	

Note:
1) The counterfactual scenario in the 2009 study was based on the period 1990-1995 extrapolated up to 2006. We believe it is more appropriate to extrapolate the period 1990-2000 as the Directives for different appliances were transposed into national legislation over a number of years, from 1994 (refrigerators/freezers) up to 2004 (air conditioning units).

Using this simple methodology, the values presented in the table above suggest that the Labelling Directive has not resulted in savings of carbon dioxide, but rather an **increase** in emissions of 5.76 $MtCO_2e$ in 2009 as compared to the baseline. The trend in electricity consumption for appliances in the EU-27 is examined further in Figure 5.27 below. The actual observed consumption from the sector has been compared to a derived counter-factual which represents the estimated consumption (in accordance with the Tier 1 approach but using the more specific electricity dataset for lighting and electrical appliances) that would have occurred in the absence of the Directive. The chart shows that between 2000 and 2009 the counter-factual is lower than the actual observed consumption.

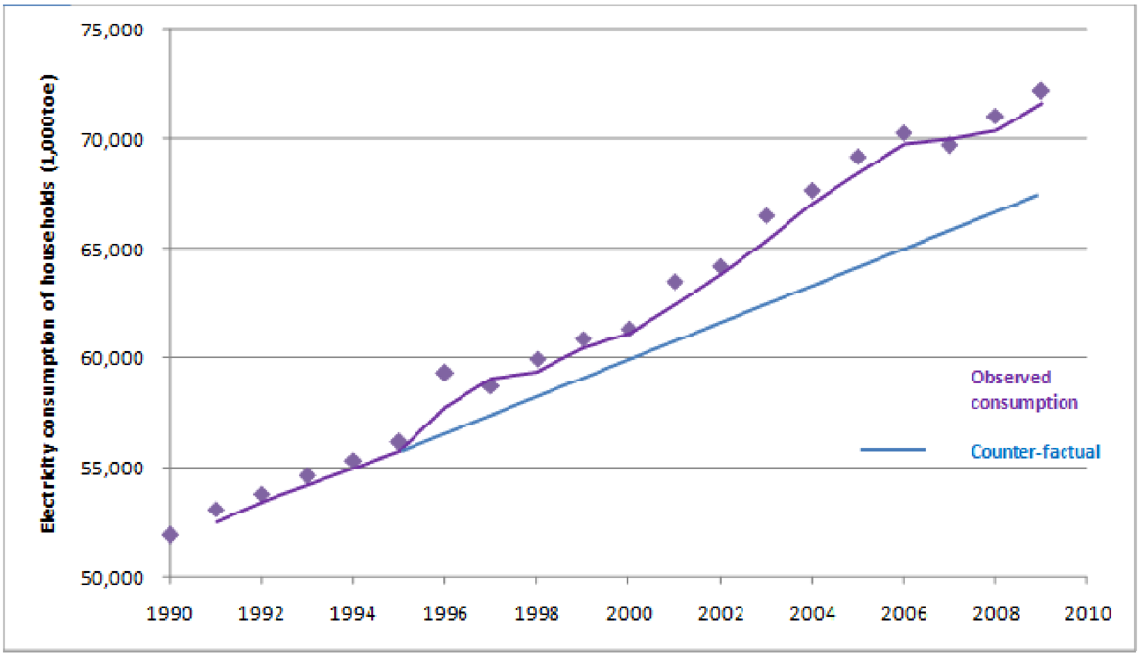
Figure 5.27 Counter-factual EU-27 electricity consumption for appliances and lighting per dwelling (kWh/dwelling) assumed under the Tier 1 approach (note variability in scale of x-axis)



To understand this result, the household electricity consumption needs to be examined in further detail. We have attempted to replicate the exact approach and data used in the 2009 study but have been unable to derive the same outcome (i.e. emissions saving as a result of the Directive). Total household electricity use in the EU-27 has increased by approximately 2% per year since 1990 (51 Mtoe in 1990 to 70 Mtoe in 2009) (see Figure 5.28)[206]. When the counterfactual (in the 2009 study this is extrapolated based on 1990-1995) is compared with the observed consumption it can be seen that total household electricity increases at a much higher rate than the extrapolated data. It is unclear how the Tier 1 approach in the previous study resulted in an emissions saving using the data and methods as described.

[206] Eurostat data – electricity consumption of households (http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tsdpc310)

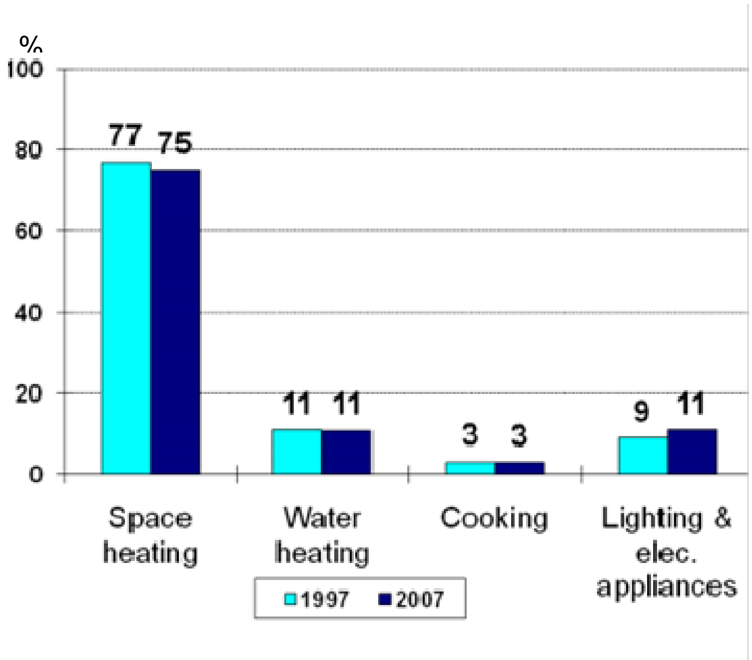
Figure 5.28 Total electricity consumption of households EU27 (ktoe)



Source: Eurostat data

According to Odyssee, this is mainly due to a higher consumption for electrical appliances and lighting (+2.6% per year since 1997) (see Figure 5.29). Consumption for space heating has, on the other hand, decreased.

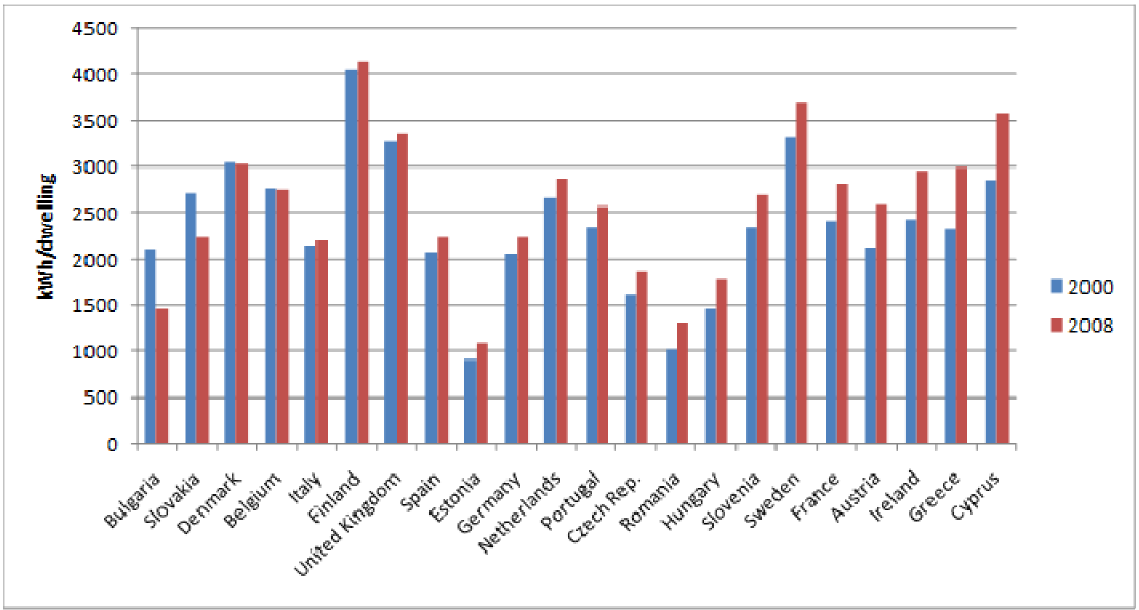
Figure 5.29 Household consumption in the EU-27, 1997 vs 2007



Source: Odyssee Database

If the trends of electricity consumption per dwelling for electrical appliances and lighting are examined at a Member State level, varying trends can be seen across Europe (see Figure 5.30). Decreasing consumption is seen in Bulgaria, Slovakia, Belgium and Denmark whereas increases can be seen in all other EU Member States. Whilst this progression has been moderate in Italy, Sweden and the UK, consumption has increased more significantly in Austria, Ireland, Cyprus and Greece.

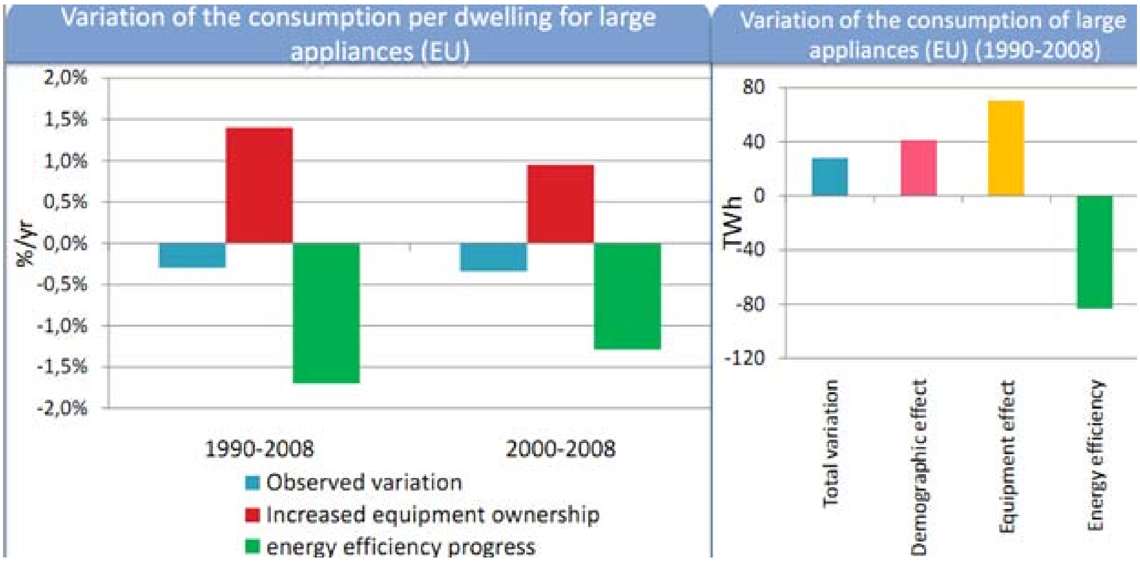
Figure 5.30 Electricity consumption per dwelling for electrical appliances and lighting in 2000 and 2008, kWh/dwelling



Source: Odyssee Database

Analysis carried out in the MURE-Odyssee project on the overall energy efficiency trend of the larger appliances shows that almost all the energy efficiency gains have been offset by an increase in equipment ownership and, as a result, the consumption per dwelling for large appliances is only slightly decreasing. The Odyssee project found that energy savings reached 83 TWh in 2008 (30% of the consumption of large appliances) compared to 1990, limiting the consumption increase to 28 TWh.

Figure 5.31 Variation in the consumption for large appliances (EU27)



Source: Odyssee

5.3.3 Tier 1: Discussion and recommendations

The revised Tier 1 has been tested using more refined electricity consumption data for appliances and lighting only. Testing indicates an increase in emissions of 5.76 $MtCO_2e$ in 2000 as compared to the baseline. This result contradicts the findings of the 2009 study which indicated a saving of approximately 21 MtCO2e using a Tier 1 approach. To check our methodology, we have attempted to replicate the 2009 approach for Tier 1 using the same data but have been unable to produce similar results; in fact using a shorter historical period for projecting forward the baseline leads to a greater calculated increase in emissions than that estimated over the longer base time period. As shown in Figure 5.28, electricity consumption by households increases sharply after 1995 and therefore the counterfactual scenario is much lower than the observed consumption in 2006. Without applying a correction factor (e.g. to account for the increase in level of appliance ownership) this results indicates an increase of emissions as opposed to a saving.

The results of the testing suggest that the Tier 1 approach, in its current form, is not necessarily appropriate for evaluating the impacts of the Labelling Directive as it does not account for any changes in level of appliance ownership – or increases in the size of dwellings – which exert a significant influence on total household energy consumption.

One alternative approach identified previously was the possible use of household income or expenditure as a more appropriate indicator as the 2009 study (and analysis completed within the Odyssee database) found it to correlate well with energy consumption for electrical appliances. However, an initial comparison of Eurostat data on household income (purchasing power standard based on final consumption per inhabitant in Euros) with Odyssee data on electricity consumption per dwelling for lighting and electrical appliances has shown that household income has increased at a faster rate than electricity consumption between 1995 and 2008. Therefore the relationship between the two has changed over time. This is identified as an area for future investigation.

5.3.4 Tier 2: Methodological approach

5.3.4.1 Overview of existing methodology (Tier 2)

In the 2009 study, this approach was based on national data collected in the Odyssee Database. This approach calculates the impact of the Directive using appliance ownership data and unit consumption (kWh/appliance/year), as follows:

Step 1. For each implementing Directive assess if it has been implemented at national level

Step 2. For each appliance type estimate the improvement in energy efficiency that would have occurred autonomously for new appliances sold on the market.

Step 3. For each appliance type calculate the average energy efficiency gain for new appliances sold on the market as compared to the no-directive (autonomous improvement) situation. The sales are calculated from stock data in this approach.

Step 4. Calculate the reduction in energy use for appliance x as a result of the implementation of the Directive.

Step 5. Calculate the reduction in CO2 emissions derived from the reduction in energy use stemming from the improvement in energy efficiency for appliances x.

Step 6. Aggregate the energy and CO2 emissions reduction associated with each appliance to calculate the aggregated impact of the Directives.

5.3.4.2 Proposed improvements and refinement of the methodology (Tier 2)

The previous Tier 2 approach relied on appliance ownership data and unit consumption from the Odyssee Database. The Odyssee database was updated in January 2011. However, the problem still remains that not all Member States are included in the coverage of the database[207] and, furthermore, the database includes semi-quantitative estimates based on expert judgement rather than actual observed data. The ODYSSEE database includes the stock of appliances but does not make use of sales

[207] Data is included for Austria, Bulgaria, Belgium, Croatia, Cyprus, Czech Republic, Spain, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Romania, Slovakia, Slovenia, Sweden and the UK.

data or labelling. It furthermore does not cover all products/appliances currently included under the Directive.

In Task 2 it was identified that an alternative method would involve using MS-level consumption data by PRODCOM code in Eurostat (for instance, consumption of units of washing machine) which is publicly available. Whilst the PRODCOM[208] database does not currently contain information on real energy use of appliances (or the label category), the European Committee of Household Appliance Manufacturers (CECED) database provides information on the average energy consumption by appliance.

A weak aspect of this methodology and also the current Tier 3 approach is that energy use per appliance is not based on the actual observed energy use per appliance per country but is based on the standardised usage for various appliances. The series "*Preparatory Studies for Eco-design Requirements of EuPs*"[209] provides a wealth of information on each of the appliances of concern (washing machines, dishwashers, refrigeration, lighting, air conditioning, ovens etc.) including actual consumer use patterns. For instance, Report 14 on Domestic Washing Machines and Dishwashers includes actual consumer usage considerations such as choice of programme temperatures, partial loading and spinning speeds. These reports could be a useful source of information for more detailed data.

Finally, the ODYSSEE database is not publicly available and therefore consideration should be given to how, on a regular basis, evaluations of the labelling scheme could be carried out.

The section below summarises our review of data availability at the MS-level (for a selection of four MSs) to improve testing of the Tier 2 methodology. We investigated two main sets of data:

- Sales data on appliances, and
- Actual energy usage and patterns of appliances.

5.3.5 Tier 2: Analysis and results

Member States are obliged to report progress of the End-use Energy efficiency and Energy Services Directive in National Energy Efficiency Action Plans (NEEAP). The NEEAPs describe the energy efficiency improvement measures that are aimed at achieving the savings targets set out in Article 4(1) of the Directive. Several Member

[208] Prodcom provides statistics on the production of manufactured goods. The term comes from the French "PRODuction COMmunautaire" (Community Production) for mining, quarrying and manufacturing: sections B and C of the Statistical Classification of Economy Activity in the European Union (NACE 2).

[209] Preparatory Studies for Eco-design Requirements of EuPs prepared for European Commission DG Energy

States have conducted ex-post evaluations of progress to report in the NEEAPs. These are summarised on the MURE-2 website[210] and are presented in Table 5.13.

Table 5.13 MS ex-post evaluation reported under the End-use Energy efficiency and Energy Services Directive

Member State	Ex-post evaluation?	Estimates[1]
Austria	Yes, for certain appliances	1.099 PJ reduced energy consumption (2007-2009) Medium
Belgium	No	High
Bulgaria	No	Low
Croatia	No	Low
Cyprus	No	Low
Denmark	Yes for certain appliances - refrigerators, freezers,	300 TJ reduced energy consumption (2000 to 2005) Low
Estonia		Medium
France	No	Medium
Germany	Yes	Oko-Institut (2008): 2,432PJ reduced energy consumption; 453kt CO2 savings (1995 for refrigerators, fridge-freezers, and freezers; 1997 for washing machines, washer-driers, and tumble driers) High/medium
Italy	No	Medium
Latvia	No	Medium
The Netherlands	Yes	300 kt CO2 savings (2000)
Portugal	No	Medium
Romania	No	Medium
Slovakia	No	Medium
Slovenia	No	Low
Spain	No	Low
Sweden	Yes	1 TJ reduce energy consumption(1995 – 2005) Medium

[210] http://www.isisrome.com/mure/index.htm

Member State	Ex-post evaluation?	Estimates[1]
UK	No	Unknown

Notes:
1) For some MSs only a semi-quantitative assessment has been conducted in order to provide a first order estimate of the impact of policy measures. These categories are: Low: energy savings < 0.1% of overall energy consumption in “household”; Medium: between 0.1 and 0.5%; High: > 0.5%.

PRODCOM

The table below summarises PRODCOM data on relevant appliances which could be used as a source of information on appliance stock for ex-post evaluations.

Table 5.14 Available PRODCOM (Rev 2.2) data

Appliance (PRODCOM Rev2.2 code)	Number of units sold/ year	Value in € of sold units per year	Sales by energy labels
Combined refrigerators-freezers, with separate external doors (27.51)	1995-2010*	1995-2010*	No data
Household-type refrigerators (including compression-type, electrical absorption-type) (excluding built-in)	1995-2010*	1995-2010*	No data
Compression-type built-in refrigerators	1995-2010*	1995-2010*	No data
Chest freezers of a capacity <= 800 litres	1995-2010*	1995-2010*	No data
Upright freezers of a capacity <= 900 litres	1995-2010*	1995-2010*	No data
Household dishwashing machines	1995-2010*	1995-2010*	No data
Cloth washing and drying machines, of the household type	1995-2010*	1995-2010*	No data
Domestic electric ovens for building-in	1995-2010*	1995-2010*	No data

Notes: *Some of the data is marked as confidential and therefore not available publicly.

EuP

As part of the preparation for the Energy Using Products Directive (EuP) a number of studies have been undertaken to establish the real use-patterns and energy consumption of a number of appliances in Europe, including:

- Boilers and combi-boilers (gas/oil/electric);
- Water heaters (gas/oil/electric);
- Personal Computers (desktops & laptops) and computer monitors;
- Imaging equipment: copiers, faxes, printers, scanners, multifunctional devices;
- Consumer electronics: televisions;

- Standby and off-mode losses of EuPs;
- Battery chargers and external power supplies;
- Office lighting;
- (Public) street lighting;
- Residential room conditioning appliances (airco and ventilation);
- Electric motors 1-150 kW, water pumps (commercial buildings, drinking water, food, agriculture), circulators in buildings, ventilation fans (non-residential);
- Commercial refrigerators and freezers, including chillers, display cabinets and vending machines;
- Domestic refrigerators and freezers;
- Domestic dishwashers and washing machines;
- Solid fuel small combustion installations;
- Laundry driers;
- Vacuum cleaners;
- Simple set-top boxes;
- Complex set-top boxes for pay content; and
- Domestic lighting.

These studies are based on extensive consultation in a number of selected MSs. The reports contain highly detailed information on appliance stocks, energy efficiencies of different energy labels and actual energy consumption in the home which could be used in ex-post evaluations.

Selected Member States

Data proformas were developed in collaboration with the Commission (see Appendix A) and sent to all Member States requesting information to be returned by 1st December 2011.

Table 5.15 provides a summary of the data received to date (January 2012).

Table 5.15 MS responses

Member State	Information received
Germany	Information on data availability received 15th December 2011
The Netherlands	Information on data availability received 19th December 2011
Slovakia	Information on data availability received 19th December 2011
Slovenia	Information on data availability received 8th December 2011
UK	Information on data availability received 20th January 2012

5.3.5.1 Germany

Data availability

In Germany, labelling obligations have existed since 1.1.1998 for large household appliances (refrigerators and freezers, washing machines, driers) and since 1.3.1999 for dishwashers. Since 1.1.2003, household electric ovens and air-conditioners have to be labelled, too.

Table 5.16 Data availability in Germany

Information	Source
Stock and sales of electrical appliances:	o The Zentralverband Elektrotechnik-und Elektronikindustrie (ZVEI) collects information on large and small domestic appliances and HVAC Equipment[211]. o The German Federal Statistical office (destatis) collects data annually on the number appliances (refrigerators, fridge-freezers, freezers, dishwashers and dryers) owned per household[212] (data is currently available for 2003-2010). o It is possible that the private market research company GfK contains a breakdown of these sales among the various label categories (A++, A+, A, etc.)
Energy consumption by end-use	o Research is being conducted by a working group BDEW (BDEW Projektgruppe "Nutzenergiebilanzen and IfE/TU Munich) under the umbrella of the German Working Group on Energy Balances (AGEB) on energy consumption for households disaggregated by different applications. o From 2001 onwards, regular surveys on energy consumption in the household sector have been carried out in Germany (survey for the year 2001: Fraunhofer ISI/DIW/TUM/GfK 2004; surveys for the years 2003 and 2005: RWI/forsa 2005, 2007).
Specific consumption of electrical appliances:	o Prognos 2009 o Information available on lighting and heaters but not for other appliances

However, according to Fraunhofer (2009) it has to be taken into consideration that these data sources are not fully comparable, which is mainly due to the use of different methodologies and definitions.

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[211] http://www.zvei.org/

[212] Fachserie 15 Reihe 2: "Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern"

Ex-post evaluations

The implementation of the Energy Consumption Labelling Ordinance in Germany was evaluated by the Fraunhofer Institute for Systems and Innovation Research (ISI) and the GfK (Schlomann et al. 2001) using a computational model. The study assessed compliance with the Ordinance among manufacturers. For six groups of appliances (refrigerators, fridge-freezers, freezers , washing machines, washer-driers, tumble driers), it was calculated what impacts the shifts of appliance sales to the higher energy efficiency classes had on energy savings and CO_2 emissions up to 2000. In addition, the development up to 2010 was estimated. This concerned a single factor of influence, not a prediction, e. g. what equipment households have and behavioural changes in use were not taken into consideration. As a result, between 1995 (1997) and 2000, 453,000 tonnes of CO_2 were saved by the shift to more efficient (A- and B-) appliances (except for dishwashers) in Germany.

An ex-post evaluation of the Labelling Directive 92/75/EEC was conducted in the 2nd National Energy Efficiency Action Plan (NEEAP) by the Federal Ministry of Economics and Technology (BMWi, 2011). Early action (1995-2007) is thought to have lead to 7.3PJ of energy savings; 2008-2010 savings are estimated at 1PJ and total savings are predicted to be 3.4PJ over the period 2008-2016.

An ex-post evaluation of the revised Labelling Directive was also conducted with savings estimated at 0.1PJ from 2008-2010 and 1.8PJ total savings forecast in the period 2008-2016.

In an impact evaluation study on behalf of the Umweltbundesamt (2008), the combined impact of the Energy Consumption Labelling Ordinance and the Ordinance on Maximum Energy Consumption (GER7) on CO2 emissions until 2020 (starting from the introduction of the regulations) was estimated at about 6.4 Mt.

In another evaluation by Prognos/IER (2004), the energy savings, which are exclusively due to the Energy Labelling Ordinance, were estimated by comparing the real development of the appliance stock with a hypothetical trend line without the Ordinance[213].

5.3.5.2 The Netherlands

Data availability

According to the proforma, annual sales of appliances that are obliged to display an energy label under the current Directives are collected on an annual basis for white goods only. Therefore, lighting and air conditioning will not be captured.

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[213] Prognos AG, IER: Analyse der Wirksamkeit von CO2-Minderungsmaßnahmen im Energiebereich und ihre eiterentwicklung. Study on behalf the Federal Ministry of Economics and Labour. Basel, August 2004

Table 5.17 Data availability in the Netherlands

Information	Available?	Source	Comments
Annual sales of appliances obliged to display an energy label	Yes, annually, only for white goods	Not known	Will not capture air conditioning or lighting
Number of appliances owned per household	Yes, infrequently	Not known	Frequency not known
Breakdown of sales among energy label categories (A++, A+, A, ETC.)	Yes, annually, only for white goods	Not known	Will not capture air conditioning or lighting
Level of compliance with the Labelling Directive	No		
Information on energy consumption for households disaggregated by different applications	Yes, infrequently	Not known	Frequency not known
Data on actual observed energy use/patterns by appliance?	No		

Ex-post evaluations

An ex-post evaluation of energy efficiency policies and measures in the Netherlands including the energy labelling Directive. The introduction of energy-labels took place at nearly the same time that REB (Regulatory Energy Tax, NLD1) was introduced. In ECN (2009) it is stated that it is not possible to separate the influence of REB and labels, so the results show the combined effects. The combined effects in 2000 were estimated at 600kt of avoided CO_2 emissions and 3-4PJ of avoided energy consumption.

5.3.5.3 Slovenia

Table 5.18 Data availability in Slovenia

Information	Available?	Source
Annual sales of appliances obliged to display an energy label	Yes	GfK
Number of appliances owned per household	Yes	Questionnaire in 2010 (every three years) and other surveys about households living conditions (yearly).
Breakdown of sales among energy label categories (A++, A+, A, ETC.)	Yes	GfK

Information	Available?	Source
Level of compliance with the Labelling Directive	No	
Information on energy consumption for households disaggregated by different applications	Yes	Model calculation (2009-2010)
Data on actual observed energy use/patterns by appliance?	Yes (for all relevant appliances)	2010 questionnaire

Ex-post evaluations

There have been evaluations made in the process of compiling the second National Action Plan for energy efficiency (implementation of first National Action Plan). The saving was calculated as a difference between consumption of a 10-year old appliance versus a new appliance. In the sum only appliances that have replaced existing appliances have been taken into account. The impacts were estimated at 66 GWh of avoided energy consumption between 2008 and 2010.

5.3.5.4 Slovakia

No data is currently available on existing stocks or sales of appliances in Slovakia. No ex-post evaluation has been conducted yet.

5.3.5.5 UK

Table 5.19 Data availability in the UK

Information	Available?	Source
Annual sales of appliances obliged to display an energy label	Yes	Not known
Number of appliances owned per household	Yes	Not known
Breakdown of sales among energy label categories (A++, A+, A, ETC.)	Yes	Not known
Level of compliance with the Labelling Directive	No	
Information on energy consumption for households disaggregated by different applications	Yes	Not known
Data on actual observed energy use/patterns by appliance?	Yes – all relevant appliances	Not known

Ex-post evaluations

No ex-post evaluation of the Labelling Directive has been conducted but there has been some evaluation of consumer understanding of the label.

5.3.6 Tier 2: Discussion and recommendations

The survey of Member States indicates that there is significant disparity in data availability between MSs. For some countries, for example, Germany and the UK, data is available at a national level which would allow for an improved bottom-up Tier 2 assessment with annual sales data by energy label class and actual observed energy use/patterns.

On the other hand, other MSs (such as Slovakia), do not collect such detailed information on appliances and energy consumption and therefore will not be able to conduct a bottom-up assessment. However, these countries may be able to conduct a mixed bottom-up/ top-down approach using available EU-wide data on:

- Unit consumption in terms of kWh/appliances per year (e.g. from EuP studies on appliances) and
- Sales data (from PRODCOM and/or GfK).

Using these data sources would still allow for a more accurate assessment of impact. The previous methodology was based on the standardised usage for various appliances. The EuP studies, however, present data on actual observed energy use and patterns of appliances/devices within the home on a country-by-country basis. In addition, the previous methodology relied on the ODYSSEE database which includes the stock of appliances but does not make use of sales data or labelling. As outlined above, sales data is available from PRODCOM and GfK and could be used to provide a more accurate picture on the stock of appliances.

5.3.7 References

ECN (2009) Energy Efficiency Policies and Measures in the Netherlands. Available online: http://www.odyssee-indicators.org/publications/PDF/netherlands_nr.pdf

Fraunhofer ISI (2009) Energy Efficiency Policies and Measures in Germany. Available online: http://www.odyssee-indicators.org/publications/PDF/germany_nr.pdf

Jožef Stefan Institute (2009) Energy Efficiency Policies and Measures in Slovenia

6 Task 4 Proposals for Indicators

Besides the direct quantified ex-post effects of policies and measures, there is also the possibility to identify suitable indicators that allow monitoring of progress in the implementation of policies. Such indicators can be used to monitor progress in the past in addition to the detailed ex-post assessment. They have the advantage that their monitoring is less time-consuming than a full ex-post assessment. Such indicators therefore present a more simple, but limited way of assessing ex-post effects of policies and measures without constructing a counterfactual scenario and a “with measures” scenario. The progress is assumed to be indicated by an improvement in the indicator values over time.

Such indicators may be helpful but are not identical to the requirements for an ex-post assessment according to the described methodologies. Whereas the methodologies for ex-post quantification require a certain amount of additional work even for simple Tier 1 methods because the current emissions time series need to be calculated at a specified level of detail, a counterfactual scenario needs to be calculated and the emissions reductions calculated by subtracting the actual emissions from the counterfactual emissions, indicators that monitor the progress in the implementation of policies are much easier to derive but do not attempt to quantify the exact emission reduction effect achieved by a policy.

Indicators can be useful in tracking the performance of a policy over time by a simple combination of available statistical data. The indicators are less resource consuming to prepare and can show a relative (percentage) improvement without a detailed assessment of an effect on emissions. E.g. for the impact of the Renewable Directive, the Tier 1 ex-post methods quantifies the impact of renewable electricity on CO_2 emissions – requiring some detailed estimation which fuels are replaced with differentiated EFs - whereas the indicator proposed ‘Share of renewables in final energy consumption’ allows for a simple and quick assessment of effects of the implementation of the policy over time, however these effects are not necessarily in terms of emission reduction, but could be in other activity rates.

It is assumed that ex-post effects may not be quantified on an annual basis as GHG inventories, whereas indicators could be provided fast and with little additional effort to show a continuous progress of policy implementation.

The ex-post indicators proposed in this section should also match with the indicators used for an ex-ante assessment of policies and measures to allow a complete indication of effects both in the past and in the future.

- The structure of the proposed indicators follows the sectors and the policies covered in the project.
- Suitable indicators are proposed for the EU climate change policies as well as specific recommendations are prepared on how to best define indicators to report on the effectiveness of different types of policies currently planned or implemented at the MS level.

A table with indicators is proposed in Annex 1 (see section 10.1) including those indicators that are directly relevant in terms of GHG mitigation and costs but also those that are relevant in the process of getting to estimating the GHG and cost impacts (e.g. share of electricity generation from renewables) or are in general relevant in connection with the policy (this may be of interest for those PAMS that only indirectly tackle GHGs). The proposed table with indicators in Annex 1 is limited to the key indicators to focus on the most relevant indicators.

The table with the proposed ex-post indicators in Annex 1 is structured around the following columns:

- Policy or measure monitored by the indicator
- Indicator name
- Composition of indicator: numerator and denominator
- Unit
- Definitions for the parameters used as numerators or denominators and if appropriate additional guidance on the calculation of the indicator
- Sources where the data to calculate the indicator can be drawn from
- Comments

The indicators proposed are differentiated in two ways:

1. Whether the indicators are based on available statistics and/ or existing EU legislation related to statistics and reporting or whether they are based on additional data that needs to be gathered at MS level. It is assumed that indicators for which information is already reported based on existing EU legislation is cost-efficient in the reporting while indicators that are based on additional information which is not part of current statistics or legislation may require additional data collection efforts at MS level and may therefore incur additional costs at least for some MS.
2. Whether the indicators are useful for tracking progress with EU policies relevant for all Member States or whether they are useful for tracking of specific policies at MS level. The latter category of indicators may not be relevant for all MS in the same way depending on the national climate change and sectoral policies as well as the relevance of certain sectors in relation to total GHG emissions.

Table 6.1 and Table 6.2 provide an overview of the indicators proposed, differentiated related to data availability. The compilation of most of the indicators proposed for the energy sector, the agriculture sector and the waste sector is straightforward based on available statistics and GHG inventories. However, policies in the transport sector, the buildings sector, electricity use in the residential sector as well as for F-gas policies usually require additional data collection efforts at MS level and will therefore be related with higher costs.

Table 6.1 Indicators based on available statistics and/ or existing EU legislation

Sector	Indicators name	Data source	EU policy and/ or national policy
Energy, Electricity	CO_2 intensity of electricity generation, E1	Energy statistics regulation (Regulation (EC) No 1099/2008) and current Monitoring Mechanism Decision (Decision 240/2004/EC)	EU policy, EU ETS, RES-E, CHP Directives
Energy, Electricity	Estimated net GHG emission savings from the use of renewable electricity , E2	Renewables Directive 2009/28/EC, Template for Member State progress reports under Directive 2009/28/EC, Table 6 (based on methodology and reporting as provided under this Directive)	EU policy, RES-E,
Energy, Electricity	Estimated net GHG emission savings from the use of renewable energy in heating and cooling, E3	Renewables Directive 2009/28/EC, Template for Member State progress reports under Directive 2009/28/EC, Table 6 (based on methodology and reporting as provided under this Directive)	EU policy, RES-E,
Energy, Electricity	Estimated net GHG emission savings from the use of renewable energy in transport	Renewables Directive 2009/28/EC, Template for Member State progress reports under Directive 2009/28/EC, Table 6, (based on methodology and reporting as provided under this Directive)	EU policy, RES-E,
Energy, Electricity	Share of CHP in electricity production, E4	Energy statistics regulation (Regulation (EC) No 1099/2008),	CHP Directive
Energy,	Energy-related CO_2intensity of industry, E5	GHG inventories, national accounts	ETS, energy efficiency targets
Energy	Share of oil and coal in energy consumption E6	Energy statistics regulation (Regulation (EC) No 1099/2008),	EU ETS, policies to promote fuel switch
Energy	Proportion of taxes in energy	Eurostat data, DG ENER	Energy taxes

Sector	Indicators name	Data source	EU policy and/ or national policy
	prices, E7		
Energy	Energy efficiency in the services sector, E8	Energy statistics regulation (Regulation (EC) No 1099/2008), employment statistics	Energy efficiency policies
Industrial processes, F-gases	F-gas emissions per capita, F1	GHG inventory, Eurostat/ national population statistics	F-gas regulation
Agriculture	Specific CH_4 emissions of cattle production, A1	Eurostat and national agriculture statistics	CAP
Agriculture	Specific N_2O emissions of fertiliser and manure use, A2	Eurostat and national agriculture statistics	CAP, national polices to reduce fertilizer use
Agriculture	milk production per cow, A3	Eurostat and national agriculture statistics	CAP
Agriculture	Specific fertilizer use, A4	Eurostat and national agriculture statistics	CAP, national polices to reduce fertilizer use
Waste	Fraction of municipal solid waste disposed to landfills, W1	Eurostat and national waste statistics	Landfill Directive
Waste	CH_4 recovery related to total CH_4 emissions from solid waste disposal, W2	GHG inventory, CRF table 6.A	Landfill Directive
Waste	Waste generation rate, W3	Eurostat and national waste statistics, Eurostat and national population statistics	Landfill Directive, policies to reduce waste generation
Waste	Fraction of municipal solid waste inciner-	Eurostat and national waste statistics	Landfill Directive

Sector	Indicators name	Data source	EU policy and/ or national policy
	ated, W4		
Waste	Fraction of municipal solid waste recycled, W5	Eurostat and national waste statistics	Landfill Directive, policies to enhance waste recycling

Table 6.2 Indicators that require additional statistics and surveys at MS level

Sector	Indicators name	Data source	EU policy and/or national policy
Transport	Passenger car CO_2 intensity, T1	GHG inventory, national transport statistics	Regulation (443/2009) setting emission performance standards for new passenger cars
Transport	Freight transport CO_2 intensity, T2	GHG inventory, national transport statistics	Setting performance standards for freight transport
Transport	Energy efficiency in the transport sector	Energy statistics, national transport statistics	Increasing energy efficiency of transport sector
Buildings	Final energy consumption for space heating (or other relevant functions) in the residential and services sector, B1	National energy statistics and surveys for space heating (or other relevant functions) consumption, Number of households and employees from Eurostat or national statistics, floor space from national statistics	Energy efficiency of buildings
Buildings	CO_2 intensity of space heating (or other relevant functions) in the residential and non-residential build-	National energy statistics and surveys for space heating (or other relevant functions) consumption, Number of households and employees from Eurostat or national statistics, floor space from national statistics	Emission intensity of buildings

Sector	Indicators name	Data source	EU policy and/or national policy
	ings sector, B2		
Buildings	Cost effectiveness of energy efficiency investments in buildings, B3	Total investments in energy efficiency from national statistics, energy consumption as previous indicators	Energy efficiency of buildings
Residential	Emission intensity for appliances and lighting in the residential sector, R1	Eurostat, Odyssee, national surveys	Energy efficiency of electric appliances in households
Residential	Electricity consumption for appliances and lighting in the residential sector, R2	Eurostat, Odyssee, national surveys	Energy efficiency of electric appliances in households
Residential	Proportion of sales of highly-efficient energy labels in new sales, R3	national surveys and market research studies	Energy efficiency of electric appliances in households
Industrial processes, F-gases	Refrigerant leakage rate, F2	to be investigated in sectoral studies, provided by industry	F-gas regulation
Industrial processes, F-gases	F-gas reclamation per tons emitted, F3	To be requested from reclamation facilities	F-gas regulation
Industrial processes, F-gases	F-gas destruction per tons emitted, F4	To be requested from destruction facilities	F-gas regulation

7 Task 5 Quality Assurance and Quality Control

7.1 Introduction and short overview of QA/QC

In the context of monitoring and evaluation, Quality Control (QC) is a system of routine technical activities to assess and maintain the quality of the assessment, usually performed by the personnel undertaking the reporting activity. A good QC system will aim to:

1. Provide routine and consistent checks to ensure data integrity, correctness, and completeness;
2. Identify and address errors and omissions;
3. Document and archive any supporting material and record the QC activities and checks made.

Quality Assurance (QA) is a planned system of review procedures, usually conducted by personnel not directly involved in carrying out the core evaluation. In general, the review will check overall coherence, and ensure that the results and methodology taken are an optimal approach given any constraints such as data availability and project resources.

Overall, the benefits of undertaking QA/QC activities include improved transparency, consistency and accuracy. However, it is important that any QA/QC activities are tailored to the requirements and scale of the evaluation, so as to be cost effective. In the context of the reporting of ex-post evaluation of PAMs, the QA/QC approach should be focussed, feasible and cost effective, and not too onerous on top of existing requirements.

The following sections firstly summarise the existing QA/QC requirements for inventories, projections and reporting on policies and measures under the Kyoto Protocol and EC Monitoring Mechanism. A proposed approach to QA/QC within the context of ex-post evaluation of PAMs is then set out, which seeks to complement the existing activities. This draws upon relevant material from the EEA and European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM).

7.2 Existing requirements under the Monitoring Mechanism

The Kyoto Protocol is implemented at EU level through Decision 280/2004/EC (or "Monitoring Mechanism Decision" (MM)). This sets out provisions for regular reporting on emissions, emission projections, and policies and measures. As part of this requirement, the reporting should be ‘complete, accurate, consistent, transparent and comparable’. This is a reference to the approach for QA/QC set out and defined in the UNFCCC documents ‘Guidelines for the preparation of national communications by Parties’ (1999) and the ‘Annotated Outline for Fifth National Communications of Annex I Parties’ (no date).

This is known as the TCCCA framework (transparency, comparability, consistency, completeness and accuracy). This framework sets out good practice to check the following:

- “Transparency”: of sources, methodology and assumptions
- “Completeness”: of sources of emissions and fuels
- “Comparability”: standardised methodology across MS
- “Consistency”: primarily internal consistency
- “Accuracy”: no errors in application of assumptions or biased assumptions

Emissions inventories and reporting

The Decision establishes a mechanism for monitoring all anthropogenic GHGs, whereby Member States and the Community establish national inventory systems. Member States must communicate these to the Commission at the beginning of each year. The Commission then prepares an inventory and a report on the greenhouse gases in the Community for the Secretariat of the UNFCCC. The reporting on inventories follows the TCCCA framework, with a formalised IPCC review procedure. According to good practice, a QA/QC plan is used to set out the planned activities, schedule and allocated roles.

Emission Projections reporting requirements

Member States are also required to compile projections for 2015 and 2020. The EU guidelines for GHG emission projections are currently being elaborated and tested in an ongoing study for the Commission, and adopt the same TCCCA framework. The guidelines aim to ensure that projections include enough information to allow readers to understand the underlying assumptions and to reconstruct the calculations for each of the estimates included. In general, the approach follows that of the GHG inventory:[214] numbers are recorded in a reporting template, whereas descriptions and explanations are set out in an accompanying report.

Provisions for reporting on PAMs

Under the Monitoring Mechanism, Member States are also required to report on policies and measures every two years, from 2005. PAMs are reported on a sectoral basis, including the status of implementation, indicators to monitor and evaluate progress and quantitative estimated of the effect of PAMs including ‘their economic impacts to the

[214] TNO, Oko Institut, Aether and AMEC (2012): General GHG Projection Guidelines report, draft version (not published).

extent feasible', and the relative contribution and overlap with domestic initiatives. QA/QC checks are also undertaken by the EEA and ETC-ACM.

The UNFCCC documents contain some guidance on how the information on policies and measures should be reported, however, compared to the standardised requirements for the reporting of the historic inventories and formalised IPCC review procedure, the reporting of the information on policies and measures is less standardised and until 2011, there was no review procedure (ETC/ACM, 2012). In an effort to improve the comparability and consistency of the reported data, the EEA and ETC-ACM put together an optional template for the reporting of projections and policies and measures in 2006 and made this available to Member States along with supporting guidance (ETC/ACM, 2012).

There were four major elements in the Quality Assurance / Quality Control (QA/QC) procedure, namely; completeness, consistency (internal consistency), comparability and the accuracy of the ex - ante emission saving figures reported for each policy.

The EEA (2012) states that the QA procedure under the MM Decision will continue to be improved in future years. Future planned developments include more detailed Accuracy checks to be conducted from 2013 using thresholds developed from the 2011 submissions. This will involve benchmarking, where possible, between Member States and the involvement of sector experts.

Table 7.1 Overview of the checks included in the EEA QA/QC plan (EEA, 2012)

Step	Criteria	Objective	Checks
1	Timeliness	To assess if information was submitted on time and identify as early as possible the potential need to gap fill missing or incorrect information.	1. Record the dates the MS submission is uploaded to the Eionet's Reportnet Central Data Repository (CDR). 2. Track the number of revised submissions made by the Member State after 15th March in the check files.
2	Transparency	To assess whether MS provide methods and references in the template or the report	Check that references and methodology descriptions are provided as links in the template or in the report.
3	Completeness	To ensure that full information has been reported for national implementation of all existing EU policies	Check that all mandatory information is included Determine the percentage of completeness for mandatory and recommended information.

4	Comparability	1. To ensure that the information reported by Member States is comparable 2. To assess whether MS are using the template 3. To ensure the use of consistent definitions for the information reported by MS 4. To ensure sectors reported following GHG inventory reporting and IPCC guidelines. 5. To ensure there is consistent use of notations	1. Comparability across Member States: Record the use of the template for each MS. 2. Comparison of the submission with the illustrative 'good practice' examples provided in the reporting guidance. This document contains practical instructions for the reporting of policy information and provides comprehensive guidance on the required information set by the MM Decision (i.e. content of each column of the reporting template), along with a set of example inputs. This year a best practice example is also provided in the first row of the template. 3. Assessment on whether each policy is recorded under the correct sector in line with the IPCC guidelines. 4. Assessment for each submission to check standard notations have been used

5	Consistency	1. To assess whether the information reported for an individual policy is consistent with the definition and objective of the policy. 2. To assess whether the policy reference numbers are consistent.	4. Internal consistency: assessment for each policy reported as to whether the information reported under different columns is consistent. 5. Consistency between and within years: confirmation that the same policy has the same reference number in: a. submissions from different years; and b. the submission, where multiple rows has been reported for a single policy (see reporting guidance)
6	Accuracy	To assess whether ex-ante estimates of policy impacts are credible.	Comparison of the quantitative ex-ante policy saving estimates with other MS and other data sets. A number of checks are based on comparisons against the reported projections and other datasets.

7.3 Proposed QA/QC framework for ex-post evaluation

There is good potential for improved transparency, comparability and consistency through the simple adoption of a tiered methodology approach. The EEA/ETCA (2012) state that in their assessment of 2011 reporting under the EU Monitoring Mechanism:

> *Just 16% of total reported policies included a reference for the source of emission estimates. Sixteen Member States did not report this information at all. However, this element of reporting was not a mandatory part of the submission.*

They also point out that common methodologies would benefit the overall comparability of the quantitative Member State submissions.

In general, QA/QC checks for ex-post evaluation should include simple comparisons of indicators, key datasets etc. Furthermore, comparisons can be made against other ex-ante and/or ex-post studies as well as with other Member States.

If a reporting template is used then this could facilitate some of these headline/output checks. The responsibility for QA/QC checks for ex-post evaluation lies mainly with the

Member States, although there are a number of fairly simple checks that can also be undertaken by the Commission.

First set of checks – T, C, C, C

The first set out checks is aimed at satisfying the transparency, consistency, comparability and completeness. These outlined checks are considered to be relatively quick, and will furthermore save time and costs further down the line if executed well at an early stage. As such, it may be most effective for these to be undertaken by MS in a first instance, supplemented by a degree of comparison between MS undertaken by the Commission or other central body.

Transparency requires that when alternative sources to those proposed (e.g. Eurostat energy statistics) are used, this should be clearly signposted and justified. The same applies for any deviation from the tiered methodologies. The methodology, sources, inputs and results should be clearly set out and labelled.

Based on the analysis of the ETC-ACM, encouraging the use of a reporting template should improve the comparability of the submissions. The following checks would be useful in the context of the comparability requirement:

6. Checking the definitions are applied correctly for sources of emissions to enable accurate comparison.
7. Checking that when a counterfactual has been derived, the same approach and time period has been selected across Member States.
8. Consistent terminology, notation keys, labelling conventions and units across Member States, indicators and tiered evaluations.

Guaranteeing internal consistency should be a priority at Member State level in a first instance. Checks could be automated to an extent in a reporting template.

Completeness consists in ensuring that all sources have been included in totals e.g. in cases such as F-gas where the sources included in absolute emissions are listed and delimited. A reporting template could be set up to display the level of completeness in the submission as is already the case on the optional Monitoring Mechanism reporting template. It also means ensuring that all PAMs and indicators have been reported on.

Second stage - accuracy

EEA (2012) describes accuracy as a ‘relative measure of the exactness of an emission saving estimate’. It adds that ‘[e]stimates should be accurate in the sense that they are systematically neither over nor under true emissions savings, as far as can be judged, and that uncertainties are reduced as far as practicable.’

The current checks undertaken by the ETC-ACM to improve accuracy include:

i. Alignment of top down and bottom up estimates

ii. Overestimates within a particular sector – identified by comparing the sum of the emission savings against the relevant sectoral projections. Clarifications are asked from Member States if the impact of EM policies is more than 20% of the projected emissions in that sector (25% in the case of 'additional measures')

iii. Large revisions since the previous submission in the cases of differences of more than 100%.

A similar approach to accuracy would be well suited to the context of PAM reporting. Comparisons with other ex-post and ex-ante assessments would be useful contextual evidence for supporting the results. This might be most appropriate in cases where irregularities are picked up, as in the three broad checks outlined above. It may be worth considering whether to set up the reporting template with validation criteria, for example to ensure that results are within a given order of magnitude, or range based on given inputs. Alternatively, in instances where the checks indicated a Member State's estimate of savings appears high or low, the Member State could be asked to reconsider the submission and provide a short explanation for how emission reductions are expected to be achieved, in line with current practice on the MM reporting template.

A set of indicative QA/QC checks are set out in Table 7.2.

Table 7.2 Indicative QA/QC checks

QA/QC Activity Reference	QA/QC Activity Description	Objective	Indicative level of resource required
Member State checks			
MS1	Verification that all mandatory/recommended information is included.	Completeness	Low
MS2	Verification that information has been reported for all existing EU policies.	Completeness	Low
MS3	Check that all relevant sources of emissions are included, and all MS level PAMs.	Completeness	Medium
MS4	References supplied for all data sources, hyperlinks still active where used.	Transparency	Low
MS5	Methodology selected and used for evaluation is stated (e.g. which Tier). Any deviations from tiered methodologies are signposted and explained.	Transparency	Low/Medium
MS6	All assumptions are made explicit.	Transparency	Low
MS7	Consistency in reporting methodology across PAMs reported.	Consistency	Low
MS8	Consistent use of terminology, notation keys, units and definitions. Counterfactual derived according to the tiered methodology approach.	Comparability	Low
MS9	Check the units.	Accuracy	Low

QA/QC Activity Reference	QA/QC Activity Description	Objective	Indicative level of resource required
MS10	Cross-check key datasets, main results and indicators with other top-down/bottom-up estimates, with estimates from previous reporting year, other MS estimates and any other ex-ante or ex-post assessments. Comment if >100% (or another threshold) difference.	Accuracy	Medium/High
European Commission checks			
EC1	Assessment of the percentage of the recommended information provided.	Completeness	Low/Medium (Note 1)
EC2	Consistent use of definitions, approach, terminology, assumptions, notation key, conversion rates applied across MS.	Consistency / Comparability	Medium
EC3	Cross-check results with previous reporting year, and any other ex-ante or ex-post assessments. Query with MS if >100% (or another threshold) difference.	Accuracy	Medium/High
EC4	Cross-check sum of the emission savings by sector against the relevant sectoral projections (Note 2) to assess magnitude of difference.	Accuracy	Medium
EC5	Comparison of indicator across MS, benchmarking.	Accuracy	Medium
EC6	Additional checks on master spreadsheet using filters, pivot tables etc. to spot any inconsistencies/data which are not comparable.	Consistency	Medium

Note 1: Very low if MS is using a reporting template with this function built in. Otherwise medium – a qualitative approach may be more appropriate depending on resource availability and priorities.

Note 2: EEA requests clarifications are asked from Member States if the impact of WEM policies is more than 20% of the projected emissions in that sector (25% in the case of 'additional measures').

Comments on PAM-specific checks are picked up in the reporting template for indicators and data collection and monitoring.

7.4 References

EEA, 2012. Quality assurance / quality control procedure for the reporting of policies and measures under Decision 280/2004/EC (the EU Monitoring Mechanism Decision) Draft Version 2 – June 2012 referred to here.

ETC/ACM, 2012. Assessment of the Member States' policies and measures submitted under the EU Monitoring Mechanism in 2011 ETC/ACM Technical Paper 2011/19 February 2012

UNFCCC, 1999. 'Guidelines for the preparation of national communications by Parties'

UNFCCC, no date. ‘Annotated Outline for Fifth National Communications of Annex I Parties’

8 Task 6 Monitoring and Reporting

This task addresses additional legal requirements for the reporting of Member States to the Commission in the area of ex-post assessment of policies and measures.

The proposal for a regulation on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change already foresees a requirement to report quantitative estimates of the effects on emissions by sources and removals by sinks of greenhouse gases in Article 14(c)(v) broken down into:

- the results of ex-ante assessment of the effects of each policy and measure. estimates shall be provided for a sequence of 4 future years ending with 0 or 5 immediately following year X, with a distinction between greenhouse gas emissions covered by Directive 2003/87/EC and those covered by Decision No 406/2009/EC;
- the results of ex-post assessment of the effects of each policy and measure on the mitigation of climate change where available, with a distinction between greenhouse gas emissions covered by Directive 2003/87/EC and those covered by Decision No 406/2009/EC.
    - Article 14(c).vi also refers to projected or realised costs.

Delegated acts under this Article could specify more detailed requirements for the reporting of the results of ex-post assessments of effects of mitigation policies and measures by MS with respect to

1. Reporting formats for the results on effects and costs to achieve comparable information across MS
2. Information on methodologies used to achieve transparency about the approaches and methods used to estimate the effects

8.1 Reporting format of results

A reporting format of the results of ex-post assessments is provided covering the following information (see 10.2- Annex 2).

- Sector and source category/ subsector for which emission reduction is assessed
- Policy or measure that is assessed
- Starting point of the evaluation
- Time series of emission trend for the counterfactual emissions for the years between the starting point and the most recent year covered by the reporting

- Time series of actual emissions between the starting point and the most recent year covered by the reporting
- Emission reduction achieved across the time series for the policy or measure assessed.
- Indication of technical reports that underpin the ex-post assessment and that describe the models, methodologies, data sources and assumptions used.

For improved transparency the template requires a separate reporting of the counterfactual emissions and the actual emissions, this also allows QA/QC checks for consistency of the actual emissions used in the estimation with the inventory data.

The number of years to be reported in the past depends on the starting point of the policies. As it also usually takes a while until adopted policies show ore significant effects, it is proposed to report at least 15 years backwards as a default.

9 Task 7 Monitoring and data collection strategies

This chapter provides an overview of the key data needed to conduct an ex-post assessment using the methodologies and Tiers as suggested in Task 2 of the report. It partly summarizes the information on data needs provided in Task 2, but combines the necessary monitored data in a clear structure. A tabular overview aims to present this information in a consistent, comparable way and thus help MS and the EC decide whether they have sufficient data available for a specific Tier or methodology. It addresses the main questions of MS and the EC in terms of:

1. What kind of data do we need?
2. What data sources are available (indicating EU legislation under which relevant data is collected) and
3. Where do we need to collect new data to achieve robust ex-post assessment results and where is data lacking?

The aim is also to include information on Tier levels and methodologies even for those that are not currently recommended. The monitoring and data collection strategies proposed shall reflect the characteristics of target sectors (energy, waste, transport, agriculture and industrial processes) and their respective heterogeneity.

In the third step, the development of data collection strategies, the project will also identify the existing legislation at EU level in which the identified data requirements could be incorporated.

Structure of tabular format:

- Specification of methodology and Tier
- Sector
- Type of data

- Unit
- Definitions used
- Sources of data
- Comments

9.1 Energy

The data needed to apply the methodologies for an ex-post assessment of the EU ETS as described in detail in this report is summarized below and shown in more detail in Table 9.1.

Data needed to apply the proposed methodologies: Methodologies for two different tier levels (Tier 2 and Tier 3) are proposed and tested within this study. Some of the data needs apply to both tier levels. This includes data on fuel prices (lignite, hard coal, natural gas, fuel oil), annual average CO_2 prices and CO_2 emission factors. This data is by and large publicly available and can be obtained from IEA statistics, point carbon and/or IPCC guidelines. Data on fuel prices may to some extent (e.g. lignite) be unpublished or confidential.

For a *Tier 2 level* analysis the following complementary input parameters are needed

- Energy consumption (data source: IEA Energy Balances)
- Energy prices (data source: IEA Energy Prices)
- Total net electricity generation per year (data source: e.g. Eurostat)
- Total CO_2-emissions from electricity generation per year (data source: e.g. CITL, Eurostat or EEA)
- Average annual electricity spot market price (data source: e.g. national electricity market)
- Assumed price elasticity (data source: e.g. Cambridge Econometrics[215])
- Fuel costs and other variable costs as well as electrical efficiency to derive specific marginal generation costs per power plant type (data source: e.g. technical literature and statistics, fuel prices could be unpublished or confidential)
- Installed capacity and average availability per fuel type specific power plant type to derive a simplified merit order (data source: e.g. IEA Electricity Information, technical literature or statistics)

[215] Elasticities are commonly available. See, for example, Cambridge Econometrics (2010), http://www.scotland.gov.uk/Resource/Doc/1035/0103829.pdf. It should be noted that it is also assumed here that all cost increases are passed on in the form of higher prices. For electricity, which is not usually subject to international competition, this assumption seems reasonable (and also is common in the Tier 3 modelling approach).

- Average residual load, which has to be covered by the power plant fleet (data source: entsoe[216] - European Network of Transmission System Operators for Electricity)
- Share of carbon costs in gross value added for ETS sectors (data source: DG Climate Action: http://ec.europa.eu/clima/policies/ets/leakage/documentation_en.htm)
- Gross value added, output, labor costs for ETS sectors (data source: Eurostat SBS)
- Price elasticities for economic sectors (data source: literature review)

To conduct a full *Tier 3 level* analysis as laid out in the report the following input parameters are needed

- Energy consumption (data source: IEA Energy Balances)
- Energy prices (data source: IEA Energy Prices)
- Power plant fleet with installed capacity (MW), availability (%), electrical efficiency (%),variable costs (€/MWh electricity), and CHP plant (yes/no)
- Electricity demand, RES feed-in and must-run generation in hourly resolution
- CHP profile in hourly resolution (generic data)
- Storage power plants with installed capacity for pumping and generation (MW), efficiency of pumping and generation (%), storage capacity (MWh) and variable costs (€/MWh electricity)
- Access to economic model and its inputs.

Identification of existing legislation at EU level in which the identified data requirements could be incorporated: Some of the data needed, such as CO_2 emissions in the power sector, is already required for reporting in the Monitoring Mechanism Decisions 240/2004/EC. Another source of information is the Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics which requires reporting on electricity generation differentiated by source as well as energy consumption by fuel type.

[216] https://www.entsoe.eu/

Table 9.1 Energy – Key data needs for ex-post quantification

No	Specify for which methodology and tier the	Sector	Type of data	Unit	Guidance / definitions	Guidance / source
Energy Policies						
1	ETS: Tier 2	Electricity	Annual net electricity generation	MWh		IEA statistics "Electricity Information"
2	ETS: Tier 2	Electricity	Annual average electricity spot market price	€/MWh		national electricity market, e.g. EEX, PXE, Nordpool
3	ETS: Tier 2	Electricity	surrendered certificates of CO2 emissions	t CO2	EUA+CER+ERU	CITL database, EEA data viewer
4	ETS: Tier 2	Electricity	price elasticity of electricity demand	%		e.g. default assumption -20% from Cambridge Econometrics
5	ETS: Tier 2, Tier 3 basic and Tier 3	Electricity	Fuel prices	€/MWh	prices of lignite, hard coal, natural gas and fuel oil	literature, e.g. IEA statistics "Electricity Information" or future prices of fuel types (e.g. Mc Closkey Coal, natural gas markets) plus transport and other costs
6	ETS: Tier 2 and Tier 3 basic	Electricity	Electrical efficiency of simplified power plant fleet	%	fuel type specific parameter	literature, e.g. 2011/877/EU on establishing harmonised efficiency reference values for separate production of electricity and heat
7	ETS: Tier 2 and Tier 3 basic	Electricity	Annual availibility of simplified power plant fleet	%	fuel type specific parameter	national energy statistics or assumption (e.g. 90%)
8	ETS: Tier 2, Tier 3 basic and	Electricity	Annual average CO2 price	€/t	spot market price	e.g point carbon
9	ETS: Tier 2, Tier 3 basic and Tier 3	Electricity	CO2 emission factor	t CO2/MWh fuel input	emission factor	e.g. IPCCC guidelines for emission inventories
10	ETS: Tier 2 and Tier 3 basic	Electricity	Marginal costs of simplified power plant fleet	€/MWh	fuel type specific marginal costs	derived from previous data
11	ETS: Tier 2 and Tier 3 basic	Electricity	Simplified Merit Order	MW and €/MWh	combination of installed capacity and marginal costs	derived from previous data
12	ETS: Tier 3 basic and Tier 3	Electricity	RES-E feed in profile in hourly resolution	MW		national grid operator or generic profile
13	ETS: Tier 3 basic and Tier 3	Electricity	Demand profile in hourly resolution	MW		grid load from entsoe database
14	ETS (as well as CHP and RES-E Directive): Tier 3	Electricity	CHP profile in hourly resolution	%	assumed heat demand of CHP plants including saisonal, day-night and weekend effects	individual plant data or generic profile
15	ETS (as well as CHP and RES-E Directive): Tier 3	Electricity	Capacity of power plant fleet	MW	installed capacity of individual power plant	UDI Platts database or other commercial power plant databases for detailed merit order

No	Specify for which methodology and tier the	Sector	Type of data	Unit	Guidance / definitions	Guidance / source
16	ETS (as well as CHP and RES-E Directive): Tier 3	Electricity	CHP plant	yes / no	specific parameter for individual plants	UDI Platts database or other commercial power plant databases for detailed merit order
17	ETS (as well as CHP and RES-E Directive): Tier 3	Electricity	Electrical efficiency of detailed power plant fleet	%	specific parameter for individual plants	specific plant data or dervied from year of comissioning, default values from literature, e.g. 2011/877/EU on establishing harmonised efficiency reference values for separate production of electricity and heat
18	ETS (as well as CHP and RES-E Directive): Tier 3	Electricity	Annual availibility of detailed power plant fleet	%	specific parameter for individual plants	literature or specific plant data (e.g. revision or off-time periods of specific nuclear power plants)
19	ETS (as well as CHP and RES-E Directive): Tier 3	Electricity	Specific investment costs and technical lifetime for	%	specific parameter for different power plant technologies	literature (e.g. scientific paper on electricity sector modelling)
20	ETS (as well as CHP and RES-E Directive): Tier 3	Electricity	Technical lifetime	%	specific parameter for different power plant technologies	literature (e.g. scientific paper on electricity sector modelling)
21	ETS: Tier 2 and Tier 3 basic	Electricity	Energy consumption	GWH, tonnes of oil equivalent, or similar	amount of energy consumed by each sector	IEA energy balances
22	ETS: Tier 2 and Tier 3 basic	Electricity	Energy prices	€ per GWh or similar	basic energy prices	IEA energy prices
23	ETS Tier 2	Industry	Share of carbon costs in GVA	%	Assumes an ETS price of €30/tCO2. Gives direct and indirect (from electricity) carbon costs. Figures provided at NACE 4-digit level for all manufacturing sectors.	DG CLIMA, http://ec.europa.eu/clima/policies/ets/leakage/documentation_en.htm
24	ETS Tier 2	Industry	GVA, output, labour costs	Mio. Euros	In Industry, Trade and Services branch. Eurostat provides data at NACE 4-digit level for all sectors.	Eurostat SBS
25	ETS Tier 2	Industry	Price elasticities	ratio	Determines output reduction in response to price change. Technically not data, as it cannot be observed in reality, but provides necessary inputs to the analysis. Suggested sources: academic analysis, econometric studies, other published literature.	Previous studies

9.2 Industry

The data needed for applying the methodologies for an ex-post assessment of emission reductions and costs of the industry related IPPC Directive as laid out in the report is briefly described below. A more distinguished tabular summary is provided in Table 9.2

Data needed to apply the proposed methodologies: In this study it has been proposed that the highest emitting sectors are prioritised for assessment (e.g. Large Combustion Plants >50MW). The specific data required for assessment will depend upon the sector under investigation. However, in general the key types of data required to perform an ex-post assessment of polices covering the industrial sector, such as the IPPC Directive, for each sector are

- Emissions from installations;
- Activity data (units produced);
- Number of installations;
- Abatement measures implemented (specifically for IPPC);
- Estimates of unit costs for abatement measures;
- Reports on changes in exogenous variables which affect the counterfactual

The general data usage in the different Tier levels is proposed as follows:

Tier 1 level:

Using EU-wide information sources such as Eurostat, PRIMES, CITL, E-PRTR and sector specific data sources such as the LCP emissions inventory.

Tier 2 level:

Uses MS-specific data such as MS-specific EFs and accounting for autonomous progress with consideration of MS policies.

Tier 3 level:

This level of assessment requires plant-specific information. Operators could be surveyed and sector experts in MS competent authorities could be consulted to obtain actual activity rates, uptake of abatement measures and emissions data.

Data needs for methodologies that are currently not recommended: A Tier 1 level analysis is not recommended. Instead Tiers 2 and 3 are recommended. However, the Tier 3 approach proposal will be extremely resource intensive due to the quantity of data required at an installation level and the work required to properly assess the impact of other policies and exogenous variables on the counterfactual.

Identification of existing legislation at EU level in which the identified data requirements could be incorporated: The Industrial Emissions Directive (IED; which now includes the IPPC Directive amongst others) will be reviewed by 7 January 2016. Data reporting requirements serving the additional indicators proposed in Annex 1 might be established in an updated IED reform.

Table 9.2 Industry – Key data needs for ex-post quantification

No	Methodo-logy	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
Industrial Sector							
1	IPPC tier 1 *Data also required for IPPC tier 2*	Industry - Separate data collection by industry category. The largest emitters of air pollutants are the most appropriate sectors to be assessed inititally: LCPs, Refineries, Coke production, Integrated steelworks, Cement, Glass and Pulp&Paper Manufacturing	Activity data - dependant on industry category	LCPs - heat / electricity production, Other industry - units of production (e.g. t clinker produced)	For industries which produce a single, uniform product, the activity unit is easily defined – e.g. for cement, production of clinker is the obvious unit to be used. For industries which produce a diverse range of products (e.g. glass, pulp&paper, refineries), it will be necessary to convert estimates of output to a single unit. For industries which have a highly diverse range of products (e.g. all industries which use LCPs), a proxy for production, such as electricty / heat production can be used.	Eurostat contains data on production for some sectors, although data is not differentiated by firm size and so may include production from installations outside the scope of IPPC and the unit of production may not include all of the relevant product information (e.g. type of refinery product). Eurostat contains information on the consumption of different types of fuel for certain sectors and processes (e.g. coke ovens, blast furnaces), which could be used as a proxy for production, but may contain production from installations outside the scope of IPPC. PRIMES contains assumptions on energy use for the main relevant sectors, which could be used as a proxy for production. However, categorisation in PRIMES does not match Annex 1 IPPC activities and PRIMES includes fuel use by installations not covered by IPPC. LCPs - total fuel consumption data from the LCP inventory.	*The appropriate data source will depend upon the sector to be investigated; it may be necessary to make assumptions or to use proxy data in order to estimate activity data.*
2			CO_2 emissions	kt CO_2 emission	Where CO_2 emission data is available at a sector-level, this may be used directly. Where CO_2 emission data is not available, fuel consumption data may be used in conjunction with fuel-specific Emission Factors to estimate emissions.	CITL – includes CO_2 emissions data an installation level, which could be summed to a sector level total. However, CITL only includes installations which are included in the EU ETS, which does not match the scope of IPPC. EPER / E-PRTR – includes CO_2 emissions data an installation level, which could be summed to a sector level total. However, only those installations above the threshold levels are included. Data sources for fuel-consumption for use in estimating CO_2 emissions: Eurostat contains information on the consumption of different types of fuel for certain sectors and processes (e.g. coke ovens, blast furnaces), but may contain production from installations outside the scope of IPPC. PRIMES contains assumptions on energy use for the main relevant sectors. However, PRIMES includes fuel use by installations not covered by IPPC. LCPs - total fuel consumption data from the LCP inventory.	*The appropriate data source will depend upon the sector to be investigated; it may be necessary to make assumptions or to use proxy data in order to estimate CO_2 emissions.*
3			Implementation costs	€		Eurostat contains data on, 'Environmental expenditure for the protection of ambient air and climate'. However, this is aggregated at a very high level and will include expenditure by installations not within the scope of IPPC, so is not normally appropriate to use here.	*This method is not reccomended - see Tier 1 / 2 (below) for alternative*

No	Methodo-logy	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
4	IPPC tier 1 / 2	Industry - Separate data collection by industry category.	Uptake of abatement measures (including abatement of air pollution)	% uptake		IRIS contains IPPC implementation reports for some sectors (currently, cement and Iron&Steel), which includes data on abatement measure uptake. BREF documents often information on abatement measure uptake across the sector. MSs may have conducted sector reviews. (Tier 2) See above for relevant data sources for estimating EFs for other air pollutants. For sectors where summary data is available on the uptake of abatement measures, this may be used directly. Where no data exists on the uptake of abatement measures, differences in EFs over time may be used to make assumptions on the uptake of abatement measures. For example, a sector's SO2 EF reduces by 90% over the time period, but the use of fuel (type) does not change; it may be assumed that there has been 100% uptake of Wet FGD with an abatement efficiency of 90%for all installations in the sector. Alternatively, if the EFs for air pollutants and the EF for CO2 reduce at the same rate, but the fuel mix remains constant, it may be assumed that energy efficiency measures have been implemented.	*Where changes in EFs are used as the basis to estimate abatement measure uptake, good knowledge of the sector is required in order to make valid assumptions on abatement uptake; this is particularly true of sectors where a wide range of abatement measures (and in varying proportions) could have been applied to achieve the same reduction in EF.*
5			Number/Capacity of installations	Number / tpd		To estimate the costs of compliance with IPPC, the capacity of, or number of installations within a sector may be required for multiplication with the unit costs. If this data is not available, costs of compliance may be estimated using estimates of emissions reductions (change in EF multiplied by activity rate), by the unit costs expressed as €/tonne emissions reduction. GAINS contains some data on the capacity of sectors. MS sector-specific reports.	*The appropriate metric will depend on the data available and format of the unit costs.*
6	IPPC tier 1 / 2 /3	Industry - Separate data collection by industry category.	Unit costs for abatement measures	€	To estimate the costs of compliance with IPPC for the sector, the uptake rate (expressed as proportion of total sector capacity or as proportion of total emissions) should be multiplied by total capacity/emissions and the unit costs for the abatement measures assumed to be implemented (see above).	GAINS contains unit cost information for some abatement measures. BREF documents and other sector reports also contain information on unit costs. It should be noted that Eurostat contains data on, 'Environmental expenditure for the protection of ambient air and climate'. However, this is aggregated at a very high level and will include expenditure by installations not within the scope of IPPC, so is not normally appropriate to use here.	*Consideration should be given to the change in input prices (e.g. electricity, labour) since the publication of the data source and the rate of inflation before/after the sources publication.*

No	Methodo-logy	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
Industrial Sector							
7	IPPC Tier 2	Industry - Separate data collection by industry category.	CO2 emissions	kt CO2 emissions		IEA Clean Coal Centre EU ETS Directive Annexes Where CO2 emission data is not available, fuel consumption data may be used in conjunction with fuel-specific Emission Factors to estimate emissions. This method of estimation can be refined at a MS-level by applying MS-specific Efs; this is particularly relevant for 'other solid fuels'.	
8			Activity data - dependant on industry category	LCPs - heat / electricity production, Other industry - units of production (e.g. t clinker produced)		Uncertainty around production at a MS-level can be reduced by consulting sector reports or MS statistics databases. For sectors with differentiated products, sector reports or MS statistics databases may also provide more disaggregated data on the type of products produced, which may be used in calculations of a standard product (e.g. CWT for oil). Uncertainty around heat / electricity production for LCPs can be reduced by using MS and fuel-specific efficiency factors	
9			Autonomous progress	Various		Sector reports Sector experts Eurostat (energy prices) EU Implementation studies for policies with overlap. The counterfactual could be refined by: - Consulting sector studies to identify exogenous variables (such as changes in alternative fuel-price differentials and business-as-usual efficiency improvements) and then updating the counterfactual estimates of emissions intensity to reflect these changes. - Conducting a literature review of EC and MS policies which may overlap with IPPC; the impact of EU ETS on GHG emissions and fuel choice is particularly relevant.	Differentiating between improvements in energy efficiency/use due to IPPC and policies with significant overlap may be extremely difficult. Input from sector experts may be required to identify measures taken up specifically for IPPC compliance.

No	Methodo-logy	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
Industrial Sector							
10	IPPC Tier 3	Industry - Separate data collection by industry category.	Activity data - dependant on industry category	LCPs - heat / electiricity production, Other industry - units of production (e.g. t clinker produced)		Sector reports MS statistics databases LCP emissions inventory Uncertainty around production (activity) can be reduced by examination of activity at an installation-level. Where activity data is not easily available, fuel-use data could be used as a proxy for activity.	Where proxy data is used instead of actual activity data, it is essential that this data is not linked to the pollutant under investigation. i.e. do not estimate activity on the basis of CO2 emissions, when the ratio of activity/CO2 is under investigation.
11			CO2 emissions	kt CO2 emissions		CITL LCP Inventory MS statistics databases Uncertainty around CO2 emissions can be removed by examination of CO2 emissions at an installation-level. Where CO2 emissions are not available at an installation level, they can be estimated through the use of fuel consumption data and installation-specific fuel emission factors.	
12			Autonomous progress	Various		Sector experts Installation operators The counterfactual could be further refined through discussions with operators and sector experts to identify exogenous variables and updating the counterfactual accordingly.	Differentiating between improvements in energy efficiency/use due to IPPC and policies with significant overlap is likely to be extremely difficult and will not always possible; even operators of installations may struggle to identify precisely which policy/exogenous factor caused improvements to be made.
13			Uptake of abatement measures (including abatement of air pollution)	% uptake		A more detailed assessment of the abatement measures implemented to comply with IPPC at an installation level can be achieved through a combination of different methods: - Operators could be surveyed to ascertain directly which abatement options have been implemented for IPPC compliance; this could take into account abatement measures which were taken up under the counterfactual scenario; - Sector experts in the competent authorities could be contacted to develop assumptions on the type of abatement option which is required for specific fuel and technology types; this could take into account abatement measures which were taken up under the counterfactual scenario; - Changes in the emissions intensity of an installation from the counterfactual (estimated in the environmental assessment) can be used to identify the type of abatement option which has been implemented; for example, if the SO2 emissions intensity of an installation has reduced by 90% in the first year of full IPPC implementation it can be assumed that FGD was installed; - The result of using a combination of these methodologies is that the abatement option taken up for IPPC compliance at each installation is known with a higher level of certainty;	
14			Implementation costs	€		Where sector experts / sector organisations state that there may be substantial differences in the unit costs, cost estimates could be improved through further investigation of installation-level costs; effort should be focussed on the most significant installations in terms of absolute cost, or difference from average unit costs.	

9.3 F-Gases

Table 9.3 gives an overview on data needed for an ex-post assessment concerning emission reductions and costs of the F-Gas Regulation.

Data needed to apply the proposed methodologies: The assessment of emission reductions for the identified key sectors builds on sector-specific data/estimates on stocks of F-gas using equipment, specific F-gas charges and compositions, equipment lifetimes, leakage rates during operation, emission rates during disposal and some specific sales and consumption statistics. For the cost assessment, in addition to data/estimates on equipment stocks and equipment cost additional data/estimates on certification cost, spent working hours and wage tariffs are needed

Technical data could be available from Tier 3 models like AnaFGas[217], national studies or emission inventories and/or sales statistics. Cost estimates are proposed in particular for personnel certification, containment and recovery and could be based on the specific findings of the Schwarz et al. 2011 study[218] published by DG CLIMA or on comparable national studies.

Data readily available from regular statistics or emission inventories will be restricted to few cases like sales of spray cans, SF_6 consumption in magnesium casting or wage tariffs. The majority of input data will need to be collected in sectoral studies on MS and/or EU levels.

Identification of existing legislation at EU level in which the identified data requirements could be incorporated: The F-Gas Regulation is presently in the revision process. Data reporting requirements serving the additional indicators proposed in Table 9.3 might be established in a revised F-Gas regulation.

[217] The bottom-up 'AnaFGas' model was developed in the context of the Schwarz et al. 2011 study (see footnote 218) for DG CLIMA. The model features 21 F-gases and 29 F-gas using sectors differentiated by Member States.

[218] Schwarz et al. 2011: Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases; Final Report & Annexes to the Final Report. Prepared for the European Commission in the context of Service Contract No 070307/2009/548866/SER/C4

Table 9.3 F-Gases – Key data needs for ex-post quantification

No	Methodology / tier	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
F-Gases							
F-gas 1	Tier 2/ 3 emissions	F-gases: key refrigeration and air-conditioning sectors	stock estimates	units		AnaFgas model (COM), other tier 3 model or national studies/ emission inventories; partly based on production, sales and population statistics	the proposed key refrigeration and air conditioning sub-sectors are: Commercial refrigeration, industrial refrigeration, moveable room air-conditioning, multi-split room air conditioning, chillers, passenger car air-conditioning; stock data in proposed methodologies differ by sub-sector: partly based on population, production or sales statistics (as described in detail in the sub-sector-specific methodologies
F-gas 2	Tier 2/ 3 emissions	F-gases: key refrigeration and air-conditioning sectors	specific refrigerant charges	kg refrigerant / unit		AnaFgas model (COM), other tier 3 model or national studies/ emission inventories	
F-gas 3	Tier 2/ 3 emissions	F-gases: key refrigeration and air-conditioning sectors	specific refrigerant composition	%	average shares of F-gas species in refrigerant charges	AnaFgas model (COM), other tier 3 model or national studies/ emission inventories	
F-gas 4	Tier 2/ 3 emissions	F-gases: key refrigeration and air-conditioning sectors	lifetime estimate for refrigeration/AC appliances	years	default or country specific estimation of average lifetime of appliances	AnaFgas model (COM), other tier 3 model or national studies	
F-gas 5	Tier 2/ 3 emissions	F-gases: key refrigeration and air-conditioning sectors	leakage rate of refrigeration/AC appliance	%/a	default or country specific estimation of average leakage rate of refrigerants	AnaFgas model (COM), other tier 3 model or national studies/ emission inventories	

No	Methodology / tier	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
F-gas 6	Tier 2/ 3 emissions	F-gases: key refrigeration and air-conditioning sectors	disposal emission factor	%	default or country specific estimation of average emission rate at end-of-life of appliances	AnaFgas model (COM), other tier 3 model or national studies/ emission inventories	
F-gas 7	Tier 2/ 3 emissions	F-gases: One-component foams	Annual sales estimate	million cans		sales statistics	
F-gas 8	Tier 2/ 3 emissions	F-gases: One-component foams	share of F-gas containing cans in sold cans	%		AnaFgas model (COM), other tier 3 model or national studies/ emission inventories	
F-gas 9	Tier 2/ 3 emissions	F-gases: One-component foams	specific charge estimate	g F-gas / can		AnaFgas model (COM), other tier 3 model or national studies/ emission inventories	
F-gas 10	Tier 2/ 3 emissions	F-gases: Magnesium casting	SF6 consumption	tonnes of SF6		company reporting to national emission inventories	
F-gas 11	Tier 2/ 3 costs	F-gases: key refrigeration and air-conditioning sectors	Personnel certification cost	million €/a	annual cost according to methodology suggested in this report	DG CLIMA F-Gas study 2011 (Schwarz et al.) or national studies	
F-gas 12	Tier 2/ 3 costs	F-gases: key stationary refrigeration and air-conditioning sectors	Containment cost	million €/a	annual cost according to methodology suggested in this report	DG CLIMA F-Gas study 2011 (Schwarz et al.) or national studies	
F-gas 13	Tier 2/ 3 costs	F-gases: key stationary refrigeration and air-conditioning sectors	Recovery cost	million €/a	annual cost according to methodology suggested in this report	DG CLIMA F-Gas study 2011 (Schwarz et al.) or national studies	

No	Methodology / tier	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
F-gas 14	add. Indicator "Net supply of F-gases (pre-charged)"	F-gases: refrigeration/air-conditioning, mobile air-conditioning; foams, aerosols; electrical equipment	F-gas imports from non-EU countries contained in products or equipment	F-gas imports from non-EU countries contained in products or equipment	separately for each regulated F-gas		no reporting obligation yet; might be included in revision of F-gas Regulation (with an appropriate threshold)
F-gas 15	add. Indicator "Net supply of F-gases (pre-charged)"	F-gases: refrigeration/air-conditioning, mobile air-conditioning; foams, aerosols; electrical equipment	F-gas exports to non-EU countries contained in products or equipment	F-gas exports to non-EU countries contained in products or equipment	separately for each regulated F-gas		no reporting obligation yet; might be included in revision of F-gas Regulation (with an appropriate threshold)
F-gas 16	add. Indicator "F-gas reclamation"	specialised reclamation facilities	Amount of reclaimed F-gases	Amount of reclaimed F-gases	separately for each regulated F-gas		present reporting obligation on reclamation covers only producers and importers of F-gases. No reporting obligation yet for specialised reclamation facilities; might be included in revision of F-gas Regulation
F-gas 17	add. Indicator "F-gas destruction"	specialised destruction facilities	Amount of destroyed F-gases	Amount of destroyed F-gases	separately for each regulated F-gas		present reporting obligation on destruction covers only a) on-site destruction by producers and importers of F-gases and b) off-site destruction by third parties on behalf of producers and importers. Destruction taking places at specialised destruction facilities which is not commissioned by F-gas producers or importers is not covered of present reporting obligation; might be included in revision of F-gas Regulation; full detailed identification of destroyed F-gas species will face difficulties as destruction facilities partly don't know the exact composition of their charges.

9.4 Road transport

The data needed for applying the methodology for an ex-post assessment of emission reductions and costs of the CO_2 regulations as laid out in the report is briefly described below. A more distinguished tabular summary is provided in Table 9.4.

Data needed to apply the proposed methodologies:

The specific data required for assessment will depend on the Tier level method of the assessment. However, in general the key types of data required to perform an ex-post assessment of CO_2 regulation for new cars are:

- Number of new cars registrations by mass, engine power and capacity;
- CO_2 emission rates from new cars for each new car registration;
- Average mileage for new cars;
- Additional Manufacturing costs

The general data usage in the different Tier levels is proposed as follows:

Tier 1 level:

Tier 1 uses EU-wide data such as averaged EF and averaged mileage travelled by new passenger cars. The possible sources of data include: EEA database[219]: Monitoring of CO_2 emissions from passenger cars and TREMOVE[220]. However this method is not recommended since all the information is already available at MS level.

Tier 2 level:

In the Tier 2 methodology, national data for the emission rate of new vehicles and distribution of cars substitutes EU averages. The MS-specific data such as total number of new cars registered by fuel type, distribution of new cars over mass, engine capacity, power classes per fuel type at national level are used. The possible sources of data include: EEA database: Monitoring of CO_2 emissions from passenger cars and TREMOVE model.

Tier 3 level:

This level of assessment requires all the data which are required for Tier 2 method and additionally information about costs. Additional manufacturing costs, market prices of the new passenger cars and fuel savings are required. The possible sources of data include the disaggregated data from the EEA database: Monitoring of CO_2 emissions from passenger cars and TREMOVE model.

[219] http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-1

[220] http://www.tremove.org/

Data needs for methodologies that are currently not recommended:

A Tier 1 level analysis is not recommended. Instead Tiers 2 and 3 are recommended. However, the Tier 3 approach requires the additional manufacturing cost, market prices of the new cars and fuel savings data which are not publicly available. Moreover the additional manufacturing costs are not available from ex-post studies and for this data ex-ante costs are recommended.

Identification of existing legislation at EU level in which the identified data requirements could be incorporated:

The Regulation (EC) No 443/2009 requires Member States to record information for each new passenger car registered in its territory. Every year, each Member State shall submit to the Commission all the information related to their new registration.

MS are not obliged to report the information about costs. The market price of the passenger cars could be included in the required information for each new passenger car.

Table 9.4 Road transport – Key data needs for ex-post quantification

No	Methodology	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
Road Transport							
1	CO2 regulations - Tier1	Road transport	Emission rates of new cars	gCO2/km	CO2 emission rates at EU level	EEA database: Monitoring of CO2 emissions from passenger cars http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-3	Tier 1 is not recommended since all data for Tier 2 are already available at National level.
2			Number of new registrations	number	Number of new registered cars at EU level	EEA database: Monitoring of CO2 emissions from passenger cars http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-3	
3			Average mileagefor passenger car	vkm	Avaraged mileage for new cars at EU level	TREMOVE model http://www.tremove.org/	
4	CO2 regulations - Tier2	Road transport	Total number of new cars registered by fuel type	number	Total number of new cars registered by fuel typeat national level	EEA database: Monitoring of CO2 emissions from passenger cars http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-1	
5			Distribution of new cars over classes	number	Distribution of new cars over mass, engine capacity, power classes per fuel type at national level		
6			CO2 emissions	gCO2/km	CO2 emissions per mass, engine capacity, power classes at national level		
7			Averaged mileage for new cars	vkm	Averaged mileage for new cars at national level per engine capacity	TREMOVE model http://www.tremove.org/	
8	CO2 regulations - Tier3	Road transport	Total number of new cars registered	number	Total number of new cars registered per fuel type per mass, engine capacity, motor class	Underlying data from the EEA database: Monitoring of CO2 emissions from passenger cars	
9			Mass for every new car	kg	Mass, engine capacity and power for every new registered car at national level.		
10			Engine capacity for every new car	cm3			
11			Power for every new car	kW			
12			CO2 emission reduction	%	The difference in CO2 emissions from the new cars comparing to the base year	EEA database: Monitoring of CO2 emissions from passenger cars	
13			Additional manufacturing costs	EUR	Additional manufacturing costs per car class categories	There are studies which provide ex-ante cost curves for additional manufacturing costs	
14			Market price of cars	EUR	Prices of passanger cars per different classes		
15			Fuel savings	EUR		Eurostat or PRIMES	

9.5 Waste

Data needs for assessing ex-post effects via the methodologies described in this report are summarized below and in more detail in Table 9.5.

Data needed to apply the proposed methodologies: Data required to perform a Tier 1 assessment of the Waste Incineration Directive is readily available from sources including Eurostat and CEWEP reports. The additional data required to perform a Tier 2 assessment will need to be collected by Member State Competent Authorities.

The data requirements to perform a Tier 3 assessment are considerable. Conducting operator surveys and collating installation-specific data would require a significant amount of resources to undertake.

Data needs for methodologies that are currently not recommended: Tier 1 is not recommended. Instead Tiers 2 and 3 are recommended.

Identification of existing legislation at EU level in which the identified data requirements could be incorporated: The Industrial Emissions Directive (IED; which now includes the Waste Incineration Directive amongst others) will be reviewed by 7 January 2016. Data reporting requirements serving the additional indicators proposed in Table 2 might be established in an updated IED reform.

Table 9.5 Waste – Key data needs for ex-post quantification

No	Specify for which	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
Waste Sector							
1	WID tier 1 *Data also required for IPPC tier 2*	Waste incineration sector & other industries where waste is co-incinerated.	Activity data - mass of MSW disposed through incineration	Tonnes	Total mass of MSW incinerated (tonnes) by MS.	Eurostat	
2			Energy recovered and available for consumption	MW	The energy recovered from waste incineration and is available to consumers in the form of heat or electricity.	Energy available for consumption - Eurostat	
3			Energy available for consumption per tonne of MSW	MW heat / tonne MSW, MW electricity / tonne MSW	The energy recovered per unit of tonne of waste is assumed to remain 'frozen' at the year of WID implementation in the counterfactual scenario. Subsequent improvements in energy recovered per unit of tonne of waste are assumed to occur due to implementation of WID. The proportion of energy available in the form of heat or electricity is based on CEWEP reports.	Calculated from the rows above and information on the proportion of energy available as heat / electricity from CEWEP reports.	
4			CO2 emissions displaced due to additional recovery of energy from incineration plants	tCO2 / tonne MSW	It is assumed that all energy 'available for consumption' will replace other sources of heat / electricity. The average CO2 EF per unit of heat /electricity replaced can be estimated using data on fuel consumption and fuel Efs in the heat/electricity supply markets. The total CO2 replaced is calculated by multiplying the total heat and electricity replaced by the average heat/electricity EF.	Large scale electricity production (Eurostat); Primary fuel consumed in electricity production (Eurostat); Emission factors for combustion of fossil fuels (IPCC).	
5			Implementation costs	€	If European studies on the costs of implementation of WID become available, these may be used in future.	None known	Implementation cost estimation is more realistic for Tiers II and III (see below)
6	WID Tier 2	Waste incineration sector & other industries where waste is co-incinerated.	Activity data - mass of MSW disposed through incineration	Tonnes	Eurostat data and CEWEP reports could again be used to determine the quantity of MSW treated by waste incineration plants	Eurostat CEWEP reports	
7			Interaction with existing MS legislation & overlapping EC legislation		Okopol (2007) includes a summary at a MS level of where stricter ELVs than those required for WID are included in permits; where this occurs, it will be a challenge to disentangle the effect of multiple policies (IPPC, WID, national policies). CEWEP reports also include information on policies in place for each MS.	Okopol on behalf of the European Commission, (2007), 'Assessment of the application and possible development of community legislation for the control of waste incineration and co-incineration'. MS WID fact sheets	Where it is found that abatement measures have been installed for compliance with legislation other than WID, these impacts should be excluded from the evaluation.
8			Moisture content of MSW	%	Estimation of the energy recovered from incineration should be adjusted to account for the moisture content of MSW. GAINS data on the proportion of food / paper / other waste incinerated could be used to approximate the change in moisture content over time at a MS level.	GAINS, MS WID fact sheets	
9			Abatement measure / energy efficiency uptake	% of plants	Summaries of abatement measure uptake, disaggregated by MS, plant and technology type are available in Okopol (2007)	Okopol on behalf of the European Commission, (2007), 'Assessment of the application and possible development of community legislation for the control of waste incineration and co-incineration'.	
10			Abatement measure unit costs	€	Okopol (2007) includes case studies for a number of types of installations which includes cost estimates for a range of abatement measures; this information can be used to determine unit costs.	Okopol on behalf of the European Commission, (2007), 'Assessment of the application and possible development of community legislation for the control of waste incineration and co-incineration'.	
11			Implementation costs	€	Implementation costs can be estimated using data on abatement measure uptake rates and unit costs (see above). MSs may have already conducted an Impact Assessment for WID, which can include useful cost data; for example AMEC has recently completed an ex-post assessment of the implementation of WID in the UK	See above.	

No	Methodo-logy	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
12	WID Tier 3	Waste incineration sector & other industries where waste is co-incinerated.	Activity data - mass of MSW disposed of through incineration	Tonnes	An operator survey would be required to accurately determine the quantity of waste treated at an installation level; alternatively MS may collect this information at a national level.	MS statistics Installation survey	
13			Interaction with existing MS legislation & overlapping EC legislation		An operator survey may be required to accurately identify the measures implemented for specific policies; ; alternatively MS may collect this information at a national level;	Installation survey	Where it is found that abatement mea
14			Moisture content of MSW	%	Estimation of the energy recovered from incineration should be adjusted to account for the moisture content of MSW.	Installation survey MS WID fact sheets	
15			Abatement measure / energy efficiency uptake	% of plants	Uptake of abatement or energy efficiency measures for compliance with WID.	Installation survey MS WID fact sheets	
16			Abatement measure unit costs	€	Installation operators may be willing to provide estimates of unit costs.	Installation survey MS WID fact sheets	
17			Implementation costs	€	Implementation costs can be estimated using data on abatement measure uptake rates and unit costs (see above).	Installation survey MS WID fact sheets	

9.6 Agriculture

This section gives an overview on data needed for an ex-post assessment concerning emission reductions and costs of the EU polices related to the agricultural sector (e.g. CAP2003 reform, Nitrates Directive), more detail can be found in Table 9.6.

Data needed to apply the proposed methodologies: In the present study based on an analysis and assessment a simplified concept was developed which identify the most relevant sectors (enteric fermentation, manure management, fertilizer use) and cost categories which would primarily need to be assessed. The assessment of emission reductions for the identified key sectors builds on sector-specific data/estimates on national statistics (see e.g. EUROSTAT, animal numbers, farm numbers, amount of minerals fertilizers) or emission inventories (e.g. emissions and background data of average gross energy intake) and/or sales statistics. The usage in the different Tier levels is proposed as follows:

Tier 1 level:

Emissions data on N_2O emissions, for example, is available from MS emission inventories reported under UNFCCC. Other technical data could be available from sources such as the DG Agriculture Farm Structural Survey (FSS) and national studies. Other data would need to come from literature review, such as using modelled information (mitigation costs, reduction potential, emissions per ha or farm) of a German standard farm. If it is possible that the information is not comparable with other Member State (MS) farm types a survey should be conducted on MS level for specific costs or technologies.

Tier 2 level:

Regional circumstances – e.g. climate conditions (temperature, humidity) – which influence enteric fermentation (methane conversion factor) and the N-cycle can be considered. It would therefore be necessary to conduct a study for at least one MS with climate conditions that differ from those in Germany, such as a Mediterranean country (e.g. France, Spain). This would enable conclusions to be drawn for different farm types and would allow for a more differentiated analysis.

Tier 3 level:

For a Tier 3 approach, model runs should be conducted on individual MS level. This entails that MS should have detailed information available to use these for a model run. If no information is available a country specific survey could be conducted. The main emitters of agricultural emissions in Europe are Germany, France and Italy, Spain and Poland. Therefore, it is recommended that a detailed model analysis of those countries should be evaluated in a Tier 3 setting.

Cost estimates are proposed in particular for milk yield and production, prize of fertilizer, investment costs could be based on the specific findings of the above mentioned models and studies or on comparable national surveys (e.g. here stable cost per animal). Despite considerably reducing the complexity of the agriculture sectors, the developed simplified approach still demands rather high efforts in terms of technical expertise and modelling capacity to be employed and specific technical data to be collected or estimated.

The majority of input data will need to be collected in sectoral studies on MS and/or EU levels.

Identification of existing legislation at EU level in which the identified data requirements could be incorporated: In 2011 a revision process of the CAP started for the period 2013 until 2020. Data reporting requirements serving the additional indicators proposed in Annex 1 might be established in an updated CAP reform.

Table 9.6 Agriculture – Key data needs for ex-post quantification

No	Methodo-logy	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
Agricultural Sector							
1	Fertilizer, Tier 1	Agriculture	Activity data, agricultural land use	Million Hectares	Area of agricultural land	Agricultural land area (FAO)	
2	Fertilizer, Tier 1	Agriculture	N20 emissions	kt N20 (expressed as CO2eqv.)	MS N20 emissions in the agricultural sector	MS inventory submissions for UNFCCC, CRF category 4.D. Agricultural soils	
3	Fertilizer, Tier 2	Agriculture	Area of land within Nitrate Vulnerable Zone (NVZ)	Million Hectares	Area of agricultural land which falls within a NVZ.	MS reports on implementation of Nitrates Directive.	
4	Fertilizer, Tier 2	Agriculture	Year of implementation	Year	Year Nitrates Directive implemented	MS documentation	
5	Fertilizer, Tier 1 / 2	Agriculture	Cost data on implementation of Nitrates Directive (cost savings from reduced fertiliser use, captial and operating cost of increased storage facilities (autumn/winter), loss in yield due to lower N application rates, increased administrative burden estimates, loss of revenue from reduced livestock, cost of additional cover crops, costs for replacing/upgrading spreading equipment).	€	Total investment and operation of equipment for compliance and any loss in revenue due to compliance minus potential savings due to lower fertiliser application.	Eurostat	Not currently available for all MS.
6	Fertilizer, Tier 3	Agriculture	Technology uptake rates	Various	Data on the uptake of compliance measures, including: transport of manure from areas of excess, treatment of manures (e.g. anaerobic digestion), increased storage of manures and any other applicable measures	Studies at MS level (unknown availability), new data collection, or use of MS assumptions from GAINS.	Collected MS level data unlikely to be available. GAINS data available, but based on assumptions.
7	Fertilizer, Tier 3	Agriculture	Cost data on technology costs	€	Data on the unit costs of specific technologies (see above). Consideration should be given to indirect costs or benefits, such as reduced yield, or reduced expenditure on chemical N fertilisers. Consideration should also be given to changes in input / output prices over time (e.g. change in price of chemical N fertiliser).	Studies at MS level (limited number), GAINS	Where cost data is transposed from one area for use in another area / time period, consideration should be given to the specific geographic conditions (soil type, surplus of manure, current N application rates and optimal application rates for
8	Fertilizer, Tier 3	Agriculture	Updated N excretion factors for livestock (especially Dairy cattle)	Kg per animal per year	Kg Nitrogen excreted per animal per year, for various categories of animal.	GAINS data is appropriate for most animal categories. However, dairy cattle show greater variation and may be calculated using methodology described in: Alterra, AEA Technology, ITP & NEIKER (2010), 'The impact of the Nitrates Directive on gaseous N emissions: Effects of measures in nitrates action programme on gaseous N emissions'.	Methodology for area-specific calculation available or alternatively MS-specific factors have already been estimated: see Alterra et all (2010).

No	Methodo-logy	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
Agricultural Sector							
9	Fertilizer, Tier 3	Agriculture	Use of MS-specific N2O Emission Factors	%	% of input N emitted as N20 for: storage and application systems for chemical fertilisers and manure. EFs should be differentiated by technique, input type, soil type and climatic conditions.	EFs may be estimated using outputs from Alterra (2010)	Requires data on soil type and climatic conditions.
10	Fertilizer, Tier 3	Agriculture	Agricultural crop area	Million Hectares	Area of agricultural land used for growing specific crops.	Eurostat	The underlying trend in crop choice should be accounted for in the
11	Fertilizer, Tier 3	Agriculture	Livestock Units (LSUs)	millions heads	Number of livestock, disaggregated by livestock type (e.g hens, sheep, pigs, dairy cattle etc.)	Eurostat	The underlying trend in LSU holdings should be accounted for in
12	Fertilizer, Tier 3	Agriculture	N fertiliser application rates	various	Quantity of chemical N fertiliser applied (volume / area)	Eurostat (FAO)	
13	Enteric Fermentation, TIER 2 and 3	Agriculture	Enteric Fermentation, CRF 4A, Manure Management 4B, animal numbers	animal head counts	Animal numbers per Member State	FAO Statistic, Eurostat numbers, or UNFCCC reporting of GHG emissions	
14	Enteric Fermentation, TIER 2 and 3	Agriculture	Enteric Fermentation, CRF 4A, Manure Management 4B, milk yield	milk amount in kg	Milk and milk products	Eurostat, Collection of cows' milk, European Commission (Eurostat and Agriculture and Rural Development DG) -	
15	Enteric Fermentation, TIER 2 and 3	Agriculture	Enteric Fermentation, CRF 4A, Manure Management 4B, N-input in soil	amount of manure fertilizers in t	the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management	Additional data for calculating Tier 1, Model "Modelfarm"; EUROSTAT, Fertilisers consumption	
16	Enteric Fermentation, TIER 2 and 3	Agriculture	Enteric Fermentation, CRF 4A, Manure Management 4B, stable cost per animal	€/head	the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management		
17	Enteric Fermentation, TIER 2 and 3	Agriculture	Enteric Fermentation, CRF 4A, Manure Management 4B, milk prize	€/t milk	exogenous factors like costs per milk and milk production	EUROSTAT	
18	Soil Emissions,	Agriculture	CRF 4D: Direct soil emissions; •a. Feeding situation, Farms	number of dairy farms	numbers of dairy farms (considering the amount of herd size and grassland, see EUROSTAT)	Additional data for calculating Tier 1, Model "Modelfarm"; Eurostat number of farms or ha size	
19	Soil Emissions,	Agriculture	CRF 4D: Direct soil emissions; agricultural area	ha	Farm size , area size (see EUROSTAT)	Eurostat number of farms or ha size, IRENA 13 - Cropping-livestock patterns	
20	Soil Emissions, Tier 1	Agriculture	CRF 4D: Direct soil emissions; •f. Use of mineral fertilisers	amount of mineral (urea) fertilizers in t	the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management	Additional data for calculating Tier 1, Model "Modelfarm"; Eurostat information IRENA 08 - Mineral fertiliser consumption; Fertilizers Europe (Fertiliser Manufacturers Association)	
21	Biogas, Tier 1	Agriculture	Biogas (CH4) plants	numbers	Numbers of biogas plants in Europe per country	http://de.statista.com/statistik/daten/studie/215697/umfrage/anzahl-der-Anzahl der Biogasanlagen zur Produktion von Biomethan in Europa nach Ländern im Jahr 2011, biogasanlagen-zur-produktion-von-biomethan-in-europa/, EUROSTAT, IRENA 27 - Renewable energy from agricultural sources	
22	Soil Emissions, Tier 1	Agriculture	CRF 4D: Direct soil emissions; •f. Use of mineral fertilisers	cost of mineral fertilizers in €/t	exogenous factors like costs per fertilzer type	LEL (2010): Agrarmärkte 2010. Betriebsmittel. Landesanstalt für Entwicklung der Landwirtschaft und der Ländlichen Räume Schwäbisch Gmünd.	
23	Soil Emissions, Tier 1	Agriculture	CRF 4D: Direct soil emissions; •g. Comparison of livestock grazing and permanent housing; maintenance costs, diesel use	maintenance costs (fence construction for dairy cattle in €)	the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management	Additional data for calculating Tier 1, Model "Modelfarm", the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management	
24	Soil Emissions, Tier 1	Agriculture	CRF 4D: Direct soil emissions; •g. Comparison of livestock grazing and permanent housing; maintenance costs, diesel use	diesel use in l/ha	the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management	Additional data for calculating Tier 1, Model "Modelfarm", the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management; EUROSTAT, IRENA 14 - Farm management practices	
25	Soil Emissions, Tier 1	Agriculture	CRF 4D: Direct soil emissions; •g. Comparison of livestock grazing and permanent housing; maintenance costs, diesel use	fuel costs €/l	the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management	Additional data for calculating Tier 1, Model "Modelfarm", the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management	
26	Soil Emissions,	Agriculture	CRF 4D: Direct soil emissions; •i. Organic farming	area under organic farming		EUROSTAT, IRENA 07 - Area under organic farming	
27	Soil Emissions, Tier 1	Agriculture	CRF 4D: Direct soil emissions; •i. Organic farming	Mitigation costs €/ha	cost efficiency of organic production, however, depends on existing premiums under agri-environment programmes and the currently commercially available premium for products that originate from organic farming.	Additional data for calculating Tier 1, Model "Modelfarm"; the information of farm types by conducting a survey on MS level for specific costs or technologies depending farm management	

9.7 Residential sector (Energy Labelling Directive)

The focus of this section is on data needed for an ex-post assessment concerning emission reductions and costs in the residential sector focussed on the Energy Labelling Directive. More distinguished information can be found in Table 9.7.

Data needed to apply the proposed methodologies: In order to conduct a simple Tier 1 assessment of the directive readily available EU-wide statistics are required including electricity consumption, number of households and private income.

For Tier 2, the use of the Odyssee database model is required to obtain appliance ownership data. For Tier 3, use of the MURE appliance stock model is proposed which includes appliance lifetime, appliance ownership rates, electricity consumption by appliance, usage data and sales data. This would be supplemented by national data to understand impacts of national policies and incentive schemes and compliance issues.

Identification of existing legislation at EU level in which the identified data requirements could be incorporated:

Data reporting requirements serving the additional indicators proposed in Section 10.1 Annex 1 might be established under a new regulation relating to the 2010 recast directive, or considered within the context of the Energy Efficiency directive, the National Energy Efficiency Action Plan reporting or the revision of the Monitoring Mechanism.

Table 9.7 Residential sector – Key data needs for ex-post quantification

No	Methodo-logy	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
Residential Sector							
1	Tier 1	Households	Electricity consumption	kWh	Electricity consumption in residential dwellings for electrical appliances and lighting	Eurostat / Odyssee database	The Odyssee database provides consumption per dwelling for lighting and electrical appliances at the EU-level and by individual Member States. This is a restricted access database. In addition, data is not
2	Tier 1	Households	Activity data, residential buildings	Households	Number of permanently occupied dwellings	Eurostat / census data	
3	Tier 1	Households	Heating degree days	Days	Number of days	Eurostat / JRC	Correct for climatic variations
4	Tier 2 / 3	Households	Electricity consumption by appliance	kWh/appliance	Electricity consumption in residential dwellings by appliance type	National statistics / Odyssee database	This data is not available for all Member States.
5	Tier 2 / 3	Households	Stock of electrical appliances	Appliances	Existing appliance stock	National statistics / MURE appliance stock model	A number of Member States (e.g. Germany) collect information on appliance stock. The MURE appliance stock tool (part of the Odyssee project) models appliance
6	Tier 2 / 3	Households	Equipment rates	Appliances by energy label	Appliance penetration rates could be based on sales data of new appliances by energy label class (A++, A+ etc.)	National statistics / GfK / MURE appliance stock model	The MURE tool includes sales on different appliances by label type by country. The private market research company GfK collects comprehensive sales data by label categories annually. GfK data is not available publicly however a number
7 8	Tier 3	Households	Autonomous progress	Various	Tier 3 improves on Tier 2 by seeking to correct for autonomous development e.g. the impact of autonomous technological improvement (i.e. innovation in technology) and also includes autonomous behaviour (consumer behaviour).	Various although some uncertainty about data availability and time series.	Corrections could be made through evaluation of the autonomous progress in the pre-agreement period. However, for many countries the time series are not long enough.
9	Tier 3	Households	Appliance lifetime	Years		National statistics / GfK / MURE appliance stock model	

9.8 Buildings (residential and non-residential) sector (EPBD)

Table 9.8 gives an overview on data needed for an ex-post assessment concerning emission reductions and costs in the buildings sector, focussed on the EPBD. This study focuses primarily on assessing impacts on space heating for the reasons discussed previously.

Data needed to apply the proposed methodologies: Data required to perform a Tier 1 assessment is readily available from sources such as Eurostat and the EEA. The additional data required to perform a Tier 2 assessment will need to be collected by Member State Competent Authorities if it is not already available in national statistics.

The data requirements to perform a Tier 3 assessment are considerable as documented in detail in AEA (2009) and summarised earlier in the report; this includes the following:

- Residential building stock characteristics split by single/multi-family, age classes, fuels and distinction by country and climatic zones.
- Technical characteristics of existing, new and refurbished buildings as well as compliance with building regulations.
- Trends in number of households and size (m^2) of buildings.
- Building energy efficiency standards and penetration rates.
- Technology uptake rates (historic and projected).

Some of the data on standards of thermal efficiency and regional variation in building stock within the EU27 is available in the BPIE (2011) study, Europe's Buildings under the Microscope, which presents survey results with additional useful qualitative analysis. There may be potential to obtain data through this route in the future if the survey is repeated. Otherwise, data would need to be collected through sectoral surveys and studies at MS and/ or EU levels. Other data sources include the Odyssee database (as discussed previously in the report), the PRIMES model and other relevant national, European and/or international datasets and studies.

Identification of existing legislation at EU level in which the identified data requirements could be incorporated: Data reporting requirements serving the additional indicators proposed in Annex 1, Section 10.1, might be established under a new regulation relating to the 2010 recast directive, or considered within the context of the Energy Efficiency directive, the National Energy Efficiency Action Plan reporting or the revision of the Monitoring Mechanism Decision.

Table 9.8 Buildings sector – Key data needs for ex-post quantification

No	Methodo-logy	Sector	Type of data	Unit	Guidance / definitions	Guidance / source	Comments
Bulidings Sector							
1	EPBD tier 1 *Data also required for EPBD tier 2*	Buildings	Activity data, residential buildings	Households	Number of occupied dwellings	Eurostat	
2			Activity data, non-residential buildings	Employees	Number of employees	Eurostat	
3			CO2 emissions	kt CO2	MS CO2 emissions in the residential and services sectors	EEA	
4			Energy consumption	GJ	Energy consumed in residential and non-residential buildings	Eurostat	
5			Heating (or cooling if considering other functions) degree days	Days	Number of days	Eurostat/JRC	Cooling degree days are not currently commonly available and are not reported in Eurostat.
6			Space heating (or other functions) shares	% fuel consumption % electricity consumption	Proportion of energy used for space heating (and/or other functions) in the residential and non-residential sectors, broken down according to fuel type if possible	MS national statistics	Optional for tier 1 - default values provided if not available (required for tier 2)
7			Year of implementation	Year	Year EPBD implemented	MS documentation	
8	EPBD tier 2	Buildings	Buildings activity data	m2	Square metres of floor space in residential and non-residential buildings	Energy consumption statistics	Not currently available for all MS, especially for commercial buildings.
9			Space heating (or other functions) shares	% used for space heating	Share of energy consumed in buildings for space heating (and/or other functions), broken down according to fuel and electricity	Energy consumption statistics	Not currently available for all MS, especially for commercial buildings. This could be part of a wider dataset on split of enery use in the household and services sector into various functions: space heating, hot water production, cooling, lighting, etc
10	EPBD tier 1 / 2	Buildings	Cost data (investment in energy efficiency in buildings and cost savings from reduced energy consumption)	€	Total investment in buildings and % spent on energy efficiency MS Energy prices	MS records and Eurostat	Not currently available for all MS.
11	EPBD tier 3	Buildings	Buildings stock characteristics	Various	MS building stock characteristics (split/single, multi-family, split by fuels) and technical characteristics of existing, new and refurbished buildings including size	MURE simulation model	Not currently publicly available. Some data is available in the BPIE study - Europe's Buildings under the Microscope - there may be potential to obtain data through this route in the future.
12			Technology uptake rates	Various	Building energy efficiency standards and penetration rates, diffusion of heating technologies per type of buildings, compliance rates	MURE simulation model	Not currently publicly available. Some data is available in the BPIE study - Europe's Buildings under the Microscope - there may be potential to obtain data through this route in the future.
13	EPBD tier 3	Buildings	Cost data (direct compliance costs and cost savings from reduced energy consumption)	€	Cost data by technology MS Energy prices	MURE simulation model Eurostat	MURE simulation model data is not currently publicly available..

10 Annexes

10.1 Annex 1: Proposal for indicators

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
1	**General**	**MACRO**	**Indicator**	**CO2 intensity of GDP**	**t CO2 / EUR million**			
			Numerator	Total CO2 emissions	kt CO2	Total CO2 emissions (excluding LULUCF) as reported in the CRF (as reported in EmissionProjections sheet)	National GHG inventory	
			Denominator	GDP	billion EUR (EC95) or (2000)	Gross domestic product at constant 1995 prices	National accounts	
Energy Sector Policies								
1	**EU ETS, RES-E, CHP Directives**	**CO2 Intensity of electricity generation, E1**	**Indicator**	**CO2 intensity of electricity generation**	**g CO2/kWh**			
			Numerator	Total CO2 emission in the power sector	million t	CO2 emissions from public and autoproducer power stations	EU ETS verified emissions, requirement in Monitoring Mechanism Decision 240/2004/EC (Indicator transformation B0)	This CO2 emissions required for the numerator are not directly reported as a specific category in the GHG inventory as CRF category 1A1a Public power and heat includes emissions from heat plants and from CRF category 1A2 Manufacturing industry and combustion may also include industrial emissions from heat production and may alo include process emissions from iron and steel which are allocated to the energy sector. Thus, the numerator requires a separate compilation of CO2 emission data which should be available aither from plant-specific reporting/ environmental reports or from the more disaggregate compilation of CO2 emissions at MS level.
			Denominator	Total gross electricity generation	TWh	Total gross electricity generation covers gross electricity generation in all types of power plants. The gross electricity generation at the plant level is defined as the electricity measured at the outlet of the main transformers, i.e. the consumption of electricity in the plant auxiliaries and in transformers are included. (Eurostat code ten00087)	Based on Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics	Data is covered by aggregate 5.2.1 required in the energy statistics regulation
2	**RES-E**	**Estimated net GHG emission saving from the use of renewable electricity, E2**	**Indicator**	**GHG emissions savings from renewable electricity**	million t GHG	Methodology and approach as in Table 6 of the Renewables Directive	Renewables Directive 2009/28/EC, Template for Member State progress reports under Directive 2009/28/EC, Table 6 (based on methodology and reporting as provided under this Directive)	

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
3	**RES-E**	**Estimated net GHG emission saving from the use of renewable electricity in heating and cooling, E3**	**Indicator**	**GHG emissions savings from renewable use for heating and cooling**	million t GHG	Methodology and approach as in Table 6 of the Renewables Directive	Renewables Directive 2009/28/EC, Template for Member State progress reports under Directive 2009/28/EC, Table 6 (based on methodology and reporting as provided under this Directive)	
4	**RES-E**	**Estimated net GHG emission saving from the use of renewable electricity in transport, E4**	**Indicator**	**GHG emissions savings from renewable use for heating and cooling**	million t GHG	Methodology and approach as in Table 6 of the Renewables Directive	Renewables Directive 2009/28/EC, Template for Member State progress reports under Directive 2009/28/EC, Table 6 (based on methodology and reporting as provided under this Directive)	
5	**EU ETS, CHP Directive**	**Share of CHP in electricity production, E5**	**Indicator**	**Share of CHP in electricity production**	**%**			
			Numerator	Electricity production from CHP plants	TWh	Electricity produced from combined heat and power plants (based upon the consideration of individual units within the plants) and the gross electricity production. However, there are several important qualifications as not all the electricity and (useful) heat produced in CHP plants can be considered CHP production. Eurostat code: tsdcc350	Based on Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics	Following a change in methodology the CHP component in electricity production is now calculated from the total production of CHP plants by considering the overall annual efficiency and the power-to-heat ratio of individual units within each plant. (see Commission Decision of 19 November 2008 establishing detailed guidelines for the implementation and application of Annex II to Directive 2004/8/EC of the European Parliament and of the Council (2008/952/EC) for more details). In the past there was no unequivocal quantitative rule to define when the separation into CHP and non-CHP components should be done at plant level. A threshold of 75% for the overall efficiency is now set as the criterion to select plants in which the CHP component of the electricity production has to be calculated. If the average annual efficiency is 75 % or higher, all the electricity produced in the plant is considered to come from CHP. If the efficiency is below that threshold, the CHP electricity (ECHP) is calculated by multiplying the CHP heat production by the characteristic power-to-heat ratio of the plant.
			Denominator	Gross electricity generation	TWh	Gross national electricity consumption comprises the total gross national electricity generation from all fuels (including autoproduction), plus electricity imports, minus exports. Eurostat Code: tsien050	Based on Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics	

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
6	**EU ETS, policies to promote energy efficiency in industry**	**Energy-related CO2 intensity of industry, E6**	**Indicator**	**Energy-related CO2 intensity of industry**	t CO2 / million EUR			
			Numerator	CO2 emissions from fossil fuel consumption industry	kt CO2	Emissions from combustion of fossil fuels in manufacturing industries, construction and mining and quarrying (except coal mines and oil and gas extraction) including combustion for the generation of electricity and heat. Energy used for transport by industry should not be included here but in the transport indicators. Emissions arising from off-road and other mobile machinery in industry should be included in this sector.	IPCC source category 1A2	part of current priority indicators for projected progress under the EU Monitoring Mechanism Decision
			Denominator	Gross value-added total industry	billion EUR (EC95) or (2000)	Gross value added at constant 1995 prices in manufacturing industries (NACE 15-22, 24-37), construction (NACE 45) and mining and quarrying (except coal mines and oil and gas extraction) (NACE 13-14)	National accounts	part of current priority indicators for projected progress under the EU Monitoring Mechanism Decision
7	**EU ETS, policies to promote fuel switch to less carbon intensive fuels**	**Share of oil and coal in energy consumption, E7**	**Indicator**	**Share of oil and coal in energy consumption**	**%**			
			Numerator	Gross inland energy consumption of oil and solid fuels	TWh	Gross inland energy consumption of solid fuel and total petroleum products. Eurostat code: tsdcc320	Based on Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics	
			Denominator	Gross inland energy consumption	TWh	Gross inland energy consumption is calculated as follows: primary production + recovered products + total imports + variations of stocks - total exports - bunkers. It corresponds to the addition of final consumption, distribution losses, transformation losses and statistical differences. Eurostat code: tsdcc320	Based on Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics	
8	**Energy taxation**	**Proportion of taxes in energy prices, E8**	**Indicator**	**Renewables share**	**%**			
			Numerator	Amount of tax	Euro	Eurostat collects price data on gas and electricity for different industry and households and presents these in three forms: 1) prices without taxes, 2) prices without VAT and 3) prices with all taxes included. The tax component of energy prices for households is calculated by subtracting prices without taxes from prices including all taxes. For industry, it is calculated by subtracting prices without taxes from prices without VAT. For the transport fuels data is provided by DG Tren (European Commission) in a similar form and the same calculations as for households are applied.	Electricity and gas taxes and share of environmental taxes: Eurostat data for structural indicator http://europa.eu.int/comm/eurostat/ Transport fuel taxes: DG TREN (Oil bulletin) http://ec.europa.eu/energy/oil/bulletin/index_en.htm	The data on the prices for electricity and natural gas for industry and households are for reference (or standard) consumers. The reference consumers are those used in the structural indicators and are characterised by a selected annual consumption, maximum demand and annual utilisation
			Denominator	Total energy price	Euro			
9	**Policies to promote energy efficiency**	**Energy efficiency in the services sector, E9**	**Indicator**	**Energy efficiency in the services sector**				
			Numerator	Services energy consumption	GJ	Final energy consumption by services. Energy consumption should be corrected from climate to avoid yearly climatic variations	Based on Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics, Eurostat data	
			Denominator	number of employees	employee	employees in services sector (with salaries employed in full time)	National employment statistics	

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
Buildings Sector								
1	**EPBD**	**Final energy consumption for space heating (or other relevant functions) in the residential and services sector, B1**	**Indicator**	**Final temperature corrected energy consumed for space heating (or other relevant functions) in the residential and non-residential buildings sector**	**GJ/household or GJ/m2 residential GJ/employee or g/m2 non-residential**			
			Numerator	Climate adjusted energy consumption for space heating in residential sector and non-residential buildings sector	GJ	MS level space heating shares data should be used where available (if not, the default MS shares given in the methodology can be used). The data should be temperature corrected.	national energy statistics and surveys (energy consumption for space heating, degree days)	
			Denominator	Residential sector: households for tier 1, m2 for tier 2 Non-residential: employees for tier 1, m2 for tier 2	number of households or m2 residential number of employees or m2 non-residential	Household and employee numbers are available on Eurostat. Square meters of floor space data, broken down into residential and non-residential sectors is not currently reported on Eurostat but may be available at MS level.	Eurostat and national statistics	Tier 1 data requirement: only number of households and number of employees Tier 2 data requirement: above plus m2 for residential and non-residential buildings
2	**EPBD**	**CO2 intensity of space heating (or other relevant functions) in the residential and non-residential buildings sector, B2**	**Indicator**	**CO2 intensity of space heating (or other relevant functions) in the residential and non-residential buildings sector**	**kt CO2/household or kt CO2/m2 residential kt CO2/employee or kt CO2/m2 non-residential**			
			Numerator	CO2 emissions from climate adjusted energy consumption for space heating in residential sector and in non-residential sector	kt CO2	CO2 emissions from space heating are not directly available from GHG inventories and need to be calculated based on data for fuel-specific energy consumption for space heating and EFs for related fuels. The fuel consumption data should be temperature corrected.	Eurostat (energy consumption, degree days), EEA (emissions data)	Emission factors for electricity could be calculated using electricity consumed as opposed to electricity produced so as not to include transmission losses.
			Denominator	Residential sector: households for tier 1, m2 for tier 2 Non-residential: employees for tier 1, m2 for tier 2	number of households or m2 residential number of employees or m2 non-residential	Household and employee numbers are available on Eurostat. Square meters of floor space data, broken down into residential and non-residential sectors is not currently reported on Eurostat but may be available at MS level.	Eurostat and national statistics	Tier 1 data requirement: only number of households and number of employees Tier 2 data requirement: above plus m2 for residential and non-residential buildings

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
Buildings Sector								
3	**EPBD**	**Cost effectiveness of energy efficiency investments in buildings, B3**	**Indicator**	**Cost effectiveness of energy efficiency investments in buildings**	**€/kt CO2 abated**			
			Numerator	Total investment in energy efficiency in buildings less the cost savings from reduced energy consumption	€	Tier 1 / 2: total investment in buildings on energy efficiency measures (top down assessment) Tier 3: Cost data by technology All tiers: MS electricity prices from Eurostat	MS records and Eurostat	Investment costs not currently available in all MS. Tier 1 / 2: Calculated using total investment in buildings and % spent on energy efficiency Tier 3: e.g. from MURE simulation model.
			Denominator	CO2 emissions abated (from climate adjusted energy consumption for space heating in residential sector and in non-residential sector)	kt CO2 abated	CO2 emissions from space heating are not directly available from GHG inventories and need to be calculated based on data for fuel-specific energy consumption for space heating and EFs for related fuels. The fuel consumption data should be temperature corrected.	Eurostat (energy consumption, degree days), EEA (emissions data)	Emission factors for electricity could be calculated using electricity consumed as opposed to electricity produced so as not to include transmission losses.
Residential Sector								
1	**Energy Labelling Directive**	**Emission intensity of lightning and electric appliances in residential sector, R1**	**Indicator**	**Emission intensity of lighting and electrical appliances in the residential sector**	**kt CO2 / dwelling**			Tier 1: At EU aggregated level Tier 2: At individual MS level
			Numerator	CO2 emissions from electricity consumption for electrical appliances and lighting in the residental sector	kt CO2	CO2 emissions from electricity consumption in households for electrical appliances and lighting. MS specific emission factors should be calculated based on EF for national fuel mix for electricity generation.	Odyssee database (electricty consumption), national statistics	The Odyssee database provides consumption per dwelling for lighting and electrical appliances at the EU-level and by individual Member States. This is a restricted access database. In addition, data is not currently available for all EU27 MS and some of the data is based on 'expert judgement'.
			Denominator	Number of permanently occupied dwellings	Number of dwellings	Number of dwellings are available on Eurostat.	Eurostat / national statistics	
2	**Energy Labelling Directive**	**Energy intensity of electric appliances and lighting in residential sector, R2**	**Indicator**	**Electricity consumption for appliances and lighting in the residential sector**	**kWh / dwelling**			Tier 1: At EU aggregated level Tier 2: At individual MS level
			Numerator	Climate adjusted electricity consumption for appliances and lighting in the residential sector	kWh	Electricity consumption in households for electrical appliances and lighting. MS specific emission factors should be calculated based on EF for national fuel mix for electricity generation.Adjusted to average EU climate using degree days.	Eurostat (electricity consumption, degree days), national surveys for energy consumption per types of application, Odyssee database	
			Denominator	Number of permanently occupied dwellings	Dwellings	Household numbers are available on Eurostat.	Eurostat / national statistics	

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
3	**Energy Labelling Directive**	**Share of highly efficient appliances in total sold appliances, R3**	**Indicator**	**Proportion of sales of highly-efficient energy labels in new sales**	**%**			Applicable for Tiers 2 and 3.
			Numerator	Sales of appliances with energy labels A++/A+/A	Number of units sold	Sales of most efficient energy labels (A++, A+, A) by appliance.	Additional national surveys on types and numbers of household appliances sold	Certain MS collect sales data of appliances in the residential sector. Such data collection may be available from private market research companies. E.g. in Germany the private market research company GfK collects comprehensive sales data by label categories annually.
			Denominator	Total sales of appliances in all energy label classes	Number of units sold	Total sales of appliances in all energy label classes	National surveys on types and numbers of household appliances sold / PRODCOM / MURE appliance stock	Certain MS collect sales data (e.g. Germany). The private market research company GfK collects comprehensive sales data by label categories. PRODCOM contains total information by individual appliance but not by energy label. The MURE appliance stock model includes sales on different appliances by label type by country.
Transport Sector								
1	ACEA agreement, Regulation (EC) No 443/2009 on CO2 emissions from passener cars	**Passenger car CO2 intensity, T1**	**Indicator**	**Passenger car CO2 intensity**	**kt CO2 / M pkm**			part of current priority indicators for projected progress under the EU Monitoring Mechanism Decision
			Numerator	CO2 emissions from passenger cars	kt CO2	CO2 emissions from the combustion of fossil fuels for all transport activity with passenger cars (automobiles designated primarily for transport of persons and having capacity of 12 persons or fewer; gross vehicle weight rating of 3900 kg or less).	IPCC source category 1A3bi	
			Denominator	Number of kilometres by passenger cars	million passenger km	Number of vehicle kilometres by passenger cars. Note: Activity data should be consistent with the emission data	National transport statistics	
2	Policies to reduce specific CO2 emissions from freight transport	**Freight transport CO2 intensity, T2**	**Indicator**	**Freight transport CO2 intensity**	**kt CO2 / M tkm**			part of current priority indicators for projected progress under the EU Monitoring Mechanism Decision
			Numerator	CO2 emissions from freight transport (all modes)	kt CO2	CO2 emissions from the combustion of fossil fuel for all transport activity including light duty trucks (vehicles with a gross vehicle weight of 3900 kg or less designated primarily for transportation of light-weight cargo or which are equipped with special features such as four-wheel drive for off-road operation) and heavy duty trucks (any vehicle rated at more than 3900 kg gross vehicle weight designated primarily for transportation of heavy-weight cargo). Includes rail and domestic air and marine transport.	CRF source categories 1A3bii and 1A3biii (excluding buses) of national GHG inventory	
			Denominator	Freight transport (all modes)	million tonnes km	Number of tonne-kilometres transported Note: Activity data should be consistent with the emission data.	National transport statistics	

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
3	Policies to increase the energy efficiency in the transport sector	**Energy efficiency in the transport sector, T3**	**Indicator**	**Energy efficiency and energy consumption in the transport sector**	Mt CO2/Mtoe	This indicator aggregates the unit consumption trends for each transport mode in a single indicator for the whole sector. It is calculated at the level of 8 modes or vehicle types: cars, trucks, light vehicles, motorcycles, buses, total air transport, rail, and water transport. For cars, energy efficiency is measured by the specific consumption, expressed in litre/100km; for the transport of goods (trucks and light vehicles), the unit consumption per ton-km is used, as the main activity is to move goods; for other modes of transport various indicators of unit consumption are used, taking for each mode the most relevant indicator given the statistics available: toe/passenger for air, goe/pass-km for passenger rail, goe/ton-km for transport of goods by rail and water, toe per vehicle for motorcycles and buses. The variation of the weighted index of the unit consumption by mode between t-1 and t is defined as follows It /It -1= 1/(It -1/It). The value at year t can be derived from the value at the previous year by reversing the calculation: It /It -1= 1/(It -1/It) with : energy share EC i (consumption of each mode i in total transport consumption); unit consumption index UC i (ratio : consumption related to traffic or specific consumption in l/100 km for cars); t refers the current year, t-1 to the previous year.		
			Numerator	Energy consumption of individual transport modes	Mtoe		**Energy consumption by transport modes** (road, water, rail, air): Eurostat data based Energy Statictis Regulation. **Energy consumption by type of road vehicle (car, truck & light vehicle, bus)** : Calculated for each type of vehicle by type of fuel (gasoline and diesel) from the the stock of vehicles. **Specific consumption of cars in litre /100 km:** Odyssee database (15 countries available, of which the 11 main EU-15 countries plus Hungary, Poland and Slovenia). **Stock of vehicles:** national	
			Denominator	Specific acitivity per transport mode	different units		National transport statistics	
F-gases								
1	**F-Gas Regulation**	**F-gas emissions per capita, F1**	**Indicator**	**F-gas emissions per capita**	**kt CO2- eq per capita**			
			Numerator	absolute F-gas emissions (PFCs, HFCs and SF6) from all sectors	**kt CO2eq**	GHG emissions from inventory source category 2.F Consumption of halocarbons and SF6	GWPs should be consistent with those used for national GHG inventories	
			Denominator	Population	**capita**	Eurostat, national statictics		
2	**F-Gas Regulation**	**Refrigerant leakage rate, F2**	**Indicator**	**Refrigerant leakage rate (per sector i)**	**%/a**			
			Numerator	emission rate	kg of refrigerant/a	for key F-gas consuming sectors involving banks: Commercial refrigeration, industrial refrigeration, moveable room air-conditioning, multi-split room air conditioning, chillers, passenger car air-conditioning, to be investigated in sectoral studies		needed for national GHG emission inventories
			Denominator	refrigerant content of appliance during operation	kg refrigerant	to be investigated in sectoral studies, provided by industry		needed for national GHG emission inventories

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
6	**F-Gas Regulation**	**F-gas reclamation per tons emitted, F3**	**Indicator**	**F-gas reclamation**	**%**			
			Numerator	Total amount of F-gases reclaimed	tonnes	information obtained from specialised reclamation facilities; full detailed identification of reclaimed F-gas species will face difficulties as reclamation facilities partly don't know the exact composition of their charges.		present reporting obligation (Art 6 of F-gas Regulation 842/2006) does not cover specialised reclamation facilities; confidentiality of data needs to be ensured
			Denominator	Total emissions of F-gases from 2F	tonnes	GHG emissions from inventory source category 2.F Consumption of halocarbons and SF6		
7	**F-Gas Regulation**	**F-gas destruction per tons emitted, F4**	**Indicator**	**F-gas destruction**	**%**			
			Numerator	Total amount of F-gases destructed	tonnes	information obtained from specialised destruction facilities; full detailed identification of destroyed F-gas species will face difficulties as destruction facilities partly don't know the exact composition of their charges.		present reporting obligation (Art 6 of F-gas Regulation 842/2006 does not fully cover specialised destruction facilities; confidentiality of data needs to be ensured; full detailed identification of destroyed F-gas species will face difficulties as destruction facilities partly don't
			Denominator	Total emissions of F-gases from 2F	tonnes	GHG emissions from inventory source category 2.F Consumption of halocarbons and SF6		

Agricultural Sector								
1	**CAP 2003**	**Specific CH4 emissions of cattle production, A1**	**Indicator**	**Specific CH4 emissions of cattle production**	**kg CH4 / head**			
			Numerator	CH4 emissions from cattle	kt CH4	CH4 emissions from enteric fermentation from cattle	IPCC source category 4A & 4B	
			Denominator	Cattle population	1000 head		FAO Statistic, Eurostat numbers, or UNFCCC reporting of GHG emissions	
2	**CAP 2003, Nitrates Directive**	**Agricultural land CO2eqv. , A2**	**Indicator**	**Agricultural land CO2eqv.**	**t CO2eqv. / Ha**			
			Numerator	N20 emissions from agriculture (converted to CO2eqv.)	t CO2eqv.	CO2eqv. emissions (e.g. N2O) from agricultural land.	MS inventory submissions for UNFCCC, CRF category 4.D. Agricultural soils	
			Denominator	Area of land used for farming (Hectares)	million Hectare of agricultural	Area of land used for farming (Ha). Note: Activity data should be consistent with the emission data, if possible.	Source: Agricultural land area (FAO)	The use of total agricultural land area as the denominator is not ideal, as changes in the use of the land (e.g. types of farming - number of LSUs) which
3	**CAP 2003, Nitrates Directive**	**Specific N2O emissions of fertiliser and manure use, A3**	**Indicator**	**Specific N2O emissions of fertiliser**	**kg N2O / kg N**			
			Numerator	N2O emissions from synthetic fertiliser and manure use	kt N2O	Direct N2O-emissions from synthetic fertilizer use and manure applied to soils	IPCC source category 4B & 4D2	
			Denominator	Use of synthetic fertiliser and manure	kt nitrogen	National statistics of fertilizer use (or fertilizer sold)		

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
4	**Increase in efficiency in milk production**	**milk production per cow, A4**	**Indicator**	**milk production per cow**	**milk yield kg /head animal**			
			Numerator	milk yield	in t		national statistics	
			Denominator	number of dairy cattle	in head		national statistics,GHG inventory. Eurostat data	
5	**Reduction of fertilizer use**	**Specific fertilizer use, A5**	**Indicator**	**fertilizer use (mineral fertilizers, manure)**	**t/ha**			
			Numerator	Fertilizer (mineral/manure) amount	t	synthetic fertilizer use and manure applied to agricultural soils	Eurostat, national statistics, FAO data	
			Denominator	agriculture area	ha	Agricultural area	Eurostat, national statistics, FAO data	

Waste Sector

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
1	**Landfill Directive**	**Fraction of MSW disposed to landfills, W1**	**Indicator**	**Specific CH4 emissions from**	**kt CH4 / kt**			
			Numerator	waste disposed to landfills	kt CH4	MSW and industrial waste	Eurostat, national waste statistics	
			Denominator	total amount of waste generated	kt	MSW and industrial waste	Eurostat, national waste statistics	
2	**Landfill Directive**	**CH4 recovery related to total CH4 emissions from solid waste disposal, W2**	**Indicator**	**CH4 recovery related to total CH4 emissions from solid waste disposal**	**%**			
			Numerator	CH4 recovery from solid waste disposal	kt CH4	as provided in GHG inventory CRF table 6.A	as provided in GHG inventory CRF table 6.A	
			Denominator	Total CH4 emissions from landfills	kt CH4	as provided in GHG inventory CRF table 6.A	as provided in GHG inventory CRF table 6.A	
3	**Policies aiming at reducing waste generation**	**Waste generation rate, W3**	**Indicator**	**Waste generation rate**	**kg/ capita**			
			Numerator	Waste generated by households and services sector	kt waste	total MSW generated	Eurostat, national waste statictics	
			Denominator	Population	capita		Eurostat, national population statistics	
4	**Landfill Directive, national waste management strategy**	**Fraction of MSW incinerated, W4**	**Indicator**	**Fraction of MSW incinerated**	**kg/ capita**			
			Numerator	Total amount of MSW incinerated	kt waste		Eurostat, national waste statictics	
			Denominator	Total amount of MSW generated	capita		Eurostat, national population statistics	

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
5	**Landfill Directive, national waste management strategy**	**Fraction of MSW recycled, W5**	**Indicator**	**Fraction of MSW recycled**	**kg/ capita**			
			Numerator	Total amount of MSW recycled	kt waste		Eurostat, national waste statictics	
			Denominator	Total amount of MSW generated	capita		Eurostat, national population statistics	
6	**Waste incineration Directive**	**Energy recovered (MW) per tonne MSW incinerated**	**Indicator**	**Energy recovered (MW) per tonne MSW incinerated**	**t CO2eqv. / Ha**			
			Numerator	Energy recovered (heat/electricity)	MW	The energy recovered from waste incineration and is available to consumers in the form of heat or electricity.	Energy available for consumption - Eurostat	
			Denominator	Mass of MSW incinerated	Tonnes	Total mass of MSW incinerated (tonnes) by MS.	Eurostat	
7	**Waste incineration Directive**	**tCO2 replaced per tonne MSW incinerated**	**Indicator**	**tCO2 replaced per tonne MSW incinerated**	**tCO2/tMSW**			
			Numerator	tCO2 replaced	tCO2	It is assumed that all energy 'available for consumption' will replace other sources of heat / electricity. The average CO2 EF per unit of heat /electricity replaced can be estimated using data on fuel consumption and fuel Efs in the heat/electricity supply markets. The total CO2 replaced is calculated by multiplying the total heat and electricity replaced by the average heat/electricity EF.	Large scale electricity and production (Eurostat); Primary fuel consumed in electric-ity production (Eurostat); Emission factors for combustion of fossil fuels (IPCC).	
			Denominator	Mass of MSW incinerated	Tonnes	Total mass of MSW incinerated (tonnes) by MS.	Eurostat	

No	Policy or measure monitored by proposed indicator	Indicator name	Indicator / numerator / denominator		Unit	Guidance / definitions	Guidance / source	Comments
Industrial Sector								
1	IPPC	**CO2 / unit of output**	**Indicator**	**CO2 intensity of activities**	**t CO2eqv. / Ha**			
			Numerator	Total GHG emissions, converted to tCO2eqv.	t CO2eqv.	Where CO2 emission data is available at a sector-level, this may be used directly. Where CO2 emission data is not available, fuel consumption data may be used in conjunction with fuel-specific Emission Factors to estimate emissions.	Data sources for fuel-consumption for use in estimating CO2 emissions: Eurostat contains information on the consumption of different types of fuel for certain sectors and processes (e.g. coke ovens, blast furnaces), but may contain production from installations outside the scope of IPPC. PRIMES contains assumptions on energy use for the main relevant sectors. However, PRIMES includes fuel use by installations not covered by IPPC. LCPs - total fuel consumption data from the LCP inventory.	The appropriate data source will depend upon the sector to be investigated; it may be necessary to make assumptions or to use proxy data in order to estimate CO2 emissions.
			Denominator	Unit of activity for the sector	Dependant on sector - tonnes of product / electricity / heat produced	For industries which produce a single, uniform product, the activity unit is easily defined – e.g. for cement, production of clinker is the obvious unit to be used. For industries which produce a diverse range of products (e.g. glass, pulp&paper, refineries), it will be necessary to convert estimates of output to a single unit. For industries which have a highly diverse range of products (e.g. all industries which use LCPs), a proxy for production, such as electricty / heat production can be used.		The appropriate data source will depend upon the sector to be investigated; it may be necessary to make assumptions or to use proxy data in order to estimate activity data.
2	IPPC	**Cost effectiveness**	**Indicator**	**Cost effectiveness**	**€/kt CO2eqv. (or other air pollutant) abated**	**Ratio of expenditure on energy efficiency / abatement expenditure to emissions abatement**		
			Numerator	Total costs of policy implementation (annual)	€	See comments in the key data sheet for estimation methodologies.	See comments in the key data sheet for data sources for different sectors and different levels of scrutiny.	
			Denominator	CO2eqv. (or other air pollutant) emissions abated from implementation of the IPPC directive.	kt CO2eqv. (or other air pollutant) abated	See comments in the key data sheet for estimation methodologies.	See comments in the key data sheet for data sources for different sectors and different levels of scrutiny.	Emission reduction estimates are likely to include reductions due to associated policies (EU ETS, CHP, WID, LCPD), or underlying trends in the sector; therefore reductions estimates may include measures not directly associated with IPPC.

10.2 Annex 2: Proposal for reporting format template

Table 10.1 Proposal for reporting format template

Member State:	
Reporting Year:	

Sector	**Name of policy or measure for which ex-post assessment was conducted**	**EU policy addressed by / related to the PAM**	**Source category/ subsector name**	**Source of additional methodological information**	**Starting year T of the ex-post assessment**		**GHG emissions**						
							Starting year T	**Year T+1**	**Year T+2**	**Year T+3**	**Year T+4**	**…**	**Year T+i (T+i = current reporting year)**
							kt CO2eq						
Selection from following list: cross-cutting, energy, transport, industrial processes, agriculture, waste, forestry	*Please use name consistent with the policy name provided in the reporting template under Article 3(2) of the MM Decision*	*Selection from the same list as currently used for reporting of policies and measures under Monitoring Mechanism Decision*	*Enter specific source category/ subsector which was used in the ex-post assessment and for which the emissions are specified*	*Indicate additional technical reports underpinning the assessments, including descriptions of the models and methodological approaches used, definitions and underlying assumptions.*	*Enter the starting year in the past when the policy was implemented and the counterfactual scenario started*	**Counterfactual scenario**							
						Of which covered covered by Directive 2003/87/EC							
						Actual emissions							
						Of which covered covered by Directive 2003/87/EC							
						Emission reduction (Counterfactual scenario - actual emissions)							