Assessment and improvement of methodologies used for Greenhouse Gas projections

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Disclaimer

The views expressed in this study represent only the views of VITO, Öko-Institut and the authors and not those of the European Commission or any other organization.

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Abbreviations

ACEA	European Automobile Manufacturers Association
CAFÉ	Clean Air For Europe
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regionalised Impact
CAPSIM	Common Agricultural Policy Simulation Model
CCPM	Common and Coordinated Policies and Measures
CDM	Clean Development Mechanisms
CH_4	Methane
CHP	Combined Heat and Power
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2 eq.	CO_2 equivalent
CRF	Common Reporting Format
EC	European Community
ECCPM	European Climate Change Programme
ETC	European Topic Centre
ETC/RWM	European Topic Centre on Resource and Waste Management
ETS	Emissions Trading System
EU	European Union
GCV	Gross Calorific Value
GDP	Gross Domestic Product
Gg	Gigagram (10^9 g)
GHG	Greenhouse gas
GJ	Gigajoule (10^9 J)
HFC	Hydrofluorocarbon
HUSIM	Hungarian Simulation Model
IEA	International Energy Agency
IEA-ETSAP	International Energy Agency's Energy Technology Systems Analysis Programme
JI	Joint Implementation
IMF	International Monetary Fund

LCA	Life Cycle Analysis
LULUCF	Land-use, land-use change and forestry
Mbtu	One million British thermal units
MS	Member State
MM	Monitoring Mechanism
MW	Municipal Solid Waste
N	Nitrogen
N_2O	Nitrous oxide
NAP	National Allocation Plan
NCV	Net Calorific Value
NEC	National Emission Ceiling
NIR	National Inventory Report
NTUA	National Technical University of Athens
PAMs	Policies And Measures
PASMA	Positive Agricultural Sector Model Austria
PFC	Perfluorocarbon
pkm	Person kilometre
SF_6	Sulfur hexafluoride
TJ	Terajoule (10^{12} J)
tkm	Ton kilometre
toe	Tons oil equivalents
VA	Value Added
UNFCCC	UN Framework Convention on Climate Change
WGII	Working Group 2
WAM	With Additional Measures
WM	With Measures
WOM	Without Measure

1 Introduction

1.1 General

The service contract "*Assessment and improvement of methodologies used for Greenhouse Gas projections*" (reference ENV.C.2/SER/2006/008) is executed by the project team comprising the Flemish Institute for Technological Research (VITO), Öko Institut, and the Institute of European Environmental Policy (IEEP).

The aims of this service contract are to:

- Improve understanding of the underlying assumptions of Member State greenhouse gas projections;
- Compare different projection methods;
- Make recommendations for an update of the requirements under Decision 280/2004/EC and its implementing provisions, based on analysis of the various projections.

The final report will give a:

- Assessment of Member State projections;
- Assessment of the methodologies for projections;
- Execute a sensitivity analysis of Member State projections;
- Comparison of the results with European top-down models;
- Give policy recommendations at EC level and disseminate this information at training sessions and a workshop.

1.2 Expected results

To understand progress towards compliance with quantitative targets under the Kyoto Protocol and to identify the need for additional action, it is necessary to have robust projections for greenhouse gas emissions at the EU level, and accurate estimates of the effects of individual policies and measures across all Member States.

Until now, work under the Monitoring Mechanism to assess whether the Community and Member States are on track to meet their targets has focused on improving the transparency of Member States' emissions projections and promoting better practice in reporting. Besides transparency, the Member States GHG projections currently are also lacking *consistency, comparability, completeness, and accuracy* with the effect of decreasing the reliability of any aggregation of Member States' projections at the EU level. The following problem areas have so far not been tackled in a systematic way with Member States (MS):

- *Comparability* problems exist regarding assumptions used for projects across MS and for the EU as a whole, but also within MS when different assumptions are used for GHG projections, in sectoral policies or under the Clean Air For Europe (CAFE) Programme.
- *Consistency* problems exist regarding the methodologies and models used for projections, and the way policies and measures are addressed in the projections.
- *Completeness* problems exist regarding the completeness of activities included in the projections in the different sectors.

- *Accuracy* problems exist regarding the sensitivity and uncertainty assessments undertaken by Member States for the GHG projections.

Because of the wide range of methodologies and models used by Member States in particular in the energy sector, because of the wide range of individual activities and sectors covered in GHG inventories, and because of different national circumstances, it is difficult to get a comprehensive understanding of the GHG projections of all Member States and to derive further good practice guidance or requirements for Member States.

Using the profound experience of the project partners in the preparation and analysis of projections as well as in the assessment of Member States' information on GHG projections, inventories, quantified effects of policies and measures, the proposed project aims to overcome the noted difficulties and to improve the understanding of Member States projections in terms of methodologies, assumptions, strengths and weaknesses, and the understanding of differences in GHG projections across Member States and with EU-wide GHG projections.

The outcomes of this project will help the European Commission to have a transparent view of:

- the methodologies used;
- underlying assumptions used for greenhouse gas emissions in the Member States;
- gaps in knowledge, needed to get a better understanding.

This improved understanding will allow:

- to establish capacity building activities for Member States to improve comparability, consistency, completeness and accuracy of Member States' projections.
- to improve the existing legal requirements regarding the preparation and reporting of projections.
- to support the Commission in meeting its reporting obligations under UNFCCC and the Kyoto Protocol, and to help Member States to respond better to the existing requirements related to projections.
- strengthen the credibility of the Commission's assessment of progress under the Kyoto Protocol by improving the reliability and accuracy of EU-wide projections and by ensuring better consistency between Member State and EU projections.

1.3 Outline of the final report

Simultaneous with this project, Öko Institute performed a project called *"Policies and Measures at Member State Level to Reduce Greenhouse Gas Emissions and Achieve Compliance With Commitments for 2008 to 2012 under the Kyoto Protocol (Contract No. 070501/2005/420765/MAR/C2)".* The result of this project are country assessments. This project and report is partially based on these country assessments. The country assessments are performed for 25 MS. Luxemburg and Malta do not have projections and are therefore not included.

Chapter 2 assesses Member States' projections with regard to the principles of comparability, consistency, completeness and accuracy.

Chapter 3 assesses the methodologies MS used for their projections, with a general overview of models, a classification of the models and an overview of specific models used by the MS.

The sector specific analysis (chapter 4-10) is performed for energy, industry, households/tertiary, transport, agriculture, forestry and waste.
For each sector there is an assessment of the projections, the models and parameters used.
The main limitation for the project team, are the gaps in information available and the differences in reporting of each MS. These two obstacles result in knowledge gaps and most of the time not being able to compare all 27 MS. It should be clear that the analyses done by the project team is based on available information and expert judgement.
The workshops held in April and May should allowed us to fill in some of the gaps and were helpful to the information included in this report. The discussions in the workshops were used to update the information and recommendations in this final report.

Chapter 11 gives the result of the performed sensitivity analyses for a selection of member states.

Chapter 12 gives recommendations for the parameters and the models. The parameters were presented at a workshop in May 21st and comments from MS are included in this report, however comments related to new data presented after June 2007 were not included. Recommendations on the models are further explored and suggestions on TIER methodologies that were discussed during a workshop and training held on the 13 and 14th of October 2008, are made available in Chapter 13 of this final report.

2 General assessment of Member States GHG projections

2.1 Introduction

2.1.1 Background and objectives

The European Community (EC) is a Party to the UN Framework Convention on Climate Change (UNFCCC) and to the Kyoto Protocol. This implies the obligation to report GHG projections as part of the national communications under the UNFCCC. For this purpose, the EC relies on Member State's (MS) projections to prepare European projections. Member State's projections are aggregated for EU-15 and EU-27. For correct aggregation comparability, consistency and completeness of Member States' projections are essential. The quality of the aggregated projections at European level depends on the accuracy of Member State's projections. This chapter assesses Member States' projections with regard to the principles of comparability, consistency, completeness and accuracy.

2.1.2 Methods and data sources

The following sources with updated projections were used for this assessment:

- Information on projections under the Monitoring Mechanism Decision (Decision 280/2004/EC) to the Commission submitted until June 2007 including information submitted on parameters used for projections as required in Annex VI of the Implementation Provisions under the Monitoring Mechanism (Decision 2005/166/EC). Indicators for projected progress submitted under the Monitoring Mechanism were also considered in the assessment. This information has been partly updated by some Member States with submissions in 2008 which could not be taken into account fully in the final reports because the tasks that assessed Member State's information were completed in 2007. Some exceptions were made for the sensitivity analysis which is based on the most recent submissions from Member States in 2007 and 2008.
- Projections submitted as part of the 4th national communications under the UNFCCC and the report on demonstrable progress under the Kyoto Protocol due by 1 January 2006. The information from 4th national communications was used when no information was submitted under decision 280/2004/EC in 2007 or the national communications presented additional information.
- Projections included in the second national allocations plan under Directive 2003/87/EC for the period to be submitted until mid 2006: The proposed new format for national allocation plans foresees that Member States submit current and projected emissions for individual years and for each activity included in Annex I of Directive 2003/87/EC (NAP summary table IV – recent and projected CO_2 emissions in sectors covered by the EU emissions trading scheme) as well as basic data on the electricity sector (NAP summary tables IIa and IIb). The information from 2nd NAPs was used when no information was submitted under decision 280/2004/EC in 2007.

Apart from Malta and Luxembourg all Member States have provided projections in one of these sources.

2.2 Completeness of Member States' greenhouse gas projections

Completeness of GHG projections relates to the coverage of sectors, source categories and greenhouse gases in national projections. The coverage of source categories is analysed under the different sectoral assessments.

All Member States' GHG projections cover the sectors energy, transport, industrial processes and agriculture. The emissions from the waste sector are projected by all Member States except Estonia. Five Member States do not cover the forestry sector in their projections (Belgium, Cyprus, Denmark, Germany and Greece). The sector 'Solvents and other product use' is the sector with the lowest coverage, nine Member States do not include this sector. Its relevance is rather low in relation to total GHG emissions, only 0.5% of the EU-27 GHG emissions are due to 'Solvents and Other Product Use'.

However, there are gaps in the coverage of F-gases in GHG projections. Five Member States do not include F-gases in their national GHG emission projections at all (Bulgaria, Czech Republic, Estonia, Hungary and Lithuania). Total F-gas emissions of these countries in 2005 were 2.043 Mt CO_2eq, thus in quantitative terms this gap is rather small.

In recent reporting cycles, the completeness of GHG projections related to coverage of sectors and source categories has considerably improved and the remaining gaps are small in quantitative terms.

2.3 Consistency of Member States' GHG projections

Consistency of GHG projections relates to a number of different aspects. The consistency with regard to methodologies and models used for projections is considered the sectoral Chapters 4 -10.

2.3.1 Consistency of past and future GHG emission trends

Consistency refers to the past and projected GHG emission trends, i.e. that the projection methodologies should be as consistent as possible with the methods for the estimation of annual GHG inventories related to emission factors and other specific parameters and methods used to calculate emissions. Different methods and emission factors for GHG projections compared with GHG inventories could lead to large discrepancies in projected GHG emissions relative to current emissions which are only due to methodological differences.

It is rather difficult to achieve full consistency between GHG emissions and projections due to the different point in times of updating of these data sets. Projects to prepare updated GHG projections are usually performed over a time period of a year or even longer periods. The projection experts then use the most recent GHG inventory data, but when they have finalized the work on the new projections, GHG inventories may have been updated and recalculated again. The inventory recalculations can then lead to new inconsistencies between GHG inventory data and projections.

Due to this updating problem, it is important that reporting on GHG emission projections is not limited to future years, but also includes a number of past years. A comparison of past trends with GHG inventories allows for the detection of differences arising from recent inventory recalculations.

Currently, the Excel template for reporting on GHG projections only includes projected GHG estimates, except for the base year. It would be useful to expand the reported years by 5-year intervals to 2000 and 2005. The base year emissions will be fixed in the future and the reported data will therefore no longer allow any analysis of effects of inventory recalculations.

A detailed assessment of consistency between past GHG emissions trends and projected emissions is provided for each Member State in the Annex to this report.

According to the information gathered in the country visits to Member States, few Member States have created a coordinated reporting system that provides regularly updated projections based on the most recent recalculations of the national GHG inventory. A positive exception is Spain where such coordinated approach is implemented.

2.3.2 Consistency in reporting under different reporting requirements

Consistency also refers to the use of consistent assumptions for emission projections for the same Member States for different purposes, e.g. for projections under the Clean Air For Europe (CAFE) Programme, the national allocation plans under the EU Emissions Trading Directive (ETS).

For GDP consistency of reported data is analysed for the following sources of information: projections under the EU Monitoring Mechanism Decision, NAPs and DG ECFIN (see sectoral assessments).

The harmonization of reporting schedules for projections under different international requirements (in Particular NEC Directive and EC Monitoring Mechanism Decision) would strongly help to improve the comparability of projections.

2.4 Comparability of Member States' greenhouse gas projections

Comparability of GHG projections mainly relates to the reporting of projected emission results and whether the projected emissions sources are comparable across Member States. Comparability also relates to general assumptions used for the projections, the type of scenarios addressed as well as the policies and measures included in the respective scenarios.

2.4.1 Disaggregation of gases

To enable a disaggregation of projections at EU level it is of great importance that all Member States and especially the EU-15 provide projections disintegrated to gases and sectors.

Almost all Member States provided projections for CO_2, CH_4 and N_2O separately. Only Italy presents only CO_2 equivalents for the GHG projections presented in the report on demonstrable process (and submissions under the EU Monitoring Mechanism Decision are missing).

Germany covers all the sectors but does not provide estimates for individual gases in the agriculture and waste sectors. However, the most recent submission under the Monitoring Mechanism Decision in 2007 was provided in the Excel template.

Italy includes the F-gases in its national total in CO_2 equivalents. Four Member States (Belgium, Cyprus, Portugal and Sweden) provided projected aggregate F-gas emissions without breakdown into individual gases HFCs, PFCs and SF_6. Sweden and Portugal now report projected emissions in the Excel template which resolved this issue from the past reporting.

The Excel template for projection emissions improved the availability of estimates for disintegrated gases from Member States.

2.4.2 Scenario types

There are three scenario types required under the UNFCCC and Decision 280/2004/EC which are 'With Measures' (WM), 'With Additional Measures' (WAM) and 'Without Measures' (WOM) projections. Only the 'With Measures' projection is required on a mandatory basis. A 'with measures' projection shall encompass currently implemented and adopted policies and measures. A 'with additional measures' projection should encompass planned policies and measures and a 'without measures' projection should exclude all policies and measures implemented, adopted or planned after the year chosen as the starting point for this projection.

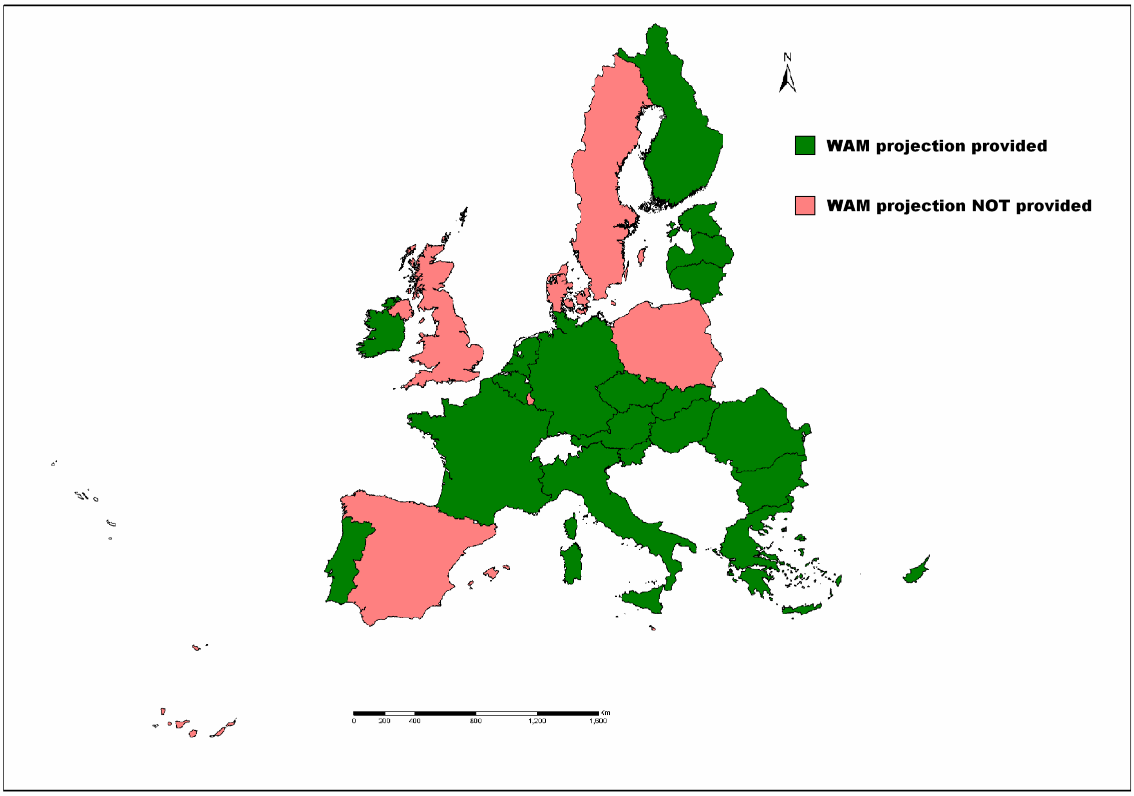
All Member States provide a 'With Measures' projection.

Five Member States do not provide a 'With Additional Measures' projection (Denmark, Poland, Spain, Sweden, UK) (see also Figure 1). Poland and Sweden argue that a WAM projection is not necessary because they will reach their Kyoto target with existing policies and measures and no additional measures are needed for the purposes of compliance with the Kyoto Protocol. However, the lack of WAM projections makes the aggregation at EU-15 and EU-27 level incomplete. Therefore despite the gaps a 'with additional measures' scenario at EU level should be elaborated in which the missing information is filled with the respective 'with measures' projection. However, the result of this approach is merely an approximation.

The 'Without Measures' projection is not mandatory; 16 MS reported this scenario (Austria, Bulgaria, Cyprus, Czech Republic, Estonia, Finland, France, Germany, Hungary, Italy, Netherlands, Poland, Romania, Slovakia, Spain and UK).

Four Member States provide additional national scenarios (Austria, Cyprus, France, and Netherlands). Those additional national scenarios either include further measures which are not decided upon yet or reflect different assumptions concerning economic growth.

Figure 1 Provision of a 'with additional measures' projection by Member States



2.4.3 Coverage of policies and measures

There are different concepts or definitions of the 'with measures' and 'with additional measures' projection. Some Member States include the effects of all adopted and implemented policies and measures in the 'with measures' scenario. Others define a cut-off date, all policies and measures implemented after that date are included in the 'with additional measures' scenario. Due to different cut-off dates used, the effects of key EU policies are in some cases included in the 'with measures' and in other cases in the 'with additional measures' projection. These cut-off dates can differ widely. For example France includes all policies and measures adopted and implemented before first July 2004, excluding the measures part of the national Climate Plan 2004-2008. The measures agreed in the Climate Plan 2004-2008 and those decided before the first October 2005 are included in the WAM projection, whereas other Member States recently updated the 'With measures' projection to reflect all adopted policies and measures in this scenario. In cases where the projected activity data is provided by different government institutions (e.g. transport or agriculture ministries), it is sometimes unclear which policies and measures were considered.

To enhance the consistency of representation of the ‘with measures’ and ‘with additional measures’ scenario at EU level; it would be useful to develop recommendations in which scenario a specific common and coordinated policy or measure should be included. Such guidance should be distributed to Member States before the start of a reporting cycle in projections. In the future it should be considered to extent the years covered in the projections.

A more detailed overview of the coverage of policies and measures in the scenarios is provided in the sectoral assessments.

2.4.4 Projected years

It is required to provide projected emissions for the years 2010, 2015 and 2020. All Member States cover these years. Additionally, three Member States provide projections for the period beyond 2020. Some Member States run their models with a projection horizon up to 2030, but report only the years up to 2020.

The revision of the Monitoring Mechanism Decision should change the projected years as the current years will soon be outdated. A time horizon up to 2030 is recommended. In addition the years should be defined in relation to a fixed bases and reporting period to avoid that Decisions have to be updated only to change the reporting years (e.g. base year + X years and 5-year updating periods).

2.5 Accuracy of Member States’ GHG projections

Accuracy of GHG projections in general relates to projections’ uncertainties and how closely the projected emissions match with the real emission trend.

The uncertainty of projections is composed by different types of underlying uncertainties:

- The uncertainties in the estimation of GHG emissions from emitting sources which are documented in the national GHG inventory report. These uncertainties are equally relevant for projections.
- The uncertainty in the approach and methodology used in the simulation models, e.g. due to simplifications and model assumptions.
- The uncertainty related to the assumed implementation of policies and measures in the projections and the real implementation of policies.
- Uncertainties related to the future economic, social and technology development as well as the effectiveness of policies.

For an assessment of accuracy of Member State’s projections, an evaluation of these different types of uncertainties would be necessary.

The current reporting of Member States covers the inventory uncertainties as part of the annual inventory report.

Uncertainties related to the models and the chosen methodology and model assumptions are usually not addressed in the Member States' reports. It is also not very common that model developers provide quantitative uncertainties related to the accuracy of the model assumptions and algorithms, neither at Member States' level, nor at aggregate EU level. It is not easy to quantify these uncertainties separately for a modelling approach because verification exercises such as comparison of ex-ante with ex-post evaluations only provide a joint result for all types of uncertainties listed above.

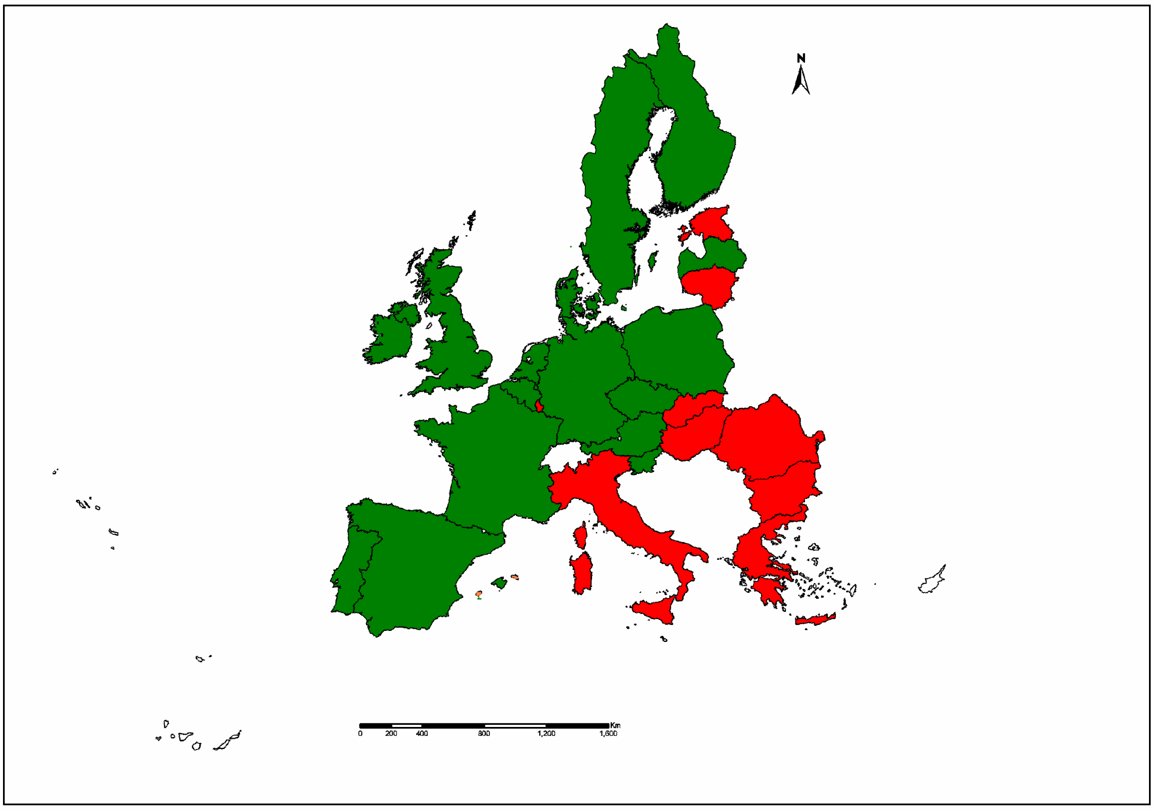
In the development of projections, it is necessary to develop specific assumptions with regard to the intensity and scope of planned policies which may not always completely match the real implementation.

The uncertainties related to future economic, social and technological developments and the effectiveness of policies are evaluated in sensitivity analysis where assumptions on input variables are varied to show the effects on the projected emissions.

2.5.1 Sensitivity analysis to reflect uncertainties related to future economic, social and technological developments and the effectiveness of policies

Figure 2 provides an overview which Member States currently report the results of sensitivity analysis in their reports under the Monitoring Mechanism Decision.

Figure 2 Overview on sensitivity analysis reported by Member States in most recent submission to the Commission



Sources: Member State' submissions under the Monitoring Mechanism Decision in 2007 and 2008

While most old Member States provide sensitivity analysis in their reports (green), this information is still missing in the reporting of many new Member States (red).

Table 1 shows which general parameters are further evaluated in Member States' sensitivity analysis. The parameter mostly tested by sensitivity analysis was GDP growth. From 15 reporting countries, 9 assessed different assumptions related to GDP growth. Consultants undertaking the sensitivity analysis may work with terms of references specifying the growth assumptions that should be used for the projections based on recent government projections. This may lead to situations where growth assumptions are not further analysed in sensitivity analysis

Different assumptions on fuel prices were evaluated by 4 Member States and 3 Member States also tested different GDP growth assumptions at sectoral level and for the price of CO_2 allowances.

Table 1 Overview on sensitivity analysis undertaken in relation to general parameters

Member State	fuel price	GDP growth general	GDP growth sectoral level	Price for CO_2 allowances	Other general parameters
Austria	✓				
Belgium		✓			
Cyprus					less impact of policies and measures (1% reduction on implementation)
Czech Republic	✓	✓			
Denmark	✓			✓	
Finland		✓	✓		
France	✓	✓			
Germany				✓	
Ireland				✓	no additional measures in non-ETS sector
Latvia		✓			
Netherlands		✓			
Portugal		✓	✓		
Slovenia		✓	✓		
Sweden					Private consumption, public consumption, investments, export
United Kingdom	✓	✓			

Source: Member States submissions under the Monitoring Mechanism Decision submitted in 2007 and 2008

Some Member States (e.g. the Netherlands or Finland) tested different economic scenarios which comprised more differences than GDP growth only which is not appropriately reflected in the simplified table above. All three parameters, fuel prices, GDP growth and prices for CO_2 allowances, seem essential for a sensitivity analysis and the recommendations related to the sensitivity analysis in the Monitoring Mechanism Decision should be more specific and list the required parameters that should be tested.

In addition to the general parameters, additional key parameters should be tested at sectoral level in sensitivity analysis of the projections. Table 2 summarizes the parameters that Member States tested in the sensitivity analysis for the energy sector.

Table 2 Scope of Member States' sensitivity analysis in the energy sector

Member State	Parameters used in sensitivity analysis in the energy sector
Belgium	number of degree days electricity import
Czech Republic	natural gas price availability of domestic brown coal
Germany	rate of construction of new buildings Use of technical modernization potential for buildings Share of renewable energies in residential sector share of oil and gas in fuel consumption of residential sector
Ireland	unregulated power market
Poland	Higher use of gas, lower use of solid fuels Higher/ lower energy consumption reduced emission factors in energy sector
Portugal	development of energy intensity in different sectors
Spain	energy consumption use of gas

The differences in tested parameters are related to the modelling approach used, e.g. when energy consumption is an exogenous parameter introduced in the energy models, it is useful to test different assumptions. However, if total energy consumption is an output parameter of a model framework, other assumptions need to be varied in such framework.

The reporting of Member States indicates that there is a wide range of options, in particular for bottom-up models that require many different assumptions, it maybe useful to test different assumptions for most input parameters.

It is unclear whether the reporting on sensitivity analysis of projections is complete and it is possible that sensitivity analysis implemented is larger in scope than the reported assessments. However, the overview shows in general that only 7 from 27 Member States report on specific sensitivity analysis in the energy sector.

Similar to the energy sector, the number of countries that report on specific sensitivity analysis in the transport sector is rather small (5 Member States) and in some cases only related to very specific sub-sources. Few sensitivity evaluations are also undertaken in the agriculture sector (see Table 5) and for the industrial processes sector there are only three Member States that reported on sector-specific sensitivity analysis (see Table 6). Many Member States do not use own models in the agriculture sector, but use forecasts for activity data from ministries or government institutions. In these cases where methodological information is often lacking, it would be essential to test the sensitivity of assumptions.

Table 3 Scope of Member States' sensitivity analysis in the transport sector

Member State	**Parameters used in sensitivity analysis in the transport sector**
Austria	Specific fuel consumption of newly registred cars Difference in fuel prices to neighbouring countries (tank tourism) elasticity between GDP and transport demand
Germany	elasticity of cheap airlines market share of traditional and cheap airlines different purposes of flight trips
Ireland	higher emissions in transport sector
Portugal	development of activities in passenger transport development of fuel consumption EFs in passenger and freight transport
Spain	number of tractors operation hours of tractors power of tractors

Table 4 Scope of Member States' sensitivity analysis in the agriculture sector

Member State	**Parameters used in sensitivity analysis in the agriculture sector**
Austria	prices for agricultural products
Denmark	pig production +25% reduction of N runoff
Poland	higher use of fertilizer higher use of manure reduction of livestock numbers
Spain	fertilizer use animal number emission factors

Table 5 Scope of Member States' sensitivity analysis in the agriculture sector

Member State	**Parameters used in sensitivity analysis in the agriculture sector**
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In general more sector-specific sensitivity evaluation should be required in the future in addition to the sensitivity analysis of the general parameters. The exact parameters will depend on input data required for the methodological approach. However currently there is a lack of sensitivity analysis for key sectoral parameters, e.g. energy demand is a very important exogenous input parameter in many countries, but only part of a sensitivity analysis in two Member States.

Table 6 Scope of Member States' sensitivity analysis in other sectors

Member State	Sector	Parameters used in sensitivity analysis in other sectors
Denmark	Industrial processes	relaxation of F-gas regulation
Ireland	Industrial processes	adoption of abatement options in cement sector delayed
Spain	Industrial processes	production level, calculation parameters for F-gases
Denmark	LULUCF	specific initiatives for extra afforestation (doubles afforestation rate)
Germany	Waste	earlier phase-out of deposition of MSW on waste disposal sites
Spain	Waste	waste generation

In the sectoral Chapters 4-10, depending on the type of model used, the most important key parameters are listed and their importance is highlighted. These give a good indication on what parameters can be used in a sensitivity analysis for the sector considered.

2.5.2 Comparison of projections with alternative sources

The accuracy of projections can also be validated by comparing the projected parameters or emissions with alternative sources of such projections. This requires the establishment of different projections methodologies for the same purpose, which is rather expensive and time consuming if conducted at Member State level. Such comparisons of results of different models are therefore only reported by few Member States. Belgium reports that it compared regional projections with technological bottom-up models are compared with national macro-economic top-down approach (HERMES), the Netherlands compared results of SVAE and NEMO and Spain compared national projections with GAINS and PRIMES.

Member States could more systematically compare aggregate projections at EU level (e.g. Primes, GAINS, CAPRI, transport models) with their national projections, however the results of these models are usually not easily available in Excel or database formats with specific details for each Member State and modellers are not always cooperative in supporting Member States with relevant methodological information and data for such exercises. It would be useful to publish model results in Excel or database formats as well as methodological descriptions on specific websites of the Commission to enhance the use for Member States.

2.5.3 Updating of projections

The uncertainty related to the assumed implementation of policies and measures in the projections and the real implementation of policies can be minimized if projections are regularly updated to reflect changes in the implemented policies and measures. Such updates are also important to reflect any changes in inventory methodologies.

Currently in most Member States there is not a regular process for updating of projections and the updates follow national requirements. Spain is an exception where a more continuous updating system was established. Austria also adjusted its projections taking into account recent changes in policies. The biannual reporting requirement under the EU Monitoring Mechanism Decision should also work in the direction of a more continuous updating of projections, however Member States updates are mostly determined by national purposes and often not related to the EU submission deadlines.

2.5.4 The consistency with past trends in GHG inventories

The consistency of future trends with past GHG inventory trends should be an important criterion of the quality of GHG emission projections. In some Member States very abrupt changes can be observed when comparing the historic emissions with projected ones, e.g. in the transport sector.

In annex to this report, the consistency of past and future trends per sector is given per MS.

2.5.5 Ex-post assessments of projections

Another key requirement for a reduction of the uncertainty in relation to the effects of policies is a systematic tracking and evaluation of policies and measures. However, currently only few ex-post assessments of projections are carried out. This is an area with great potential for improvement which could be promoted e.g. with workshops and expert meetings.

Some countries (e.g. Austria) undertook detailed decomposition analysis of past trends. Such decomposition analysis is an important basis for emission projections because it identifies the key drivers of GHG emissions on a quantitative basis. In addition Austria assessed the ex-post effects of policies and measures in three steps: in a first step it was analysed whether and how policies were finally implemented at national and regional level. The 2nd step assessed the emission reductions achieved and a 3rd step summarized the results for the national emission reduction targets. A further exchange of experiences between Member States as recently initiated seems very useful.

2.6 Transparency of Member States' GHG projections

Currently there is no guidance with regard to any explanations of the projection methodologies or with regard to the projected trends and many reports are not very transparent because they only provide the results in projected emissions, but not many additional descriptions on the assumptions or methods. Such descriptions cannot be fully harmonized in terms of specific parameters due to the use of different modelling approaches, however it would be useful to provide additional guidance on the elements of the reports on GHG emission projections.

The following structure and elements of such reports are recommended:

- General methodology for GHG emission projections
  - General methods, models and approaches used
  - Scenario definition for WOM, WM and WAM projection
    - Approach for WOM
    - Inclusion of PAMs in different scenarios
    - Starting point for WM projection
  - General assumptions used

  - Institutions involved, integration of sectoral results in overall approach
  - Sensitivity analysis
  - Quality procedures (e.g. consistency with inventories, comparison with results from other models)
- Sectoral information
  - Sectoral methodology, model used with references to detailed descriptions of models
  - Sectoral assumptions for key parameters
  - Sectoral emission calculation (EFs, tier approaches)
  - Sectoral results and interpretation of results
  - Sectoral sensitivity analysis

For transparency it is also important that data is provided in tables and not only in graphs – an approach chosen by some Member States which considerably reduces transparency and comparability.

2.7 Assessment of general projection parameters

2.7.1 Population

This section compares some of the important general assumptions for greenhouse gas projections which are the population development and the economic trend (GDP).

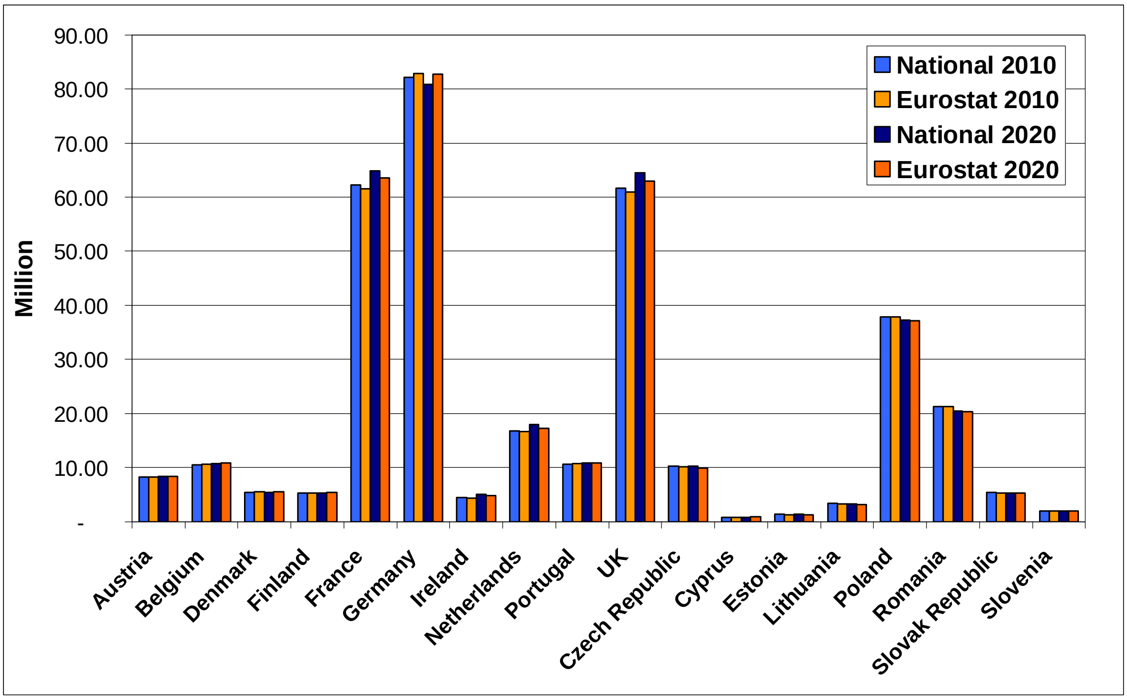
For three Member State no data on projected population is reported in national projections (Luxembourg, Malta and Spain; see Table 7). Mostly the population projections are made by the national statistical offices, sometimes updated or adapted for the purpose of GHG projections.

The assumed population development is rather consistent between national 'with measures' projections and Eurostat projections (see Figure 3). For 11 Member States, the projections are almost the same as Eurostat population projections or differ by maximum 1% in 2020. The largest difference in 2020 occurs for Estonia (national projections 17% higher than Eurostat) and Cyprus (national projections 7% lower than Eurostat). For Ireland, the Netherlands and the Czech Republic the discrepancy between national population projections and Eurostat is 4-5%. The sum for all Member States with population projections is 417.4 Mio. for 2010 from national projections, and 416.3 Mio. from Eurostat projections. For 2020 the projected population for EU-15 is 341.6 Mio. (national) versus 340 Mio. (Eurostat), thus national population projections are slightly higher than Eurostat projections.

Table 7 Overview on reporting on projected population

	Population and population growth		
	Projected population data provided	Absolute	population growth
Austria	Yes	Yes	No
Belgium	Yes	Yes	No
Bulgaria	Yes	No	Yes
Cyprus	Yes	No	Yes
Czech Republic	Yes	Yes	No
Denmark	Yes	Yes	No
Estonia	Yes	Yes	No
Finland	Yes	Yes	Yes
France	Yes	Yes	No
Germany	Yes	Yes	Yes
Greece	Yes	Yes	Yes
Hungary	Yes	No	Yes
Ireland	Yes	Yes	Yes
Italy	Yes	Yes	No
Latvia	Yes	Yes	No
Lithuania	Yes	Yes	Yes
Luxembourg	No	No	No
Malta	No	No	No
Netherlands	yes	Yes	No
Poland	Yes	No	Yes
Portugal	Yes	Yes	Yes
Romania	Yes	Yes	No
Slovakia	Yes	Yes	Yes
Slovenia	Yes	Yes	Yes
Spain	No	No	No
Sweden	Yes	Yes	No
United Kingdom	Yes	Yes	Yes

Figure 3 Projected population from Member States' national projections and Eurostat for 2010 and 2020



Source: Member States' submissions under the EC Monitoring Mechanism in 2007, Eurostat http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,39140985&_dad=portal&_schema=PORTAL&screen=detailref&language=en&product=Yearlies_new_population&root=Yearlies_new_population/C/C1/C11/caa11024, last update July 2006, download November 2007.

Table 8 Projected population in 2010 and 2020 – comparison of national projections and Eurostat projections

Member State	National 2010	Eurostat 2010	National 2020	Eurostat 2020
Austria	8.3	8.3	8.4	8.4
Belgium	10.5	10.6	10.7	10.8
Denmark	5.4	5.5	5.4	5.5
Finland	5.3	5.3	5.3	5.4
France	62.3	61.5	64.9	63.6
Germany	82.1	82.8	80.8	82.7
Greece		11.3		11.4
Ireland	4.4	4.3	5.0	4.8
Italy	58.5	58.6	58.1	58.3
Luxembourg		0.5		0.5
Netherlands	16.8	16.7	17.9	17.2
Portugal	10.6	10.7	10.8	10.8
Spain		44.6		45.6
Sweden[1]	9.3	9.2	9.7	9.6
UK	61.6	60.9	64.5	62.9
Total of MS from EU-15 with national figures	**335.1**	**334.4**	**341.6**	**340.0**
Bulgaria		7.4		6.8
Czech Republic	10.3	10.1	10.3	9.9
Cyprus	0.8	0.8	0.8	0.9
Estonia	1.4	1.3	1.4	1.2
Hungary		10.0		9.7
Latvia		2.2		2.1
Lithuania	3.4	3.3	3.2	3.2
Malta		0.4		0.5
Poland	37.9	37.8	37.3	37.1
Romania	21.2	21.3	20.5	20.3
Slovak Republic	5.4	5.3	5.3	5.3
Slovenia	2.0	2.0	2.0	2.0
Total of MS from EU-27 with national figures	**417.4**	**416.3**	**422.4**	**419.9**

[1] National values from linear interpolation

Source: Member States' submissions under the EC Monitoring Mechanism in 2007, Eurostat http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,39140985&_dad=portal&_schema=PORTAL&screen=detailref&language=en&product=Yearlies_new_population&root=Yearlies_new_population/C/C1/C11/caa11024, last update July 2006, download November 2007.

In general the projected future population development is rather consistent between Member States and Eurostat and no further action seems necessary for the improvement of consistency or accuracy in this area.

The outstanding issue related to population data is completeness because not all Member States provide projected population data and the completeness of the dataset should be further enhanced. However, some Member States base their projections on projected activity data from national sources (e.g. ministries), e.g. projected energy demand or projected transport energy consumption or transport demand. In such cases, population projections were already taken into account in the projected energy or transport activities, but may not directly be available to the compilers of GHG projections, depending on the transparency of the national documents. In some countries (e.g. Spain), this is the reason for the lack of reporting on future population data. If population data is not a direct input parameter in the projection models, some Member States may not report the assumed population growth.

2.7.2 Gross Domestic Product

All Member States except Luxembourg and Malta provide the underlying GDP growth assumptions. Six Member States (Cyprus, France, Greece and the Netherlands) provide growth rates. Some Member States provide GPD figures per sector, others only aggregated. GDP projections are mostly provided by national ministries of economy or finance or national agencies.

The GDP assumptions of the reporting Member States are difficult to compare because Member States report in many different units (national currency or Euro, real prices, constant prices with different price basis) and assumptions have to be used to make the data comparable.

The following section shows the comparison of projected GDP by Member States (GDP at 2000 constant prices) with the following other data sources:

- European Commission DG Economic and Financial Affairs, AMECO online database. Provides GDP forecasts for Member States up to 2009
- GDP projections published in 2nd National Allocation Plans
- Primes GDP projections[1]

For a large number of Member States the projected GDP growth from the different sources are very close (Austria, Belgium, France, Germany, Hungary, Italy, Portugal, UK). For some Member States, there is a constant difference in the level of the national projections and other estimates, but the trend is the same which indicates some methodological differences in the estimates, which is unlikely to strongly impact the projection’s quality (e.g. Finland, Greece, Spain). The differences for old Member States are mostly lower than the differences for new Member State which indicates a higher uncertainty in the projected economic growth for new Member States.

For a number of countries the GDP projection provided as part of the NAP II shows a different trend and recent GDP projections are more in line with other data sources.

[1] Primes Ver. 3 Energy Model, from 17.07.2007, more recent Primes projections have been published in 2008 after this comparison had already been performed for this report.

Figure 4 Comparison of Austria's projected GDP at 2000 constant prices with other data sources

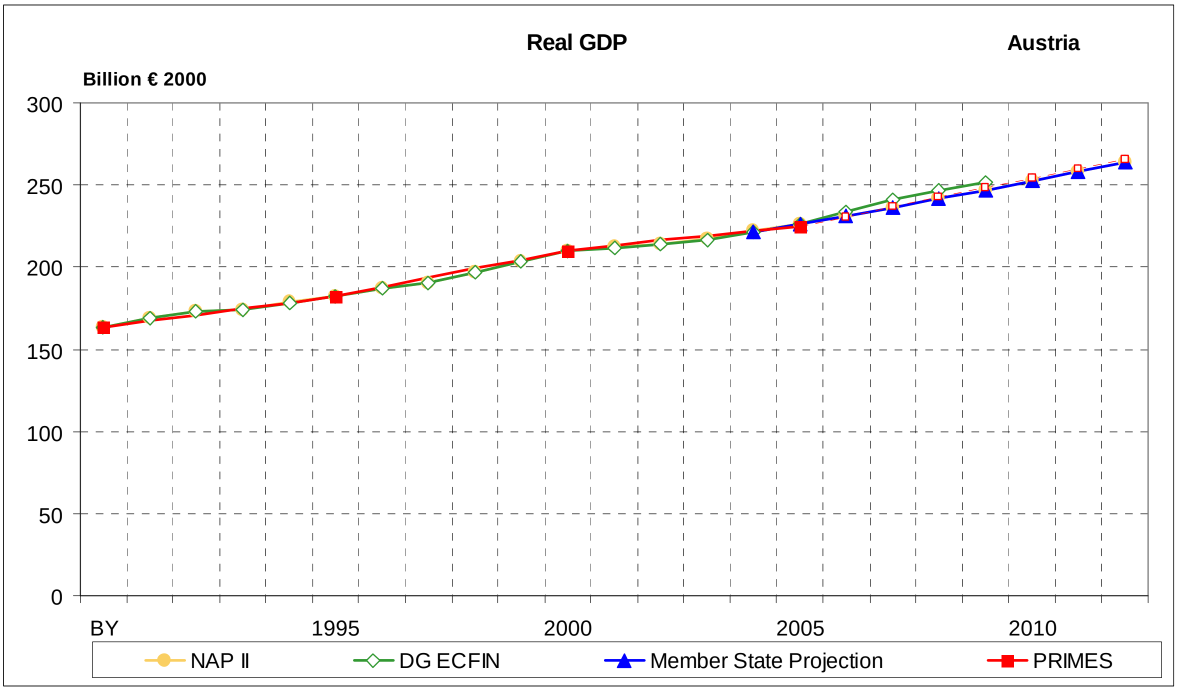


Figure 5 Comparison of Belgium's projected GDP at 2000 constant prices with other data sources

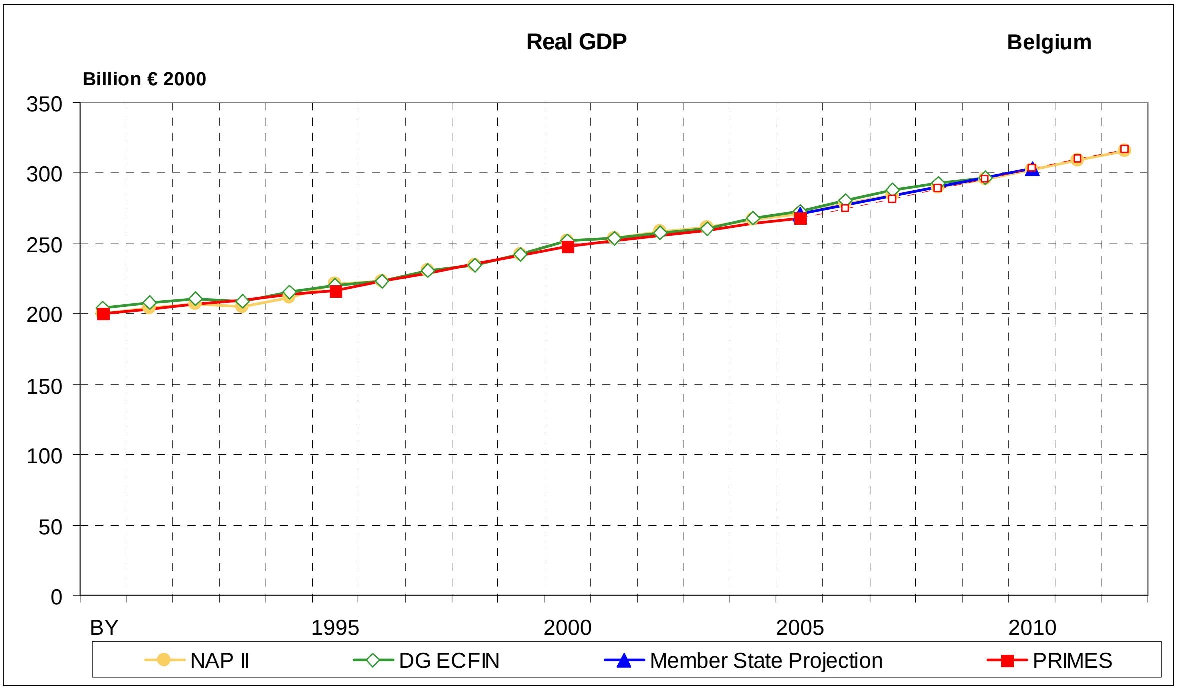


Figure 6 Comparison of Finland's projected GDP at 2000 constant prices with other data sources

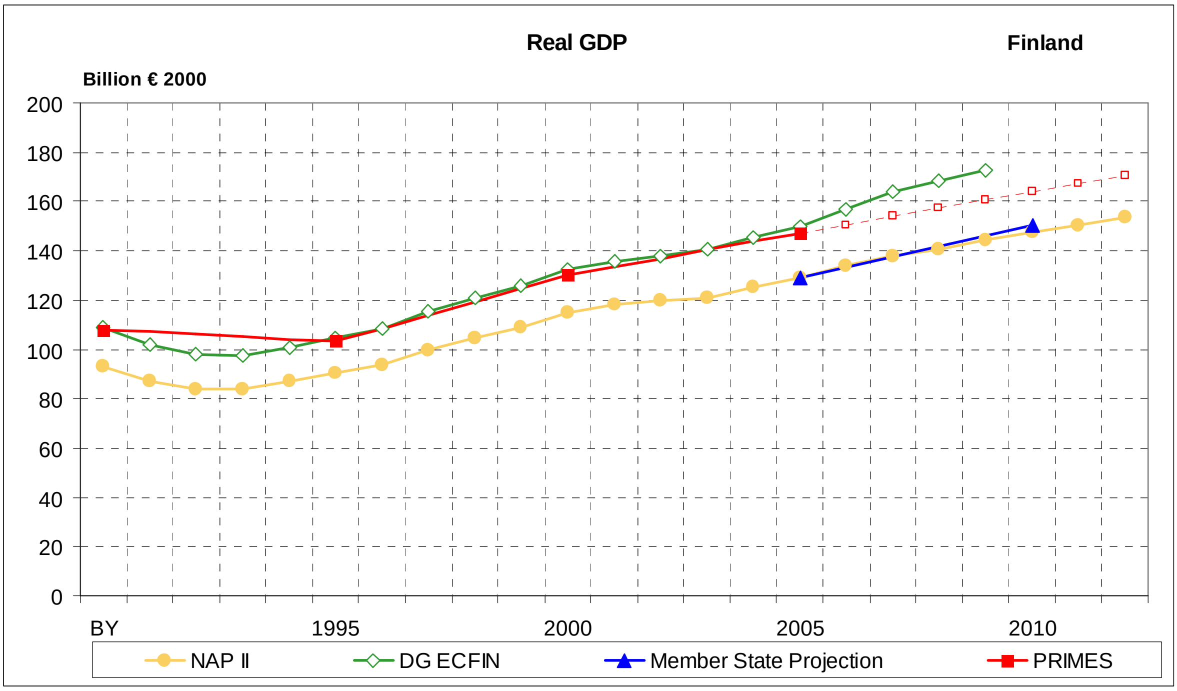


Figure 7 Comparison of France's projected GDP at 2000 constant prices with other data sources

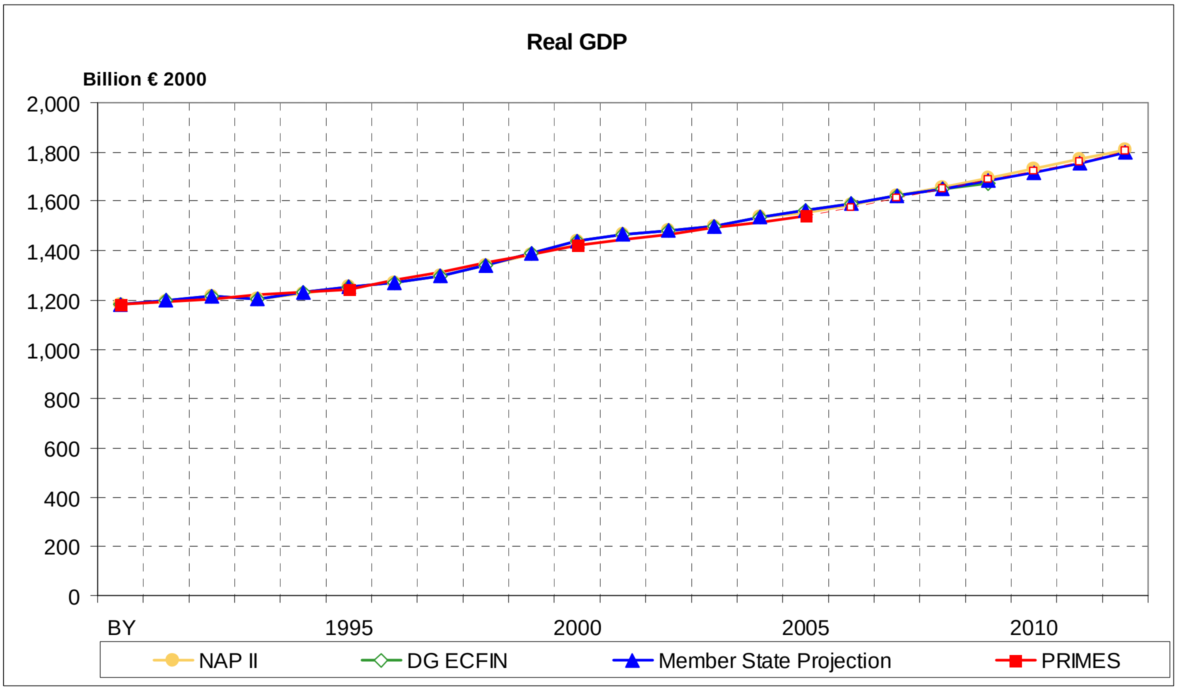


Figure 8 Comparison of Germany's projected GDP at 2000 constant prices with other data sources

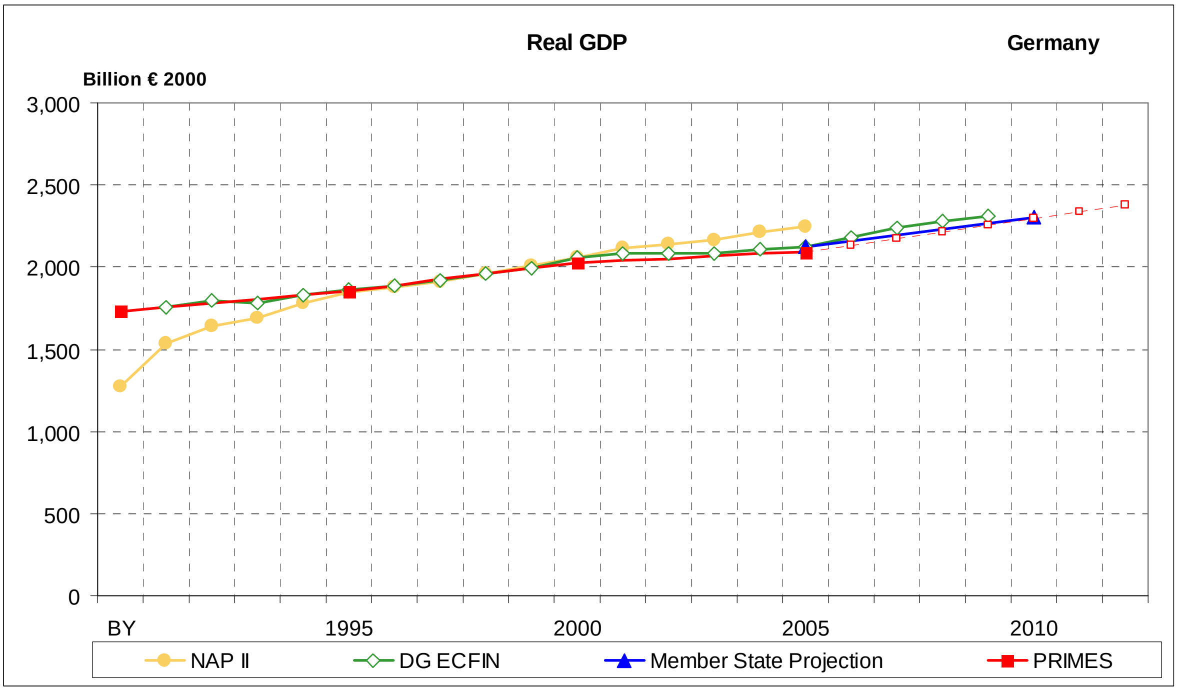


Figure 9 Comparison of Greece's projected GDP at 2000 constant prices with other data sources

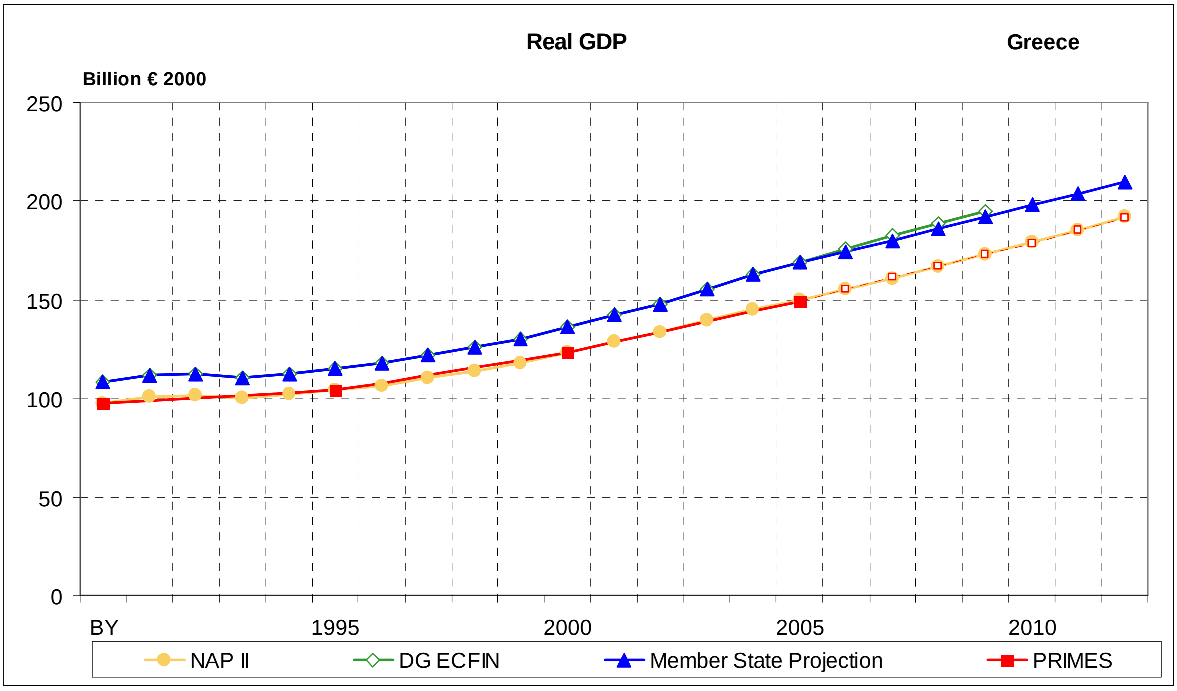


Figure 10 Comparison of Italy's projected GDP at 2000 constant prices with other data sources

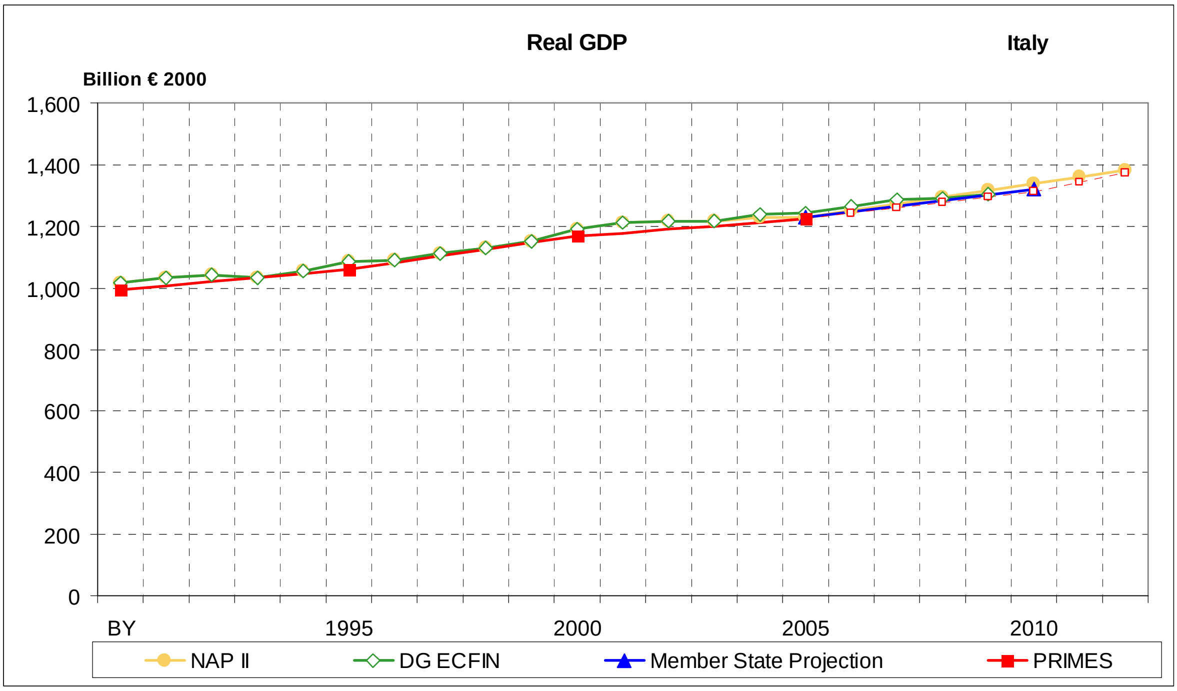


Figure 11 Comparison of Portugal's projected GDP at 2000 constant prices with other data sources

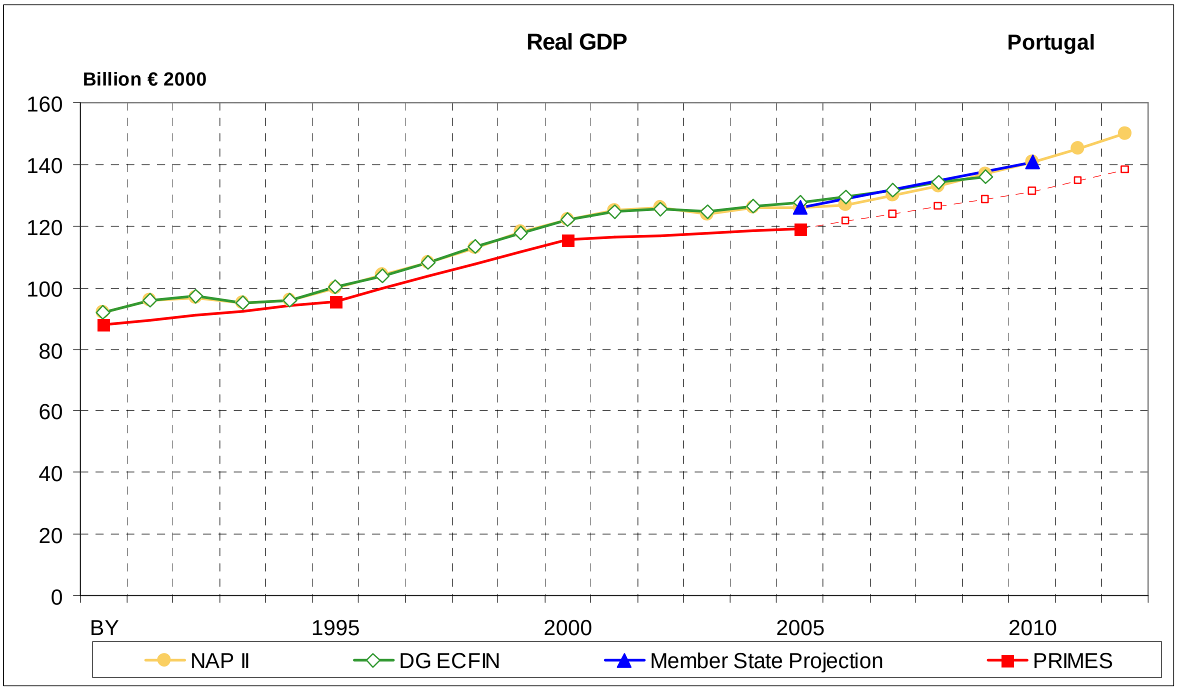


Figure 12 Comparison of Spain's projected GDP at 2000 constant prices with other data sources

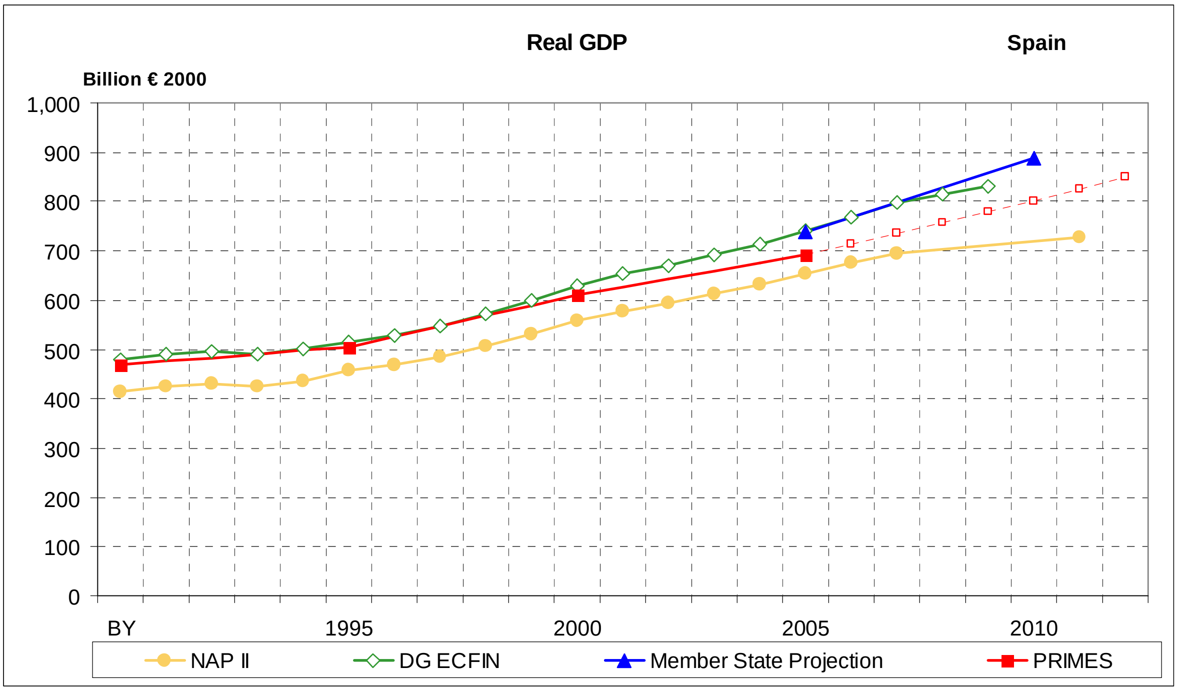


Figure 13 Comparison of Sweden's projected GDP at 2000 constant prices with other data sources

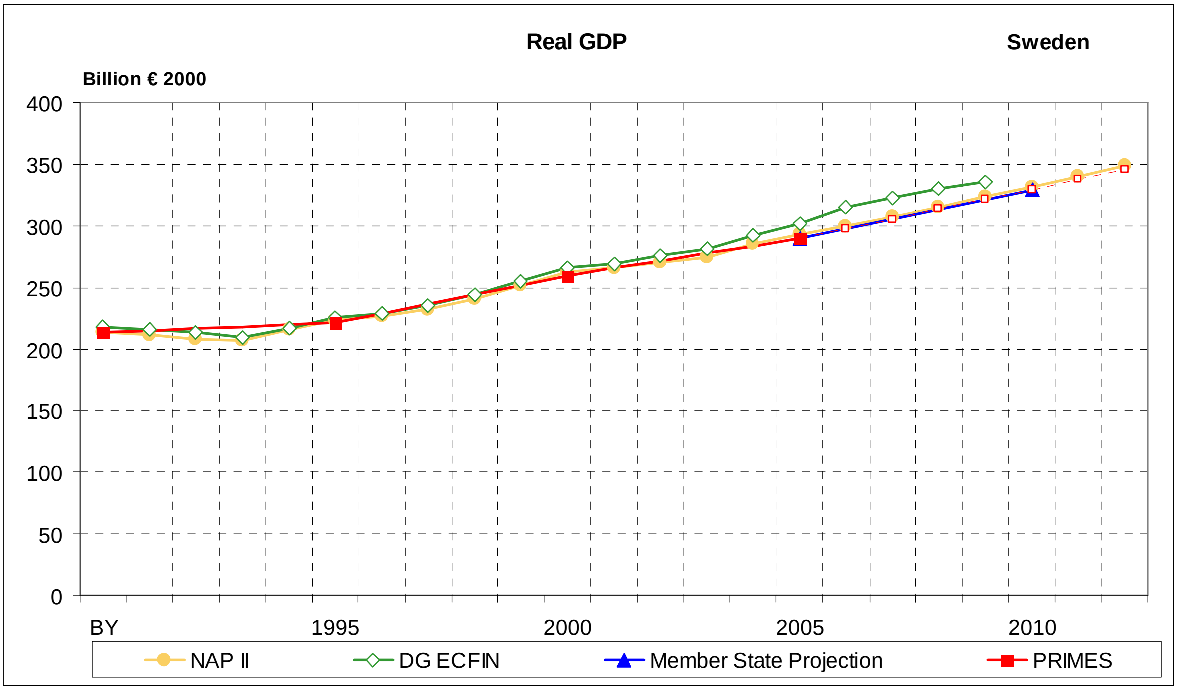


Figure 14 Comparison of UK's projected GDP at 2000 constant prices with other data sources

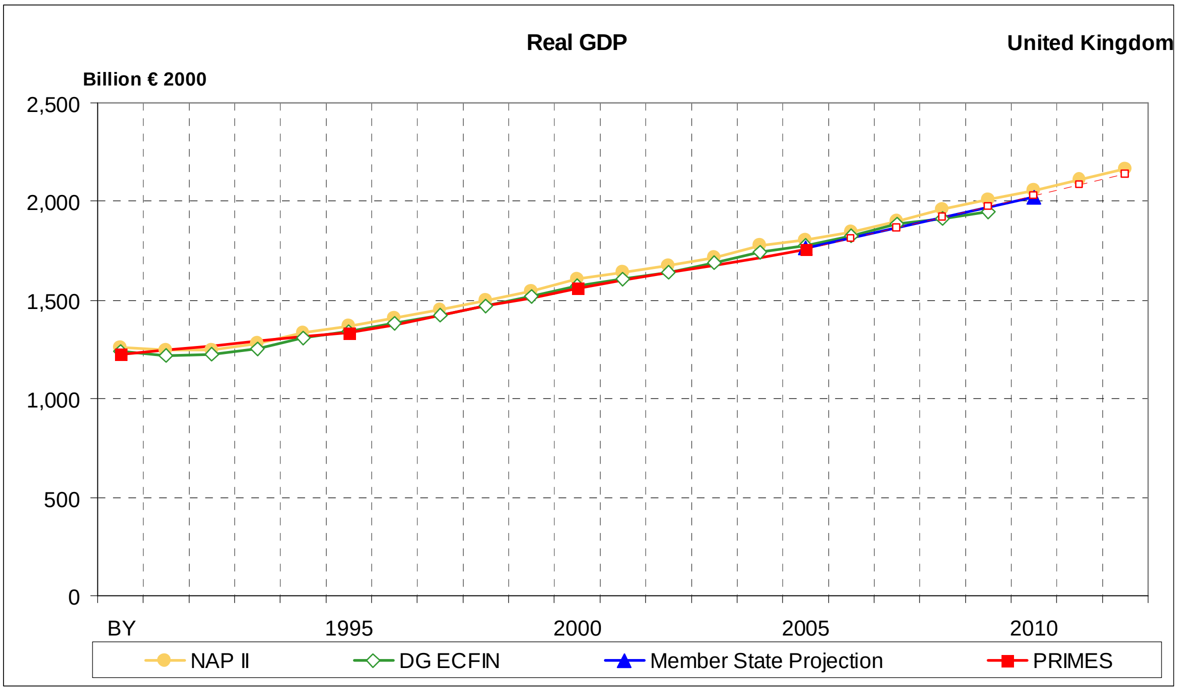


Figure 15 Comparison of Cyprus' projected GDP at 2000 constant prices with other data sources

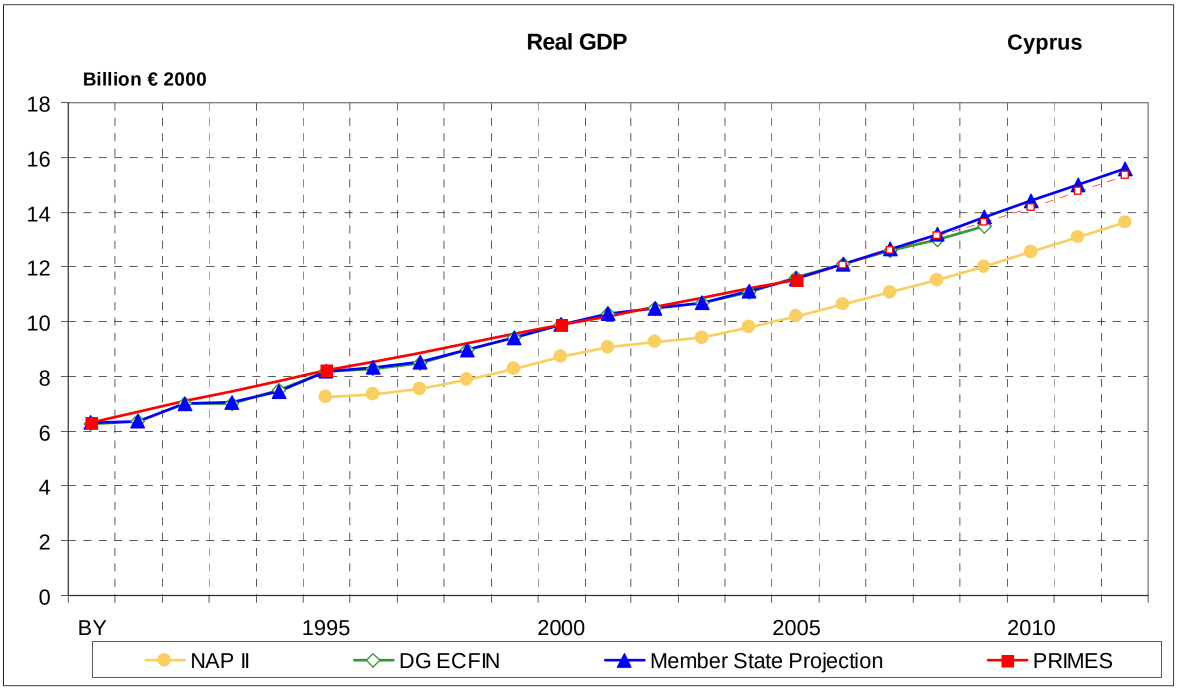


Figure 16 Comparison of Estonia's projected GDP at 2000 constant prices with other data sources

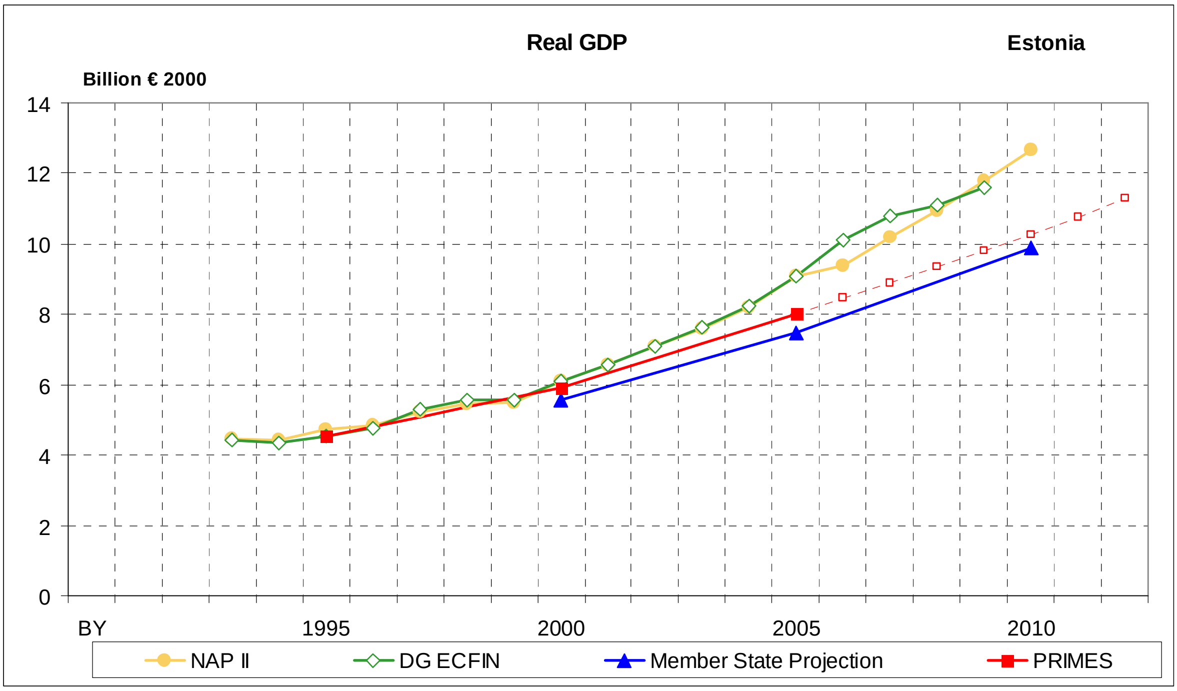


Figure 17 Comparison of Hungary's projected GDP at 2000 constant prices with other data sources

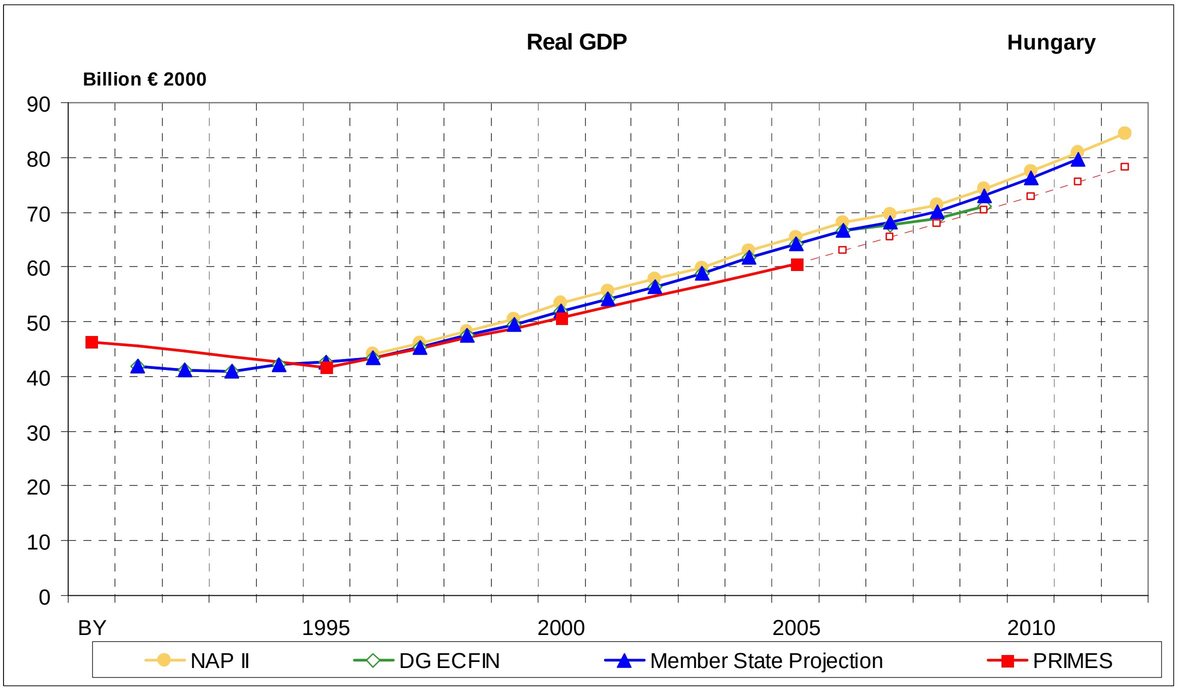


Figure 18 Comparison of Latvia's projected GDP at 2000 constant prices with other data sources

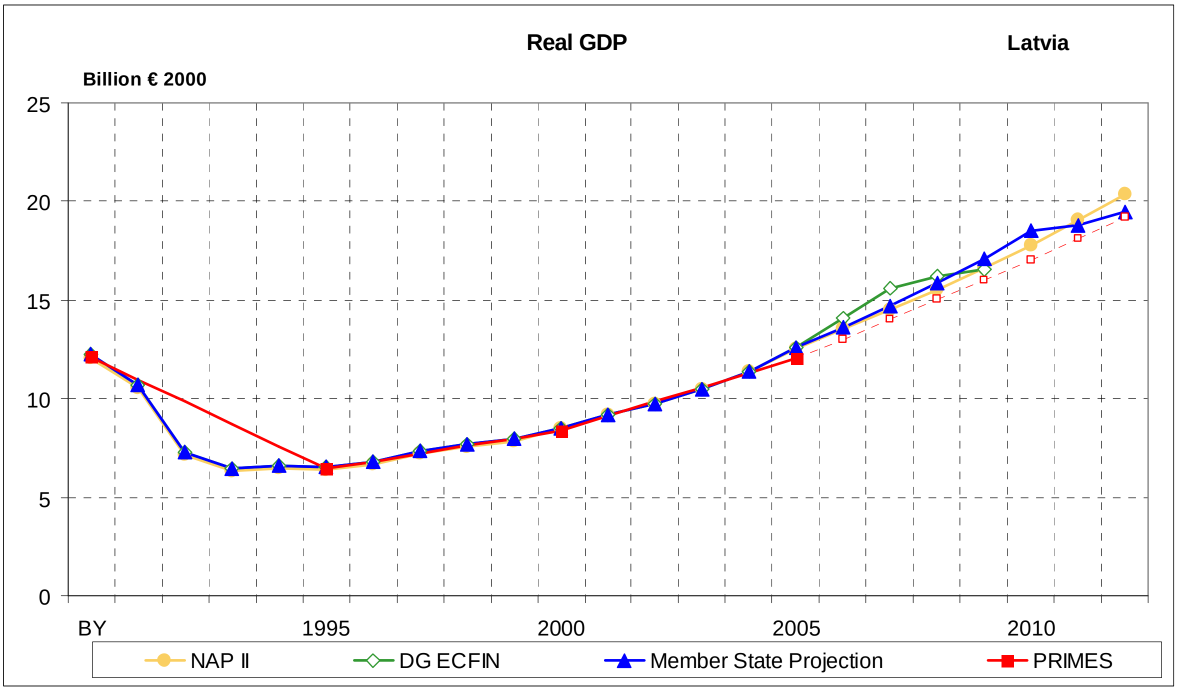


Figure 19 Comparison of Lithuania's projected GDP at 2000 constant prices with other data sources

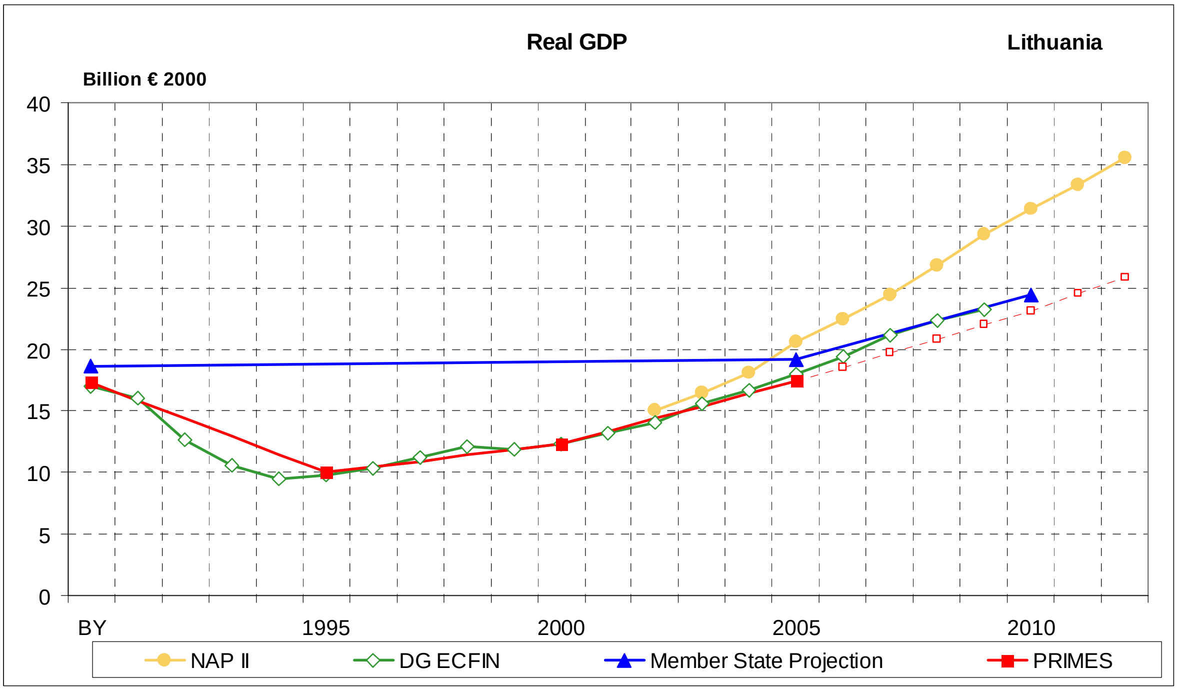


Figure 20 Comparison of Poland's projected GDP at 2000 constant prices with other data sources

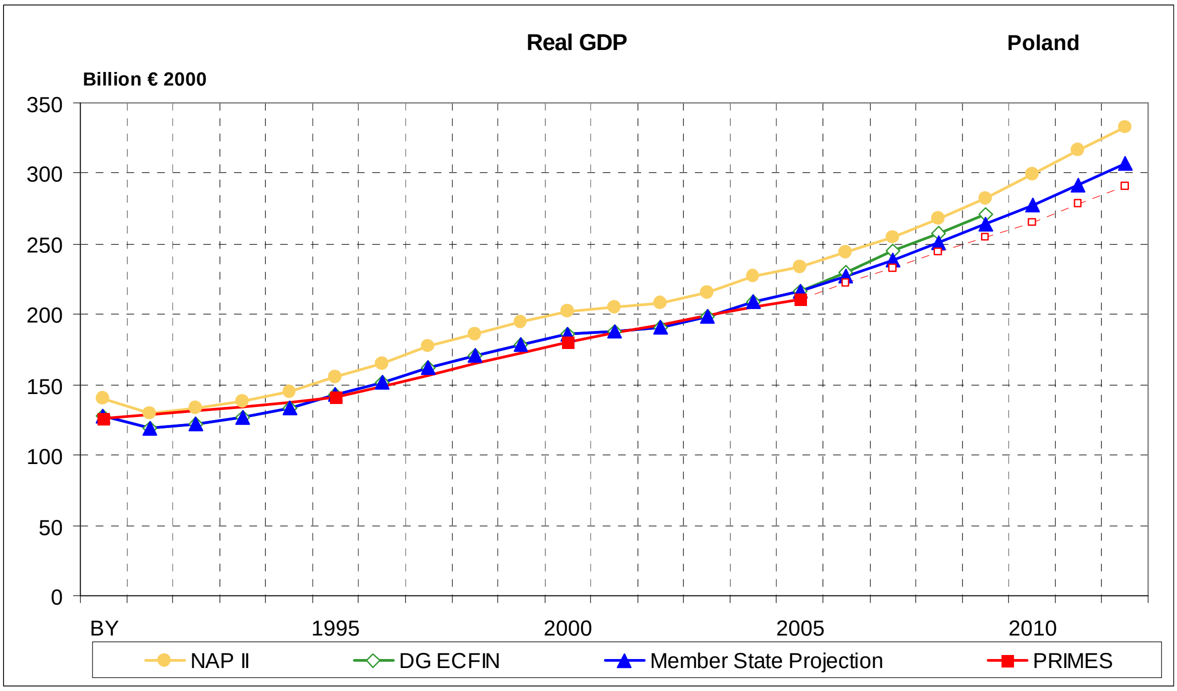


Figure 21 Comparison of Slovak Republic's projected GDP at 2000 constant prices with other data sources

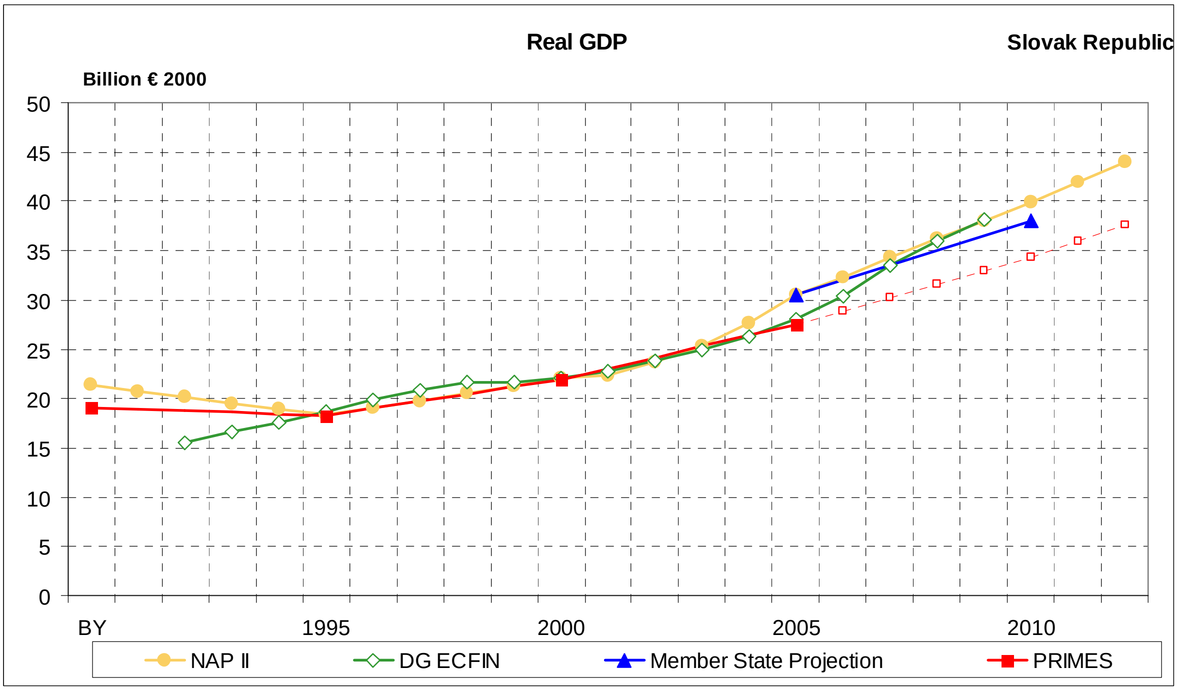
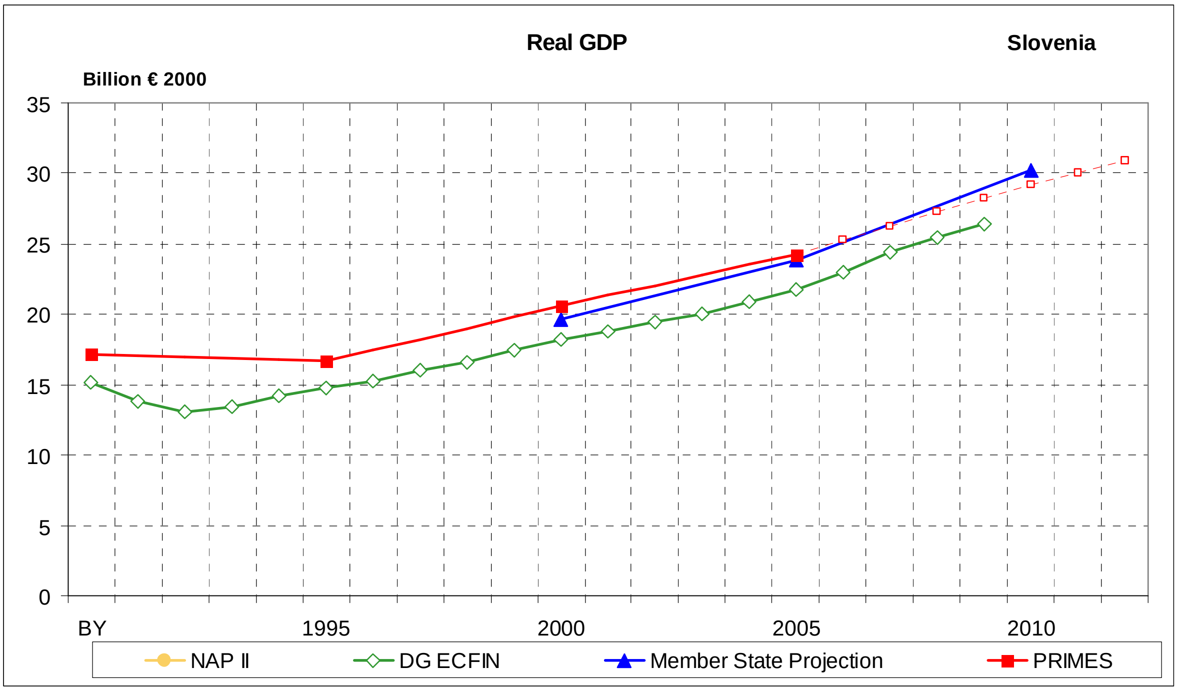


Figure 22 Comparison of Slovenia's projected GDP at 2000 constant prices with other data sources



Denmark, Ireland and Bulgaria reported GDP at 1995 constant prices, Romania at 2005 prices and are therefore not included in this comparison. The Czech Republic presented GDP information in graphs only and not in tabular format. For Non-EURO Member States, data indicated in national currency were converted by using EURO-national currency exchange rates for the year 2000 from DG ECFIN AMACO database.

With regard to the reporting on GDP projections, it should be discussed with Member States and Eurostat how the reporting on GDP in constant prices should be implemented in the future with regard to the following aspects:

- The base year for computation of constant prices is traditionally a single, fixed benchmark year, which is moved ahead about each five years. The whole time series available is then expressed in prices of the new base year. Therefore the revision of the reporting guidance should implement a flexible approach that takes automatically into account of the periodic change of the benchmark year. The periodic updating of the base year avoids the drawback of this method that the further one moves away from the base year, the more irrelevant becomes the price structure of the base year for the economic area.
- Commission Decision 98/715/EC demands that the base year must be the previous year and Eurostat started to published so-called chain-linked series of GDP data. This guarantees that volumes are measured using the most recent price structure. However, this also means that the base is moved ahead with the observation period, and no two years have the same price base, so that volume growth rates cannot be calculated directly from series at previous year's prices. The choice of reference year in chain-linking is arbitrary and a mere convention without effect on

growth rates (unlike the choice for a fixed base year, which can have a significant effect on growth rates). While the moving price base brings more accurate description of economic developments, it comes at a price: chain-linking involves the loss of additivity (i.e. the total does not equal the sum of the parts) for all years except the reference year and the directly following year, which are the only ones actually expressed purely in prices of the reference year. For other years, chain-linked Member States' GDP will not sum to chain-linked EU GDP. The use of chain-linked GDP data has recently started, but it may become more popular in the future.

GDP is a key parameter for MS' projections and it is recommended to prepare a set of scenarios among at least one scenario reflects GDP growth as provided by a common source for all Member State. Such common source could be the mid-term GDP forecast provided by DG Economic and Financial Affairs. This forecast is not sufficiently long in time and would need to be extrapolated for the required period of projections.

2.7.3 Fuel price assumptions

Fuel prices for gas, oil and coal are not provided by 8 Member States (Bulgaria, Hungary, Italy, Portugal, Romania, Slovakia, Slovenia and Spain). Cyprus reports oil and coal prices, Austria oil prices only.

It is difficult to compare the fuel prices used in GHG projections across Member States because units differ widely; some prices are given in Dollars and others in Euro with different reference years (US$1997, US$2000, US$2004, €1990, €2000, €2004, €2005). Exchange rates are rarely given. Oil is measured in barrel, toe or GJ; gas prices in GJ, 1000 m^3 or Mbtu; coal prices in GJ, toe or ton. Estonia, Finland, Lithuania and Sweden did not clarify to which year the currency refers to. A conversion of the units is not straightforward due to the following reasons:

- Member States provide quantities in physical units such as tons, m3 and in energy units (TJ, toe). For conversion of physical units to energy units calorific values are necessary, but it is not completely clear whether MS use net calorific values (NCV) or gross calorific values (GCV) and which calorific values should be chosen for this calculation. There exist general, but varying recommendations for conversion in literature, but these are not very precise and provide rather rough assumptions.
- Member States provide prices in current or constant prices. When current prices are provided they need to be converted to constant prices which involves assumptions on projected inflation for each country. This introduces considerable uncertainties in the comparison of resulting prices.
- Some Member States do not provide units.

In Table 9 an attempt was made to convert the reported fuel prices for a comparison across Member States. However large uncertainties are connected with the methodological approach used.

Table 9 Comparison of fuel price assumptions for 2010 across Member States

Fuel prices 2010							
	Oil	**Unit**	**Gas**	**Unit**	**Coal**	**Unit**	**Source oil/gas**
Austria	5.22	€2000/GJ	NA		NA		NA
Belgium	6.10	€2000/GJ	5.11	€2000/GJ	2.13	€2000/GJ	PRIMES 2005
Cyprus	3.02	€2000/GJ	NA		2.47	€2000/GJ	NA
Czech Republic	5.81	€2000/GJ	3.95	€2000/GJ	1.64	€2000/GJ	American Energy Outlook 2006, Enviros
Denmark	6.59	€2000/GJ	4.90	€2000/GJ	1.83	€2000/GJ	NA (DEPA 2007 p. 166)
Estonia	5.77	EUR/GJ	4.16	EUR/GJ	1.60	EUR/GJ	NA (Report 2007)
Finland	4.30	EUR/GJ	3.40	EUR/GJ	1.70	EUR/GJ	NA (MMD 2007 excel)
France	6.10	€2000/GJ	3.96	€2000/GJ	1.61	€2000/GJ	IEA, study by environemental ministry
Germany	3.56	€2000/GJ	2.84	€2000/GJ	1.43	€2000/GJ	"Klimaschutz in Deutschland bis 2030", Federal Environmental Agency 2005
Greece	3.97	€2000/GJ	3.00	€2000/GJ	1.48	€2000/GJ	World Energy Outlook Report (2004) of the US Department of Energy
Ireland	6.39	€2000/GJ	4.69	€2000/GJ	1.86	€2000/GJ	ICF Consulting
Latvia	2.93	€2000/GJ	2.67	€2000/GJ	1.80	€2000/GJ	World Energy Organisation (2002)
Lithuania	3.96	€/GJ	5.43	€/GJ	NA		
Netherlands	4.41	€2000/GJ	2.89	€2000/GJ	1.70	€2000/GJ	
Poland	6.43	€2000/GJ	5.14	€2000/GJ	1.85	€2000/GJ	NA
Sweden	6.22	€/GJ	4.98	€/GJ	2.05	€/GJ	World Energy Outlook 2005, IEA
United Kingdom	4.73	€2000/GJ (taking 2006 exchange rate)	4.07	€2000/GJ (taking 2006 exchange rate)	1.36	€2000/GJ (taking 2006 exchange rate)	

Notes: yellow colour: converted data, orange colour, not sufficient data for conversion.

Sources: 2007 MS submissions under the Monitoring Mechanism Decision, conversion Öko-Institut

The overview in Table 9 shows that the differences in oil price assumptions for the year 2010 are more than a factor of 2 for crude oil and gas, and 1.8 for coal. A general methodology for the conversion of fuel prices should be developed in cooperation with Eurostat and IEA. This would provide assistance to Member State that may face problems with conversions as well. And this would ensure a coordinated and consistent approach for a comparison across Member States.

The IEA World Energy Outlook is the most widely used source for fuel price scenarios, apart from national data. However, due to different updating dates for projections, different IEA fuel price scenarios are used in Member States projections. The IEA energy outlook seems to be the most popular candidate for a harmonized source for fuel prices. There exist efforts by the Commission to develop fuel price assumptions, but these activities and results do not seem to be well known in Member States.

Fuel prices are a key parameter for MS' projections and it is recommended to develop a common assumption that should be used by Member States at least in one scenario. Such common fuel price assumption could either be the fuel prices assumed in the IEA World Energy Outlook or results from POLES projections as currently used for PRIMES. This would strongly enhance the consistency of projections with regard to key assumptions.

2.7.4 Carbon prices

The current reporting requirements do not include the reporting of carbon price assumptions used in the economic models for the emission projections. As a consequence few

Member States report on this key assumption. This is an important addition for future projection parameters.

Similar as fuel prices and GDP, there should be a common assumption for carbon prices at EC level that should be used by Member States in at least one scenario. Future carbon prices already have to be determined for aggregate projections and these assumptions could also be made available to Member States.

2.8 Approaches to quantify effects of policies and measures

Member States use different approaches to quantify and account for the effects of policies and measures in the national GHG emission projections. The approaches differ on the one hand with regard to the model types and their possibilities to estimate the effects of certain policy types, which is discussed in chapter 3.

2.8.1 References for the quantification of policies and measures

Another key difference is the reference used to calculate the emission reduction effects of policies and measures.

One option is the definition of a 'Without measures' (WOM) scenario. The impact of PAMs is the difference between the WOM scenario and the WM and WAM scenarios. According to the UNFCCC reporting guidelines, a 'without measures' projection excludes all policies and measures implemented, adopted or planned after the year chosen as the starting point for this projection. The WOM scenario projects a future situation without certain PAMs that are actually adopted and implemented. In the EU, 13 Member States develop WOM projections. However, the definitions used vary considerably as shown in Table 10. France and Denmark used the earliest reference year and excludes all PAMs implemented after 1990, whereas Slovakia used the latest reference year (2003). The quantified effects of PAMs of course vary largely whether they relate to 1990 or to 2003 and the earlier the reference year, the higher are usually the effects of policies and measures.

Table 10 Overview of definitions used for 'without measure' projections

Member State	Definition of WOM projection
Austria	Likely development of final energy consumption and emissions without implementation of climate strategy (only mentioned for residential and commercial sector)
Denmark	The "without measures" projection is a projection without the effect of measures since 1990 – i.e. estimates of what the volume of average annual greenhouse gas emissions would have been between 2008-2012 if the measures initiated prior to 2001 had not been initiated.
France	The nature of the WOM projection is not clearly explained in the 4th NC. It is only stated that it is based on updated estimation of the 'without measures' projection of the 3rdNC. In the 3rd NC, it is explained that the 'WOM' scenario eliminates the impact of all PAMs to

	reduce emissions after 1990. The French submission in 2007 under the EC Monitoring Mechanism does no longer include a WOM scenario.
Bulgaria	The “without measures” scenario is based on the assumption for intensive economic development with emphasis on energy intensive technologies and limited application of energy efficiency improvement measures in industry and agriculture. This scenario was originally developed in 1994 (before Bulgaria ratified the UNFCCC).
Czech Republic	Only measures that came into force up to 1994
Estonia	Without measures (WOM) scenario where all measures described in were excluded.
Cyprus	A “Business as Usual” (BaU) Scenario was formulated, which represents the future development of emissions under current policies and behaviour of consumers, as well as under the emerging future trends. The BaU Scenario considers only the application of the agreement between EU and car manufacturing industries (ACEA, KAMA, JAMA) for the decrease of fuel consumption in new cars.
Germany	WOM projection represents the hypothetic trend if the measures implemented in the 2000-2006 period would not have been implemented.
Hungary	The “without measures” scenario is treated as the baseline scenario, which is modified with the effects of various policies and measures to arrive at the “with measures” and “with additional measures” scenarios. The emission calculations for the “without measures” scenario already assume that some steps are taken towards energy efficiency, fuel-switch, renewables use, to an extent that this is enforced by existing EU regulation, but no domestic measures have been included.
Netherlands	The “without measures” scenario shows how emissions would develop in the absence of all climate change policies since 2000. The policy effects already realised before 2000 are included in the baseline scenarios.
Poland	No clear period provided up to which PAMs are included. In the case of the “without measures” scenario, the forecast of GDP growth was made upon a multi-year 1995–2004 trend based on data of the Central Statistical Office – GUS, which was then extrapolated for the 2005–2020 period, by applying the growth rates used in Energy Policy, i.e. 5.8% growth during 2005–2010 and 5.1% growth in 2011–2020. Moreover, a modified trend of primary energy use to GDP ratio for the period 1995–2020 was assumed, which assumes slower but continuous decrease of that ratio. A linear, decreasing trend of the

	ratio was assumed with annual decrease by 0.35%. The starting year for the assumed trend was 1997. Based on the modified trend of primary energy use to GDP ratio, a new projection was made for the primary energy use: “without measures” scenario.
Romania	No clear definition of years reported, but different assumptions used.
Slovakia	WOM is reference scenario without any measures impact, as if no PAMs with direct and/or indirect impact on the GHG reduction are in place. That means situation when even legislation focused on air pollution (start year 1991) was not considered, therefore “energy and environmental stage” of the year 1990 has been “extended” to the base year of projection (2003). A correct definition and improved understanding of the WOM scenario will be necessary in next projections.
Spain	The WOM scenario reflects the future situation when all drivers keep the observed past trend. For this scenario the best regression with the past time series was used. The base year for all projections is the year 2000.

It is also possible that a specific reference is developed for individual policies or measures that are quantified separately without developing a general WOM projection and that in a 2nd step to estimate the cumulative effects from all measures. E.g. several references could be chosen to estimate the impact of an increased electricity generation from renewable energies, either the type of power station that would have been most likely been built depending on marginal costs or the general fuel mix for electricity generation in the country.

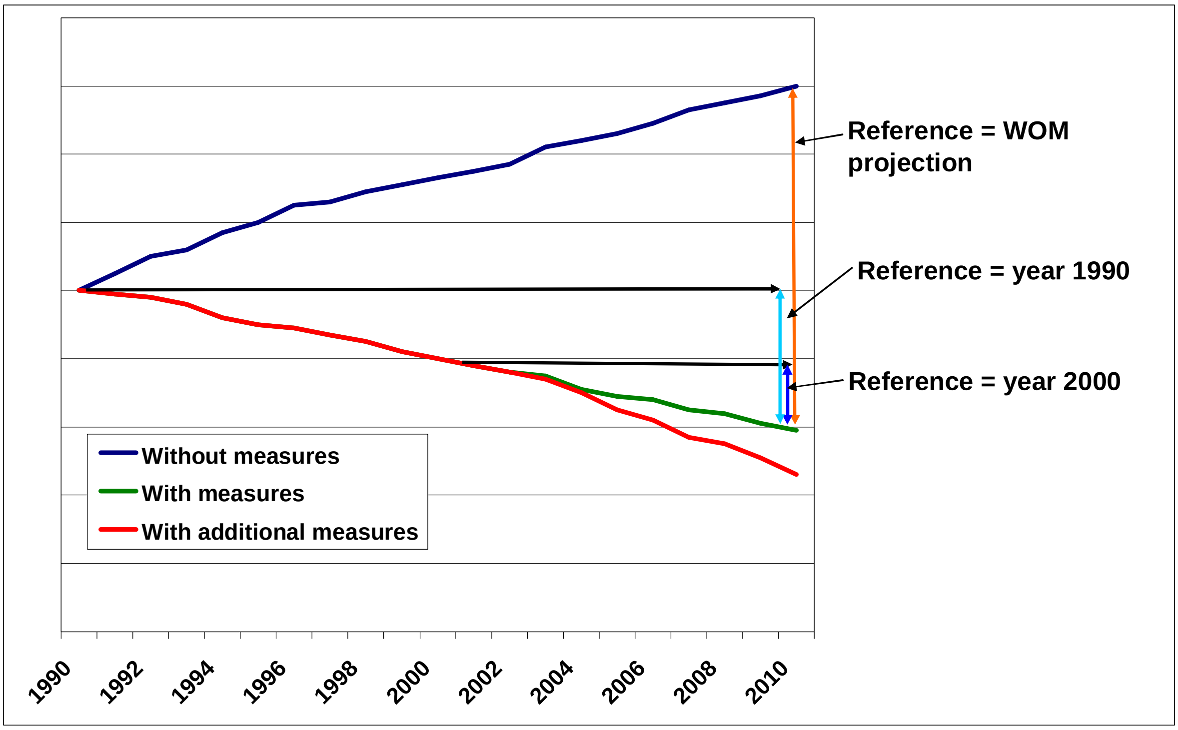
Instead of the development of a hypothetic scenario for the emission development without the implementation of certain PAMs, a simpler method is to use a specific past year or a past period as the reference for the calculation of the emission reductions achieved. One specific year can be used consistently for all policies and measures included in the projections, however it is also possible that this reference year is different for different PAMs or for different sectors.

Another option is that the effects of PAMs are directly estimated by varied assumptions and the emission reduction effect reported is the difference to the current status of implementation, e.g. the achievement of a certain target of biofuels in transport fuels is used in the WM scenario compared to the actual share of biofuels and the emission reduction resulting from such increase is reported as the emission reduction of a certain policy.

For those Member States that do not use WOM projections as a reference, it remains frequently unclear which reference they use instead to assess the quantified impacts for the PAMs. Even during the country visits conducted to most Member States, it remained difficult to understand the reference used in different areas or such questions remained unanswered.

Figure 23 aims at providing a schematic presentation of the different options described above and their quantitative impacts on the emission reduction effects.

Figure 23 Options to estimate the cumulative effects of policies and measures, arrows indicate the emission reduction effects for difference references chosen



2.8.2 Empiric approaches versus policy assumptions

Frequently no sophisticated methods are chosen to determine the effects of policies and measures, in particular in the non-energy sector. Instead assumptions on the effects of PAMs are directly used to project the emission reductions. E.g. in the waste sector, future objectives for the amounts of waste generation are taken from waste management plans or waste strategies and are used directly as activity rates in the projections. In addition objectives for landfill gas collection and CH_4 recovery are estimated for all landfills based on the policy objectives. This means that frequently the objectives of the climate policy are expressed in the WM and WAM projections, but then the projections don't present an assessment of the potential effects of the implemented policies. Thus, a key difference in the projected emission reduction in relation to policies and measures is whether the projections use empirically established relationships or elasticity's between emissions reductions and different types of measures (e.g. the effect of fuel tax increases on fuel consumption) and their implementation rates, or whether projections only express a political objective that is directly used as assumption and converted in emission reductions.

Some Member States have developed more sophisticated empirical approaches for a consistent and accurate estimation of the effects of policies and measures, which are presented in the following sections.

2.8.3 Austria: decomposition analysis, ex-post and ex-ante assessment

In a report entitled 'Evaluierungsbericht zur Klimastrategie'[2] published in 2006, Austria undertook a comprehensive and consistent assessment of the effects of policies and measures in the past and developed recommendations regarding projections on the basis of such ex-post assessment. In a 1st step the trend from 1990 to 2003 was analysed and a decomposition analysis was showed the impacts of key drivers for the emissions. Secondly, all PAMs as part of the national climate strategy were analysed with regard to their real implementation. The decomposition analysis was used to calculate the potential emission reduction for the PAMs. The results from such ex-post assessment were then used to calculate the ex-ante projections until 2010.

2.8.4 France: Indicators for policy impact

For the preparation of the 4th national communication in France, ADEME in cooperation with the French Ministry for Environment developed a range of indicators to track the progress of policy and measures in France..[3] The report only covers CO_2 from energy and developed two types of indicators

- Diffusion indicators measuring the degree of diffusion of policy impacts
- CO_2 emission indicators measuring the impact of policies related to the emission reduction

The analysis was undertaken at sectoral level and in some cases only combined effects of a bundle of policies could be evaluated due to statistical limitations and conceptual problems.

2.8.5 Netherlands: Comparison of methods for explaining emission trends

In the Netherlands, RIVM analysed and compared different methods to determine the individual effects of policy and measures and other trends (Gijsen and Lohuis 2005). When an empiric approach for the quantification of the effects of PAMS is used, there are various methods to determine the effects of PAMs on GHG emissions (Gijsen and Lohuis 2005) that differ whether the measure is considered individually or in a sequence of policies and measures that affect the same parameter (e.g. electricity production)[4]: The different method could be separated to

- analysing the effects of each individual PAM separately;
- composition method; and
- decomposition method.

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[2] Austrian Energy Agency, Umweltbundesamt: Evaluierungsericht zur Klimastrategie 2002. Endbericht Wien 2006.

[3] ADEME (D. Bosseboeuf, S. Monjon) 2005: Indicateurs d'impact de la politique climatique Française – cas du CO_2 énergie. Rapport final édité pour les Rendez-Vous Climat 2005.

[4] Gijsen, A., J O Lohuis (2005): From reference to reality: Methods for explaining emission trends. Environmental Sciences 2005: 2(1): 47-55.

Method 1 analyses each policy or measure separately based on an individual reference. The composition method 2 starts from the actual situation in which all effects are included and then calculates what the emissions would have been if effect A had not occurred, and the if effects A and B had not occurred. With this method, every effect is being compared with another baseline. The baseline of effect A is the 'real world', the baseline of effect B is 'the real world + effect A' etc.

The decomposition method starts from the situation in which no effect is included, and then calculates what the emissions would be if only effect A had occurred, and then if effects A and B had occurred, etc.

Composition and decomposition methods assume that a number of changes occur simultaneously which influence each other and that the sequence of the measures determines the final result. Gijsen and Lohuis (2005) compared the effects of various methods for calculating CO_2 emission reductions in 2000 compared to 1990 (Table 11). This comparison clearly shows the influence of the estimation method chosen on the total effects. All calculations were done based on the same data by the same experts resulting in a difference of the total effect from -6.5 Mt CO_2 to -15.9 Mt CO_2.

Table 11 Comparison of various methods for calculating CO_2 emission reductions in 2000 compared to 1990 according to Gijsen and Lohuis (2005)

	Method (Mt CO_2)					
	Individual effects		**Composition**		**Decomposition**	
Effects	**Reference CCGT**	**Reference average central power station**	**Sequence 1**	**Sequence 2**	**Env. Balance sequence**	**Policy sequence**
Imports	-3.6	-6.0	-6.1	-6.0	-4.4	-4.4
CHP	-1.6	-6.1	-6.2	-6.1	-5.4	-4.4
Renewables	-0.7	-1.2	-1.2	-1.2	-1.1	-1.0
Efficiency improvements central power station	-2.8	-2.8	-2.6	-4.1	-2.7	-3.9
Fuel mix central power stations	2.2	2.2	2.2	1.5	2.3	3.4
Total	**-6.5**	**-13.9**	**-13.8**	**-15.9**	**-11.2**	**-10.4**

Source: Gijsen and Lohuis (2005), Notes: CCGT: Combined cycle gas turbine

This exercise shows that apart from the reference chosen, the empirical relationship between the policy and the emission reduction effects, there is a another dimension which is the combined or individual calculation of different effects as well as the sequence of calculation of different effects that determines the quantitative result.

The biggest problem however is, that the reference for the reduction effects is usually not clearly reported and therefore remains unclear for many quantified estimates.

A joint feature of the reporting of quantified effects of policies and measures in all sectors is the general lack of information on methodologies which would explain how these estimates were derived. The basis on which the effects were estimated, or what reference was used, is often not provided.

2.8.6 Bottom-up approaches versus top-down approaches for the quantification of the effects of policies and measures

In many Member States a combination of bottom-up approaches and top-down approaches is used to incorporate the effects of policies and measures in the projected GHG emissions. Chapter 3 describes the modelling approaches used in different sectors and explains which models are able to quantify the effects of which type of PAMs. The effects of PAMs that cannot be addressed in a specific model, are frequently quantified in a separate, bottom-up approach for individual or groups of PAMs. It usually remains unclear how such bottom-up approaches or separate estimations are integrated in the general projection result based on the models used The interaction and the interfaces between top-down modelling approaches and bottom-up approaches are usually not explained in the methodological documents provided by Member States and this area remains rather unclear for most Member States. During the country visits performed, even those experts that contributed to some parts of the projections with their models could frequently not explain how the integration of the different parts of the estimation to the total WM or WAM projection was finally achieved.

2.9 Institutional arrangements

From a more advanced perspective, it would be useful to establish national GHG projection systems in a similar way as national GHG inventory systems or to advance the GHG inventory system to a more complex integrated reporting system that includes reporting on policies and measures and projections.

Such an integrated reporting system can still integrate different models and different institutions dealing with certain sectoral projections, but would ensure a consistent planning and consistency of methods used for emissions estimation based on the actual or projected activity data.

Such system should also ensure a consistent approach for the quantitative evaluation of policies and measures and the GHG projections.

A considerable number of Member States have used the establishment of the national inventory system required under the Kyoto Protocol to establish a more comprehensive national institutional framework for reporting of GHG inventories and projections, both for GHG emissions under the UNFCCC and for air pollutants under the CLRTAP and the NEC Directive. Many Member States have made considerable progress in the recent years and in this process have improved the consistency of GHG projections with GHG inventories and the consistency of projections for GHG emissions and air pollutions. Examples for Member States with such integrated systems are Austria, France, Finland or Slovakia.

In the energy and transport sector, most Member States established models and specific methodological approaches with independent consultants for the establishment of national GHG projections. These consultants work on the basis of individual contracts to develop updated projections.

However in those sectors, in which Member States mostly project the trend in AD without sophisticated models (agriculture, waste, F-gases, industrial processes), the inventory agency is frequently involved in the establishment of national GHG projections. In quite a number of Member States, the staff that is responsible for the inventory estimation is also estimating GHG emissions from the projected activity rates using consistent methods. This increases accuracy of projections to a considerable extent and provides a key advantage to Member State's national projections in the agriculture or waste sector compared to aggregate projections at EU level performed by aggregate modelling approaches. Such aggregate projections cannot reflect higher tier methods used for the inventory estimation, e.g. in agriculture or waste and have to rely on simplified, mostly tier 1 methods. However , if such simplified methods are applied in key source categories for which Member States use higher tier methods, the resulting errors can be as high as 25-30% only related to the emission calculation (with the same activity data). From this point of view, it is essential that most Member States have made considerable progress in consistency between the estimation methods for projections and national GHG inventories. Additional work on the improvement of Member State's projections should therefore be concentrated on the projection of the activity rates.

An improved national system for GHG projections would also include QA/QC procedures for projections which are currently not defined. At EC level, QA/QC procedures could encompass the following steps:

- Check for completeness of Member States' projections in terms of gases, sectors and source categories, gap-filling procedures in case of incomplete projections of Member States for the aggregation of projections at EC level.
- Comparison of Member States projected emissions with trends from GHG inventory at the level of sectors and source categories
- Comparison of projection parameter with trend of these parameters based on Eurostat data
- A checklist of completeness in reporting of all required elements for projections (gases, sectors, source categories, required scenarios, sensitivity analysis, projection parameters, projection indicators, sensitivity analysis, availability of methodological description, availability of information on PAMs included in the different projections) should be compiled on the basis of new submissions and sent to Member

States with a request to provide outstanding information in case of gaps in reporting.

2.10 Conclusions and recommendations

2.10.1 Completeness

Member States' projections improved considerably in terms of completeness in recent years and Member States should aim at filling current gaps in projected emissions. Member States should in particular ensure that aggregated projected total GHG emissions are equivalent to aggregated total GHG inventory emissions.

At EC level it is important to check for the gaps in Member States' projections before they are aggregated to EU projections. In case of gaps related to specific source categories there are two methodological options for corrections of data to ensure complete coverage at the aggregate level:

- Use the projected current year and compare with the GHG inventory for that year and derive an adjustment factor for completeness of the national total
- Adjust the missing source categories with values from most recent GHG inventory.

The requirement to report projections for a all sectors and gases covered by the national GHG inventory is generally included in the UNFCCC reporting guidelines for national Communications of Annex I Parties. With regard to the revision of the Monitoring Mechanism Decision, this requirement could be spelled out in greater detail, enlisting all gases and sectors. The reporting template for projections already clarifies which source categories should be included in the GHG projections and strongly assists the objective of more complete projections.

2.10.2 Consistency

New submissions of projections from Member States should be regularly checked for consistency with GHG emission trends reported in GHG inventories. Such checks could be assisted by specific tools. For this purpose it is important that more Member States report the projected estimates in the template. This step will quickly identify obvious discrepancies with inventory data and strange trends in the projected results.

Such checks should be part of the regular QA/QC procedures for Member States projections performed by the Commission/EEA.

In addition to the consistency checks for GHG emissions, such checks should also be performed for activity data, e.g. comparing projected AD with past trends from Eurostat data. This is also a useful exercise to assess differences of Member States data in underlying activities with Eurostat data which is important for aggregate modelling approaches at EC level.

Consistency would also improve, if a number of key general assumptions for projections, in particular for fuel prices, GDP and carbon prices would be agreed at EU level (e.g. in the Climate Change Committee) and used consistently by all Member States in one scenario.

2.10.3 Comparability

The harmonization of reporting schedules for projections under different international requirements (in particular NEC Directive and EC Monitoring Mechanism Decision) would strongly help to improve the comparability of projections under different requirements. Currently updating of data and assumptions leads to inconsistencies in the projection data.

To enhance the comparability of the representation of the ‘with measures’ and ‘with additional measures’ scenario at EU level; it would be useful to develop specific guidance At EC level for common and coordinated policies and measures defining in which scenario a specific common and coordinated policy or measure should be included. This list should be updated and distributed to Member States prior to each reporting cycle.

It is recommended that a common basis and reference should be developed, by means of which the emission reduction effects are to be quantified. For common and coordinated policies and measures, the basis should be the same across Member States, since only such a harmonised approach allows for the comparison and aggregation of emission reduction effects at a European level. A future revision of the Monitoring Mechanism Decision could include such a joint reference or baseline. Further work on this issue is needed in order to develop a simple, straightforward approach that can be implemented across all Member States.

The most important element for an enhanced comparability of Member States GHG projections, is the mandatory requirement to use the reporting template for projections and projection parameters in the revision of the Monitoring Mechanism Decision. The format considerably improves the information available at sectoral level.

2.10.4 Transparency

With regard to the Revision of the Monitoring Mechanism Decision it is recommended that elements for the reporting on projections are agreed in order to obtain all necessary elements from all Member States on a regular basis. At the moment the reports provided by Member State largely differ in depth and scope because no guidance is available.

2.10.5 Accuracy

Sensitivity analysis should be required with regard to key general parameters (fuel prices, prices of CO_2 allowances, economic growth), but also related to additional parameters in each sector. Sensitivity analysis is a rather easy tool to assess uncertainties of projections.

Comparison of Member States projections with aggregated projections at EU level should be conducted more regularly. However this requires that country-specific data on emissions and activities are published in specific formats (databases, excel) and that Member States also submit data in Excel templates.

Updating of projections in Member States should be sufficiently frequent to take into account recent policy developments to enhance accuracy with regard to the scope and intensity of policies.

2.10.6 Institutional arrangements

Both Member States and the Commission should advance the GHG inventory system to a more complex integrated reporting system that includes reporting on policies and measures and projections. Such an integrated reporting system can still integrate different models and different institutions dealing with certain sectoral projections, but would ensure a consistent planning and consistency of methods used for emissions estimation based on the actual or projected activity data.

Enhanced QA/QC procedures for the aggregation of Member States' projections should be implemented at EC level as described in section 2.9. A communication process should be established with Member States clarifying any results pointing at inconsistencies, in a similar way as done for the initial checks of GHG inventories. Such process could be included in the revision of the Monitoring Mechanism Decision as part of a generally enhanced institutionalization of the processes of establishing GHG projections.

3 Assessment of projection methodologies

3.1 Introduction

Throughout the EU there is a wide variation of models being used to develop GHG projections. A superficial look at MS reporting on GHG projection methodologies prevails also large differences in the use of models. Some MS report on the use of different models for different sectors and other MS report on the use of only one model or no model at all. However, when assessing the different models it becomes clear that one major difference relates to the question: what is called a model. MS might use spreadsheets to do exactly the same calculations as some software package very often referred to as being a model.

Apart from the differences, we can also notice similarities in the different approaches used by MS. The first one is that CO_2 projections from the electricity sector are almost always based on models with a detailed technology representation. The second one is that projections for F gasses are usually done outside any model. Industrial process emissions for CH_4 and N_2O are also frequently done without any model. Indeed, most models concentrate on the relation energy-environment whereas non CO_2 process emissions depend on the use of end-of-pipe abatement technologies.

To understand the world of model building one should keep in mind that any model is a simplified abstraction of the real world and that any model is build to answer specific questions. As developing GHG projections involves both engineering and economic aspects, these aspects can be assessed by different types of models.

3.2 General assessment of different projection methodologies

The quality of GHG projections depends on:

- the appropriateness of the applied methodology
- the quality of the data: underlying parameters and external supplied assumptions

The quality of the data is discussed in chapter 2. In chapter 3 we will mainly focus on the applied methodology.

The following sections will deal with the relationship economy-energy-GHG emissions and how different modelling methodologies deal with this relationship. We start with an overview of the requirements and objectives of the Monitoring Mechanism. Individual MS can also have supplementary or other objectives when making their GHG projections. These are also briefly discussed. Then we will present a typical classification of the different methodologies of models used for the preparation of GHG projections. We will look at the characteristics of these methodologies, baring in mind the questions that need to be answered or issues that need to be evaluated. These characteristics will relate to the type of input and output, the type of measures to be evaluated, the type of scenarios (without measures, with measures and with additional measures), various policy instruments that can be evaluated and some intrinsic qualities.

In Annex A we also briefly introduce some useful terminologies to classify different type of models.

3.2.1 Requirements of the Monitoring Mechanism

In this section, an overview is given of the requirements and objectives of the Monitoring Mechanism. Sometimes, individual MS can have supplementary or other reasons to develop GHG projections. So depending on the starting point of view, the objective to develop GHG projections can be different.

How projection models take into account these requirements and objectives is discussed in the next sections, when discussing the characteristics of the different methodological approaches.

The MM decision establishes a mechanism for monitoring all anthropogenic emissions by sources and removals by sinks of GHGs and evaluating progress towards meeting commitments.

Article 3.2 (a) of the MM decision refers to the policies and measures. This article requires to report on a two-yearly basis the national policies and measures which limit or reduce GHG emissions or enhance removals by sinks, including the type of policy instrument (economic or fiscal agreement, regulatory …), the status of implementation, indicators to monitor and evaluate progress over time and quantitative estimates of the effects of PAMs for 2005, 2010 and 2015.

Article 3.2(b) of the MM decision requires the reporting of national 'with measures' and 'with additional measures' projections of GHG emissions and removal by sinks organised by GHG and sector for 2005, 2010, 2015 and 2020, clear identification of the policies and measures included in the projections, sensitivity analysis on the projections and thorough documentation on the methodologies, underlying assumptions and key input and output parameters.

To fulfil these requirements, Member States have to develop or implement methodologies and models to develop GHG projections. Member states are left free to choose the methodology as this depends i.e. on local circumstances. Reporting of parameters and indicators is required to allow for comparability among member states. A list of parameters is mandatory, the list of indicators is recommended.

The requirements are made so the EU has the information to evaluate if the MS and the EU will reach its reductions targets. For the EU it is important to know whether or not the PAMs already implemented will be sufficient. It is therefore important to have reliable projections for all MS.

From a member states' point of view, the choice of models for developing GHG scenarios could be based on:

- their **ability or usefulness in developing accurate GHG scenarios**. This criterion is necessary to know whether individual MS or the EU as a whole will fulfil the Kyoto requirement. The accuracy criterion involves various aspects like the ability to develop a WITHOUT MEASURES scenario, the ability to evaluate different types of PAMs, the ability to count for overlapping and rebound effects, uncertainty aspects related to the methodology and underlying assumptions.
- their **usefulness in developing and evaluating cost-effectiveness of PAMs.** This is a much more important criterion than the previous one. Indeed, as IPCC concludes that emission reductions of 30% to 50% (and even more) are required in the long run, then effective global warming abatement strategies will require extensive long term planning and decision making. The decision on PAMs could be based on a quantification of the effect and an estimation of the cost of the policy to the MS, with "cost" interpreted in the broad sense: it might be a private cost in terms of extra expenses to consumers or a public cost expressed in terms of loss of GDP or loss of welfare.

3.2.2 Classification and description of the modelling approaches

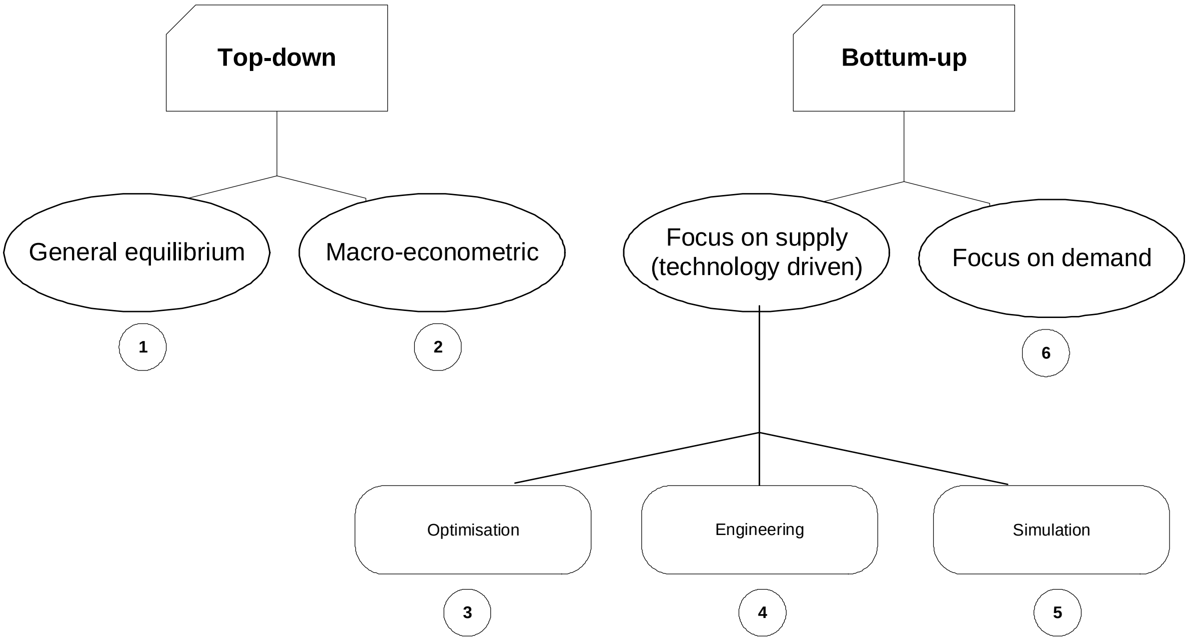
3.2.2.1 Typical classification of modelling approaches

Any classification of models is somewhat arbitrary but for the purpose of discussing the properties of different types of models an appropriate classification is given in Figure 24. This classification is derived from the different types of models used by EU-MS.

One major distinction is made between the **macro-economic models** and the more **technically oriented bottom-up models**. The first type of models can provide consistent scenarios in terms of GDP, labour productivity, consumption and investment expenditure, government balance etc. The major disadvantage is that these models have a rather poor representation of the energy system and do not fully incorporate technological options to reduce GHG emissions.

The macro-economic models are opposite to the more technically oriented bottom-up models, as these types of models have a better representation of the technical determining factors of emissions and incorporate engineering data and technological choices.

Figure 24 A classification of model approaches



The modelling approaches are first briefly described and will be looked at more in detail in chapter 3.2.2.3

- **Top-down models**
  - ***General equilibrium models***
    General equilibrium models assume that all economic agents optimise their behaviour, and price mechanisms work to clear all markets by equating supply and demand for goods and factor inputs. Their focus is therefore on long-term resource allocation. They incorporate exogenous increases in factor supply and productivity to reflect changes over time and the accumulation of capital through investment decisions. This formulation means that economy-wide and long-term costs of reduction policies, including trade effects, are well represented. Like macroeconomic models, their representation of technology details is weak. The assumption that markets always work efficiently, particularly over the short term, is questionable. Important parameters include GDP and output by sector.

  - ***Macro-econometric models***
    Econometric models represent final user sectors by econometric equations that relate energy demand to other variables such as prices and income or output levels. They implicitly incorporate historic trends in efficiency, but because of their reliance on past trends they are limited in their representation of structural shifts or changes in behaviour. Macroeconomic models represent the behaviour of the economy through relationships based on key economic factors such as GDP. In these types of model, the effect of individual policies and measures, where they are primarily economic measures, can be assessed but it is more difficult to assess the effect of other instruments.

The advantage of these approaches is that they can provide analysis of economic feedback effects for greenhouse gas abatement on the whole economy. Important parameters for the macroeconomic models are economic factors such as GDP growth and share of GDP by sector, as well as energy prices and taxes. In these models, changes in energy efficiency due to technical improvements may not be distinguishable from changes in energy intensity due to structural shifts.

- **Bottom-up models**
  - ***Optimisation models (Linear programming models)***

    Linear programming models are a popular instrument to develop GHG scenarios, especially in the energy sector. They represent the energy system of a MS by a detailed set of technology options. These options are characterised by physical parameters such as fuel type, efficiency, lifetime of technology and cost components. The demand for energy is determined exogenously in a reference scenario (basically corresponding to a WITHOUT MEASURES scenario). The model is solved by choosing the cheapest solution (choices of technologies) that satisfies the demand for energy in all subsectors and satisfying environmental and technological constraints.

    Although optimisation models primarily focus on engineering aspects of energy systems and the results have some prescriptive nature due to the optimisation procedure, some economic interpretation of the results can be given. Indeed, its optimisation procedure simulates perfectly competition among technology options and fuels, driven by demand in each sector and sub sector. Some models assume perfect foresight and other models are myopic.

    These models are useful for assessing and identifying efficiency potentials and for assessing supply and demand-oriented policies to curb energy-related emissions. However, they neglect feedback effects on the rest of the economy and undervalue transaction costs of mitigation polices. In some cases, they are linked into top-down economic models to help overcome some of the limitations.

  - ***Engineering models***

    These are usually for specific sectors such as waste, agriculture, residential and the tertiary sector and transport. At their simplest, projections are made based on measures of activity, such as livestock numbers and types, and emissions factors. Changes in efficiency can be taken into account through the emissions factor. The strengths of these models lie in the detail that can be included and their relative simplicity. Their formulation is not necessarily linked directly with past trends. The representation of global policies and measures, particularly economic measures, is limited and feedback to the rest of the economy is not included. However, sector specific PAMs can by assessed most appropriately.

The parameters needed for the models include activity data and emissions factors, plus technology data. Frequently, engineering models are used in the preparation of a linear programming model.

- ***Simulation models***
  Similar to optimisation models, simulation models represent the energy system by a number of technologies and energy carriers. A number of arbitrarily defined allocation rules and price mechanisms are introduced. Typical elements are price elasticity for energy demand, price-supply functions for energy supply, taxation rules. The model is solved by a stepwise iterative procedure.

- ***Focus on demand (End-use models for energy planning)***
  This type of models provides a pre-defined framework for the development of energy demand scenarios for specific end-users on a disintegrated level. They basically rely on accounting relationships. They do not consider price effects. The user should supply a socio-economic scenario, determining important key variables such as the penetration of fuel types and the evolution of energy efficiencies.

- **Hybrid models**
  Hybrid models combine different methodologies. Some hybrid models combine the properties of top-down and bottom-up models. For instance the combination of a general equilibrium model and an optimisation model with explicit representation of technologies. The strength of this type of models is that they allow to evaluate macro-economic effects of technology choices. Models that combine properties of optimisation and simulation models can also be considered as hybrid models. A typical example within this category is the Primes model.

These 6 modelling approaches will be discussed in detail in chapter 3.2.2.3. Various aspects that will be part of this analysis are:

- **Theoretical background and principles** (underlying economic paradigm; structural formulation)
  This is already briefly discussed in the previous paragraphs.

- **Type of data (input/output)**
  Input and output data can consist of different types of data:
  - data related to the international context (e.g. fuel prices)
  - data related to macro-economic development
  - technological data
  - fuel and electricity consumption data
  - GHG emissions

- **Ability to consider technological evolution**
  Is technological evolution considered and how is it done? Is it implicit or explicit?

- **Evaluation of Policies And Measures (PAMs)**
  We define measures as special realizations taken by individual citizens or companies to reduce GHG emissions, such as placing a solar boiler, roof insulation, low-energy light bulbs, wind turbine, replacing a traditional boiler by a CHP installation. Measures are technical by nature. Policies are defined as actions taken by legal authorities that should lead to the realization of measures by citizens and companies. Policies can be fiscal (subsidies, taxes), regulatory(standards) or voluntary (agreements). The implementation by the member states of the European common coordinated policies and measures are considered as policies. The evaluation of a measure involves the quantification of the savings in GHG emissions and identification and quantification of overlapping with other measures. The evaluation of a policy is more complex. It involves economic aspects (cost-efficiency), effectiveness, timing of implementation, rebound effects.

- **Type of policy scenarios**
  A policy scenario is defined as a set of assumptions of economic activities and policies and measures. Typical scenarios are WithOut Measures (WOM), With Measures (WM) and With Additional Measures (WAM)

- **Economic consistency**
  This terminology relates both to models and scenarios. A scenario can be said to be economic consistent if the basic national accounting rules have been respected. This accounting rules are defining some limitations in the way an economy can evolve. For instance an increase in energy prices increases the share of the family budget spent for energy and consequently reduces spending for other consumer goods.

- **Level of detail**
  How detailed is or can the model be?

- **Time horizon**
  Is the model more suited to short term or long term scenarios?

- **Account for overlapping and rebound effects**
  These are specific issues. The definition and various sources of possible overlapping and rebound effects are discussed in section 3.2.2.2

3.2.2.2 Specific Issues: overlap and rebound effects

In this section specific issues that can underestimate emissions are discussed, like overlapping and rebound effects. Not correctly counting for overlapping and rebound effects will result in an overestimation of the effects of PAMs, and consequently in underestimating emissions in projections. Overlapping corresponds to situations where reductions in GHG emissions are accounted twice and this is basically due to wrong calculations. The rebound effect is a behaviour mechanism, resulting is higher activities and less reductions.

- **Overlapping effects**
  Overlapping effects occur when the effects of two or more PAMs can not be simply aggregated. We can differentiate between different types of overlapping effects that exist:

  - ***Overlapping with Without Measures scenario***
    Although there is no formal obligation to report a scenario without measures, it is common practise to use some kind of baseline scenario to quantify the effects of policies and measures. The development of a WOM scenario is also based on a methodology and may include assumptions on what is very often called the "autonomous" energy efficiency improvement.

    If the WOM scenario has been developed at some aggregated level, either by using econometric demand equations or by extrapolating historical trends, then the results may contain implicit assumptions on energy efficiency improvements.

    One example is the way MS have implemented directive 2006/32/EC. MS grant subsidies to citizens for the use of energy efficient equipment such as low-energy light bulbs, condensing boilers, heat pumps, insulation, water-saving shower heads, solar boilers and other mainly mature energy saving technologies. This will definitely speed-up the penetration of these technologies but the relevant question is how far these technologies would have been used without subsidies, especially as these technologies are often cost-effective.

  - ***Combinations of technical measures with multiplicative effects***
    The combined effect of two or more measures is not always the sum of the individual effects. This problem is easily illustrated with the following example. Assume we have two identical buildings, each of them not very well insulated and equipped with a low efficiency boiler. Improving the insulation of one building and changing the boiler in the other building will save more energy and reduce more GHGs than taking both measures in one building and doing nothing in the other one. This example illustrates that one needs detailed information to make the right calculations. Other examples of measures that need to be evaluated in the right combinations are:
    - In residential and building sector: fuel switching to natural gas or biomass, insulation measures, improving the regulation of the temperature.
    - In transport sector: bio fuels and measures to control mobility.

    The problem is strictly related to the availability of detailed information.

- ***Overlap with Emission Trading***
  Various policies have been defined at national or EU level that affect GHG emissions from the electricity sector and industry.

  The EU-ETS interacts with PAMs aiming at domestic level:
  - the promotion of electricity from renewable energy – by means of financial mechanism, tax deductions or regulatory policies
  - the promotion of co-generation – by means of financial mechanism or regulatory policies
  - improving energy efficiency in the industry such as benchmark agreements, voluntary branch agreements
  - reducing electricity consumption by end-use sectors

Table 12 Overlap of the EU-ETS and domestic policies

WOM scenario	Unabated emissions					
EU-Level	NAPs	JI-CDM	Savings EU-ETS			
MS level	Abated emissions		Renew. Energy	CHP	Dom. PAMs	EU-ETS

This overlap is illustrated in Table 12, representing the EU-wide emissions of the sectors covered by the EU-ETS. At the EU-level, the sum of the NAPs is not fully limiting as JI and CDM credits can be used, but apart from that, all savings in CO_2 emissions can be attributed to the EU-ETS. Indeed, if emissions tend to be higher, then the CO_2 price should increase which will reduce emissions elsewhere.

However, at MS level, the NAP is not a binding limit, and should not be used as a reference in developing scenarios. For instance, MS will be interested to know whether they will be net-importers or net–exporters of EU-ETS credits. Therefore, they will make an evaluation of the effects of all domestic measures and attribute only additional savings to the EU-ETS.

A common practice is to look at the CO_2 trading price as an opportunity cost, regardless of the allowances allocated in the NAP, and to model the interactions of a CO_2 price with financial or regulatory mechanisms of domestic PAMs. A CO_2 price will make the use of renewable energy and CHP more profitable and will also enhance other domestic PAMs to improve energy efficiency.

- **Rebound effects**
  Rebound effect is a terminology referring to economic reactions of energy-efficiency improvements. The question is whether engineering calculations on the improvement of the energy-efficiency will produce reliable estimates of energy savings. Economic theory suggests that engineering calculation would rather produce over-

estimates of energy savings due to the existence of rebound effects.

Direct rebound effects: if the improvement of the energy efficiency leads to price decrease of the energy service[5], then this will lead to an increase of the consumption of this service. For instance, the price difference between light bulbs and low-energy light bulbs will be overcompensated by the savings in electricity. Therefore, consumers might not longer switch off the light or install additional lighting. This effect is called the price effect.

Indirect rebound effects: Consumers will spend released income from a price decrease for an energy service to other goods and services. As far as the production of these goods and services involves energy, this will lead to an increase in energy consumption. This is called the income effect.

So far we have only considered consumer behaviour but economic theory suggest also the existence of analogous producer rebound effects. Indeed, an improvement of energy efficiency reduces the cost of energy and implies a shift in the production factor mix. Secondly the efficiency improvement results in a per unit reduction cost which might result in an increase in production due to higher demand.

Although rebound effects of single measures can be relatively small, the cumulative effect of various PAMs in all EU member states might have considerable effects on consumers and producers behaviour. The existence of rebound effects is widely accepted among economists but there is still discussion on the order of magnitude.

A few studies suggest that rebound effects can be sufficiently important to offset energy savings from improved energy efficiency – a situation termed ‘backfire’ (Brookes, 1990), other studies suggest rebound effects in the range of 0% to 30%.

When evaluating rebound effects the following aspects appear to be important:

- The rebound effect is a price effect of an energy service. In general the energy efficiency improvement is a result of additional capital spending. The more expensive the capital, the less important the rebound effect.
- Rebound effects are related to the policy instruments involved. Non-price regulations might result in higher rebound effects than price regulations.
- Direct rebound effects

[5] The energy service is not the same as energy consumption. The energy service relates to the utility we obtain from consuming an amount of energy: vkm driven in transport sector, room temperature in residential sector, light in an office…. The energy service is the result of the combination of energy and technologies transferring the energy into utility. The price for the energy service is constituted by the price of a energy (fuel) and the price of the technology.

3.2.2.3 Typical aspects and characteristics of modelling approaches

Top-down models

Typical top-down models can be divided in 2 large categories: macro-econometric and general equilibrium. These models represent the whole economy as a closed system. They differentiate the behaviour of different types of economic agents (consumers, producers, and government) in a consistent framework.

Econometric models and general equilibrium models are different in the following aspects:

- Economic background
- Scientific methodology
- Model specification
- Empirical verification – and calibration

In the following sections we will explain the basic principles used in these types of models. However, to understand why different types of models exist it is necessary to have a closer look at the equilibrium concept in economic theory (Box 1).

Recent developments in econometrics and general equilibrium model building have brought the two types of models close to each other. Some CGE models (Computable General Equilibrium) incorporate disequilibrium aspects in the labour market. Modelling of the supply side in modern econometric models has strongly improved due to better differentiation of long term and short term effects. For some types of policy analysis, both types of models might now produce very similar results. Then one could argue that the choice of the model doesn't matter anymore. But not al types of simulations can be done by both types of models.

Box 1 ***The equilibrium concept***

Economic textbooks usually describe economic markets for goods and services in a graphical way. A demand curve expresses the willingness to pay for a certain amount of goods as a function of the price. This curve is downward sloping, expressing that, the more expensive a certain good is, the less consumers are willing to buy it. Basically a demand curve for one particular good is determined by maximising the utility behaviour of the consumers.

The supply curve expresses the willingness to produce (or to offer on the market) an amount of goods in function of the price. Basically the supply curve is derived from the profit maximisation behaviour of the supplier. Generally, this curve is upwards sloping, expressing that producers are willing (or are able) to produce more if the price is higher.

When a new product is coming into the market, producers do not know the consumers willingness to pay for this product and vice versa, consumers do not know the producers willingness to produce for a given price. The producer will have to guess the initial price for this product, not knowing the consumers expectations. If this price is too low, there will soon be a shortage of this product. If the price is too high, there will be an excess supply. In both cases the producer will react. In the case of excess supply, the producer will lower its price and the amount of goods. In the case of excess demand, an opposite movement will follow. After some time, an equilibrium price will be reached and supply and demand are in balance. This mechanism is the market clearing mechanism.

The labour market is treated in a very similar way. The demand for labour is determined by the producers. Also this demand is downward sloping, expressing that the demand for labour increases when the price goes down. The supply of labour is determined by the willingness to work at a given price and depends on people's preferences for leisure.

The equilibrium concept applies for goods, services, and labour. If all markets for goods, services and labour are in equilibrium, one speaks about a general equilibrium. A general equilibrium is a very interesting concept, as well for economists as for policy makers, because general equilibrium corresponds to a situation of maximum welfare. It means that the market clearing mechanism brings us to a situation of maximum welfare.

The equilibrium concept is a rather static view on the world. Technological and scientific evolution are constantly moving the production constraints, thus changing the optimal quantity of labour at given price. Consumer preferences might depend on several factors such as social and cultural values which are independent of the economic context. A small economy, like the Belgian one, is very sensitive to changes in the international environment. So the real world is rather complex, and the equilibrium conditions are probably never realised, but the market clearing mechanism is constantly working thus moving the world towards a new equilibrium.

From this discussion the following questions arise:
What is the speed of adjustment towards the new equilibrium? What is moving faster, the move towards the new equilibrium or the new equilibrium itself? Do the markets need government intervention?

A basic difference between econometric models and general equilibrium models is how they look at equilibrium. Macro-econometric models concentrate on the disequilibrium in different markets, frequently with a special emphasis on the labour market. General equilibrium models concentrate on the welfare aspects associated to the equilibrium position.

(1)[6] General equilibrium models – and partial equilibrium models

- *Theoretical background and principles (underlying economic paradigm; structural formulation)*

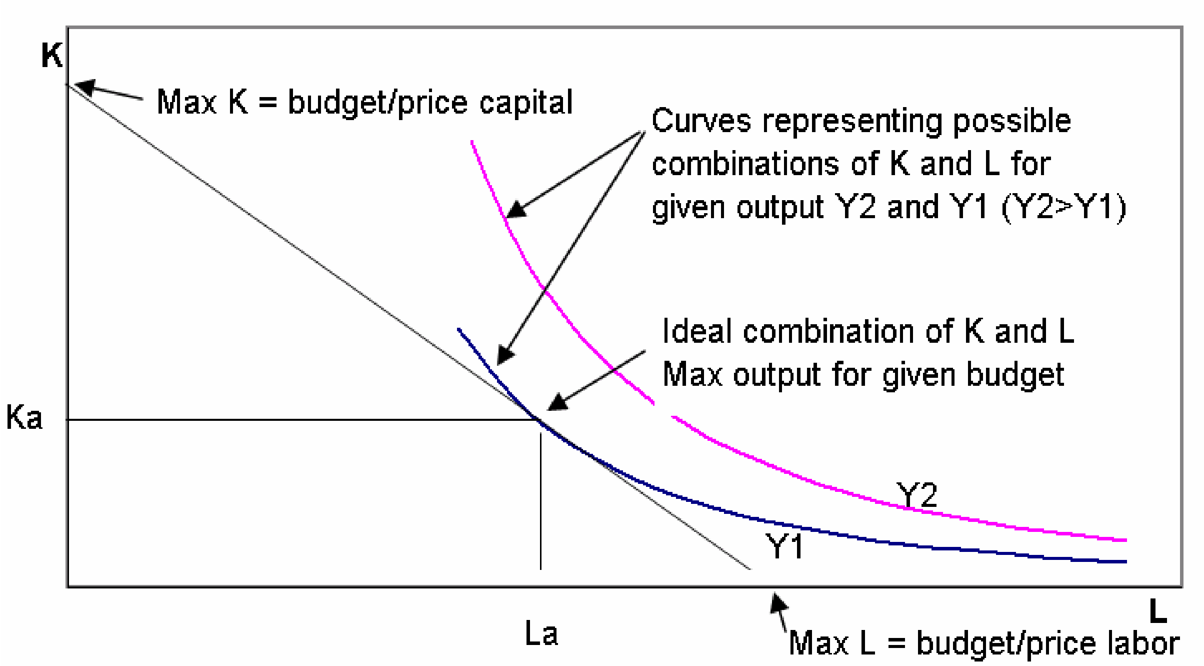
  General equilibrium models are also called Computable General Equilibrium models (CGE). These models focus strongly on the welfare aspects related to the equilibrium conditions of the economy. The underlying paradigm of general equilibrium models is of a neo-classical nature. Basically micro-economic theory is implemented in the modelling structure.

[6] *These numbers refer to the numbers in* Figure 24

General equilibrium models also present the whole economy in a consistent way and differentiate the behaviour of different economic agents: consumers, producers and government.

Contrary to econometric models, general equilibrium models represent the economy by subsets of demand- and supply equations and use a global market clearing mechanism as simulation technique. Producers are represented in the model by production functions. Production functions express the amount of output that can be produced by given combinations of different production factors. As producers want to minimize production costs, the equilibrium quantities of production factors are determined by the relative prices. The principle is explained in Figure 25.

Figure 25 Illustration of the principles in CGE models[7]



The curve presents possible combinations of production factors to produce a given amount of output. The equilibrium quantity of production factors is determined by the tangent of the relative prices.

General equilibrium models use nested structures of production functions. Frequently CES production functions are used for this purpose. At the outer nest, producers are assumed to choose between intermediate goods at the one side and a capital, labour energy bundle at the other side. At the second nest, producers are

[7] *The curves Y1 en Y2 represent possible combinations of labour and capital to produce output levels Y1 and Y2. The straight line from Max K to Max L represents the budget constraint, i.e. all possible combinations of labour and capital that can be paid with a given budget. Ka and La are the optimal (equilibrium) amounts of capital and labour to produce Y1.*

assumed to choose between labour and the capital-energy bundle. At the third nest, producers choose between capital and energy.

Consumers are modelled in a similar way, starting from a utility function. Utility functions express the degree of satisfaction corresponding to a basket of different quantities of goods. Under the consumers budget constraint, the relative price of different consumption goods will determine the amounts consumed, maximising the utility.

The model uses different types of parameters. Substitution elasticity appear in the production functions. These are rarely estimated econometrically. Frequently they are taken from the literature. Scaling parameters are derived in a calibration procedure so that the model reproduces the base year data .

The scientific methodology in general equilibrium models is highly theoretical and deductive. In fact, production functions and utility functions are very abstract concepts which are very difficult to observe empirically.

Partial equilibrium models use a similar approach to describe the market for one family of goods, like energy or agricultural goods. Partial equilibrium models ignore macro-economic feedbacks but are able to present a particular sector in detail.

- *Type of data (input/output)*
  Typical inputs to these type of model are data related to the international (economical) context: world market development, exchange rates, fuel prices and emission trading prices. Outputs are typical macro-economic data like GDP, (un)employment and labour activity data, government balances, sectoral values added. The outputs are fuel consumption data per fuel type, electricity consumption and CO_2 emissions. Energy & process related GHG emissions are linked to (aggregated) activity levels.

- *Ability to consider technological evolution*
  CGE have a weak technological representation. Technological evolution is usually represented as trend factors, derived from historical observations or literature. It is difficult to represent breakthrough or discontinues evolution.

- *Evaluation of policies and measures*
  CGE models are not useful for evaluating measures as they lack the required technological representation. However, they can be useful is assessing some impacts of policies. For instance, environmental cost functions, derived outside the model, can be represented by continuous functions in the CGE framework, allowing to evaluate wealth effects of fiscal policies and to quantify rebound effects of such a policy. It is also possible to introduce an upper bound on emissions and to analyse the sectoral distribution of such an effort. Regulatory and voluntary policies are difficult to asses in any aspect by CGE models.

- *Type of policy simulation*
  General equilibrium models are typically designed to make comparative analyses between different scenarios for long periods. They are not designed to make a real forecast. Indeed these models require some type of baseline scenario which must largely be based on *external* assumptions for sectoral growth rates, technological progress and others. Consequently they are not very useful for the development of a WOM scenario. Some aspects of WM and WAM scenarios can be explored (cf. wealth aspects of fiscal policies, rebound effects) but the accuracy is low due to the weak technological representation. One particular strength of CGE models is that they represent some long term flexibility due to relative price changes which is usually ignored in other modelling techniques.

  It is possible to introduce a emission reduction objective as a constraint in the model. The model will be able to calculate derived price and income effects on sectors and activities and the economy as a whole.

  It is also possible to introduce a tax on energy consumption or emission, and calculate the reduction realized, based on the elasticity included in the model.

  The effect of the emission trading scheme as such can not be calculated, but the comparison of effects on welfare due to different emission trading schemes and energy prices can be made. For instance, CGE models are very useful in analyzing the advantages/disadvantages of auctioning/granting permission rights.
  Other technical options for reducing emission can not be derived from the model due to its weak technical representation:
    - Derivation of cost curves to reduce GHG is not possible
    - Effect (technical) regulations on buildings, equipment is not possible to calculate
    - Effect of (industrial) benchmarking and other agreements is not possible to calculate

- *Economic consistency*
  The strength of these models is that they are able to produce a coherent picture of the economy in the long term. Coherence of a long term scenario means:
    - a balance between production and consumption of goods and services
    - a balance between exports and imports
    - a balance between savings and investments
    - a balance between labour supply, limited by demographic development, and labour demand
    - a balance between government expenditure and government revenues.
    - national production explained as sum of sector activities.

- *Level of detail*
  The level of detail in general equilibrium models can be very high. Some models differentiate more then 60 sectors and even more types of products. However, the

technological representation is very weak so level of detail is limited to sectors or activities.

- *Time horizon*
  These type of models are used for long term projections.

- *Ability to account for overlapping and rebound effects*
  In general we can say that top-down models are suited to study rebound effects. General equilibrium models have a theoretical structure that fully represents the underlying mechanism to analyse direct and indirect rebound effects from consumers and producers. These models are the most suited ones to analyse various theoretical aspects related to rebound effects.

  Regarding overlapping effects we have to differentiate according to the different types of overlapping that have been defined. The consistent theoretical structure of CGE models allow to asses overlapping with EU-ETS in an appropriate way. Overlapping with WOM is difficult as the exogenous nature of the WOM scenario is high. In general, overlapping of different measures is also problematic as the necessary technical representation is missing.

- *Examples*
  CAPRI
  CAPSIM
  DREMFIA

(2) Macro-econometric models

- *Theoretical background and principles (underlying economic paradigm; structural formulation)*
  Econometrics is a synthesis between mathematics, economic theory and statistics. In these models, it is the task of economic theory to formulate hypotheses, which are in turn formed into mathematical relations that are subsequently estimated by the use of statistical data. The underlying economic theory is of a neo-Keynesian nature.

  Macro-economic models represent the economic circle: people work and earn money which they can spend, thus generating demand for consumer goods and services. The supply of goods is represented by some type of production functions, determining the amounts of production factors (employment, capital, energy…) needed to produce the desired level of goods and services, based on relative prices of the production factors.

  Econometric models represent the economy in a system of equations, determining simultaneously the value of the endogenous variables. Frequently, reduced form equations are used to describe the behaviour of economic agents. While economic textbooks describe markets by demand and supply curves and the price and the quantity of goods as the result of the confrontation of supply and demand, econometric models use behavioural equations linking prices and quantities directly to other variables in the model, without going explicitly through the system of demand and supply. Typical examples of reduced form specifications are:

- a consumption equation, relating consumption to income, consumption price, interest.
- a consumption price equation, relating consumption price to production costs and capacity utilization.

We can distinguish different types of parameters in an econometric model: income elasticity, price elasticity, speed of adjustment parameters, and scaling parameters. Income elasticity express the way consumers react to changes in income. Price elasticity express the reaction to changes in prices. Speed of adjustment parameters are used to differentiate reaction in the short term (for instance 1 year) and the long- or medium term. In this way econometric models differentiate between short term and long term income and price elasticity.

The scientific methodology applied in building econometric models is highly empirical.

Historical data (on yearly, quarterly or monthly basis) or cross section data (for instance data related to different provinces or regions) are used to determine model parameters and functional specifications. Regression techniques produce parameter values and regression statistics allowing to judge the quality of equations and the statistical significance of parameters. However econometricians will never judge the quality of equations on regression statistics only but will use economic insights (does this result make sense?) and past experience.

The number of equations in an econometric model can vary widely – from 10-20 equations to several hundreds or thousands of equations, depending on the level of sector breakdown, geographical coverage and other level of detail.

Weaknesses of econometric models in environmental issues:

- Econometric models usually face problems in simulating structural changes and shocks.
- An important limitation is related to the reduced form specifications. For instance, upward shifts of the supply curves due to environmental regulations are difficult to incorporate in the model as the model does not consider costs explicitly. Econometric models have a strong emphasis on the demand side of the economy, assuming supply will follow automatically. This paradigm is typical for the short or medium period.

- *Type of data (input/output)*
  Typical inputs to these type of model are data related to the international (economical) context: world market development, exchange rates, fuel prices and emission trading prices. Outputs are typical macro-economic data like GDP, (un)employment

and labour activity data, government balances, sector values added. Other outputs are fuel consumption data per fuel type, electricity consumption and CO_2 emissions.

- *Ability to consider technological evolution*
  Econometric models, usually do not have explicit representations of technologies and technological improvement. Technological improvement is frequently hidden in a number of constants in behavioural equations.

- *Evaluation of Policies and Measures*
  Traditional econometric models have not a detailed technological representation, but the last decade, there has been a special emphasis on introducing more technological detail for some sub sectors such as the electricity sector, thus allowing to quantify the emissions reduction obtained by the introduction of renewable energies in the electricity sector. However, when more complex issues, such as an evaluation of CHP is difficult. Evaluating the emission trading scheme is difficult due to a poor technological representation. Regulatory policies and voluntary agreements can not be assessed too.

  Econometric models have some strengths in evaluating fiscal policies, in particular taxes.
  Consumers behaviour towards price changes is represented by demand price elasticity. Energy is also considered as a production factor. Substitution elasticity represent the reactions of producers against price changes. Elasticity are derived from historical observations.

- *Type of policy simulation*
  Econometric models produce economic consistent scenarios, based on lagged historical observations and assumptions on exogenous variables. Typical exogenous variables are: international energy prices, exchange rates, ECB interest rate, tax rates, VAT rates and demographic variables. Econometric modelling is probably the most suited methodology for developing a WOM scenario.

  It is not possible to make general statements about the usefulness of econometric models for constructing WM en WAM scenarios, as it depends on the characteristics of the model and the characteristics of the PAMs. Some PAMs are easy to asses, changing only the variable of some exogenous variable. Other PAMs require active manipulation of the model by changing the structure or using add-factors, based on other calculations. Then the model becomes useful to evaluate macro-economic feed-backs and rebound effects.

- *Economic consistency*
  Econometric models respect national accounting rules and provide economic consistent scenarios.

- *Level of detail*
  In principle is the level of detail not limited by the methodology but by the availability of appropriate historical data. In practice we see that the statistical properties of the econometric relationships are not very well when the disintegration level is high. Therefore, econometricians prefer to work at some aggregated level.

- *Time horizon*
  For methodological reasons, the simulation horizon is limited to 10-15 years. From a technical point of view there is no limitation to the time horizon. A typical horizon is 10 years.

- *Ability to account for overlapping and rebound effects*
  There is a risk for overlapping with the WOM scenario from energy-efficiency granting schemes, in particular schemes that have been introduced in the framework of the implementation of directive 2006/32/EC (energy efficiency improvements by end-users). Energy-improvement trends from historical data are incorporated in the econometric equations. Historical energy efficiency improvements have resulted from the application of new technologies. As it is difficult to avoid granting subsidies for energy efficiency improvements that would have happened anyhow some overlapping with WOM scenario is difficult to avoid.

  Overlapping of multiplicative effects will not be discussed here as it is a general issue.

  As evaluating EU-ETS with econometric models is difficult, the issue is not discussed either.

- *Examples*
  ADAM/EMMA
  Prometeus
  HERMES

Bottom-up models
Bottom-up models are of a completely different nature then top-down models. They better represent the physical parameters determining the level and evolution of energy use and emissions.

One major disadvantage of this type of models is that they do not cover the full economy, but only concentrate on particular aspects, like the energy production and consumption. For this reason, the use of technical bottom-up models does not guarantee the coherence of scenarios. The technical bottom-up models take the final demand in economic sectors (residential, tertiary, industry, agriculture, transport) as a starting point.

In this section we will discuss the pros and the cons of bottom-up organised simulation and optimisation models. Sector specific engineering models are very useful if the economic aspects of any policy can be ignored.

(3) Optimisation models (Linear programming models)

- *Theoretical background and principles (underlying paradigm; structural formulation)*
  Optimisation models are often formulated as a linear programming problem. Processes are represented by variables. The minimum requirements to represent a process are the technical coefficients for input and output flows for energy and materials, technical coefficients for emissions of different pollutants and the operational cost associated to the process. Additional information relates to existing capacities and investment cost for new capacities. An important aspect is that emerging and future technologies can be represented as well.

  The energy and material flows are represented by inequality constraints, expressing that the supply (output from one process) should exceed, or be equal to, the demand (input for next process).

  The system cost is defined as the sum of all cost components in the system: cost of raw materials and primary energies, operational costs for the processes, investment cost for new capacities and possibly environmental taxes. The values for the variables (= processes) are determined by minimizing the total system cost. This means that, from all possible solutions to fulfil the final demand requirements, the combination is chosen that minimizes the systems cost.

  The basic difference with simulation models is the determination of the value of process variables. In simulation models these values are determined from historical observations or based on ad-hoc analysis, in optimisation models these are determined by the optimisation process. To illustrate the difference we consider the determination of primary energy consumption per energy carrier in the electricity sector. In optimisation models, this will be determined by the characteristics of different technologies and the energy prices. In simulation models this will be based on historical information or on ad hoc analysis.

  Demand for energy services and/or materials is determined by the model user in optimisation models. The marginal price of energies (or energy services) and materials is given by the shadow prices as a results of the solution algorithm. Exogenous demand levels are transformed in demand equations by introducing demand elasticity and a calibration procedure. This allows to take price effects of alternative policies into consideration.

  Optimisation is often criticized as being a normative or prescriptive approach, rather than explorative or descriptive. The model tells us what should be done rather than what will be done. Some authors claim that this hypothesis is only valid for systems controlled by a central decision maker, owning all relevant information. It is worthwhile to discuss the advantages and disadvantages of this particular approach:

- Flip-flap behaviour
  Optimisation will always select the cheapest technology to fulfil the full capacity needs, unless it is constrained by the user. The result is that small deviations in prices can have a very strong impact on model results, especially in the choice of fuels and technologies. In reality these shifts will only occur from a certain threshold. This phenomenon is known as the flip-flap behaviour in optimisation models.

  One related issue is the *temporal disintegration level*. Energy prices fluctuate over time (day by day, month by month, year by year). When working with low temporal disintegration (for instance 5 yearly period) the average prices over the period is used in the model, but this will not necessarily correspond to the results obtained by introducing the price fluctuations in a model with a high temporal disintegration level.

- Transparent and univocally defined solutions
  In developing scenarios for 2020-2050, hundreds of parameters relating to the choice of technologies will have to be defined. Thousands of possible solutions exist to fulfil the demand requirements. Optimisation will select only one without any arbitrary rules. This is particularly useful in comparing scenarios being developed under different external conditions.

- *Rational and consistency with economic theory*
  The behaviour of people is conditioned by social and cultural values and therefore they may be not fully rational in the economic sense, but the rationality hypothesis is fully consistent with the economic theory. Minimisation of the system costs corresponds to the solution of a free market under the hypothesis of full competition. However, the solution does not correspond to solutions when market imperfections are considered, like oligopoly and monopoly.

- *Endogenous investment decisions*
  Optimisation allows for endogenous technology choices in a consistent framework. This becomes very relevant in establishing long term scenarios as all remaining capacities are scrapped.

- *Shadow prices for energy, materials and emissions*
  One particular advantage of optimisation is the generation of shadow prices for energies, materials and emissions. Shadow prices correspond to the marginal costs, evaluated at the solution point.

- *Development of conditional scenarios*
  Optimisation models are very well suited to develop conditional scenarios. Other constraints such as environmental regulation for other pollutants or limiting primary energy supply for some energy carriers can be easily handled.

  Optimization allows endogenous technology choices and the calculation of "shadow prices" (marginal costs) for use with price elastic demands. As it is based on cost minimisation, it is well suited for sectors where costs can be well defined, such as the electricity sector. It is also useful to sort out complex combinations of technologies such as may be envisaged in the long term energy supply, e.g. with the introduction of coal conversion, hydrogen technologies, storage etc.

- *Type of data (input/output)*
  Linear programming models have as input the physical characteristics of the sectors they model: characteristics for power plants, fluctuations in electricity demand, load curves for electricity, industrial installations, housing stock, other building types, transport equipment,…. These models require an external scenario for end-use energy consumption. Fuel prices and emission trading prices are also needed as input.

  Typical output data are: fuel consumption per fuel type and sector, energy related GHG emissions, GHG emissions linked to specific processes are outputs, load of electricity plants, unused capacity, shadow prices (marginal production costs) for energy.

- *Ability to consider technological evolution*
  This type of model has good technological representation and is very well suited to consider technological evolution. Some models are able to consider technological evolution by endogenous learning.

- *Evaluation of policies and measures*
  Linear programming models are very well suited to analyze the effects of various policies and measures in different aspects: reduction potential, cost-effectiveness and how it fits into the broader picture. They are very useful for analyzing PAMs in the electricity sector as the complexity of the electricity sector is fully represented. Also refineries can be analyzed by LP models. They allow to:
  - analyze in detail the impact of financial mechanisms on renewable energies and CHP.
  - to evaluate the effect of the EU-ETS by introducing a price for CO_2
  - to analyze the effects of changes in fuel prices
  - to analyze the distribution of efforts between sectors based on equalizing marginal reduction costs.

- *Type of policy simulation*
  The construction of a WOM scenario requires exogenous assumptions of energy services by end-users. Once a WOM scenario has been constructed, various policies and measures can be introduced to obtain WM and WAM scenarios.

  A great asset of this methodology is the possibility to develop cost curves for reduction of GHG and so identify cost effective measures and technologies.

  A tax on energy or emissions can be introduced in the model, and will result in accurate demand and supply effects.

  If the technological representation is detailed enough, technical measures can be evaluated, such as: regulations on buildings and equipment, reduction agreements in industry,…

- *Economic consistency*
  Economic consistency is not guaranteed as these models only consider the energy sector.

- *Level of detail*
  Level of detail can be high, depending on the level of detail of the technological representation of sectors and activities.

- *Time horizon*
  Modelling horizon is typically 10 to 30 years, but it might be extended up to 50 or 100 years.

- *Ability to account for overlapping and rebound effects*
  Linear programming models (optimisation) use disintegrated data and technologies are kept constant at the lowest disintegrated level. This means that they use explicit assumptions on the improvement of the energy efficiency, allowing to avoid overlap with WOM scenario. Linear programming models are suited to handle overlapping problems for multiple measures, as they have a detailed representation of the technologies.

  Linear programming models are suited to handle overlap due to emission trading. It depends on the nature of domestic measures how it should be done.
    - Domestic policies based on regulation.
    - The domestic objectives are introduced as lower bounds and a CO_2 price is introduced as a tax. The CO_2 price will enhance cost-efficiency of domestic measures. The combined result may be that the domestic objectives are satisfied or exceeded. Only in the case domestic objectives are exceeded there is an additional effect from the CO_2 price.
    - Domestic policies based on financial mechanism

- The financial mechanisms are modelled explicitly. Without CO_2 price the model will select saving measures up to the level of zero profitability. A CO_2 price will enhance profitability and additional saving measures will be selected.

Most linear programming models (optimisation) have facilities to introduce demand price elasticity. This allows to analyse direct rebounds effects. As these models only represent the energy system, it is difficult to analyse indirect rebound effects.

- *Examples*
  MARKAL/TIMES
  MESSAGE
  EFOM/ENV

(4) Engineering models

- *Theoretical background and principles (underlying paradigm; structural formulation)*
  Engineering models explain emissions by looking at physical and chemical properties of systems. Their structural formulation is straightforward. They use exogenous assumptions on activity levels and do not consider any feedback mechanisms. They may contain very detailed information on capital stock of certain sub-sectors. A common spread example is the COPERT methodology for the transport sector. In fact, many MS use COPERT both for emissions inventory and projections.

- *Type of data (input/output)*
  The input parameters needed for the models include activity data and emissions factors, plus technology data. Frequently, engineering models are used in the preparation of a linear programming model.

- *Ability to consider technological evolution*
  Technological evolution is represented explicitly.

- *Evaluation of Policies and Measures*
  Depending on the detail of technological representation, these models can very well calculate the technical potential of a measure as well as regulatory policies. They lack the economic component and are not useful to evaluate fiscal policies and price effects or any other component.

- *Type of policy simulation*
  They can contribute to the development of WOM scenario, as well as to the quantification of reduction potentials in WM and WAM scenarios. For instance, the reduction potential of new insulation regulation for buildings can be quantified using this type of models.

- *Economic consistency*
  No guarantee of economic consistency.

- *Level of detail*
  The level of detail is usually high, but can vary.

- *Time horizon*
  The time horizon mainly depends on the type of problem handled wit this type of models.

- *Ability to account for overlapping and rebound effects*
  Building a WOM scenario requires assumptions on the introduction of new technologies, and this requires a lot of expert judgement. As such the methodology does not give any particular advantages on other methodologies in avoiding overlapping with WOM scenario. On the contrary, overlapping of different measures can be assessed given that the structural specification is correct.

  Engineering type of models are lacking the economic component, necessary to make the evaluation of effects by an emission trading scheme. For the same reason, engineering models are not suited to analyse rebound effects.

- *Examples*
  TEMAT
  EPM
  Copert III

(5) Simulation models

- *Theoretical background and principles (underlying paradigm; structural formulation)*
  The ENPEP-BALANCE module provide a framework for developing a partial equilibrium model for an energy system of a nation. The system is based on a representation of energies (fuel types) and technologies. The system includes a number of economic reactions:
  - Behavioural equations representing energy consumers
  - Balancing cost accounting rules and capital costs allocation rules for multiple output technologies
  - Market shares of competing fuels based on relative prices
  - Price–supply functions for primary energy
  - Taxation

  Similar to econometric models, the structural equations include price elasticity and lagged variables. The user can influence the magnitude and the speed of reaction by changing parameter values. Unlike econometric models, there is no flexibility in the structural specifications and no empirical verification of the parameters.

  Major disadvantages of this approach are:
  - Capacities are exogenous and have to be defined by the user. Evaluating the penetration of new technologies becomes problematic.

- the user could face problems in identifying the values for the sensitivity parameters. There is no methodology to determine the values and no empirical verification.
- economic decisions are based on average prices and costs. In optimisation models reactions are based on marginal prices and costs.
- The methodology is not suited to analyse the sector specificities for the electricity sector and refineries.

- *Type of data (input/output)*
  The model requires base-year energy balance data (energy consumption per fuel type and per sector), base year price and tax levels and characteristics of energy-conversion technologies (efficiency of conversion, lifetime of equipment).

  Activity levels are exogenous and have to be supplied by the model users. Other typical input variables are international fuel prices.

  Fuel consumption per fuel type, energy related GHG emissions and GHG emissions linked to specific processes are outputs.

- *Ability to consider technological evolution*
  Technological evolution can be represented in a model either by considering technology choices in an explicit way, either by a trend factors in average technologies. Trend factor for projections are difficult to quantify and subject to a high degree of uncertainty. The possibilities to model explicit technology choices are limited as allocations are based on average costs of technologies (instead of marginal costs) and the use of arbitrary sensitivity parameters.

- *Evaluation of measures*
  Introducing end-use price elasticity allows for the evaluation of some fiscal policies and other price effects. It is difficult to calculate the technical or economical potential of a measure. Financial systems such as green certificates, CHP certificates or white certificates can not be assessed.

- *Type of policy simulation*
  Simulation models can be used to calculate WOM GHG emissions scenarios from external supplied activity scenarios. As the possibilities to evaluate individual measures is limited, the use for WM and WAM scenarios is limited as well.

- *Economic consistency*
  There is no economic consistency.

- *Level of detail*
  The level of detail is determined by the user methodology but generally spoken one can argue that the methodology is more suited to be used at some aggregation

level. Detailed information on housing statistics of transport equipment is difficult to handle.

- *Time horizon*
  As capacities have to be supplied by the user, the time horizon is limited for practical reasons.

- *Ability to account for overlapping and rebound effects*
  The possibilities to analyse PAMs as well as the ability to account for overlapping are limited.

- *Examples*
  BALANCE
  ENPEP

(6) Focus on demand (End-use models for energy planning)

- *Theoretical background and principles (underlying paradigm; structural formulation)*
  This type of models provides a pre-defined framework for the development of energy demand scenarios for specific end-users on a disintegrated level. They basically rely on accounting relationships. They do not consider price effects. The user should supply a socio-economic scenario, determining important key variables such as the penetration of fuel types and the evolution of energy efficiencies.

- *Type of data (input/output)*
  Typical inputs are sectoral values added, sectoral energy efficiency improvements.

- *Ability to consider technological evolution*
  These can be indirectly included in the input variables.

- *Evaluation of measures*
  These models are not developed or suited to evaluate different measures.

- *Type of policy simulation*
  The WOM scenario is based on external input data. These models are not really developed to analyse different policies.

- *Economic consistency*
  There is no economic consistency.

- *Level of detail*
  The level of detail can vary.

- *Time horizon*
  10-15 years

- *Ability to account for overlapping and rebound effects*
  These models depend on external data and are not suited to analyse overlapping and rebound effects.

- *Examples*
  MAED
  MED-PRO

3.2.2.4 Summary of the characteristics of modelling approaches

In the following tables (Table 13 and Table 14), the characteristics of the modelling approaches are put together in an overview.

Table 13 Typical input and output parameters in different types of models (I = input, O = output)

	Top-down		Bottom-up			
	General equilibrium	**Econometric**	**Focus on demand**	**Linear programming**	**Engineering**	**Simulation**
International context						
World market development	I	I				
exchange rate	I	I				
International fuel prices	I	I		I		I
Macro-economic development						
Tax rates, VAT rate, social security contribution rates	I	I				
GDP	O	O				
Employment, unemployment, labour productivity	O	O				
Trade balance						
Government balance	O	O				
Sectoral value added	O	O	I			
Sectoral demand energy	O	O	O	I	I	I
Technologies						
Economic characteristics of technologies				I		I
Physical characteristics of technologies						
power plants				I	I	I
industrial installations				I	I	I
housing stock				I	I	I
Other buildings				I	I	I
transport equipment				I	I	I
Sectoral energy-efficiency improvements			I	O	O	O
Load curve electricity			O	I		

	Top-down		Bottom-up			
	General equilibrium	Econometric	Focus on demand	Linear programming	Engineering	Simulation
Emissions trading price	I	I		I		
Electricity consumption	O	O	O	I	I	I
Fuel consumption by fuel type	O	O	O	O	O	O
CO_2 emissions	O	O	O	O	O	O

Table 14 Other characteristics of modelling methodologies

	Top-down		Bottom-up				Remark
	General equilibrium	**Econometric**	**Focus on demand**	**Linear programming**	**Engineering**	**Simulation**	
Other output							
Other energetic GHG emissions	Linked to aggregate activity levels. More sectoral detail is favourable.		Linked to specific processes.				
Process related GHG emissions	Linked to aggregate activity levels. More sectoral detail is favourable. Endogenous end-of pipe measures difficult to consider		NA	Linked to specific processes. End-of pipe measures endogenous or exogenous	Linked to specific processes. End-of pipe measures only exogenous		
Energy related (non GHG) emissions SO_2,NO_X,PM	Approximated by fuel specific factors, no policy reactions		NA	Plant specific emissions			
				Policy evaluation and interaction with energy system			
Level of sectoral detail	Different sector may be considered but usually no-detail on energy intensive sectors		Energy intensive processes considered separately				
Measures							
Reduction by sector	Price effects and income effects derived from historical observations- likely underestimation		NA	Demand price elasticity and technology choices	exogenous technology choices, no price effects	price effects	
Technical potential by measure	Technical measures are not identified		NA	Explicit representation		Difficult	
Economic potential by measure	Technical measures are not identified		NA	Explicit representation		Difficult	

	Top-down		Bottom-up				Remark
	General equilibrium	**Econometric**	**Focus on demand**	**Linear programming**	**Engineering**	**Simulation**	
Direct reduction cost	Including macro-economic feedbacks	"Cost" are difficult to consider due to reduced form specifications	NA	Yes		No	
Investment	NA		NA	Yes	Yes		
O&M	NA		NA	Yes	Yes		
Derived economic effects on							
GDP	Yes		No				
Employment	Yes		No				
Government balance	Yes		No				
Consumer and producer surplus	Yes	No	No				
Sectoral effects on activities	Price effects and income effects		No	Price effects	No	Price effects	
Policy simulations							
WOM scenario 2012	Exogenous, economic consistent scenario	Endogenous economic consistent scenario	based on exogenous assumptions of activities and energy-efficiency	energy services and materials demand exogenous, optimal technology choices selected by model	energy services and materials demand exogenous		2
WOM scenario 2030		No					2

	Top-down		Bottom-up				Remark
	General equilibrium	**Econometric**	**Focus on demand**	**Linear programming**	**Engineering**	**Simulation**	
Derivation of cost curves for GHG	No		No	Identification of measures and technologies	No	No	
Emission reduction objective	Objective introduced as constraint, derived price and income effects	Not possible to introduce objective as constraint possible to explore limits of policies	No	Objective introduced as constraint, price effects taken into account	explorative exercises	No	
Tax on energy consumption	Estimation of reduction with elasticity Recycling government income considered Supply effects	Estimation of reduction with elasticity Recycling government income considered	No	Accurate demand and supply (substitution) effects	No	Demand effects	
			Effects on government income ignored				
Tax on emission	Idem tax on energy consumption	Indirectly, variation in energy taxes	No	Idem tax on energy consumption	No	difficult	
Emission trading	Analysis of welfare aspects of different permitting schemes	No	No	Similar effects as emission tax	No	No	
Financial mechanism to promote renewable (green certificates, feed-in tariffs)	No		No	Yes	No	difficult	

	Top-down		Bottom-up				Remark
	General equilibrium	**Econometric**	**Focus on demand**	**Linear programming**	**Engineering**	**Simulation**	
Financial mechanisms to promote CHP (certificates, feed -in tariffs)	No		No	Yes	No	No	
Alternative energy prices	Yes		No	Yes	No	Yes	
Subsidies	Yes, recycling effects considered		No	Yes, no recycling effects	No	Yes, no recycling effects	
Regulations							
Thermal regulations on buildings	No		No	Yes		No	
Performance regulations on equipment	No		Information required for this analysis is gathered to build the model				
Benchmarking	No		Benchmarking requires detailed analysis of installations worldwide. If this is available, bottom-up models can be used for evaluations			No	
Voluntary branch agreements	No		Bottom-up models are useful to support the government in negotiating voluntary branch agreements				
Other intrinsic qualities							
Macro-economic consistency	Yes		No				
Level of detail of emission projections	See remark baseline scenario	Accurate WOM projections within relevant time horizon	Bottom-up models take structural shifts into account more explicitly				
Transport specific methodology	Non-specific	Non-specific	Non-specific				1
Explicit representation of technology choices in the energy sector, modelling of co-generation	Weak representation			Very high detail, including base-load and peek-load considerations		No-consistent co-generation	
Easiness to learn	experts - level required		easy to learn				

	Top-down		Bottom-up				Remark
	General equilibrium	Econometric	Focus on demand	Linear programming	Engineering	Simulation	
Time horizon	Long term	10-15 years	Typical 10-15 years	Typical 10-30 years	variable	Limited for practical reasons	
Overlapping and rebound effect	Rebound: yes Overlapping: depending on type	Overlapping: difficult		Rebound: only direct effects Overlapping: yes	Rebound: no Overlapping: difficult	limited	

Remarks:

1. Many models have similar structure for the transport sector as for other energy consuming sectors. The question is if the models can handle the typical problems associated to the transport sector: mobility, congestion, modal shift

2.GHG emissions for 2030 will largely depend on technological choices in the energy sector, industry, residential construction and office building. These technological choices are much better represented in bottom-up models. General equilibrium models can be used to check the macro-economic consistency of sectoral growth paths. The typical simulation period for econometric models is about 5-10 years.

3.2.3 Overview of the projection methodologies used by the MS

Table 15 is listing the models being used by MS in developing GHG projections. This table is an attempt to establish a sector classification of the methodologies used by MS.

Elements to take into account when using the table:

- Some models have characteristics of different methodologies. These models have been classified on what was thought as being the major part.
- Member states often use different models for demand and supply aspects. For instance, econometric models are often used to make consistent projections for final energy-service demand and engineering type of models are used to handle the supply aspects and/or to evaluate the effects of PAMs. In this case the classification has been based on the supply model.
- We use the abbreviation ATP for the use of anonymous tabular processor models.
- We use NIP when no info is provided.

Table 15 Summary of the models used by members states

	Energy - supply	Industry	Transport	Residential	Tertiary	Agriculture	Waste	Forestry	Industrial processes	F-Gases
Austria	Prometeus		AUTRAF /GLOBEMI	Prometeus		PASMA	NIP	NIP	IPCC	ATP
Belgium	Markal	Markal/EPM	EPM/ TEMAT	EPM/ ATP		IPCC	NIP	NIP	NIP	NIP
Bulgaria	ENPEP / WASP / BALANCE	ENPEP/ MACRO-DEMAND-BALANCE-IMPACT				IPCC	NIP	ATP	NIP	NIP
Cyprus	ENPEP - Balance					IPCC	NIP	NIP	IPCC	NIP
Czech Republic	EFOM/ENV	EFOM/ENV ATP				IPCC	IPCC	ATP	IPCC	NIP
Denmark	RAMSES/ ADAM /EMMA	ADAM /EMMA	Copert III	ADAM /EMMA		IPCC	IPCC	NIP	NIP	NIP
Estonia	Markal									
Finland	Times/ EV-Model (combines engeneering model and key industrial sectors to a CGE model)					DREMFIA	IPCC	Model Finish forest research institute	covers also industrial energy emissions	NIP
France	Poles	MED-PRO				MAGALI	IPCC	NIP	PAM's of VA	Model for refrigeration?
Germany	Elias	Seperate module	Astra	Model from University Julich		Projections from environmental agency			Activity data from industru sub-module	
Greece	BALANCE	BALANCE/ ATP	MAED			ATP	ATP	ATP	ATP	ATP
Hungary	Anonymous					HUSIM (activity data) + tier1 IPCC	IPCC	model from REKK	Anonymous	NIP
Ireland	IPM	Hermes/ESRI?				FAPRI-Ireland	Projections from DEHLG	CARBWARE	consultations with industry	consultations with industry
Italy	Markal					ATP	ATP	ATP	ATP	ATP
Lativia	Markal		Copert III	Markal		Ministry of agriculture data, based on plans	NIP	NIP	NIP	NIP
Lithuania	Message	MAED				ATP	ATP	NIP	NIP	NIP
Netherlands	Powers/Selpe /SERUM	Athena /SAVE-		Athena /SAVE		CO2 form Athena/Save -	IPCC	improving methodology		

	Energy - supply	Industry	Transport	Residential	Tertiary	Agriculture	Waste	Forestry	Industrial processes	F-Gases
		powers				Activity data + emission factors				
Poland	MESSAGE/WASP	MAED / BALANCE				Activity data+ emissions factor	ATP	ATP	ATP	ATP
Portugal	Times	detailed sector accounting model	seperate model	simulation model	simula-tion model	CAPSIM	ATP	Forestry planning 2025 inter-polations for activity data	ATP	
Romania	ENPEP		NIP	ENPEP		Activity data + emission factor	NIP	NIP		Extrapola-tion of his-torical data
Slovakia	MESSAGE	ENPEP/BALANCE				Activity data + emission factors	ISI method (maste water) + IPCC	NIP	ATP	ATP
Slovenia	MESAP / REESLO	?	Copert III	?	?	IPCC	IPCC	NIP	NIP	NIP
Spain	SEP	SEP	SEP	SEP	SEP	SEP	ATP	NIP	ATP	ATP
Sweden	Markal/EMEC (CGE)	ATP	Sampers - Samgods	DoS		CAPRI	IPCC	HUGIN	ATP	ATP
United Kingdom	Lin PGM	DTI				Activity data + emission factors	NIP	NIP	NIP	NIP

Legend *Table 15*

Econometric model	Equilibrium model	Optimisa-tion model	Engineer-ing type	Simulation model	End use demand
Not identified processor	Anonymous tabular processor (ATP)		IPCC	more info needed for classification	

3.3 Conclusions

From the discussion above, it is clear that there exists no single model or even one modelling approach providing answers to all relevant questions related to the development of GHG projections and the evaluation of PAMs. All different models have their own weaknesses and strengths.

The choice made by a MS to use a particular model is mostly based on the original questions asked for. However, also coincidence has played a role. In most MS, the modelling work has been accomplished by external institutions, based on experience in similar tasks. These institutions have used existing or easy to access modelling tools. With time and with changing questions, these tools have been adapted and/or further developed. As such the methodologies used by MS between NC3, NC4 and MM submissions have changed.

In the sectoral analysis (Chapter 4-10) we will discuss the models used by MS on a sector basis following an identical scheme:

- Introduction of the sector
- Model requirements for the (specific) sector
- Assessment of models used by member states
    - Overview of the models used
    - Analysis of the sectoral requirements
    - Integration of PAMs in the models
- Recommendation – best model choice

We will give an overview of some specific elements and model requirements regarding input-output parameters as well as the inclusion of PAMs for each specific sector.
Based on the theory of the models discussed in the previous sections (summarized in Table 13 and Table 14), we know which input and output parameters models use theoretically and which typical characteristics models have. In the assessment of the models used by the MS, we will discuss for each sector what model requirements are important, looking specifically at the model parameters and at the inclusion of PAMs related to the sector.

4 Sectoral Analysis – Energy

4.1 Assessment of Member States projections

4.1.1 Completeness

Most countries include fugitive emissions in their projections (see also Table 16). Only five Member States do not cover fugitive emissions at all (Cyprus, Estonia, Latvia and Romania). It differs from Member State to Member State whether fugitive emissions from both solid fuels and from oil and natural gas are relevant. Therefore we checked for the 22 Member States where the National Inventory Report 2007 was available and indicated whether fugitive emissions from solid fuels or from oil and natural gas are a key source category. Estonia and Romania both do not project fugitive emissions even though they are a key source category.

Table 16 Reporting of projections of fugitive emissions and key source category

	Reporting of fugitive emissions				Key source category?	
	1.B.1 Solid fuels	1.B.2 Oil & natural gas	1.B Fugitive emissions aggregated	Included in energy emissions	1.B.1 Solid fuels	1.B.2 Oil & natural gas
Austria	x	x			x	
Belgium		x				
Bulgaria	x	x			x	x
Cyprus					NIR not available	
Czech Republic	x	x			x	x
Denmark		x				x
Estonia					x	x
Finland		x				x
France[1]			x		x	x
Germany				x	x	x
Greece	x	x			NIR not available	
Hungary				x	x	x
Ireland		x				
Italy		x				x
Latvia						
Lithuania		x				x
Luxembourg		no projections available				
Malta		no projections available			NIR not available	
Netherlands		x				x
Poland	x	x			x	x
Portugal	x	x				x
Romania					x	x
Slovakia	x	x			NIR not available	
Slovenia	x	x			x	
Spain[2]			x		x	x
Sweden			x		x	
United Kingdom	x	x			x	x

1 Only CO_2 emissions covered.

2 Included in "group 5, extraction and distribution of fossil fuels and geothermal energy".

Nine Member States (Austria, Bulgaria, Czech Republic, Greece, Poland, Portugal, Slovakia, Slovenia and UK) report fugitive emissions disintegrated to CRF category 1.B.1 Solid fuels and 1.B.2 Oil and natural gas. Seven Member States (Belgium, Denmark, Finland, Ireland, Italy, Lithuania and Netherlands) report fugitive emissions from natural gas only, for all of these countries fugitive emissions from solid fuels are not a key source category as coal mining is no major activity. The other Member States either report projections of fugitive emissions aggregated only (France, Spain and Sweden) or include them in overall energy emissions (Germany and Hungary).

4.1.2 Comparability

4.1.2.1 Allocation of emissions

It is not always very clear whether the allocation of energy emissions follows the recommendations for GHG inventories, in particular related to the coverage of energy emissions of 'industry', 'agriculture' and 'waste'. Some MS do not allocate combustion emissions from industry, agriculture or waste to 'energy', but to the sectoral estimates (e.g. Netherlands). This leads to inconsistent trends when projections are compared with inventory trends. Consequently sectoral allocation of energy emissions should follow those for GHG inventories.

4.1.2.2 Coverage of common and coordinated policies and measures in the energy sector

Whereas some Member States provide a very clear overview including common and coordinated policies and measures in the 'with measures' or 'with additional measures' projection, for a number of Member State it is unclear whether a measure which might be implemented is also taken into account in the projections. This will improve with the use of the Excel template for projections as PAMs included in projections can be selected from drop down list.

The Directive on Emissions Trading (Directive 2003/87/EC) is not included in the 'with measures' projections of all EU-15 Member States (e.g. Finland, Greece, Portugal and UK do not include the EU ETS). Finland argues that the possibility given to installations to buy credits from flexible mechanisms or from installations situated in other countries leads to a very high uncertainty on how the emissions trading scheme will influence national emissions. The projections to the emissions trading (ETS) sector were updated by some Member States based on the NAP II decision by the Commission.

The Renewables Directive (Directive 2002/91/EC) was included in the projections of most EU-15 Member States at least partly; Greece and Italy do not include the directive. For the new Member States the inclusion is sometimes unclear.

The Biofuels Directive (Directive 2003/30/EC) is covered in the projection of all EU-15 Member States except Finland and Portugal, but not always in new Member States. Usually the estimates concerning the biofuels directive were updated in the 2007 submission under the Monitoring Mechanism Decision.

It is not always clear, whether the Directive on promotion of CHP (Directive 2004/8/EC) is taken into account in the projections. Portugal includes the CHP directive in the WAM projection.

The Directive on energy performance of buildings (Directive 2002/91/EC) is treated very differently across Member States. Some Member States include the directive in the 'with measures' projection based on the fact that the Directive was approved at European level; whereas others include the directive in the 'with additional measures' projection, because some elements of the Directive were adopted and implement at national level after the elaboration of projections. Most Member States assume only long-term effects of the directive, but some Member States do project emissions reduction effects of the directive already in the first commitment period.

Table 17 Inclusion of ECCP policies and measures in the reported projections

	ECCP policies and measures covered in WM projections					
	Renewables Directive	CHP Directive	Biofuels Directive	Energy performance of buildings	EU ETS	Linking Directive CDM/JI
Austria	Yes	Partly	Yes	Partly	Yes	No
Belgium	Yes	Yes	Yes	Yes	Yes	Yes
Bulgaria	No	No	No	No	No	No
Cyprus	Partly	No	No	Yes	No	No
Czech Republic	no	no	no	yes	yes	no
Denmark	Yes	Yes	Yes	Yes	Yes	Yes
Estonia	Partly	Partly	No	No	Unclear	Yes
Finland	Yes	Yes	No	No	No	No
France	Yes	Yes	Yes	Yes	Yes	No
Germany	Partly	Partly	Unclear	Unclear	Yes	No
Greece	No	No	Yes	Yes	No	No
Hungary	Unclear	Unclear	No	No	Unclear	No
Ireland	yes	yes	yes	yes	yes	yes
Italy	No	Yes	Yes	Partly	Yes	Unclear
Latvia	Yes	Yes	Yes	Yes	Unclear	Unclear
Lithuania	Yes	Yes	Yes	Yes	Yes	No
Netherlands	yes	yes	yes	yes	yes	yes
Poland	No	No	No	No	No	No
Portugal	Yes	No	No	Yes	No	No
Romania	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Slovakia	No	No	No	No	No	No
Slovenia	Yes	Yes	Yes	Yes	No	Unclear
Spain	Yes	Yes	Yes	Yes	Yes	NA
Sweden	Yes	Yes	Yes	Yes	Yes	NO
United Kingdom	Yes	No	Yes	Yes	No	No

4.1.2.3 Energy – presentation of projected data

In the energy sector currently only total emissions can be aggregated as reports from Member States differ widely. Ten Member States only provide total energy emissions or use a country-specific disintegration (Austria, Bulgaria, Cyprus, Estonia, Germany, Hungary, Italy, Latvia, Netherlands and Poland). Two Member States (Greece, and Spain) present projected emissions separately for energy, industry, residential and services. Only 13 Member States (Belgium, Czech Republic, Denmark, Finland, France, Ireland, Lithuania, Portugal, Romania, Slovakia, Slovenia, Sweden and UK) use the CRF categories or a disintegration close to these categories to present the projected emissions data in the energy sector. No Member State uses a disintegration similar to the energy balance or Primes.

The different ways of disintegration in the energy sector is a key problem for the disintegrated analysis of projection results for EU-15 and EU-27 in the energy sector. Currently only total projected emissions from total energy can be compiled for the EU, but a more specific disintegration would be key to compile future trends of key sources at EU level. Only when projections use the same source categories as in the GHG inventories, past trends can be compared with future trends. Currently no check for consistency at more disintegrated level is possible.

The projection template has improved the situation related to reporting: four Member States now report at a more disintegrated level. However this requires that MS elaborate projections based on inventory source categories, which is currently not yet the situation in all MS.

Table 18 Comparison of the way and level of sectoral disintegration of GHG projections from the energy sector

	Only total energy emissions	Energy + industry emissions separated	Emissions from Energy, Industry, Residential, Services separated	Similar to categories in energy balance/ Primes	Close to source categories in GHG inventory	Country-specific disaggregation
Austria						x
Belgium					x	
Bulgaria	x					
Cyprus	x					
Czech Republic					x	
Denmark					x	
Estonia	x					
Finland					x	
France					x	
Germany						x
Greece			x			
Hungary						x
Ireland					x	
Italy						x
Latvia	x					
Lithuania					x	
Netherlands						x
Poland	x					
Portugal					x	
Romania					x	
Slovakia					x	
Slovenia					x	
Spain			x			
Sweden					x	
United Kingdom					x	

4.1.2.4 Energy – presentation of assumptions and background data

All Member States report background parameters and assumptions, but there is considerable variation on parameters and units used.

Almost all Member States report some of the projection indicators requested under the Article 3(2)(a)(iv) of Decision No 280/2004/EC and presented in Article 9(c): annex III of the Implementing Provision. Many Member States report additional assumptions e.g. on the year of commissioning or decommissioning of specific power plants. Some Member States include projected primary energy balances or fuel splits.

The information given on background parameters and assumption is currently too heterogenic for any aggregation at EU level. Neither Member States nor PRIMES provide clear definition on background parameters, which creates large uncertainties for comparison.

The reporting of background parameters is an area where improvement and a new approach would enhance significantly the quality of Member States and EU projections. A smaller set of key background energy data, which should be consistently reported by all Member States should be required. The same parameters should be available for EU projections such as PRIMES. Further elaborations of such recommendations are included in chapter 12.

4.2 Assessment of Member States models & parameters

4.2.1 Introduction

Developing GHG scenarios for the electricity sector requires an understanding of some basic characteristics. Today, electricity is produced by private owned companies trying to maximise profit. Profit is the difference between revenues and production costs. Hence maximising profit is equivalent to maximising revenues and minimizing production costs. Individual companies have limited impact on revenues in a competitive or regulated market as sales prices are determined by the global market, but they have to have a strong impact on production costs. Production costs are determined by the choice of the technology (capital cost, operational cost, maintenance), fuel prices and the efficiency of the installation and future GHG emissions depend entirely on the choice of the production technology.

As storage possibilities are rather limited, electricity is almost only produced for immediate consumption. Consumption fluctuates by hour, day, weak and season. These fluctuations are expressed in load-curves and they have a very significant impact on the choice of technologies.

4.2.2 Model requirements

Any model is a simplified representation of reality, but the level of simplification should not be too high in order to be able to produce adequate projections and to asses various aspects of PAMs models. Models should be based on sound economic principles. Regardless the methodology we can define a number of sector specific issues the models should deal with, either as input parameter or as a model[8] result. Taking into account the main objectives of the monitoring mechanism[9] **we believe that a model for the electricity sector preferably should:**

- incorporate rigidities of the system related to the existing production park, characterised by capacities, efficiencies and lifetime of existing plants;

[8] This is a requirement to answer the typical question: Have you considered … in your projections?

[9] (1) Accurate GHG emission projections (in absolute figures and possibility to evaluate and (2) correctly account for PAM's

- consider investment decisions in different technologies. Investment decisions can be exogenous (input parameter) or endogenous (model results) based on economic and technological characteristics of technologies. The longer the historical perspective, the more preferential are endogenous investment decisions;
- be able to evaluate the impact of fuel prices assumptions on operational load factors for different technologies;
- be able to explore the growth potential and the limitations for renewable energies;
- be able to explore the growth potential and the limitations for CHP;
- be able to analyse the effect of a CO_2 tax;
- be able to evaluate emission trading;
- be able to analyse the effect of the liberalisation of the electricity sector; on international exchanges and on pricing of electricity;

Demand for electricity and load–curves are determined by end-use sectors. This is common to all projection methodologies. But some MS use integrated models where end-use demand for electricity is an output variable while other models more concentrate on the supply aspects.

4.2.3 Assessment by Member States

4.2.3.1 Overview of Models Used

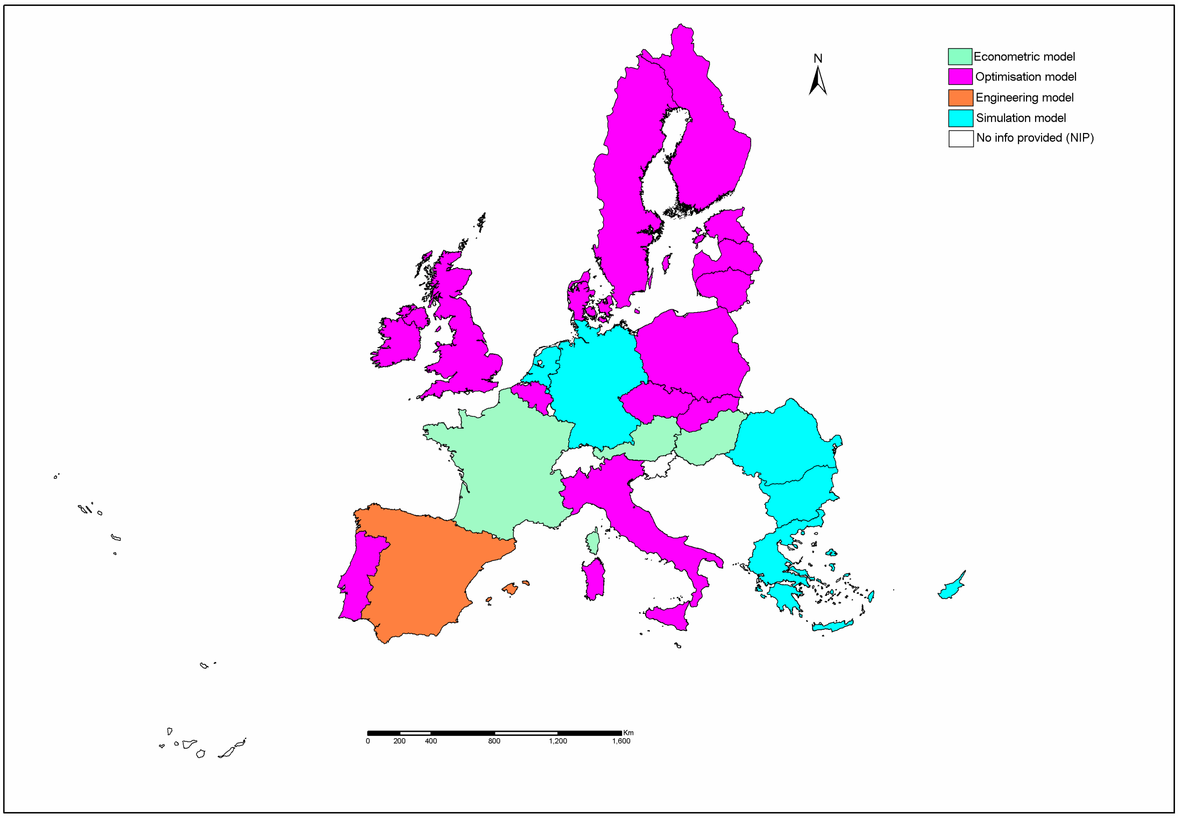
Belgium, Estonia, Latvia and Sweden use the MARKAL model, a linear programming model developed by ETSAP, an implementing agreement of the I.E.A., first established in 1976. Finland uses TIMES which is the new tool developed by ETSAP. Poland, Lithuania and Slovakia use the MESSAGE model, that has been developed by IIASA. Recently also Portugal and Italy started using the Markal/Times models for their projections. Ireland (IPM), Denmark (RAMSES) and UK use country specific linear programming models for the electricity sector.

Econometric models have as many equations as unknown variables. Therefore it is difficult to implement the “technology choice issue”, which is typical for the electricity sector. Econometric models can be used to produce a WOM scenario, but only for a limited horizon. Evaluating PAMs, related to CHP or renewable energies becomes problematic as cost-efficiency is no issue in the Neo-Keynesian paradigm which is implemented in most econometric models. Most member states have recognised these shortcomings as typical econometric models are rarely used for the electricity sector. Austria is using an econometric model. Hungary relays on “robust statistical models”. The projections for France are based on the Poles model. The Poles model is sometimes classified as an econometric model, based on the structure of the equations. However, the simulation horizon, and the empirical verification of parameter values are atypical for an econometric model.

A few member states use the ENPEP modules BALANCE and WASP. The BALANCE module is a bottom-up simulation tool, simulating supply and demand for energy. The WASP module determines an expansion path for the electricity sector. The WASP module has limited features. For instance, the WASP module does not allow to evaluate the CHP

Directive. A few member states have recently moved from the WASP module to the MESSAGE model to produce scenarios.

Figure 26 Overview of the models used in the MS



Optimization models are the most wide-spread type of models used by Member States.

The Netherlands are taking a particular position. The POWERS model is a dynamic simulation model for the pricing of electricity on a temporarily disintegrated level. It uses a scenario for electricity demand and capacities to simulate electricity pricing in a market with oligopoly characteristics. It attempts to simulate the effect of the liberalisation on the electricity market on the price of electricity. However, it is common knowledge that the Netherlands are using a wide variety of models, to asses different aspects, and the POWERS model is only one model in the chain.

Spain is using an inventory methodology. It is not clear how the typical aspects of the electricity sector are handled.

4.2.3.2 Sectoral requirements

In the following table (Table 19) we combine the classification of the model types used by MS with the typical model requirements. The table summarizes how models used by MS are dealing with sector specific input or output parameters.

Table 19 Sector specific characteristics of models used by MS for GHG projections of the energy sector

		electricity consumption	existing production capacities	investment in new capacities	load curves	renewable	CHP	CO_2 tax
optimisation	**BE,CZ,DK,EE,FI,IR IT,LV,LT,PL,PT,SL, SW,UK**	user supplied for WOM scenario	detailed representation characteristics (1) of existing technologies	choice from user supplied technologies in function of requirements, based on cost minimisation	determined by cost minimisation	cfr investment decisions. Feed in tariffs, subsidies and penalties introduced in model	cfr. Investment decision heat demand chararteristics (2)	evaluated as additional cost factor
simulation	**BU,CY,DE,NL,GR, RO**	user supplied for WOM scenario	detailed representation characteristics (1)	difficult	historical occupation rates	to be introduced as input	not possible	not possible, requires endogenous investment and load management
econometric	**AT,FR,HU**	model determined from macro-economic indicators	some aggregation level, considering fuel types	difficult	historical occupation rates	to be introduced as input	not possible	requires endogenous investment and load management
engineering	**ES**	user supplied for WOM scenario	detailed representation characteristics (1) of existing technologies	user supplied	historical occupation rates	input variable, policy objective can be used	input variable, policy objective can be used	not possible, engineering models don't rely on economic relationships

Legend Table 19

(1) characteristics of capacities: fuel type, efficiency, availability, lifetime, investment cost, operational cost, emissions of other pollutants (SO_2, NOX, PM); (2) characteristics of heat demand: quantity, temperature, pressure, load curve

- **Evolution of electricity consumption**
  Econometric models have a closed representation of the whole economy and demand of electricity is generated by the model. However, some optimisation models and some simulation models as well are able to evaluate endogenous demand reactions in alternative scenarios. Then demand for electricity can be considered as input in the WOM and output in the WM scenario. It is recommended to be included in the required parameters to be reported by the MS.

- **Representation of existing production capacities**
  All types of models use this information in as input.

- **Endogenous investment**
  This property becomes important the longer the historical period considered in the projections. For projections in the Kyoto commitment period this might be not so important as the process of planning and building new plants may exceed several years and new plants are usually announced some years in advance. But endogenous investment decisions become important when developing scenarios for 15-30 years ahead. As an alternative, one can explore different investment scenarios, but this increases dramatically the workload and still requires some arbitrary decision rules.

  Optimisation models take investment decisions based on rational and sound economic principles in a perfect foresight hypothesis.

  France and Germany are using a particular approach. The France model (Poles) uses a continues mathematical formulation to simulate increasing market shares for the cheapest technologies in 6 operational load categories (730 to 8760 hours per year). In the German model, fixed load factors are assigned for different technologies and a local optimisation is done, taking into account fixed capital costs and future energy prices.

- **Load management**
  Basically two modelling approaches are used. Either load management is fixed, based on historical observations. This approach is used by Germany, and likely as well by econometric models. All optimisation models have endogenous load management based on the principle that technologies with the cheapest operational costs are selected first. Based on available information from the country reports, 4 MS (France, Ireland, The Netherlands, Slovenia) reported to have considered the load management of the power plants in their projections.

- **Renewable energies**
  Basically we can distinguish between two situations. Either the result of a separate analysis is used as input for the model. In this case the model is used to analyse the consequences for the classical power plants. Either the model is used to analyse the opportunities for renewable energies in the electricity sector. This requires that the model is able to make endogenous investment decisions and has endogenous load management. Still renewable energies have their own physical and economical constraints and require a different approach.

  - ***Solar energy***
    Physical constraints and impact on classical power plants are of a minor importance due to limited opportunities for economical reasons. Solar energy is far form competitive unless it is supported by special programs (subsidies, feed-in tariffs, green certificates, fiscal incentives). The model can be used to evaluate the modalities of the program.

  - ***Wind energy***
    The potential for wind at competitive prices is much higher. Complex interactions between physical constraints (geographical , erratic wind and need for backup) and economical constraints (including feed in tariffs, green certificates, EU-ETS) and consequences for classical electricity production can be analysed with optimisation models.

  - ***Biomass co-firing in existing coal plants***
    The effect of co-firing in existing coal plants can be analysed wit different type of models.

  - ***Biomass fired plant***
    This technology competes with classical gas, fuel or coal fired plant. Constraints related to availability and price conditions of biomass requires a separate analysis and can be used as input in optimisation models as well as in some simulation models.

Based on available information from the country reports, 5 MS (Finland, Ireland, The Netherlands, Romania and Sweden) have projected renewable energies in detail. 8 MS have not done so. France has reported partly.

It is difficult to identify how member states have proceeded with renewable energies in the projections. We can identify three options:

- A separate detailed analysis has been done and the results of this analysis have been used in the model for the electricity sector.
- The policy instruments (green certificates..) have been introduced in the model and the renewable energies is an endogenous output of the model.
- The political objectives have been introduced exogenously.

It is recommended that the EC gives clear guidance on this issue.

- **Combined heat and power**
  An analysis of CHP potential requires a detailed analysis of heat demand characteristics in end-use sectors (different categories of required heat demand, temperature, load factors). Then this input, and the financial modalities of CHP policy, can be used in optimisation models to evaluate the potential for CHP and the interaction with the classical plants. Other model types do not offer similar possibilities to analyse CHP.

- **CO_2 tax**
  All models with endogenous load management can be used to analyse the direct effect of a CO_2 tax and models with endogenous investment can be used to analyse the effect on the choice of technologies.

  The effect of ETS on the projections will be discussed in Chapter 4.2.3.3. As most of the models only deal with the local situation, emissions trading is difficult to asses. Only the Poles model (France) has an international dimension. Most MS analyse the effect of emissions trading indirectly, by introducing a CO_2 tax, representing the emissions trading price. Methodologically this approach is correct but uncertainty is related to the CO_2 price.

  Its is recommended to include in the reporting parameters, the emission trading price that was used. A harmonised price or a range would be ideal.

- **Liberalisation of the electricity market**
  The liberalisation of the electricity markets generates different effects. One is that electricity is no longer produced by government regulated companies but by private profit maximising companies. This has particular consequences for the pricing system. Most optimisation models are using marginal cost pricing principles, reflecting profit maximising principles, but this facility is not always used by MS. The ENPEP simulation models is based on average costs pricing principles.

A second aspect is the change in the conditions for international trade in electricity. As models used by MS are only dealing with local aspects, they face some difficulties. Only the Netherlands use a model specifically designed to handle this type of analysis.

It is recommended that MS report their assumptions on import/export of electricity and when assessing the reported assumptions, to get a overall check whether the reported data are consistent (taking into account some extra-EU import/export). Based on the country reports available, 11 MS have reported their (net) import of electricity, 5 have not. The 11 MS that have reported electricity import are Bulgaria, Czech Republic, Finland, France, Greece, Hungary, Italy, the Netherlands, Poland, Slovenia, Sweden. Not reported does not mean they have not used it as similar assumption. The number of reports indicates that electricity import as such is an important parameter in projections established by the MS.

- **Other parameters**
  In the country reports and country visits, other assumptions have been reported. Some MS like Sweden and Romania have given explicit information on their nuclear programs.

4.2.3.3 Integration of PAMs in models

In Table 20 we combine theory and practice of PAMs evaluation by MSs. The first column for each PAM gives an idea on whether relevant parameters to evaluate the PAM are in theory input or output parameters, and the second column indicates whether this PAM is included in the WM scenario according to the information gathered from the country visits. The question is whether a correlation exist between the theoretical ability to use models for PAMs evaluations and the reporting.

In the reporting for **EU-ETS** it seems to be difficult to include it in the projections. For 4 MSs the answer is unclear and 9 MSs even answer that EU-ETS is not included in the projections. Only 12 MS report that EU-ETS is included in the projections. This clearly conflicts with the fact that this PAM has been fully implemented in all member states. It is not clear whether there is consistency in the MS answers and the applied methodology. It might well be that some MS have introduced a tax in the model and consider this as an evaluation of the EU-ETS while other MSs have some doubt about this conclusion.

The picture for **renewable energies** looks different. 14/25 MS report that the renewable energies directive has been included the projections. MS who are using the more appropriate models for evaluating renewable energy, almost all report positively. Only Slovakia (no) and Estonia (partly) report differently. This means that the answers *partly, unclear* and *no* are more frequent when the MS are using other models, not allowing endogenous renewable evaluation.

As mentioned before, the evaluation of **CHP** is quite complex. Optimisation models allow to evaluate the competitiveness of CHP given the boundaries of an energy system an considering the modalities of the local policies to support CHP. But still this requires detailed information on heat demand in end-use sectors, which might be difficult to collect. Other types of models do not allow to make this type of analysis. Out of 25 MS, 12 report that the CHP directive has been included in the projections. For the MS using optimisation models this ratio is 8/14 and for other types of models this ratio is 4/11.

Apparently this raises two questions: "How have these 4 MS proceeded?" and "Why have 6/14 MS not reported yes?"

The 4 MS are France, Netherlands, Slovenia and Spain. France is a particular case as CHP would compete with nuclear power, resulting in an increase of GHG emissions. For the Netherlands, Slovenia and Spain, possible explanations are: have other models been used to analyze CHP? Do the modalities of local CHP policy not require extensive modelling?

From the 6 MS, using optimisation models, five have reported *no* (not included in the projections), namely Czech Republic, Poland, Portugal, Slovakia and United Kingdom. Estonia has only included CHP partly in its projections.

Table 20 Theory and practise of PAMs evaluation by MS

	type of model	EU ETS		RENEW directive		CHP directive	
		theory	*reported*	theory	*reported*	theory	*reported*
Austria	Econometric model	Input	*yes*	Input	*yes*		*partly*
Belgium	Optimisation model	Input	*yes*	Output	*yes*	Output	*yes*
Bulgaria	Simulation model	Input	*no*	Input	*no*		*no*
Cyprus	Simulation model	Input	*no*	Input	*partly*		*no*
Czech Republic	Optimisation model	Input	*yes*	Output	*no*	Output	*no*
Denmark	Optimisation model	Input	*yes*	Output	*yes*	Output	*yes*
Estonia	Optimisation model	Input	*unclear*	Output	*partly*	Output	*partly*
Finland	Optimisation model	Input	*no*	Output	*yes*	Output	*yes*
France	Poles	Output	*yes*	Output	*yes*		*yes*
Germany	Engineering type	Input	*yes*	Input	*partly*	Input	*partly*
Greece	Simulation model	Input	*no*	Input	*no*		*no*
Hungary	Econometric model	Input	*unclear*	Input	*unclear*		*unclear*
Ireland	Optimisation model	Input	*yes*	Output	*yes*	Output	*yes*
Italy	Optimisation model	Input	*yes*	Output	*no*	Output	*yes*
Latvia	Optimisation model	Input	*unclear*	Output	*yes*	Output	*yes*
Lithuania	Optimisation model	Input	*yes*	Output	*yes*	Output	*yes*
Netherlands	Simulation model	?	*yes*	Input	*yes*	Input	*yes*
Poland	Optimisation model	Input	*no*	Output	*no*	Output	*no*
Portugal	Optimisation model	Input	*no*	Output	*yes*	Output	*no*
Romania	Simulation model	Input	*unclear*	Input	*unclear*		*unclear*
Slovakia	Optimisation model	Input	*no*	Output	***no***	Output	*no*
Slovenia		?	*no*	?	*yes*	?	*yes*
Spain	Engineering type	Input	*yes*	Input	*yes*		*yes*
Sweden	Optimisation model	Input	*yes*	Output	*yes*	Output	*yes*
United Kingdom	Optimisation model	Input	*no*	Output	*yes*	Output	*no*

Legend Table 20

EU-ETS theory: Input indicated that a CO_2-price is used as input; Output means the CO_2-price is an output of the model

RENEW directive theory: Input indicates that a% relative to a total or MW installed RENEW are used as input; Output means these parameters are outputs of the model.

CHP directive: Input means the electricity /heat and MW installed CHP are input parameters; Output means these are outputs

4.2.4 Recommendation – best model choice

In Chapter 13, possible approaches (tier methods) are proposed to estimate the GHG emissions projections for the energy sector.

5 Sectoral Analysis – Industry (energy and process emissions)

5.1 Assessment of Member States projections

11 Member States report process emissions disintegrated to the three main industrial branches: mineral, chemical and metal production. Hungary does not report totals but the three subsectors. 7 Member States (Austria, Bulgaria, Cyprus, Germany, Latvia, Portugal and Romania) project emissions for the industrial processes as total without specifying the expected emissions of different industrial branches (see also Table 21).

Apart from mineral, chemical and metal production some Member States forecast emissions for other industrial sectors with national relevance. These include Pulp and paper, food and beverages, tobacco, textile, extractive industries, forest industry, ceramics, glass and magnesite use.

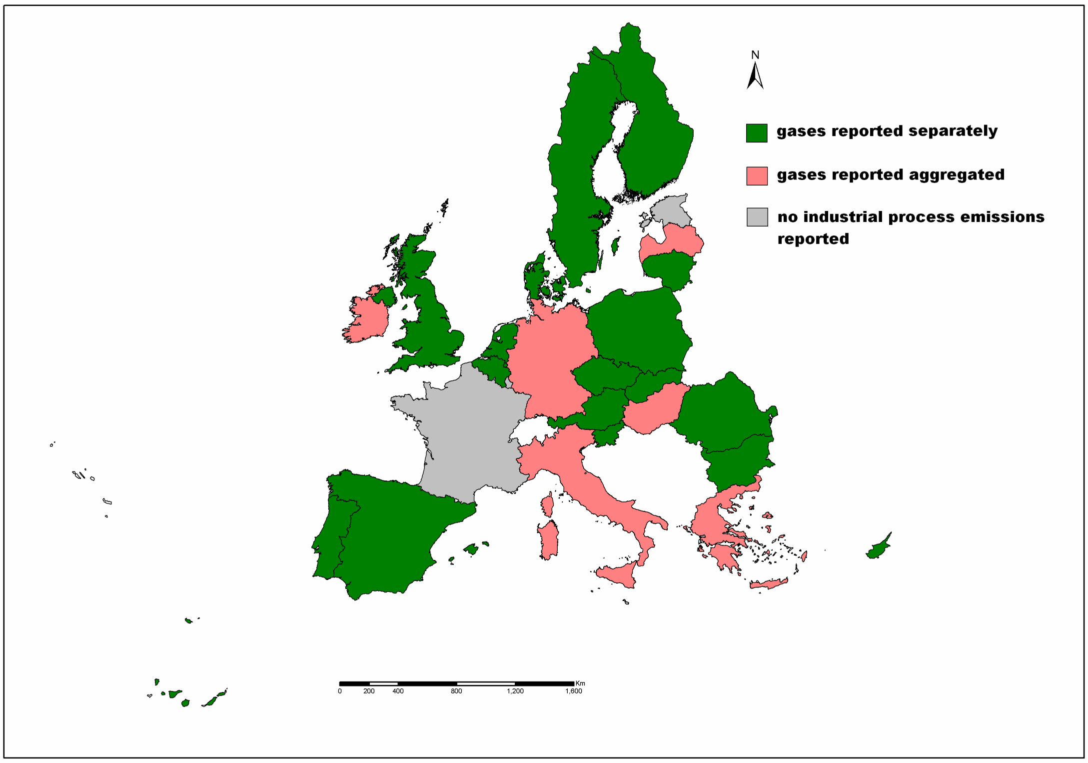
Estonia and France do not provide estimates of process emissions. In the French projections the process emissions seem to be included in the overall total, but no details are given. Luxembourg and Malta do not provide any projections at all; consequently no process emissions either.

Table 21 Projection of process emissions in the industrial sector by Member State

	Total sector industrial processes	Mineral production	Chemical Production	Metal production
Austria	x	NA	NA	NA
Belgium	x	x	x	x
Bulgaria	x	NA	NA	NA
Cyprus	x	NA	NA	NA
Czech Republic	x	x	x	x
Denmark	x	x	x	x
Estonia	NA	NA	NA	NA
Finland	x	x	x	x
France	included in total	NA	NA	NA
Germany	x	NA	NA	NA
Greece	x	x	x	x
Hungary	NA	x	x	x
Ireland	x	x	NA	NA
Italy	x	x	x	x
Latvia	x	NA	NA	NA
Lithuania	x	x	x	NA
Luxembourg	NA	NA	NA	NA
Malta	NA	NA	NA	NA
Netherlands	x	NA	NA	NA
Poland	x	x	x	x
Portugal	x	NA	NA	NA
Romania	x	NA	NA	NA
Slovakia	x	x	NA	x
Slovenia	x	x	x	x
Spain	x	x	x	x
Sweden	x	x	x	x
United Kingdom	x	x	x	x

The reporting of gases separately has significantly improved with the 2007 submissions under the monitoring mechanism decision. Currently 17 countries report CO_2, CH_4 and N_2O emissions from industrial processes separately. 6 countries (Germany, Greece, Hungary, Ireland, Italy and Latvia) report aggregated process emissions in CO_2eq. only (see also Figure 27).

Figure 27 Reporting of GHG emissions from industrial processes



The common and coordinated policies and measures in the industrial sector aim at the reduction of F-gases (Regulation No 842/2006 on F-gases and Directive 2006/40/EC on HFC emissions from air conditioning in motor vehicles).

There are gaps in the reporting of F-gas projections. 8 Member States (Bulgaria, Cyprus, Estonia, Hungary, Lithuania, Luxembourg, Malta and Portugal) do not project F-gas emissions. Six Member States project F-Gases at aggregated level (Czech Republic, Finland, France, Italy, Romania and Sweden). The other Member States report PFC, HFC and SF_6 separately, three of them only cover one or two of these gases (see also Table 22).

Projections of F-gases are often rather simple, assuming constant levels or extrapolating the past trend.

Table 22 Reporting of F-Gases by Member States

	F-Gases aggregated only	PFC	HFC	SF6
Austria		x	x	x
Belgium		x	x	x
Bulgaria				
Cyprus				
Czech Republic	x			
Denmark		x	x	x
Estonia				
Finland	x			
France	x			
Germany		x	x	x
Greece		x	x	
Hungary				
Ireland		x		
Italy	x			
Latvia			x	x
Lithuania				
Luxembourg				
Malta				
Netherlands		x	x	x
Poland		x	x	x
Portugal				
Romania	x			
Slovakia		x	x	x
Slovenia		x	x	x
Spain		x	x	x
Sweden	x			
United Kingdom		x	x	x

5.2 Assessment of Member States models & parameters

5.2.1 Introduction

The industrial sector is not a homogenous sector: it includes energy intensive industry and consumers with less energy intensive activities. Energy use and greenhouse gas emissions are related, but next to these energy-related emissions, other more specific emissions per process also exist. Energy efficiency improvements or potentials are difficult to assess from an outsider point of view.

5.2.2 Model requirements

Regardless the methodology we can define a number of sector specific issues the models should deal with. Taking into account the main objectives of the monitoring mechanism[10] **we believe that a model for the industry preferably should:**

- *Have activities projection at appropriate aggregation level*
  There are options to quantify the level of activity in industry, namely value added and production volume (or output or revenue).

[10] (1) Accurate GHG emission projections (in absolute figures) and possibility to evaluate and (2) correctly account for PAM's

- *Value added* is expressed in euros at constant prices. Value added equals income generated by the sector and it consist of three elements: sum of labour costs, capital depreciation and operating surplus. By definition GDP equals the sum of value added of different sectors. So value added can be used to check consistency with macro-economic growth scenario.
- *Production volume* equals value added + intermediate deliveries (or purchases of goods, energy and services). Production can be expressed in euros at constant prices or in physical quantities (ton steel, cement…). Production volumes can not be aggregated in a meaningful way.

Energy intensive activities are best represented by production volume data. For other industrial activities a more generic and aggregated approach can be used. As production figures can not be aggregated in a meaningful way value added should be used as indicator to verify macro-economic consistency

The modelling requirements for energy intensive industries are described in more detail in Box 2..

- *Estimate autonomous energy-efficiency improvement*
  Even without any policy in place energy-efficiency is improving due to technological changes. New installations tend to be more energy–efficient than older installations. At aggregated level, this creates a more or less continuous process of autonomous energy-efficiency. However, quantifying this parameter is difficult. From historical observations one can derive some estimates. However, these figures include shifts in the basket of processes considered. An increasing share of more energy-intensive processes might results is a seeming deterioration of energy efficiency.

- *Include fuel choice modelling*
  Industrial boilers are often able to burn different types of fuel, allowing them to shift to a particular fuel type for economic or environmental raisons.

- *Include coordination with energy-supply scenario for CHP*
  CHP improves overall energy-efficiency but also creates an accountability problem as greenhouse gas emissions of CHP are accounted, either in electricity sector, either in the end-use sectors.

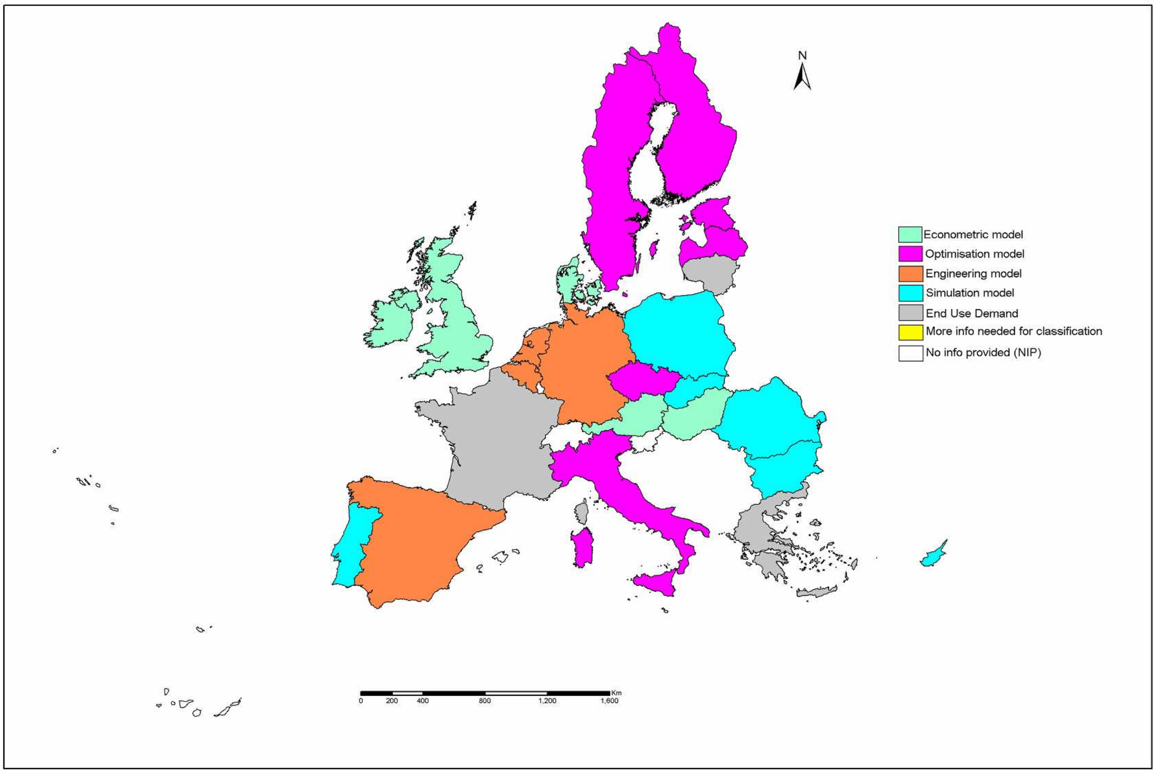
  Besides the evaluation of domestic PAMs, the model should allow to evaluate the EU-ETS and the energy-efficiency-improvement directive (2006/32/EC) for sectors not covered by the EU-ETS. It is difficult to make general statements about this as it depends on the local implementation of the PAMs.

5.2.3 Assessment by Member states

5.2.3.1 Overview of models used

The type of models used by MS looks different from the energy sector. Optimisation models are no longer favourite as they are used by 6 member states compared to 15 for energy supply. Member states using the Message model use end-use-demand or simulation models for the industry. Engineering type of models are used as frequently as optimisation models. Econometric models are now used by 4 member states.

Figure 28 Overview of the models used by MS



5.2.3.2 Sectoral requirements

In Table 23 we indicate how the model types used by member states are dealing with the modelling requirements as discussed in Chapter 5.2.2.

Table 23 Sector specific properties for models used by member states

		aggregation level	activities	macro-economic consistency	autonomous energy efficiency improvement	fuel choice	CHP	CO_2 tax	new technologies
engineering	BE, DE,NL, ES	energy intensive activities isolated	Production level based on external industry scenario or expert judgement	by external industry scenario	expert judgement	fixed	determination of physical potential	no -effect	N.A.
optimisation	CZ,EE,FI,IT,LV	energy intensive activities isolated	Production level based on external industry scenario or expert judgement	by external industry scenario	expert judgement	price dependent	integration in electricity model, physical and economic potential	evaluated as additional cost factor, generating income and substitution effects	model choice from user defined options
simulation	BG, CY,GR, PO,RO,SK	energy intensive activities isolated	Production output based on expert judgement or	by external industry scenario	expert judgement	price dependent	not possible	generating output volume effects	N.A.
econometric	AT, DK, HU, IE UK	mostly based on national account statistics	determined by model	by methodology	trend determined from historical observations	price dependent	not possible	generating output volume effects	N.A.
end use demand	F, LT	energy intensive activities isolated	Activities expressed as shares in value added	by methodology	expert judgement	shares determined by expert judgement	not possible	no -effect	N.A.

Legend Table 23

(1) detailed representation of the very energy intensive activities is recommended; (2) activities can be either expressed as production volume (output) or value added. However, value added of energy intensive activities is relatively small; (3) consistency requires that the value added of the different sector add up to GDP

- **Adequate aggregation level**
  Defining the optimal disintegration level is not independent from the model as some modelling methodologies face limitations from the availability of data.

  Engineering type of models and optimisation models are flexible in this respect. The aggregation level can be chosen free and allow to isolate the most energy intensive activities.

  Econometric models are based on national account statistics and sector input-output tables. Usually they face limitations in defining the most appropriate aggregation levels for GHG emissions projections as it is not possible to separate the most energy intensive activities.

  Models that are using value added as activity variables might face some problems to in particular in chemical industries. The complexity of endothermic and exothermic processes is not reflected in available value added statistics.

- **Defining activity levels**
  Econometric models define industrial activities in terms of value added and/or in terms of production volume endogenously. Other methodologies require expert judgement to define these parameters. Engineering models and optimisation models use activity variables expressed as production volume, frequently expressed in physical terms (tons of steel, ..) or immediately expressed as energy (useful energy demand). In simulation models and end-use demand models, the activities are defined by value added.

When looking at the country reports, some MS indicate the source for activity used in the projections. Some MS indicate that activity data for industry are based on expert judgement or consultations within industry (Finland, Ireland Sweden). Finland also reports that partly data are based on the NAP. Sometimes, the assumptions are given (like "no growth expected"), but the base for that assumption is not always clear. Cyprus and Slovakia both report that industrial growth is based on added values or part of industry in future GDP.

For most MS it is not clear whether they make a distinction between energy-intensive industries and less energy intensive activities.

- **Macro-economic consistency**
  Econometric models are the only one's representing the whole economy and generate consistent WOM, WM or WAM scenarios. Simulation models can be said to be partly consistent. The summation of the sectoral value added figures equals GDP in the WOM scenario. However, simulation models are partial equilibrium models and not allow to quantify the feedback from the economy to PAMs. Therefore the WM scenario is not fully consistent. Engineering models and optimisation models use activity variables based on production volume This approach does not guaranty macro-economic consistency.

- **Autonomous energy efficiency improvement**
  The determination of the autonomous energy efficiency improvement is an important issue in developing GHG scenarios and uncertainty related to this is high.

  In econometric models, some kind of extrapolation from past historical figures will be automatically incorporated in the scenarios. So one can argue that econometric models incorporate autonomous energy efficiency improvement endogenously.

  In optimisation models, end-of-life equipment will be replaced by new equipment witch higher efficiency, resulting in energy efficiency improvement. This as well can be interpreted as autonomous energy efficiency improvement. The practical problem is that one needs detailed information on residual lift time.

  End use demand models and simulation models can handle autonomous energy efficiency as well although the methodology does supply a reference for the determination of the value.

  In the available country files based on the MS reporting and the country visits, the MS that have reported anything on energy efficiency of industry (in total) or by sector are limited. 3 MS have reported data on energy efficiency (Germany, Poland, Portugal), 13 MS have not reported this item. Slovakia does report that an assumption was made of 1% energy efficiency improvement yearly. Energy efficiencies per sector were also provided by Poland and Portugal.

- **Fuel choice based on energy prices**
  Industrial boilers are often able to burn different type of fuel. Some industrial processes can be based on different types of fuels too, including gas, liquid fuels, coal and biomass (for instance cement production). In practice the choice of the fuel depends on the opportunity price of using a particular fuel. This opportunity price includes the CO2 emissions price. Optimisation models are the most suited one's to simulate this behaviour. Simulation models also include some price based fuel choice mechanism. Engineering type of models are not using this type of information.

- **CHP accounting**
  The analysis of CHP itself belongs to the electricity sector. However, if MS using different model types for the electricity sector and for industry, then the industry results should be corrected for growth in industrial CHP installations as these will replace industrial boilers. MS integrating industry and electricity into one optimisation model don't face this problem as the savings in fuels and GHG emissions are accounted for correctly.

5.2.3.3 Integration of PAMs in the models

The appropriate methodology to assess domestic PAMs depends on the (voluntary, regulatory, financial) nature of the PAM. Engineering models are useful for regulatory and voluntary agreements. Financial mechanisms can be assessed by optimisation models or simulation models.

The common coordinated PAMs affecting industry GHG emissions are EU-ETS, CHP directive, the energy efficiency improvement directive and the linking directive. We will not discuss the CHP directive as it has been done in discussion of the energy-supply sector. Besides the common coordinated PAMs, local PAMs have been implemented in different member states. A number of MS have implemented voluntary agreements to reduce industrial N2O emissions by implementing end-of pipe techniques. Other agreements relate to emissions of PFCs, HFCs and SF_6. MS have also implemented measures in direct relation to the EU-ETS. The development of the NAP is often based on local agreements to improve energy efficiency. Other measures intent to improve energy-efficiency and reduce GHG emissions for activities in companies not covered by the EU-ETS. Often these measures overlap with the energy efficiency improvement directive.

Table 24 Theory and practice of PAMs evaluation by member states

	type of model	EU ETS		Energy effciency improvement directive		CDM/JI linking directive	
		theory	reported	theory	reported	theory	reported
Austria	Econometric model	partial	yes		0		no
Belgium	Engineering type		yes		yes		yes
Bulgaria	End use demand		no		0		no
Cyprus	Simulation model	partial	no		0		no
Czech Republic	Optimisation model	CO_2 tax	yes		0		0
Denmark	Econometric model	partial	yes		0		yes
Estonia	Optimisation model	CO_2 tax	unclear		0		yes
Finland	Optimisation model	CO_2 tax	no		0		no
France	End use demand		yes		0		0
Germany	Engineering type		yes		0		no
Greece	Simulation model	partial	no		0		0
Hungary	Econometric model	partial	unclear		0		0
Ireland	Engineering type		yes		0		no
Italy	Optimisation model	CO_2 tax	yes		0		no
Latvia	Optimisation model	CO_2 tax	unclear		0		unclear
Lithuania	End use demand		yes		0		no
Netherlands	Engineering type		yes		0		0
Poland	Simulation model	partial	no		0		0
Portugal			no		0		no
Romania	Simulation model	partial	unclear		0		unclear
Slovakia	Simulation model	partial	no		0		no
Slovenia			no		0		unclear
Spain	Engineering type		yes		0		NA
Sweden	Engineering type		yes		0		0
United Kingdom	Econometric model	partial	no		0		no

Legend Table 24

EU-ETS: CO_2 price is an input; yes means the model type is in theory capable to evaluate the effect of the EU-ETS scheme; no means the model type can not evaluate this PAM

Reported (all PAMs): what MS have reported as included in their projections

- **EU-ETS**
  A first conclusion from Table 24 is that only a few member states use models allowing to evaluate EU-ETS for the industry. In optimisation models, the effect of EU-ETS can be approximated by a CO_2 tax. The EU-ETS trading price is then considered as an opportunity cost. However optimisation models do not provide a methodology to evaluate directly national allocation plans.

MS have not been asked whether EU-ETS was included in the projections for the industry in particular. They have only been asked whether EU-ETS was included in the projections or not. This raises some interpretation problems as MS have often used different models for industry and electricity sector.

Whether the price of emissions rights is a real cost or only an opportunity cost, depending on the allocation system, should have no influence on the energy efficiency policy of companies, neither the choice of fuels, at least not in a theoretical world. This economic theorem is used in optimisation models to simulate the effect of EU-ETS by introducing an emission tax.

This theorem conflicts with the MS reporting in Table 24. Indeed, only Finland, Bulgaria, Greece and Ireland, seem to be in harmony with this theorem, the first one because they have included EU-ETS in the projections and the other ones because they have not.

12 other MS have reported that the EU-ETS is included in the projections, although there models used do not allow to evaluate EU-ETS. As mentioned it might be that the answers relates to the electricity sector. Another reason is that MS have used the NAP allocation plan for the development of the industry projections.

- **Energy Efficiency Directive**
  No information available

- **Linking Directive**
  Evaluating the linking directive in GHG projections is similar to EU-ETS. The inclusion of the linking directive is putting downward pressure on the emissions trading price by offering an alternative.

BOX 2 ***Particular case: Energy Intensive Industry***

One particular aspect of the industry is a high concentration of energy use and GHG emissions in a limited set of industrial installations. These installations produce high volumes and little value added. Changes in activities have little effect on GDP and value added is not a very good indicator of activity as it is strongly influenced by price changes in output products. For instance, a 5% price increase may result in a 20% increase in value added at constant production levels. For these sectors it is better to express activities as production volume, even in physical quantities so to eliminate all price effects. Among these activities (non exhaustive list): blast furnace steel, refineries, ethylene and propylene (crackers), ammonia production, cement and lime, glass, paper and pulp, caprolactam (polyamide production) and nitric acid (N_2O emissions), aluminium and chlorine (electricity consumption)

A three step methodology could be applied:

- develop a projection for the activities of the energy intensive industries
- develop a scenario for the autonomous energy-efficiency improvement
- quantify the effects of the PAMs

However, for the energy-intensive industries each of these steps involves a lot of uncertainties.

Step 1: Activity projections
As discussed before, there is only a very weak relationship between the macro-economic development and the activities of the energy-intensive industries. In terms of value added, the energy-intensive industries may represent only a very few percent of GDP, but the energy-intensity expressed as energy consumption/value added may be 20 to 50 times as high as in the services sector. Also from the demand side, there is little impact from domestic GDP to activities from energy intensive industries as these companies produce for export markets and expansion and investment decisions are mainly driven by profit maximising behaviour of multi-national companies. Consequently – neither an econometric top-down methodology nor a bottom-up methodology may be able to provide accurate activity projections for energy-intensive industries.

Step 2: Autonomous energy efficiency improvements
Extrapolating historical trends of energy efficiency improvements might result in overestimations of future energy efficiency improvements.

Step 3: Quantification of the effects of PAMs
For market based PAMs (like EU-ETS) it seems appropriate to assume profit maximising behaviour. But for model builders/developers and policy makers, the quantification of the effects of market based PAMs remains a difficult issue as it requires both knowledge of the current situation and possible actions in very specific circumstances, and industries are usually scarce in providing accurate information. Even if there exists sufficient knowledge on all technological options available, then the CO_2 market price is still an unknown variable.

The situation in the electricity sector is different. Almost all countries have detailed information on the current situation and future options. Domestic demand for electricity should be closely related to GDP or other macro-economic components. Efficiency improvements of electrical appliances should have only smooth effects on electricity demand. The major source of uncertainty, from a methodological point of view, relates to the possible <u>lack of consistency in import and export of electricity in MS projections</u>.

The EU-ETS has been established to realise cost-effective emission reductions by industry and energy sectors. NAPs are developed at MS level but being approved by the EC. So, GHG emissions from these sectors are beyond control of Member States. At the EU level, there are no guidelines on how to deal with NAPs in GHG scenarios.
Actually MS use inconsistent approaches in there GHG projections for EU-ETS sectors:

- *NAP is used as WM projection for industry*
  This assumption does not imply that the industry GHG emissions will equal the NAP, but it rather means that, due to the existence of the EU_ETS, deviations form the NAP are no longer the responsibility of the MS.
- *A Benchmark methodology*
  In this case an activity projection (either top-down or bottom-up, with all its uncertainties) is combined with a scenario for energy efficiency improvement. This methodology requires ex-

tensive auditing of individual plants. The energy efficiency of the local industry is compared with a 10% world top level. Improvement of energy efficiency is determined on the current gap with the world top level. A methodological weakness is that the energy efficiency of the world-top is still to be determined on a arbitrary basis.

- *A cost minimising approach*

  This methodology requires very good knowledge of the current and possible situations in the local industry. In this case alternative technologies are modelled in a optimisation framework.

Given all uncertainties related to industrial GHG projections and especially due to the existence of the EU-ETS system, a European approach is required for all installations under the EU-ETS. Some elements of this approach are:

- mandatory reporting of underlying assumptions of the production in physical terms (tons of…) for a limited number of energy intensive goods: oxysteel and electro steel, cement, ammonia, ethylene and propylene, refineries crude input, pulp and paper;
- reporting of the underlying assumptions of outside EU exports for the same products;
- mandatory reporting of assumptions related to international trade of electricity.

5.2.4 Recommendation – best model choice

In Chapter 13, different tier methods are proposed to estimate GHG emissions for industry, depending on the information that is available.

5.2.5 Possible data sources

Possible sources of relevant information to get (historical) activity data and information on abatement techniques for the chemical industry:

- Eurostat prodcom statistics:

http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2594,63266845&_dad=portal&_schema=PORTAL

Label	***Description***
24143385	Adipic acid; its salts and esters
24151050	Nitric acid; sulphonitric acids
24145270	6-Hexanelactam (epsilon-caprolactam)

- Production data on fertilizer (Nitric acid is used as a raw material mainly in the manufacture of nitrogenous-based fertiliser.):
  - International Fertilizer Industry Association (http://www.fertilizer.org/ifa/ifadata/search)
  - European Fertilizer Manufacturers Association (http://cms.efma.org/EPUB/easnet.dll/execreq/page?eas:dat_im=000BCE&eas:template_im=000BC2)

- Information on abatement techniques can be found at the EIPPC. This information can be used in order to get an appropriate emission factor: (http://eippcb.jrc.ec.europa.eu/pages/FActivities.htm)

For fugitive emissions, some links to possible sources for (historical) activity data can be found below:

Coal production data:

- Eurostat website
- IEA website and statistics (by topic, coal)
- EIA website: http://www.eia.doe.gov/emeu/international/coalproduction.html See also estimated reserves
- UNECE, info on coal mine methane (http://www.unece.org/energy/se/cmm.html)

Petroleum production

- Eurostat website
- IEA website and statistics (by topic, oil)
- EIA: http://www.eia.doe.gov/emeu/international/oilproduction.html
  See also estimated reserves

Gas production

- Eurostat website
- IEA website and statistics (by topic, natural gas)
- EIA: http://www.eia.doe.gov/emeu/international/gasproduction.html
  See also estimated reserves

6 Sectoral Analysis – Residential and services

6.1 Assessment of Member state projections

There were not sufficient data to perform this analysis.

6.2 Assessment of Member State Models & parameters

6.2.1 Introduction

The residential and service sector contribute to the energy related greenhouse gases due to combustion emissions mainly for heating. Energy consumption for buildings-related services accounts for approximately one third of total EU energy consumption. CO_2 emissions of the building sector account to 13% of total GHG emissions. This figure hides a high reduction potential as emissions from district heating systems, electricity consumption in buildings and alternative uses of biomass are not considered. Approximately 70% of these emissions are residential and the remaining 30% is related to the service sector.

Directive 2002/91/EC on the energy performance of buildings is the common policy most important to these sectors. It foresees minimum standards on energy performance of new buildings and buildings undergoing a major renovation. Member States are responsible for setting the minimum standards. It also foresees systems for energy certification of buildings11, regular inspections on boilers and air conditioning systems.

Another important directive is Directive 2006/32/EC (repealing council directive 93/76/EEC). The purpose is to make the end use of energy more economic and efficient. It introduces amongst others an indicative target for energy savings (excluding activities under the ETS). Member States must adopt and achieve an indicative target for saving energy of 9% by 2015 (calculated in accordance with the method set out in Annex I to the Directive). However, this directive was not considered in most projections assessed in this report, since it only came into force after the projections were made. It may play an important role in the future.

Additionally it is important to be aware of the inherent differences between the MS concerning their building stock and climatic conditions. Innovations in the building stock and new buildings will only have an impact on long term basis.

6.2.2 Modelling requirements

Energy consumption in buildings is determined by three elements, namely people and there expectations, climate and building characteristics. Building characteristics and peo-

[11] There is already a directive on the energy certification of buildings (Directive 93/76/EEC repealed by Directive 2006/23/32/EC), it was adopted in a different political context before the Kyoto agreement and the uncertainties with the security of energy supply in the Union.

ples expectations can be influenced by various sorts of policies, measures or other external influences.

The ideal model should consider these elements and meet the following requirements:

- *be able to make a projection on the evolution of the needs for housing and service* buildings
  An accurate projection requires detailed knowledge of the various parameters that influence the needs for housing and service buildings.

- *be able to explore the reduction potential by various measures*
  MS have to be able to quantify the effect of various measures, implemented in the framework of the end-use efficiency and energy services (Directive 2006/32/EC) and other local policy actions in the residential sector and services building sector.

- *be able to develop and evaluate long term scenarios*
  Lifetime of buildings exceeds largely lifetime of industrial or transport equipment. Consequently, decisions taken today have consequences for many decades. Cost effective emission reductions can be realised in the building sector within the first commitment period of the Kyoto protocol but the real reduction potential is spread over decades.

Policy makers are confronted with different policy objectives for energy use in residential and commercial buildings:

- 15% energy efficiency improvement in 2015 by EU directive on end use energy efficiency
- Proposal EU-objectives on climate change and renewable energy for 2020.
- 30% to 50% reduction by 2050 needed according to IPCC

Therefore models should support policy makers by developing and evaluating various policy scenarios. One particular question for policy makers is to find a balance between short term realisations and actions that result only in the long term. This issue should be addressed by the model too.

- *be able to evaluate the basic aspects of sustainable development in scenarios*
  The realisation of environmental objectives requires a mix of different policy actions, some of them focusing on long term objectives and others on short term objectives. Anyhow, there is a very long way to go and more as in other sectors, the realisation of environmental objectives involves millions of people for many decades. Therefore, the pathway to sustainability should be based on the principles of sustainability too and besides ecological targets, economical and social aspects should be considered.

- *be able to account for rebound effects*
  In the residential sector we consider rebound effects related to behaviour changes and non-voluntary rebound effects. An example of the first category is that people

change the thermostat to increase inside temperature after implementation of insulation measures. This type of rebound effects can be considered as price reaction.

The second category is only related to the physical properties of buildings. Insulating the roof or walls of a house will also increase the temperature in rooms with a lower temperature demand.

- *be able to account for climate differences and climate fluctuations*
  Among European MS the number of degree days varies between 500 (Cyprus) and 5500 (Finland), but the Mediterranean MS have increasing electricity consumption for cooling purposes.

  Besides important differences between MS, the model should be able to quantify the effect of long term climate changes as well as short term fluctuations.

- *be able to quantify the effect of changing energy prices.*
  Increasing fuel prices might result in a decrease of fuel consumption by increasing the use of residential wood fires, lowering inside temperature or increasing insulation.

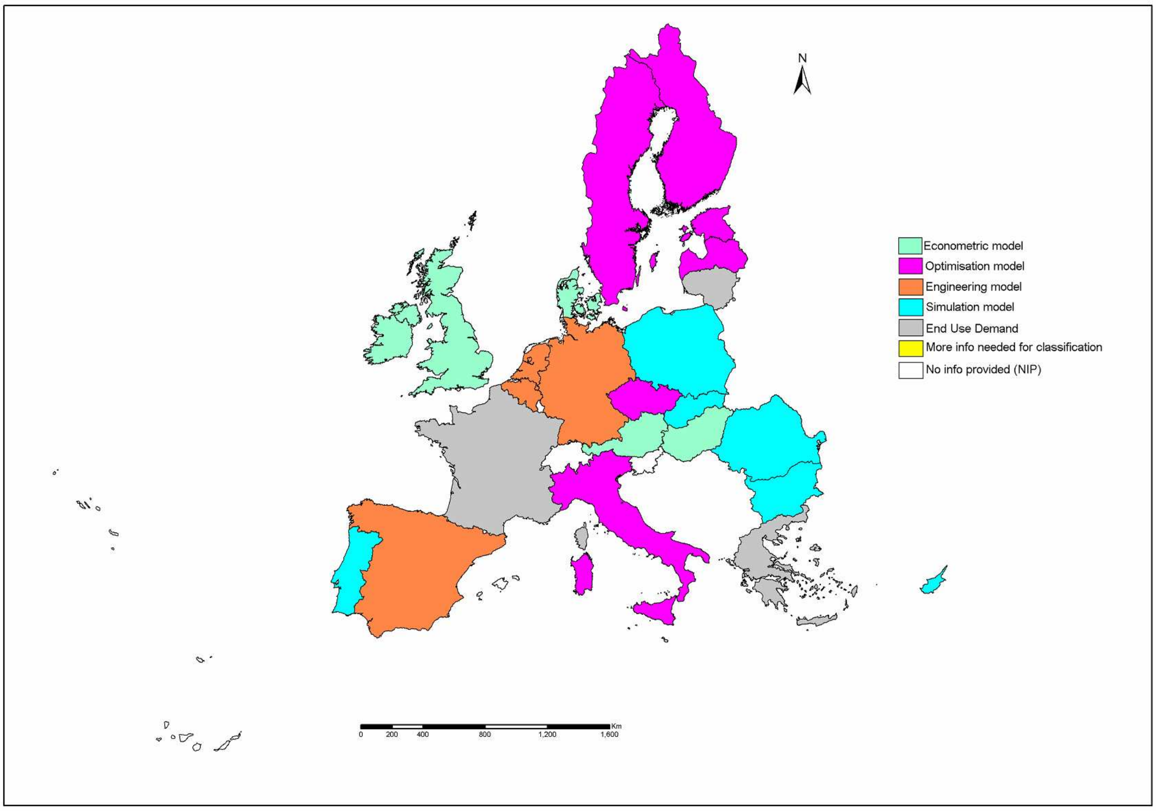
6.2.3 Assessment of Member States

6.2.3.1 Overview of the models used

The variety of model types used in the MS, is diverse.

- MS use simulation type of models (Bulgaria, Cyprus, Poland, Portugal, Romania, Slovakia); All use 1 or more modules of the ENPEP model.
- 6 MS use optimisation models (Czech Republic, Estonia, Finland, Latvia, Sweden); the Czech republic uses the EFOM/ENV model, Estonia, Italy, Latvia and Sweden use the MARKAL model; Finland uses the Times/EV model.
- 3 MS use an end use type of model (France, Greece, Lithuania)
- 5 MS use an econometric model (Austria, Hungary, Denmark, UK, Ireland); Austria uses the Prometeus model, Ireland uses Hermes, Denmark uses the ADAM/EMMA model. Hungary and the UK also use their own econometric models.
- 4 MS use an engineering type of model (Belgium, Germany, the Netherlands, Spain). The model of the Netherlands is described as the Athena/SAVE model.

Figure 29 Overview of models used by MS for residential and service sector.



6.2.3.2 Sector requirements

Table 25 Sector specific characteristics of models used by MS for GHG projections of the residential and service sector (- not possible; 0 neutral; + possible; ++ very well suited)

		evolution of needs for housing and services building	ability to quantify measures	ability to develop and evaluate long term scenario's	accounting for unvoluntary rebound effects	accounting for voluntary rebound effects	quantify effect of energy prices	accounting for climate fluctuations
engineering	BE, DE, NL, ES	input	++	+	+	-		+
optimisation	CZ,EE,FI,IT,LV,SE	input	+	+	+	+	price effect	+
simulation	BG, CY,PO,PT,RO,SK	output	-	-	-	+	price effect	+
end-use demand	FR,GR,LT	input	-	-	-	-		+
econometric	AT, HU,DK, UK, IE	output	-	-	-	+	price and income effects	++

- **Evolution of the needs for housing and service buildings**
  Demand for housing and services building is modelled endogenous as a function of demographic and macro-economic parameters in econometric models, end use demand models and simulation models, (top-down approach).

  This type of information should be supplied to the model-user when using engineering models or optimisation models.

- **Ability to quantify measures**
  Engineering models start from the characteristics of different type of buildings (the resolution is often very detailed) and data on climate conditions to calculate the energy consumption for space heating, cooling, hot water production and electrical appliances bottom-up wise and use some calibration method to fit the global result with observed data from national energy balances. The level of detail might be very high. The following characteristics are often considered: type of dwelling (apartment, houses with 2, 3 or 4 outer walls), floor space, insulation of walls, windows, roof, floor, efficiency of heating system and fuel type, age). The main advantage of such a detailed representation is that it allows to identify and quantify opportunities for improvement.

  Optimisation models have a similar bottom-up approach, although the resolution might have been reduced for practical reasons. Optimisation models also represent various alternative technological options for saving energy in existing buildings and alternative characteristics for new dwellings. Alternative technological options are represented by their ability to save energy as well and the costs of implementation.

  Unlike engineering models and optimisation models, the other model types do not include a detailed representation of the housing stock. They simulate energy use in residential sector starting from historical observations. Quantifying effects of measures is often done outside the model, using other tools and data.

- **Ability to evaluate long term scenarios**
  A typical horizon for econometric models is 10-15 years. A similar remark holds for end-use demand models and simulation models. These type of models are not able to capture structural changes taking place over longer simulation periods.

  Bottom-up type models are better suited to develop scenarios that exceeding several decades and evaluate and quantify intermediate and final objectives.

- **Accounting for rebound and overlapping effects**
  The un-voluntary rebound effect is a pure technical issue and can be solved in bottom-up models by adapting the savings attributed to different measures.

  Human related rebound effects can be simulated by introducing a price elasticity. So theoretically this can be considered in all methodologies using price elasticity. In practice there will be a problem as the model should have sufficient detail to quantify the appropriate price change.

- **Accounting for climate fluctuations**
  Climate fluctuations are expressed by changes in heating and cooling degree days and accounting for climate changes can be introduced in any methodology. As historical data on degree days and fuel use for space heating are available, econometric estimation can be used to quantify this effect.

- **Quantify effect of changing energy prices**
  Changing energy prices generate price and income effects. Econometric models have a full representation of the economic structure and are able to analyse price and income effects. Price elasticity can also be introduced in simulation models and optimisation models. Engineering models and end-use energy models do not consider price effects and are not useful to quantify effect of changing prices.

- **Support in developing sustainable policies**
  Obviously all models are dealing with environmental effects but non of the models mentioned is dealing with three dimensions of sustainable development namely, ecology, economy and a social dimension. Optimisation models are dealing with the economic aspects as they can be used to explore cost efficient strategies.

6.2.3.3 Integration of PAM's in the models

To evaluate the effect of Directive 2002/91/EC on the energy performance of buildings, it is necessary to have an appropriate representation of the building stock. This is best done by using a engineering type of model or optimization type of model. Most of the simulation models, currently in use by MS, don't have a detailed representation of the building stock, and are not really suited to evaluate different possible measures.

Detailed representation is not present in econometric models. However, the UK, Ireland, Denmark and Austria state they have included the energy performance directive in some way. It is not clear how and based on what input this was done. MS using an end use type of model, do not have an appropriate level of detail needed to evaluate this PAM. However, France, Greece, Lithuania claim to have included the effect of the regulation into their projections.

Table 26 Theory and practice of PAMs evaluation by member states

	type of model	E performance of buildings	
		theory	*reported*
Austria	Econometric model		**partly**
Belgium	Engineering type	input	yes
Bulgaria	Simulation model	input	no
Cyprus	Simulation model	input	yes
Czech Republic	Optimisation model	input	yes
Denmark	Econometric model		**yes**
Estonia	Optimisation model	input	no
Finland	Optimisation model	input	no
France	End use demand		**yes**
Germany	Engineering type	input	unclear
Greece	End use demand		**yes**
Hungary	Econometric model		no
Ireland	Econometric model		**yes**
Italy	End use demand		**partly**
Latvia	Optimisation model	input	yes
Lithuania	End use demand		**yes**
Netherlands	Engineering type	input	yes
Poland	Simulation model	input	no
Portugal	Simulation model	input	yes
Romania	Simulation model	input	unclear
Slovakia	Simulation model	input	no
Slovenia			yes
Spain	Engineering type	input	yes
Sweden	Optimisation model	input	yes
United Kingdom	Econometric model		**yes**

6.2.4 Recommendation - best model choice

In Chapter 13 different tier methods are proposed to estimate GHG emissions for the residential and service sector, depending on the information that is available.

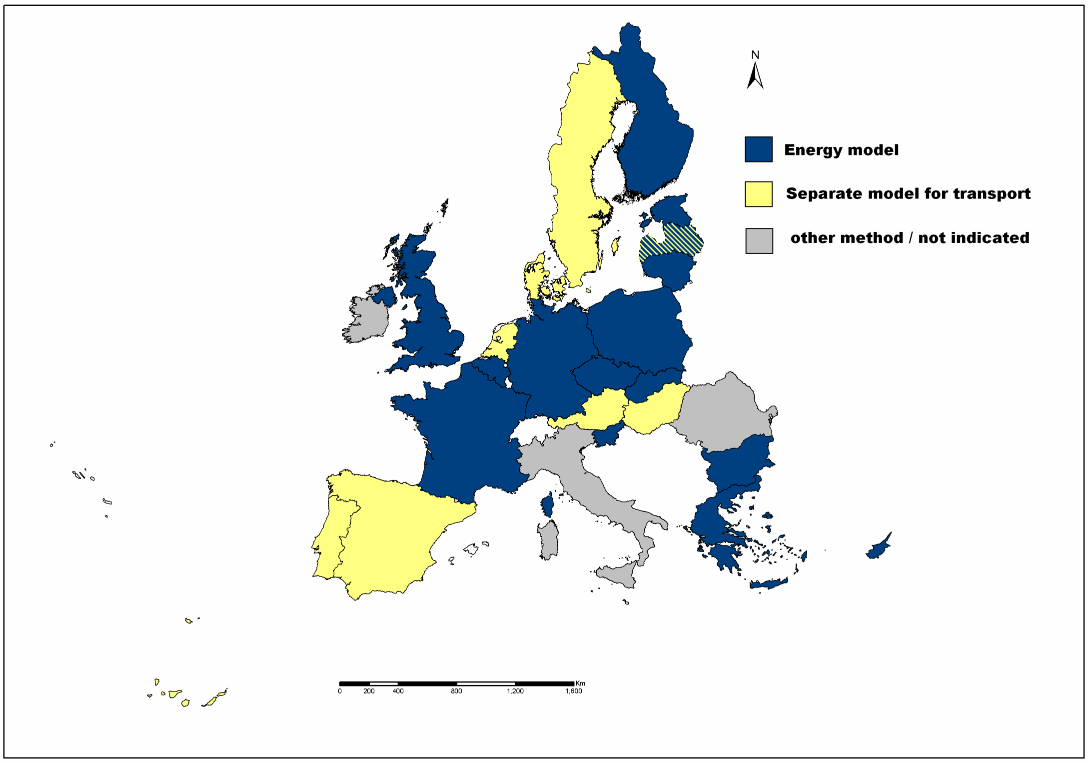
7 Sectoral Analysis – Transport

7.1 Assessment of Member States projections

Emissions in the transport sector are projected by Member States either using the energy model (15 MS) or running a separate transport models (8 MS) (see also Figure 30). Latvia uses a combination: the transport model COPERT III is run to estimate emissions from road transport whereas other means of transport are covered by the fuel consumption forecasted by the energy model MARKAL.

12 Member States indicated that all modes of transport (road, rail, aviation and ship-ping) are covered. For some other Member States it is unclear if all transport modes are covered. Especially in the transport sector more background data would be very valuable.

Figure 30 Model types used for transport projections



Two of the most important common and coordinated policies and measures (CCPM) with significant impact on the projected emissions from transport are the voluntary agreement with car manufacturers to reduce specific CO_2 emissions (ACEA agreement) and Directive 2003/30/EC on the promotion of the use of biofuels of other renewable fuels for transport (biofuels directive). 14 Member States state that the ACEA agreement was taken into account when projecting future emissions in the transport sector and 15 Member States include the Biofuels Directive (see also Table 27). Finland includes the implementation of the Biofuels Directive in their 'with additional measures' projection.

Table 27 CCPM in the transport sector included in national WM projection

	ACEA agreement	Biofuels Directive
Austria	x	x
Belgium	x	x
Bulgaria		
Cyprus	x	
Czech Republic		x
Denmark	x	x
Estonia		
Finland	x	
France	x	x
Germany	x	
Greece	x	x
Hungary		
Ireland	x	x
Italy	x	x
Latvia		x
Lithuania		
Luxembourg		
Malta		
Netherlands		x
Poland		x
Portugal	x	x
Romania		
Slovakia		
Slovenia		
Spain	x	x
Sweden	x	x
United Kingdom	x	x

7.2 Assessment of Member States models & parameters

7.2.1 Introduction

Transport is the fastest growing source of GHG emission in Europe and abroad, in particular road transport. Transport involves severe environmental aspects, not only for GHG emissions but also for other pollutants (NO_x, PM) and involves external effects.

Transport involves a complex relation with the economy and does not fit well into the classical macro-economic thinking. Cars are used for professional reasons – and should be considered as production factor, thus generating income, but they are used for private raisons as well, thus consuming income. Freight transport is one of the most productive services, not only producing value added, but it is crucial element of trade which is the basics of the economic system (not all transport is related to the local economy). Duties and value added taxes generate government revenues but transport infrastructure is a cost factor.

European research projects have resulted in complex tools to analyse different aspects of transport. They have resulted in very detailed network models (SCENES and TRANS-TOOLS project), and tools to analyse externalities, welfare aspects and policy instruments (TREMOVE).

7.2.2 Modelling requirements

The time horizon for projections determines the complexity of the projections methodology in the transport sector. If the time horizon is limited to 5-8 years, then a simplified approach, based on few assumptions on mobility, fuel choices and characteristics of new transport equipment can be used. However, when extending the projections horizon up to 15-30 years, then an appropriate methodology becomes more complex. Then a traditional way to develop a GHG emissions scenario starts with a global *mobility scenario*, expressing the changes in mobility related to economic growth and demographic changes. The second step is to split the mobility scenario into different *transportation models*. From that level the requirements for transport equipment are derived. The final step allocates the mobility on the *transport equipment* and calculates *fuel consumption and GHG emissions*.

- *Mobility scenario*
  The development of a mobility scenario requires an understanding of the driving forces. Revenue has been the most important driving force in the past for persons transport, but will this continue in the future or should we expect saturation effects? Population is also a driving force, but what about aging of population on mobility demand? How does infrastructure relates to mobility demand? What about fuel prices and fiscal measures? Freight transport is closely linked to the economy as well as to neighbouring economies.

- *Modal shift scenario*
  The choice for and the interactions between different transport modes is a second issue. Different elements determine the choice of a transport mode: availability of alternatives, habits, capacity constraints, … The modelling of modal shift is a rather complex issue including generalised cost concepts and calibration techniques to count for subjective appreciation.

- *Transport equipment – technology representation*
  The current status of the transport equipment is very well known but the longer the projection period the more fundamental the questions to be answered. What are the characteristics of new transport equipment? What about penetration of new technologies? The assumptions on the evolution of the car stock are an essential element in emission projections. The choice for smaller or bigger cars, the fuel choice and the penetration of new technologies have significant impacts on emissions. Member states have implemented fiscal policies aiming at the promotion of cars with lower CO_2 emissions. The evaluation of this type of measures requires models where the choice on what new cars will be chosen is endogenously to the model.

- *Economic feedbacks-price mechanism*
  A lot of the domestic PAMs are tax related. So important a model is able to evaluate price (or tax effects).

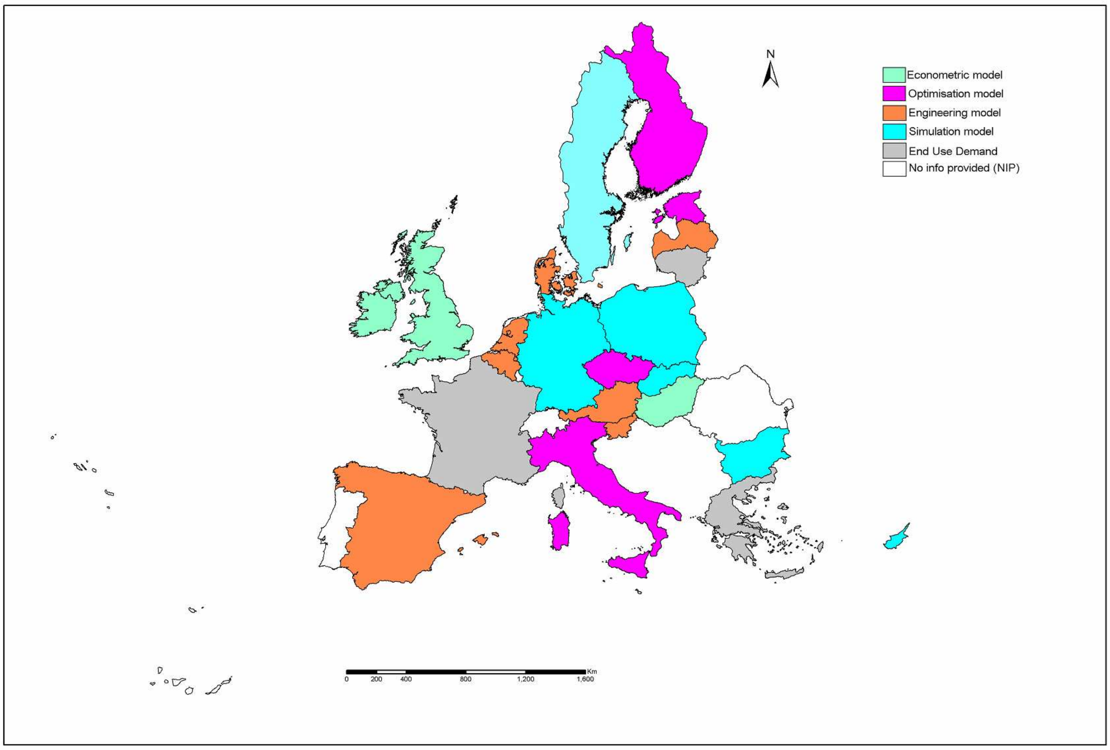
7.2.3 Assessment of member states

7.2.3.1 Overview of the models used

The variety of model types used in the MS, is diverse.

- 6 MS use simulation type of models (Bulgaria, Cyprus, Poland, Slovakia, Germany, Sweden); Within the family of simulation models we have to consider two sub categories. Germany and Sweden use state of the art simulation models with a high spatial, temporal and technological resolution. The other simulation models use a generic approach which is not particular for the transport sector.
- 4 MS use optimisation models (Czech Republic, Estonia, Finland, Italy);
- 3 MS use an end use type of model (France, Greece, Lithuania)
- 3 MS use an econometric model (Hungary, UK, Ireland);
- MS use an engineering type of model (Austria, Slovenia, Latvia, Denmark, Belgium, the Netherlands, Spain).

Figure 31 Overview of the models used by MS



7.2.3.2 Sectoral requirements

Table 28 summarizes how models used by MS are dealing with sector specific modelling requirements.

Table 28 Sector specific characteristics of models used by MS for GHG projections of the transport sector

		mobility	modal shift	techno-logical resolution	lifetime equipment	fuel / technology choice	efficiency improvement	empirical verification	flexibility in model structure	economic feedbacks / price mechanism
engineering	AT, BE, NL, LV, SI, ES, DK	model input expert judgement	model input expert judgement	fuel, size, age (yearly)	survival rates	fixed or expert judgement	embedded in new technology characteristics	not considered	low	not considered
optimisation	CZ, EE, FI, IT	model input expert judgement	model input expert judgement	fuel, size, age (5-yearly)	fixed average lifetime	lowest cost kilometrage cat. (flip-flap)	embedded in new technology characteristics	not considered	low	price effects
simulation	BG, CY, PL, SK	model input expert judgement	model input expert judgement	fuel	not considered	price mechanism	expert judgement	expert judgement, literature values	low	price effects
end-use demand	F, GR, LT	macro-economic drivers	model input expert judgement	fuel	not considered	expert judgement	expert judgement	expert judgement, literature values	low	not considered
econometric	HU, UK, IE	macro-economic drivers	driven by economic parameters	fuel, age	fixed average lifetime	price driven, continuous specification	extrapolation of historical trend	statistical tests using historical or cross section data	high	price effects, income effects, government revenues
advanced transport simulation models	DE, SE	macro-economic drivers	driven by economic parameters	fuel, age, size	survival rates	price driven, continuous specification	embedded in new technology characteristics	expert judgement, statistical testing	high	price effects, government revenues

- **Mobility scenario**
  The complex relationship with economy, makes it difficult to get sound mobility scenarios. For the objective of the MM to get accurate projections, it is however important, to have a mobility scenario that is neither to high or to low. Member states have often used mobility scenarios produced by any other government service (ministry of transport for instance).

  Econometric models consider a two directional relationship between transport and economy. They can be used to evaluate aspects that involve feedbacks from the economy.

  End-use demand models use macro-economic indicators to produce mobility scenarios, but can not be used to evaluate any type of macro-economic feedback from transport policies and do not consider any price effects.

  Simulation and optimisation models use exogenous provided mobility scenarios.
  The models used by Germany and Sweden are however closely linked to macro-economic modules that ensure macro-economic consistency of these scenarios used.

  Also MS using a simulation model like ENPEP are implicitly based on an exogenous mobility scenario. However, it is not always clear in the reports from the countries how the mobility scenarios were created.

  Engineering type of models are not based on economic relations.

- **Modal shift**
  Modal shift is not adequately represented in most of the models used by MS. The models used by Germany and Sweden focus on this issue. Econometric models use behavioural equations and can be used too. Engineering type of models and end-use demand models do not consider modal shift.

- **Transport equipment - Technology representation**
  Engineering type of models are often based on a very detailed representation of transport equipment. The car stock is represented by vintage, mileages, fuel types, power classes and European emission standards. Scrapping of old equipment is based on survival functions and characteristics of new cars or based on European emissions standards. The methodology for emission projections is almost identical to the emissions inventory for other pollutants. New transport equipment is considered exogenous in engineering type models. This means that the choice on what new equipment (what fuel choice) will be used in the future is decided outside the model. This improves the facilities to evaluate the ACEA agreement, but limits the possibility to evaluate/calculate the impact of fiscal measures.

  Econometric models usually don't use a high resolution, but this is not intrinsic to the methodology. In practice some aggregation level is required to allow statistical justification of parameters in behavioural equations. But the simulation technique allows for a high level of detail.

  Usually the technological resolution is not very high in optimisation models as well, although in principle it could be extended.

  Simulation model usually have not a very detailed technological representation. However, the examples of Germany and Sweden show it can be included.

  End use demand models don't use a vintage representation of transport technologies. This is a particular problem in evaluating the effect of the ACEA agreement.

  Optimisation models have endogenous investment but they assume 100% rational behaviour which is often considered too simple for the transport sector.

7.2.3.3 Integration of PAMs in the model

The *ACEA agreement* is not a real CCPM but it should be considered in the emission projections for member states anyhow. The realisation of the ACEA agreement is supported by domestic fiscal measures. The ACEA agreement can be assessed using models with endogenous or exogenous new transport equipment functions and preferably with a high technological resolution. 14 member states have reported that the ACEA was included in the projections. 6/14 are not using the most adequate tools to quantify the ACEA effect.

MS can evaluate the *bio-fuels directive* in two ways. Either they translate the political objectives in the projections directly. This approach does not require sophisticated models. A more detailed analysis would focus on the supply side of bio-fuels, production of crops, refining capacities for bio-fuels etc. We are unaware of this type of analysis by member states.

Table 29 Theory and practice of PAMs evaluation by member states

	type of model	ACEA agreement		Biofuels directive	
		theory	***reported***	**theory**	***reported***
Austria	Engineering type	I	yes		yes
Belgium	Engineering type	I	yes		yes
Bulgaria	Simulation model				
Cyprus	Simulation model		yes		
Czech Republic	Optimisation model	I			yes
Denmark	Econometric model	?	yes		yes
Estonia	Optimisation model	I			
Finland	Optimisation model	I	yes		
France	End use demand		yes		yes
Germany	Astra	I	yes		
Greece	End use demand		yes		yes
Hungary	Econometric model	?			
Ireland	Engineering type	I	yes		yes
Italy	Engineering type	I	yes		yes
Latvia	Engineering type	I			yes
Lithuania	End use demand				
Netherlands	Engineering type	I			yes
Poland	Simulation model				yes
Portugal			yes		
Romania					
Slovakia	Simulation model				
Slovenia	Engineering type	I			
Spain	Engineering type	I	yes		yes
Sweden	Sampers Samgods	I	yes		yes
United Kingdom	Econometric model	?	yes		yes

7.2.4 Recommendation – best model choice

In Chapter 13, possible approaches (tier methods) are proposed to estimate the GHG emissions projections for the transport sector.

8 Sectoral Analysis – Agriculture

8.1 Assessment of Member States projections

Apart from Luxembourg and Malta only two Member States (Germany and Latvia) do not report emissions from agriculture (see also Table 30). Six countries report agricultural emissions as totals only and do not specify the sub sectors (Cyprus, Netherlands, Portugal, Romania, Spain and Sweden). The other Member States all cover the categories enteric fermentation, manure management and – with exception of Bulgaria – Emissions from soils. Only few Member States project emissions from fields burning of agricultural residues (Hungary, Italy and Poland). Rice cultivation does play a significant role neither in the inventories nor in the projections; Italy is the only Member State which projects emissions from rice cultivation.

Most Member States report also the projected activity data for dairy and non-dairy cattle, swine, sheep and poultry. Other animals reported include goats, horses, mules, asses, fallow deer, buffalos and rabbits. Many Member States report additionally the projected fertilizer consumption. Only few present management systems, manure application and the organic cultivation of soils.

Italy is the only Member State reporting the gases aggregated, all other Member States provide N_2O and CH_4 emissions separately.

Table 30 Coverage of subcategories and gases in the agricultural sector

	Enteric fermentation	Manure management	Rice cultivation	Emissions from soils	Fields burning of agricultural residues	Gases reported separately
Austria	x	x		x		Yes
Belgium	x	x		x		Yes
Bulgaria	x	x				Yes
Cyprus	only totals for BAU scenario provided					Yes
Czech Republic	x	x		x		Yes
Denmark	x	x		x		Yes
Estonia	x	x		x		Yes
Finland	x	x		x		Yes
France	x	x		x		Yes
Germany	NA	NA	NA	NA	NA	No
Greece	x	x		x		Yes
Hungary	x	x		x	x	Yes
Ireland	x	x		x		Yes
Italy	x	x	x	x	x	No
Latvia	NA	NA	NA	NA	NA	No
Lithuania	x	x		x		Yes
Luxembourg	NA	NA	NA	NA	NA	No
Malta	NA	NA	NA	NA	NA	No
Netherlands	only totals provided					Yes
Poland	x	x		x	x	Yes
Portugal	only totals provided					Yes
Romania	only totals provided					Yes
Slovakia	x	x		x		Yes
Slovenia	x	x		x		Yes
Spain	only totals provided					Yes
Sweden	only totals provided					Yes
United Kingdom	x	x		x		Yes

In the agricultural sector there are major differences in the projections method. 7 Member States use a separate model to project the GHG emissions from agriculture. These models can be very detailed and include feedbacks with global agricultural markets and the implementation of the CAP reform in all EU Member States. 8 Member States use projected activity data such as animal numbers and fertilizer consumption provided by national authorities (mostly the ministries of agriculture) to project emissions. For a number of Member States the origin of the projections and/or the activity data is not clear.

Agriculture is the sector with largest methodological gap related to GHG projections. More exchange of experiences with regard to methodologies for GHG projections from agriculture would be very valuable.

8.2 Assessment of Member States models & parameters

8.2.1 Introduction

The agricultural sector contributes significantly to the emission of N_2O and CH_4 of the different MS. The most important sources distinguished at this moment are enteric fermentation (CH_4), manure management (CH_4 and N_2O) and agricultural soils (N_2O). All these sources are from microbiological origin. Emissions related to combustion (horticulture, off road transport…) are, according to the IPCC methodology (IPCC, 1996), considered as part of the energy sector.

Agricultural policy - and the related GHG emissions - are largely determined by the EU through its Common Agricultural Policy (CAP). Changes in arable area, livestock and fertilizer application rate will affect total GHG emissions. According to the communication to the UNFCCC (2006) there is:

- a continuous decrease in agricultural land use area within the EU-25;
- a change in composition and/or number of livestock (decrease of cattle and increase of pigs and poultry within the EU-15);
- a decline in the intensity of fertilizer consumption.

Additionally it is important to be aware of the inherent differences between the MS concerning the most important animal types, the composition of the agricultural area (cropland/grassland), manure management, climatic conditions etc.

8.2.2 Model requirements

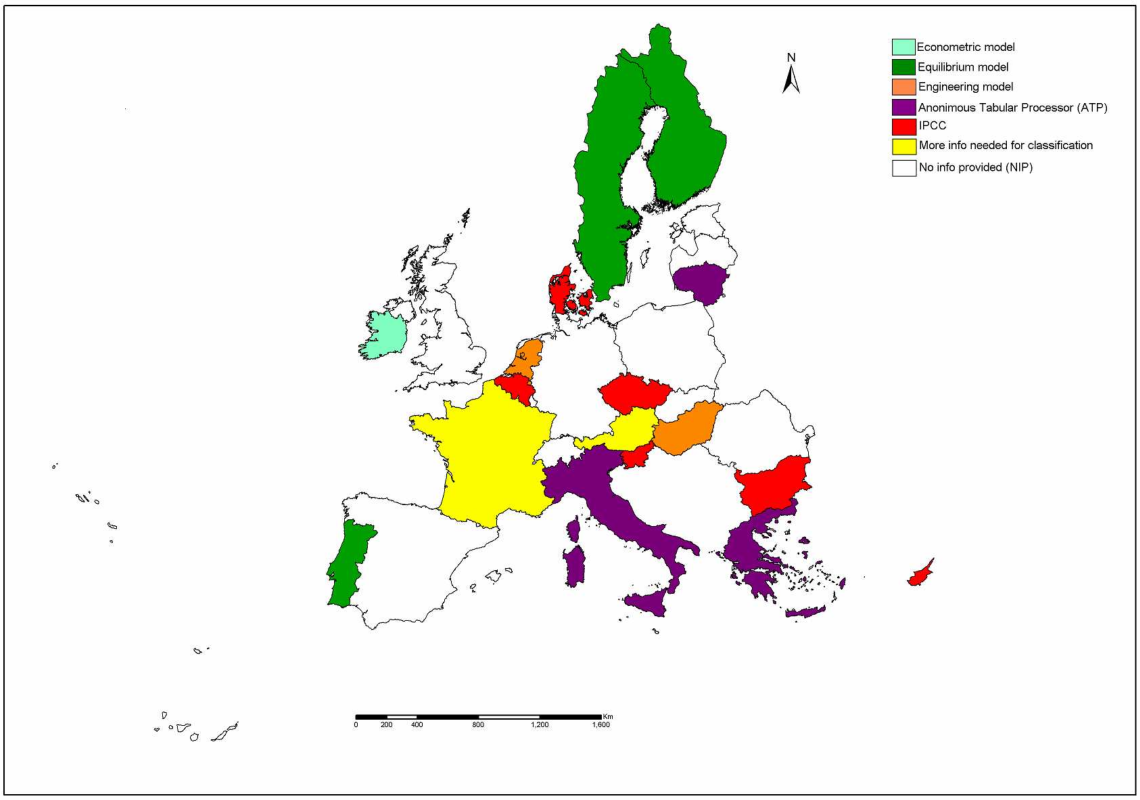
Considering the main objectives of the monitoring mechanism an ideal projection system for the agricultural sector should:

- take the inherent differences (cropland/grassland, animal types,…) between the MS into account
- be able to take changes (amount of cows,…) at MS level into account
- be able to assess the impact of European legislation
- be able to take global changes in trade into account

8.2.3 Assessment of Member States

8.2.3.1 Overview of the models used

Figure 32 Overview of models used by MS



Most MS use a simple approach based on the use of the layout of the revised 1996 IPCC guidelines to make projections for the GHG emissions. The common calculation is straightforward. GHG emission projections are based on the multiplication of an activity level (number of animals, area of crops) with an emission factor (EF). Projections of activity levels are taken from trends of former evolutions, experts views or are based on results from models. Emission factors can be (IPCC) default values (tier 1) or regionally adapted values (tier 2).

Some MS do use more complex models. Models used for activity level projections are generally partial equilibrium models. Next to differences in model characteristics (recursively dynamic, comparatively static, positive mathematical programming or not,…) a main difference is the area considered.

Some focus on one country (*Finland*: Dremfia; *Austria*: PASMA) while others were developed for larger areas (CAPSIM; CAPRI; FAPRI-EU GOLD). CAPSIM and CAPRI used respectively in *Portugal* and *Sweden*, are European models. The former model simulates at MS level (EU-15; link to the IDARA model for the other countries); the latter model (supply module for EU-27 + Norway) can even be broken down up to NUTS2 level. Just as the CAPRI model, the FAPRI model is a world scale agricultural trade model. However, its origin is American. The FAPRI-EU GOLD model, used in *Ireland* is an off-shoot of the FAPRI model which disaggregates the EU in a few (5) distinguished countries and the rest of Europe (Rehman, 2006).

8.2.3.2 Sectoral Requirements

Differences between MS and changes of activity data
The correct projected activity data are essential for the projections when using a simple excel type model, since they are the only input data. When looking at the country reports, some MS report their assumptions on activity data like animal numbers (16 MS) and fertilizer consumption (14 MS). When using a simple excel sheet type of model, activity data are usually obtained from agricultural ministries or agricultural agencies related to agriculture.

For top-down models, animal numbers and other ‘physical’ projected activity data are output data resulting from ‘economical’ inputs and historical activity data. An example is the reporting of ‘production per head’ data: 4 MS have explicitly reported these data. The MS are Austria, Portugal, Ireland and Denmark. 3 out of 4 use a top-down type of model.

- **European legislation**
  IPCC type of models do not use assumptions on exact measures or relates to the effects of CAP reform.

- **Global changes in trade**
  Only top-down type of models can take into account in a proper way the global changes in trade that occur on the agricultural market.

8.2.3.3 Integration of PAMs in the models

There is no specific ECCPM for the agricultural sector.

8.2.4 Recommendation – best model choice

In Chapter 13, possible approaches (tier methods) to estimate GHG projections for the agricultural sector are proposed.

9 Sectoral Analysis – Forestry

9.1 Assessment of Member States projections

Member States should use the national inventory methodology, based on the source categories of the UNFCCC common reporting format to make projections for GHG emissions. Transparency and harmonization are among the key reporting issues in the forestry sector and the Good Practice Guidance for LULUCF (IPCC 2003) must be followed when preparing emission information for the LULUCF sector.

Despite the fact that most Member States deliver their data to the Commission, for the time being there exists no unique methodology within the EU27 to estimate CO_2 sinks and sources for LULUCF.

Only few Member States provided projections for the forestry sector in accordance with the CRF categories. Other MS are only in the initial phase of building up an operational systematic approach to estimate the raw data needed for the LULUCF part of the GHG inventory. Thus, the capacities and resources are needed for the estimation of the historic years and not much efforts are spent on projections before the work on the inventory is finalized.
Unlike in the other sectors forestry policy making for GHG projections is dispersed over several administrative and policy levels in most MS's. The span goes from the local, regional to the national levels of the MSs.

Some countries do have a long standing forestry tradition and assess their sampling errors for the total timber volume as low as 0.6%. Other MS never perform forest inventories but set up questionnaires sent to forest owners. Others make an inventory once a decade or lasting for some decades. Even within a country highly different procedures may be applied in different regions.

Differences between MSs regarding key forestry parameters are discussed in the following paragraphs.

9.1.1 Forest area

The definition of a forest is highly variable between the MSs. The differences may not be tremendous compared to other uncertainties involved in sink calculations. Nevertheless the differences may be relevant in special cases, e.g., plantations of Christmas trees in Denmark, which are explicitly included in the national forest area definition, whereas in Germany they are excluded. Available but not used for reporting to UNFCCC can be data on forest surface area for different tree species (or groups).

For methodological reasons, some countries start their calculations directly with annual roundwood increment ($m^3.y^{-1}$). Other MS give more or less detailed information on their calculations, starting with the forest areas for different tree species (or groups). Obviously there is a wide variability in data quality with regard to the actual status of the forest data and their uncertainty level.

There are also remarkable differences in what is included into subchapter 5A of the GHG inventories. While most countries report data on managed forest and plantations only, others like FR include single trees, hedges, and wine-/ fruit- trees also. IT and PT include coppice. Both are not contrary to the IPCC guidelines, which allow that "…other types of biomass such as non-forest trees… and woody shrubs in grasslands should be included when they are a significant component of total changes in biomass stocks" (Ref. Manual p.5.13).

9.1.2 Growth rates

All MS used national values for different tree species or groups when reporting growth rates. This is well in-line with the IPCC Guidelines, which recommend the use of default values only in those cases when no (better) national values are available. Due to the original field survey data from forest inventories, nearly all MS values are based on m^3 roundwood over bark.ha^{-1}.y^{-1}. This requires the subsequent multiplication with an expansion factor to account for the whole tree volume increment and a biomass density factor. The annual volume increment of marketable stemwood reported by MS for different trees and tree-groups is between 0.5 and 16 m^3.ha^{-1}.y^{-1}, averaging at 6.9 m^3.ha^{-1}.y^{-1}. There appear to occur inconsistencies like different poplar growth rates for Flanders and Wallonia reported by BE, very high growth rates of conifers in IR compared to the UK (16 *vs.* 7 m^3.ha^{-1}.y^{-1}), or very low values for Portuguese oak and other hardwood species.

9.1.3 Stemwood expansion factor to total tree wood volume

There is a high variability of expansion factors to extrapolate the growth of stemwood to total tree biomass increase. The range for forest trees is from 1.14 in DE for coniferous trees to 2.0 in DK, the reason being different parts of the trees, included in the total biomass. The IPCC Guidelines recommend only aboveground wood but mention that the belowground tree biomass "…is an area for further development by the relevant expert groups…" (Reference Manual p.5.53). Hence, DE, NL and SE expand to above ground biomass only, while AT, BE, DK, ES, FI, FR, GB, IR, and PT include roots as well. IT gives growth-rates for total trees directly but remains unclear whether roots are included. Apart from these differences some MS include more biomass in their expansion. DK additionally includes "some carbon in the undergrowth and soil" (Fenhann, 1999), ES includes "part of the surrounding shrub vegetation" (Ferrero, personal communication) and FI states that "the used factor contains foliage as well" (Tomppo, personal communication).

9.1.4 Biomass density and Carbon fraction

In their calculations ES and NL use the IPCC default value of 0.5 for the biomass density (conversion factor biomass volume to dry matter). All other MS use national values for the different tree species (groups), varying between 0.35 and 0.70, in accordance with the IPCC Guidelines. The IPCC default value for the carbon fraction of dry matter (Conversion factor dry matter to carbon in table 1) is 0.5. It is used by BE, DE, DK, FR, GB, IT and NL. The other MS are using slightly different national values, ES, PT and SE 0.45, FI up to 0.519, IR 0.43 and 0.45, AT 0.48 and 0.49.

9.2 Assessment of Member States models & parameters

9.2.1 Introduction

European wide, the forestry sector contributes to the emissions of GHGs - mainly CO_2 - of the Union. This however, is not strictly the case for a number of individual MS's, which have a net sink capacity.

9.2.2 Model requirement

Data used for LULUCF projections are based on IPCC guidelines.

The model for the estimation of emissions/sources for LULUCF includes:

- good historical data on forest area

For this sector, historical activities are very important.

9.2.3 Assessment of Member States

9.2.3.1 Overview of the models used

Most MSs use a national inventory methodology and based on the CRF source categories for projections for GHG emissions. The common calculation is straightforward. GHG emission projections are based on the multiplication of a forest area with factors for C stock changes for different pools. Projections of activity levels are taken from trends of former evolutions, experts views or are based on results from models. C stock changes can be (IPCC) default values (tier 1) or regionally adapted values (tier 2).

As lined out a few MSs apply more complex models focussing at the European level. Hence the main difference is the total area considered as well as the spatial resolution with goes to 1 km², much higher than inventory based models.

Of the models focussing on the European level Finland applies the EFISCEN model, The Netherlands the CO2FIX model and Belgium the C-Fix model.

9.2.3.2 Integration of PAMs in the models

Although there is no specific ECCPM for the forestry sector except in the R&D 3rd and 4th framework programmes of the EC, the CAP includes quite a lot of afforestation/deforestation policy. At this moment in time, some of the models developed for the framework programmes can serve as policy tools at the European level for a standardized approach, including the issues of forest productivity, wildfires, rural development and sustainable tourism.

Only top-down type of models can take into account the global changes in trade that occur on the forestry market, especially at the international level. Substantial changes in forestry products trade are taking place at this moment in time, due to the increasing demand for wood from especially Asian countries.

9.2.3.3 Recommendations

At this moment in time full implementation of estimation methodologies, especially with respect to a complete estimation of all pools in the land use, land-use change and forestry sector, is not achieved by the individual MS's. Clearly, sink estimation represents still a methodological gap for many MSs.

- *Make consistent and comparable inventories*
  LULUCF projections are based on inventory data. The first step will be to make sure that the inventory data of the different MSs in the EU are consistent and comparable. Only with such data it will be possible to make correct projections for this sector.

  Although the IPCC guidelines give some guidance, many issues remain open for the LULUCF sector in the sense that each MS treats these issues in its specific way. These country-specific issues, together with the flexibility in definitions, make the reporting still very strongly country-specific and therefore not always directly comparable.

  The methodological comparison identifies a lack of transparency, consistency and completeness for the reporting of the National GHG Inventories for the UNFCCC and EU Monitoring Mechanism, the state-of-the-art of forest inventorying and C-sinks/emission reporting is highly variable in different European countries. The key problem remains that forest inventories are performed to assess marketable stemwood and not to assess C-sink/emission relationships.

  The sector background datasheet for LULUCF adapted to the needs of EU15 would represent a big leap forward towards increased transparency.

- *Verification of data:*
  At COP7 guidelines for review teams were conceived, that outline quality control and quality assurance activities. Review teams shall "verify that data quality objectives are met, ensure that the inventory represents the best possible estimate of emissions and sinks given the current state of scientific knowledge and data available, and support the effectiveness of the QC (quality control) programme "(UNFCCC, 2001).

  New methodologies for verification of data should be implemented at EU level.

- *Take into account forest wild fires*
  Forest fires are an important factor or at least not negligible in Europe in the emissions of greenhouse gases. The amount of forest biomass burning over the past 100 years has increased dramatically and is now recognized as a significant global source of atmospheric emissions. The techniques used to reduce the risk for forest wildfires, have the potential to mitigate forest carbon emissions within the framework of the Kyoto Protocol.

At the European scale we are faced once more with a large knowledge gap with respect to the full exploration of forest carbon emission reduction, by reducing forest wildfire risk. Very limited data are available at the European scale to fully explore the scale of the attainable emission reduction from forest wildfires. It is clear however that significant reductions can potentially be obtained especially in fire prone countries of the European Union. Out of 33 countries investigated the major conclusion is that a reduction in forest wildfires, has typically the highest effect on emission reduction in those countries with the highest wildfire occurrence.

10 Sectoral Analysis – Waste

10.1 Assessment of Member States projections

Projections in the waste sector have considerably improved. Whereas in the past the waste projections were characterized by many gaps, currently only four countries (Estonia, Germany, Luxembourg and Malta) do not estimate future waste emissions. Latvia is the only country reporting waste emissions aggregated, the other Member States indicate emissions from solid waste disposal, wastewater handling and waste incineration separately (see also Table 31).

Projections are rather straightforward on the basis of tier 2 inventory models. Most Member States use the tier 2 approach resulting in future estimates that are highly consistent with GHG inventory. The emissions from wastewater handling decline with larger shares of wastewater treatment and more use of biogas for energy purposes. In the first order decay approach, a large part of the future emissions are determined by past waste deposited on landfills. Therefore the assumptions on future waste disposal only partially influence the resulting emissions. As the tier 2 FOD approaches are easily applicable for projections of CH_4 emissions from solid waste disposal, the waste sector is no priority area for further methodological improvements.

Table 31 Disintegration of Waste projections in Member States

	Solid waste disposal	Wastewater handling	Waste incineration	Waste aggregated only
Austria	x	x	x	
Belgium	x	x	x	
Bulgaria	x	x		
Cyprus	x	x		
Czech Republic	x	x	x	
Denmark	x	x		
Estonia				
Finland	x	x		
France	x	x	x	
Germany				
Greece	x	x		
Hungary	x	x	x	
Ireland	x	x	x	
Italy	x	x	x	
Latvia				x
Lithuania	x	x	x	
Luxembourg				
Malta				
Netherlands	x	x	x	
Poland	x	x	x	
Portugal	x	x	x	
Romania	x	x	x	
Slovakia	x	x	x	
Slovenia	x	x	x	
Spain	x	x	x	
Sweden	x	x	x	
United Kingdom	x	x	x	

Uncertainties are mostly related to the implementation of the assumptions used regarding generation of future waste amounts and the implementation and efficiency of CH_4 capture systems in landfills.

10.2 Assessment of Member States models & parameters

10.2.1 Introduction

The waste sector contributes most to MS emission from waste due to CH_4 emissions from solid waste management on land (land fills). Energy recovery from landfills is according to the IPCC methodology (IPCC, 1996), considered as part of the energy sector. Other emissions in this sector are the treatment of liquid waste (also CH_4) and the incineration of waste without energy recovery (CO_2). According to the Directive 2000/76/EC of 4 December 2000 on the incineration of waste, the heat generated by the incineration process has to be put to good use as far as possible. Therefore, in most MS, energy from waste incineration is mostly used and therefore only small amounts of emissions from waste incineration are reported in the waste sector.

We concentrate on the most important source of greenhouse gases in the waste sector, the solid waste disposal on land. The European Union has laid down strict requirements for waste and landfills to prevent and reduce as far as possible the negative effects on the environment from landfills. (Directive 1999/31/EC of 26 April 1999 on the landfill of waste). One of the issues that is covered in the Directive is a system of operating permits for landfill sites. This includes information on:

- types and total quantity of waste to be deposited;
- the capacity of the disposal site;
- a description of the site;
- the proposed methods for pollution prevention and abatement;
- the proposed operation, monitoring and control plan;
- the plan for closure and aftercare procedures;

10.2.2 Model requirements

The model for the estimation of emissions from land fills includes:

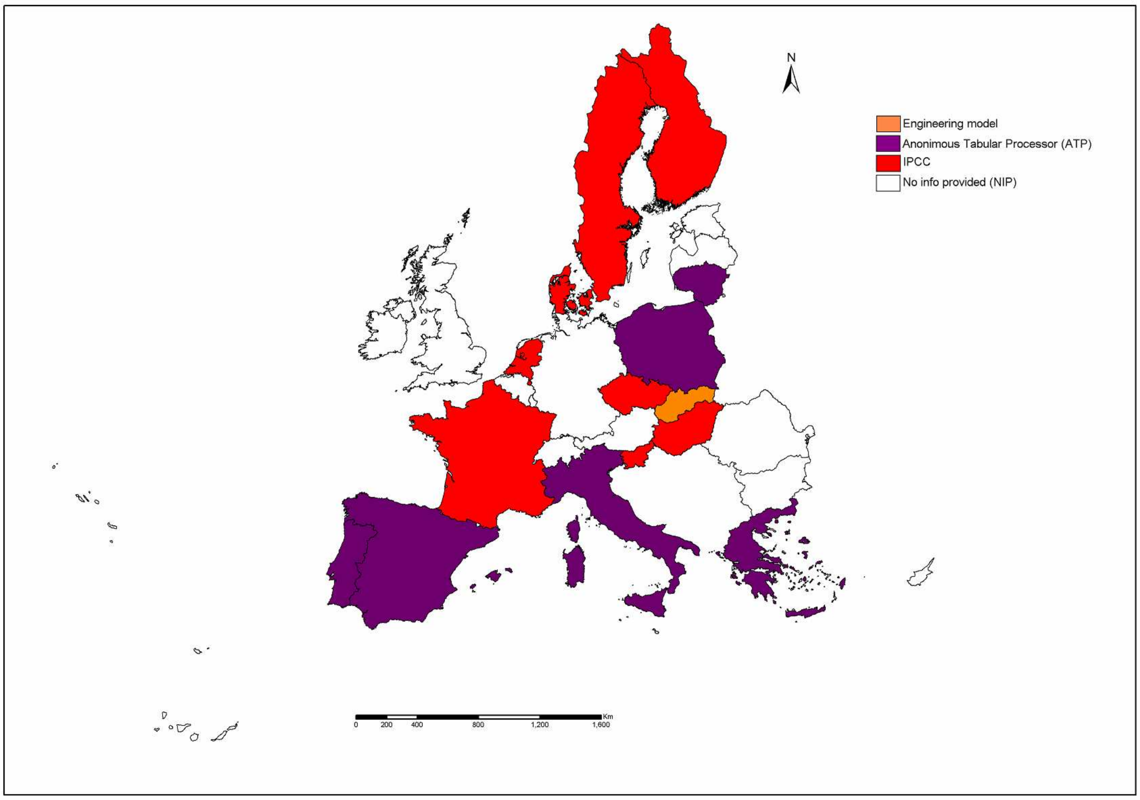
- good historical data on waste deposited on land (amount, composition of waste, site specific info)
- info on energy recovery (and other abatement techniques in place)

For this sector, historical activities are more important than projected ones.

10.2.3 Assessment of Member States

10.2.3.1 Overview of the models used

Figure 33 Overview of the waste models used by MS



Most MS use an approach based on IPCC guidelines to make projections for the GHG emissions. Most use the first order decay model used for emission inventories also for their projected emissions. This makes good sense. However, energy recovery rates or other abatement techniques might change and evolve, and this should be taken into account.

10.2.3.2 Sectoral Requirements

Since historical data are most important in the methods MS used, we looked at the reported assumptions. 11 MS reported the waste amount going to landfills (out of 19 that were regarded); 8 MS reported on the waste generated (of 17 MS regarded). CH_4 recovery rates were reported in the country files by 7 out of 16 MS. Consideration of different waste fractions was reported by 9 out of 17 MS.

10.2.3.3 Integration of PAMs in the models

Important directives for this sector are Directive 1999/31/EC of 26 April 1999 on the landfill of waste, others are Directive on waste (Dir 2006/12/EC) and Packaging and packaging waste (Dir 94/62/EC, 2004/12/EC, 2005/20/EC).

10.2.4 Recommendation – best model choice

In chapter 13, tier methods are proposed to estimate projection for GHG emissions for the waste sector.

10.2.5 Possible data sources

Among different other possible sources, national inventory data submitted to the UNFCCC[12] can be used to obtain (historical) activity data.

[12] http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/4303.php

11 Sensitivity analysis

In this chapter we present a quantitative assessment of the MS WM projections. The objective of this analysis is to get a global impression of the reliability of MS projections.
- identifying areas of improvement for MS projections
- defining a interval range of the possible outcome of EU wide emissions in 2010.

This analysis covers the main sources of CO_2 emissions in:
- Energy sector
- Industry - including CO_2 process emissions
- Residential sector
- Services

11.1 Methodology

An ex-post assessment of past projections concentrates on the deviations between the observed and the projected data.

Future projections can not be assessed in a similar way. Comparing with alternative projections, like the primes baseline scenario, can provide some insights on possible deviation but will not allow to drawn hard conclusions as neither of the projections can be considered as being the reference case. If the projections are made independently from each other, then the deviation between the projections can be seen as an expression of the uncertainty.

Sensitivity analysis on the other hand can be used to quantify the sensitivity of the projections to the most significant driving factors.

Based on the comparison with alternative projections we will define a feasibility interval (lower and upper boundary) for EU wide emissions, relative to the projections of the member states. This is based on a discussion of the nature of the projections and the PAMs which are in place.

Finally the Monte Carlo analysis was used to evaluate the global effect. For simplicity we use uniform probability distributions for the different sectors.

11.2 Residential sector

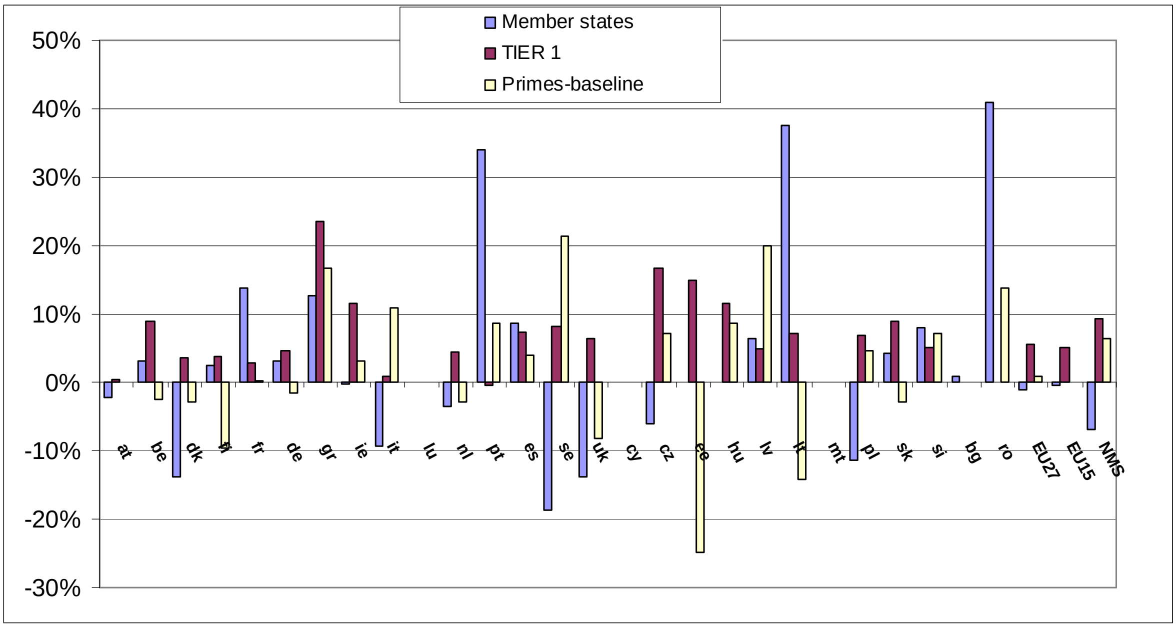
In the monitoring mechanism a number of MSs report separately projections for residential and services sector while others only report the aggregated category others sectors. For the purpose of this analysis we have split the latter category based using the 2005 historical shares.

Member states projections are compared with two alternative projections:
- A new set of projections are based on the TIER 1 methodology as described in the guidelines.
- Primes baseline scenario

This analysis has been done for 22 MS[13].

The trends 2005-2010 of these projections are presented in Figure 34. Positive figures indicates 2010 projections to be higher the 2005 observations. At MS level we observe considerable differences. The TIER 1 projections are highest for 14 MS and while MS projections and Primes baseline scenarios are both highest in 4 cases.

Figure 34 Trends in MS CO_2 projections 2005 – 2010 for the residential sector



At EU level MS projections have a 1% decrease in emissions between 2005 and 2010, while TIER 1 and Primes baseline scenario results in 5.5% and 0.9% increase respectively. The TIER 1 projections are 32 Mton higher and the Primes baseline scenario is 8 Mton higher compared with the MS projections.

The TIER 1 projections are a reflection of the historical trends in energy consumption in the period 1990-2005. These projections only partly reflects the effect of measures taken to reduce energy consumption in residential housing. The shares of different fuels have been kept constant at there 2005 observations. Therefore we should consider TIER 1 as a without measures scenario which overestimates the true evolution.

The optimistic view of the MS projections might reflect some policy objectives rather than expressing an independent view. There is also some doubt whether rebound effects in the residential sector have been correctly considered in the MS projections. On the other hand we can identify 4 MS (FR, PT, LT and RO) for which MS projections seem to be relatively high.

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[13] LU, MT, CY, BU, RO were excluded due to lack of data.

Feasibility interval

- *Lower boundary*
  The EU-MS projection is considered as the best case scenario. It is the most optimistic of the three projections. This level has been chosen as the lower boundary.

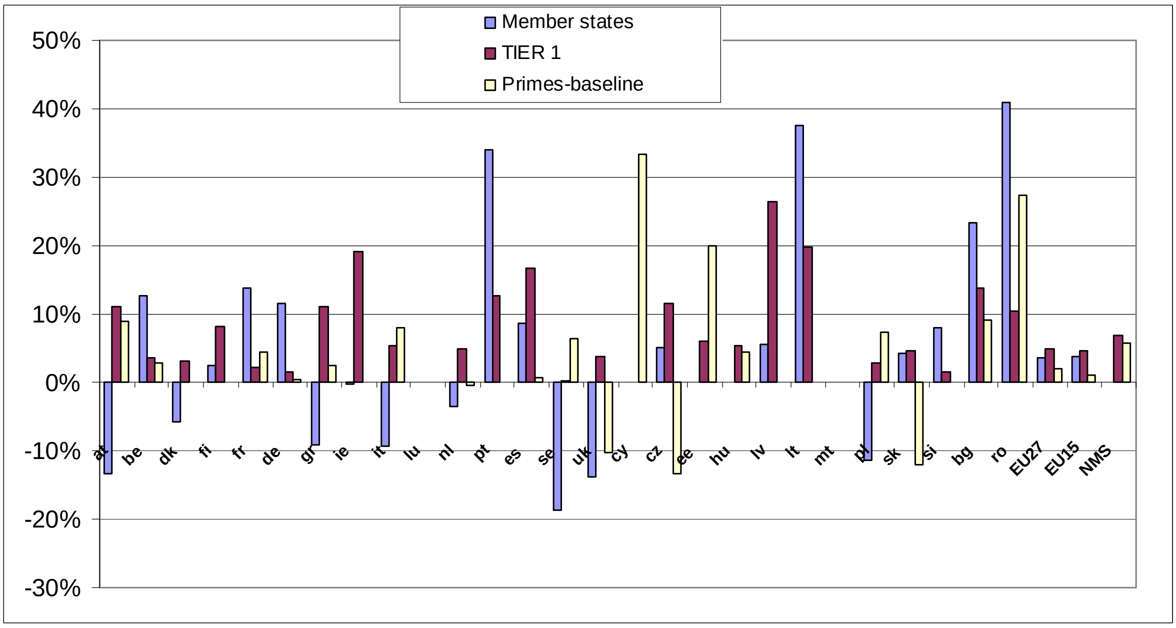
- *Upper boundary*
  A worst case scenario defines the upper boundary. As worst case scenario we choose + 15 Mton. This figure corresponds to approximately half of the difference between the MS projections and the TIER 1 projections, the latter being considered as without measures scenario. So it can be interpreted that we consider the measures only half as effective as assumed by the member states.

For the global analysis of the residential sector we use a feasibility interval [0, +15 Mton].

11.3 Services

The methodology is identical as for the residential sector. Here we observe that the MS projections reflect an economic growth factor, which results in small differences between the MS projections, TIER 1 methodology and the Primes baseline scenario. At EU level TIER 1 projections are 1.5% above MS projections (2.8 Mton) and Primes baseline scenario is 1.5% below MS projections.

Figure 35 Trends in MS CO_2 projections 2005 – 2010 for the services sector



Here as well we should consider the TIER 1 projections as without measures.

Feasibility interval

- *Lower boundary*
  Fixing the lower boundary at –2 Mton is based on the following considerations:

- At EU-27 level all three projections are very close. The MS projection is not the most optimistic one
- Economic growth effects are explicitly embedded in the TIER 1 projections. As argued before, TIER 1 projections only partial reflect effects of PAMs. Still we observe MS (BE, DE) with relative high projections, compared to the residential sector. The economic growth effect might be somewhat overestimated by some MS.

- *Upper boundary*
  - The upper boundary is fixed at +2 Mton which is based on the consideration that rebound effects might not have been considered correctly in all MS projections.

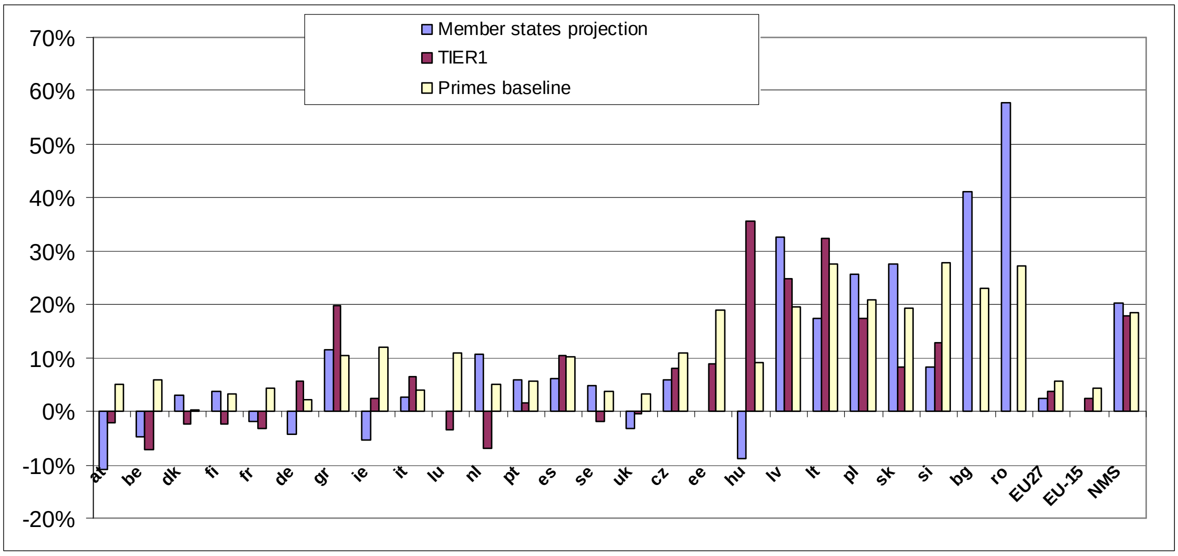
For the global analysis of services we use a feasibility interval [-2 Mton, +2 Mton].

11.4 Transport sector

MS projections are compared with TIER1 projections and Primes baseline scenario. The TIER 1 methodology for persons transport is fully documented in the guidelines. For goods transport the following additional assumptions have been used in the TIER1 projections:

- goods-vehicle km statistics are available in EUROSTAT for 2006-2007. These figures have been used.
- For 2008-2010 a yearly EU wide growth factor of 3.3% has been applied.
- The growth has been distributed uneven among MS. For new member states a growth of 7% has been used, consistent with recent observations
- For IE, IT, ES, PO, GR 5% yearly increase as been used.
- The growth for other has been calculated as the difference. This results in a growth of 1.5% yearly

Figure 36 Trends in MS CO_2 projections 2005 – 2010 for the transport sector



In the TIER1 we consider 5.7% bio-fuels, equally distributed among member states. An increase in energy efficiency of cars is considered too. Therefore TIER 1 reflects a with measures scenario.

The increase in the MS projections is 2% between 2005 and 2010 whereas the TIER 1 and Primes baseline increases with 3.8% and 5.9% respectively. The correspondence between the three projections is very high for the new member states too where increase between 18 and 20% are considered.

Feasibility interval

For the global analysis of transport we use a feasibility interval [0 Mton, + 30 Mton].

- *The lower boundary*
  is based on the following consideration:
  - Aggregated EU emission projections look very reasonable, compared with TIER 1 and Primes baseline scenario, MS projections are still the lowest one.
- *The upper boundary*
  is based on the following consideration:
  - The bio–fuels directive is implemented in the MS scenarios and in the TIER 1 projections. However, today it looks very unlikely that we will reach 5.7% bio-fuels in all member states by 2010.

11.5 Energy sector and industry

The emissions of the energy sector and the industry are mainly covered by the EU-ETS system. The analysis is mainly based on two propositions:

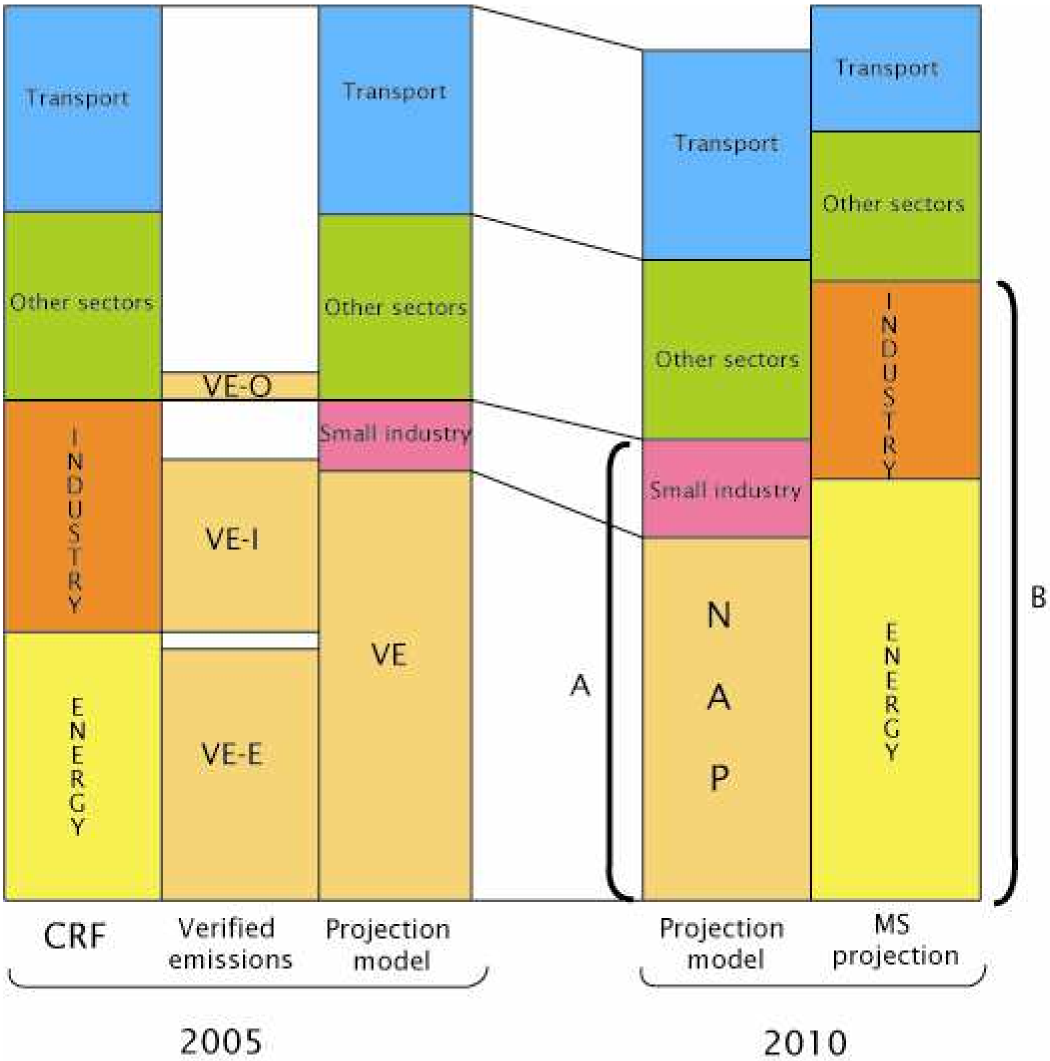
- The cap is binding at EU level. The cap equals the sum of the approved national allocation plans.
- The level of emissions is finally determined by the emissions trading system. Actions undertaken by MS to facilitate CHP and renewable energies might have a lowering effect on the trading price but will have no effect on the final emissions level.

The use of Emission Reduction Units (ERUs) and Certified Emission Reductions (CERs) to fulfil the requirements of the EU-ETS is an exception of the first proposition. However, as ERUs and CERs can also be used to fulfil the Kyoto requirements this is not considered as a major obstacle in this analysis.

The methodology is explained in Figure 37. For 2005 we consider the historical emissions from CRF tables, and the 2005 verified emissions from the installations that operate under the EU-ETS system. The verified emissions are mainly situated in the energy sector and the industry. Additionally a small amount of verified emissions might be situated in other sectors.

In the projection model we use a simplified categorisation when assuming that all emissions from the energy sector are under the emissions trading system, as well as an important part of the emissions form the industry. Verified emissions from other sectors are considered as belonging to the industry and/or energy sector.

Figure 37 Explanation of the methodology



A new emissions category is defined in the projections model, namely “small industries” (SMI).

For 2005 we define SMI in the following way:

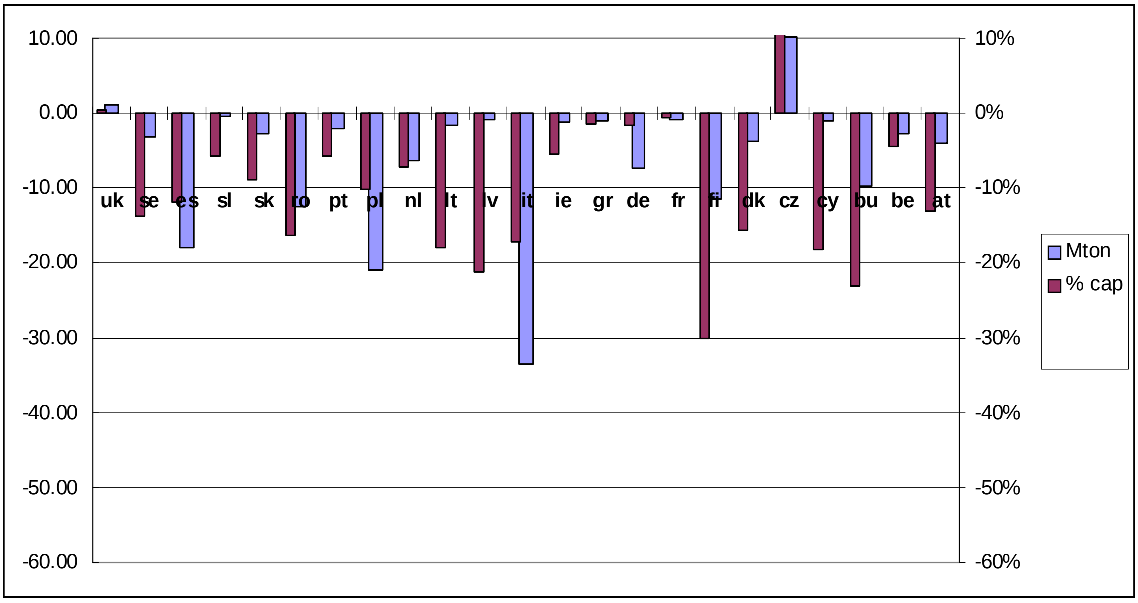
SMI = CRF- Energy + CRF Industry – approved national verified emissions.

The sector manly consist of various industrial activities in non-energy intensive sectors: manufacturing textile, leather, wood , rubber, machinery, electrical equipment transport equipment. These activities stabilise in EU-15 in favour of the new member states. There we observe yearly growth rates of 11%.

For this category we make an new projection, based on econometric trend analysis for 2010. The verified emissions are replaced by the national allocation plans.

For comparison with MS projections we look at A (NAP + SMI projection) en compare with B in the MS projections. The results (A-B) are expressed in Figure 38 in absolute levels (left axis) and as% of the national cap (= approved NAP).

Figure 38 Additional reductions in the sectors energy and industry related to the EU-ETS



The emission projection obtained in this way is 133 Mton below the emissions projections from the member states. For EU 15 we obtain – 94 Mton, and for the new member states – 40 Mton.

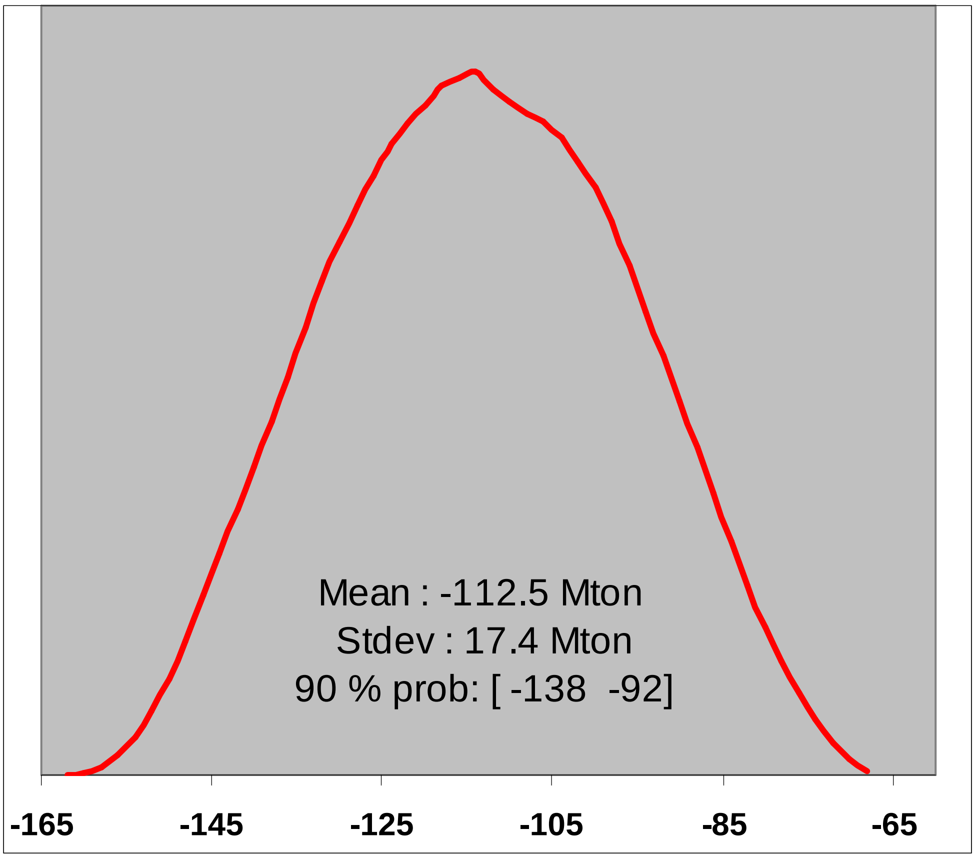
Feasibility interval

This result is sensitive to projection of the category “small industries”. Unlike the other sectors we can not make a comparison with alternative projections as neither MS projections or Primes produce projections for this category. Therefore we obtain an uncertainty range by sensitivity analysis on the driving parameters (growth expectations and energy efficiency improvements). Using extreme values (lower and higher growth figures for the sectoral growth and energy efficiency improvements) we obtain an under-bound of -160 Mton and an upper-bound of -100 Mton. This uncertainty interval of 50 Mton corresponds to 12% of the emissions of the category small industries or 2% of the CO_2 emissions for the sectors energy, industry and industrial processes.

11.6 Global result

We assume uniform probability distributions in the sectors considered. The result from 50000 random drawings is presented in Figure 39. Based on this analysis we conclude that in the MS –WM projections, the emissions at EU-27 level are overestimated by 112.5 Mton. In this analysis we have not considered the consequences of a world wide financial crisis.

Figure 39 Probability distribution of likely outcome of EU-27 CO_2 emissions compared with MS projections



12 Recommendations and conclusions from the sectoral analysis

12.1 Assessment of mandatory parameters for projections

12.1.1 Purposes of projection parameters

The first step of the project was to determine the purposes for which the reported information on projection parameters could and should be used.

These purposes are:

- improved understanding of methodologies and models used for GHG emission projections;
- presentation of additional information and parameters that underpin the projected emission trends in sectors and source categories providing an improved understanding of existing and future trends in GHG emissions;
- comparison of key underlying projection parameters and assumptions across Member States (e.g. fuel price assumptions) and analysis of the consistency and reasons for deviations of key parameters to enable a further discussion of key assumptions at EU level;
- comparison of assumptions of Member States GHG projections with EU-wide GHG projections (e.g. with emissions estimates from PRIMES, GAINS, CAPRI and potentially other sources of aggregate projections) and analysis of reasons for deviations of projected emissions.

A set of numerical values will fulfil the purpose of delivering an improved understanding of methodologies and models used for GHG emission projections in a rather limited way. An improved understanding of methodologies and models for projections could be achieved by more comparable, more systematic and more complete descriptions of the models and methodologies used. Thus additional guidance on these descriptions are considered to be more helpful for the understanding of projections than the reporting of individual numerical input or output parameters.

The following sections will present the recommendations with regard to the individual projection parameters. Sections ‘what to do with the parameter’ describe the potential use of the reported parameter at EU level.

Some of the findings summarized below were already incorporated in the draft revision of the reporting template distributed in May 2008. This was limited to those findings that are consistent with the implementing provisions. However the intention of the report is to analyse the need of a more general revision of the projection parameters as part of the planned revision of the Monitoring Mechanism Decision.

12.1.2 General issues

The reporting template requires the reporting of projection parameters for the years 2005, 2010, 2015 and 2020. When the Annex to the implementing provisions was developed, the year 2005 was a projected year, now it has become a past year. Therefore it is no longer clear whether the reported information is historic or projected data for the year 2005.

The original intention to limit reporting of these parameters to future years hinders any consistency checks of the parameters with historic information from other sources. For example, if there is a sudden jump of a parameter compared to historic data from other data sources, it is not possible to verify whether the dataset used for comparison is inconsistent or whether the projected increase reflects the assumed trend.

Recommendation

- The years for which projection parameters are reported should include two historic years (e.g. 2000 and 2005 would be appropriate years for the actual reporting)
- The reporting years should be defined in a flexible way with the consequence that every 5 years – when a previously future reference year has become a past year - one historic reference year is dropped and one future reference year is added, thus the entire reporting moves in time every 5 years.

12.1.3 General economic parameters

12.1.3.1 Gross Domestic Product (GDP) (value at given years or annual growth rate and base year)

All Member States except Spain provide the underlying GDP growth assumptions. Six Member States (Bulgaria, Cyprus, France, Hungary, Latvia and Netherlands) provided growth rates only without giving a reference value to which the growth rate refers to. Some Member States provide GDP data per sector, others only aggregated.

GDP projections are mostly provided by national ministries of economy or finance or national agencies.

The GDP assumptions of the reporting Member States are difficult to compare because Member States report in many different units (national currency or Euro, real prices, constant prices with different price basis) and assumptions have to be used to convert the data to comparable units. If future GDP is reported in real prices, it is difficult to convert GDP in constant prices because the assumed future inflation is unknown.

Different base years are provided for GDP in constant prices, because the base year for computation of constant prices is traditionally a single, fixed benchmark year, which is moved ahead about each five years. The whole time series available is then expressed in prices of the new base year. Therefore the revision of the reporting guidance should implement a flexible approach that takes the periodic change of the benchmark year into account. The periodic updating of the base year avoids the drawback of this method that the further one moves away from the base year, the more irrelevant becomes the price structure of the base year for the economic area.

Eurostat is currently changing the reporting of GDP in constant prices to the so-called chain-linked series of GDP data.[14] This guarantees that volumes are measured using the most recent price structure. However, this also means that the base is moved ahead with the observation period, and no two years have the same price base, so that volume growth rates cannot be calculated directly from series at previous year's prices. The use of chain-linked GDP data has recently started, but it may become more popular in the future. Eurostat already stopped the reporting of GDP in constant prices and recalculated the entire time series based on chain-linked series. However, the new method seems less useful for the purposes of projections for which constant price basis will continue to be a valid approach. Further discussion with and information from Member States is necessary to know whether Member States may face problems in reporting of GDP in constant prices in the future and whether the national statistical offices will also switch to the chain-linked GDP data.

Recommendation

- Further harmonization of reported units is necessary. There are two options to achieve improved comparability:
    - Member States convert their currencies and price basis to a harmonized unit in the reporting under the implementing provisions
    - The conversions are calculated at EU level.
- Both absolute data and growth rates should be reported
- The basis for constant prices should be updated every 5 years (1995, 2000, 2005, 2010 etc). This should be included in Monitoring Mechanism Decision as an automated update of price basis to achieve improved harmonization of reporting.
- Definition of GDP in constant prices should be included in the reporting template: EUROSTAT definition: *'GDP (gross domestic product) is an indicator for a nation's economic situation. It reflects the total value of all goods and services produced less the value of goods and services used for intermediate consumption in their production. Valuation at constant prices means valuing flows and stocks at the price of a previous period (called base year). The purpose of the valuation at constant prices is to assess the dynamics of economic development irrespective of price movements. This is achieved by decomposing changes of values over time into changes in prices and changes in volume. The base year for computation of constant prices is traditionally a single, fixed benchmark year, which is moved ahead about each five years. The whole time series available is then expressed in prices of the new base year'.'* The part of constant prices is taken from EUROSTAT online methodologies description.
- A column for the source of GDP projection should be included in the template and the source of information should be indicated.
- The annual growth rate requested at the moment does not specify to which period the growth rate refers. E.g. does a growth rate indicated in the column of the year 2000 only indicate the annual growth for this particular year, or an average annual

[14] Commission Decision 98/715/EC demands that the base year must be the previous year

growth rate related to the next 5-year period provided? This should be clarified and the growth rate over the 5-year period should be requested.
- It should be further discussed with Member States whether they will continue to be able to report GDP in constant prices.

What to do with the parameter
- If reporting of projected GDP in consistent units is achieved, the projected GDP development could be aggregated from Member States to an aggregate estimate at EU level which could be compared with other GDP projections for the EU. This would provide a useful cross-check of assumptions at aggregate level.
- Projected GDP is an important parameter to assess differences or consistency of MS projections with other sources of emission projections (e.g. PRIMES, GAINS).
- Projected GDP provides an improved understanding of existing trends and projected future trends in GHG emissions and is useful for the explanation of future trends in the annual report on GHG emission trends and projections.

12.1.3.2 Population (value at given years or annual growth rate and base year)

For three Member State no data on projected population is reported in national projections (Luxembourg, Malta and Spain; see Table 32). Mostly the population projections are made by the national statistical offices, sometimes updated or adapted for the purpose of GHG projections.

Table 32 Overview on reporting on projected population

	Population and population growth		
	Projected population data provided	Absolute	population growth
Austria	Yes	Yes	No
Belgium	Yes	Yes	No
Bulgaria	Yes	No	Yes
Cyprus	Yes	No	Yes
Czech Republic	Yes	Yes	No
Denmark	Yes	Yes	No
Estonia	Yes	Yes	No
Finland	Yes	Yes	Yes
France	Yes	Yes	No
Germany	Yes	Yes	Yes
Greece	Yes	Yes	Yes
Hungary	Yes	No	Yes
Ireland	Yes	Yes	Yes
Italy	Yes	Yes	No
Latvia	Yes	Yes	No
Lithuania	Yes	Yes	Yes
Luxembourg	No	No	No
Malta	No	No	No
Netherlands	yes	Yes	No
Poland	Yes	No	Yes
Portugal	Yes	Yes	Yes
Romania	Yes	Yes	No
Slovakia	Yes	Yes	Yes
Slovenia	Yes	Yes	Yes
Spain	No	No	No
Sweden	Yes	Yes	No
United Kingdom	Yes	Yes	Yes

The outstanding issue related to population data is completeness because not all Member States provide projected population data and the completeness of the dataset should be further enhanced. However, some Member States base their projections on projected activity data from national sources (e.g. ministries), e.g. projected energy demand or projected transport energy consumption or transport demand. In such cases, population projections were already taken into account in the projected energy or transport activities, but may not be directly available to the compilers of GHG projections, depending on the transparency of the national documents. In some countries, this is the reason for the lack of reporting on future population data.

Recommendation

Absolute numbers of population data should be requested (at the moment it is an option to report either absolute numbers or a growth rate). If only growth rates are reported, the information is less suitable for aggregation at EU level. Historic absolute population data in combination with future growth rates would also enable such aggregation. If absolute numbers are provided, growth rates can be calculated and are not necessary as reporting item.

What to do with the parameter

- If reporting of projected population is complete and consistent, the projected population forecast could be aggregated from Member States to an aggregate estimate at EU level which could be compared with other sources of population growth at EU level. This would provide a useful cross-check of assumptions at aggregate level.
- Eurostat publishes population forecasts in 5 year intervals, thus Member States' population projections can regularly be compared with Eurostat projections.

12.1.3.3 Fuel price assumptions

8 Member States (Bulgaria, Hungary, Italy, Portugal, Romania, Slovakia, Slovenia and Spain) did not provide fuel price assumptions for gas, oil and coal. Cyprus reports oil and coal prices, Austria oil prices only. Different assumptions in fuel prices are an important factor explaining different levels of projected emissions in the future.

It is rather difficult to compare the fuel prices used in GHG projections across Member States because units differ widely; some prices are given in US-Dollars and others in Euro with different reference years (US$1997, US$2000, US$2004, €1990, €2000, €2004, €2005). Assumed Exchange rates are rarely given. Oil is measured in barrel, toe or GJ; gas prices in GJ, 1000 m^3 or Mbtu; coal prices in GJ, toe or ton. For some Member States it is not clear to which year the currency refers to. A conversion of the units to one comparable unit is difficult due to the following reasons:

- Member States provide quantities in physical units such as tons, m^3 and in energy units (TJ, toe). For conversion of physical units to energy units, net calorific values are necessary, but it is unclear which calorific values should be chosen for this calculation at rather aggregate level (general NCV for oil or coal). There exist general, but varying recommendations for such conversions in literature, but these are not very precise and provide rather rough assumptions.
- Member States provide prices in real or constant prices. When real prices are provided they need to be converted to constant prices which involves assumptions on projected inflation for each country. This introduces additional uncertainties in the comparison of resulting prices.
- Most Member States and also other sources such as IEA and PRIMES refer to energy import prices. This is currently not specified for projection parameters to be reported by Member States, thus projections parameters should refer to
    - International coal price
    - International crude oil import price
    - International gas import price

The IEA World Energy Outlook is the most widely used source for fuel price scenarios, apart from national sources. However, due to different updating dates for projections, different IEA fuel price scenarios are used in Member States projections. The IEA energy outlook seems to be the most popular candidate for a harmonized source for fuel prices in the EU. DG Tren also publishes regular fuel price assumptions for the energy sector, based on the POLES and Prometheus models /taking into account world energy resources and the formation of world energy prices as a result of interactions between energy demand and energy supply reflecting resource availability and technological progress).[15] However, Member States do not refer to such European sources for fuel price assumptions.

Recommendation

- A general methodology for the conversion of fuel prices should be developed in co-operation with Eurostat and IEA (potentially DG Tren). This would provide assistance to Member State that may face problems with conversions as well. And this would ensure a consistent approach for the conversion of fuel prices and a comparison across Member States.
- As IEA World Energy Outlook is the most commonly used source of fuel price assumptions, it should be discussed whether this is a suitable harmonized source of fuel price scenarios for WM projections. Other national fuel price scenarios could be used as part of sensitivity analysis.
- Different to other parameters, it seems not necessary to request fuel prices for one or two historic years.

What to do with the parameter

- Compare fuel price assumptions regularly across Member States and include this comparison in report on EC GHG emission trends and projections.
- Compare fuel price assumptions in the EU with PRIMES, other European energy scenarios or other global emissions or energy scenarios (e.g. IEA World Energy Outlook) for a better understanding of the differences.

12.1.3.4 Carbon price

The current reporting requirements do not include the reporting of carbon price assumptions used in the economic models for the emission projections. As a consequence few Member States report on this key assumption. This is an important addition for future projection parameters as the introduction of international emissions trading and the EU ETS have established new carbon markets and carbon price is one of the key parameters in the models in the energy sector.

Recommendation

- Add a mandatory requirement for carbon price in € per ton CO_2 for the projected years

What to do with the parameter

- Compare carbon price assumptions regularly across Member States and include this comparison in report on EC GHG emission trends and projections.

[15] Most recent publication is DG Tren: Trends to 2030 – update 2007, 2008.

12.1.4 Assumptions for the energy sector

12.1.4.1 Total gross inland consumption in Petajoule (PJ) (split by oil, gas, coal, renewables, nuclear, other)

Table 33 provides an overview on reporting categories for gross inland consumption as requested under the Monitoring Mechanism Decision and as reported by PRIMES and EUROSTAT. Gross inland consumption is currently requested as a total number and for the following fuel split:

Table 33 Comparison of reporting categories for gross inland consumption

Projection parameters	**PRIMES**	**EUROSTAT**
Total	Total	Total
Oil (fossil)	Oil	Oil
Gas (fossil)	Natural gas	Natural gas
Coal	Solids	Solids
Renewables	Renewable energy forms	Renewable energy forms
Nuclear	Nuclear	Nuclear
Net electricity import	Electricity	Electricity
Other, please specify	-	Derived heat

Total gross inland consumption is currently reported by 16 from 27 Member States (AT, DK, FI, DE, NL, SE, UK, BG, CZ, CY, EE, LT, PL, SK, SI)

Recommendation

- A definition for gross inland consumption should be included. EUROSTAT provides the following definition: '*Gross inland consumption is defined as primary production plus imports, recovered products and stock change, less exports and fuel supply to maritime bunkers (for seagoing ships of all flags). It therefore reflects the energy necessary to satisfy inland consumption within the limits of national territory*'
- The definitions should also specify which fuels should be reported under which categories, e.g. the current split is not clear related to peat. But also for renewables it would be useful to add a definition with regard to the coverage.
- A considerable problem in using the currently reported parameters for projections is the fact that only the projected parameters, but no past years are reported. This does not allow and checks for consistency with other datasets (e.g. Eurostat data) of the information provided. At least the year 2000 and maybe the year 1995 should be introduced in the requested parameters in addition to the years currently requested. The base year is currently requested, however for many Member States other datasets such as Eurostat data do frequently do include data for the base year (in particular for new Member States).

What to do with the parameter

- Comparison of past and future trends for gross inland consumption at MS and aggregate EU level. For past trends Eurostat data can be used. But consistency checks for some individual historic years should be performed as quality control.

- Compare assumption on gross inland energy consumption with other sources of emission projections at European level (e.g. PRIMES projections).

12.1.4.2 Total electricity production by fuel type

The current Annex to the implementing provisions do not specify whether net or gross electricity production should be reported. This should be defined and definitions should be added.

Eurostat uses the following definitions:

- Gross Electricity Production is the sum of the electrical energy production by all the generating sets concerned (including pumped storage) measured at the output terminals of the main generators. (UNIPEDE Definition 3.5.1)
- Net Electricity Production is equal to the gross electricity production less the electrical energy absorbed by the generating auxiliaries and the losses in the main generator transformers. (UNIPEDE Definition 3.5.5)

PRIMES and Eurostat include a reporting category for electricity generation from conventional thermal power plants. Such category may be useful for the reporting under the Monitoring Mechanism Decision as well because electricity generation could then be split to three main categories (thermal, renewables and nuclear which would provide a rather good overview on future trends (which categories increase or decrease) that are closely related to GHG emissions without the need for presenting many individual numbers and categories. However, this would require a clear categorization of biomass and waste fuels.

Recommendation

- Improved definitions should be provided and it should be defined whether gross or net electricity production is requested. For the revised template gross production was used, because it is the more complete parameter, but it cannot be inferred from Member States data whether gross or net electricity production is available.
- Peat fuels are not clearly indicated in the existing template and would most likely be reported under other fuels, because they do not fit under 'coal'. In the revised template it is suggested to replace the coal category by 'solid fuels' and it is indicated that peat should be allocated to solid fuels.

What to do with the parameter

- If the data reported under this parameter would be comparable and complete, the aggregation of Member States data at EU level would be an essential parameter for the explanation of the future EU trend in GHG emissions from electricity generation. In particular the data from Member States with important shares in GHG emissions would be necessary for an EU aggregation.
- At EU level and Member State level, Member States data can be compared with aggregate projections for the EU (such as Primes) and key differences in the assumptions on fuel mix or total electricity production as well as electricity imports/exports could be analysed.

12.1.4.3 Energy demand by sector split by fuel (delivered) (suggested sectors are energy industries, industry, commercial or tertiary, residential and transport)

Table 34 provides an overview on reporting categories for energy demand as requested under the Monitoring Mechanism Decision and as reported by PRIMES and EUROSTAT.

Table 34 Comparison of reporting categories for energy demand

Projection parameters	**PRIMES**	**EUROSTAT**
Energy demand	Final energy demand	Final energy consumption
Sectors: **Energy industries** Industry Commercial Residential Transport	Sectors: Industry Tertiary Residential Transport	Sectors: Industry (further disintegration) Households/services (further disintegration) Transport (further disintegration)
Fuels: Oil (fossil) Gas (fossil) Coal Renewables Other	Fuels: Oil Gas Solids **Electricity** **Heat** Other: Biomass-waste Biofuels Solar thermal Geothermal heat Other energy forms	Fuels: Oil Gas Solids **Electricity** **Heat** Renewables (disintegrated to Solar heat, Biomass, Geo-thermal, Wastes, Hydro, Wind, Photovol-taics, Biofuels)

- Energy demand is currently reported by 9 from 27 Member States (AT, DK, FI, DE, BG, CY, EE, LT, RO, SI).
- The definitions for this parameter should be clarified. Final energy consumption/ demand as used by PRIMES or Eurostat includes all energy delivered to the final consumer's door (in the industry, transport, households and other sectors) for all energy uses. It excludes deliveries for transformation and/or own use of the energy producing industries, as well as network losses. The current template requests data for the sector 'energy industries', however it is not clearly defined what MS should report as energy demand from energy industries, i.e. whether this is the own use of energy producing industries or deliveries for transformation or also distribution losses. As this sector is not clearly defined, the coverage is different across Member States. For this reason also the total energy demand parameter lacks comparability with other sources.
- The requested energy demand parameters under the MM decision should be disintegrated to the fuels oil, gas, coal, renewables and other. Table 35 compares this energy source split with the split used in Eurostat and Primes data for the residential and commercial sector. Eurostat energy statistics include additional subcategories of electricity and heat which are important subcategories for these sectors. Electricity and heat are also important energy sources for industrial consumption. For the transport sector a general fuel split is also not very useful, but a disintegration of

diesel and gasoline would strongly improve the background information on future trends as well as a disintegration for jet kerosene.

Table 35 Fuel split for residential and commercial sector

Projection parameter MM decision	Eurostat	Primes	Recommen-dation
16a. Oil (fossil)	Gas oil	Oil	Oil
16b. Gas (fossil)	Natural gas	Gas	Natural gas
16c. coal	Solid fuels	Solids	Solid fuels
16d. Renewables	Renewables		Renewables
	Electricity	Electricity	Electricity
	Heat	Heat	Heat
16e. - Other Please Specify		Other	Other (please specify)

Table 36 Comparison of subsectors used by different institutions and reporting formats for energy consumption related to residential and commercial sectors

Projection parameter MM decision	Eurostat	GHG Inventories	Primes	Recommendation	Recommended Definition
Energy Demand by Sector	Total final energy consumption	Total consumption	Total final energy demand	Total final energy consumption for the sectors	Final energy consumption covers energy supplied to the final consumer's door for all energy uses.
16. Residential	Households	Residential	Residential	Households	Final energy consumption - households covers quantities consumed by households, excluding the consumption of motor fuels for personal transport. Household consumption covers all use of electricity and use of fuels used for space and water heating.
15. Commercial (Tertiary)	Services	Commercial/ Institutional	Services	Services	Definition: Final energy consumption - services consists of consumption of public administration and private services
	Fisheries				
	Agriculture	Agriculture/ Forestry/ Fisheries	Agriculture	Agriculture / Fisheries	Definition: Final energy consumption - agriculture consists of quantities consumed by agriculture, including engines used for agricultural transportation; Final energy consumption - fisheries consists of quantities consumed by the fishing industry, excluding fishing on the high seas which is included under bunkers.
	Other sectors	Other sectors		Other sectors	Definition: Final energy consumption - other sectors consists of final energy consumption not classified under any other subcategory

- Table 36 shows that the requested projection parameters 15. 'Energy demand for commercial (tertiary)' and '16. 'Energy demand for residential' are consistent with other classifications as used for GHG inventories or by Eurostat. However, it the projection parameters do not include a subcategory for energy demand from "Agriculture/Forestry/Fisheries" is provided (CRF table 1.A(a)s4). Also the CRF category

1A5 Other (in particular military fuel use) is not represented in the projection parameters. Thus, the total energy demand in the projection parameters may not be complete because the addition of the sub-sectors does not sum all necessary components and it is unclear whether Member States included energy demand for agriculture/ Forestry/fisheries under other categories or whether this is was excluded form the data provided. Thus, either the total should be different from the addition of subsectors or these subcategories have to be attributed to other subsectors which makes the reporting less transparent. This situation creates difficulties for comparison with past trends as well as for the aggregation of data at EU level.

Recommendation

- Apply consistent definition with Eurostat total final energy consumption.
- The projection parameters should match the Eurostat disintegration and should follow the Eurostat definitions of sub-categories. This would avoid confusion and potentially incomplete indications for the projection parameters. This would imply to delete ‘energy industries’ and to add the sub-categories ‘agriculture, forestry, fisheries’ and ‘Other sectors’.
- The fuel split should be chosen specifically for each subsector and include the relevant energy sources for each sub-sector. This recommendation is already taken into account in the revision of the reporting template of May 2008.

What to do with the parameter

- More regular comparisons of past and future trends should be made with the reported parameters.
- If better comparability is achieved, the data should be aggregated at EU level and consistency of past and future trends at EU level should be checked. More background information on key drivers for future emission trends could be provided with an improved dataset.

12.1.4.4 Assumptions on weather parameters: 18a. heating degree days and 18b. cooling degree days

- While the heating degree days are essential for the projection methods because projections are usually based on normalized data for those sectors where weather conditions influence the energy demand (e.g. commercial and residential). However, it remains unclear for which purpose Member States should report these data and how these parameters could be used for any further assessment.
- Normalized data for past trends can provide further insights in the trend development without climate influences, but the use of projected heating degree days remains difficult. It should be expected that first past trends are normalized and that projections are developed on this basis and would represent ‘normalized’ years. In such an approach, heating degree days are not projected.

Recommendation

- Proposal to delete these parameters

12.1.5 Assumptions for the sector industry

For the sector industry the parameters requested under the Monitoring Mechanism Decision include the following:

- Parameter 19: Gross value-added total industry
- Parameter 20. The share of industrial sector in GDP split to industrial sectors as defined by Member States
- Parameter 21: The growth of the industrial sector in GDP split to industrial sectors as defined by Member States
- Parameter 22: The production index for industrial sector split to industrial sectors as defined by Member States

The different selection options and the lack of pre-defined industrial sectors make it impossible to aggregate the data that is currently reported for the assumptions in the sector industry.

The lack of clearly defined sectors also makes it impossible to compare MS data with other sources of emission projections.

Recommendation

- Further discussion is necessary whether it is possible to define the most important industrial sectors that should be reported in this category. It is unlikely that a wide range of subsectoral disintegration will ever be complete for 27 Member States. Therefore this information may be limited to 3-4 important sectors.
- An alternative to the definition of specific sub-sectors would be to improve the guidance on the description of projection methodologies and assumptions for the sector industry and to delete the specific parameters 20, 21 and 22 and only keep the general parameter 19 of gross value-added for total industry. An improved guidance on the methodological description would enable Member States to report on the relevant and available industrial parameters which are likely to provide a better understanding.
- The final intensity indicators seem to be the most important product for the sector industry that should be gathered for each Member State and at aggregate EU level. However a general industry energy and carbon intensity indicator seems to be sufficient for the purposes to monitor the past and future trend. Such information is compiled as industry indicator A1 ‘energy related CO_2 intensity of industry (t/Mio €)’. This indicator uses the information provided in the projection parameters.

What to do with the parameter

- If only parameter 19 would be kept, the parameters is incorporated into the indicators and should provide additional information to explain the projected trend in industrial emissions.
- If some key subsectors would be defined, the information could be aggregated and serve as additional explanatory information for the projected trend.

12.1.6 Assumptions for the transport sector

For the transport sector the parameters requested under the Monitoring Mechanism Decision include the following:

- 23. The growth of transport relative to GDP
- 24a. Growth of Passenger person kilometres, Million passenger km
- 24b. Number of kilometres by passenger cars, Mkm
- 25a. The growth of freight tonne kilometres, Mtkm
- 17. Energy demand by transport (PJ), split to oil, gas, renewables and other.

The number of Member States providing data for the transport parameters is rather limited: 8 Member States (AT, DE, PT, UK, CZ, LT, SK, SI) report projected passenger transport activity in Gpkm and 12 Member States (AT, DK, FR, DE, NL, PT, UK, CZ, LT, PL, SK, SI) report projected freight transport activity (in Gtkm). About 10 Member States reported kilometres by passenger cars (vehicle kilometres).

It seems misleading that parameters 23, 24a and 25a are entitled “growth of” which seems to point at relative changes, but then requests absolute figures when units indicated are considered. The language should be clarified.

Again the aggregation of transport parameters is difficult, because of the lack of clear definitions. For parameters 23 and 24a it is not completely clear which transport modes should be included, in particular related to air transport. The unclear coverage of ‘total transport’ hampers any comparisons or aggregations in the transport sector.

Eurostat provides a similar indicator to no. 23. The growth of transport relative to GDP, however the Eurostat data is split to passenger and freight transport. The Eurostat indicator ‘Volume of passenger transport relative to GDP’ is defined as the ratio between passenger-km (inland modes) and GDP (Gross Domestic Product in constant 1995 EUR). It is indexed on 1995. It is based on transport by passenger cars, buses and coaches, and trains. All data was asked to be based on movements on national territory, regardless of the nationality of the vehicle. However, data collection methodology is not harmonised at the EU level. The Eurostat indicator ‘Volume of freight transport relative to GDP’ is defined as the ratio between tonne-kilometres (inland modes) and GDP (in constant 1995 EUR). It is indexed on 1995. It includes transport by road, rail and inland waterways. Rail and inland waterways transport are based on movements on national territory, regardless of the nationality of the vehicle or vessel. Road transport is based on all movements of vehicles registered in the reporting country.

A key problem in the requested parameters is that road transport is not clearly separated in the requested information. Parameter 24b (vehicle kilometres by passenger cars) is the parameter related to road transport. However, none of the parameters provided gives information on total road transport which is the main subcategory for transport and which is also the category for which projected emissions should be disintegrated. For a better explanation of the future emission trend for transport, the current parameters seem to be insufficient in terms of transport modes (road, rail, air, navigation).

The requested parameter ‘final energy demand by transport’ is not clearly defined, e.g. it is unclear whether this parameter should include all transport fuels, including international aviation and marine bunkers or if Member States should use similar boundaries as for emission in GHG inventories, i.e. whether they should exclude bunker fuels. Due to the lack of precise definition, the projected parameters are difficult to compare with the past trends in GHG inventories.

Some Member States report vehicle kilometres by passenger cars, other Member States report total passenger kilometres. For a conversion car occupancy rates would be necessary which are not reported and not easily available. Eurostat data on either vehicle kilometres and passenger kilometres show considerable gaps. For further analytical exercises, it may be sufficient to report future parameters that can be compared with the inventory parameters where fuel consumption of different transport modes is reported.

Recommendation

- The parameters requested should be comparable to past trends and to data in the GHG inventories. This would include final energy demand for road transport, rail, domestic aviation and inland navigation in a revised list of transport parameters. The projected final energy demand could then be compared with the fuel consumption for transport from GHG inventories. Parameters 24 a (Total passenger kilometres) and 25a (total freight tonne kilometres) may be deleted instead and only parameters 24b and 25b should be kept because they are used for the projection indicators.
- Carbon intensity should be compared across Member State and is important as an explanation of future trends. For this reason a more broadly available definition and parameter should be chosen. Carbon intensity for road transport seems to be the most important intensity parameter (CO_2 emissions from road transport/ final energy demand for road transport). The separation of road transport from other transport modes may be easier to report because this is consistent with inventory information and the split between freight and passenger transport may be much more difficult to get.

What to do with the parameters

- Compare past and future trends and check consistency
- Aggregate data at EU level to improve the explanations of the drivers of the future transport emissions.
- Compare with aggregate projections for transport emissions

12.1.7 Assumptions for buildings

In the residential sector, parameters differ whether macroeconomic models or more detailed bottom-up models are used for the projections. But there can also be combinations of approaches. Table 37 shows that parameters can differ widely. Whether detailed bottom-up models can be used for the projections in the buildings sector also depends on the availability of data of the existing building stock and technologies.

Some Member States have collected time-series with good datasets for the buildings that allow the development of detailed bottom-up models that have good potentials to reflect the effects of policies and measures, whereas in other Member States such data is not available and the resulting modelling approaches are more general. From this perspective, Member States will always use a broad variety of assumptions in the residential sector which are not well comparable across Member States. When the reported information is not comparable, it is also not possible to derive messages for the Community level. From this perspective, it is recommended to delete the detailed parameters 27, 29 and 31a from the list of projection parameters. Similar to the sector industry, it seems preferable to improve the guidance on the description of methodologies and parameters used for the residential sector. As approaches are quite different, such guidance may add more relevant information for the understanding of projection methodologies.

Table 37 Comparison of parameters used for projections in the residential sector

Projection parameter MM decision	**Primes**	**Austria**	**Germany**
Population	Population (mio)		Population (mio)
27. The level of private consumption (excluding private transport)	Household Income (in Euro'05/capita)	The level of private consumption (excluding private transport)	
29. Average floor space per dwelling (m2/dwelling)			
31a. The number of dwellings (1000 dwellings)			
	Number of households (mio)	Number of housholds	Number of households (mio)
	Households size (inhabitants/household)	household size	
			Building stock (floor space)
			Rate of construction of new buildings (floor
			Modernization rate for old buildings
			Combustion installations in residential sector
			Renovation cycles of buidlings and heating plants
			Use of potential for insulation in existing building stock

Recommendation

- Delete the parameters 27 (level of private consumption) , 28 (share of tertiary sector in GDP), 29 (average floor space per dwelling), 30 (average floor space per employee) and 31 (number of dwellings, number of employees in tertiary sector).
- Add the number of household as new parameter.
- Develop some general indicators based on aggregate information that can be reported by all Member States and that give clear information on the future emission trend in the residential and services sector. Such indicators for the residential and services sectors could be:

  Residential:
    - Population related carbon intensity: GHG emissions from residential sector/capita
    - Fuel consumption related carbon intensity: GHG emission from residential sector/total final energy consumption in the residential sector

  Services:
    - Population related carbon intensity: GHG emissions from services/capita
    - Fuel consumption related carbon intensity: GHG emission from services sector/total final energy consumption in the service sector

These indicators could be automatically calculated on the basis of the population data and the final energy consumption data provided as part of the projection parameters.

What to do with the parameter

- Compare past and future trends and check consistency
- Use additional indicators to improve the explanations of the drivers of the future emissions.

12.1.8 Assumptions in the agriculture sector

For the agriculture sector the parameters requested under the Monitoring Mechanism Decision include the following:

- For Member States using macroeconomic models:
- 32. The share of the agriculture sector in GDP and relative growth
- For Member States using other models:
- 33. – 37. The livestock numbers by animal type (for enteric fermentation beef, cattle and dairy cows, sheep, for manure management also pigs and poultry)
- 38. The area of crops by crop type
- 40.-47. The emissions factors by type of livestock for enteric fermentation and manure management
- 48. Emission factors by type of crop and the fertilizer use (tonnes)

The reporting requirements for projection parameters with regard to animal numbers are consistent with Eurostat data and GHG inventories.

The requested projection parameters for emission factors are aggregated for all gases and are presented in tonnes CO_2eq/heads, which requires some conversion of the inventory parameters which are expressed in CH_4 or N_2O/heads. It seems strange that the current template requires a much more detailed reporting of implied emission factors for animal subcategories, while the projected emissions only require total emissions from enteric fermentation and manure management. It seems more logic to provide the animal numbers in line with the projected emissions and to calculate the implied emission factors on such basis. From this perspective it may be useful to request a further disintegration of projected emissions under enteric fermentation and manure management to the most important animal subcategories (cattle, sheep and swine).

For the projection parameters that are requested with regard to direct N_2O emissions from soils, only the EFs are requested in a detailed way disintegrated for synthetic fertilizer, animal manure applied to soil, N-fixing crops and crop residues, but not for the activity data where synthetic fertilizer and animal manure are aggregated and where no activity data for N-fixing crops are requested. N_2O emissions from the cultivation of histosols are missing from both AD and EF in the projection parameters, however in some Member States they can be an important contributor to emissions. Therefore the projection parameters cannot be compared in a detailed way with the inventory emissions. In addition, the majority of Member States uses the IPCC default EFs for N_2O emissions from soils, which is the same value in kg N_2O-n/kg N for all subcategories. Therefore, it does not seem to be so essential to request these EFs in a disintegrated way, but it would be more important for the AD. This means, parameter 48 with the subcategories could be deleted, however new parameters for 1. Synthetic Fertilizers, 2. Animal Manure Applied to Soils, 3. N-fixing Crops and 4. Crop Residue and 5. Cultivation of histosols should be requested in the projection parameters. This split would also allow a better comparison with Eurostat data where the quantity of commercial fertiliser consumed in agriculture is provided which is equivalent to the data for synthetic fertilizers.

As many Member States use approaches to project AD in the agriculture sector and subsequently calculate emissions with the inventory methods, the projection parameters in this sector should be generally close to the inventory parameters in order to be able to detect inconsistencies.

Recommendation

- Keep projected activity data for livestock numbers
- Further disaggregate projected emissions for enteric fermentation and manure management to cattle, swine and sheep and replace parameters 40 -47 (emission factors requested)
- Add projected activity data categories based on inventory data for the parameters relevant for emissions from agricultural soils (Nitrogen input from application of synthetic fertilizers, Nitrogen input from manure applied to soils, Nitrogen fixed by N-fixing crops, Nitrogen in crop residues returned to soils, Area of cultivated organic soils) and replace parameters 38 (area of crops by crop type), 39 (fertilizer uses (synthetic and manure), 48 (fertilizer use and crops).

What to do with the parameter

The following regular comparisons could be made with the reported parameters:

- Past and future trend of animal numbers for different animal categories (from inventory data and projection parameters)
- Past and future trend for IEFs for emissions from livestock (from inventory data and projection parameters)
- Direct N_2O emissions from soils: past and future trends of AD (from inventory data and projection parameters)

12.1.9 Assumptions in the waste sector

For the waste sector the parameters requested under the Monitoring Mechanism Decision include the following:

- 49. Municipal solid waste generation
- 50. The organic fraction of municipal solid waste
- 51. Municipal solid waste disposed to landfills (%)
- 52. Municipal solid waste disposed incinerated (%)
- 53. Municipal solid waste disposed composted (%)
- 54. Municipal solid waste disposed to landfills (kt)

These parameters provide a good overview on the future strategies for waste management, however they do not reflect the necessary parameters for the emission calculation. For a comparison with GHG inventories, it would be essential to get information on the assumed share of CH_4 recovery in total CH_4 generation from landfills (in%). The landfill gas collection and use is one of the essential measures to reduce emissions from landfills and this additional parameter therefore provides an important future assumption.

Eurostat provides data for the generation of municipal waste and the MSW disposed to landfills as well as the composition of municipal waste. Eurostat also provides data for the different types of treatment of MSW.

The current list of projection parameters does not include parameters relevant for wastewater handling. This category is less relevant in quantitative terms for most Member States and any comparison and explanation of the trend would require a rather large number of different parameters. From the point of view of resources, it may therefore not necessary to add additional reporting parameters for wastewater handling.

The organic fraction of municipal solid waste may not be easily available from more advanced models that use different organic fractions for different components (wood, paper, food). From this perspective parameter 50 may be deleted.

Recommendation

- Add parameter CH_4 recovery from total CH_4 generation (%). Delete parameter 50, the organic fraction of MSW.

What to do with the parameter

The following regular comparisons could be made with the reported parameters:

- Past and future trend in Municipal solid waste disposed to landfills (from inventory data and projection parameters)
- Past and future trend in the share of CH_4 recovery from CH_4 generated (from inventory data and projection parameters)
- Past and future trend in IEF for CH_4 for solid waste disposal (from inventory data and projection parameters)
- Past and future trend for types of MSW treatment (landfill, incineration, composting from Eurostat data and from projection parameters).

These comparisons would provide all essential drivers and explanations for the assumed changes in future emissions from solid waste disposal.

12.1.10 Assumptions in the forestry sector

Currently the following parameters are requested:

- 55. Forest Definitions
- 56. Area of Managed Forest
- 57. Area of Unmanaged Forest

It is likely that forest definitions chosen will remain constant based on the definitions provided in the initial reports. This information does not add information to understand the projections

Most EU MS do not report areas of unmanaged forests. All forest areas are considered to be managed and emissions and removals on these areas are reported. This parameter should be deleted as it does not provide any additional information on projected emissions and removals from LULUCF.

Recommendation

- New reporting parameters should be developed for the LULUCF sector in cooperation with the few Member States that currently prepare projections in this sector.

12.2 Recommendations on model use

There exists no single model or even modeling approach providing answers to all relevant questions related to the development of GHG projections and the evaluation of PAMs. Different models have their own weaknesses and strengths. Therefore, it is not possible to make a single model recommendation for all sectors considered. All selection elements should be taken into consideration for which preferences regarding specific situations in the sector analysis were given.

In view of this limitation the project team suggested to develop preliminary guidelines for developing GHG projections. This methodology could be improved and further elaborated by bringing into practice. These preliminary guidelines are discussed in Chapter 13.

The project results show clearly that the projections of the different MS have a potential to improve. Improvement could be introduced at different stages of the projection work. In first instance by better data collection and secondly to adapt the projection methodology. It is of course clear that the first necessity for good projections is sufficient data on past trends as well as capacity and budget which is not always available at MS level.

Data collection

- Good quality *activity data* is a very important basis for projections. A good understanding of the activity data used in the projections is a prerequisite for a reliable database. Good quality activity data could, in first instance, be obtained with better cooperation between the different governmental departments. This should result in better understanding of the data and real data ownership by the government department responsible for GHG projections. Data availability for historic trends varies considerably across Member States for example with regard to energy efficiency and detailed transport data. Advanced methods for projections often require good data availability of past trends which is not always available. Therefore some Member States have to advance their current data collection before they can move to improved methods for GHG projections.
- Not all required activity data can be obtained from literature, surveys, etc. For example, the large competition in the industrial sector prohibits public information on e.g. the expected efficiency improvements. The relevance of *independent expert judgement* has to be recognized for the completion of these missing data. The independency of this judgement is very important, which is not always easy to find in a competitive sector like the industry.
- A large amount of the MS data is based on the Eurostat database which contains a lot of information. Nevertheless, these data are not always consistent with the numbers of the Member States themselves. Further assessment of Member States' data and Eurostat data is needed to enhance the understanding of differences and to highlight the areas that may need improvements.
- Low data availability for individual parameters could be addressed with *European benchmark figures*. (e.g. for the residential energy requirements of houses, CO_2 emission factors of pig iron,…).The creation of such a database by the European Commission would improve the data availability for Member States where data is missing and would improve the consistency of data used between the different Member States.

Projection methodology

- A primary requisite for the projections is a *good correspondence of the past and future emissions*. This means that the emissions of the last reported year in the inventory of each MS correspond to the reference emissions in the projections. A better integration of the inventory and projection team in the Member States can avoid large discrepancies between past and future.
- While comparing the projections of different Member States, a large variety in the *projection assumptions* was detected. For instance, the evolution of the assumed

energy prices differs strongly between the EU countries. Therefore European consistent assumptions could improve the accuracy and comparability of the projections.

The following list gives an idea for these EU assumptions but is not limitative:

- The evolution of energy prices;
- The prices of CO_2 allowances;
- Source for GDP growth assumptions
- Technology prices for optimization models
- …

- The European Commission has to set up clear and *unambiguous definitions of the different sectors*. A different interpretation of the sectoral definitions will result in incomparable emissions between the EU countries. Current examples of confusion are:
  - Should CHP be appointed to the industrial sector or the energy sector?
  - Does every Member State considers the same sort of emissions as process emissions or energy emissions? How is it done in the inventories?
  - …
- Attention should be paid also to the *consistency of projections between the different sectors.* E.g. the production and the use of biomass should be correctly divided at sectoral level to make sure the impact of the use of biomass is mapped in a correct way.
- Although definitions *for 'without measures', 'with measures' and 'with additional measures' scenarios* are given in the MM it is clear that these definitions are subject to different interpretations by the MSs. To be able to compare the different MS scenarios the definitions should be better explained. The future relevance of the WOM scenario could be put into question, because it will become more and more difficult to have historical data without the influence of policies.
- For some sectors it is recommended to have a coordinated approach:
  - The agriculture sector, aggregated models at EU level that reflect global agricultural markets and the common agriculture policy could assist Member States in improving the approaches to project activity data in the agriculture sector. However, the accurate estimation of GHG emission in the agriculture sector for projections depends on a large number of country-specific parameters and methodological approaches that have been developed by Member States and are not well represented with simple calculation approaches in aggregate models. With regard to the emission estimation, aggregate models would benefit from a closer cooperation with countries.
  - "Fuel tourism" mainly related to transport of goods is an issue that should be taken up in the near future. Some Member States have developed detailed approaches to separate emissions from domestic transport and fuel tourism. An exchange of experiences of such approaches would be useful to better acknowledge fuel tourism in GHG emission projections. At EU level it would be useful to develop methodological approaches that project GHG emissions from transport including and excluding fuel tourism (e.g. based on vehicle

kilometres driven and based on fuel sales) to enable a quantification of the impacts of fuel tourism.

In general we can conclude that further coordination between EU Commission and MSs with the development of best practice guidance will improve comparability and quality of MS projections.

Elements to take into account for the revision of Decision 280/2004

- set up European benchmarking figures to improve data availability
- inventory data and projection data should be put in one graph. Under normal circumstances, emissions of the last reported year in the inventory of each MS should correspond to the reference emissions of the projections. Any deviation in starting point or trend between projection and inventory should be explained.
- develop procedure to distribute European assumptions before projections has to be made
- improve definition of WM, WAM and WOM
- set up unambiguous definitions of the different sectors
- suggest coordinated approach for international transport
- continue working on the guidelines – long term consistency between MS methodologies (see also 13.10)

13 Preliminary guidelines for greenhouse gas projections

The guidelines in this chapter are preliminary because they should be seen as a starting point of a procedure that will need some time to be completely developed, approved and accepted by MS (this is longer then the timeframe of this project).

Nevertheless these preliminary guidelines should, once finalised, be able to guide MSs with no or limited projections in the sectors energy, industry, transport, residential, agriculture and waste to make or improve their emission prognoses. Special attention is given to the data needed for these prognoses and their possible sources.

On the basis of inventory data the following sectors are considered to be important enough to have a substantial impact on the projections in case these are not performed correctly.

CO_2

- ETS sector (energy supply and industry) – electricity sector and industry
- road transport
- residential (& services)

CH_4

- solid waste (27%) - waste
- enteric fermentation (43%) - agriculture
- fugitive emissions (17%)
- manure management (12%) – agriculture

N_20:

- agricultural soils (58%) - agriculture
- chemical industry (15%)
- manure management (8%) - agriculture

For this selection of sectors and gases a preliminary set of guidelines is put forward in the next paragraphs. The guidelines were sent to participants of WGII; participants of workshop "Assessment of GHG projections" (May 2008), policy makers, modelers,… to get feedback by email.

The preliminary guidelines are tested with test cases. Errors shown by these tests and the comments received by email were used to adapt these preliminary guidelines and the results were presented at the final workshop on the 13 and 14th of October 2008 in Brussels.

13.1 Preliminary guidelines for the electricity sector (CO_2)

13.1.1 Introduction

Developing GHG scenarios for the electricity sector requires an understanding of some basic characteristics. Today, electricity is produced by private owned companies trying to maximize profit. Profit is the difference between revenues and production costs. Hence maximizing profit is equivalent to maximizing revenues and minimizing production costs. Individual companies have limited impact on revenues in a competitive or regulated market as sales prices are determined by the global market, but they have a strong impact on production costs. Production costs are determined by the choice of the technology (capital cost, operational cost, maintenance), fuel prices and the efficiency of the installation and future GHG emissions depend entirely on the choice of the production technology.

As storage possibilities are rather limited, electricity is mainly produced for immediate consumption. Consumption fluctuates by hour, day, weak and season. These fluctuations are expressed in load-curves and they have a very significant impact on the choice of technologies.

Many common policies of the EC influence this sector, like the promotion of CHP, renewables and the emission trading scheme. It is important the projection method is able to incorporate these policies in a correct way.

13.1.2 Tier methods

Simplified methodologies in the electricity sector are not recommended. Next to that we saw that already many member states are using models for projections in the electricity sector. Therefore we will not develop a simple tier methodology. Instead, we recommend to use an optimisation model. This may need detailed enough data on the electricity system, but for most countries, statistics in this sector are already available.

Optimisation models have the most attractive properties for developing scenarios for the energy sector for the following reasons:

- Representation of sector specific issues is present: representing level of detail of installations, load curves for electricity use…,
- Cost minimisation is a sound economic principle for developing long run scenarios.
- Optimisation models allow to evaluate the competitiveness of CHP in given the boundaries of an energy system an considering the modalities of the local policies to support CHP.
- The model is able to analyse the opportunities for renewable energies in the electricity sector. The model is able to make endogenous investment decisions and has endogenous load management.
- Emission trading is difficult to assess, since the models are usually at a local level. The model can analyse the effect of emissions trading indirectly, by introducing a CO_2 tax, representing the emissions trading price. Methodologically this approach is correct but uncertainty is related to the CO_2 price.

Points of critic to optimisation models are that they tend to overestimate the speed of implementation, and have some normative characteristics (what should be done). However, we should realise that there exist no “what will happen” methodology for long term projections.

Examples of internationally developed optimisation models are Markal, Times, Message. Relevant information on Markal and Times can be found on the website of the Energy Technology Systems Analysis Programme (http://www.etsap.org/index.asp). Message was developed by IIASA, and is now distributed by the International Atomic Energy Agency (http://www.iaea.org/). Also country specific optimisation models exist.

13.2 Preliminary guidelines for the sector industry (CO_2)

13.2.1 Introduction

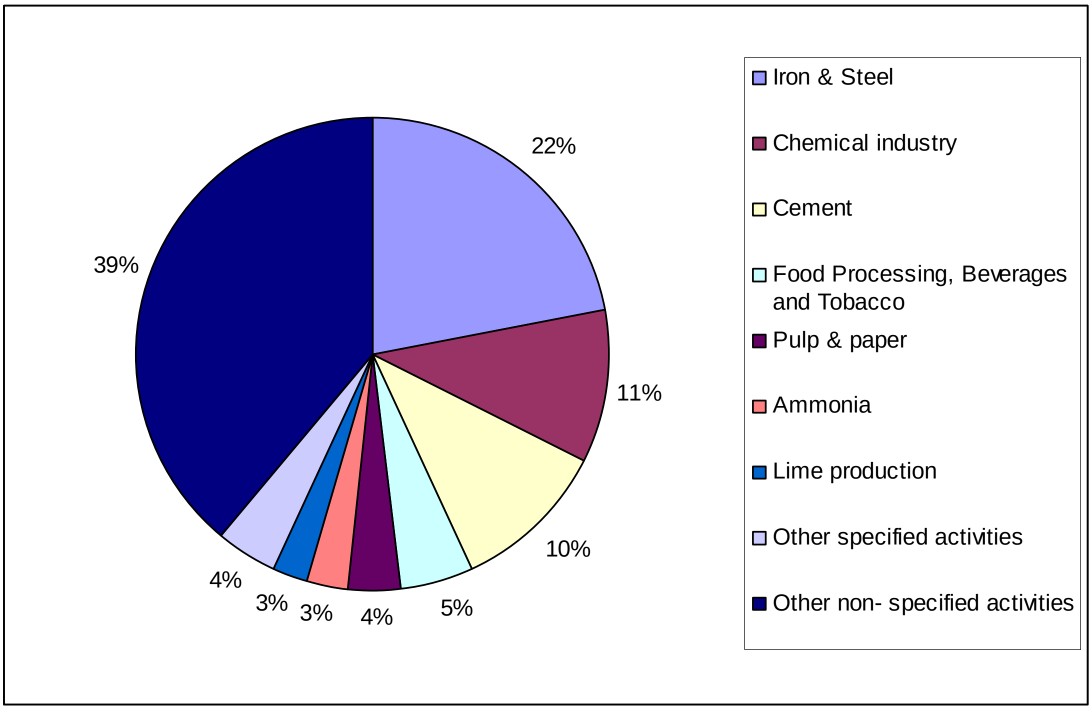
This paragraph relates to energy related GHG emissions reported in CRF table Table1s1 – Manufacturing industries and construction - and CO_2 process emissions reported in Table2(I)s1. The analysis of data reported by EU member states demonstrates that MS use different definitions for energy and process emissions. For example Germany reports 80% of GHG emissions from steel production as process emissions whereas Belgium reports only 15% as process emissions. Germany also reports all emissions from the chemical industry as process emissions.

13.2.2 European trends

Other non specified activities is the major source of CO_2 emissions in the CRF classification, followed by Iron & steel industries, Chemical industries, and Cement production in EU-27 (Figure 40).

Total industrial CO_2 emissions decreased by 0.6% yearly between 1995 and 2005 in EU25. This figure reflects changes in production volumes, fuel switches and energy efficiency increases, as well as increases in CHP use.

Figure 40 CO_2 emissions from industrial sources in EU-27 in 2005



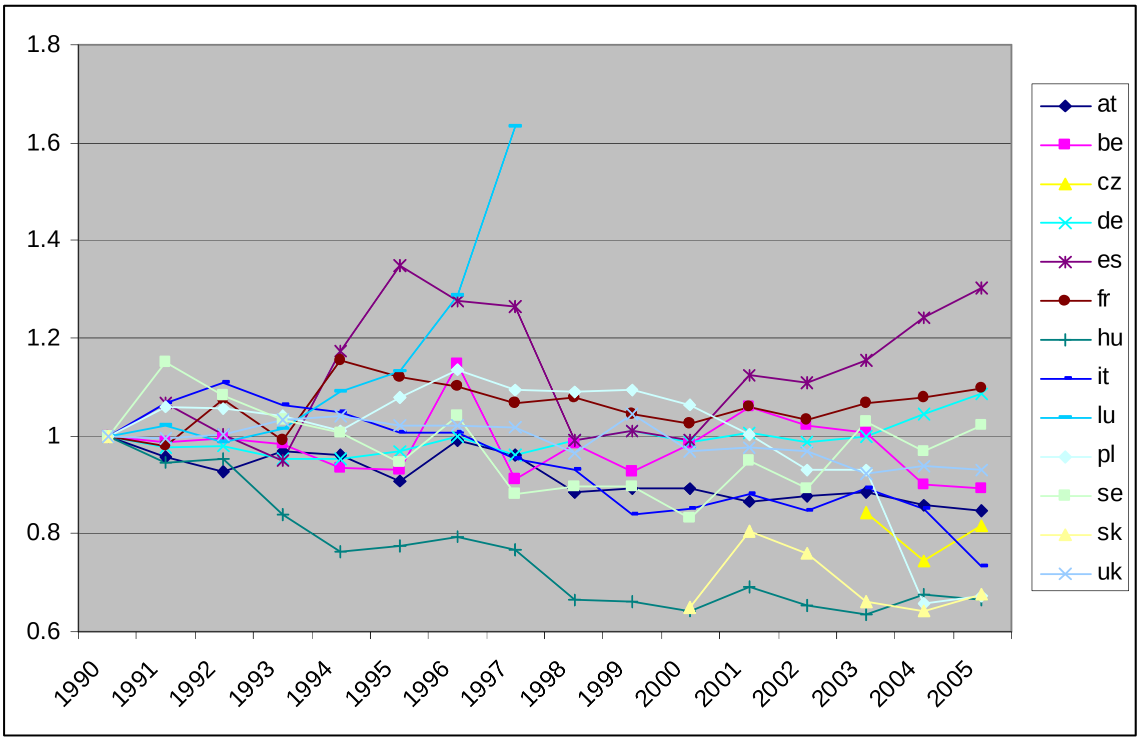
13.2.2.1 Iron & Steel

CRF Table 1s1 2. Manufacturing industries a. iron and steel and Table 2(I)s1 C. Metal production 1. iron and steel production

CO_2 emissions from Iron & Steel fell by 1.3% yearly between 1995 and 2005, whereas steel production increased by 0.8%. This opposite trends are mainly explained by a partial shift from oxygen (or blast furnace) steel to electro steel, the latter one starting from scrap. Shifting from oxygen steel to electro steel reduces CO2 emissions approximately by 85%.[16]

The production of pig iron from iron ore, using coke and other carbon as reducing agent, is the most CO_2 intensive process in the steel production. Differences between MS reflect differences in steel quality (flat steel - construction steel, remaining C content) differences in processes and differences in iron ore qualities. However, we can conclude that Poland and Hungary have improved the process dramatically compared by the 1990 situation. The observed differences can relatively be explained by the arguments mentioned above.

Figure 41 CO_2 emissions of steel production expressed as a fraction of pig iron production



[16] Own calculation

Activities projection

At EU-15 level we have not found a stable statistical relationship between GDP and steel production and value added of the steel sector is less then 0.5% of GDP. According to this analysis the GDP can not be used as an indicator for steel production.

Steel activity is driven by international steel markets. After 10 years of relative stable activities, the Europeans steel market is booming by a sharp increase in demand from China. Steel prices have doubled. Profitability of steel production is at a very high level. Actually European steel production is *limited by production capacities* but European steel producers are taking actions to increase production, even by reactivating *mothballed installations*[17].

This situation is not in favour of reducing GHG emissions from steel production. GHG efficiency of steel production might even decrease as mothballed installations might not be as efficient as newer plants.

13.2.2.2 Chemical industries

CRF table 1s1 and Table 2(I)s1 B row B Chemical industry 5. other

Chemical industries includes various organic and anorganic processes. One of the staring points of organic chemistry is steam cracking of naphtha to produce ethylene, propylene and butadiene (EPB). This basic process is biggest source of GHG emissions in chemical industry[18]. The production of EPB has increased by 25% from 1995 onwards and even by 47% from 1992 onwards[19].

Cracking capacities are mainly concentrated in 7 member states (Belgium, Germany, Netherlands, France, Italy, UK and Spain).

By this we can not drawn any hard conclusions regarding GHG efficiency improvements in EU level, nor can we draw any unbiased conclusion regarding CO_2 emissions and value added.

Reported EU-27 CO_2 emissions have increased by 1.9% between 2000 and 2005 which correlates to the increase in value added in the same period. Between 1995 and 2002 per unit of value added CO_2 emissions have decreased by 30%, but from 2002 onwards this trend has not been observed any longer. The change in trend might reflects different facts:

- changes in production patterns, stronger growth of fine chemicals
- increased use of CHP
- improving energy efficiency by reducing heat losses, improved catalysts …

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[17] Acerlor Mittal recently reactivated one blast furnace in Belgium

[18] European CO_2 emissions from ethylene production are estimated at 37.4 Mton , based on CEFIC production figure of 21600 kton and a IPCC tier1 emission factor of 1.73 ton CO_2 / ton ethylene, which equals 38 % of the CO_2 emissions of the chemical sector (excluding ammonia production).

[19] CEFIC

Figure 42 European cracking capacities (2005) and CO_2 emissions in CRF tables

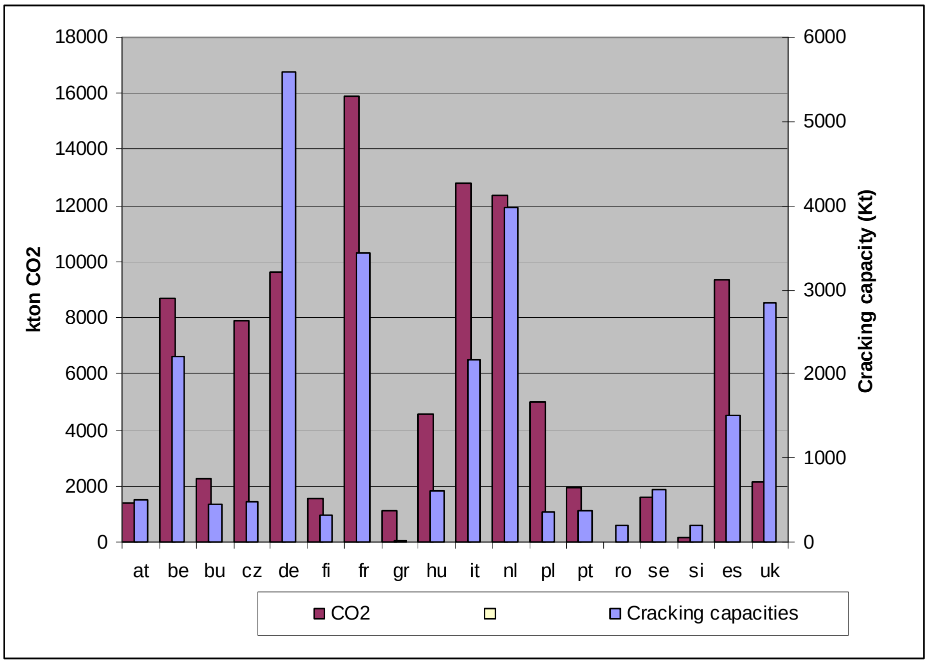
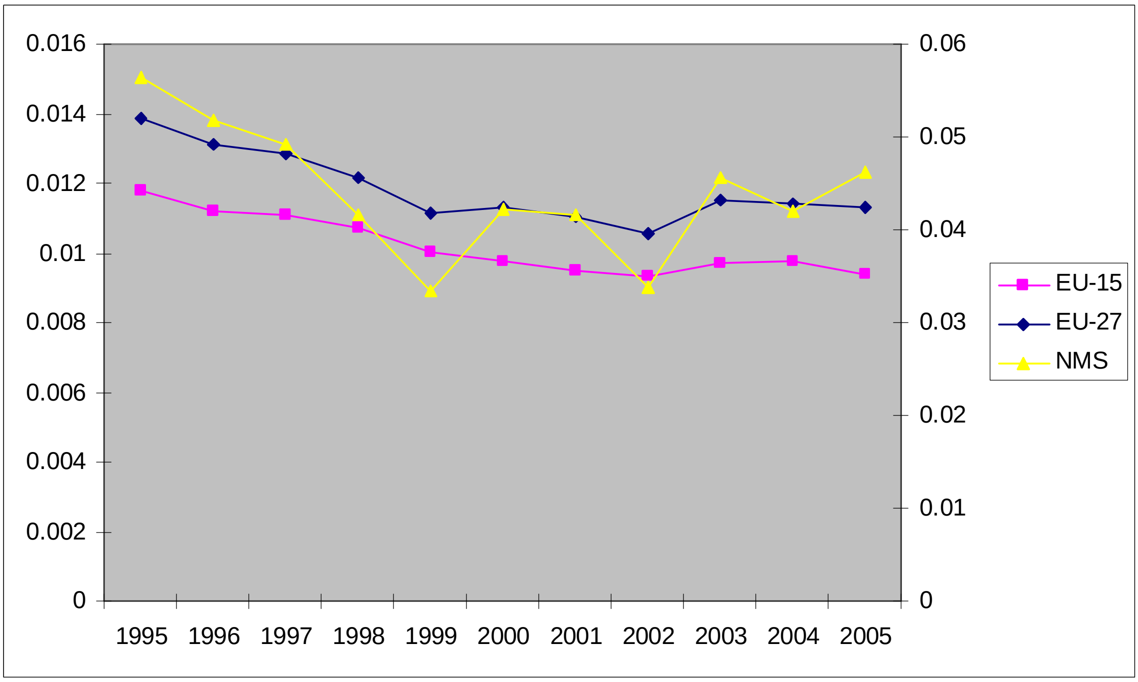


Figure 43 CO_2 emissions per unit of value added in chemical industries in EU-27 (EU-15 and EU-27 left scale, NMS right scale)



Activity projection

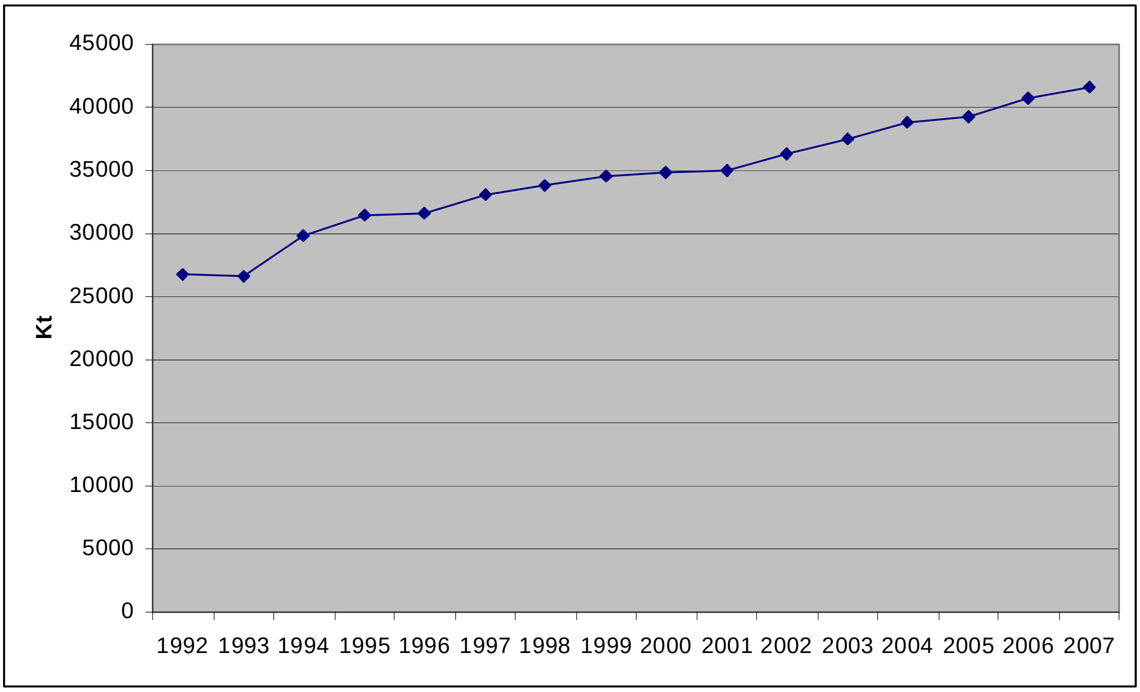
For GHG projection purposes we recommend to separate crackers and other chemical installations.

In CRF tables relevant indicators (ethylene production, methanol production) have been defined but only a few MS have reported these figures and this is not sufficient to give a representative picture.

The production EPB in Europe has followed a stable growth path between 1992 and 2007. Between 2000 and 2007 the production increased by 2.5% yearly.

Whether this trend will continuo is difficult to say. World demand for ethylene and derived products is likely to continue to grow but it is difficult to say how this will affect European production capacities. A further expansions would be logical in a WOM scenario but the European emissions trading system might have an effect on investment decisions for additional capacities in EU but a slow-down of the production is very unlikely.

Figure 44 Production of Ethylene, Propylene and Butadiene in West Europe (source: CEFIC)



For other chemical industries we don't have any useful output indicator. In EU-25 chemical industries had an average growth rate of 1.7% whereas GDP grew by 2.1% [20].

13.2.2.3 Cement production (clinker production)

Table 2(I)s1 B row A Mineral products 1. Cement industry

The production of clinker is the most energy intensive process in cement production. Alternatively blast furnaces slacks are used in cement production. Cement produce from blast furnace slacks is far less energy intensive.

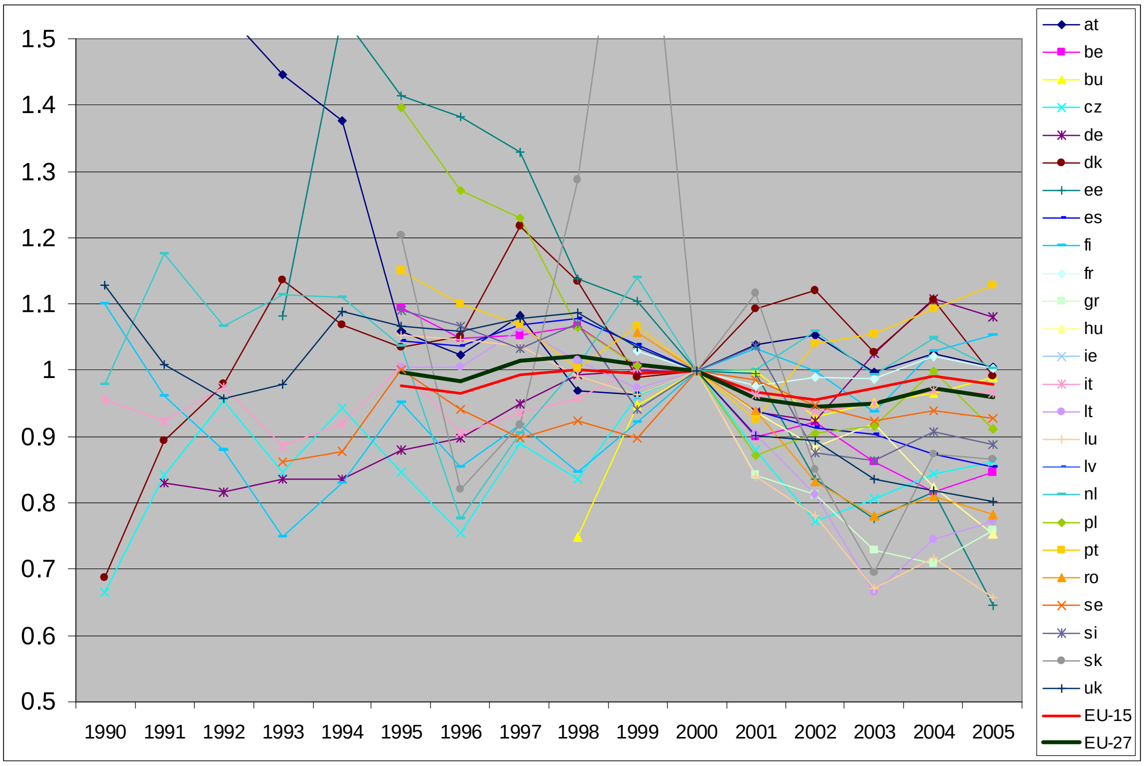
[20] CEFIC Facts and figures 2007 (www.cefic.org)

In CRF tables, only process emissions from clinker production are considered. According to the BREF[21] approximately 62% of the CO_2 emissions originate from the calcination process and whereas 38% relate to energy consumption. Germany report GHG emissions related to energy consumption in cement production, but most other member states have included this in Table1s1 f. Other. Separate reporting would allow to analyze changing trends among member states. *For GHG projections it would also be logic to use the same activity variables for process emissions and energy consumption.*

Activities projection

Cement is mainly produced for local consumption and is exceptionally transported over long distances. However, a map of EU-27 looks like patchwork and exports and imports of cement are still considerable compared to local production. For smaller member states net trade (export – imports) can take up to 50% of local production.

Figure 45 Clinker production related to value added in construction sector



Imports and export of cement are not the only reason for changing trends and fluctuations in the clinker production/value added relationship ratio. Changes in the clinker content in cement and changes in production methods and choice of building materials are important too. However, for EU-15 and EU-27 we can observe a relative stable relationship between clinker production and value added of the production sector.

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[21] IPPC, Reference document on Best Available Techniques in the Cement and Lime industries.

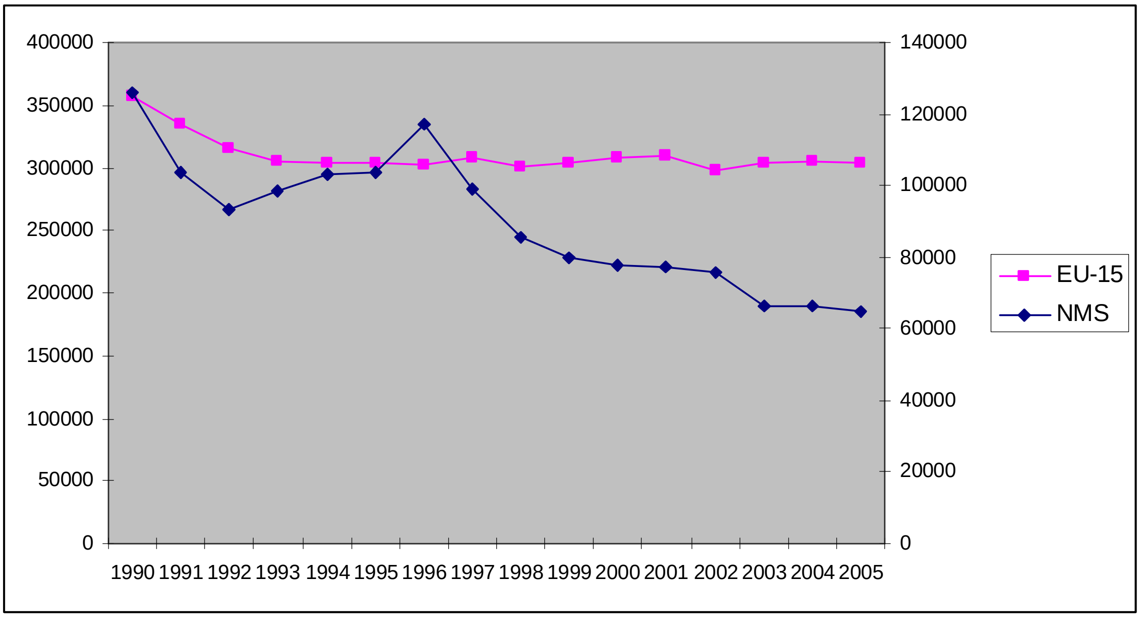
MS facing high economic growth figures might expect strong growth figures for the construction sector as well. Growth figures for the construction sector might exceed GDP expectations in those countries.

13.2.2.4 Other non-specified activities

This sector covers 39% of the industrial CO_2 emissions in EU. Approximately 5% of this relates to energy consumption in cement production. The remaining 34% covers other activities, not elsewhere mentioned in the CRF tables (see annex).

CO_2 emissions for this category have decreased by 1% per year between 1995 and 2005. For EU-15 these emissions have stabilized from 1995 onwards, whereas for the new member states they have decreased by 4.6% yearly between.

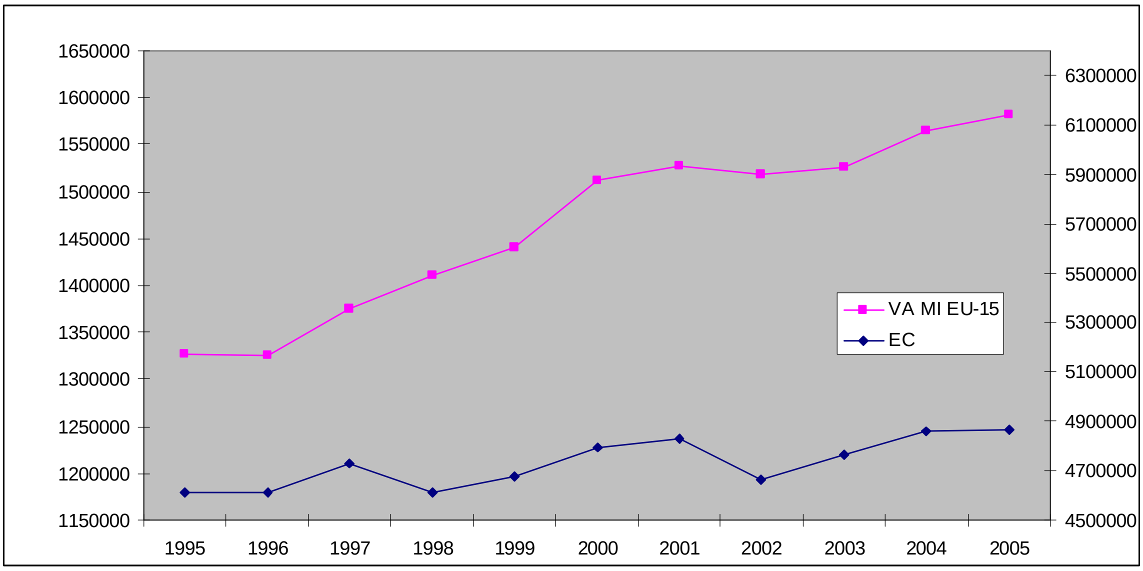
Figure 46 Trends in GHG emissions for other industries



In EU-15 energy consumption increased by 0.5% yearly between 1995 and 2005. The stabilization of GHG emissions in this period is the result from fuel switching.
The share of gas in energy consumption increased from 46% in 1995 to 53% in 2005 and biomass increased from 3.9% to 5.9% in the same period. Solid fuels decreased from 16% to 10%.

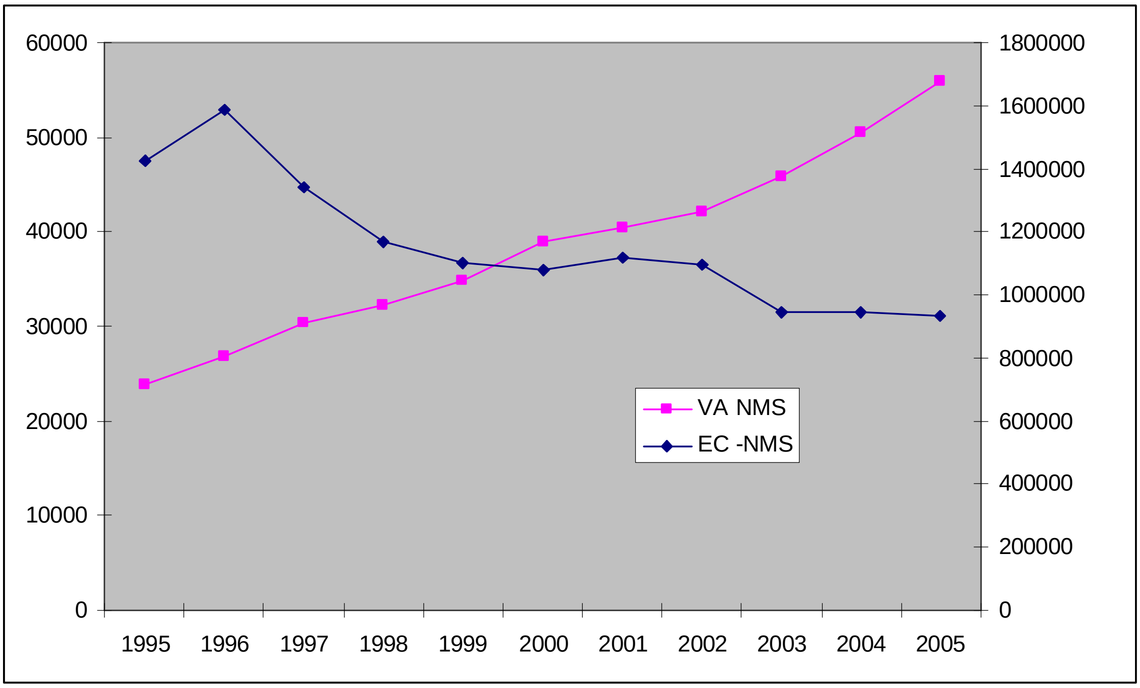
Value added has increased by 1.87% yearly. The relationship between energy consumption and value added in presented in Figure 47. This graphs can be interpreted in different ways. Either we can say that there is a one to one relationship (unit elasticity) and an energy efficiency improvement, either we can say that we only observe an elasticity of 0.27. An analysis at MS level might provide more insight into this.

Figure 47 Energy consumption of other industries and value added in EU-15



For the new member we have a complete different situation Value added has increased by 8.9% yearly whereas energy consumption has decreased by 4% yearly.

Figure 48 Energy consumption of other industries and value added for the new member states



13.2.3 Tier 1: Simple approach based on activity data

The development of GHG emission scenario requires an activity scenario expressed in physical terms or in value added.

Step 1: Defining the appropriate country specific aggregation level.

A high level of sector detail does not necessarily improve the accuracy of GHG projections. Increasing the level of detail often involves additional problems:

- historical data are difficult to obtain at low aggregation levels
- establishing a statistical relationship with the global economy (GDP) is difficult at low aggregation levels.
- unless specific additional information is available, one is often forced to use the same trends for different activities within one sub-family. In this case the low aggregation level does not provide any value added.
- the economy is constantly changing. New activities (products, production methods) arise at the cost of existing activities. In practice (for psychological and political reasons) it appears to be difficult to develop down sizing activity scenarios while new activities are always granted with an optimistic view.

One common characteristic of energy intensive activities is that they produce huge amounts of GHG emissions compared to value added. Typical energy intensive industries are: iron and steel (in particular pig iron), clinker production, cracking activities (ethylene, propylene..).

Generally the principle can be used that individual industrial activities for which GHG emissions amounting to 5% of total industrial GHG emissions should be handled individually and activity variables preferable expressed in physical units. Value added is a poor indicator of economic activity

For other sectors it is difficult to express economic activity in terms of physical output. Also output data expressed in monetary terms are scarcely available. If relevant output variables are not available it is recommended to express these activities in terms of value added.

Step 2: Defining activity projections

In principle activity projections should be consistent wit a macro-economic scenario. Economic consistency can be considered in two directions:

- Industrial sectors produce value added and consequently contribute to GDP
- GDP as the driving factor for demand of industrial goods.

A. Activities are expressed in physical quantities

The value added of these activities is limited. Economic consistency in the first sense is not relevant here. However, economic consistency in the second sense is still relevant. It depends whether the production is mainly for domestic use or for exports. If the domestic market is dominant then analysis of historical data can be used as a framework.

If the historical trend to GDP tends to be stable, this relationship and GDP projection can be based to produce activity projection. If this relationship does not demonstrate a stable relationship (based on graphical or statistical analysis), then this trend should not be extrapolated. More detailed levels in the macro-scenario can be used too (e.g. construction activities for cement production)
In exceptional cases it might be appropriate to keep this ratio constant at the latest observed level or at another level if the latest observed level seems to be exceptional.

Use of additional information:
Energy intensive sectors tends to be very capital intensive and maximum profitability is obtained when operating at full capacity. Capacity limits can be considered in projections. Large expansions require huge investments, involving new environmental permits. Independent industry experts can often provide useful insights too. Sometimes it is useful to contact industry representatives.

B. Activities are expressed as value added.
In this case activity data should be consistent with the macro-economic scenario as well.

National statistical sources can be used or EUROSTAT national account statistics branches in 17 or 31 branches can be used.

Step 3: Energy efficiency improvements.

Historical energy efficiency improvements can be derived from historical activity indicators and sector fuel consumption statistics reported in CRF. Energy efficiency improvements are the result of technological innovation.

Step 4: Emissions calculations

Emissions are calculated based on constant fuel shares and implied emission factors as specified in Table1.A(a)s2. Process emissions are calculated by multiplying the implied emissions factors of Table2(I).A-Gs1 and the activity data.

13.2.4 TIER 2 - Integration of industry in linear programming model for the electricity sector.

In TIER1 the focus is on the demand side (development of an activity scenario). In TIER 2 we add an additional focus on the supply side.
TIER 2 is based on an explicit representation of the technologies. This allows to

- explicitly introduce capacity limitations
- represent different options
- to evaluate the new technologies
- to have a consistent framework to evaluate CHP policies

- to model the interactions between industry and the electricity sector and between different industry sub-sectors (cfr. blast furnace gas use by power sector, slacks use for Cement production)
- to evaluate const-effectiveness of PAMs

Requirements: basic training in developing Markal -Times or Message model.

Remark: Nace codes for sector other industries

db: textile and textile products
dc: leather and leather products
dd: wood and wood products
dh: rubber and plastic products
dk: Manufacture of machinery and equipment n.e.c.
dl: Manufacture of electrical and optical equipment
dm: Manufacture of transport equipment
dn: Manufacturing n.e.c.

13.3 Preliminary guidelines for the chemical industry (process N_2O)

N_2O emissions from the chemical industry are an important contributor to greenhouse gas emissions. N_2O emissions from caprolactam, adipic acid or nitric acid production plants are most important.

13.3.1 Tier method

There is only 1 tier method present in the good practice guidelines for inventories (http://www.ipcc-nggip.iges.or.jp/public/). It estimates emissions by multiplying production by a specific emission factor, corrected for specific abatement technologies:

N_2O emissions = EF * production * [1 – (N_2O destruction factor * abatement system utilisation factor)]

The best is to use the method on a plant level, if this is not possible, default factors are available in the good practice guidelines.

For projections, the same method can be used as for inventories. The method needs future production data and future possible abatement techniques that will be implemented. If no information on future trend is available, the production data and abatement techniques can be kept constant as a first estimate.

13.3.2 Elements for further development of the guidelines

Since the methodology for inventories and projections as such is straightforward, the important issue is to get good (projected) activity data and information on possible abatement techniques. This is something that needs to be further elaborated. In the following paragraph, some links to possible information sources are given.

Possible sources of relevant information to get (historical) activity data and information on abatement techniques

- o Eurostat prodcom statistics:

http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2594,63266845&_dad=portal&_schema=PORTAL

label	*description*
24143385	Adipic acid; its salts and esters
24151050	Nitric acid; sulphonitric acids
24145270	6-Hexanelactam (epsilon-caprolactam)

- o Production data on fertilizer (Nitric acid is used as a raw material mainly in the manufacture of nitrogenous-based fertiliser.):
  - International Fertilizer Industry Association (http://www.fertilizer.org/ifa/ifadata/search)
  - European Fertilizer Manufacturers Association (http://cms.efma.org/EPUB/easnet.dll/execreq/page?eas:dat_im=000BCE&eas:template_im=000BC2)

- o Information on abatement techniques can be found at the EIPPC. This information can be used in order to get an appropriate emission factor: (http://eippcb.jrc.ec.europa.eu/pages/FActivities.htm)

13.4 Preliminary guidelines for fugitive emissions (CH_4)

Sources of fugitive emissions can come from coal mining or handling and oil and gas operations. When mining and handling coal, the trapped CH_4 in the coal comes free. Fugitive emissions from oil and gas activities include emissions during exploration, production, processing (including venting and flaring), transport, distribution and use of oil and gas and non productive combustion (like flaring). Other emissions occur also, but CH_4 emissions are the most important.

13.4.1 Tier methods

13.4.1.1 Coal mining and handling (CH_4 emissions)

The 1996 inventory guidelines and the Good practice guidelines for inventories (http://www.ipcc-nggip.iges.or.jp/public/) describe 2/3 tier methods for underground mining, surface mining and post mining. The tier methods described for these sources, can also be used for projections.

- A tier 1 method (no key source) calculates emissions by multiplying coal production with an average emission factor. Future coal production data should be gathered or estimated and multiplied with the emissions factors used in inventory.

- A tier 2 method uses more detailed country specific or basin specific data and emission factors that reflect the average methane content of the coal that is mined. Sometimes even measurement data are available. The same method can be applied for future projections, if data on future coal production data per basin are available.

Both tiers rely on future coal production data. If no information is available, the values can be kept constant from the last year of inventory data as a first estimate.

In the 2006 guidelines[22], additional guidance is given to calculate emissions from abandoned coal mines. If these coal mines are not fully flooded, CH_4 can leak through to the surface and should be included in the inventory (and projections). This CH_4 could be used as energy source (and should then be included as energy source with resulting emissions in the energy sector), or can be flared on site. If included in inventory results, estimates should be made also in projections, using the same tier method as in the inventory.

13.4.1.2 Oil and gas operations (CH_4 emissions)

Again, the inventory methods are best used for projection estimates. The 1996 inventory guidelines and the Good practice guidelines for inventories describe 3 tier methods for oil operations and 2 tier methods for gas operations (tier 1 and tier 3, no tier 2):

- Tier 1: production based average emission factor approach
- Tier 2: mass balance approach (only for oil, not for gas)
- Tier 3: source specific approach

The methods are described in the guidelines. These can also be used in projections, using future production data and emission factors. When these are not available, they can be kept constant to the last year of inventory as a first estimate.

13.5 Preliminary guidelines for the residential sector (CO_2)

13.5.1 Introduction

Energy consumption in dwellings is determined by three elements, people and their expectations, climate and building characteristics. Building characteristics and peoples expectations can be influenced by various sorts of policies, reduction measures or other external influences.

The ideal projection model should consider these three elements and meet the following requirements:

- be able to make a projection on the evolution of the needs for housing;
- be able to explore the reduction potential by various energy reduction measures;
- be able to develop and evaluate long term scenarios (due to the large lifetime of buildings);
- be able to evaluate the basic aspects of sustainable development in scenarios;

[22] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf

- be able to account for the two kind of rebound effects:
  - rebound effects related to behaviour changes: this type of rebound effects can be considered as price reactions;
  - non-voluntary rebound effects related to the physical properties of buildings.
- be able to account for climate differences and climate fluctuations (degree days);
- be able to quantify the effect of changing energy prices.

Different European policies influence the energy consumption of the European households. The following policies considered as the most important:

- Directive 2006/32/EC on energy end-use efficiency and energy services;
- Directive 2002/91/EC on energy performance of buildings (EPBD);
- Directive 92/75/EECon labeling of household appliances;
- Directive 2005/32/EC on ecodesign for energy-using appliances.

Accurate projection models should incorporate the impact of these policies.

Optimization models, and also the engineering models[23], are able to incorporate a detailed representation of the building (and appliances) stock, so the impact of policies can be estimated. On the other hand, if a MS has a poor knowledge of the building (and appliances) stock, other projections methods will need to be used. These latter projection methods will estimate the energy projections for the dwelling stock in a rather simple manner, mainly based on demographical data.

The energy consumption of the residential sector has to be subdivided into two major pillars: the energy consumption for heating and sanitary hot water (SHW)[24] on the one hand and the electricity use for appliances and lighting on the other hand. The CO_2-emissions of the residential sector are only related to the energy consumption for heating and SHW[25], because the emissions of the electricity consumption are accounted to the energy sector. So, the residential electricity projections form input data for the electricity model.

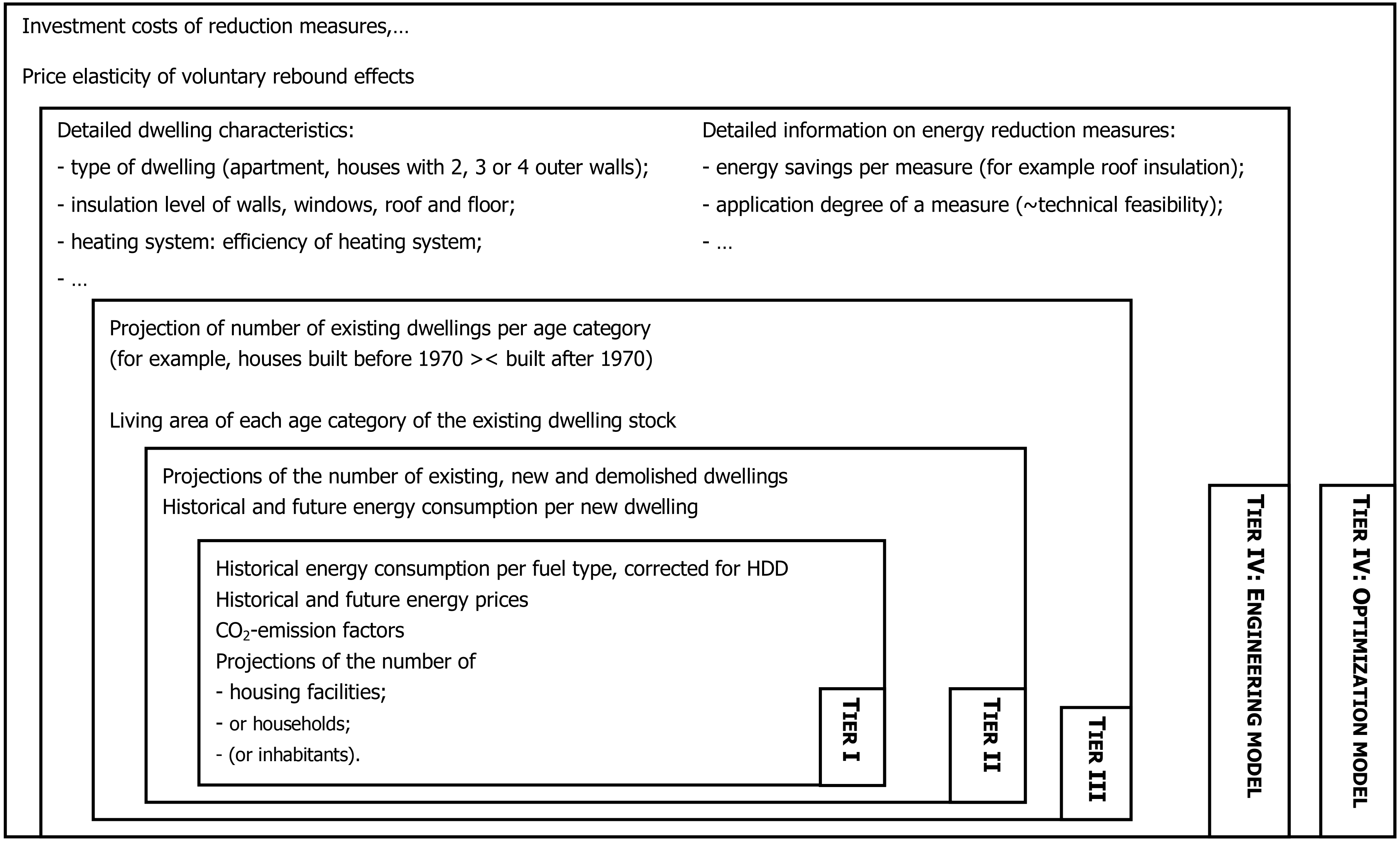
In the next paragraphs, different methodologies are described to forecast the residential energy use, for the energy consumption for heating and SHW on the one hand and electricity use for appliances and lighting on the other hand. The lower Tiers will result in rather simple models, the higher Tiers in very detailed models, but these methodologies will need a detailed knowledge of the building stock. The required data for the different Tier methods are presented in Figure 49.

[23] For a general definition of optimization and engineering models, see Annex 3.

[24] Mainly fuel use, but also electric heating, and district heating.

[25] Except the emissions of electric heating, which are related to the electricity sector. The electricity use for heating and SHW has to be estimated in the same way than the fuel use for heating and SHW. But, the CO_2-emissions of this electricity use are related to the electricity sector, so they can't be estimated according to these Tier methods of the residential sector.

Figure 49 Summary of Tier methods for estimating future energy consumptions for heating and SHW



13.5.2 Energy use for heating and sanitary hot water

13.5.2.1 Correction of historical data

How to handle Heating Degree Days

The energy use for space heating of the residential sector is highly dependent on the outside temperature. As a consequence, this dependency is taken into account in the calibration of the projections for households by means of the Heating Degree Days (HDD).
Heating degree days are quantitative indices designed to reflect the heating demand of a house. The higher the figure, the higher the need for heating. These indices are derived from daily temperature observations. The heating requirements for a house are considered to be directly proportional to the number of heating degree days. More specifically, the number of heating degrees in a day is defined as the difference between a reference value of e.g. 18℃ and the average outdoor temperature of that day. To know the number of heating degree days of a year, the daily heating degree days are added over this year to provide a rough estimate of the yearly heating requirements:

$HDD_{year\ n} = \sum (18\ ℃ - T_m)$ *for the days of 'year n' that* $T_m \leq 15\ ℃$

With: $T_m = (T_{min} + T_{max})/2$ = *the mean outdoor temperature of a day;*
15 ℃ can be considered as the heating threshold.

Historical degree days (18-15) statistics are now available in EUROSTAT for all EU-member states from 1980 to 2007 and are plotted as indices in Figure 50 and Figure 51. Some countries may possess HDD data for other thresholds, like 20-12.

Fluctuation of degree days is the most significant parameter explaining short term fluctuations of residential energy consumption for heating. Therefore, it is recommended to calibrate the historical figures in order to determine (changes in) trends in historical energy consumptions (other than temperature). How this calibration is performed is explained in Annex C - 3.
Concerning the GHG projections, they are also explicitly or implicitly based on expectations of degree days. Preferably, the energy projections for heating and SHW depart from an average value over a longer period, for instance the average value of 1990-2005.

Figure 50 Evolution of the heating degree days (18-15) in EU15 (1990-2005)

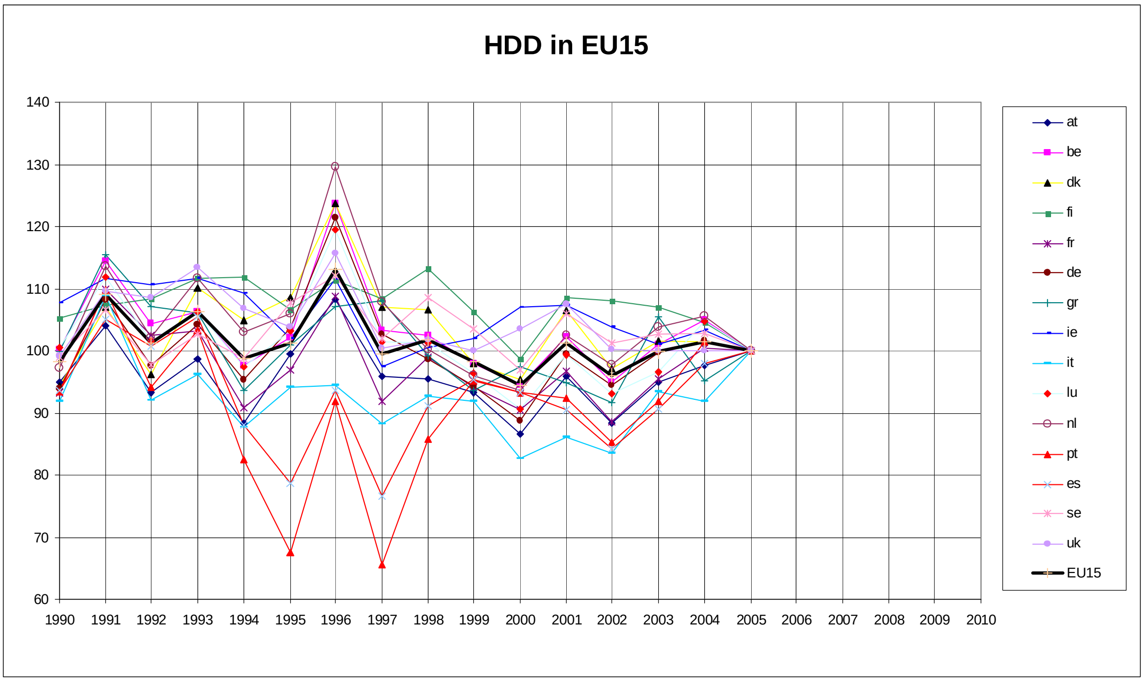
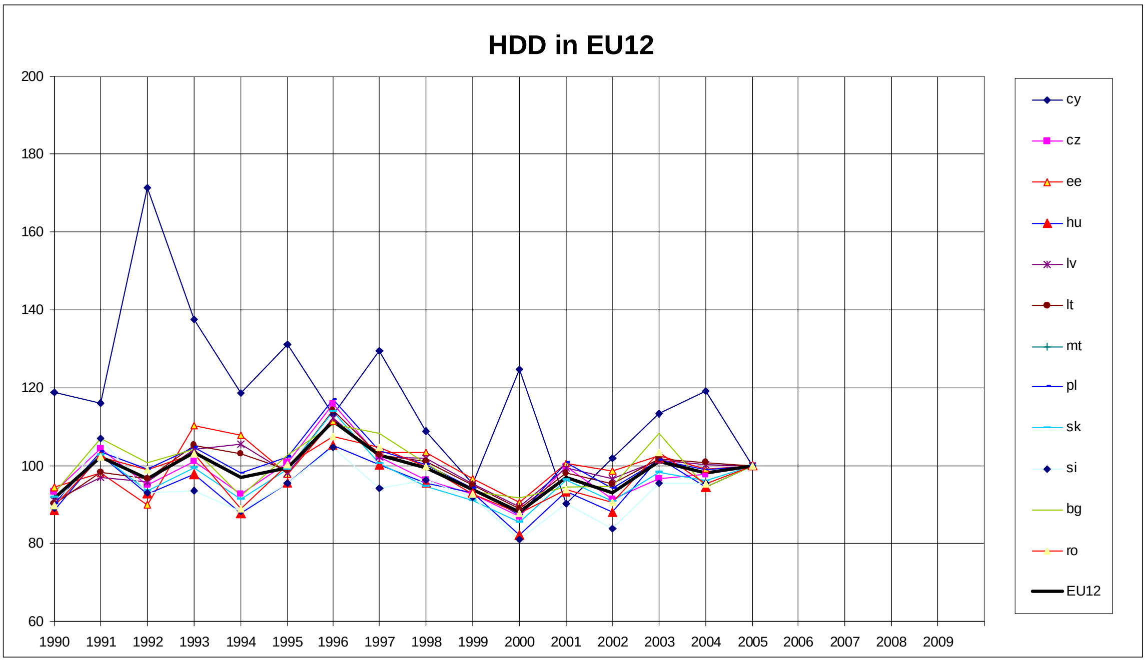


Figure 51 Evolution of the heating degree days (18-15) in EU12 (1990-2005)



Importance of historical observations

In the TIER methods, it is recommended to estimate the future energy consumptions for heating by means of building characteristics, demographic data and energy prices. Nevertheless, these three factors can't explain the trends of the historical numbers entirely. Other hidden effects, for instance the increase of the frequency of taking a shower, can influence the energy consumption. Great changes in a country's politics has also a large impact on the energy consumption. A lot of East-European countries show a strong change of energy use during the nineties, as you can see in Annex C - 1. The energy consumptions during this transition period are to variable to be used as references for the energy projections. Instead, historical data of a rather stable period are recommended as basic data.

So, before making the energy projections, a close look to the historical energy consumptions is required. The understanding of historical trend(s) could make the projections more accurate.

13.5.3 Tier methods for heating and sanitary hot water

In the next paragraphs, different Tier methodologies are described to estimate the residential energy use. The lower methods will result in rather simple models, the higher method in very detailed models, but this methodology will require a detailed knowledge of the building stock.

Whatever the level of detail of the Tier methodology, the projection methodology can always be reduced to one or more of the following pillars (see also Figure 1 and Figure 2):

- Demography;
- Building characteristics:
    - Compactness determined by the total surface of heat loss and protected volume;
    - Insulation level;
    - Boiler efficiency.
- Influence of energy prices.

Only a detailed model allows a good analysis of the impact of reduction measures on the energy consumption of the residential sector. The simple Tier methods can be used to estimate the impact of some policies, like the EPBD for new dwellings, but these impact studies are very limited.

It should be mentioned that before making the energy projections, the historical data of heating and SHW need to be corrected for heating degree days based on the above methodology. As a result, accurate reference data are obtained.

Another remark concerns the emissions of electric heating and district heating. The energy consumption for electric and district heating has to be estimated according to the next Tier methods[26], but the related CO_2-emissions are estimated by the Tier methods of another sector. Concerning electric heating , the CO_2-emissions are accounted to the energy sector. Concerning district heating, the CO_2-emissions can be accounted to the energy sector or another sector.

[26] Normally, the share of electric heating in the total electricity consumption isn't known. So, to separate electric heating from the total electricity consumption, assumptions on this share need to be made by the MS.

13.5.3.1 Tier I: Top-down projection based on demography

The most important variable of this projection methodology is demography. In general, the future energy consumptions will be estimated based on future projections of the number of households or the number of dwellings.

Step 1: Collecting of demographical projections

The projections of the number of inhabitants are normally estimated by the national statistics bureau. Often, the number of households will be projected too. On the other hand, the projections of the number of dwellings are more difficult to obtain. The current number of dwellings and the estimation of the future number of dwellings per household will determine the latter projections.

To estimate the future energy consumption, the number of dwellings will obviously be the most accurate variable. If this is not available, it is recommended to use the projections of households. The number of inhabitants can also be used, but will result in less reliable energy projections.

Because a dwelling can have more than one housing facility, like an apartment, it is more appropriate to use the number of housing facilities, instead of the number of buildings.

Step 2: Making projections based on the energy consumption per dwelling (household or inhabitant)

The historical data of the total energy consumption of the residential sector, corrected for HDD, have to be expressed in energy consumption per dwelling (or per household or per inhabitant). Once this is calculated, projections of the energy consumption can be obtained in two different ways.

Option 2a

The average of the historical energy consumptions per dwelling (household or inhabitant) is calculated. It is advised to base this average on the last three yearly moving average (see Annex C - 1) of the historical energy consumptions (corrected for HDD):

$$C_x = Xcal_{av} / (\text{mean } \#dwellings_{t-1,t,t+1})$$

With: C_x = *historical, average energy consumption per dwelling in country x;*
$Xcal_{av}$ = *three yearly moving average of the most recent observations corrected for HDD;*
mean $\#dwellings_{t-1,t,t+1}$ = *average total number of dwellings of the three most recent years for which historical observations are available.*

To make the energy projections, one assumes a constant energy consumption per dwelling for the entire estimation period. So, the future energy consumption in a year will be the historical, average consumption per dwelling C_x multiplied by the projected number of dwellings of that year:

$X_{t,x} = C_x * \#dwellings_t$

With: $X_{t,x}$ *= estimated energy consumption for year t in country x;*
$\#dwellings_t$ *= projected number of dwellings for year t in country x.*

So, the driven force of this prognosis is the demography.

A constant energy consumption per dwelling assumes no implementation of reduction measures, neither in the existing building stock, nor in the new building stock. To estimate the effect of reduction measures, a more detailed projection method will be necessary (see Tier IV).

> Remark: If the number of inhabitants or households is used in the projections, it will be necessary to incorporate the economic growth of a country if a strong correlation is detected between the private consumptions of households CPO (or Gross domestic Product GDP) and the residential energy consumption. Based on the CPO elasticity indicated in Table 38 of Annex C - 3 and the projections of CPO (or GDP), the correction of the future energy uses for economic growth can be performed.

Option 2b
Instead of a constant energy consumption per dwelling, the trend of this variable observed in the historical data will be linear extrapolated to the future. It is recommended to base this trend on the last six years, more specifically on the last three or four 'three yearly moving averages $Xcal_{av}$ (see Annex C - 1)'. So, besides a projection of the number of dwellings, an extrapolation of the energy consumption per dwelling is taken into account.

But, an extrapolation of the historical trend is only permitted, if the following holds true:
- The historical trends seems logically, based on policy, demography,…
- Price elasticity (see Annex C - 2):
    - The price elasticity is small or
    - The price elasticity is big, but: although the energy prices increases (decreases), the historical, corrected energy consumptions increase (decreases) too.

  In the latter case, an extrapolation of the trend, and not Option 2a is advised.

The obtained projection can't be a reference scenario to calculate the impact of reduction measures. To this end, the Option 2a is more suitable, because of the constant energy use per dwelling.

Step 3: Taking energy price effects into account

To account for the impact of changes in fuel prices on the energy projections, price elasticity will be used (see Annex C - 2). The average short term fuel price elasticity has been estimated econometrically and amounts -0.11 on average. A MS can use this average value as a default value for price elasticity, if no other country-specific value can be estimated.

Besides the price elasticity, assumptions on the evolution of future fuel prices are required. This evolution is determined by the MS. In addition, the changes in fuel prices have to be compared with a reference fuel price. This reference is the last observed fuel price for example from Eurostat.

In summary, the impact of changes in fuel prices is estimated based on the following formula:

$$\%(X_{t,x,fuel\ price} - X_{t,x}) = \alpha\%(p_t - p_{Eurostat})$$

With: $X_{t,x,fuel\ price}$ *= estimated energy consumption for year t in country x corrected for energy prices;*

$X_{t,x}$ *= estimated energy consumption for year t in country x (Step 2);*

$\%(X_{t,x,fuel\ price} - X_{t,x})$ *= Change of energy consumption in terms of percentage;*

α *= short term fuel price elasticity;*

p_t *= estimated fuel price for year t;*

$p_{Eurostat}$ *= last observed fuel price, for example out from Eurostat;*

$\%(p_t - p_{Eurostat})$ *= Change of fuel price in terms of percentage.*

Step 4: Translating energy projections into CO_2-projections

In this step, the total, projected energy use will be expressed in CO_2-emissions. Therefore, the total energy use has to be distributed among the different fuels, like natural gas, wood, etc. Two options exist to perform this, which resembles the two options of the preceding step.

Option 4a

The average of the historical shares of each fuel in the total energy consumption. It is advised to base this average on a recent period with good, representative data. The period used for the three yearly moving average $Xcal_{av}$ could be a good base period. These average shares are held constant for the entire projection method.

Option 4b

Instead of a constant share for each fuel, the trend of the fuel shares observed in the historical data will be linear extrapolated to the future. It is advised to base this trend on a recent period with good, representative data, for instance the last six or five years. To obtain good results, it is necessary to rescale the extrapolated shares so the sum of all shares remains 100%.

Once the energy projections per fuel are known, they can be transformed into CO_2-projections by means of their CO_2-emission factors. These emissions factors are based on IPCC default factors (IPCC guidelines 1996 or good practice guidelines) or country specific emission factors per fuel type. Of course, the electric and district heating can't be transformed immediately to CO_2-emissions, but has to be input parameter of the electricity model,…

The sum of all CO_2-emission projections per fuel will result in the total CO_2-prognosis of the residential sector concerning heating and SHW.

Impact of reduction measures

With Tier I methodology estimating the impact of reduction measures is more or less impossible. But, the policy which effects the fuel mix in a country (like a policy which increases the possibility of dwellings to connect to the natural gas network or a policy which promotes renewable energy) can be incorporated into the projections. So, the difference between the projections with or without this policy reveals the impact of these reduction measures. To this end, one has to translate the objectives of this policy into assumptions concerning the fuel shares in the future.

13.5.3.2 Tier II: Top-down projection based on demography: existing versus new dwellings

The Energy Performance of Buildings Directive (EPBD) has a great influence on the regulation of the new dwellings stock. The impact of this measure on the energy projections can be estimated by separating the existing and new dwelling stock.

Step 1: Separating dwelling stock into existing and new dwellings

Besides the projections of the dwelling stock (housing facilities), a division between existing and new dwellings is required. The start year of effective legislation for new dwellings (e.g. EPBD) can be taken as the start year of the building of new dwellings (=st new). As a consequence, all houses built before this year can be considered as existing houses.

The rise of the number of dwellings - corrected for demolition - between this start year and the end year of the projections corresponds approximately with the number of new dwellings:

$$\#new\ dwellings_{t,x} = \#dwellings_{t,x} - \#existing\ dwellings_{st\ new,x} + demolition_{t,x}$$

With: $\#new\ dwellings_{t,x}$ *= cumulative number of new dwellings built until year t in country x;*

$\#dwellings_{t,x}$ *= estimated total number of dwellings for year t in country x;*

$\#existing\ dwellings_{start\ new,x}$ *= total number of existing dwellings in country x based on the start year of considering new dwellings (st new);*

$demolition_{t,x}$ *= cumulative number of demolished dwellings until year t in country x.*

The quality of the number of demolished dwellings is often limited. As a consequence, assumptions are often required. An example of an appropriate assumption is keeping the yearly amount of demolished dwellings constant.

If demolition is considered, a MS can't keep the number of existing houses constant in the entire projection period, because demolition causes a yearly decrease of the existing housing facilities.

As a result, the MS will obtain projections of the existing and new dwelling stock.

Step 2: Estimating future energy consumption of the existing dwelling stock

This step corresponds to step 2 of Tier I (Option 2a). But attention should be given at:

- Instead of using the projections of the total dwelling stock, the number of existing dwellings need to be used.
- Only Option 2a can be used, otherwise the impact of energy efficient new dwellings can't be estimated.
- The determination of the total historical energy consumption of existing dwellings can be difficult:

If the start year of the projections corresponds with the start year of new dwellings, the historical energy use of the existing housing stock can be easily defined because all observed energy consumptions are accounted to the existing housing facilities.
But, if the start years differ and new dwellings are consequently already built before the start year of the projections, the total historical energy consumption of new dwellings has to be estimated first (see next step). The remainder part of the observed energy consumption are attributed to the existing dwellings:

$\text{Total historical energy use existing dwellings}_t =$
$\text{total observed energy use}_t - \text{estimated total historical energy use new dwellings}_t$

The estimation of the historical energy consumptions of new dwellings can start from assumptions on the historical energy consumption per new dwelling (next step). Surveys of theoretical estimations based on building physics can give these assumptions a basis.

Step 3: Estimating future energy consumption of the new dwelling stock

The EPBD demands a certain energy level of new dwellings in the MS, which has to decrease in the future. In this step, the energy level must be translated into an average energy consumption per dwelling. Typical housing characteristics of new dwellings (higher insulation level, higher boiler efficiency, a certain compactness) will result in a lower energy level compared to existing buildings, according to EPBD. This energy level can be kept constant or can decrease during the entire projection method. This depends on which policy a MS would like to implement.

Multiplying the average energy consumption of a new dwelling by the projections of the number of new dwellings will result in the prognosis of the energy use of the new dwelling stock:

$Xnew_{t,x} = Cnew_x * \#new\ dwellings_t$

With: $Xnew_{t,x}$ *= estimated total energy consumption of new dwellings for year t in country x;*
$Cnew_x$ *= energy consumption per new dwelling in country x;*
#new $dwellings_t$ *= projected number of new dwellings for year t in country x.*

Step 4: Estimating future energy consumption of the entire dwelling stock

The aggregation of the projections of step 2 and step 3 results in the projections of the entire stock.

Step 5: Taking energy price effects into account

This step corresponds to step 3 of Tier I.

Step 6: Translating energy projections into CO_2-emissions

This step corresponds to step 4 of Tier I. Option 4a, as well as 4b are appropriate estimation methods.

Because the energy projections are known for the existing as well as for the new dwelling stock, it can be interesting to make different fuel mix projections for both dwelling categories. Based on national policies or, if available, on historical evolutions, the fuel mix of the new dwelling stock can be determined. The fuel mix of the existing dwelling stock can be kept constant or can evolve based on historical numbers (if available) or national policy goals. In this way, policies affecting the fuel mix of existing as well as new dwellings can be estimated.

The sum of all CO_2-emission projections per fuel will result in the total CO_2-prognosis of the residential sector concerning heating and SHW.

Impact of reduction measures

Estimating the impact of reduction measures by means of the Tier II methodology is still very limited. The impact of EPBD on the new building stock and the impact of policies which effect the fuel mix can be calculated for a MS. The latter impact was already mentioned in the previous Tier methodology.

13.5.3.3 Tier III: Top-down projection based on demography: different age categories of the dwelling stock

In this Tier methodology, the existing building stock will be subdivided into at least two age categories. The new dwelling stock will also be considered as an individual age category. The surplus of this age division is the possibility to take a more accurate demolition of dwellings into account. This way, structural measures in the housing market, like the promotion of new dwellings coupled to an increase of the demolition of existing building, can be investigated.

Step 1: Separating the building stock

The division of the existing stock is only possible, if data on the ages of the existing housing facilities are available in a MS.
When the existing building stock will be divided into two age categories, the separation year has to be an important year concerning the dwelling characteristics of houses. For example, in Belgium, the houses built before 1970 are less insulated than the houses built afterwards. The oil crisis of the seventies explains this change in dwelling characteristics. So, 1970 will be used as separation year for the existing stock in Belgium.

The existing stock may also divided into more than two categories. But, if a MS wants to do this, one has to make sure that enough data on living area etc. of the different age categories are available (see next step).

Once the entire existing stock is subdivided, the future number of existing dwellings per age category has to be estimated too. The number of existing housing facilities will decrease because of demolition. Because of the extra information on the ages of dwellings, assumptions on demolition can be made for each age category separately. For instance, the oldest age category will be affected solely or mostly by demolition. Other assumptions are also possible.

The estimation of the number of new dwellings is described in step 1 of tier II.

Step 2: Estimating future energy consumption of the existing dwelling stock for each age category

This step corresponds to step 2 of Tier II, but this time the energy consumption per existing dwelling can't be based only on historical energy data, because of the age separation.

A possible way to calculate the average historical energy consumption for each age category of the existing dwelling stock, is taking the average living area per dwelling of each age into account.
So, first of all a MS expresses the historical data of the total energy consumption of the existing dwellings, corrected for HDD, in energy consumption per dwelling (see step 2 Tier II). This average corresponds to the average energy use per existing dwelling of the entire existing dwelling stock. Subsequently, a MS can split this average consumption up into the different age categories by using the proportions of the living area of each dwelling age. This splitting up is based on the following equation:

$$C_x = La_1/(La_1 + La_2) * Cx_1 + La2/(La_1 + La_2) * Cx_2$$

With: C_x = *historical, average energy consumption per existing dwelling in country x;*
La_1 (La_2) = *average living area of age category 1 (2);*
Cx_1 (Cx_2) = *energy consumption per existing dwelling of age category 1 (2).*

As a result, the average historical energy consumptions per dwelling for heating and SHW of each age category are obtained.

If a country possesses other information than living area of each age category, this info can be used too to separate the average energy consumption. Other good indicators of energy consumption are the insulation level of a dwelling, the boiler efficiency, the compactness of a house, etc.

In this Tier III method, the energy consumption per existing dwelling will be kept constant in the entire projection period. As a consequence, no reduction measures are considered in the existing stock. To estimate the effect of reduction measures, a more detailed projection method will be necessary (see Tier IV).

The multiplication of the projections of the number of existing dwellings (Step 1) and the average energy consumption per dwelling for each age results in the energy projections of the existing dwelling stock for each category.

Step 3: Estimating future energy consumption of the new dwelling stock

This step equals Step 3 of Tier II.

Step 4: Estimating future energy consumption of the entire dwelling stock

The aggregation of the projections of step 2 and step 3 results in the projections of the entire stock.

Step 5: Taking energy price effects into account

This step corresponds to step 3 of Tier I.

Step 6: Translating energy consumptions into CO_2-emissions

This step corresponds to step 6 of Tier II.

It should be mentioned that if the fuel mix of the existing dwelling stock is known per age category, this needs to be taken into account, because demolition in a certain age category will change the fuel mix too.

The sum of all CO_2-emission projections per fuel will result in the total CO_2-prognosis of the residential sector concerning heating and SHW.

Impact of reduction measures

Estimating the impact of reduction measures by means of the Tier III methodology is still limited. Besides the impact of EPBD on the new dwelling stock and the impact of policies which effects the fuel mix (see Tier I and Tier II), the impact of structural measures can also be estimated for a MS. An example of a structural measures in the housing market could be the building of new dwellings coupled to more demolition of existing building.

13.5.3.4 Tier IV: Bottom-up projection based on detailed housing stock information

As already mentioned in the introduction, an accurate model should meet different requirements. Engineering models and optimization models are very accurate models because they are able to:

- explore the reduction potential by various energy reduction measures;
- develop and evaluate long term scenarios because of the large lifetime of buildings;
- account for rebound effects.

Engineering models can only take un-voluntary rebound effects into account, in contrast to the optimization models which can incorporate un-voluntary as well as human related rebound effects. The latter rebound effect will be estimated by introducing a price elasticity. The un-voluntary rebound effect can be solved in every bottom-up model by correcting the energy savings attributed to the different reduction measures.

Engineering models, as well as optimization models, calculate the energy consumption for space heating and hot water production bottom-up wise. They also use some calibration method to fit the global result with observed data from national energy balances. Both model types start from a detailed representation of the dwelling stock. The main advantage of such a detailed structure is that it allows to identify and quantify opportunities for improvement.

The largest difference between engineering and optimization models is the considering of various alternative reduction measures in the optimization model. Alternative reduction options are represented in the optimization model by their ability to save energy as well as by their costs of implementation. Sometimes the resolution of the dwelling stock might have been reduced compared to the engineering model for practical reasons.

Besides the impossibility to take voluntary rebound effects into account, another disadvantage of engineering models is the limited ability to estimate changes of energy prices by means of price elasticity. Like in the preceding Tier methods, it is possible to correct the final energy projections for price effects afterwards by means of elasticity. In optimization models, this correction is more realistic because the investment costs of the reduction measures and energy prices are considered together.
It should be mentioned that optimization models show a ‘flip-flop’ behaviour, because the model assumes ‘rational’ behaviour in the choices people make. A small difference in costs, will make the model go for the least cost option immediately, which is not realistic for the household sector. When this result is observed, caution is necessary and corrections may be required.

These two model types require not only projections of the number of existing and new dwellings, but also a detailed dataset of the dwelling stock. The following dwelling characteristics are often considered:

- type of dwelling (apartment, houses with 2, 3 or 4 outer walls);
- floor space;
- insulation level of walls, windows, roof and floor;
- heating system:
    - efficiency of heating system;
    - fuel type.
- age categories of the dwellings;
- …

There are different ways to get these data, like national detailed dwellings surveys, energy certificates of the EPBD, …even information of chimney cleaners can be useful.

Besides the above mentioned data, other parameters have to be calculated to estimate the total future energy consumption. For instance, the energy savings of each reduction measure have to be known for each dwelling category. To his end, more detailed data of the dwellings may be required, like the surface of the walls and windows, etc. Another important input of the model is the application degree of a reduction measure. Some dwellings can't implement every measure because of technical obstructions. For instance, the application of floor insulation has a lot of limitations, e.g. the height of the floor, risk for thermal bridges, etc. These technical limitations can be included into the model by using application degrees.

The optimization models need also reliable information on investment costs of the technological options for saving energy. Because energy price effects are incorporated into this model, the evolution of energy prices and price elasticity (from Annex C - 2) are model inputs, in contrast to engineering models. The latter models don't consider this, so price effects have to be estimated after the energy projections, also by means of the same price elasticity.

A general model structure, which can be used in every MS, can't be defined, because each MS will have different kind of available data. As a consequence, every MS has to build their own model structure so accurate energy projections will be possible.

To clarify the above theoretical recommendations, an example of an optimization model, used in Flanders to estimate the residential energy projections, will be explained shortly in Annex C - 4.

Impact reduction measures

The impact of the EPBD on the existing & new dwelling stock, the European directive on end use energy efficiency and the directive on ecodesign can be estimated. The influence of other policies, like policies affecting the fuel mix, can also be calculated.

13.5.4 Electricity consumption for electric appliances, lighting and cooling

13.5.4.1 Evolution of the total electricity consumption of the residential sector

The share of the residential electricity consumption in the total, final electricity consumption in the EU27 amounts approximately to 31%. This share remains more or less stable during 1990-2005 in most of the MS, except in some East-European countries, like Estonia, Slovakia etc. The share of the residential electricity consumption in these EU12-countries rises until 1994 from approximately 23 to 30%.

The next two figures describe the evolution of the total electricity consumption in all MS. Figure 52 representing the EU15, shows that there is a global tendency of increasing electricity consumption. In some EU15 countries, e.g. Austria, Sweden and Denmark, the electricity consumption has a less increasing progress. Figure 53 of the EU12 shows a smaller and more volatile increase of the total electricity consumption.

This means that the rise of the implementation level of household appliances,… had a stronger impact compared to the efficiency improvement of the appliances induced by the European directive on the promotion of end-use efficiency and energy services and the European directive on Energy Labelling of Domestic Appliances.

Figure 52 Evolution total electricity consumption of residential sector in EU15 (1990-2005)

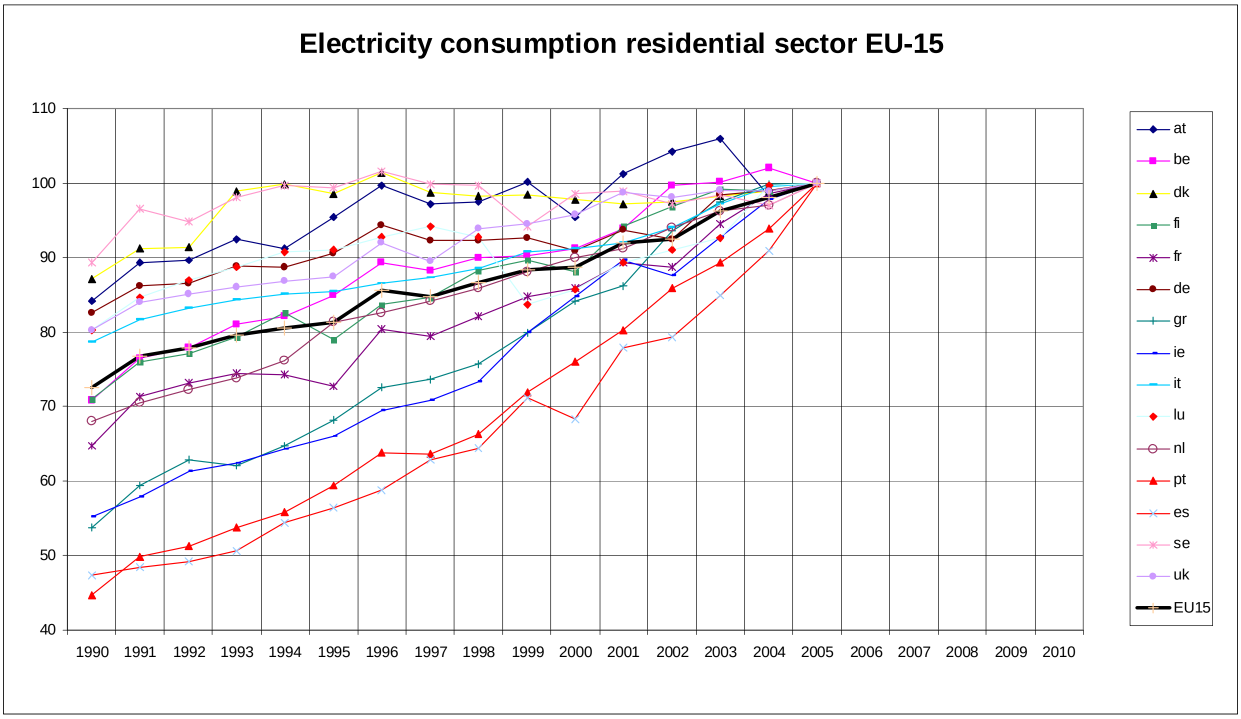


Figure 53 Evolution total electricity consumption of residential sector in EU12 (1990-2005)

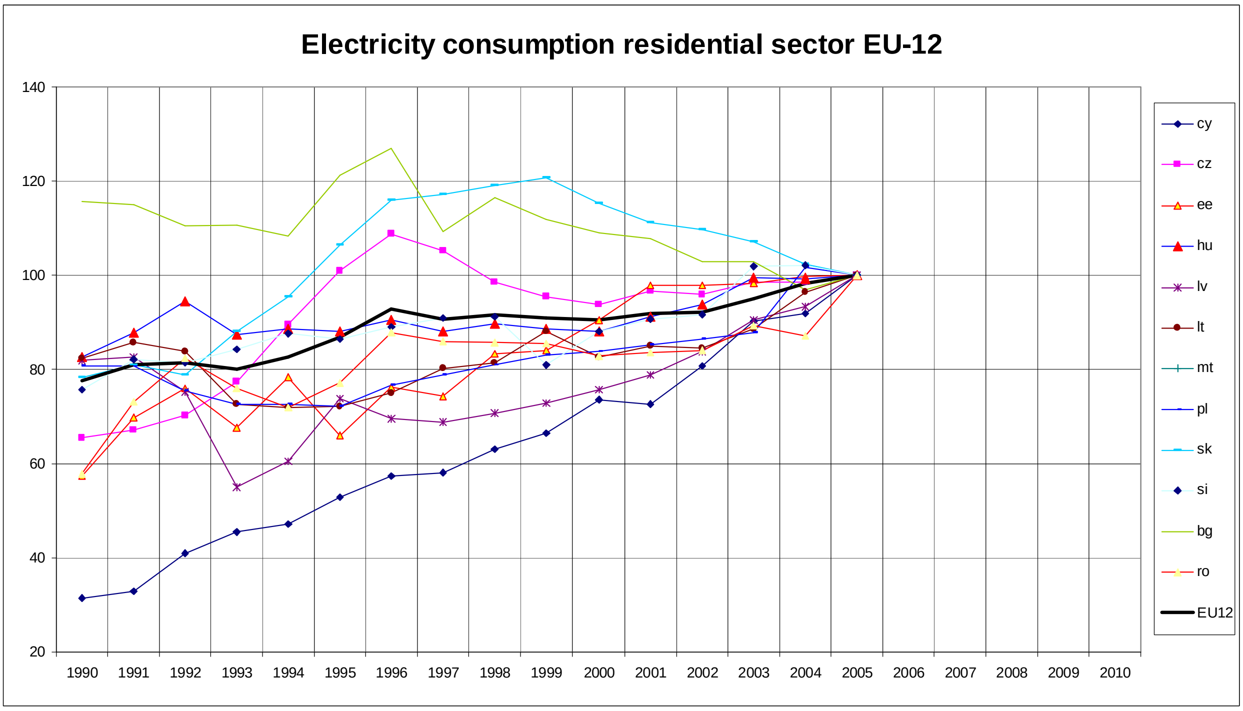
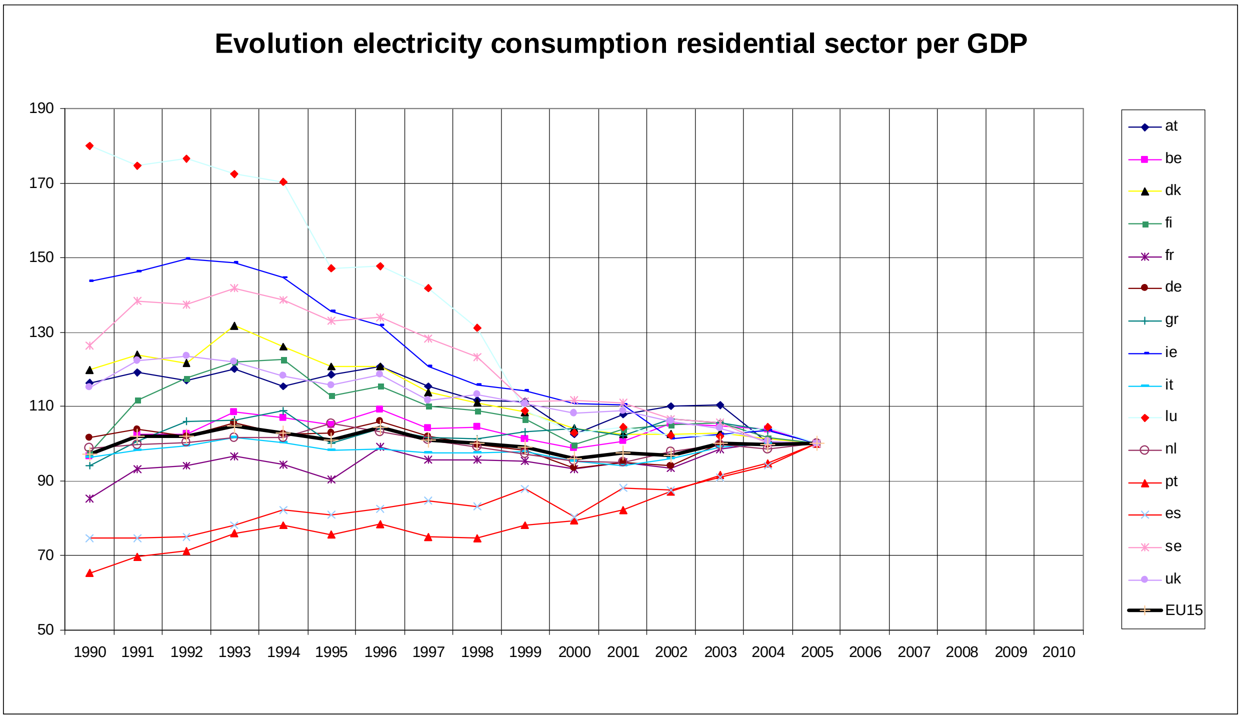


Figure 54 presents the residential electricity consumption per GDP in the EU15 during 1990-2005. It shows that in the global EU15 this parameter is more or less stable, but increases as well as decreases depending on the MS. As a consequence, in some countries, like Luxembourg, the GDP rises faster than the residential electricity consumption, in contrast to other countries, like Spain, Portugal,…

Figure 54 Evolution total electricity consumption per GDP of residential sector in EU15 (1990-2005)



13.5.5 Projections of electricity consumption for electric appliances, lighting and cooling

Besides electricity consumption for electric appliances and lighting, the total electricity consumption of the residential sector comprises electricity use for heating and cooling. So, before estimating the energy projections, a MS needs to divide the total electricity consumption into electricity use for heating on the one hand, and electricity consumption for electric appliances, lighting and cooling on the other hand. If the share of cooling in the total electricity use is known and significant (e.g. a country with a warm climate), it is recommended to consider it as a third end use of electricity. The dependency of cooling on cooling degree days explains this requirement. As a consequence, the electricity consumption for cooling has to be corrected for cooling degree days (analogous to the correction for heating degree days).

In the remainder of this document, electricity use for cooling will be part of the electricity use for electric appliances and lighting. This aggregation doesn't exclude an accurate projection, because in most of the MS cooling in the residential sector is rather scarce. Separate projections for appliances and cooling are only recommended in MS with a high implementation level of air conditioning.

The European directives on ‘the promotion of end-use efficiency and energy services’, on ‘energy labelling of household appliances’ and on ‘ecodesign for energy-using appliances’ are the most important policies influencing the electricity consumption of households. The first two policies have already induced a large efficiency improvement of the household appliances, etc. in the preceding years. To estimate the impact of these policies in a MS detailed information on the household appliances is required.

The electricity consumption for electric appliances and lighting is dependent on many factors. These factors can be subdivided into two main parts:

- Demography: number of households;
- Electricity consumption per household:
    - Implementation level of household appliances and lighting:
        - Number of appliances;
        - Frequency of use;
    - Energy efficiency improvement of household appliances and lighting due to:
        - Reduction measures and policy;
        - Autonomic efficiency improvement.

To estimate the future electricity consumption, knowledge on one or more of these parameters will be necessary. The more detailed information is available in a MS, the more accurate projections will be possible and the more the impact of reduction measures can be estimated.

It should be mentioned that in this section, the total electricity demand of the residential sector is calculated and not the related CO_2-emissions. The CO_2-emissions are emitted by the electricity sector. As a consequence, the final electricity consumption of the residential sector forms an input parameter of the electricity model.

In the next paragraphs, two Tier methodologies are described to estimate the future, residential electricity consumption. The first method results in a rather simple model, in contrast to the second model which requires more detailed data. Only the detailed model allows a good investigation of the impact of reduction measures on the electricity use.

It is important that the electricity consumption for heating is subtracted from the total electricity consumption[27]. The Tier methods of the energy use for heating are described in the previous section.

[27] Normally, the share of electric heating in the total electricity consumption isn’t known. So, to separate electric heating from the total electricity consumption, assumptions on this share need to be made by the MS.

13.5.5.1 Tier I: Top-down projection based on demography

The most important variable of this projection methodology is demography. In general, the future electricity consumptions will be estimated based on future projections of the number of households (or the number of dwellings), received from the national statistics bureau.

Based on historical data the average electricity consumption per household can be calculated. It is advised to base this average on a recent period with good, representative data. The period 2000-2005 could be a good base period. This average historical energy consumption is assumed to be constant, so only the increase/decrease of the number of households will cause changes of the residential, electricity consumption. It can be necessary to incorporate the economic growth of a country if a strong correlation is detected between GDP and the residential electricity consumption.

Instead of a constant, future electricity consumption per household, this parameter can evolve based on an extrapolation of historical observations.

13.5.5.2 Tier II: Bottom-up projection based on detailed appliances stock information

This Tier method won't be described into detail, because each MS will have different kind of data available and some input parameters can be estimated in many ways. So, in this section, only some suggestions will be briefly discussed.

As already mentioned in the introduction, the electricity consumption for electric appliances and lighting is dependent on many factors. These factors can be subdivided into two main parts, namely demography (number of households) and the electricity consumption per household. The estimation of the future electricity consumption per household can be done in different ways.

The future electricity consumption per household is dependent on the following factors:

- Implementation level of household appliances and lighting:
    - Number of appliances per household;
    - Frequency of use;
- Energy efficiency improvement of household appliances and lighting due to:
    - Reduction measures and policy;
    - Autonomic efficiency improvement.
    - …

So, first of all, assumption on future implementation levels will be required. These assumptions can be based on literature, historical observations, economic expectations like GDP, etc.

If the total appliances stock (and lighting) can be subdivided into the most important appliances categories (like refrigerators, washing machines, brown good appliances,…), the impact of reduction measures can be estimated. Policies will mainly impact the efficiency of the household appliances. This efficiency improvement can be incorporated into the model.

Engineering models or optimization models are again the most suited model types to perform this energy projection (see Tier IV of Energy use for heating and SHW).

13.6 Preliminary guidelines for the service sector (CO_2)

Estimating projections for the service sector means estimating the future energy consumption of a sector with a great variety of activities. The service sector comprises a lot of subsectors:

- Offices and administrations;
- Education:
    - Primary and secondary education;
    - Higher education and other education activities;
- Health services;
- Social services with accommodation, mainly rest homes;
- Social services without accommodation: crèches, day nursing homes for elderly and (para)medical practices;
- Other social and personal services, like swimming pools, cultural centres,…;
- Trade;
- Catering: hotels, restaurants,…

The above subdivision forms only an example and can vary from MS to MS.

A property of all the subsectors is the use of energy to heat and cool buildings. For that reason, this sector has a certain affinity to the residential sector. But, often reliable data of the service sector are missing, so different estimation methodologies are required.

Like the residential sector, the energy consumption of the service sector can be subdivided into two main categories:

- Energy use for heating of buildings, sanitary hot water (SHW) included. To this purpose, mainly fuels are consumed The energy consumption for heating is dependent on heating degree days (HDD).
- Electricity use for electric appliances, lighting, cooling,…in buildings[28]. Electricity consumption for cooling is dependent on cooling degree days (CDD).

In most of the EU27 countries, the electricity use by the service sector is higher than its fuel[29] consumption. The share of services fuel consumption in the total fuel consumption of the EU27 is constant during 1990-2006 and amounts to only 8%. On the other hand, the higher share of the electricity consumption of the service sector has slightly increased, namely from 20% in 1990 to 26% in 2006, which is shown in Figure 55. The figure also shows that these two portions differ strongly between MS and can be very variable.

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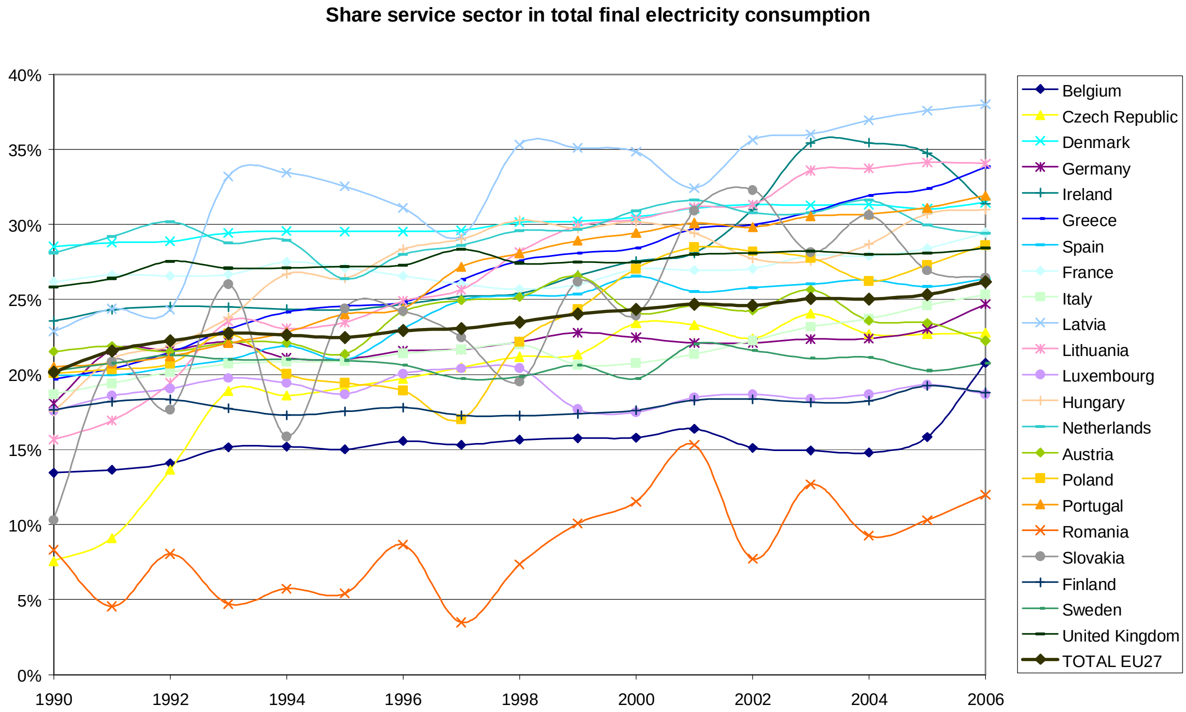
[28] The emissions of the electricity consumption are related to the energy sector. So, in the Tier methods of the service sector, only the final electricity consumption will be estimated, not the corresponding CO_2-emissions.

[29] Including district heating

Figure 55 Evolution of the share of the service sector in the final electricity consumption of EU27 countries



Different European policies influence the energy consumption of the European service sector. The following policies are the most important:

- Directive 2006/32/EC on energy end-use efficiency and energy services;
- Directive 2002/91/EC on energy performance of buildings (EPBD);
- Directive 2006/1005/EC on energy efficiency of office equipment: the Energy Star Programme;
- Directive 2005/32/EC on ecodesign for energy-using appliances.

Accurate projection models should incorporate the impact of these policies.

In the first part, three Tiers methodologies will be described briefly to estimate the energy projections for heating and sanitary hot water of the service sector. Like the Tier methods of the residential sector, the first two methods are rather simple because it assumes that only a limited dataset of the service sector is available. The third method uses an optimization or an engineering model which requires a lot of information on the service sector. Estimating the impact of policies and reduction measures is only possible with the highest Tier method. In the second part, a method to estimate electricity use for appliances and cooling is described. The data needed for the different Tier methods are summarized in Figure 56 and Figure 57.

It should be noted that historical energy uses need to be corrected for HDD (and CDD). The correction for HDD is analogous to that of the residential sector. The only difference is a smaller HDD elasticity (See Annex D - 1).

Before calculating the energy projections, it is recommended to have a close look at the historical energy consumptions. The understanding of historical trend(s) could make the projections more accurate.

Figure 56 Summary of Tier methods for estimating future energy consumptions for heating and SHW

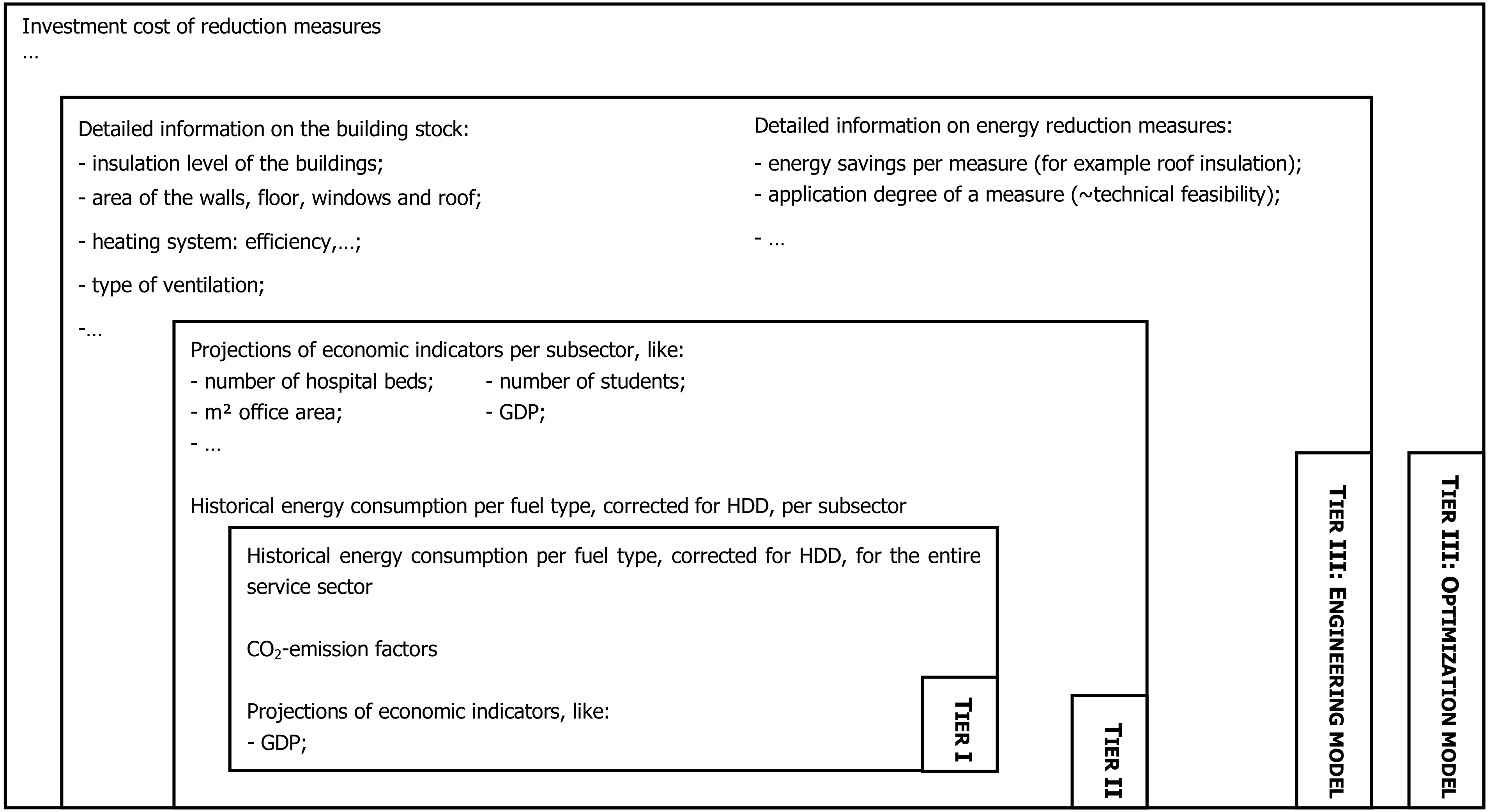
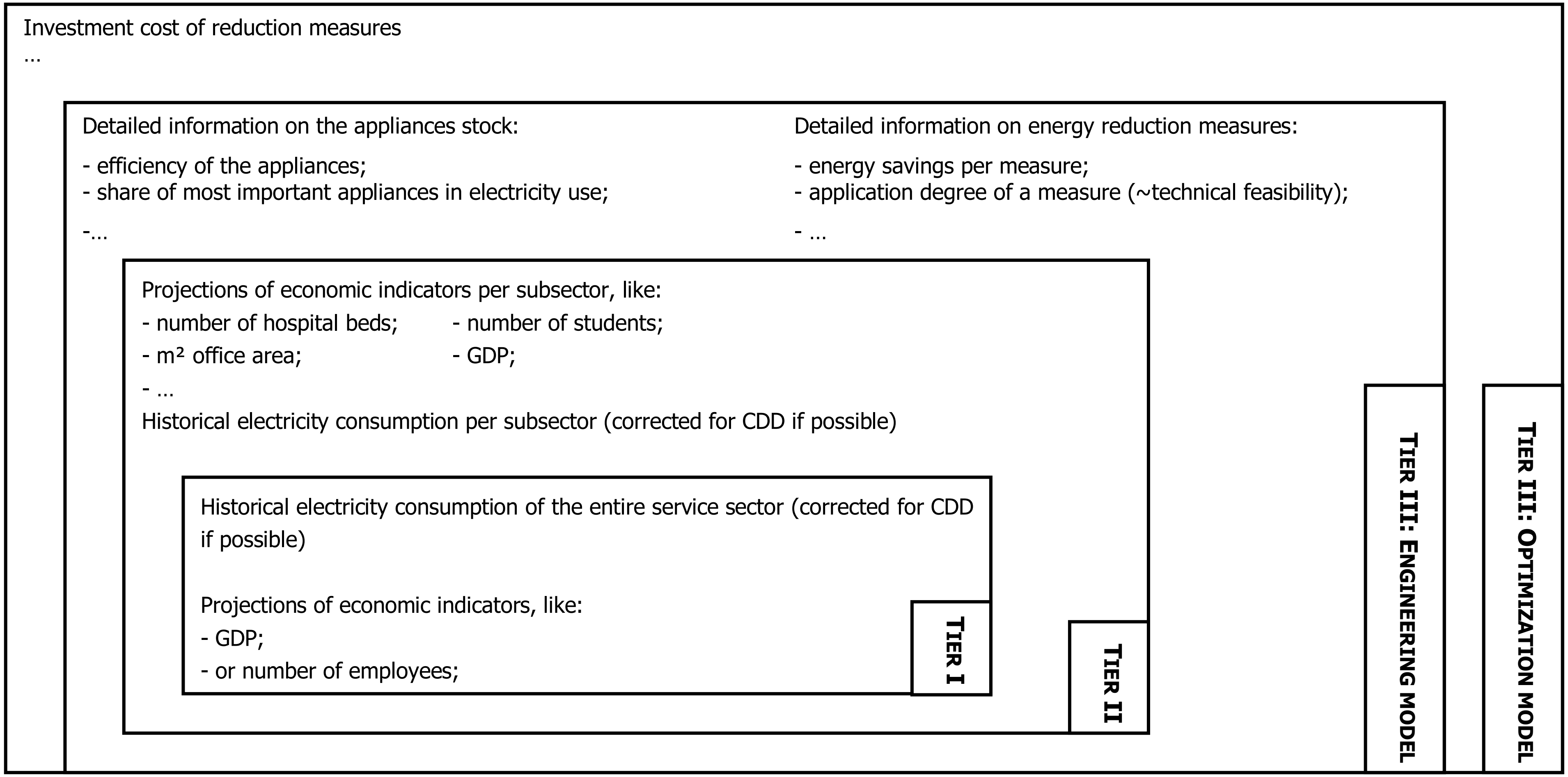


Figure 57 Summary of Tier methods for estimating future electricity consumption



13.6.1 Energy use for heating and sanitary hot water

In this section, Tier methods will be briefly described to estimate the energy projections for heating and sanitary hot water. Mainly fuels (and district heating) are used to heat the tertiary buildings[30].

13.6.1.1 Tier I: Top-down projection based on economic activity

The most important variable of this projection methodology is the evolution of economic activity of the total service sector. This economic activity can be expressed by means of the Gross Domestic Product (GDP), total number of employees or the value added etc.

Step 1: Collecting projections of economic activity:

To express the size of the service sector, economic indicators, like the GDP, total number of employees or the value added are often used. In Annex D-2, the correlation between GDP & the energy use for heating and between the number of employees & the energy use is described. The elasticity shows that there is a statistical significant, but small correlation between GDP and energy use. A small correlation holds also true between the number of employees and energy use, except for the East-European countries. For these countries, the analysis shows a great relationship. It can't be determined if the correlation between the number of employees and the energy use is significant (see Annex D-2).

Projections of one of these indicators have to be collected to estimate energy projections based on this simple Tier methodology. But before using them as base indicators of the total energy use, MS need to check if there is a relationship between one of these two indicators and the energy consumption of the service sector. If the latter doesn't hold true, other economic indicators have to be used for the projections.

Step 2: Making energy projections based on elasticity

Annex D- 2 describes the statistical analysis of the correlation between an economic indicator (GDP and number of employees) and the total energy use of the service sector. Only GDP and number of employees are considered in this Annex. Concerning other accurate economic indicators, MS have to perform their own statistical analysis.

The statistical analysis resulted in elasticity values called GDP elasticity and employee elasticity. The values can be found in Annex D-2 for different MS, besides an average value. A MS can use these results if better data aren't available.

Starting from the historical, total energy consumption of the three most recent years, namely the three yearly moving average corrected for HDD (see Annex D-1) and the values of the accurate economic indicator in this time period, a MS can estimate the future energy consumption based on the following equation:

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[30] Electric heating isn't considered in this Tier methods. In some countries, this kind of heating may exist, so it has to be taken into account in the projections.

$\%(X_{,t,x} - Xcal_{av,ref}) = \%(econ\ indic_t - mean\ econ\ indic_{ref})$

With: $X_{t,x}$ = estimated energy consumption of the service sector for year t in country x;
$Xcal_{av,ref}$ = three yearly moving average of the most recent observations corrected for HDD;
$econ\ indic_t$ = projected values of the economic indicator for year t in country x
$mean\ econ\ indic_{ref}$ = average of the economic indicator of the three most recent years for which historical observations are available.
% = in terms of percentage

In contrast to the residential sector, fuel price elasticity isn't considered given the limited impact of energy prices on the energy consumption of the tertiary sector.

The only variable influencing the energy projections is the economic indicator, so it is more or less impossible to estimate the impact of reduction measures. To estimate the effect of reduction measures, a more detailed projection method will be necessary (see Tier III).

Step 3: Translating energy projections into CO_2-projections

In this step, the total, projected energy use will be expressed in CO_2-emissions. Therefore, the total energy use has to be distributed among the different fuels, like natural gas, fuel oil, etc. and district heating[31]. Two options exist to perform this.

Option 3a

The average of the historical shares of each fuel in the total energy consumption. It is advised to base this average on a recent period with good, representative data. The period used for the three yearly moving average $Xcal_{av}$ could be a good base period. These average shares are held constant for the entire projection method.

Option 3b

Instead of a constant share for each fuel, the trend of the fuel shares observed in the historical data will be extrapolated to the future. It is advised to base this trend on a recent period with good, representative data, for instance the last six or five years. To obtain good results, it is necessary to rescale the extrapolated shares so the sum of all shares remains 100%.

Once the energy projections per fuel are known, they can be transformed into CO_2-projections by means of their CO_2-emission factors. These emissions factors are based on IPCC default factors (IPCC guidelines 1996 or good practice guidelines) or country specific emission factors per fuel type.

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[31] The energy consumption for district heating has to be estimated according to this Tier methods, but the related CO_2-emissions are estimated by the Tier methods of another sector, because the CO_2-emissions are accounted to the energy sector or another sector.

The sum of all CO_2-emission projections per fuel will result in the total CO_2-prognosis of the service sector concerning heating and SHW.

Impact of reduction measures

With Tier I methodology estimating the impact of reduction measures is more or less impossible. But, the policy which effects the fuel mix in a country (like a policy which promotes renewable energy) can be incorporated into the projections. So, the difference between the projections with or without this policy reveals the impact of these reduction measures. To this end, one has to translate the objectives of this policy into assumptions concerning the fuel shares in the future.

13.6.1.2 Tier II: Top-down projection based on economic activity per subsector(s)

Like already mentioned in the introduction, the service sector comprises different subsectors. In this Tier methodology, the energy projections of the different subsectors (or an aggregation of subsectors) will be estimated separately, based on subsector specific economic indicators.

Step 1: Collecting historical energy uses per subsector(s), corrected for HDD:

This Tier II methodology is only possible if the observed energy consumptions of the service sector (corrected for HDD) can be divided among the different subsectors (or an aggregation of subsectors). The required information can be found in national energy balances, or derived from other statistics.

Step 2: Collecting projections of economic activity per subsector(s):

In contrast to Tier I, different economic indicators will be used for each subsector (or an aggregation of subsectors). For instance, the number of students can be an accurate indicator for the subsector education, the number of beds for the subsector health services, floor area for the subsector offices,… Besides historical data of these indicators, projections are required too. If projections aren't available of these subsector specific indicators, it is recommended to use the general indicator of Tier I (together with their elasticity).

But before using the subsector specific parameters as base indicators of the total energy use, MS need to analyze if there is a relationship between these indicators and the energy consumption of the concerned subsector.

Step 3: Making projections based on the energy consumption per economic indicator

The historical data of the energy consumption per subsector, corrected for HDD, have to be expressed in energy consumption per economic indicator. Once this is calculated, projections of the energy consumption per subsector can be obtained in two different ways.

Option 3a

The average of the historical energy consumptions per economic indicator is calculated for each subsector. It is advised to base this average on the last three yearly moving average (see Annex D - 1) of the historical energy consumptions (corrected for HDD):

$C_x = Xcal_{av,x} / (mean\ econ\ indic_{x,(t-1,t,t+1)})$

With: C_x = *historical, average energy consumption per economic indicator for subsector x;*

$Xcal_{av,x}$ = *three yearly moving average of the most recent observations for subsector x corrected for HDD;*

mean econ indic$_{x,(t-1,t,t+1)}$ = *average of the economic indicator of subsector x of the three most recent years for which historical observations are available.*

To make the energy projections, one assumes a constant energy consumption per economic indicator for the entire estimation period. So, the future energy consumption for a subsector will be the historical, average consumption per economic indicator C_x multiplied by the future values of the economic indicator:

$X_{t,x} = C_x * econ\ indic_t$

With: $X_{t,x}$ = *estimated energy consumption for year t for subsector x;*

econ indic$_{x,t}$ = *projected values of the economic indicator for year t of subsector x.*

A constant energy consumption per economic indicator assumes no implementation of reduction measures. To estimate the effect of reduction measures, a more detailed projection method will be necessary (see Tier III).

Option 3b

Instead of a constant energy consumption per economic indicator, the trend of this variable observed in the historical data will be linear extrapolated for each subsector. It is recommended to base this trend on the last six years, more specifically on the last three or four 'three yearly moving averages $Xcal_{av,x}$' (see Annex D - 1). So, besides a projection of the economic indicator, an extrapolation of the energy consumption per economic indicator is taken into account for each subsector.

But, an extrapolation of the historical trend is only permitted, if the historical trend seems logically, based on policy, economic activity,…

Step 4: Translating energy projections into CO_2-projections

In this step, the total, projected energy use will be expressed in CO_2-emissions. Therefore, the total energy use has to be distributed among the different fuels, like natural gas, fuel oil, etc. and district heating. Option 3a en 3b of Tier I are two possible ways to perform this translation.

If the fuel distribution is known for each subsector, these data have to be used, instead of the global shares of each fuel for the entire service sector.

The sum of all CO_2-emission projections per fuel will result in the total CO_2-prognosis of the service sector concerning heating and SHW.

Impact of reduction measures

With Tier II methodology estimating the impact of reduction measures is more or less impossible. But, the policy which effects the fuel mix in a country (like a policy which promotes renewable energy) can be incorporated into the projections.

13.6.1.3 Tier III: Bottom-up projection based on detailed building stock information

In the Tier methods of the residential sector, the advantages and disadvantages of optimization or engineering models are already described. An important advantage is the ability to explore the reduction potential by various energy reduction measures. But, these two model types require a detailed dataset of the building stock, besides an appropriate estimation of the economic activity of each subsector (see tier II).

The energy consumption per economic indicator for each subsector is an important input parameter of the model These parameters will decrease by means of reduction measures.

To estimate the impact of reduction measures, several building parameters need to be known, like:

- The insulation level;
- The area of the walls, floor, windows and roof;
- The type of heating system;
- The type of ventilation, for instance, with or without heat recovery,…
- Application degrees (technical feasibility) of each measure;
- The share of each room type, for instance clinical rooms versus non-clinical rooms in the hospitals: in other words, the average occupancy rate;
- Investment costs of reduction measures, if an optimization model is used;
- …

There are different ways to get these data, like national statistics, detailed surveys of each subsector,…

Because the service sector comprises a great variety of subsectors, it is very difficult to obtain a detailed dataset of each subsector. Therefore, it can be useful to limit this Tier III method to the most important subsectors, like offices and administrations. The other subsectors can be estimated by means of Tier I or Tier II. The combination of using two different Tier methods makes accurate projections still possible.

A general model structured can't be defined, because each MS will have different kind of available data. As a consequence, every MS has to build their own model structure.

13.6.2 Electricity use for appliances and cooling

The Tier methodologies for estimating the future electricity use are the same as those of the energy consumption for heating and SHW. The most important differences are:

- The GDP elasticity,… of Tier I is different from that of the energy use for heating and SHW (Annex D-2). The statistical relationship between GDP or number of employees and the electricity consumption have to be determined by the MS.
- The energy projections are translated into CO_2-emissions at the level of the electricity model for the energy sector.
- Besides detailed appliances stock information, the Tier III methodology requires only building stock information for cooling, heat pumps, ventilation,…

In the residential sector, it was mentioned that cooling of dwellings is rather limited. But in the service sector, cooling is more present. So, if possible, it is advised to separate the electricity use for cooling and correct if for CDD. The projections of the electricity use for cooling according to Tier III, require not only information on the efficiency of the cooling installations, but also on the building stock (like the presence of sunblinds,…).

13.7 Preliminary guidelines for the transport sector

13.7.1 Introduction

Transport, in particular road transport, has been the fastest growing source of GHG emissions in the past decade.

Traditionally a GHG scenario for transport will be developed in two steps:

- Develop mobility scenario
- Translate mobility scenario into GHG projection.

For the second step, many member states use bottom–up methodologies such as COPERT[32]. This methodology can be considered as state of the art. In this document we will concentrate on the development of a mobility scenario as this remains in most MS a major source of uncertainty.

Mobility is a complex issue and is affected (influenced) by different policies, including infrastructural policies, fiscal policies, safety considerations, traffic jam, urban parking problems, improvement of public transport and environmental issues.

The objective of this document is to present a number of reference figures MS can use to compare with. The focus of these reference figures is on the relationship between (A) Transport and GDP and (B) transport and energy prices.

[32] Computer Programme to calculate Emissions from Road Transport (http://lat.eng.auth.gr/copert/

13.7.2 Private cars transport

13.7.2.1 Mobility statistics

Any projection methodology starts by analyzing historical figures. EUROSTAT produces vehicle km statistics, but these statistics lack data and are often of poor quality. In Annex E-1 you find vehicle km statistics, as published in EUROSTAT and the completed tables. These data have been calculated, following the methodology described in Annex E-1.

13.7.2.2 GDP elasticity

GDP Vehicle km elasticity have been estimated econometrically (Annex E- 2).
Obtained values are in the range [0.295 -2.45] and median value 0.8. Only for two MSs the values are significant greater then the ones being observed.

0.8 is suggested as default value.

13.7.2.3 Vehicle km fuel price elasticity

Vehicle km fuel price elasticity have been estimated econometrically for 14 MS out of EU-15 Obtained values are all in the range [-0.486 – 0] and median value -0.1. For Austria and Denmark we have found zero price elasticity. It was not possible to estimate price elasticities for the new member states due to lack of historical data.

-0.1 is suggested as default value.

13.7.3 TIER1: Developing a Mobility Scenario for Private Cars

Data requirements

- Mobility statistics on Vehicle km (annex E)
- GDP elasticity: default factor of 0.8 (annex E)
- Vehicle km fuel price elasticity: default factor of -0.1 (annex E)
- %Δ GDP: yearly real growth rate of GDP

Note: The data provided in Annex E are based on EUROSTAT figures. When national data are available it is recommended to use those.

Step 1: Vehicle km projection

a. Total Vehicle km

$$Vhkm_{(t)} = Vkm_{(t-1)} \times (1 + \alpha\%\Delta\ GDP_t)$$

or more exactly as

$$Vhkm_{(t)} = Vhkm_{(t-1)} \times (GDP_t / GDP_{t-1})^{\alpha}$$

$Vhkm_{(t)}$ = Vehicle km of year t (annex E)

$Vkm_{(t-1)}$ = Vehicle km of year t-1 (annex E)
α = refers to the GDP (or income) elasticity

b. Vehicle km split in petrol, diesel and gasoline cars

The share of diesel cars depends on the national taxation policy (price difference of petrol and diesel, differentiation in road taxes) as well as technological improvements. In most MS both the share of diesel cars and the share of vehicle km driven by diesel cars are increasing.

For projection purposes, it is recommended to start from extrapolation of the share of Vhkm driven by diesel cars, and not the share of diesel cars[33].

DShare Vhkm = Vhkm driven by diesel cars / total vhkm

PShare Vhkm = (1-Dshare Vhkm)

DShare = Share of diesel cars
PShare = Share of petrol cars

Step 2: Energy efficiency improvement

Energy efficiency of new cars has significantly improved. As a result the average energy efficiency improves as well, although at a much slower rate. Average observed yearly changes in energy efficiency are presented in Table 38.

These EE values have been calculated for the existing cars (mixture of old and new cars) and the trends are likely to continue. Average improvements in order of 0.7% - 1.3% are observed in Germany and Belgium.

Table 38 Average observed yearly changes in energy efficiency

Yearly change in energy consumption / km: YCEC-km				
	2005-2000		2005 -1995	
	Germany	Belgium	Germany	Belgium
Petrol cars	-0.7%	-0.9%	-0.9%	-0.7%
Diesel cars	-0.9%	-1.3%	-1.0%	-1.2%

Step 3: Fuel consumption and GHG projections

Petrol and diesel consumption are calculated as follows:

[33] The reason for this is that an increasing trend in the share of diesel cars frequently coincides with a decreasing trend in the average km driven by diesel cars.

Δ% Petrol = Δ% Vehicle km driven by petrol cars + YCEC-km

Δ% Diesel for cars = Δ% Vehicle km driven by diesel cars + YCEC-km

Step 4: GHG projections

GHG emissions are calculated from fuel consumption figures, based on the same emission factor as in the Guidelines for national GHG inventory (http://www.ipcc-nggip.iges.or.jp/public/index.html)

Step 5: Evaluating PAMs

1. The ACEA agreements to reduce average emissions up to 140 gr CO_2/km should be reflected in the value of YCEC-km. However precise quantification is difficult since it is not clear whether the values in Table 38 already reflect the ACEA agreement or not.

2. The bio-fuels directive can be evaluated by lowering the emission factor for Petrol and gasoline for the% of bio-fuels used.

13.7.4 Higher TIER methodologies to develop a mobility scenario for private cars

In TIER 1 technological improvement is represented by one single factor (energy efficiency) and the technology choice is simply based on extrapolation of a trend. Modal shift is not considered. Usefulness of TIER 1 is rather limited for policy analysis.

Higher TIER methods are different in many aspects.

Technology representation
The car fleet is represented by fuel technology, age and size. Scrapping of cars is often based on survival rates.

Endogenously technology choice
Economic mechanism introduced to explain the choice for diesel and petrol cars (and or alternative fuels).

Mobility differentiation
Mobility is differentiated between rural, urban a highway and trip purposes.

Modal shift mechanism
Private transport by cars is considered within the mobility picture. Other alternatives (public transport by bus, train, …) are considered too.

13.7.5 Other Road Transport

The other road transport comprises:

- Transport of goods (trucks)

- Public and private transport by busses

Goods transport is responsible for more than 90% of the diesel consumption. Energy consumption for busses is only a small fraction of the energy consumption of other road transport and is therefore not considered into account in a simple projection methodology. However, more refined methods should include busses as it plays an important role in model shifts.

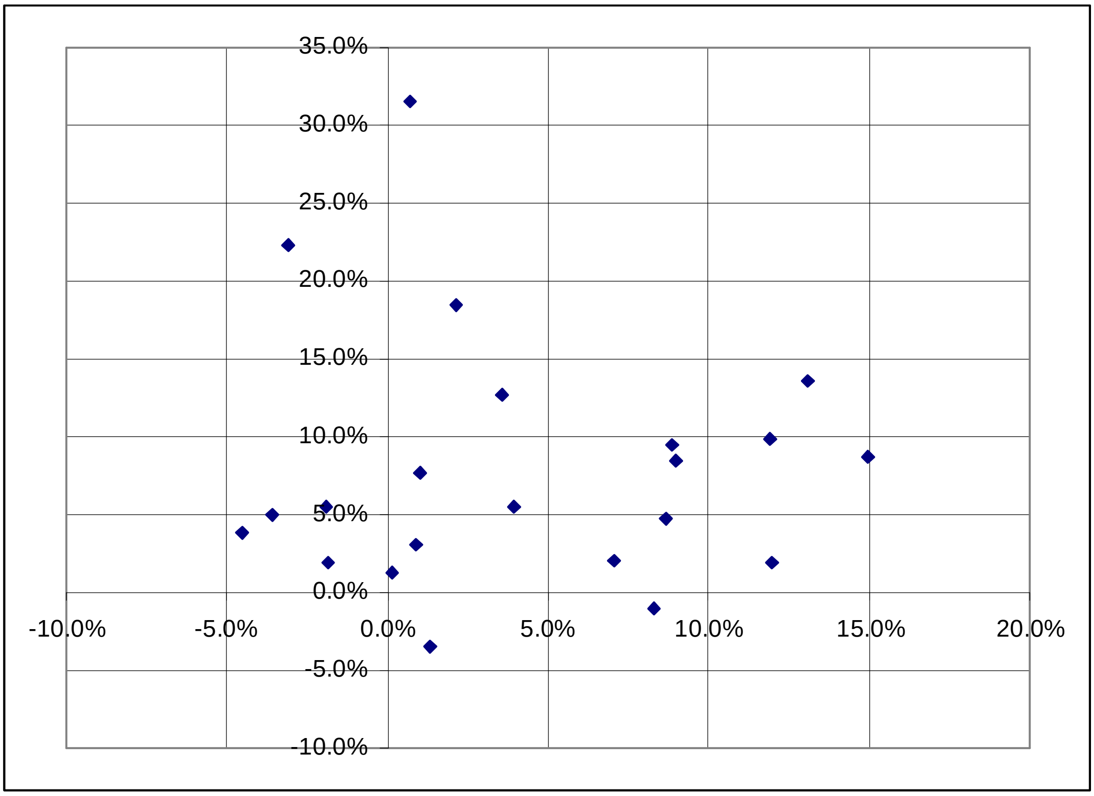
Although economic growth can still be seen as the main driving factor for transport of goods, this relationship is rather complex, in particular for international transport. To illustrate this complexity we consider a transport of goods from MS A to MS B, which passes MS C.

- The goods to be transported: MS A is the exporting country and MS B is the importing country. International trade is a major driving force for economic growth in the EU and abroad. Logically this should be expected to continue. Growth figures for imports and exports tend to be higher than GDP
- The localization of the transport company (or registration of the truck): In national account statistics, transport companies belong to the service sector and generates value added. When the exporting company is responsible for the transport, then it is likely that a transport company of MS A will be selected. However, a foreign transport company can be selected too. The ton-km and vehicle km statistics of EUROSTAT are based on the localization of the transport company.
- Road km: Here we have three member states involved. MS C has no economic benefits.
- Fuel sales: Any profit maximizing transport company will optimize fuel sales. If fuel is cheaper in MS C, then the truck will refill after passing the border of MS C.

Historically there was a strong tradition that the exporting country was responsible for the transport as well. However, the opening of the European services markets has changed this picture. Actually we observe two trends in transport activities:

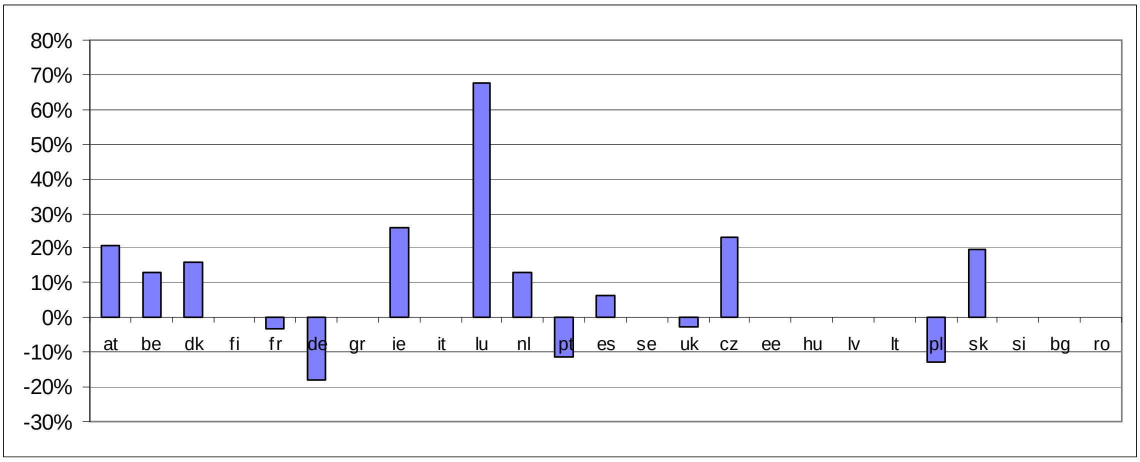
- There is as shift in transport activities in favour of the new member states. Indeed, ton-km in EU-15 increased by 2.5% yearly and, but 7 new member states (ee, hu, lv, lt, pl, sk, si) have even realized a growth of 12%. This sharp increase is unlikely to be explained by increasing economic activity only.
- There is no stable relationship between domestic vehicle-km and local fuel sales. This is demonstrated in Figure 58. Apparently there is no correlation and this is mainly due to differences in fuel prices which results in “fuel tourism”. Indeed, fuel sales for international transport can be very sensitive to even small price differences between MS as any profit maximizing company will buy fuel at the cheapest price.

Figure 58 Observed correlation between vehicle-km increases and fuel consumption increases. (increase of vehicle-km on the x axis, increase of fuel sales for transport on the y axis)



Own estimates of the 2005 diesel net sales to foreign transport companies are presented in Figure 59. The figures are only illustrative as they are not based on a proven methodology. Two limitations have been assumed while constructing these figures. Firstly, the balance is zero at the European level. Secondly, we have assumed that the transfers are explained by price differences between neighbouring countries. Member states with positive net sales have significantly lower diesel prices then neighbouring countries. One exception is Poland, which is very competitive on the European International transport market.

Figure 59 Estimates of the share diesel sales to foreign transport companies



Based on own calculations and available data in EUROSTAT we observe the following trends in European transport of goods statistics. Comparison of goods vehicle statistics and ton-km statistics indicates an increasing efficiency in the transport sector. But the comparison with diesel consumption statistics still lacks consistency.

Table 39 Observed trends in transport of goods statistics

	ton-km		Goods Vehicle km		Diesel for transport of goods consumption (1)	
EU-15	2.5%	(2000-2006)	1.3%	(2000-2006)	3.5%	(2000-2005)
NMS	12.0%	(2004-2007)	7.2%	(2004-2007)	7.5%	(2000-2005)
EU-27	3.2%	(2004-2006)	2.1%	(2004-2006)	3.9%	(2000-2005)

(1) own calculations

Under the above described circumstances, we believe that it is very difficult to develop accurate projections for GHG emissions originating from goods transport at MS level. Maybe a European top-down approach should be considered.

13.8 Preliminary guidelines for the agricultural sector (CH_4 and N_2O)

The projection methodologies for agriculture is based on the Tier methodology of the IPCC inventory and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Because of the large amount of detail and data available, these methodologies should permit to make accurate and complete projections for the most important sources.

13.8.1 General

These preliminary guidelines give an overview of the sources of agricultural greenhouse gas emissions which should at least be taken into account to obtain the overall size of projected emissions. The basic calculation methodology of the IPCC is a multiplication of activity data with emission factors (EF).

In the IPCC guidelines default EF can be found (Tier 1) and can be used for projection purposes. A more appropriate methodology, resulting in better time-consistencies between inventory and projections, is to use the EF from the latest year of the last submission of the national inventory. This EF can be held constant for the whole projection period or, if reasons for changes are well-founded (e.g. another type of cows is introduced into the country), time-consistent changes can be adopted. For this recalculation we refer to the methodologies described below. Certainly for higher Tier methodologies, several parameters have to be estimated. However, one has to be aware that certain changes are limited in size and unfounded extrapolations have to be avoided.

Projections of activity data (number of animals, amount of N applied,…) are generally known from country-specific sources. However, if this data is not available the activity data of the last reported year of the inventory can be used. Remarks similar to these of the EF can be made for projections of these activity data.

Also other assumptions (e.g. share of different manure management systems in a country) can be taken from the national inventory reports.

13.8.2 Livestock - Enteric fermentation(CH_4)

13.8.2.1 Tier 1: revised 1996 IPCC methodology based on the number of animals and the default EF

$$CH_{4\,Enteric} = \sum_i EF_i \cdot N_i$$

Where

- EF= emission factor for the defined livestock population (kg CH_4/head/yr)
- N= number of head of livestock species in the country
- i= species of livestock under consideration

Default emission factors can be found in paragraph 4.2.3 of the revised 1996 IPCC guidelines.

It is, however, advisable to use higher Tier methodologies for dairy cows and other cattle.

Data needed: projected annual average population of each category of animals as defined by the IPCC

13.8.2.2 Tier 2: estimation of country-specific emissions from animals based on feed energy) intake

This methodology is analogous to Tier 1 though incorporates more specific emission factors:

$$EF = \frac{GE \cdot \frac{Y_m}{100} \cdot 365}{55.65}$$

Where

- GE= gross energy intake (MJ/head/day)
- Y_m= methane conversion factor, per cent of gross energy in feed converted to methane

For each category of livestock, the required data has to be collected.

Formulas to calculate GE can be found in paragraph 4.2.4 of the revised 1996 IPCC guidelines.

Data needed: projected annual average population of each category of animals as defined by the IPCC, methane conversion factor and average daily feed intake (if not available, additional information on weight, average weight gain per day, feeding situation, milk production per day and fat content, average amount of work performed per day, percentage of females that give birth in a year, wool growth, number of offspring and feed digestibility are required to estimate this value).

13.8.2.3 Tier 3: additional country-specific information

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,… The model should be well documented.

13.8.3 Live stock - Manure management - CH_4

13.8.3.1 Tier 1: based on the number of animals and the default EF

$$CH_{4\,Manure} = \sum_i EF_i \cdot N_i$$

Where

- EF= emission factor for the defined livestock population (kg CH_4/head/yr)
- N= number of head of livestock species in the country
- i= species of livestock under consideration

If different temperature zones are present, it is advisable to calculate a weighted average emission factor based on the animal numbers in the different zones as emissions from manure management systems are highly temperature dependent. Default values which can be found in the guidelines (paragraph 4.2.3) represent ranges in manure volatile solids content and manure management practices used in each region.

Data needed: Annual average temperature for the climate zone where the livestock is managed, projected annual average population of each category of animals as defined by the IPCC

13.8.3.2 Tier 2: country-specific emission factors based on manure and management system characteristics

$$EF_i = VS_i \cdot 365 \cdot B_{0i} \cdot 0.67 \cdot \sum_{j,k} \left(\frac{MCF_{j,k}}{100} \cdot MS_{i,j,k} \right)$$

Where

- EF= annual CH_4 emission factor for livestock category i (kg CH_4/ head/yr)
- VS= daily volatile solid excreted for livestock category i (kg dry matter/head/day)
- B_0= maximum methane producing capacity for manure produced by livestock category i (m^3 CH_4/kg VS excreted)
- $MCF_{j,k}$= methane conversion factor for each manure management system j by climate region k (%)

- $MS_{i,j,k}$= fraction of livestock category i's manure handled using manure management system j in climate region k

Additional default data and VS estimation method are described in the guidelines.

Data needed: Annual average temperature for the climate zone where the livestock is managed, annual average population of each category of animals as defined by the IPCC, VS produced in the manure, maximum amount of methane able to be produced from that manure, system types used to manage manure and system-specific methane conversion factors

13.8.3.3 Tier 3a and b

Some countries for which livestock emissions are particularly important may wish to go beyond the Tier 2 method and develop well documented models for country-specific methodologies (Tier 3a) or use measurement-based approaches (Tier 3b) to quantify emission factors.

13.8.4 Live stock -Manure management - N_2O

13.8.4.1 Tier 1: based on the number of animals and default factors

$$N_2O_{manure} = \sum_i \left(N_i \cdot Nex_i \cdot AWMS_i \cdot EF_{AWMS}\right)$$

Where

- N_i= number of animals of type I in the country
- Nex_i= N excretion of animals of type i in the country (kg N/animal/yr)
- $AWMS_i$ = fraction of Nexi that is managed in one of the different distinguished animal waste management systems for animals of type i in the country
- EF_{AWMS}= N_2O emission factor for an AWMS (kg N_2O-N/kg of Nex in AWMS)

Default values can be found in the revised 1996 IPCC guidelines (section 4.5.3).

13.8.4.2 Tier 2: country-specific emission/excretion factors and/or share of different animal waste management systems

13.8.4.3 Tier 3a and b: model or measurement approaches

Some countries for which livestock emissions are particularly important may wish to go beyond the Tier 2 method and develop well documented models for country-specific methodologies (Tier 3a) or use measurement-based approaches (Tier 3b) to quantify emission factors.

13.8.5 Non CO_2 emissions sources on land - Direct N_2O emissions from managed soils

13.8.5.1 Tier 1: revised 1996 IPCC methodology: default emission factors and country-specific activity data

Generally, direct N_2O emissions can be summarized by:

$$N_2O_{direct} - N = N_2O - N_{N\ inputs} + N_2O - N_{OS} + N_2O - N_{PRP}$$

Where

- $N_2O\text{-}N_{N\ inputs}$= annual direct emissions from N inputs (mineral fertilizer, organic fertilizer, crop residues and soil mineralization) to managed soils (kg N_2O-N/yr)
- $N_2O\text{-}N_{OS}$= annual direct emissions from managed organic soils (kg N_2O-N/yr)
- $N_2O\text{-}N_{PRP}$= annual direct emissions from urine and dung inputs to grazed soils (kg N_2O-N/yr)

Each of these factors is determined by an emission factor and an application rate. Default emission factors are profoundly described in the guidelines (paragraph 4.5.2 and 4.5.3).

Data needed: projected amount of mineral and fertilizer manure nitrogen (calculated under livestock manure production and management, crop yield statistics (yields and area harvested, by crop).

13.8.5.2 Tier 2: country-specific emission factors and activity data

The approach is similar to Tier 1 though using more country-specific data. If the data allow, formulas can be further disintegrated (e.g. specific emission factors per type of N application).

13.8.5.3 Tier 3a and b: model or measurement approaches

13.8.6 Non CO_2 emissions sources on land - indirect agricultural N_2O emissions

13.8.6.1 Tier 1: based on the number of animals and default factors

$$N_2O_{indirect} = N_2O_{(G)} + N_2O_{(L)}$$

where

$$N_2O_{(G)} = \left(N_{fert} \cdot Frac_{GASF} + Nex \cdot Frac_{GASM}\right) \cdot EF_4$$

and

$$N_2O_{(L)} = \left(N_{fert} + Nex\right) \cdot Frac_{LEACH} \cdot EF_5$$

Where

- N_{fert}= fertilizer nitrogen use in country (kg N/yr)
- Nex= livestock nitrogen excretion in country (kg N/yr)

- $Frac_{GASF}$= fraction of synthetic fertilizer nitrogen applied to soils that volatilizes as NH_3 and NO_x
- $Frac_{GASM}$= fraction of livestock nitrogen excretion that volatilizes as NH_3 and NO_x
- $Frac_{LEACH}$= fraction of nitrogen input to soils that is lost through leaching and runoff
- EF_4= emission factor for atmospheric deposition (kg N_2O-N/kg NH_3-N and NO_x-N emitted)
- EF_5= emission factor for leaching runoff (kg N_2O-N/kg N leaching/runoff)

More information can be found in 4.5.2 and 4.5.3 of the revised 1996 IPCC guidelines.

13.8.6.2 Tier 2: country-specific emission/excretion factors and/or share of different animal waste management systems

13.8.6.3 Tier 3a and b: model or measurement approaches

Some countries for which livestock emissions are particularly important may wish to go beyond the Tier 2 method and develop well documented models for country-specific methodologies (Tier 3a) or use measurement-based approaches (Tier 3b) to quantify emission factors.

13.9 Preliminary guidelines for the waste sector (CH_4)

The projection methodologies waste is based on the Tier methodology of the IPCC inventory and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Because of the large amount of detail and data available, these methodologies should permit to make accurate and complete projections for the most important sources.

13.9.1 General

The link between inventory and projection methodology is very strong for disposal of solid waste as historical disposals determine current and future emissions. The first order decay method as described in the 2006 IPCC methodology corrects a possible underestimation and can as such result in slightly higher values compared to former IPCC methodologies (2006 IPCC guidelines, p. 3.8). The main advantage of the latest IPCC methodology is that a ready-made Excel model is at the user's disposal. So, it can be advised to use the latest guidelines for waste (Tier 1 and 2) under the condition that projected emissions are in line with the emissions reported in the inventory.

13.9.2 Solid waste disposal

To enable good estimates of future CH_4 emissions from solid waste disposal, good historical data are important. The IPCC suggests as good practice to use data of 3 to 5 half-lives (50 years). However, if these data are not available, the missing data can be obtained using surrogates (extrapolation with population, economic or other drivers). A full explanation can be found in the IPCC documents.

An important aspect in estimating CH_4 emissions from solid waste disposal on land, is the recovery of CH_4 on the site. There is a large uncertainty on the recovery rate of CH_4 from solid waste disposal. The default value is 0.

13.9.2.1 Tier 1: Estimate emissions using the IPCC FOD (first order decay) method with default data to fill in missing country-specific data.

$$CH_4 = \left[\sum_x CH_4\, generated_{x,T} - R_T \right] \cdot (1 - OX_T)$$

Where

- CH_4 generated= CH_4 produced in the landfill during year T for waste category x (based on first order decay kinetics) (Gg)
- R= recovered CH_4 in year T (Gg)
- OX= oxidation factor in year T (fraction)

An extended description of this model can be found in the 2006 IPCC guidelines (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf). The model itself (IPCC waste model) can be downloaded from the website (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html). In the excel file additional information is provided to complete the form.

It can also be operated in two different modi: bulk waste data only or waste by composition. Both methodologies deliver a similar result under the condition that the composition of the waste does/will not change. Otherwise it is recommended to use the more detailed approach (waste by composition).

Data needed: historical data and projections of population number and GDP

13.9.2.2 Tier 2: Estimate emissions using the IPCC FOD method with default parameters and good quality country-specific activity data

The same model as Tier 1 is applied though additional country-specific activity data is added.

Extra data which can be used: waste per capita (population), composition of the waste, percentage to waste disposal, waste generation rate (industry), specific recovery rate of CH_4

13.9.2.3 Tier 3: Estimate emissions using country-specific methods or IPCC FOD method with country-specific key parameters and good quality country-specific activity data.

This approach could employ the development of sophisticated, site-specific models, use site-specific measurement data,… The model should be well documented.

13.10 Lessons learned and further developments

Based on the developed preliminary guidelines (chapter 13) and the case studies (annex F) we summarize here some conclusions and possible further developments for the preliminary guidelines. For more in depth information, we refer to the relevant sections in the report.

- As stated before, the choice of specific models will depend on various local circumstances: availability of data, available resources, experience of the team, etc. A number of characteristics for different model types have been listed in the general overview of section 3.2.2. Even within one family of models there exist still important differences. However:
  - Developing models is a continuous improving process and model developers, being familiar with the weaknesses of a particular methodology, have improved their models by implementing principles of other methodologies in their models. For instance, some economic optimisation principles might have been introduced in simulation models.
  - The need for a particular projection model also depends on the modalities of the PAMs. Policies involving command and control and economic instruments (taxes, subsidies, feed in tariffs..) require a different approach and often even a different type of model.

  Therefore we can not give one overall recommendation suited for all 27 MS and for all purposes. Instead, per sector, some general advises and points for attention are given.

  Nevertheless, to perform projections, many member states use software packages that have been developed abroad. As such, the development of local models is mainly limited to the collection of domestic information (Markal, Times, Message, ENPEP-Balance). These models can be made operational in any MS with limited resources.

- Currently assumptions and model choice still affect the results in an important way. Assumptions should therefore carefully be considered, described in detail and whenever possible be compared with other MS. Model choice may result in a different outcome, however, differences in projections should be examined thoroughly and if reasons can be found for these differences, adjustments should be made whenever possible.

- Specific country projection data and information were available to perform (new) country projection (used in the sensitivity analysis and described in the development of the preliminary guidelines). The available data allowed, however, in most cases only using low level tier methodologies. It is advised that better projections using improved methodologies are rather performed by the MS itself because background and more detailed or up to date information will be more easily accessible.

- Some sectors, however, could benefit from a more European view: agriculture (production increase of certain means in one MS can result in a decrease in another) and transport (international truck transport and fuel consumption) are 2 examples.

- Projections and inventories can best be made by the same agency. If different agencies are involved they should work in close collaboration. As such assumptions in historic inventories and projections can be similar and unrealistic behaviour (drops, jumps and large switches between historic data and projections) can be avoided.

13.10.1 Energy

From all possible models, the optimisation models have the most attractive properties for developing scenarios for the energy sector for the following reasons:

- These models have been elaborated to represent the sector specific issues: representing level of detail of installations, load curves for electricity use…
- Cost minimisation is a sound economic principle for developing long run scenarios.

Points of critic to optimisation models are that they tend to overestimate the speed of implementation, and have some normative characteristics (what should be done). However, we should realise that there exist no “what will happen” methodology for long term projections.

13.10.2 Industry

The conclusions for the industry are very similar as for the electricity sector. Finally the choice for a particular model should be based on knowledge of the local circumstances.

In comparison with the electricity sector we note two major differences:

- Activities of installations are more directly related to the activity (or demand) scenario. Indeed, in the electricity sector different installations are used to produce one perfect homogenous product (electricity) whereas in the industry different installations produce different products. So the loading of installations depends more directly on the activity scenario. Therefore the need of using an optimisation model to determine activities of installations is not as urgent as in the electricity sector.
- The second difference is that is that in practice it is far more difficult to have the relevant sector specific knowledge and to represent alternative technologies in the industry. The industry tends to be very specific. Therefore the important issue is to get good (projected) activity data and information on possible abatement techniques. This is something that needs to be further elaborated.

These two raisons probably explain that the use of optimisation models for industry is not as widespread as in the electricity sector.

However, one major advantage of integrating industry and electricity sector into one optimisation model is that this allows to quantify the effect of the CHP directive on the industrial emissions and to account correctly between the sectors.

13.10.3 Fugitive emissions

The preliminary guidelines for fugitive emissions are based on inventory methods for historical emissions. However, these methods can also easily be adapted for projection purposes. Development of good activity data and emission factors are primordial. To improve projections, this issue needs to be further elaborated.

13.10.4 Residential

- Obtaining the required data for the energy projections can be quite difficult. So it could be helpful for the MS projections to add methodologies which describe ways to collect or estimate these data. Another difficulty forms the estimation of the projections of activity data, like the number of dwellings,… So, a description of estimation methods to obtain these projections could lead to more accurate projections of a MS.
- In the described Tier methods, the number of HDD is kept constant during the entire projection period. To take the impact of climate change into account, this number of HDD could be changed based on observed trends.
- It could be interesting to estimate the electricity projections based on a model that take behavioural aspects into account. This type of model will require detailed data, but might give good projections.
- The impact of price effects could be investigated more into detail. In these Tier methods, the energy price is dependent on the price of oil and natural gas. But, if the price increases of these two fuels, the use of inefficient wood can rise too. As a result, the final energy consumption can increase.

13.10.5 Services

- Obtaining the required data for the energy projections can be quite difficult. So it could be helpful for the MS projections to add methodologies which describe ways to collect or estimate these data. Another difficulty forms the estimation of the projections of activity data, like the number of employees, future GDP values,… So, a description of estimation methods to obtain these projections could lead to more accurate projections of a MS.
- In the described Tier methods, the number of HDD is kept constant during the entire projection period. To take the impact of climate change into account, this number of HDD could be changed based on observed trends.
- It could be interesting to develop a Tier II½ method which will form an alternative Tier method between the highly detailed Tier III method and the rather simple models of Tier I and Tier II. This method might be based on expert judgement when the exact data needed for an engineering/optimization model is not possible to obtain but still more information than needed in Tier I or Tier II exists.

13.10.6 Agriculture

- In contrast to country-specific studies, European studies can focus on the exchanges and the limits of exchanges of products and goods between different countries. Even more, European legislation determines strongly projections of activity data and/or EF. So European studies providing projected activity data and taking cross-country effects into account could be useful.
- A further harmonization (taking country-specific legislation into account) and the provision of activity data from several scenarios would enhance the applicability of these European data sources.
- Harmonization of the greenhouse gas projections with other European projection methodologies (GAINS, DNDC,…) will improve the comprehensibility of all available data.
- If inventory methodologies adopt the 2006 IPCC guidelines, these guidelines will have to be updated.
- Some additional information for the current projection methodology would be useful: amount of N manure excreted, amount of N fertilizer used,…

13.10.7 Waste

- As CH_4 emissions from solid waste disposal is a key category for most Member States for the inventories, First-Order-Decay models (FOD) have to be used for the inventory preparation. It is straightforward to apply the same model for the projections, because future emissions are determined to a large extent by past amounts of waste deposited on landfills. As such, information on historical activities is more important than projected ones.
- An important parameter for the projection is the assumed CH_4 recovery from landfills. This parameter should on the one hand be consistent with the GHG inventory for past years and should provide a reasonable trend in the future taking into account technological efficiencies, leakages and national activities for the implementation of CH_4 recovery.
- Some additional information for the current projection methodology would be useful: ratio of waste generation per capita, amount of industrial solid waste disposed,…

14 References

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