Quantification of the effects on greenhouse gas emissions of policies and measures
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Methodologies Report Appendix II: Case study applications of the Tier 3 methodology

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Daniel Forster
AEA group
The Gemini Building
Fermi Avenue
Harwell International Business Centre
Didcot
OX11 0QR

Tel: 0870 190 6474
Fax: 0870 190 6318

AEA is a business name of AEA Technology plc

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Author	Name	**ACEA:** Jonathan Köhler (Fraunhofer ISI) **Appliances:** Stefano Faberi (ISIS), Wolfgang Eichhammer (Fraunhofer ISI) **Biofuels:** Wolfgang Eichhammer (Fraunhofer ISI), Felipe Toro (BSR Sustainability) **EPBD:** Stefano Faberi (ISIS), Wolfgang Eichhammer (Fraunhofer ISI) **ETS:** Joachim Schleich, Frank Sensfuss, Wolfgang Eichhammer (all Fraunhofer ISI) **RES-E:** Mario Ragwitz (Fraunhofer ISI)

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1 ACEA agreement: Voluntary agreement of car manufacturers to reduce new car emissions

This chapter describes in detail an example "Tier 3" approach for the evaluation of the ACEA agreement taking into account the interaction of this measure with other measures aiming at the same target, including national measures. The main focus here is on the description of the methodology, although some discussion is also provided on the results from the application of the methodology.

The approach to developing the Tier 3 methodology has followed five sequential steps. These are:

- Step 1 Mapping of GHG measures in the context of the European Climate Change Programme (ECCP): This is the qualitative description of the "measure network" which may include EU-ECCP measures, EU-pre-ECCP measures, ECCP-triggered national measures as well as independent national measures aiming at the same target.
- Step 2 Compilation of quantitative evaluation evidence: This consists of the compilation of quantitative evaluation evidence such as in-depth national bottom-up evaluations, estimates from top-down impact indicators or simple estimates.
- Step 3 Screening step: This consists of the exclusion of unimportant national measures and pre-ECCP measures from the measure map, reducing the measure map to a simpler picture that can be modelled more easily.
- Step 4 Modelling step: The model-based harmonised evaluation of the simplified measure map provides an evaluation of impacts under harmonised assumptions.
- Step 5 Impact Delimitation: The impacts obtained in the previous step are in general "gross impacts". Further treatment of issues such as independent national measures aiming at the same target, autonomous progress, the impact of market energy price changes etc. may be necessary.

Each of these steps is described further below, following a more general discussion of the methodology and the data context.

1.1 Introduction: Brief description of the measure

In 1995, the EU set itself an ambitious goal of reducing emissions of carbon dioxide from new cars to 120 grams per kilometre (g/km) as a measure to combat climate change. The Commission tried to achieve this target through a voluntary agreement with European car manufacturers, who promised to gradually improve the fuel efficiency of their new cars[1]. The 1998 voluntary agreement between ACEA (the EU's Automobile Manufacturers Association) and the Commission included a commitment by the European carmakers to achieve a target of 140g/km by 2008. Japanese and Korean car producers made a similar commitment for 2009. Although significant progress was made, average emissions fell only from 186g/km in 1995 to 163g/km in 2004.

The ACEA was part of the first European Climate Change Programme. The EU Strategy on CO_2 emissions reductions from cars and LDVs was reviewed in EU (2007). It found that most of the reductions have been due to technological improvements, rather than demand side measures. Further, "*The progress achieved so far goes some way towards the 140 g CO2/km target by 2008/2009, but in the absence of additional measures, the EU objective of 120 g CO_2/km will not be met at a 2012 horizon*" (EU (2007 p.6). A series of supply and demand side legislative measures are proposed to achieve the 120g CO_2/km target. These measures have yet to be implemented; legislation has recently been adopted[2] setting mandatory emission limits for manufacturers of passenger cars.

[1] Commission Communication - Fourth Annual Report Year 2002, COM (204)78 final, Brussels, 11.02.2004
[2] See http://ec.europa.eu/environment/air/transport/co2/co2_home.htm

1.2 Methodological approach and data context

The approach taken to evaluate the GHG policies and measures introduced to implement and support the ACEA agreement has the five steps, as detailed below. The scope of the analysis includes measures specifically aimed at reducing CO_2 emissions from passenger cars.

For Step 1, the mapping of measures was informed by a review of available literature. An overall measures map was drawn up, based on this literature search. The measures were then grouped, to simplify presentation, and then interactions between the different measures were identified. This was not just in terms of reducing passenger car emissions, but also in terms of identifying complementarities between measures. For example, consumers must be informed of the emissions performance of different models of car, if they are to make choices based on emissions performance, in addition to other criteria. This implies that a tax based on emissions of a vehicle will much more easily affect choices if it is combined with a vehicle labelling scheme of sufficient detail to inform consumers of the performance of different vehicles in this respect.

Step 2 involved a review of the quantitative evidence on the impacts of the GHG-PAMs identified in Step 1, for the 11 countries specified. Evidence was taken from the MURE database[3], published articles, as well as EU and EEA reports, together with project reports. For Poland, Czech Republic and Romania, there is very little evidence. Bak (2008) and Bruhova-Foltynova (2008) (personal communications) were the two main sources for summarising transport policy in these countries.

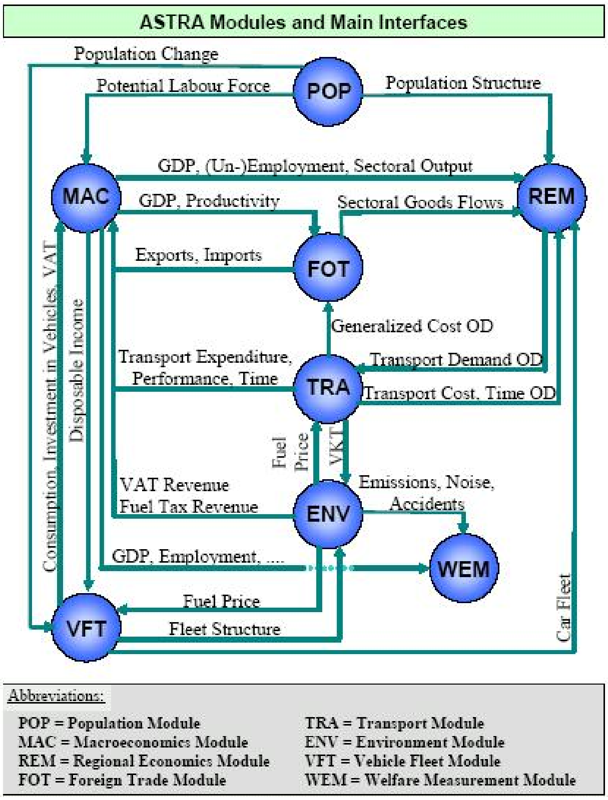
Step 3 involved screening the comprehensive list of measures developed in Step 1, to identify those which have had a measurable impact on GHG emissions from transport in the EU during the period of the ACEA agreement, 1998-2008. These measures were then summarised in a reduced measure map.

In Step 4 and 5, the quantification of the impacts in terms of GHG emissions reductions and impact delimitation was carried out using the ASTRA model, the structure of which is presented in

[3] MURE, (2008), MURE II database, www.isis.it.com/mure

Figure 1-1. ASTRA is an Integrated Assessment Model for the assessment of transport policies at a national and EU level, including GHG mitigation policy. It combines top down macroeconomic analysis, including disaggregated national consumption, with a bottom-up analysis of transport demand and technologies. Since it has explicit representation of all EU member states, analyses for the 11 EU countries chosen as case studies can be undertaken at the national level, with common policy assumptions for all countries where appropriate. ASTRA (=Assessment of Transport Strategies) is a System Dynamics model generating time profiles of variables and indicators needed for policy assessment. A detailed description of ASTRA is provided by Schade (2005). The ASTRA model consists of eight modules and the version described in this section covers the 27 European Union countries (EU27) plus Norway and Switzerland. Major interlinkages and feedbacks between the eight modules are shown in Figure 1-1.

Figure 1-1 Main features of the ASTRA transport model



1.3 Step 1: Mapping of the ECCP measure ACEA voluntary agreement with car manufacturers and identification of complementary measures

1.3.1 Overview

There are three useful databases which help to establish the measure maps: MURE II[3] and WEO Policy Database[4] both contain information on transport CO_2 policies. ECMT (2007) has a comprehensive list of policies. The measure map for the ACEA agreement is shown in

[4] IEA, (2008) WEO Policy Database www.iea.org/Textbase/pm/?mode=weo

Table 1-1. It comprises in particular:

- Different types of measures linked to the same target of the ACEA agreement to reduce emissions from new cars), such as car labels and various fiscal measures at the national level.
- The definition of the top-down impact indicator which measures the impacts of this measure package (g CO_2 /km for the new car fleet in a country).

Table 1-1: Measure mapping of the ACEA Agreement

MEASURE	TARGET	GOAL FOR TOP-DOWN IMPACT
ECCP1		
ACEA agreement	Emissions of new car fleet	
Car labelling		140g CO_2/km average for new cars sold in EU in 2008
Complementary to ECCP1		
Fuel taxes		
Annual Vehicle registration taxes differentiated by GHG implications		
Car purchase tax (VAT)		
EU biofuels directive		
CAP EU subsidy €45/ha for energy crops since 2003 up to 1.5Mha for whole of EU		
Vehicles in EU Emissions trading system (ETS)		
Technology promotion measures		
R&D networks (e.g. H_2)		
Subsidies for technology development		
Biofuel production subsidies		
Tax reductions on biofuels		
Biofuels quotas and warranty		
Technical standards		
Voluntary agreements		
Consumer/retailers' information campaign		
LNG directive		
LNG policies as for biofuels		
Measures for Vehicle Components – tyres, lubricants, air conditioning systems		
Labelling		
Standards		
Subsidies		
Consumer measures		
Subsidies for early retirement		
Fuel efficient driving – information and education	**Only indirect impact on emissions of new car fleet**	
Infrastructure measures		
Road pricing	**Only indirect impact on emissions of new car fleet**	
Subsidies for new control, monitoring technologies		
Public expenditure on infrastructure for GHG-PAMs		
Road pricing		

1.3.2 Detailed description of measures to reduce the emissions of the new car fleet

The following policies and measures have been introduced to deliver emissions reductions from passenger cars.

ECCP1

- ACEA agreement: main measure so far, not achieved, so binding restrictions now proposed.
- Car labelling: little measurable effect so far (TNO, 2006; EVA, 1999). Needs strengthening; in Germany this has been in operation since 2004.

Complementary to ECCP1

- Fuel taxes: restrict demand growth, reduction in fuel use reduces CO_2 emissions in proportion, so has same economic inventive effect as a tax directly on CO_2. E.g. UK fuel tax escalator.
- Annual Vehicle registration taxes differentiated by GHG implications, weight, engine capacity, measured CO_2 emissions in some countries.

- Car purchase tax (VAT), increases cost of cars, so may have a slight impact on modal split. Can be differentiated by emissions performance.
- EU biofuels directive, implemented in many countries
- Congestion charging differentiated by emissions performance
- Eco Tax for Germany.

Technology promotion measures

Some are long term, so may not impact within ACEA time scales:

- R&D networks (e.g. H_2)
- Subsidies for technology development e.g. Japanese electric car programmes (but most money spent by auto-producers).

Promotion of biofuel crops and biofuels for vehicles

- Biofuel production subsidies are present in many EU countries as a result of the EU biofuels directive with a 2020 target, Directive 2003/30/EC on the Promotion of the Use of Biofuels or Other Renewable Fuels for Transport.
- Tax reductions on biofuels
- Quotas
- Mandatory targets per country, biofuel obligation (quota) on fuel suppliers at EU level.
- Modified transport fuel quality directive to require minimum proportion of biofuels.
- Voluntary agreement
- Labelling, publicity campaign for retailers and consumers.
- Warranty for cars that can use a high proportion of biofuels as fuel input (10% instead of current 5%).

LNG vehicles

- Directive similar to the biofuels directive with EU target
- Tax incentives, public purchase, vehicle purchase subsidy, filling station subsidy, inclusion in manufacturer's bubbles for achieving targets.

Technologies for Vehicle Components

Low Rolling Resistance Tyres, Tyre Pressure Monitoring Systems (TPMS)

- Tyre Labelling,
- Database of tyre efficiency data,
- Purchase incentive programme (low cost),
- Manufacturer incentives (subsidies)
- Dealer/driver education
- Tyre performance testing
- TPMS performance standard – to support legislation

Low viscosity lubricants (LVL) for engines

- Purchase incentive programme
- Database, Labelling
- R&D policies for engines and lubricants

Consumer measures

Subsidies for early retirement (e.g. Italy)

Fuel efficient driving (only indirect impact on emissions of new car fleet)

- Gear Shift Indicator – regulation or voluntary agreement
- Real time fuel consumption indicator
- Eco-driving training
- Awareness campaigns for eco-driving

Infrastructure measures (only indirect impact on emissions of new car fleet)

- Road pricing – motorways/interurban roads, urban congestion charging differentiated by GHG performance of vehicle, Passenger cars, LGVs, HGVs.

Main EU measures

- Amendment of the Eurovignette directive (1999/62/EC) and adoption of a Directive on the interoperability of tolling systems (2004/52/EC) (Kitou, 2006).
- Subsidies for new technologies (Galileo, SESAR).
- Public expenditure on infrastructure for GHG-PAMs e.g. congestion charging / road pricing infrastructure

1.3.3 Measure Interactions

Supply measures acting on producers must usually be complemented by measures to ensure market demand by consumers. The effectiveness of the ACEA voluntary agreement will in part be related to the availability of measures that impact consumer choices. Conversely, fiscal measures such as fuel taxes can only have an effect if the consumer has a choice between low and high efficiency/emissions vehicles.

Measures on commercial car fleets are semi-independent of consumer measures, but form a large part of demand. Public procurement works in a similar manner. Both can serve to create markets, which can then be expanded through diffusion into mass consumer markets. LGVs – policies as for passenger vehicles (current incentives often different to passenger cars), biofuels, H_2, LNG and hybrid/all electric cars all require their own sets of complementary support measures. H_2, LNG and all electric vehicles also require supporting refuelling infrastructure. H2 fuel cell vehicles are strongly complementary to electric vehicles, as they are also electric. But this is not so for H_2 combustion vehicles.

Biofuels measures largely act independently of the other measures. Incentives for agriculture to grow fuels also requires infrastructure to produce fuel and supporting measures on vehicles, standards and targets for biofuels proportions to enable market take-up.

Labelling measures need to take into account overall emissions performance of vehicle. Low resistance tyres and Tire Pressure Monitoring System (TPMS) and LVLs both need to be incorporated into the overall label. Labelling also requires a realistic test programme for new cars.

Education for drivers requires supporting information, about GSI, real time fuel consumption, road pricing. Likewise, road pricing requires complementary measures to provide the systems for charging and monitoring.

1.4 Step 2: Compilation of quantitative evaluation evidence

TNO (2006) provides a comprehensive review of the evidence of the effectiveness of GHG-PAMs for passenger cars. Zachariadis (2006), EEA (2008) and T&E (2007) review the trends in fuel consumption and specific CO_2 emissions for passenger cars. Note that, for diesel and petrol fuels, CO_2 emissions are directly proportional to fuel consumption. Previous evaluations suggest that the ACEA agreement has made no observable difference to the long run trend in specific CO_2 emissions. The ACEA agreement has led to a moderate improvement in emissions performance of new vehicles, mostly through a switch from petrol to diesel fuel (Fontaras & Samaras, 2007). This improvement has been offset by a behavioural trend to purchase larger cars (Zachariadis, 2006).

Vehicle labelling

TNO (2006) reports zero measurable effect of labelling. EVA (1999) reports potential reduction in emissions of up to 5%. ECCP1 labelling measures not clear and not accompanied by information campaigns for sales people or consumers. More stringent measures might realise an effect closer to the assessment of EVA (1999).

Fiscal measures

Dannenberg et al. (2008) summarise Boeters et al. (2003) who examine the economic implications if the ACEA standard is introduced in 2005, corresponding to a 30% increase of fuel efficiency. It reduces CO_2 emissions of the transport sector by roughly 19% in 2015 and 23% in 2035. Standards are implemented as an implicit fuel tax to reach the standard.

Kunert & Kuhfeld (2007) survey EU taxes on cars. They argue that the only significant taxes with CO_2 differentiation are in Austria for the registration charge and in Denmark for the annual vehicle tax. Differentiation between diesel and petrol taxes is the most significant fiscal measure affecting energy use and hence GHG emissions in cars. Taxes with differentiation by CO_2 emissions are not otherwise significant.

In contrast, Sterner (2007) calculates the hypothetical effect on the OECD if all countries in the ECD had applied (for a long period) the price (tax) policy pursued by the European countries with the highest tax level (Italy, UK and the Netherlands). Assuming a price elasticity of -0.8 (from reviews of empirical evidence), OECD emissions of carbon from transport would have been 44% lower. Price elasticities of -0.7 and -0.6 resulted in emissions being 40% and 36% lower, respectively. The hypothetical OECD total with US prices is more than twice as high (+133%) as the corresponding hypothetical OECD total with Dutch prices. The differences in gasoline demand analyzed are very large, partly explained by an increased use of diesel. This suggest that EU levels of fuel taxation have a significant impact on fuel demand and hence GHG emissions.

TNO (2006) also conclude from their survey that the CO_2 taxation introduced by Denmark has had a significant effect on vehicle emissions. The CO_2 differentiated tax system introduced in the UK has, in contrast, had no measurable impact on consumers' purchase decisions, although fleet buyers have responded to the fiscal incentives.

Jacobsen et al. (2003) show that the registration tax on new vehicles and taxes on petrol combine with a weight duty on cars to make vehicle taxation relatively high compared to other countries. This has reduced the number of new registrations in Denmark.

Benke et al. (2002) evaluate Austrian policies for reducing GHG emissions. They find that transport policy had not been effective in reducing emissions. The low levels of fuel taxation compared to surrounding countries led to exceptionally high levels of 'tank-tourism'. Therefore, increasing taxation levels i.e. harmonisation of petrol taxes, would be the most effective measure in reducing GHG emissions from Austria.

Congestion charging differentiated by emissions performance has only been implemented in a few cases, so overall assessments by country are not available.

Biofuel measures

Ryan et al. (2006) estimate the cost of subsidising the price difference between European biofuels and fossil fuels per tonne of CO_2 emissions saved as €229–2000. This is at the top of the range of the marginal abatement costs of CO_2 emissions for the road transport sector given by Blok et al., (2001) of €73–350/tCO_2. So biofuels are not currently economically efficient. Steenberghen & López (2008) report that Europe has a lead position in the production of biodiesel across the world, with production of over 500,000 tons and an installed capacity of 1 million tons in over 20 production sites, with sales of 1% of the diesel market. The Directive on the promotion of Biofuels Directive 2003/30 set an indicative target of replacing 5.75% of petrol and diesel consumption by biofuels for transport purposes by end 2010. They report a potential for both biodiesel and bioethanol of 12% of market share by the year 2020, which equates to 45 million tons of biofuels.

Hammond et al. (2008) show that the UK Government's Renewable Transport Fuel Obligations Order (RTFO) sets EU targets out specifically in a national framework. The UK Government has estimated that, if the RTFO of a 5% blend is achieved in AD 2010, it will save around a million tonnes of carbon per annum, assuming biofuels have a 60% carbon saving compared with fossil-fuels.

Vehicles in EU Emissions trading system (ETS)

Not implemented and legislation not yet in progress for ECCP2.

Alternative technologies

- H2 not yet sold in the market, so not relevant to ACEA timescale.
- Electric vehicles only sold in market in very small proportions, mainly as hybrids with relatively small improvement in emissions performance - so no significant effect on emissions by 2008.
- LNG vehicles only small proportion of the passenger car market by 2008, so no significant effect on emissions by 2008.

Technologies for vehicle Components

These have not yet been incorporated in production vehicles, so no significant effect on emissions by 2008.

Consumer awareness and education measures

Not yet implemented on a large scale, so no significant effect on emissions by 2008.

Road pricing

Mainly adopted for Heavy Goods Vehicles (HGVs) on motorways, with the only large scale implementation for cars in the countries under consideration in the UK for London.

Subsidies for vehicle replacement

Subsidies for vehicle replacement in Italy discontinued after 2003, in France discontinued after 1999.

1.5 Step 3: Screening

The criteria for screening is that a measure should have had a significant and measurable impact on GHG emissions from new passenger cars within the period of the ACEA agreement i.e. after 1996 and by 2008.

1.5.1 Screening of individual measures

Vehicle labelling: TNO (2006) reports zero measurable effect of labelling. EVA (1999) reports potential reduction in emissions of 5%. ECCP1 labelling measures not clear and not accompanied by information campaigns for sales people or consumers. More stringent measures might realise an effect closer to the assessment of EVA (1999).

Fiscal measures: Sterner (2007) argues that high fuel prices through high fuel taxes reduce demand and therefore emissions significantly. Kunert & Kuhfeld (2007) find that the actual CO_2 based measures are negligible. However, Sterner (2007) supports the conclusions of TNO (2005), that fuel taxes are the most important single measure for GHG emissions reduction from transport in the short to medium term and form the most important element of GHG-PAMs to be modelled.

Biofuel measures: These have achieved some market penetration, but only to a limited extent (1% of diesel in EU, Steenberg & López, 2008).

Vehicles in EU Emissions trading system (ETS): Not applied by 2008, so can be excluded from the modelling.

Alternative technologies: Not applied by 2008, so can be excluded from the modelling.

Technologies for Vehicle Components: These have not yet been incorporated in production vehicles, so no significant effect on emissions by 2008 and can be excluded from the modelling.

Consumer awareness and education measures: Not yet implemented on a large scale, so no significant effect on emissions by 2008 and can be excluded from the modelling.

Subsidies for early retirement: These have been employed in France and Italy, but have only led to small reductions in emissions (see Appendix).

Road pricing: This can be seen as another form of taxation on vehicles. Scenarios including road pricing for cars have been modelled extensively. If the tax level is high enough, then considerable reduction in transport activity can result (e.g. Köhler, Jin and Barker, 2008) and a strong incentive for improvements in emissions performance are provided. However, such extensive charges have not yet been imposed in practice.

1.5.2 Summary: reduced measures map

Target: Emissions of new car fleet

Goal for top-down impact: 140g CO2/km average for new cars sold in EU in 2008

Measures to reduce emissions of new car fleet:

Main measures implemented so far for passenger cars are:
- differentiated fuel tax (petrol and diesel)
- differentiated annual and vehicle registration taxes
- biofuel promotion and sales as mixture with fossil fuel petrol

However, as explained above, biofuels promotion policies have had relatively little effect up to 2008. Therefore, the most important instruments to be considered for the purposes of this case study are fuel taxes and registration taxes. Biofuels should be considered in future ex-post evaluations of VAs.

Summary tables for the 11 countries to be considered are in Appendix 1. The tables include assessments of the CO_2 reductions achieved by the measures. The assessments in the different countries show that the most effective measures are various forms of taxation, but that such measures are not widely implemented. The reductions of CO_2 emissions from measures implemented in all 11 countries are small, with the possible exception of the fuel tax escalator in the UK (discontinued after 2000) and the company car tax in the UK.

1.6 Step 4: Modelling step

The ASTRA model has been used to assess the impact of the ACEA agreement. This analysis has the following aspects:

1. What would the emissions in the 11 EU countries under consideration be, if the ACEA targets were achieved in 2008 and if they were the only relevant factor impacting on the indicator g/km? The ASTRA vehicle fleet and environmental performance model is used to calculate emissions from the passenger car fleets. The result is the **gross savings from the ACEA agreement under the assumption of complete achievement of the agreement and no other factors acting**.

This gross or potential impact is the starting point for an evaluation of the ACEA agreement. There are a variety of other factors impacting also on the indicator g/km which must be taken into consideration in an evaluation of the actual impact of the ACEA agreement:

2. Firstly, what is the rate of **autonomous technological progress**? This can be identified from the historical trend of gCO_2/km per vehicle in the period before the ACEA agreement, e.g. in the period 1990-1996. This arises from various factors, such as firms' R&D decisions, perceptions of changes in consumer preferences, new applications of scientific progress etc. A particularly important factor is changes in crude oil prices leading to changes in fuel costs for the consumer. This was a period of low energy prices, so the main driving force was technical progress, not energy prices.

An important factor improving efficiency is the **mix of Petrol and Diesel cars**. In most EU countries there there was a shift from the former to the latter. In principle this could have been the impact of the ACEA ACEA agreement as the producers might have chosen to promote Diesel cars as the more efficient cars. cars. Nevertheless, there are other factors influencing the choice of Diesel cars, notably the difference in difference in taxation until very recently (

3. Figure 1-3). It can be deduced that the tax difference was the main influencing factor for the trend towards a greater proportion of Diesel cars.
4. The **change in the composition of the vehicle stock by size class**, reflecting the development of manufacturers' marketing policies, consumer preferences and wealth. Recent developments have been in the direction of more wealthy consumers (on average) choosing larger private cars. While the trend is not as extreme as in the US, with the 2-3T SUV taking a large market share there, there has been a trend to 4x4 vehicles and people carriers. This increase in vehicle size, and the corresponding fuel consumption, has offset the impact of technology improvements to a large extent.
5. **Fiscal policies such as the car taxation according to CO_2 impact** alter the costs of fuel to the consumer. However, such measures have only been taken very recently in some EU Member States so that their interaction with the ACEA agreement is close to zero.
6. **Fuel price** for the consumer consists of the cost of the fuel plus taxes. The international oil price, as reflected in the costs of the fuel, is a large component of the fuel price and is a significant component of the utilisation costs of a vehicle.
7. **Low emissions fuels**. In the last 2-3 years, there has been considerable emphasis on the introduction of biofuels. If biofuels are produced such that they are carbon neutral and if they are adopted on a large scale, this could reduce CO_2 emissions considerably. However, this movement is too recent (policies on biofuels and the commercial availability of biofuels have only been significant since 2005) to have a significant impact within the timescale of the present analysis. Further, biofuels are currently used in a mixture with fossil fuels where the proportion of biofuels is only 5-10%. This has the advantage of the engines requiring no alteration to run on the mixed fuel. The adaptation of biofuels is a measure running in parallel to the ACEA agreement, which is directed at reducing overall emissions by improvements in fuel efficiency of cars. The car manufacturers have mostly interpreted the ACEA agreement as requiring improvements in fuel efficiency, rather than leading to fuel switching.

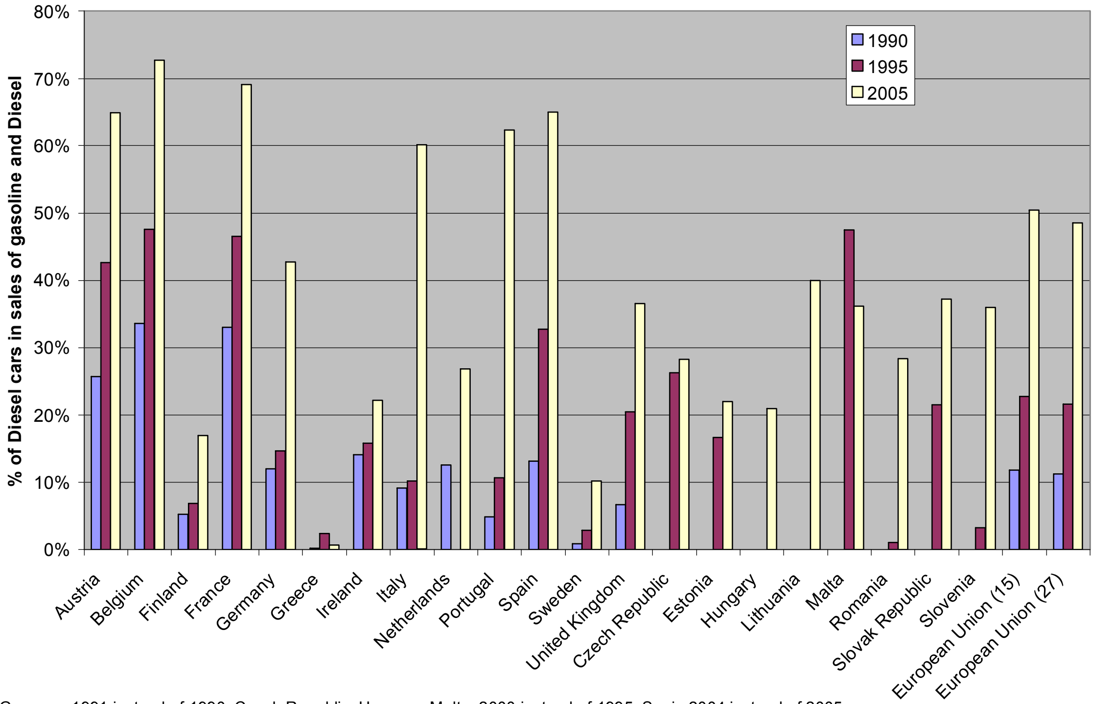
Interdependencies between the factors

These 7 factors are not independent, but have causal relationships between them. In particular, the decisions of consumers play a central role. The size and fuel type of car bought is the consumer's decision, influenced of course by the manufacturers' marketing policies. The decision reached will be dependent partly on their budget constraint, partly on purchase and running costs including taxes, but also on consumer tastes and marketing policies by manufacturers. Taxation policy and fuel price have an impact on diesel vs. fuel shares and the distribution of vehicle size.

In principle, new/alternative technologies such as biofuels and petrol/electric hybrids have also become part of consumers' choices, but these developments are too recent to have a significant impact before 2006-7. Biofuels do not affect car choice, as the vehicles do not have to be changed and the share of hybrids is still very small (less than 0.1% of new cars).

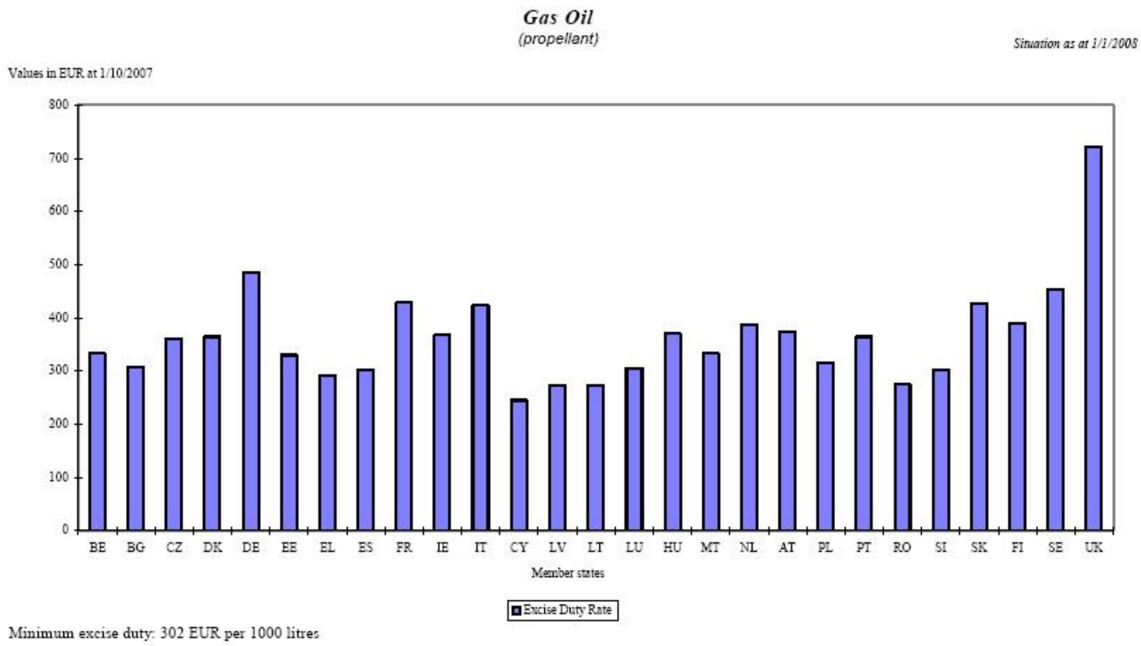
In a final step the net impacts of the ACEA agreement are calculated from the gross impacts (1) by adding the effects (2) to (7). Note that the effect (4) has increased the g/km emitted over the past 10 years.

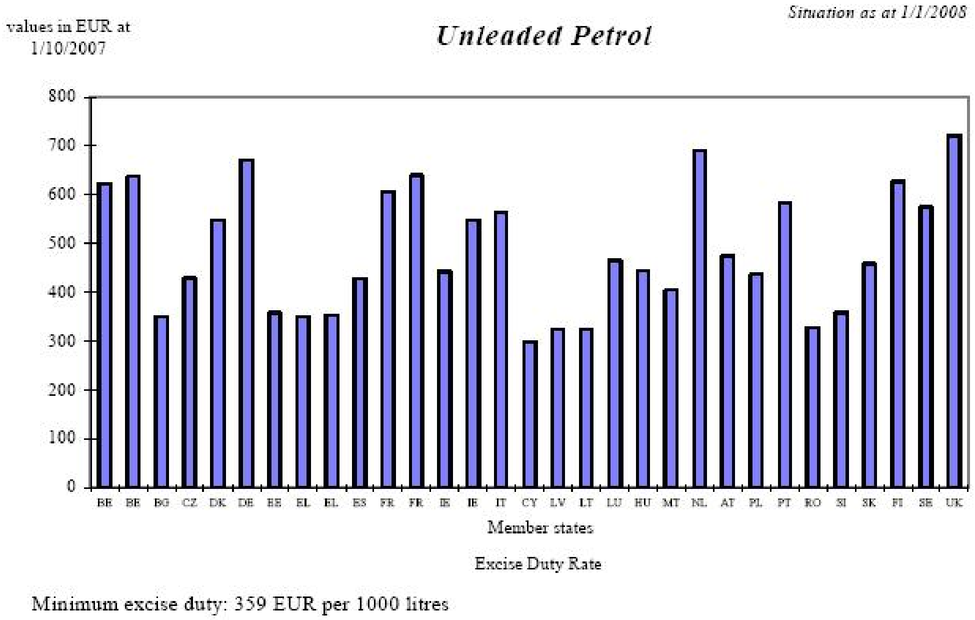
Figure 1-2 Share of Diesel cars in the sales of gasoline and Diesel cars together (2005 – 1995 - 1990)



Germany 1991 instead of 1990; Czech Republic, Hungary, Malta: 2000 instead of 1995; Spain 2004 instead of 2005

Figure 1-3 Comparison of Diesel and Gasoline excise duties (2008)





Source: Excise Duty Tables Part II 2008 – Energy products and Electricity
http://ec.europa.eu/taxation_customs/resources/documents/taxation/excise_duties/energy_products/rates/excise_duties-part_II_energy_products-en.pdf

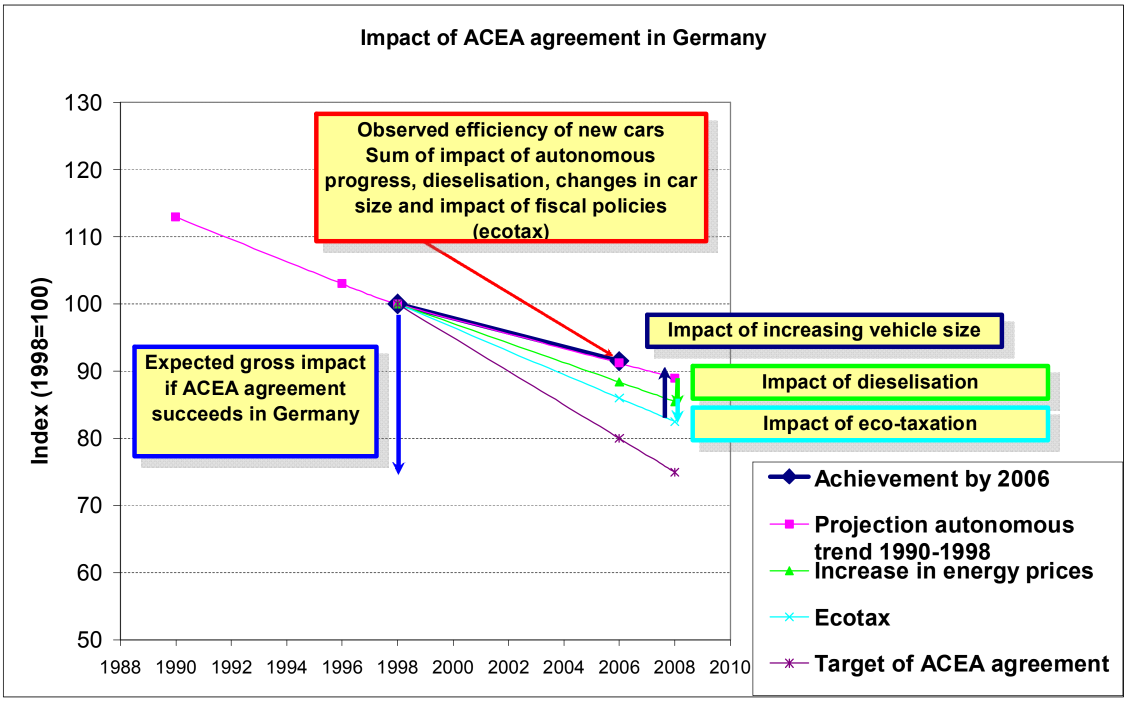
1.7 Step 5: Impact Delimitation

1.7.1 The decisive role of the impact delimitation for the evaluation results

The impact delimitation step is an integral part of the assessment of the ACEA agreement as described above, unless the gross impact is taken which is not recommended here. The procedure as described above is demonstrated, taking the case of Germany.

The arrow on the left hand side of **Figure 1-4** shows the theoretical impact of ACEA in Germany, if the agreement were fully achieved and if it were the only policy acting on the indicator g/km or l/100km which is shown here as an index. However, the actual impact of the ACEA agreement has to be assessed by comparing the observed technical progress to the various factors that contribute to the overall change. Autonomous progress is assumed to be a continuation of the recent historical trend (pink line with squares in **Figure 1-4**). This can be thought of as the baseline to which other factors are added. The impact of the move from petrol to diesel cars (green line with triangles in **Figure 1-4**) and the effects of energy taxation in Germany (light blue line with crosses in **Figure 1-4**) are complimentary to the ACEA agreement in that they act to reduce average fuel consumption. The trend to increasing vehicle size offsets these effects (dark blue arrow). In the case of Germany, the trend to larger cars approximately offsets the gains from dieselisation and the eco-taxation programme. This would still leave some room for the ACEA agreement to contribute to the reduction. In the case presented in **Figure 1-4**, the observed indicator is only at the level of the technical progress observed previously (heavy blue line “achievement 2006” in the figure). This implies that that the factors increasing the indicator g/km or l/100km such as increased weight and increased power of the cars due to consumer choices (blue upward arrow) have been compensating for the fiscal policies as well as for any possible additional improvement of the cars through the ACEA agreements so that the net impact of these agreements would be close to zero. This shows the importance of a transparent discussion of the different evaluation parameters. For this purpose therefore, the approach based on the evaluation with the ASTRA model was chosen.

Figure 1-4 Impact of the ACEA agreement in Germany and interaction with other factors impacting on the g/km indicator



1.7.2 Impact delimitation calculations with the ASTRA model

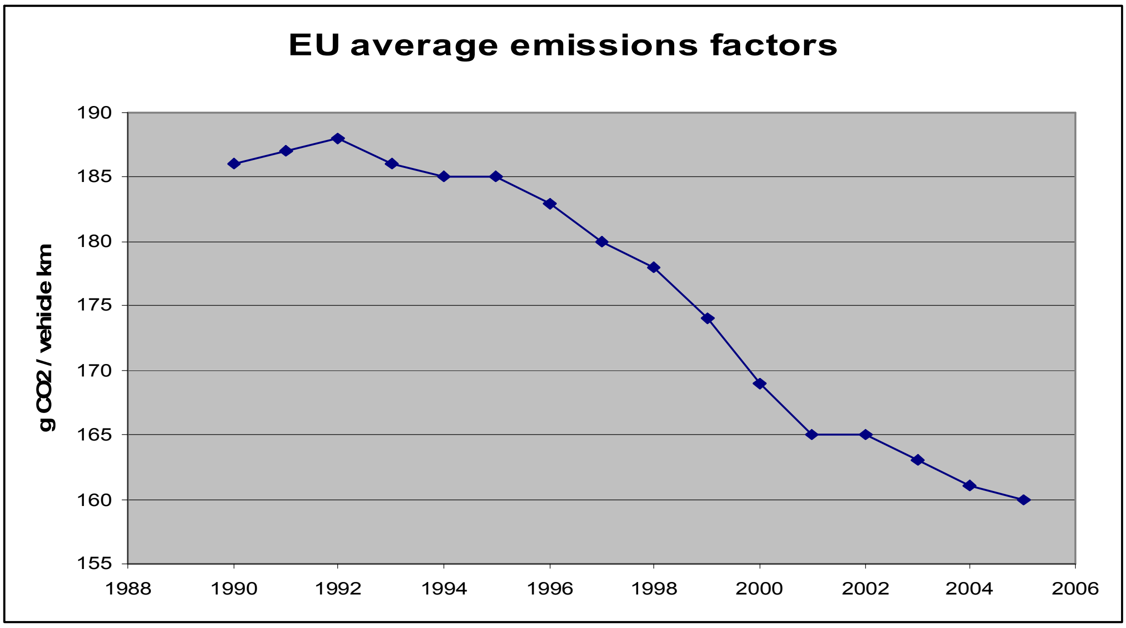
Overall, the methodology for an ex-post analysis is as follows:

1. Reproduce the historical data, given the bottom-up calculation methodology in the ASTRA model,
2. Assess the importance of factors 1 – 7 above, as described above.
3. The 'unexplained' change in emissions factor can then be taken as the impact of the ACEA agreement (which assumes, of course, that all the major factors have been identified and their impact accurately assessed).

ASTRA has been adapted to calculate the CO_2 emissions of new cars. Such calculations in the ASTRA model are performed on a bottom-up basis. Data on new car sales for each EU country by type of fuel and size class are combined with data on emissions factors for the different types of car to calculate national and EU average emissions factors in g CO_2/vehicle km, the unit of measurement of the ACEA agreement. Since the historical data series for the actual EU average is available, the model's bottom-up calculations are corrected such that the historical data is exactly reproduced as a starting point. This can then form a basis for examining the various factors that have contributed to the historical time series.

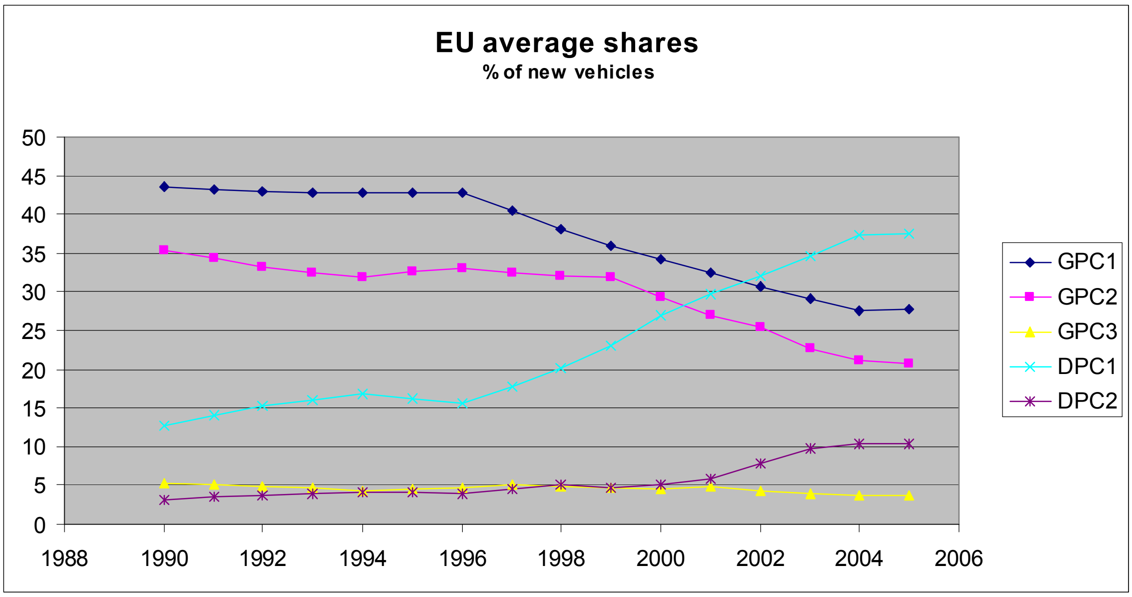
The theoretical EU average emissions factors for new cars calculated by ASTRA differ by between 10 and 20% from the ACEA data shown in figure 1-5. This data is the same as reported in EU (2007). There are two main reasons for this. ASTRA performs a more complex calculation than that used to produce the ACEA data. The ACEA calculation quoted by car manufacturers to measure the impacts of the agreement is based on tests of simulated urban trips and interurban trips. ASTRA, on the other hand, has a separate calculation for cold start emissions and also has a weighting by five distance bands: local (<3.2km), very short (3.2-8km), short (8-40km), medium (40-160km) and long (>160km).

Figure 1-5 EU average specific CO_2 emission for new cars (g CO_2/km)



Source: EU (2007) draft, ACEA

Figure 1-6 Shares of new car purchases by fuel and size (definition in text)



Source: Calculations for ASTRA based on EUROSTAT data

ASTRA makes the simplification to five size classes of diesel and petrol vehicle:

- Petrol >1400cc (GPC1), 1400-2000cc (GPC2), >2000cc (GPC3)
- Diesel <2000cc (DPC1), >2000cc (DPC2)

Emissions data are calculated for these distance bands and size categories, which are not used in the ACEA calculation. Therefore, ASTRA was run as a base case to calculate the overall average EU emissions factor. The difference between this calculated factor and the historical data was then used to calculate an average scaling factor for further calculations. It was possible to reproduce the historical data to within 0.01%.

Figure 1-5 and Figure 1-6 present the basic data, as used in the analysis. Since the shares data is available from 1990, it is possible to use the 1990-1996 data as a calibration period, to determine trends before the period of the ACEA agreement. It can be seen that the share of diesel vehicles increases slightly, while the share of large vehicles (GPC3 and DPC2) is more or less constant.

1.8 Results and comparison with Tier1/2 approaches

The overall results from the application of the Tier 3 analyses are shown in Table 1-2 (cumulative results for the period mentioned) and Table 1-3 (results for the years 2005 and 2007; the latter for the Tier3 approach only). The tables include a comparison with the results from the Tier 1 and Tier 2 approaches, which are based upon a more simplistic methodology. Further details on the Tier 1 and Tier 2 approach can be found in the main report.

Table 1-2 Cumulative results of Tier1, Tier2 and Tier3 analysis for the period indicated

		Tier1	**Tier 2**		**Tier 3**	**Tier 3**
Group/Ms	**Tier 1 / 2**	**Freezing emission rates at earliest value (1995)**	**Removing the effect of dieselisation**	**Tier 3**	**actual vkm**	**constant 1996 vkm**
	Policy impact period	**(Mt CO2)**	**(Mt CO2)**	**Policy impact period**	**(Mt CO2)**	**(Mt CO2)**
EU27	1995 to 2005			1996 to 2007	-135.8	-135.2
EU15	1996 to 2005	-119.9	-109.9	1997 to 2007	-114.9	-114.4
Germany	1997 to 2004	-25	-22.5	1998 to 2007	-24.8	-24.7
France	1998 to 2005	-14.8	-14.4	1999 to 2007	-24.2	-24.1
Spain	1999 to 2003	-4.3	-3.4	2000 to 2007	-3.5	-3.5
Italy	2000 to 2003	-11.2	-11.2	2001 to 2007	-19.0	-18.9
UK	2001 to 2003	-28.5	-30.4	2002 to 2007	-25.7	-25.6
Denmark	not possible			2003 to 2007	-2.5	-2.5
Austria	1995 to 2005	-1.1	-0.6	2004 to 2007	-0.6	-0.6
Netherlands	1996 to 2002	-3.8	-1.7	2005 to 2007	-4.5	-4.5
Poland	not possible			2006 to 2007	-3.5	-3.5
Czech Republic	not possible			2007 to 2007	-3.4	-3.4
Romania	not possible			2008 to 2007	-1.0	-1.0

Table 1-3 Results for CO_2 savings in the year 2005 and 2007

	Tier1	Tier 2	Tier 3	Tier 3
	2005	2005	2005	2007
Group/MS	Freezing emission rates at earliest value (1995)	Removing the effect of dieselisation		
	(Mt CO_2)	(Mt CO_2)	(Mt CO_2)	(Mt CO_2)
EU27			-21.2	-30.2
EU15	-29.4	-26.4	-17.9	-25.4
Germany	-4.7	-4.1	-3.9	-5.7
France	-3.7	-3.3	-3.8	-5.3
Spain	-1.4	-1.4	-0.6	-0.8
Italy	-	-	-2.9	-4.0
UK	-8.1	-8.3	-4.0	-5.8
Denmark			-0.4	-0.5
Austria	-0.3	-0.1	-0.1	-0.1
Netherlands	-0.7	-0.6	-0.7	-1.0
Poland			-0.5	-0.8
Czech Republic			-0.5	-0.8
Romania			-0.2	-0.2

Results for case study Member States

The savings from the ACEA agreement for Member States correspond approximately to the population and GDP, as these are the main drivers of car ownership. However, some countries stand out. France has a relatively low effect compared to Germany and the UK. This is probably because of the exceptionally strong shift to diesel in France. Spain has a surprisingly small effect, given its size. This is due to the rapid increase in car ownership, especially of larger cars, and an increase in the km driven/year in Spain. The Czech Republic shows a surprisingly large impact, probably due to the rapid adoption of advanced engines, in comparison with other New Member States.

Results for EU-27

Overall, the impact of the ACEA agreement is assessed to have been considerable – of the order of 135 Mt CO_2 for the EU 27 between 1996 and 2007 (cumulative savings). On an annual basis, for the latest year in which impacts were calculated (2005) the savings were around 18 Mt CO_2 for the EU15 and 21 Mt CO_2 for the EU27. Given the relative weakness of supporting policies, this can be attributed to the highly competitive nature of the automobile industry. While directive 1999/94/EC provides the basis for adoption of efficiency labelling of cars, TNO (2006) found no measurable effect of labelling policies in the assessment literature. While it cannot be plausibly argued that fuel efficiency is the main consideration of consumers' new car purchases, fuel efficiency figures are readily available and can be regarded as a point of competition between auto manufacturers. Therefore, the ACEA agreement can be seen to have reinforced this effect. However, the non-binding nature of the agreement is clearly demonstrated, in that the agreed ACEA targets have not been met.

1.9 Sensitivity analysis

A series of experiments were performed with the model. These were intended to identify the impact of changes from petrol to diesel and size shares and of any changes in policy on fuel and vehicle taxation and of changes in fuel prices since 1996. Separate runs were undertaken in which the share of diesel vehicles, the distribution of size of vehicle, the taxation of fuel and vehicles and finally fuel prices were all held constant from 1996. These runs could then be compared to the historical development to identify any changes in the average emissions factor due to these four effects.

The results are shown at Table 1-4. Firstly, the average EU emissions based on historical data from 1990 to 2007 are shown. This run also takes external data on fuel prices from the POLES model, hence including historical data on fuel tax policy as well as crude oil prices and prices for diesel and petrol in the individual EU member states. As a check, the fuel prices calculated within ASTRA (i.e. using ASTRA data on oil prices and vehicle policies) were used for a control run, shown in the second row of Table 1-2. This demonstrated that there was very little difference between the ASTRA calculations and external data. Four historical scenarios were then run and emissions factors for the new car fleets for each country and the EU calculated:

i) Assuming that the proportion of diesel to petrol cars remained constant at the 1996 level, in contrast to the switch to diesel fuel shown in Figure 1-6. Surprisingly, this had only a small effect on overall new vehicle emissions, but with an increase over the historical development. This is partly because while diesel vehicles have lower fuel consumption, they emit approximately 8% more CO_2/litre of fuel than petrol vehicles. This decreases the gain in specific emissions from the shift, but does not explain an increase in specific emissions. The increase comes about because diesel cars tend to be purchased with larger engines than the equivalent purchase of a petrol car. Also, technical progress in diesel engines has been less rapid than in petrol engines.

ii) Assuming that the distribution of the size of vehicle purchased remained constant at the 1996 distribution. It is commonly argued that there has been a 'fashion' or consumer trend to purchase larger cars, wiping out any benefit that improvements in engine efficiency may have had. This run also showed very little difference to the historical development, with a slight increase in average specific emissions between 2000 and 2004 and a subsequent decrease to 2007. This suggests that there was only an increase in the size of vehicles purchased between 2000 and 2004. This is actually shown in the data in **Figure 1-6**. This shows that the move to larger vehicles (classes GPC3 and DPC2) started in 2000 and was only true for diesel vehicles, with a decrease for petrol vehicles. Also, large vehicles only form a small proportion of the distribution by size in the European market – shifting from 10% of new vehicles in 2000 to 14% in 2005. Therefore, the overall effect is slight.

iii) A run to test the impact of fuel taxation policy, in which fuel taxes were held constant at 1996 levels. This had almost no effect on the results, showing that there has been no significant strengthening or weakening of taxation policy since 1996 as a result of the ACEA agreement.

iv) A run to test the impact of changes in fuel prices, in which diesel and petrol prices were held constant at 1996 levels. This also had almost no effect on the specific emissions of new cars up to 2005 (it should be noted that the strong price increase in transport fuels only occurred after this period).

Table 1-4: Sensitivity analysis, assessing the changes due to the different factors (based on the specific CO_2 emissions per km

g CO_2/km	Historical development	Historical development ASTRA fuels prices	Const. diesel share	Const. size share	Const fuel tax	Const fuel price
1990	186.0	186.0	186.0	186.0	186.0	186.0
1992	188.0	188.0	188.0	188.0	188.0	188.0
1994	185.0	185.0	185.0	185.0	185.0	185.0
1996	183.0	183.0	183.0	183.0	183.0	183.0
1998	178.0	178.0	178.0	177.5	178.0	178.0
2000	169.0	169.0	169.3	169.7	168.9	169.0
2002	165.0	165.1	165.5	166.4	165.1	165.1
2004	161.0	161.4	161.6	162.5	161.3	161.3
2006	156.4	156.7	158.0	155.4	156.7	156.7
2007	152.9	153.0	154.3	150.1	153.1	153.0
2008	149.3	149.4	150.6	144.9	149.4	149.4

Source: ASTRA calculations

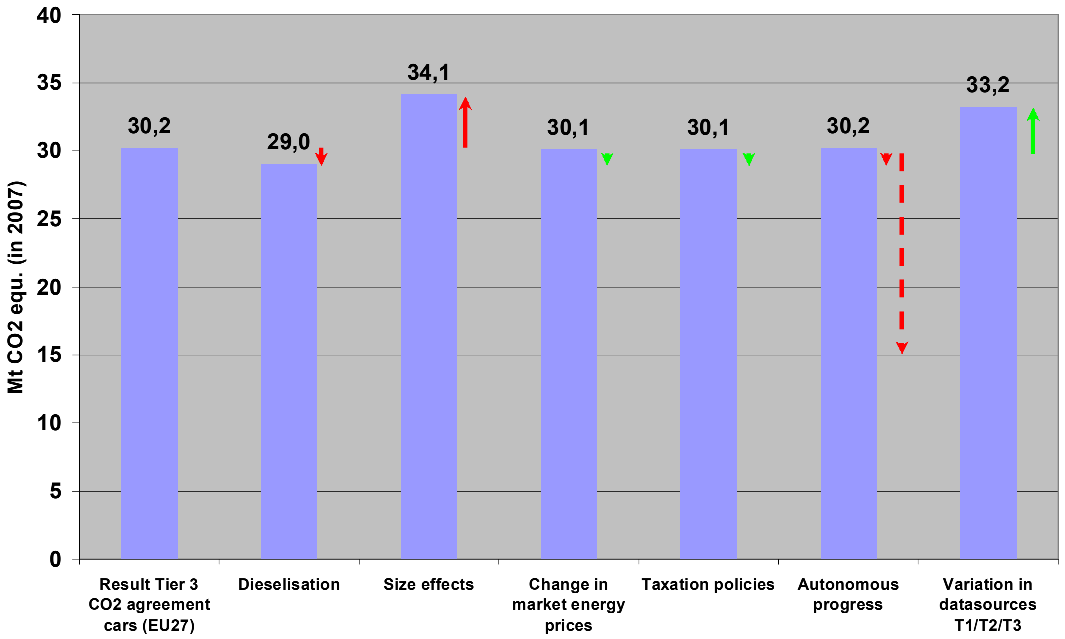
These factors were assessed by performing separate analyses; each particular variable was kept fixed. The results were then compared to the historical data. As can be seen from the figure, the impact of all these variables was assessed to be very small. This is because these variables did not alter dramatically between 1990 and 2006. The period of very high oil prices, which did lead to a certain increase in fuel prices, came at the end of this period, too late to have a major effect on the data.

The weakness of policy supporting the ACEA agreement should also be emphasised. While there have been a few interesting policy initiatives, such as company car taxation in the UK or the 'ecological tax' in Germany, as well as labelling initiatives following EU directive 1999/94/EC car labelling, these policies have had no noticeable impact on the fuel efficiency of the car fleet. The conclusion is that improvements in performance have come from a combination of the autonomous technological improvement and the ACEA agreement itself.

A further critical element in the analysis is the estimate of the autonomous technological improvement. In the Tier 3 analysis, this trend was estimated as the average reduction in the period immediately before the agreement became effective, 1990-1996. It would be possible to estimate the trend over a longer time period. However, the estimated trend then contains more changes in other factors such as the oil price shock of 1973-74, or the swings in economic activity of the 1970s and 1980s, which are outside the scope of the Tier 3 analysis. Differences in data sources between Tiers 1/2 and Tier 3 methodologies have also contributed to differences in the results.

The different factors that have an impact on the result are shown in a sensitivity analysis by varying each parameter at one time in **Figure 1-7**. This shows the impact of using specific methodological assumptions, and the influence of data uncertainties, upon the overall results. The arrows show the relative variability in the results depending upon the particular assumptions that are used. The solid arrows show the influence of the specific factors, as calculated within this study. The dashed arrows are used to highlight the significant uncertainty in the factors themselves, and the potential range in the results that can arise from alternative assumptions. Highly sensitive for the result may be the choice of the base period for the determination of the autonomous progress.

Figure 1-7 Sensitivity analysis for the different factors affecting the cumulated CO2 savings of the ACEA agreement (impact in 2007 for the EU27).



Note: Variations due to methodological choices are in red. Variations due to data issues are in green in the figure.

Critical parameters and assumptions

In ASTRA, the quantity and choice of vehicle type is undertaken using a logistic cost comparison with a comprehensive consideration of all the cost aspects of owning and driving a car in each country. This logistic function is calibrated to the EU data, transformed to the ASTRA car categories as shown in Figure 1-6 for the size distribution. Hence the most critical aspect of the modelling is the goodness of fit of the calibration of the logistic function. While this cannot be 100%, the model does reproduce the data in Figure 1-6 quite closely. Given the size and distribution of new vehicles, the emissions results follow from well-established coefficients for petrol and diesel emissions. This shows the advantage of an ex-post analysis: the results are directly dependent on the input data, without requiring any major assumptions on new cars. The results for CO2 savings are dependent on the assumption for the calculation of the autonomous technical improvement. In particular, the data between 1990 and 1996 in Figure 1-5 is not linear, but shows a turning point in 1992. If the trend was calculated with the data series from 1992 to 1996, the autonomous technological improvement would be somewhat stronger, achieving around 170g CO2/vehicle km in 2005. This would roughly halve the calculated savings in CO2 attributed to the ACEA agreement. However, the autonomous trend should be calculated using the whole data range available.

1.10 Conclusions

These surprising results show that of the factors discussed above, policy, fuel price, share of new diesel cars and the share of new large cars in the fleet have had very little impact on the specific emissions of new cars. As was discussed above, low carbon fuels also had very little impact in the period under consideration, 1990-2007. Hence it can be concluded that the improvement in specific emissions was almost entirely due to improvement in technology through firms' development. The next consideration is 'were the firms reducing the specific emissions of new cars anyway?'. This can be answered by considering the trend in average emissions of new cars before the ACEA agreement was under discussion and agreement reached, i.e. in the period 1990-1996. This shows that there was an autonomous technological improvement, but a slight one, from around 186g CO_2/vehicle km in 1990 to around 184 in 1996. Projecting this trend forward to 2007 would lead to an average of around 180g CO_2/vehicle in 2007. This leads to the conclusion that the manufacturers did increase the rate of technological progress during the period of the ACEA agreement and given the lack of influence of other factors, the ACEA agreement provided an incentive (although not through economic policy) for manufacturers to increase their efforts to reduce fuel consumption of cars.

This can be argued to act through an 'awareness effect'. The activity of manufactures meeting with the EU commissions and going through the negotiations to reach an agreement, will have concentrated the attention of manufacturers on the fuel performance of vehicles. Also, the obvious priority placed on emissions performance by the EU could be assumed to reflect a change in the priorities of society. While this was not demonstrated to a significant extent in consumer choices of new cars, it could be assumed that there would be a shift in preferences in the longer run. Therefore, in such a highly competitive market, manufacturers would make increased efforts to improve fuel consumption to ensure that future sales shares were maintained.

1.11 Recommendations

The evaluation has shown three points for recommendation

1. The data basis for this analysis is sufficient. In the area of road vehicles, member states report the data (Decision 1753/2000/EC, EU, 2008 draft).

2. Ex-ante evaluation of future policies must include a realistic appreciation of the trends in consumer preferences and manufacturers' marketing policies. Factors leading to the adoption of new technologies and alternative modes of transport need to be assessed.

3. It is not sufficient to analyse a single policy on its own. The effectiveness of a policy such as the ACEA is dependent on supporting measures such as fiscal incentives to buy more fuel efficient cars and information measures to ensure that information on fuel efficiency is readily available. Such an analysis may be carried out with transport models such as the ASTRA model used in this work in order to reflect well the interactions between different factors.

1.12 References

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Appendix 1

Simplified Measure Maps: National Tables and assessments in the literature.

MURE qualitative impacts definitions for Annual savings (MtCe/ yr): low impact: <0.1%, medium impact: 0.1-<0.5%, high impact: ≥0.5%

Table A1-5 National Tables of main measures

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
Poland	Biofuels subsidies			
	Total			0

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
Czech Republic	No Transport GHG polices for Passenger cars			
	Total			**0**

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
Romania	No Transport GHG polices for Passenger cars			
	Total			**0**

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
Austria	Benke et al. (2006) Awareness building measures bewusstseinsbildende Maßnahmen Consumer information Travel management in businesses Mobility advice centres in Bischofshofen, Perg und Graz Ecodrive training campaign Traffic reduction community Langenlois	2000-2003	2000	~ 0% of overall emissions
	ECMT (2007) Biofuels exemption from excise tax (outside ACEA period) Fuel consumption based registration tax (introduced 1992 before ACEA period)			Up to 0.35
	Total			**~0.4**

Austria

Steininger et al. (2007) report that transport CO2 emissions increasing i.e. ACEA has failed to control CO2 emissions. The main effect has been 'tank tourism', foreign vehicles refuelling in Austria because of low fuel taxes and prices compared to neighbouring countries.

Benke et al. (2006) find that ex-post, the Climate strategy measures have not achieved a clear reduction in GHG emissions. They argue that this is because the measures planned in the Climate strategy have either not been implemented or have been implemented too weakly to have any significant impact in the observed period 2000-2003.

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
Denmark	Lund & Münster (2006) Kyoto mechanisms: JI, CDM Not yet active			
	TNO (2006) reporting ADAC (2005) Fuel consumption based tax MURE Increased taxes on gasoline halted	1998-2002	1998	diesel car fleet share from 4.7% to 19.3% up to 0.167
	Total			**0**

Denmark

Lund and Münster (2006) report that CO2 transport emissions are increasing in Denmark and that policies have so far failed to control CO2 emissions.

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
France	Bernard & Prieur (2007) Biofuels support EU subsidy €45/ha for energy crops since 2003 and production quotas for firms Tax reductions for biodiesel from fuel tax	2003-2007	2003	1.0 (MURE)
	ECMT (2007) Progressive increase of diesel tax to petrol tax			estimated at 2.0 in 2010, already mostly achieved in 2008
	Total			**3.0**

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
Germany	MURE Ecological tax reform 1999 -2003 increased tax on motor fuel Tax reductions for biodiesel from fuel tax Emission based annual vehicle tax 1997			2.5(medium MURE) ~0 (MURE) 1.0 (low MURE)
	Total			**3.5**

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)

Italy	MURE Grants for Old Vehicles Scrapping and Replacement Grants for the Purchase of Vehicles with a Low Environmental Impact			0.06 MURE) (low MURE)
	ECMT (2007) Vehicle tax based on engine power			1.3 (2010)
	Total			**~1.4**

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
Netherlands	MURE increases in fuel taxes from 1990 speed limits in urban areas	1990-2005		3% C02 =0.8 1% max ~0.3
	Total			**1.1**

Spain

Gutiérrez et al. (2008) show data to demonstrate that transport CO2 emissions have been increasing rapidly.

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
Spain	ECMT(2007) ecodriving measures in cars for tourist industry		 2007 2007	 0.624 0.903 (buses and cars) ~ 0.4 Cars
	Total			**~1.0**

MS	National Policy	Evaluation period	Base year for savings	Annual savings (MtC02e/ yr)
UK	MURE Graduated vehicle excise duty Company car tax from 2002	 1998-2007 2002-2005	 2005 2005	 0.05 med MURE 0.3 MURE
	ECMT(2007) biofuels incentives from 2002 Fuel Duty escalator	 1993-2000		 ~0 in ACEA period 5
	Total			**~4.0**

2 Labelling Directives on Large Appliances

The purpose of this paper is to describe a "Tier 3" approach for the ex-post evaluation of the Labelling Directives on Large Appliances, taking into account the interaction of this measure with other measures and policies aiming at the same target, including national measures. The main focus here is on the description of the methodology, although some discussion is also provided on the results from the application of the methodology.

The approach to developing the Tier 3 methodology has followed five sequential steps. These are:

- Step 1 Mapping of GHG measures in the context of the European Climate Change Programme (ECCP): This is the qualitative description of the "measure network" which may include EU-ECCP measures, EU-pre-ECCP measures, ECCP-triggered national measures as well as independent national measures aiming at the same target.
- Step 2 Compilation of quantitative evaluation evidence: This consists of the compilation of quantitative evaluation evidence such as in-depth national bottom-up evaluations, estimates from top-down impact indicators or simple estimates.
- Step 3 Screening step: This consists of the exclusion of unimportant national measures and pre-ECCP measures from the measure map, reducing the measure map to a simpler picture that can be modelled more easily.
- Step 4 Modelling step: The model-based harmonised evaluation of the simplified measure map provides an evaluation of impacts under harmonised assumptions.
- Step 5 Impact Delimitation: The impacts obtained in the previous step are in general "gross impacts". Further treatment of issues such as independent national measures aiming at the same target, autonomous progress, the impact of market energy price changes etc. may be necessary.

Each of these steps is described further below, following a more general discussion of the methodology and the data context.

2.1 Introduction: Brief description of the measure

2.1.1 The EU Directives on appliance labelling

Council Directive 92/75/EEC of 22 September 1992[5] on the indication by labelling and standard product information on the consumption of energy and other resources by household appliances is aimed at harmonising national measures to enable consumers to choose the most energy efficient appliances. From 1992 up to the end of 2008, eight implementing Directives[6] have been adopted (Table 2-1) which regulate the labelling specifications for each product type. Some Directives have been updated during this time period. The Directives are applied to the following types of products:

- refrigerators, freezers and their combinations
- washing machines, dryers and their combinations
- dishwashers
- ovens
- water heaters and hot water storage appliances
- lighting sources
- air conditioning appliances

Strictly related to the labelling legislation are the two Directives establishing minimum efficiency requirements for ballasts for fluorescent lighting and for household electric refrigerators, freezers and their combinations[7]. Through an amendment, these Directives have became the first implementing measures of the recently

5 Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances Official Journal L 297 of 13.10.1992
6 Energy Labelling of Household Electric Refrigerators, Freezers and their Combinations (Directive 2003/66/EC amending Directive 94/2/EC), Energy Labelling of Household Washing Machines (95/12/EC amended 96/89/EC), Energy Labelling of Household Electric Tumble Driers (95/13/EC), Energy Labelling of Combined Washer Driers (96/60/EC), Energy Labelling of Household Dishwashers (97/17/EC amended 99/9/EC), Energy Labelling of Household Lamps (98/11/EC), Energy Labelling of Household Air-conditioners (2002/31/EC), Energy Labelling of Household Electric Ovens (2002/40/EC).
7 Fluorescent lighting Directive 2000/55/EC and Household electric refrigerators, freezers and combinations Directive 96/57/EC

adopted Eco-design of Energy Using Products (EuPs) Directive[8] that provides coherent EU-wide rules for eco-design. The Eco Design Directive does not introduce directly binding requirements for specific products, but establishes a framework of conditions and criteria that need to be respected by the implementing measures (to be issued) for the setting of eco-design requirements for energy-using products. Since 2007, the Commission has established a working plan to set out an indicative list of product groups which will be considered as priorities for the adoption of implementing measures, over the following three years.

2.1.2 The transposition of the EU Labelling Directives into the national legislation

As shown in Table 2-1, all the 27 MS have transposed either partially or completely the EU Directives related to labelling and to energy efficiency minimum requirements into national legislation. The Table refers to the year when the Directives were first transposed into national legislation and does not show the transposition of any subsequent amendments issued afterwards[9].

Table 2-1 shows that the first wave of implementing measures of the Directive 92/75/EEC related to large appliances such as i.e. refrigerators, freezers and their combination, washing machines and electric tumble driers. There were adopted and transposed by the old Member States (EU15) either at the end of the period 1994-1996 or the beginning of the period 1997-2000. Between 2001 and 2004 most of the new European Members States (EU12) transposed the 'package of European Labels Directives' which by then also included the implementing Directives regarding dishwashers, air conditioners, electric ovens adopted at European level between the 1999 and the 2002. These last directives have been implemented by the old Member States during the same time span. The two appliance groups of freezers, refrigerators and their combinations, and lighting systems have more stringent regulations in both the Labelling Directive and the minimum efficiency requirements Directives. Overall the deadlines for transposition of the Labels Directive have been respected by most of the EU Member States and full implementation of the Directives in the 27 MS took place mainly during 2001-2004.

Member States are required to communicate to the Commission the main provisions of domestic law which they adopt in the field covered by a Directive. Beyond this, there are no particular requirements for EU Member States to report on the implementation of the Labelling Directive nor are there regular statistical investigations on the shift in the labelling classes triggered by the Directive.

8 Directive 2005/32/EC of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council - Official Journal L 191 , 22/07/2005

9 Source: Mure Database

Table 2-1: Countries that have implemented the EU Directives by yearly intervals[10]

	1994- 1996		1997- 2000		2001-2004		2005-2008	
	Number of countries	Countries	Number of countries	Countries	Number of countries	Countries	Number of countries	Countries
Refrigerators, Freezers and their Combinations (94/2/EC)	11	AT, DK,FR,NL,RO,SP, SE, BE, EL,PT, UK	2	IT, DE	8	CY, CZ,EE, HU,LV,MT,SK,SI	2	BG, PL
Washing Machines (95/12/EC)	1	FR	11	AU, BE, DK, DE, EL,IT, NL, PT, SP, UK, CZ	8	CY,EE, HU, MT, RO, SK, SI, LV	2	BG, PO
Electric Tumble Driers (95/13/EC)	9	AU, DK,FR, DE, EL, NL, PT, SP, SE	2	BE, IT	10	CY,CZ,EE,HU,LV, MA,PL,RO,SK,SI,	1	BG
Washer Driers (96/60/EC)	3	AU,FR, NL	9	BE,DK,DE,EL,IT, PT,SP,SE,UK	11	CY, CZ, EE, HU, LV, LT, MT, PO, RO, SK, SI	1	BG
Dishwashers (97/17/EC)	1	FR	8	AU, BE, FI, DE, IT, NL, PT, SP	10	CY, CZ, EE, HU, LV, MT, PL, RO, SK, SI	1	BG
Air-conditioners (2002/31/EC)					22	AU, BE, CY, CZ; DK, EE, FI, DE, EL; HU, IT, LV, LU, MT, NL, PT, RO, SK, SI, SP, SE, UK	2	BG, PL
Energy Labelling of Household Electric Ovens (2002/40/EC)					22	AU, BE, CY, CZ; DK, EE, DE, EL; HU, IT, LV, LU, MT, NL,PL, PT, RO, SK, SI, SP, SE, UK	1	BG
Minimum standards for Refrigerators, Freezers (Directive 96/57)			15	AU, BG, CZ, DK, FI, FR, AL, IE, LT, NL, PT, RO, SP, SE, UK,	7	CY, EE, HU, MA, PT, SK, SL		
Energy Labelling of Household Lamps (98/11/EC)			6	AU, BE, FR, DE, SP, UK	11	CY, CZ; EE, HU, LV, NL, PL, PT, RO, SK, SL	1	BG
Energy efficiency requirements for ballasts for fluorescent lighting (00/55/EC)					20	AU, BE, CY, CZ, EE, FR, DE, EL, HU, IE, IT, LT, MT, NL, PT, RO, SK, SL, SP, SE	2	BG, PL
	Number of countries	Countries	Number of countries	Countries	Number of countries	Countries	Number of countries	Countries
	1994- 1996		1997- 2000		2001-2004		2005-2008	

2.2 Methodological approach and data context

2.2.1 Methodology for evaluation

The energy impact of the EU Directives concerning the cold and wash appliances has been calculated by using a stock model. The model has been developed in the framework of the Ecodesign studies on the cold (Lot 13) and wash (Lot 14) appliances. For more references please see the web sites www.ecocold-domestic.org and www.ecowet-domestic.org. For Denmark and The Netherlands a further scenario based on the additional market change has been developed due to subsidies for high efficiency appliance purchase.

10 Information for Finland, Luxemburg and Lithuania was not available and information regarding Greece, Ireland, United Kingdom, Sweden and Denmark is not complete.

To evaluate the impact of the EU Labelling Directives on the energy consumption a backcasting analysis was carried out starting in 1990, and carried through to the year 2004[11]. Within this period two different scenarios have been set up:

- The baseline scenario that provides the energy consumption trends in the hypothesis that neither the Labelling Directives nor other type of energy efficiency measures would have been implemented in the reference period.
- The Directive scenario that gives an estimation of the energy consumption trends in accordance with the real appliances sales mix as provided by the GfK market panels.

As part of this exercise a critical decision is the choice of the baseline scenario.

The figures in the Annex to this chapter illustrate the development of the specific energy consumption (kWh/year) for refrigerators, washing machines and dishwashers from the Odyssee Database 2008 (www.odyssee-indicators.org) for some EU countries. In theory, this data could be used to derive a baseline scenario using econometrics analysis of the key parameters. However, there are several problems in deriving a baseline from econometric estimates:

1. Many countries have limited information over the period before the introduction of the labelling directives to enable a robust estimate of the pre-directive relationships.
2. The split of classes was not known before the introduction of the labelling classes.
3. Very different developments occur in different countries, which make it difficult to derive a baseline across a range of countries. For example, countries like Sweden show a pre-directive trend of strongly decreasing energy consumption due to previous efforts (in the case of refrigerators). Others like Portugal show at best a stabilisation of energy consumption due to the overwhelming impact of growth in income which lead to larger sized appliances. Countries like Greece showed little impact, if any. In the case of Germany most of the impact can be attributed to the impact of the directives although in the early nineties reunification drove up energy consumption. In some countries, such as France, a reduction in the rate of decrease was observed after the introduction of the labels.

These observations show that many factors have influenced the development of specific energy consumption of appliances. Any other hypothesis of different autonomous energy efficiency progress to that described above is obviously conceivable, but based on empirical developments difficult to argue. Nevertheless, we calculate one variant where half of the progress achieved is due to autonomous progress and previous policies.

On this basis, for the baseline scenario in this analysis we have chosen to freeze the unitary energy consumption of the analysed appliances at the value they had achieved in the year 1990, in accordance with the estimations provided for this year by a CECED study[12]. Freezing of energy efficiency at the year 1990 provides a measure of the maximum impact of the EU Directives and this value can be used as a benchmarking reference for any other baseline hypothesis.

For the conversion of electricity savings to CO_2 emissions several possibilities exist. Three general methodological approaches can be pursued **to account for the national emission reductions based on electricity savings from the labelling Directives**.

1. Average EU emission factor

This approach assumes that electricity savings are replacing the average European fossil fuel mix of the EU-27 of public and auto producers[13]. This is the approach chosen by the Tier 1 method (see main report for a full description of this method).

2. Average national emission factor

This approach is the same as the first one but with the exception that it assumes that electricity savings are replacing the average domestically applied fuel mix of public and auto producers[13]. This is the approach chosen by the Tier 2 method (see main report for a full description of this method).

[11] The year for which we have the last updated data on the energy labelling categories sales by country
[12] R. Stamminger, R. Kemna *Report on Energy Consumption of Domestic Appliances in European Household* - CECED
[13] Nuclear plants shall be excluded, because their operation was not influenced by renewables in the past.

3. Emission factors based on marginal power plant in terms of Short Term Marginal Costs (STMC)

This approach assumes that the marginal conventional power plant along the merit order curve is replaced regarding to the short term marginal generation costs of the plants. That means that the operation of the power system is optimised in a way that the most expensive fossil and nuclear plants are replaced by electricity savings. This is the approach chosen here. More details will be given in a later section

4. Emission factors based on marginal power plant in terms of Long Term Marginal Costs (LTMC)

This approach assumes that the marginal power plant along the merit order curve is replaced regarding to the long term marginal generation costs of the plants. This means that investments into the power system are optimised in a way that the most expensive fossil and nuclear plants are replaced by electricity savings.

2.2.2 Data

The following table provides the main input variables used by our stock model and the corresponding sources:

Table 2-2: Main Input Variables to Stock Model

Input variables	Source
Appliances Lifetime	CECED study
Lifetime standard deviation (i.e. +-3 years)	
Ownership rate	
Energy labelling shares of the yearly sales	GfK (CECED for the years before the 1995)
Specific energy consumption by energy labelling category	CECED databases
Household number	Census data

The energy labelling shares of the yearly sales are the only scenario drivers. For the remaining input variables, the lifetime variables and the stand-by energy consumption values have been kept constant during the considered period, while the ownership rates and the specific energy consumption by energy labelling category (but only for refrigerators and freezers) was allowed to vary along the scenarios steps.

2.3 Step 1: Mapping of the ECCP measure Labelling Directives on Large Appliances

2.3.1 Overview

Table 2-3 maps the different policies that may interact with the Labelling Directives. However, a variety of these policies can be excluded by a screening process (see section 2.5).

Table 2-3: Measure mapping of the Appliance Labelling Directive

MEASURE	TARGET	GOAL FOR TOP-DOWN IMPACT
ECCP1 **Labelling Directives + Minimum Efficiency Standards** Implementing labelling directives for various appliances Minimum standards for appliances	**(Indirect) GHG emissions of large electric appliances**	**20% improvement in energy efficiency**
EU ETS Phase 1 (2005-2007) Phase 2 (2008-2012) Phase 3 (2013-2020) (proposed)	**GHG emissions of large installations from energy and industry**	**20% improvement in CO_2 emissions**
Complementary national measures Mainly support schemes for efficient appliances (see below) White certificate trading schemes (including obligations on energy suppliers/distributors) Electricity taxes Information and awareness campaigns	**Final energy** **Final energy** **Final energy** **Final energy**	

2.3.2 Member States facilitating measures

The most important interacting measures are accompanying or facilitating measures. Along with the transposition of the Labelling Directives, 11 countries have decided to reinforce the market transformation effect of these directives with the establishment of ‘accompanying or facilitating measures’.

In most cases, these measures consist of subsidies or rebates granted to citizens and directed to foster the renewal of old appliances and to support the purchase of highly efficient appliances labelled A/A+ or compact fluorescent lamps.

Table 2-4 shows each of the Member States that have issued this type of measure the titles of the measures themselves, the issuing year and the instruments chosen for their implementation.

Table 2-4: Facilitating Measures for the EU Labelling Directive at national level

	Facilitating Measures: Main Instruments
Cyprus	Scheme for subsidising CFL lamps (2007): free distribution of CFLs lamps to the households (up to 6 lamps/household)
Denmark	Electricity Saving Trust (1997 - 2008): Information, Issuing of consumers guidelines
Germany	Program for introducing new, highly efficient household appliances to the market: Subsidies to very efficient household on the basis of the "Top Runner Strategy" (Measure proposed)
Italy	Financing Laws 2007 & 2008: Tax Subsidies for the purchase of A+ (or better) models.
Malta	Rebates on investments in energy efficiency by domestic consumers (2007): subsidies for the purchase of A (or better) models (rebate on the purchase price)
The Netherlands	The energy premiums scheme (1999 - 2003): subsidies for the purchase of A (or better) models
Romania	The promotion of the use of energy-efficient household electrical appliances (proposed): subsidies for the purchase of an appliance with an A/A+ label.
Spain	Action Plan 2005 - 2007 and 2008 - 2012: subsidies to the households to replace the "D" appliances with the A (or better) ones.
Slovenia	Stimulation of the investments in energy efficiency measures in households: subsidies for the purchase of CFLs (1996) and efficient appliances (2008)
UK	Energy Efficiency Commitment: mainly addressed to energy suppliers that are required to achieve targets for the promotion of energy efficiency improvements in the household sector. Tax rebates are also foreseen for low income households

2.4 Step 2: Compilation of quantitative evaluation evidence

The following section discusses electricity consumption for large appliances and the ODEX energy efficiency indicator developed in the Odyssee-MURE project. It also gives quantitative evidence on the impacts of the labelling directives at national level and discusses other influencing factors on electricity consumption from large appliances such as appliance ownership and the average income per households.

2.4.1 Results from ex-post and ex-ante studies

Comparison with alternative estimates

Paul Waide estimated in IEA (2003) that in European IEA Members, existing measures for appliance Labelling and Minimum Efficiency Performance Standards for appliances (MEPS) have saved 7.6 Mt CO_2 in 2000, generating net economic benefits of 224 Euro for each tonne of CO_2 avoided (see also Table 2-5 in the following section).

Bosseboeuf et al. (2005) estimate electricity savings of 14 TWh from 1994 to 2000 for the EU15, which fits well with the 21 TWh estimated here for the EU27 in 2004.

At the national level, a number of impact studies have been carried out. For example in Germany various studies and analysis exist that consider climate change policies and national measures such as the Policy Scenarios IV from 2008. These studies evaluated the emission reductions due to labelling policies. Differences between the studies occur in the treatment of autonomous savings, which may substantially influence the outcome. In Germany, in 2004 savings of 2.2 TWh from Labelling policies and MEPS were estimated, somewhat less than the 3.6 TWh estimated in this study.

Comparison with ex-ante results

Annex I of the ECCP progress report (EC 2003), based on the results of the ECCP Working Group on ‘Energy efficiency and end-use equipment and industrial processes’, estimates for white goods a CO_2 reduction of 25 Mt CO_2 for the 2010 baseline with respect to 1990, despite the increased demand for appliances such as dishwashers and tumble dryers. Industry analysis shows that this is mainly as a consequence of energy labelling and the related measures by Member States. Partitioning one third of the saving to restrictive measures at the lower end of the market (minimum standards, voluntary agreements), the CO_2 savings from Commission Directives issued before 1999 amount to 17 $MtCO_2$. If the negative effect of an increased market penetration of dishwashers and tumble driers, the contribution of existing energy labels is estimated at 20Mt CO_2eq. This ex-ante estimate is mostly in line with the estimates presented here which estimate 12 Mt CO_2 for the EU 15 in 2004 and 14 Mt CO_2 for the EU27. This is not surprising given that these estimates are calculated based on the same basic data for appliance sales by labelling class.

Another ex-ante estimate for the OECD Europe is presented in IEA (2003). The savings resulting from OECD Europe appliance labelling and MEPS policies were estimated at 7.6 Mt CO_2 in 2000 and 16.9 Mt CO_2 in 2005 (Table 2-5). These results are in line with the results reported here in this evaluation. In the projections, these impacts may further increase by almost triple in 2030, due to the market transformation initiated.

Table 2-5: Ex-ante and ex-post CO_2 impact projections by IEA (2003) for the OECD Europe Labelling and MEPS policies

Year	Energy cost saving (billion €)		Equipment purchase cost increase (billion €)		Net cost saving (billion €)		Carbon dioxide reduction		
	Annual savings	Cumulative savings from 1990	Annual increase	Cumulative increase from 1990	Annual savings	Cumulative savings from 1990	Annual ($Mt-CO_2$)	Share of residential total in 1990 (%)	Cumulative ($Mt-CO_2$)
1995	0.4	0.8	0.0	0.0	0.4	0.8	1.4	0%	2.9
2000	2.4	8.2	0.8	2.4	1.7	5.8	7.6	3%	26.0
2005	5.4	29.4	1.5	7.9	4.0	21.5	16.9	5%	92.1
2010	9.1	67.5	2.0	16.8	7.1	50.7	28.4	8%	210.7
2015	11.1	119.2	2.5	28.6	8.5	90.6	34.7	10%	372.5
2020	12.5	179.1	2.7	41.8	9.8	137.3	39.3	10%	560.3
2025	13.7	245.4	3.0	56.3	10.6	189.1	43.2	11%	769.1
2030	14.5	316.4	3.4	72.6	11.1	243.8	46.0	11%	993.6

Source: IEA (2003)

2.4.2 The electricity consumption for households appliances in the EU

Evidence for Electricity Consumption Levels

In EU countries the electricity consumption per dwelling is higher for specific electricity appliances and lighting than for thermal uses (

Figure 2-1), except for Sweden, France, Ireland, Finland and Slovenia

Between 1997-2006 the electricity consumption per dwelling due to electrical appliances and lighting has shown across the European countries two opposite trends:

- decreasing consumption in Bulgaria and Slovakia, countries with relatively low consumption levels (approximately 2500 kWh/dw), as well as decreasing consumption in Norway the country with the highest consumption level (approximately 4500 kWh/dw).
- an increasing consumption trend in all the other EU Member States.

However, this progression has been a rather moderate increase in consumption in Sweden, Germany, United Kingdom and Denmark while it has been a steady and remarkable increase in Ireland and in all the southern countries where the use of air conditions system has grown (Figure 2-2).

Figure 2-1: Electricity consumption per dwelling: thermal uses & specific electrical appliance

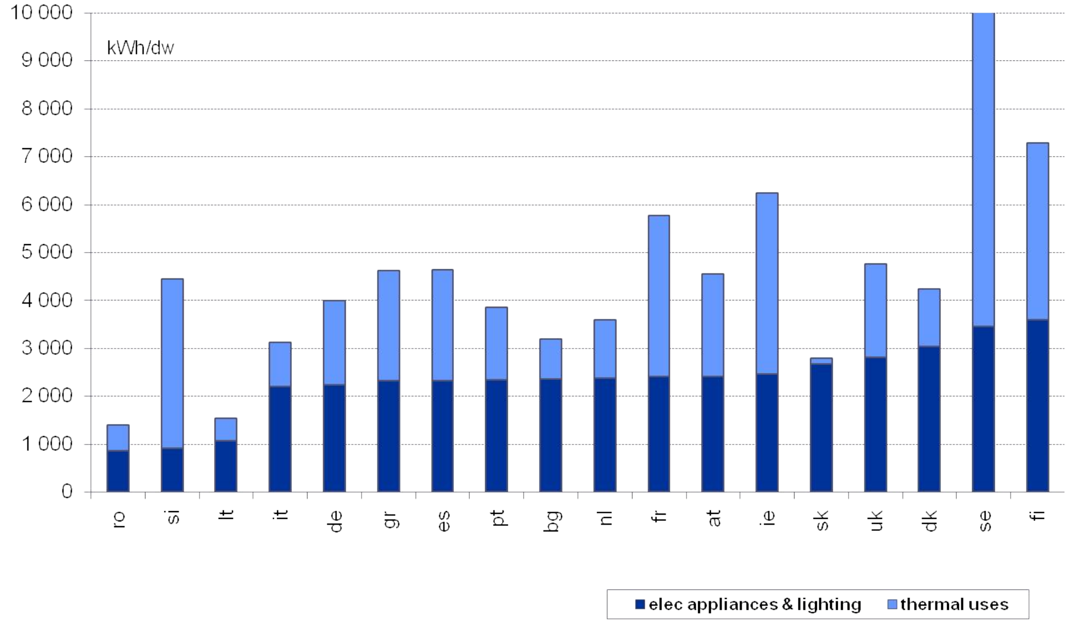
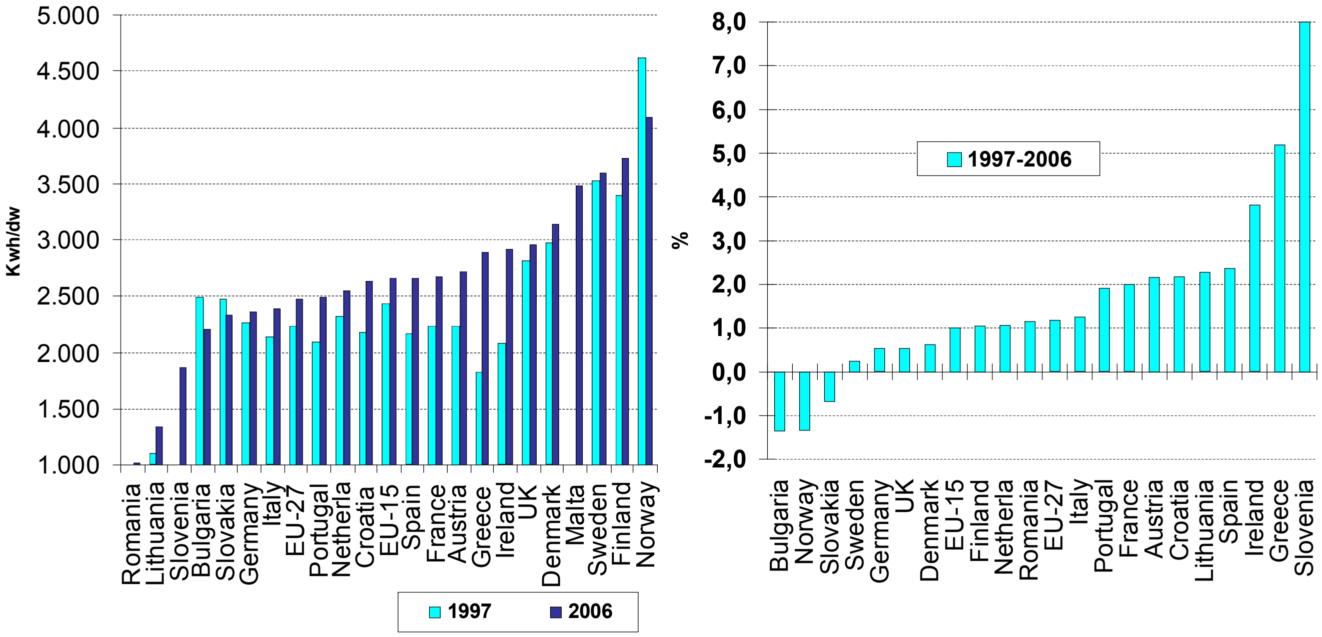


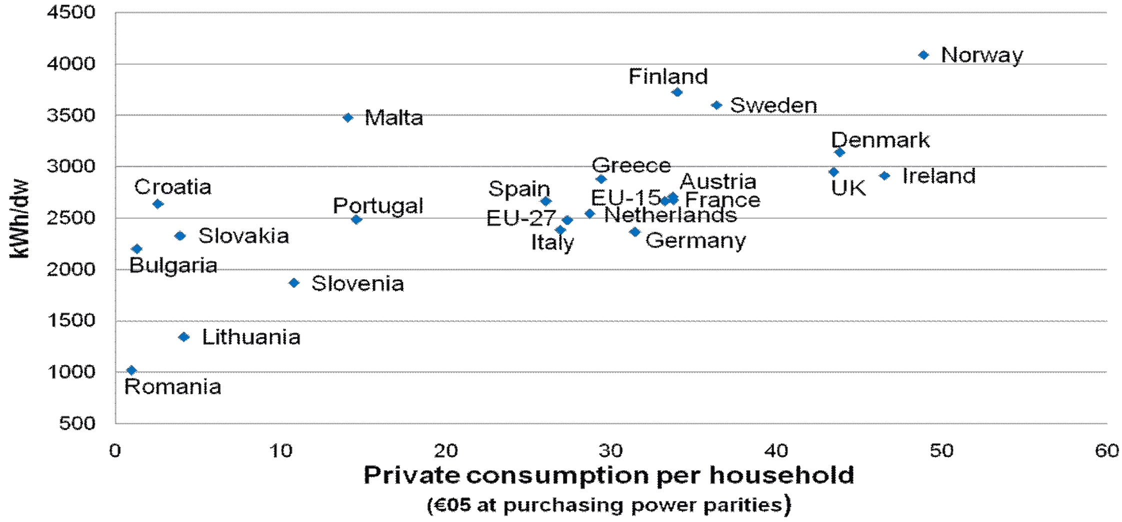
Figure 2-2: Electricity consumption per dwelling for electrical appliances & lighting (excl. thermal uses)



Electricity consumption and average income

Figure 2-3 shows a direct correlation between the level of energy consumption for electrical appliances and the average income. The correlation is well represented by the two countries at the opposite ends of the distribution: Norway and Romania. Norway has the highest average income as well the highest consumption rate of electricity for electrical appliances which is approximately 4000 kWh/dw, while Romania has the lowest purchase power and the lowest consumption rate, at almost 1000 kWh/dw. As discussed previously Norway has a declining electricity consumption trend, while Romania, as in most eastern European countries, shows a steady increasing electricity consumption trend. Nearly all the old Member States of EU (EU 15) have a purchasing power of around 30 kEuro per household, which corresponds to an electricity demand between 2500/3000 kWh/household, subject to a limited increase.

Figure 2-3: Electricity consumption of electrical appliances per dwelling and private consumption per households (2006)



Source: Odyssee Database 2008 (www.odyssee-indicators.org)

Electricity consumption breakdown by final uses

The breakdown of electricity consumption by domestic appliance between 1990 and 2005 (Figure 2-4 and Figure 2-5) shows that the strongest growth was in small appliances. These had an increase in electricity consumption share from 27% in 1990 to 38% in 2005, of which 15% (25 TWh) is due to IT appliances (not including TV). The consumption of large appliances shows modest growth and its electricity consumption share declined from 54% in 1990 to 45% in 2005. With an electricity consumption share of approximately of 20%, the lighting sector is stable.

Figure 2-4: Breakdown of consumption between large and small appliances and lighting in Europe

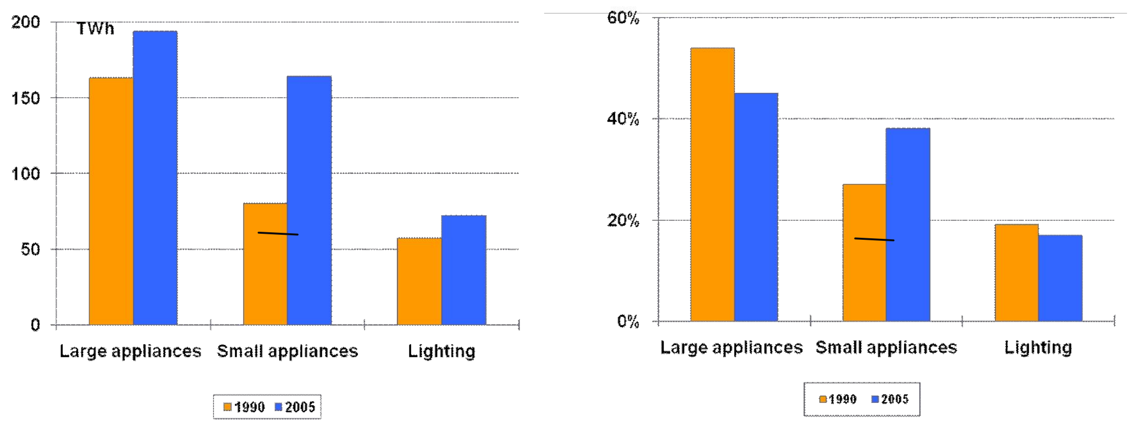
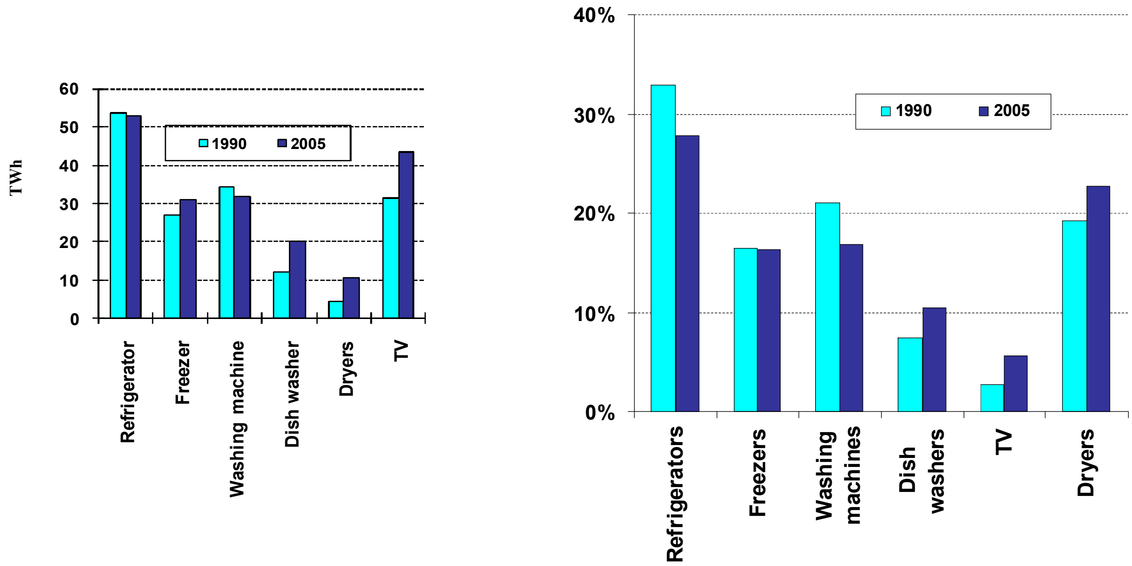


Figure 2-5: Consumption of large electrical appliances by type (EU-15)

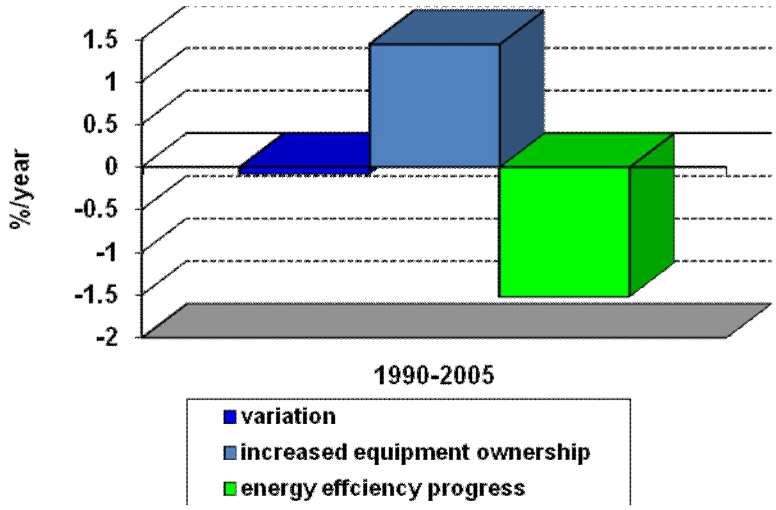


An analysis of the large electrical appliance market during the years 1990-2005 highlights a significant increase of the energy consumption for televisions, dryers and dish washers, closely followed by the freezers. Conversely, the energy consumption of refrigerators and washing machines register a slight decline.

The energy efficiency trend

The analysis carried out in the MURE-Odyssee project on the overall energy efficiency trend of the large appliances shows that (Figure 2-6) almost all the energy efficiency gains of the last 15 years have been offset by an increase in equipment ownership: as a result, the consumption per dwelling for large appliances is about at the same level in 2005 as in 1990.

Figure 2-6: Variation of the consumption per dwelling for large appliances (EU-15)



2.4.3 The impact on the market

During the past decade the EU Directives have profoundly transformed the large appliances market contributing to radically improved energy efficiency of the appliances sold in the EU Member States. In addition, the implementation measures put in place at a national level have further contributed (and are contributing) to a change in awareness, and the purchasing habits, of final consumers.

Figure 2-7 shows clearly the rapid and steady increase of sales of energy efficient appliances as a consequence of the Directives approval and the national measures implemented. Nevertheless, as highlighted above the overall energy efficiency trend, calculated by the MURE-Odyssee - ODEX indicator[14], shows a relatively modest increment (+ 12 % in 10 years) due to the energy efficiency improvements of the products sold counterbalanced by the increase the level of appliance ownership.

Figure 2-7: The EU Directives impact: market share of A/A+-labels for cold and washing appliances (EU)

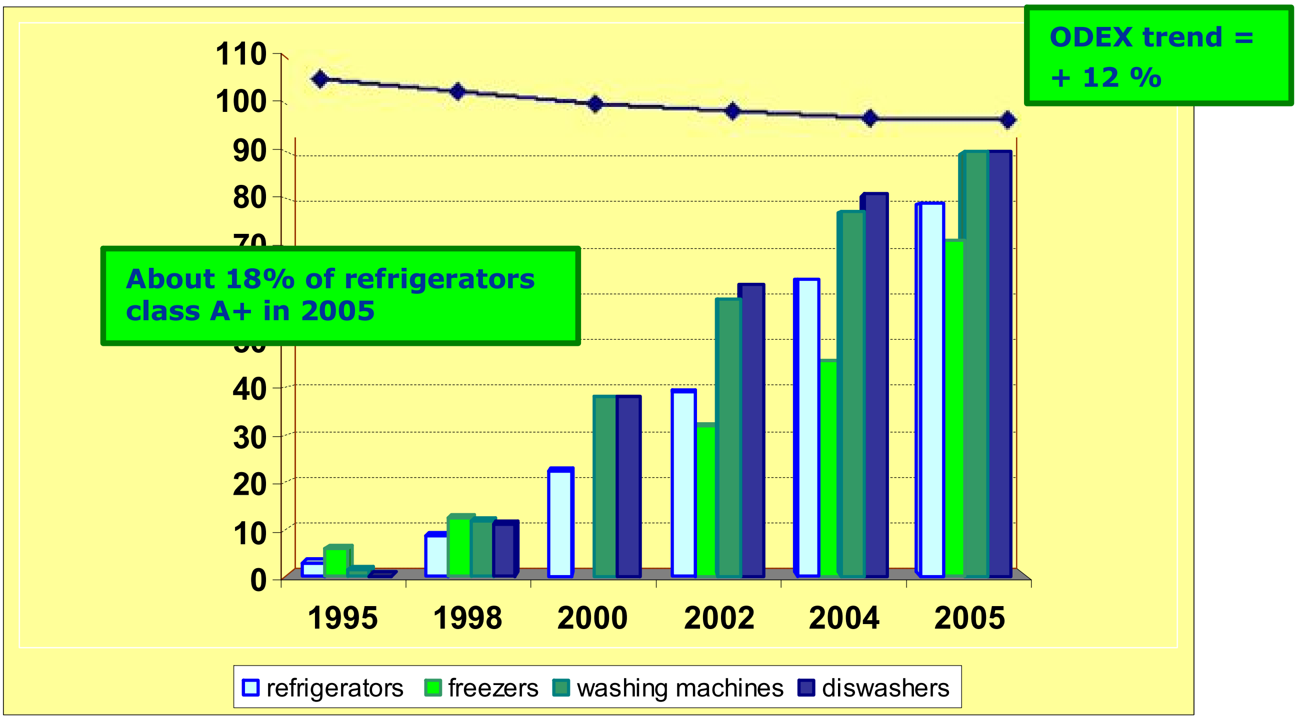


Figure 2-8 and Figure 2-9 show the penetration of the labelling categories A and A+ in the EU 27 countries for refrigerators and washing machines (2004). In the EU15, the average level of washing machines purchased with either an A or A+ rating is 60%, but there are some countries in which this level is low and correspondingly much scope for improvement. For washing machines (as well as dishwashers) the situation is more homogeneous as the penetration of the labelling categories A and A+ in the majority of the Member States is around 80%. It is worth noting that the manufacturers of the washing appliances are nowadays practically producing only A and A+ models and that in a few years these models will constitute 100% of the market. This means that should no more energy efficiency categories be created, the residual energy efficiency potentials of these appliances are practically zero.

[14] Energy efficiency index for electrical appliances (5 appliances : refrigerators, freezers, washing machine, dishwashers, TV)

Figure 2-8: Penetration of labels A/A+ for refrigerators (2004)

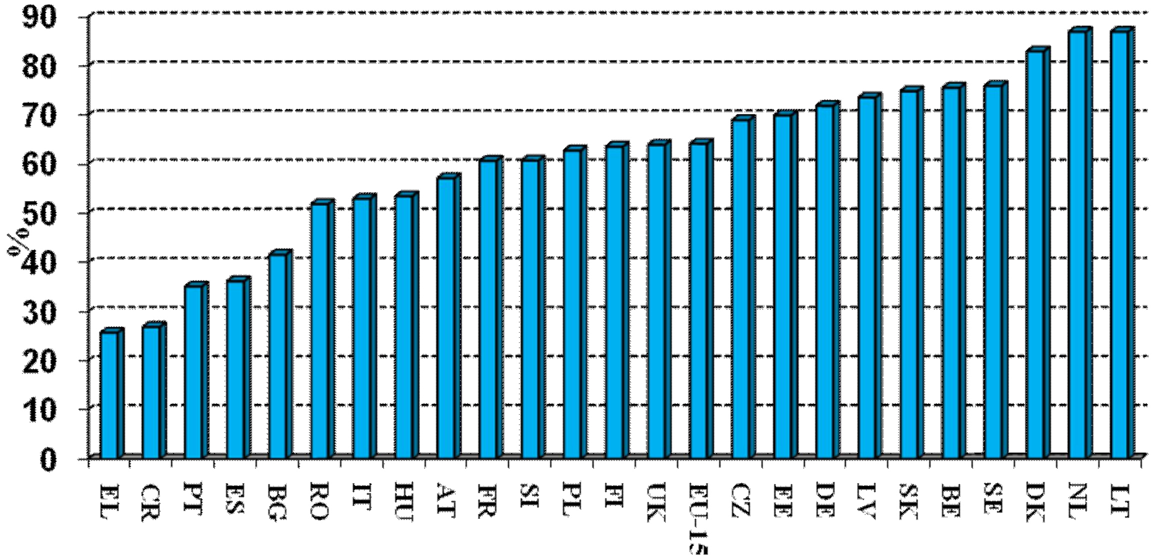
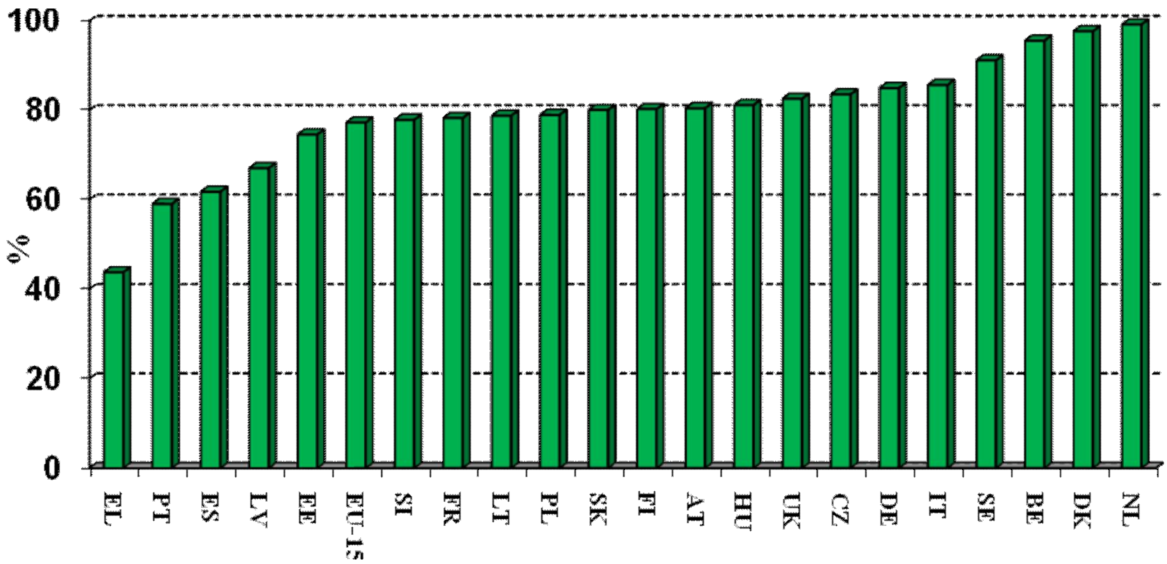


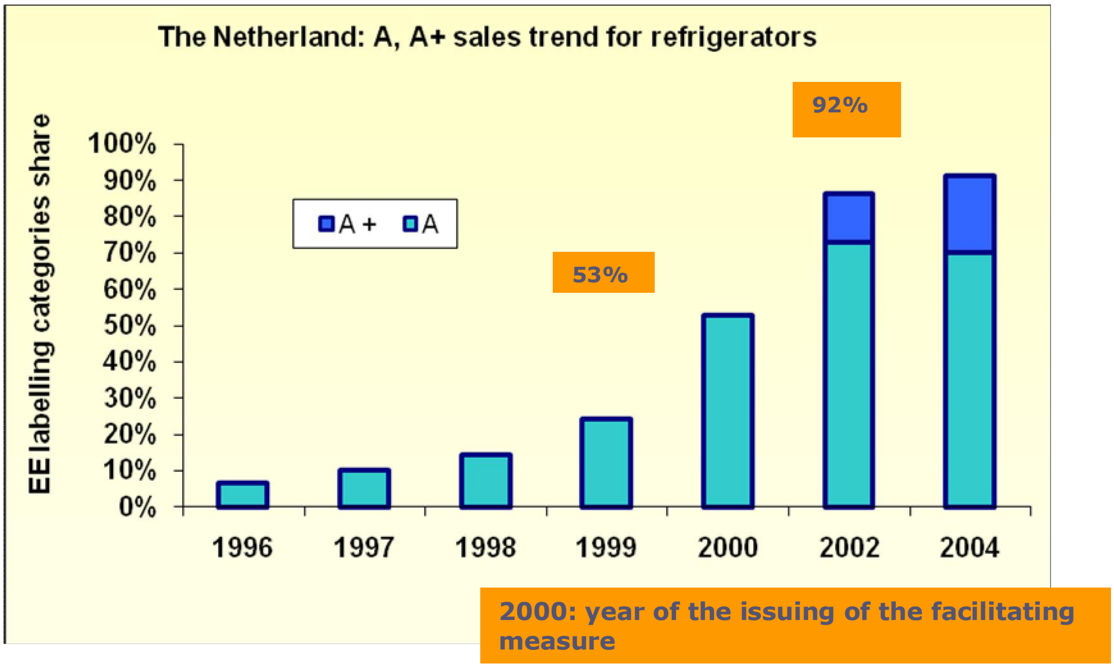
Figure 2-9: Penetration of labels A/A+ for washing machines (2004)



2.4.4 The impact of the facilitating measures on the market: some examples

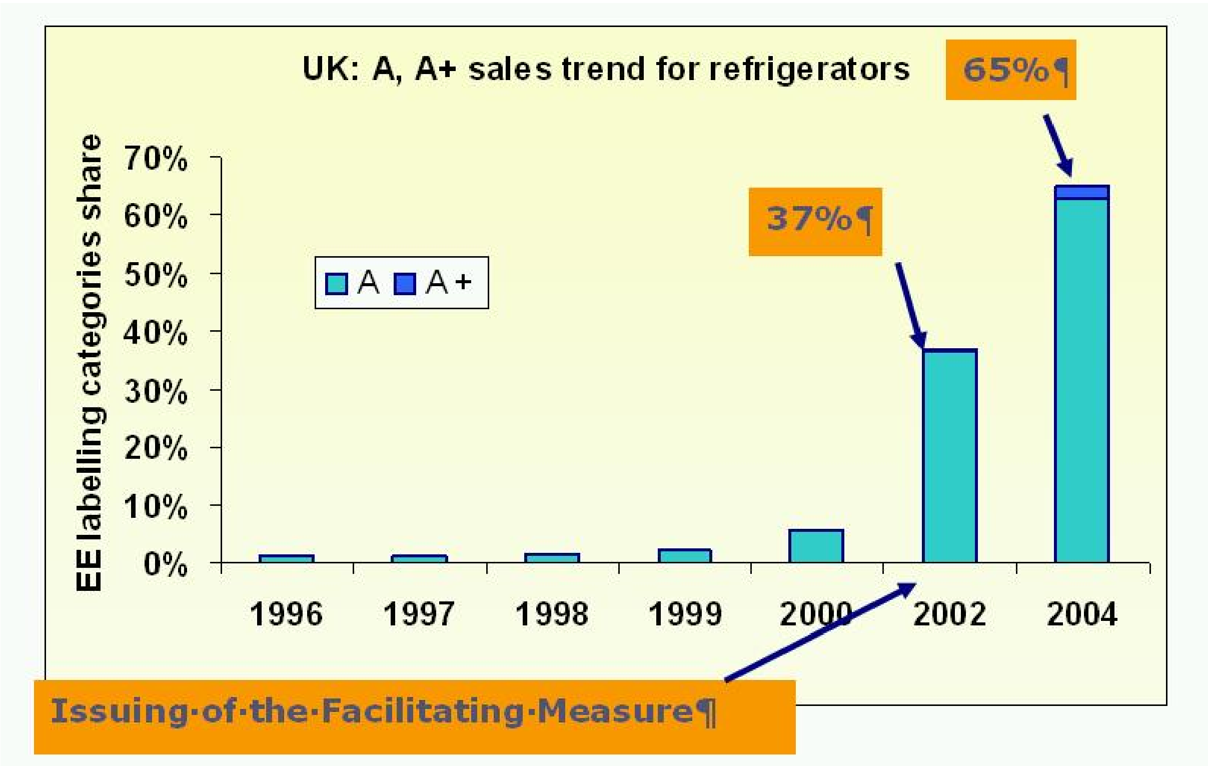
Between 1999 and 2000, the Netherlands initiated 'The Energy Premiums Scheme' that granted subsidies for the purchase of highly efficient appliances labelled A and A+. This initiative resulted in the sales for A/A+ refrigerators increasing from 53% in 2000, when the measure was implemented, to 92% in 2004 (+ 74% of A/A+ sales).

Figure 2-10: The effect of the Facilitating Measures- The Netherlands, cold appliances



In 2002 the United Kingdom implemented a facilitating measure targeting both equipment producers and to citizens; in particular it created tax rebates for the purchase of highly efficient appliances. Between 2002 and 2004 the market share of cold appliances labelled A and A+ increased from 37% in 2002 to 65% in 2004 (+ 75% of A/A+ sales), and the facilitating measure introduced was a significant factor in this development.

Figure 2-11: The effect of facilitating measures - UK cold appliances



2.5 Step 3: Screening

The following remarks can be made with respect to the screening of the policies, to identify the more important policy drivers:

- The main national measures interacting with the labelling directives were national support measures, mainly subsidies
- The (indirect) interaction between demand side measures and the EU ETS is discussed in a separate case study on the EU ETS
- White certificate schemes are relevant so far only for the UK, France and Italy. The greatest level of impact was observed in the UK. The mechanism was however similar to a subsidy scheme, and hence is included in the evaluation of national support schemes for the Labelling Directive.
- Electricity taxes, for example in Germany, have had little impact on consumer choices so far, given the low tax rates applied.

2.6 Step 4: Modelling step (draft results)

2.6.1 Electricity Savings

This section discusses the quantitative impacts calculated from the appliance stock model described above. Figure 2-12 to Figure 2-15 provide the total energy consumption trends of the ten countries considered in this study for the cold and wash appliances. Table 2-6 to Table 2-9 provide, for each of these countries, the savings in the year 2004 due to the implementation of the Directives in absolute (GWh) and relative terms (%).

It is worth noting that in relative terms the total savings are not so different across the various types of appliances. They vary from 12% for refrigerators to 9.6% for freezers with the wash appliances in the middle (11% for the washing machines and 10% for the dishwashers). The situation is different if analysed by country. The savings are very different country by country but, more or less, the countries keep the same level of saving across the appliances. Overall, considering the four appliances and all the countries, the total savings due to the Directives implementation are 21.7 TWh, corresponding to an average energy gain of 11%. It is interesting to note that, for freezers and the wash appliances, the energy efficiency increase provided by the implementation of the Directives barely counterbalances the energy consumption growth of the baseline scenario, which is due to both the increasing number of households and the increasing ownership rates per household.

Figure 2-12: EU 10 countries - Total energy consumption for refrigerators by scenario.

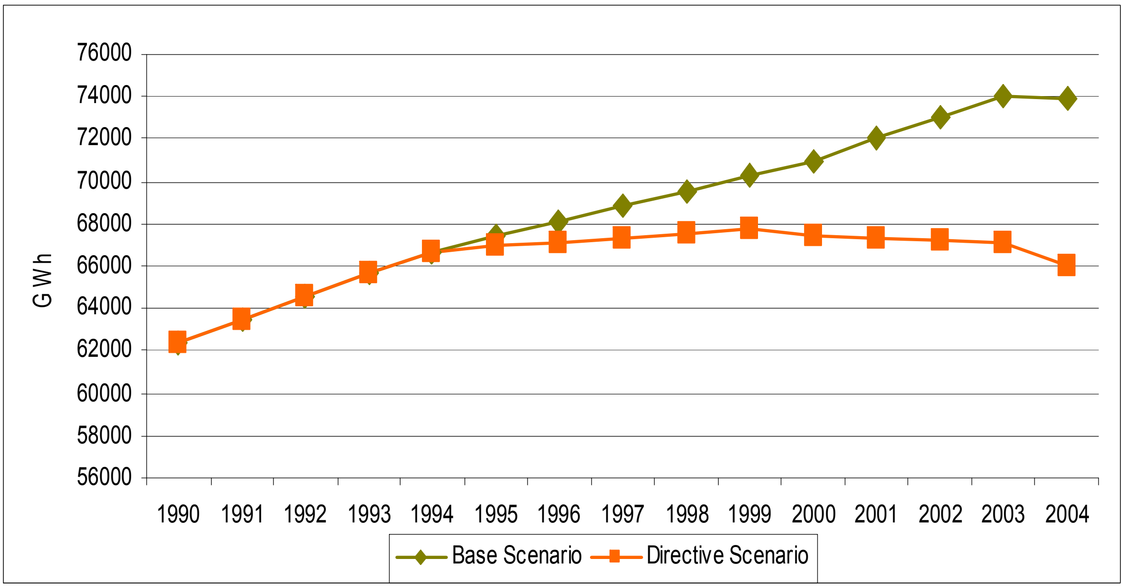


Figure 2-13: EU 10 countries - Total energy consumption for freezers by scenario.

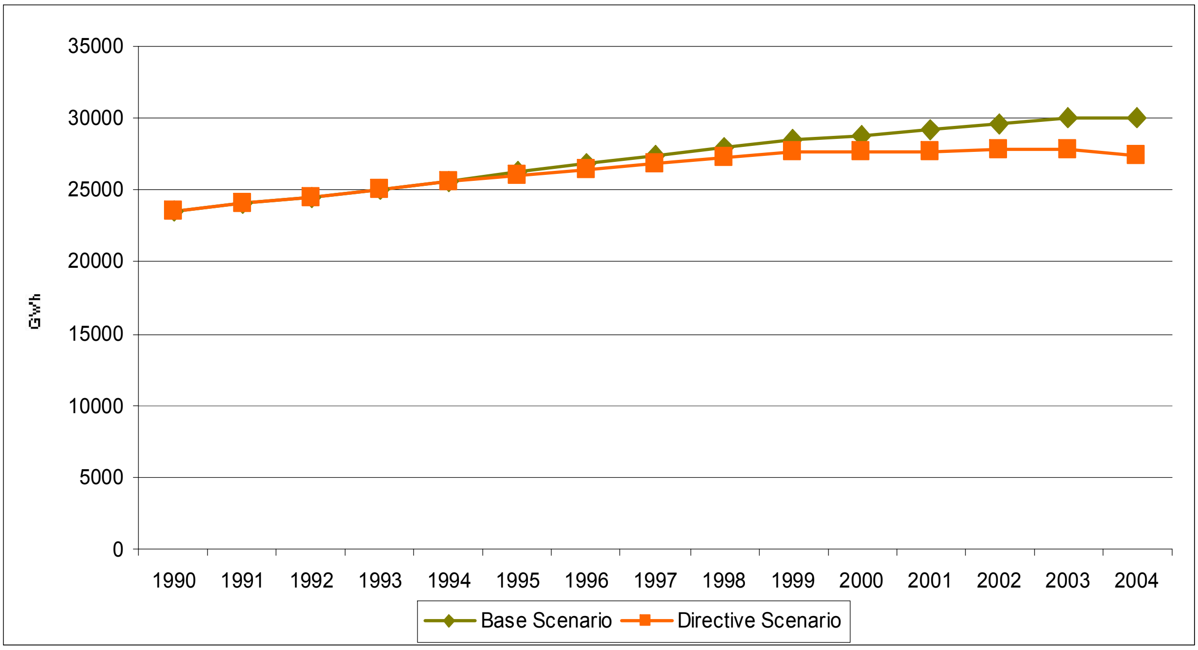


Figure 2-14: EU 10 countries - Total energy consumption for washing machines by scenario.

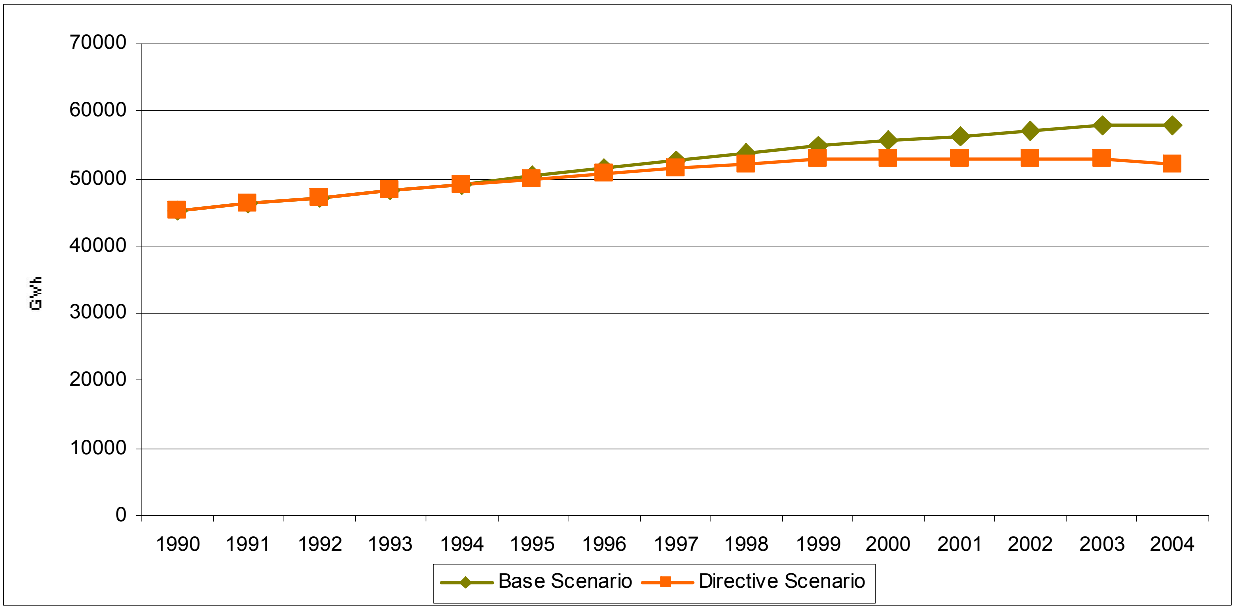


Figure 2-15: EU 10 countries - Total energy consumption for dish washers by scenario.

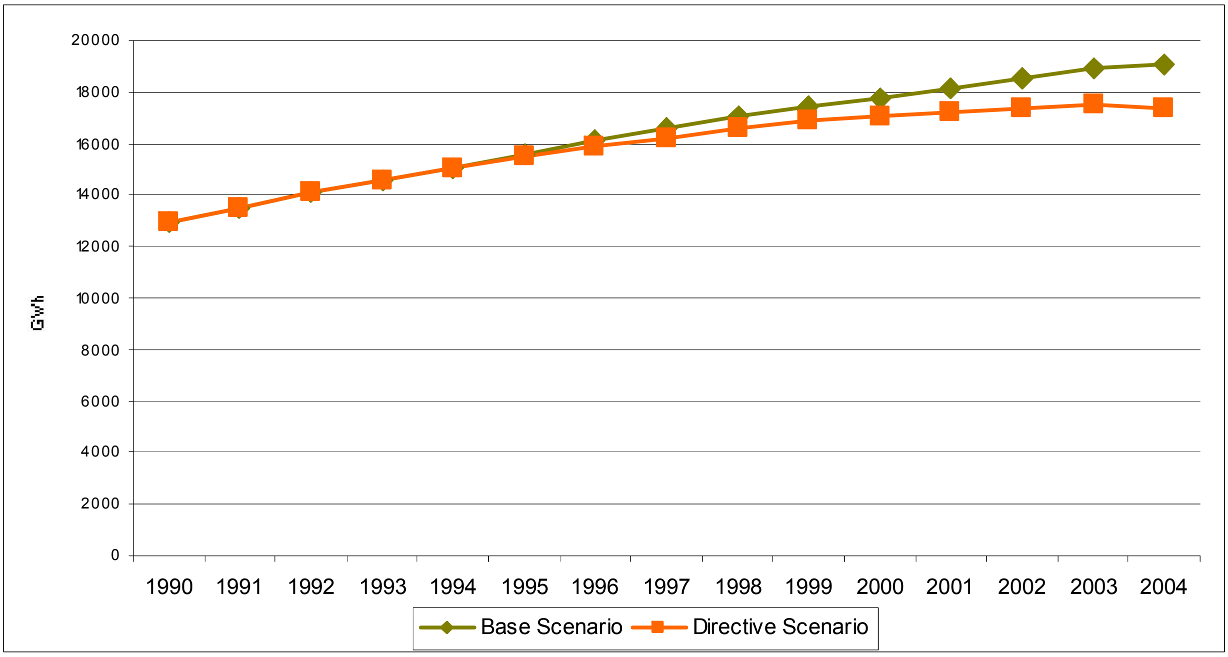


Table 2-6: Energy savings contribution by country due to the implementation of the EU Labelling Directives: refrigerators (year 2004)

COUNTRY	GWh	%
AT	177	14.2%
CZ	304	19.9%
DE	1622	11.6%
DK	95	14.8%
ES	382	6.0%
FR	2013	19.1%
IT	1549	14.1%
NL	565	20.6%
PL	352	6.5%
UK	841	6.8%
Total	**7900**	**12.0%**

Table 2-7: Energy savings contribution by country due to the implementation of the EU Labelling Directives: freezers (year 2004)

COUNTRY	GWh	%
AT	57	7.1%
CZ	45	9.0%
DE	613	6.7%
DK	74	15.0%
ES	305	18.2%
FR	598	11.6%
IT	294	10.5%
NL	217	19.9%
PL	102	5.8%
UK	327	8.4%
Total	**2632**	**9.6%**

Table 2-8: Energy savings contribution by country due to the implementation of the EU Labelling Directives: washing machines (year 2004)

COUNTRY	GWh	%
AT	83	7.5%
CZ	67	9.5%
DE	916	7.1%
DK	83	16.0%
ES	1008	19.2%
FR	1071	12.2%
IT	964	11.0%
NL	450	21.2%
PL	195	6.1%
UK	777	8.9%
Total	**5615**	**10.8%**

Table 2-9: Energy savings contribution by country due to the implementation of the EU Labelling Directives: dishwashers (year 2004)

COUNTRY	GWh	%
AT	41	7.1%
CZ	3	9.0%
DE	436	6.7%
DK	39	15.0%
ES	219	18.2%
FR	421	11.6%
IT	240	10.5%
NL	128	19.9%
PL	6	5.2%
UK	173	8.4%
Total	**1704**	**9.8%**

The very low contribution of Eastern countries (Czech Republic and Poland) is due to the ownership rates for these countries being very low (but are steadily and rapidly increasing).

Finally Table 2-10 to Table 2-13 provide a comparison of the stock unitary consumption of the analysed appliances for the two scenarios. It is worth noting that the target stock unitary consumption in 2004 is, according to the different countries, between the classes C (477 kWh/year) and B (398 kWh/year) for the cold appliances (being A = 292 kWh/year) and between D and C for the wash appliances[15] (A = 224 kWh/year)

Table 2-10: Baseline and Directive scenarios unitary consumption for refrigerators in the year 2004 (kWh/appl.)

Country	Unitary consumption Baseline Scenario	Unitary consumption Directive Scenario
AT	427	374
CZ	454	379
DE	410	367
DK	486	423
ES	447	422
FR	478	402
IT	499	437
NL	459	381
PL	416	391
UK	497	466

[15] 5 kg of load and 220 cycles/year for the washing machines and 12 settings and 280 cycles year for the dishwashers

Table 2-11: Baseline and Directive scenarios unitary consumption for freezers in the year 2004 (kWh/appl.)

Country	Unitary consumption Baseline Scenario	Unitary consumption Directive Scenario
AT	405	378
CZ	406	373
DE	403	378
DK	379	330
ES	440	372
FR	421	378
IT	417	377
NL	395	330
PL	395	374
UK	409	378

Table 2-12: Baseline and Directive scenarios unitary consumption for washing machines in the year 2004 (kWh/appl.)

Country	Unitary consumption Baseline Scenario	Unitary consumption Directive Scenario
AT	385	358
CZ	386	353
DE	383	358
DK	359	310
ES	420	352
FR	401	358
IT	397	357
NL	375	310
PL	375	354
UK	389	358

Table 2-13: Baseline and Directive scenarios unitary consumption for dishwashers in the year 2004 (kWh/appl.)

Country	Unitary consumption Baseline Scenario	Unitary consumption Directive Scenario
AT	405	378
CZ	406	373
DE	403	378
DK	379	330
ES	440	372
FR	421	378
IT	417	377
NL	395	330
PL	406	386
UK	409	378

2.6.2 CO_2 Savings

The conversion of electricity savings from TWh to Mt CO_2 is based on the use of short term marginal emission factors for each Member States. This issue is discussed in detail in the document for the evaluation of the RES-E Directive which faced a similar problem. The most precise procedure would be the use of an hourly model representation of the power sector in a country together with detailed load profiles for the electric appliances in order to calculate which power plants are substituted by the electricity savings. Such a model does exist for Germany (the PowerAce model); it does not yet exist for all EU countries, although an extension of the PowerAce model is underway. However, there are also limitations in what is known in terms of load patterns of the more efficient appliances. Therefore, in order to cover all countries, a more simplified approach was developed by using either the average fossil fuel mix or an existing typical gas-fired power plant with a relatively low efficiency[16] of 40% (around 500 gCO_2/kWh) depending on whether the appliance is mainly or to a large degree used during peak-time (e.g. driers) or has a regular pattern over day and night (e.g. refrigerators) (accounting method I) as compared to the hourly approach (accounting method II). In the absence of precise load patterns for efficient appliances they were classified into two categories as follows:

Table 2-14 Classification of efficient appliances according to load patterns

Appliances with load patterns mainly or frequently during peak hours	Appliances with load patterns mainly off-peak and during base load time
Washing machine	Refrigerators
Driers	Fridge-Freezers
Dishwashers	Freezers
Air conditioners	Lighting
Short term marginal emission coefficient: average gas-fired plant	Short term marginal emission coefficient: average fossil-fuel-fired plant

This approach is simplified in that it uses a rather crude classification. A range of the appliances cited in the left hand column will have off-peak users. Similarly, a proportion of use of the devices in the right hand column will occur during peak time or near peak-time. There is however, no statistical information on the usage patterns.

Determination of emission coefficient based on the average fossil fuel mix/gas-fired plant - accounting method I

In this method the emission coefficient of the average fossil generation is determined according to the data provided by EUROSTAT. As the operation of nuclear power is not affected in a significant manner in any of the EU countries only the fossil power generation is taken into account.

The emission factors calculated for each country are presented in Table 2-15. As discussed in the following section the most exact analysis of the past emission reductions due to renewable electricity would be based on the determination of the emission coefficient based on marginal power plant in terms of the short term marginal costs (STMC) of the power sector. For such an analysis a detailed model based assessment using a model with a very high temporal resolution (e.g. hourly) is required. Such model based assessment is highly sophisticated, since it involves hourly data of electricity demand, renewable electricity generation and power plant operation. Despite the fact that modelling tools showing the required level of detail exist for individual countries (e.g. Germany) a complete assessment of this kind for most EU countries is currently not feasible, although work is underway to extend the model used for Germany also to other countries. Therefore the calculation of the marginal emission coefficient will be approximated in this analysis by the average coefficient for all power plants, which are in principle affected by renewable electricity generation in each country. Generally all thermal power plants except nuclear plants belong into this category. An exception from this general rule is France, where it is assumed that electricity savings affect the operation of nuclear power plants - it is assumed that electricity savings replace 70% thermal plants and 30% nuclear plants. Therefore the emission coefficient is calculated based on the assumption that in all countries except France the operation of all thermal power plants is equally affected and the operation of nuclear plants is not affected. As a result of this procedure the emission factors shown in Table 2-15 have been determined for the year 2005.

Table 2-15 Average emission coefficient of the power sector of selected EU countries (including all fossil plants) according to PRIMES

	AT	CZ	DE	DK	ES	FR	IT	NL	PL	RO	UK	EU-27	EU-15
t/MWh	0.84	1.29	0.96	0.90	0.71	0.70	0.64	0.66	1.22	1.27	0.71	0.86	0.79

[16] This can be justified by the fact that many gas-fired plants in the EU are still fairly old and in peak load not used in an optimal range.

Generally, the emission factor determined in this way is a weighted average of gas and oil plants, hard coal plants and lignite plants. In particular in countries with little electricity savings and a large share of gas plants in the conventional portfolio, one could argue that mainly gas would be avoided and the average might lead to an overestimation of the coefficient. However, very often a significant share of coal plants is replaced by electricity for the following reasons: first during night times gas plants are often not operated but base-load lignite plants dominate the market. Therefore during these times coal plants are replaced in many countries. Secondly many gas power plants are coupled with CHP or industrial processes and cannot easily be turned off. This is a second reason why coal plants are frequently replaced by energy efficiency options. See also the following section for the justification of this approach with the detailed hourly calculation of the emission coefficient.

Determination of emission coefficient based on marginal power plant in terms of the short term marginal costs (STMC) of the power sector - accounting method II

Alternatively the emission coefficient could be determined based on the operation of the power sector, where electricity savings would replace the marginal power plant in terms of the short term marginal costs (STMC) of the power sector. In this approach the electricity savings replace the most expensive power plant along the merit order curve in every hour of the year. It is assumed that the electricity savings occur fairly regular over the day (which would be the case of cold appliances). In this way the plants characterised by high fuel costs (i.e. first oil and gas fired plants, secondly hard coal fired plants, thirdly lignite fired power plants) and low efficiencies are replaced first. It has to be considered however, which part of the power plants is not dispatchable, e.g. due to cogeneration heat. This procedure leads for Germany to an emission coefficient of **0.929 tCO_2/ MWh** for the years 2004 and 2005 (according to AGESTAT). As compared with Table 2-15 which shows the average fossil emission coefficient it is seen that that the average fossil emission coefficient is a much better approximation in the case of Germany than the assumption of a gas-fired power plant would have been.

Determination of the total emission reductions

By multiplying the total additional electricity savings presented in the previous section with the emission coefficients, the total emission reductions can be calculated. The results of this are shown Table 2-18 together with the emission coefficients used (Table 2-17) and the summary of the electricity savings (Table 2-16). Therefore the impact on the emission reductions in the German power sector, scaled to EU27[17] amounts to 20.7 Mt CO_2 in the year 2004. As the shift towards more efficient appliances has continued, applied to an ever increasing range of appliances, it can be hypothesised that substantially higher amounts of savings have been accumulating up to today (2008).

Table 2-16 Summary of electricity savings by type of appliance (2004)

GWh COUNTRY	Refrigerators	Freezers	Washing machines	Dishwashers	4 appliances
AT	177	57	83	41	358
CZ	304	45	67	3	419
DE	1622	613	916	436	3587
DK	95	74	83	39	291
ES	382	305	1008	219	1914
FR	2013	598	1071	421	4103
IT	1549	294	964	240	3047
NL	565	217	450	128	1360
PL	352	102	195	6	655
UK	841	327	777	173	2118
Total 10 countries	**7900**	**2632**	**5614**	**1706**	**17852**
Estimate scaled to EU27*	**9165**	**3053**	**6513**	**1979**	**20710**

***scaled with private consumption. The 10 countries represent 86% of EU27**

17 By using shares in household income as a measure for wealth and usage of appliance, the 10 countries analysed represent 86% of the total household income in the EU27

Table 2-17 Summary of emission factors - accounting method I (emission factor based on average fossil fuel mix or average gas-fired plant)

Emfactor (kt CO2/GWh) COUNTRY	Refrigerators	Freezers	Washing machines	Dishwashers
AT	0,84	0,84	0,5	0,5
CZ	1,29	1,29	0,5	0,5
DE	0,96	0,96	0,5	0,5
DK	0,9	0,9	0,5	0,5
ES	0,71	0,71	0,5	0,5
FR	0,7	0,7	0,5	0,5
IT	0,64	0,64	0,5	0,5
NL	0,66	0,66	0,5	0,5
PL	1,22	1,22	0,5	0,5
UK	0,71	0,71	0,5	0,5

Note Emission factors are either average fossil fuel emission factor or gas-fired power plant emission factors

Table 2-18 Total emission reductions in Mt CO_2 due electricity savings from the Labelling Directives up to 2004 - accounting method I (emission factor based on average fossil fuel mix or average gas-fired plant)

CZ	Refrigerators	Freezers	Washing machines	Dishwashers	4 appliances
AT	149	48	42	21	259
CZ	392	58	34	2	485
DE	1557	588	458	218	2822
DK	86	67	42	20	213
ES	271	217	504	110	1101
FR	1409	419	536	211	2574
IT	991	188	482	120	1782
NL	373	143	225	64	805
PL	429	124	98	3	654
UK	597	232	389	87	1304
Total 10 countries	**6255**	**2084**	**2807**	**853**	**11999**
Estimate scaled to EU27*	**7256**	**2418**	**3256**	**990**	**13920**

***scaled with private consumption. The 10 countries represent 86% of EU27**

2.7 Step 5: Impact Delimitation

The impact delimitation corrects for, but is not limited to, the:

- treatment of independent national measures aiming at the same target;
- treatment of autonomous progress;
- treatment of the impact of energy price variations

The issue of autonomous progress has been discussed previously. It the absence of alternative evidence it was decided to adopt a starting appliance energy efficiency that was frozen at the base year. A variant to this approach would be to determine the autonomous progress from the electricity consumption per appliance before the entrance of the Directives i.e. the pre-Directive appliance energy efficiency trend. However, as mentioned, the data for this approach is scarce and influenced by many factors. A further issue that has not been addressed is multiplier, or market transformation effects. Since the appliance market is a European one, improvements in energy efficiency to meet the demand from one (national) market may filter through to the other markets.

The increase of electricity prices was limited in the period observed due to the liberalisation of the market leading to relatively stable electricity prices for households. In more recent years, however, electricity prices have been increasing due to increasing fuel prices and the impact of the EU ETS.

This section therefore concentrates on estimation of the facilitating measures impact at Member State level. Two countries among the 10 considered were outstanding in terms of facilitating measures, the Netherlands and Denmark.

For the Netherlands and Denmark the results obtained within the Directive Scenario also include the facilitating measures adopted to foster the purchase of more efficient appliances. To evaluate the impact of these measures we have hypothesized that, without the subsidies, the A and A+ trend of these countries would have been the same as for Germany and France, averaged, neither of which had particular promotion measures in place.

The results are shown in **Table 2-19** in which the first column for each country shows the savings achieved in the year 2004 within the Directive scenario (see Table 2-10 to Table 2-13) while the second column shows the savings that these two countries would have achieved without the facilitating measures. In accordance with the data, we estimate that during the period 2000-2004 and for the four large appliances considered:

- In Denmark the energy savings attributable only to subsidies was 796 GWh, equal to 8.3% of total energy savings.
- In the Netherlands the energy savings attributable only to subsidies was 2,485 GWh equal to 7.5% of total energy savings.

In practice the facilitating measures seem to provide an additional 4% of savings for each year in which the measures were implemented.

Table 2-19: The impact of the facilitating measures: Denmark and the Netherlands (2000-2004) (GWh)

APPLIANCES	DK		NL	
	Relative savings Directive Scenario	Relative savings without subsidies for the purchase of high efficient appliances	Relative savings Directive Scenario	Relative savings without subsidies for the purchase of high efficient appliances
Refrigerators	14,77%	10,98%	20,59%	11,11%
Freezers	15,01%	6,58%	19,93%	8,29%
Washing Machines	15,98%	7,01%	21,21%	8,77%
Dishwashers	15,01%	6,58%	19,93%	8,35%

In conclusion for both Denmark and the Netherlands the contribution of the national subsidy schemes has been substantial in the shift towards more energy efficient appliances.

2.8 Discussion of results

2.8.1 Results for case study Member States

Table **2-20** illustrates the CO_2 emission[18] savings for Tier 1, Tier 2 and Tier 3 for Europe and Germany respectively. The overall results are within the same range for all three methods, especially if the fact that geographic delimitation is not always the same is taken into account. The results indicate savings in the range of 13-21 Mt CO_2 for the period 1995-2004/6, with somewhat higher results for the Tier 1 methodology. Differences may, however, arise for individual countries or individual appliances.

Differences between Tier 1, 2 and 3 results are explained by:

[18] N_2O emissions have been neglected in this analysis but may be considered in future evaluations.

- The degree of disaggregation: while the Tier 1 methodology does not distinguish between the different electrical appliances, i.e. those covered or not by the Labelling Directive, the Tier 2 and 3 methodologies do. The Tier 2 methodology is limited by the number of countries in the Odyssee database for which information on individual appliances is available. Tier 3 methodology is limited by the detailed labelling information available for the sales of the different appliances in the different EU countries.
- The treatment of autonomous progress.
- Differences in the emission factors used.
- The treatment of national promotion policies for the appliance labels.

Table 2-20 CO_2 Savings in Tier 1/2/3 methodologies for the Labelling Directive for Europe (1995-2004/6)

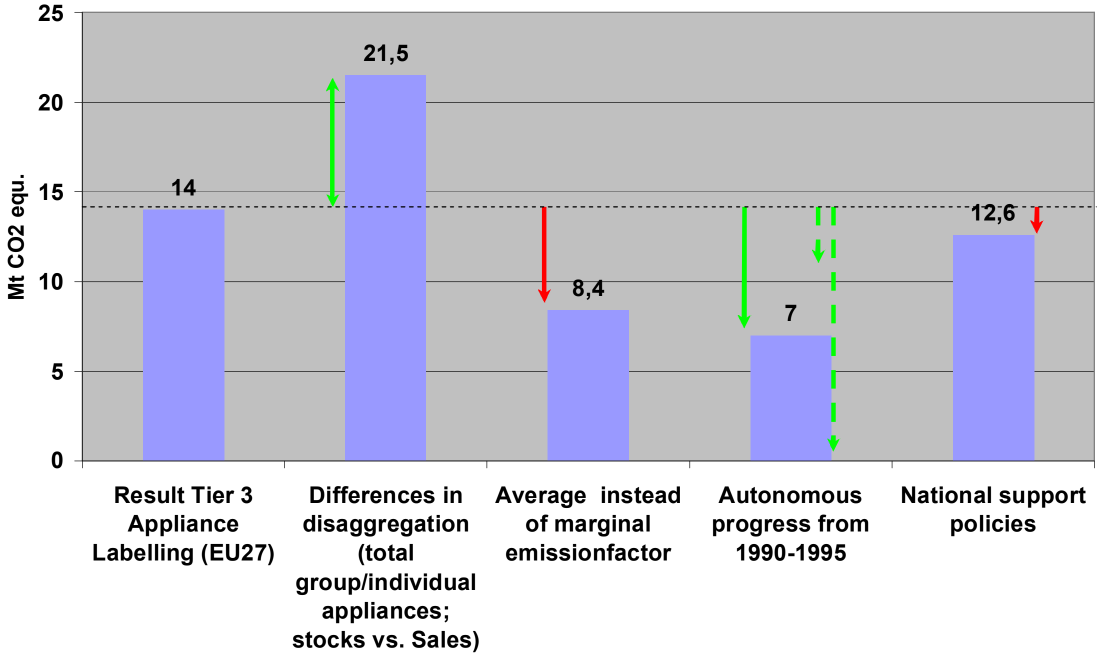
	Tier 1		Tier 2		Tier 3
kt CO2 Total: refrigerators, freezers, washing machines, dishwashers, driers (Tier 2 only)	2005	2006	2005	2006	2004
EU-27	**-15302**	**-21485**	**-**	**-**	**-13290**
Sum of countries investigated	**-9206**	**-12169**	**-6258**	**-7356**	**-11999**
Austria	-340	0	-80	-100	-259
Czech Republic	-5580	-5972	-	-	-485
Denmark	-1446	-1525	-187	-215	-213
France	0	0	-302	-372	-2574
Germany	-327	-1890	-3512	-4171	-2822
Italy	-1131	-1640	-439	-463	-1782
Netherlands	-383	-366	-56	-61	-805
Poland	0	0	-	-	-654
Spain	0	0	-	-	-1101
UK	0	-777	-1682	-1973	-1304
Refrigerators	-	-	-1724	-2058	-6255
Freezers	-	-	-2031	-2336	-2084
Washing machines	-	-	-880	-1000	-2807
Dish washers	-	-	-833	-991	-853
Driers	-	-	-790	-970	-

2.8.2 Sensitivity analysis

In the Figure 2-16 the results of a sensitivity analysis testing the impact of using specific methodological assumptions and of data uncertainties upon the results is shown. The arrows show the relative variability in the results depending upon the particular assumptions that are used. The solid arrows show the influence of the specific factors, as calculated within this study. The dashed arrows are used to highlight the significant uncertainty in the factors themselves, and the potential range in the results that can arise from alternative assumptions.

A further differentiation is made between sensitivities that relate to methodological choices and those that relate to data issues.

Figure 2-16 Sensitivity analysis of the impacts of the Labelling Directive



Note: Variations due to methodological choices are in red. Variations due to data issues are in green in the figure.

It can be seen that a variety of factors may have substantial impacts, linked mainly to data uncertainties. In particular these are:

- The differentiation between individual electrical appliances in the residential sector, subject or not to the Directives.
- The differentiation of sales and stocks.
- The differentiation of labelling classes.
- Data necessary to correct for autonomous progress. For the Tier 3 approach no detailed data on labelling classes is available prior to the Directives. A correction could be used, according to the same procedures as for Tier 2. But this is only available for some countries and some appliances, unless more detailed figures are available from the manufacturers or GfK.

Other factors are linked to methodological choices. These are in particular:

- Choices in the emission factor (average EU/MS or MS marginal).
- Whether corrections for national support policies are taken into account or not.

2.8.3 Comparison of results from the different methods

The three different methods Tier 1, Tier 2, Tier 3 provide results which are reasonably comparable. Nevertheless the methodology based on the detailed sales data by efficiency classes which is used as input for the MURE stock model, is much more precise and less subject to annual fluctuations. For example the Tier 1 approach also contains electric heating (not covered by the Labelling Directive) which cannot be corrected for annual climatic variations (this is only explanation for the rather large increase in impacts from 2005 to 2006 in
Table **2-20**). This approach needs to be extended to cover further appliances and to integrate more recent observations on the split by labelling classes. With the Tier 3 methodology and the stock model approach there is nevertheless a good evaluation scheme in place and the weakest point of the assessment is the autonomous progress made before the start of the Labelling Directives.

2.8.4 Comparison of impacts across Member States

The impact of the Labelling Directive across Member States differs significantly (Table 2-18), depending on the type of appliance and the ownership rates. Refrigerators/freezers account for the largest amount of savings because this was the earliest implementing Directive to the Labelling Directive (from 1994), hence the market has been most completely transformed. Also the proportion of households with refrigerators is much larger than the proportion of households with dishwasher, although the latter use has been growing considerably over time.

Table 2-21 Total emission reductions in Mt CO_2 due electricity savings from the Labelling Directives up to 2004

CZ	Refrigerators	Freezers	Washing machines	Dishwashers	4 appliances
AT	149	48	42	21	259
CZ	392	58	34	2	485
DE	1557	588	458	218	2822
DK	86	67	42	20	213
ES	271	217	504	110	1101
FR	1409	419	536	211	2574
IT	991	188	482	120	1782
NL	373	143	225	64	805
PL	429	124	98	3	654
UK	597	232	389	87	1304
Total 10 countries	**6255**	**2084**	**2807**	**853**	**11999**
Estimate scaled to EU27*	**7256**	**2418**	**3256**	**990**	**13920**

***scaled with private consumption. The 10 countries represent 86% of EU27**

Note: emission factor based on average fossil fuel mix or average gas-fired plant

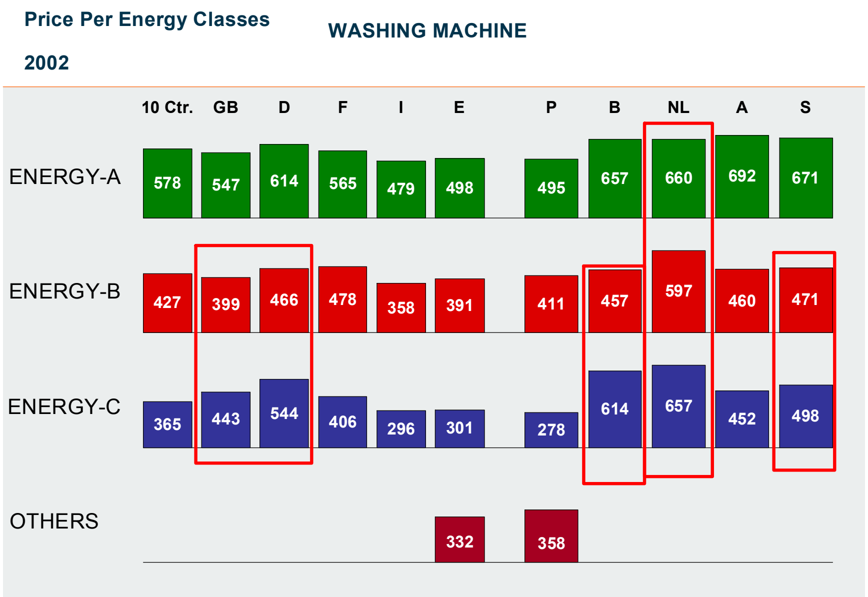
2.8.5 Cost effectiveness

Generally electricity savings from electric appliances are one of the most cost effective options to avoid CO_2 emissions. In addition the relatively small difference between the most efficient appliances and the average of the market, as well as the fact that with market penetration a rapid decrease in the differential costs occurred in the past, the consumers face less important investment barriers to energy efficiency than in other sectors.

The IEA (2003) estimates that "savings can be achieved at negative cost to society, since the extra costs of improving energy efficiency are more than offset by savings in running costs over the appliance's life. In the US, each tonne of CO_2 avoided in this way in 2020 will save consumers $65; while in Europe, each tonne of CO_2 avoided will save consumers €169 (reflecting higher electricity costs and currently lower efficiency standards in Europe)." See more details on the cost savings in the previous section in Table 2-5.

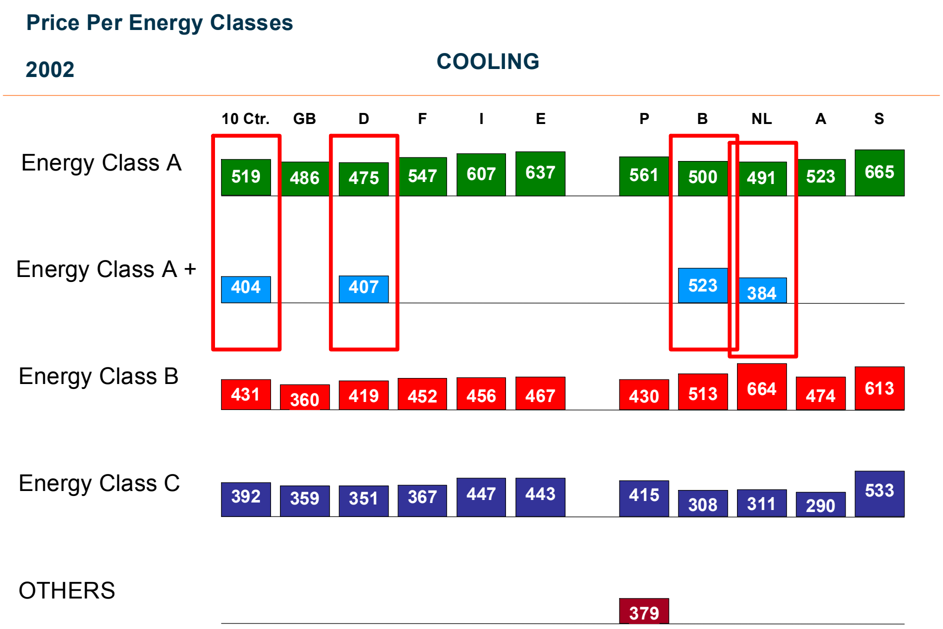
Many other investigations have shown that there is no correlation between the price of a more efficient appliances and its performance (Figure 2-17 and Figure 2-18). While the energy efficiency performance of appliances has drastically improved in a decade, the prices for the appliances have dropped in Europe and across the world (Figure 2-19 and Figure 2-20).

Figure 2-17: Do energy efficient washing machines really cost more?



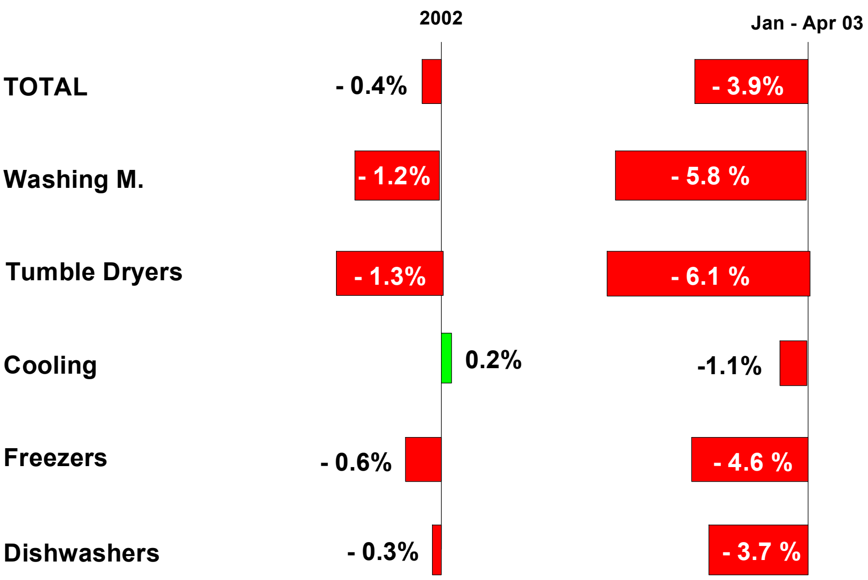
Source: GfK (2005)

Figure 2-18: Do energy efficient cooling appliances really cost more?



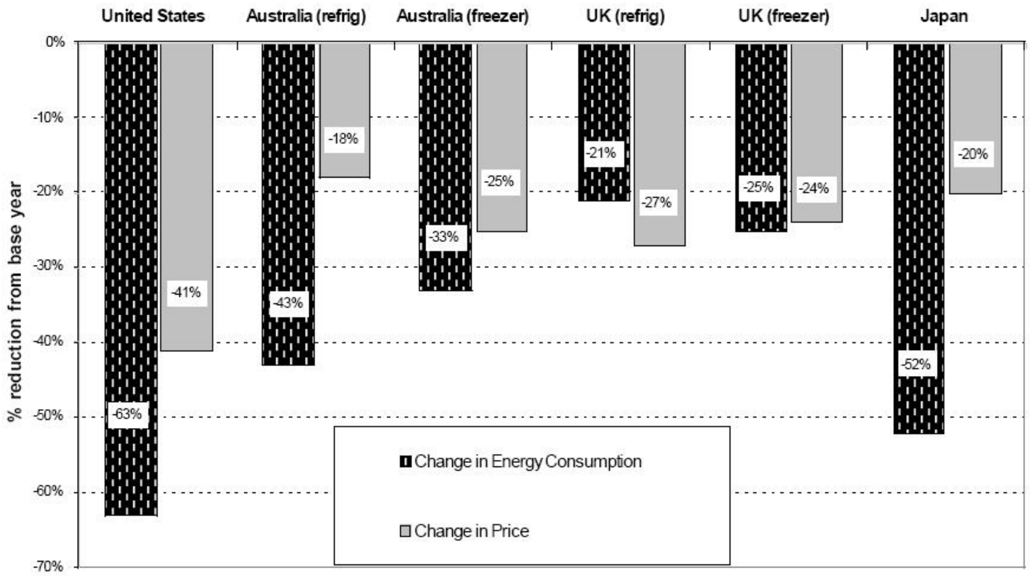
Source: GfK (2005)

Figure 2-19: Changes in the average price for electric appliances are not really linked to the penetration of labelling classes…



Source: GfK (2005)

Figure 2-20: Efficiency and real price trends for cold appliances (varying time scales)



Source: M. Ellis et al. (2007)

2.9 Conclusions

The different tiered methodologies discussed in this chapter deliver results which are comparable. If autonomous progress is not corrected for then they deliver an upper limit for the quantitative impact estimate. However, it is difficult to project autonomous progress from the pre-Directive period for two reasons. Firstly, data on the efficiency of appliances before 1994 (the start of the first implementing Directives) is relatively scarce and secondly, because the progress in this earlier period might have been easier to achieve – so many not be representative of progress that is achievable more recently. On this basis we consider that correction for autonomous progress should be done with caution. If long run-trends in efficiency are simply extrapolated then there is a danger that policy impacts will be calculated as close to zero.

The size of the CO_2 savings indicates that the Labelling Directive has a “medium size impact” compared to, for example the RES-E. Nevertheless, as the projections show (IEA 2003) this impact has the potential to almost triple by 2030 with the existing policies in place. Furthermore, the labelling schemes and MEPS may be enhanced and expanded to other appliances, especially through the Eco-design Directive, increasing the overall impacts.

Another methodological correction that has been examined is policy overlaps. The separation of impacts from national support policies seems feasible by comparing countries or sets of countries with and without supporting policies.

2.10 Recommendations

The evaluation has shown two important points for discussion in further evaluations:

- The **data basis which is available for the evaluation of the Directive** in the Tier 3 methodology is not a public one, but belongs to private actors such as GfK and the appliance association CECED. Care should therefore be taken to clarify how, on a regular basis, evaluations of the labelling schemes can be carried out. The most recent exercise of this type is just being finished (Fraunhofer ISI/GfK/BSR Sustainability 2008) and the results could be integrated in an evaluation of the Labelling Directive to a more recent date. The data used for the Tier 1 and 2 methodologies are public but are either relatively aggregate and include appliances not covered by the Labelling Directive, or are not available for all appliances and all countries
- The issue of correction for autonomous progress has been discussed and improvements to the methodology for corrections should be sought through discussions with experts from the appliance producers or by identifying more detailed time series data before 1994.

2.11 Next steps

In addition to the further development of the methodology for calculating emission factors for electricity savings, the most important next steps to be carried out are:

- Increase the number of appliances covered in the Tier 3 approach, in particular labels for air conditioning and lighting.
- Discuss with GfK and manufacturers whether more detailed data sets may be obtained to improve the issue of autonomous progress, or try to clarify the issue through further expert consultations.
- Integrate the most recent study results to improve on the time period covered (Fraunhofer ISI/GfK/BSR Sustainability 2008). These results became available too late to integrate them into the present study.
- Clarify the availability of private data sets for regular evaluations of the Labelling Directive.

2.12 References

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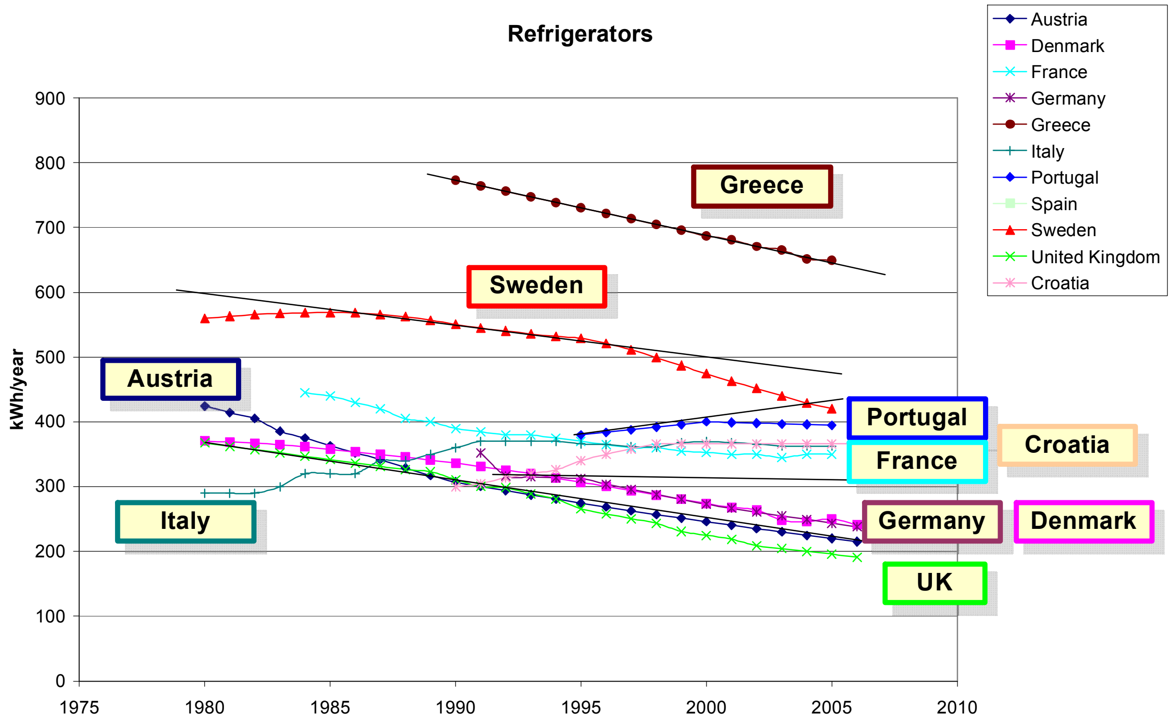
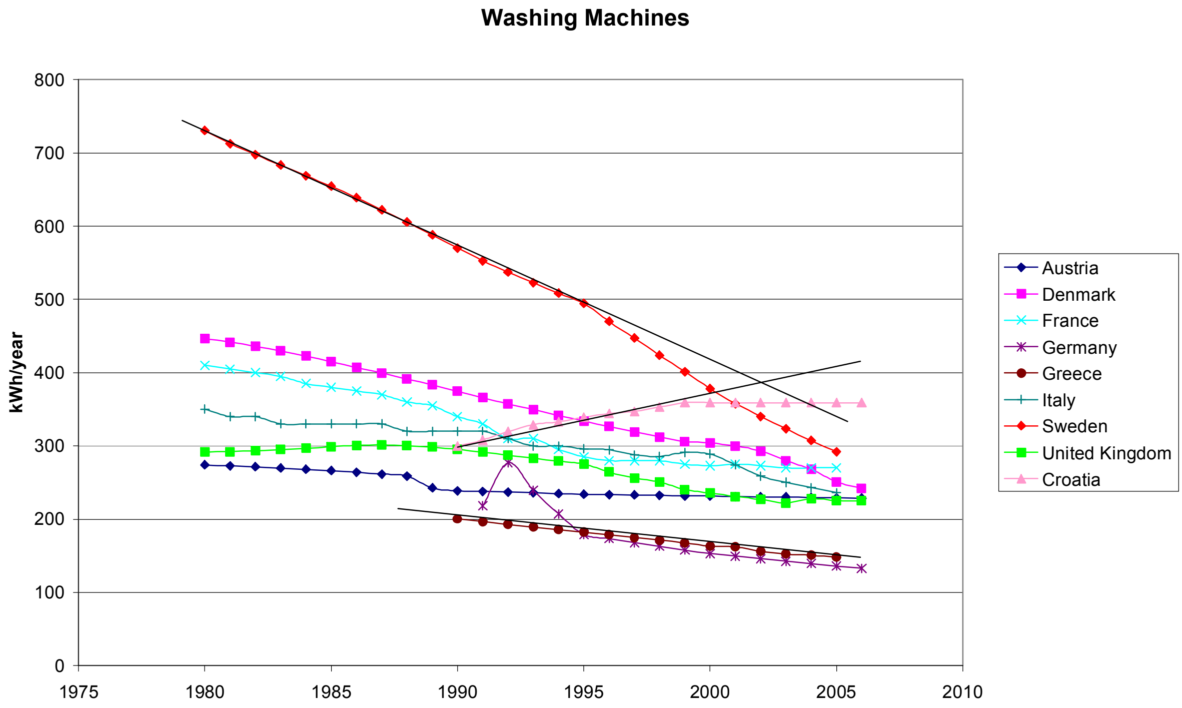
Annex 1

Figure A-21: Development of the specific energy consumption (kWh/appliance) for refrigerators



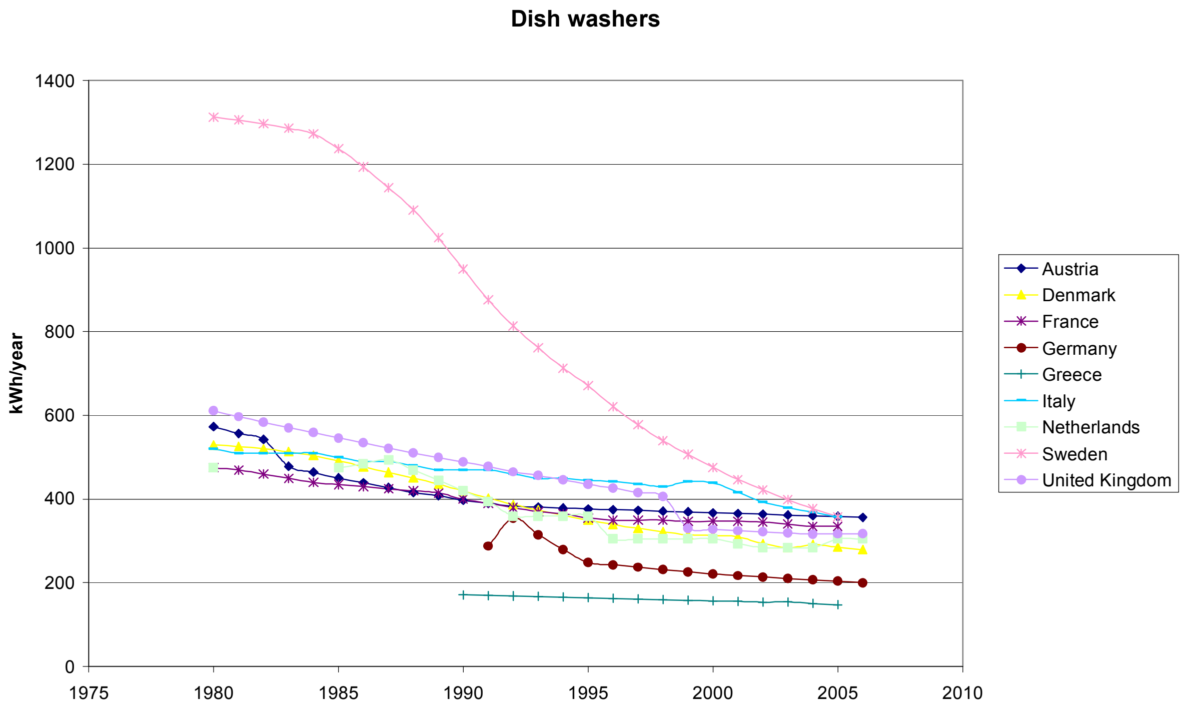
Source: Odyssee Database 2008

Figure A-22: Development of the specific energy consumption (kWh/appliance) for washing machines



Source: Odyssee Database 2008

Figure A-23: Development of the specific energy consumption (kWh/appliance) for dishwashers



Source: Odyssee Database 2008

3 European Directive for the Energy Performance of Buildings (EPBD)

The purpose of this section is to describe a “Tier 3” approach for the evaluation of the Directive for the Energy Performance of Buildings (EPBD), taking into account the interaction of this measure with other measures aiming at the same target, including national measures. The main focus is on the description of the methodology.

The approach to developing the Tier 3 methodology has followed five sequential steps. These are:

- Step 1 Mapping of GHG measures in the context of the European Climate Change Programme (ECCP): This is the qualitative description of the "measure network" which may include EU-ECCP measures, EU-pre-ECCP measures, ECCP-triggered national measures as well as independent national measures aiming at the same target.
- Step 2 Compilation of quantitative evaluation evidence: This consists of the compilation of quantitative evaluation evidence such as in-depth national bottom-up evaluations, estimates from top-down impact indicators or simple estimates.
- Step 3 Screening step: This consists of the exclusion of unimportant national measures and pre-ECCP measures from the measure map, reducing the measure map to a simpler picture that can be modelled more easily.
- Step 4 Modelling step: The model-based harmonised evaluation of the simplified measure map provides an evaluation of impacts under harmonised assumptions.
- Step 5 Impact Delimitation: The impacts obtained in the previous step are in general “gross impacts”. Further treatment of issues such as independent national measures aiming at the same target, autonomous progress, the impact of market energy price changes etc. may be necessary.

Each of these steps is described further below, following a more general discussion of the methodology and the data context.

3.1 Introduction: Brief description of the measure

3.1.1 The EU Directive on the Energy Performance of Buildings

The Directive on the Energy Performance of Building[19] (EPBD) aims to ‘promote the improvement of the energy performance of buildings within the EU, taking into account outdoor climatic and local conditions as well as indoor climate requirements and cost effectiveness’. The GHG emissions targeted by the EPBD are essentially CO_2 emissions from fuel combustion. The Directive has the long term objective of transforming the market practices of the building sector and represents a first step towards European-wide harmonised legislation for thermal regulation in buildings. However, it is important to underline that the approach adopted by the EPBD is fully in line with the subsidiary principle; its dispositions are laying down a general framework of principles and procedures leaving the individual Member States (MS) to create its practical definitions and applications. The main elements of the EPBD together with an overview of the transposition measures adopted are described below, and an indication of the opportunities and challenges for an overall evaluation and for an assessment of their impacts is given.

Art.1 of the EPBD lists the main elements covered by the Directive and which are analysed in the following paragraphs:

A. Setting of a general framework of calculating the integrated energy performance of buildings.
B. Application of minimum requirements on the energy performance of new buildings and, to a certain extent, to existing buildings when subject to major renovation.

19 Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings Official Journal L 001 , 04/01/2003

C. Creation of certification schemes for new and existing buildings on the basis of the above standards and the imposition of an obligation of public display of the energy performance certificates in public buildings and buildings frequented by the public.
D. Establishment of regular inspection of boilers and heating/cooling systems and the imposition of an obligation of assessment of the heating installation for boilers which are older than 15 years.

The current EPBD policy approach is under discussion: the European Commission has recently opened a 'public consultation for the recasting of the EPBD'[20]. The recast is based on the reasoning that there are still many unexploited cost-effective energy efficiency measures available in the building sector that could be promoted through the legislative re-formulation of the Directive.. Many of the issues included in the recast reveal the identified short-comings and problems experienced in the early years of implementation. The recast intends to address the following issues:

- the simplification and clarification of the wording of some dispositions;
- the review of the EPBD thresholds which cover the appropriate proportion of buildings and installations. In particular, the one set in Art.6 that limits the introduction of specific energy efficiency requirements to newly constructed buildings and to those with a floor area of above 1000m^2 which undergo major renovation;
- the strengthening of certain requirements;
- the enhancement of public buildings having a leading role.

Certification will likely include the 'payback time' as mandatory information, and the inspection of boilers and air conditioning systems (indicating specifications, requirements and objectives) will be regulated in more detail. In addition, in order to allow for the comparison of energy performance and to improve transparency, the creation of a benchmarking system has been proposed.

3.1.2 The transposition of the EPBD in the Member States

Overview

The EPBD, published on the 4th January 2003, set 4th January 2006 as the deadline for the implementation of the first two provisions[21], A and B, while allowing a further transition period of up to three years (i.e. until 4th January 2009) for C and D[22] - due to the challenges faced by the Member States as regards training and accreditation of experts to carry out the certification and inspection. When evaluating the impact of the Directive, it is necessary to take into account that the transposition of the Directive has been more or less substantially delayed by most of the MS. In April 2008, the Commission had sent 'reasoned opinions', as the second step in infringement procedures, to several Member States for failure either of notifying the national measures requested in the EPBD or for having adopted inadequate transposing norms[23].

Two observations can be made with regard to the partial implementation of the EPBD in Member States:

The EPBD contains a wide range of legislative measures and, in some cases, countries have failed to transpose all four mentioned elements of the Directive. The full transposition of the EPBD requires MS to adopt highly technical initiatives involving the review of national calculation methods as well as administrative measures aiming at the creation of new structures and professional curricula. In addition, the responsibility to adopt the adequate legislation is shared in many countries between national and regional authorities, and, as a consequence, 'fragmented implementation' has occurred in more than one country. Taking Belgium as an example: the Flemish Region has effectively transposed the Directive, while the Walloon Region has not specified energy performance requirements for buildings and has not determined inspection procedures for boilers and air conditioning systems. The Capital Region of Brussels has failed to define the methodology to calculate the energy performance of non-residential buildings and the complete specification of minimum energy performance requirements for existing buildings which undergo major renovations. A second example of partial implementation has occurred in the UK with regard to the implementation of the Directive in

20 See http://ec.europa.eu/energy/demand/consultations/buildings_dir_en.htm
21 A) Establishment of a general framework methodology for the calculation of the integrated energy performance of buildings, B) Application of minimum requirements on the energy performance of new buildings and to a certain extent also to existing buildings when they are renovated.
22 C) Certification schemes for new and existing buildings on the basis of the above standards and public display of energy performance certificates, recommended indoor temperatures and other relevant climatic factors in public buildings and buildings frequented by the public, D) Regular inspection and assessment of boilers and heating/cooling installations, the latter for boilers older than 15 years.
23 See http://europa.eu/rapid/pressReleasesAction.do?reference=IP/06/863&format=HTML&aged=0&language=, http://www.eeb.org/061106-Briefing-Buildings-Directive.pdf http://ec.europa.eu/energy/demand/consultations/doc/2008_public_consultation_buildings_background_en.pdf

Gibraltar as well as provisions related to energy performance certificates and to the inspection of boilers and air conditioning systems in Northern Ireland.

The transposition of the Directive's four main elements into the national legislation and the adoption of a common methodology for integrated energy performance standards

Art. 3 of the EPBD states that Member States shall set and apply at national or regional level a methodology of energy performance calculation for buildings on the basis of the general framework set out in the Annex of the Directive. The article specifies that the energy performance of a building shall be expressed in a transparent manner and may include a CO_2 emission indicator.

Part 1 of the Annex requires that *at least* the following aspects are to be included in the methodology for the calculation:

a) thermal characteristics of the building
b) heating installations and hot water supply
c) air conditioning installations
d) ventilation
e) built-in lighting installations
f) position and orientation of the building
g) passive solar systems and solar protection
h) natural ventilation
i) indoor climatic conditions, including the designed indoor climate.

Part 2 indicates a series of aspects that shall be taken into consideration when relevant for the calculation:

a) active solar systems and other heating and electric systems based on renewable energy sources
b) electricity produced by CHP
c) district or block heating and cooling systems
d) natural lighting.

Part 3 proposes a number of categories for the classification of buildings to facilitate the enforcement of the calculation method.

When evaluating a building's energy efficiency, the EU legislation adopts an 'integrated approach' which grants more flexibility to designers to meet energy reduction standards in the most cost-effective way. In order to support the national development of methodologies, especially for those countries with limited experience in the field of energy performance standards, a mandate was given by the EC to the European Committee for Standardization (CEN) to develop a set of standards. This set of standards is based on a list of about 40 topics covering calculation, measurement and inspection procedures, including methods on the level of building components and systems. By 2006 only the draft version of the standards was available and the harmonised version was finalised in the second half of 2007.

Although the proposed standards are not mandatory, MS methodologies shall, however, be at least in broad compliance with them. From the information compiled by the EPBD Platform[24], the following summary emerges:

- 24 countries have introduced a single national procedure of calculation while three countries have regional procedures,
- Most of the countries have different procedures for residential and non residential buildings and have adopted at least some of the CEN standards even if many regulations do not refer directly to these standards but describe the calculation method themselves.

Most countries have adopted **calculated ratings** but **measured ratings** are also widely used, especially for non-residential buildings.

A comparison/overall assessment of the methodology adopted and the EP requirements set by the different MS would be extremely challenging. The project ASIEPI[25] has underlined that the calculation methodologies, definitions and references values adopted in the EU countries present substantial differences, in particular:

24 See http://www.buildingsplatform.org/cms/index.php?id=7&no_cache=1
25 See http://www.asiepi.eu/ ; 'Comparing Energy Performance Requirements over Europe' published by EPBD Building Platform paper n.65 of 18/03/2008.

- The building components and systems are described by different characteristics in the EU countries. The proper information is often lacking for foreign products as measurements are only performed according to the national measurement standards of the countries in which the products are sold. When foreign products are not measured according to national standards, they are characterised by default efficiency values that can penalise the energy efficiency evaluation of the product.

- The input parameters to calculate how a building is rated differ to a certain extent from country to country. Aspects taken into account in some countries are considered of no importance in others (e. g. thermal bridges are considered in Flemish building description and not in Portugal).

- Furthermore the parameters are in some cases differently described (e. g. the power for lighting can be given with or without the power of the ballast).

Over time, these differences will probably be reduced through the adoption by the MS of the European Standards, and, in the longer term, a common methodology could then form the basis for integrated minimum energy performance standards, reflecting local circumstances.

The setting of energy performance requirements for new and existing buildings

Art.4 of the EPBD calls on MS to set, on the basis of the approved methodology, minimum energy performance (EP) requirements for buildings which must then be reviewed at regular intervals of at most 5 years in order to be updated with the technical progresses in the sector. In determining minimum energy performance requirements, MS shall take into account:

- general indoor climate conditions
- local conditions
- the designated function of the building
- the age of the building.

The minimum energy performance requirements shall be applied to:

- **All new buildings**: For those with a useful floor area of over 1000 m^2, Art.5 prescribes as well to take into account the technical, environmental and economic feasibility of alternative solutions[26].

- **Existing buildings with a total floor area of over 1000 m^2 which undergo major renovation.** However, Art. 6 specifies in these cases, the minimum requirements will be applied 'in so far this is technically, functionally and economically feasible'.

MS may differentiate between new and existing buildings as well as between categories of buildings, some of which can be excluded from the application of the minimum requirements due to their historical importance, their religious function or their partial/temporary use. **It is important to underline that these are regulated at national level as the Directive itself does not fix the minimum performance standards**. As a consequence, the strictness of the requirement level varies between EU MS. Part of the EPBD recasting is intended to enable the comparison and ultimately harmonise the EP requirements at a European level. However, the numerous differences discussed for the calculation methods directly impact ability to compare the adopted Energy performance requirements.

The ASIEPI project highlights the difficulties of such comparisons. The project demonstrates that comparing national standards on the basis of energy use per square meter, as well as the calculated total energy use, can be misleading. The comparison between **calculated national energy use per square meter** is impaired by the different definitions adopted for the floor and envelope areas. The definitions may vary though:

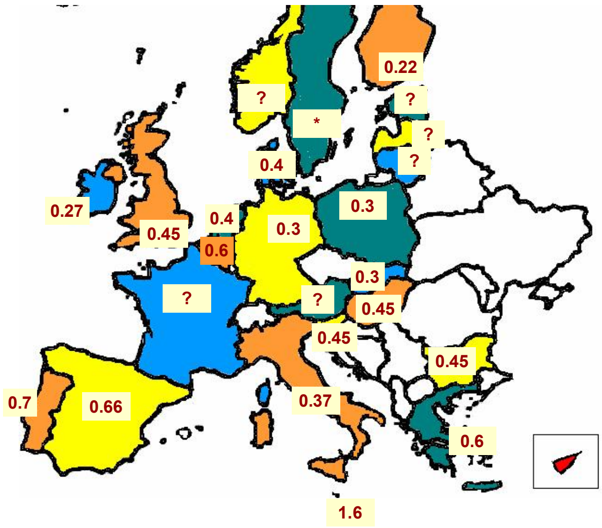
- the inclusion of outdoor, indoor and mixed areas;
- the consideration of the different buildings parts to be excluded;
- the definition of heated and non-heated zones.

26 Art. 5 mentions the following 'alternative solutions': decentralised energy supply systems based on renewable energy, CHP, district or block heating or cooling if available, heat pumps under certain conditions.

Consequently the floor area can differ by up to 15% depending on the national legislation applied. The ASIEPI project suggests that some of these differences could be cancelled out through a comparison of the differences in the **ratio** of the calculated total energy use and the maximum energy use.

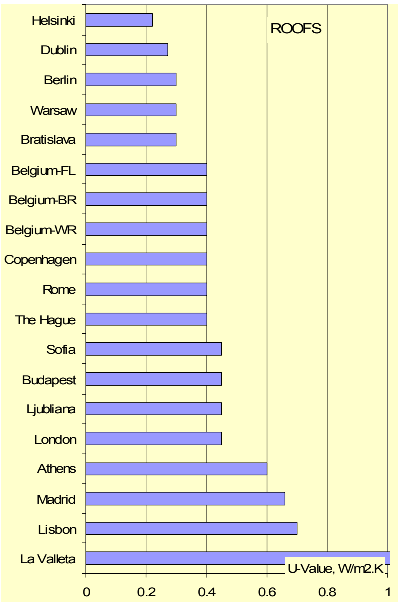
The disparity between the minimum requirements set at national level are underlined in the figures below which present the U-values[27] for wall, roof and floor ground in the different Member States.

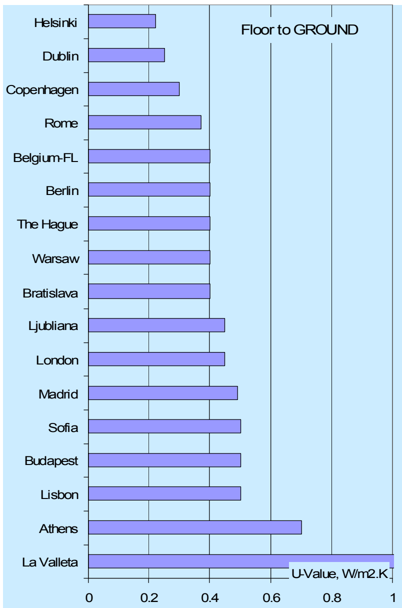
Figure 3-1 Minimum Requirements: Wall U-values in EU Member States[28]



[27] The U-value measures how well a building component, e.g. a wall, roof or a window, keeps heat inside a building
28 Eduardo Maldonado, Coordinator EU EPBD Concerted Action, presentation at the EURIMA General Meeting, Cannes 2 June 2006.

Figure **3**-**2** Minimum Requirements: U-values for roofs and floor-to-ground (indicative, usually combined with global energy targets)**28**





As part of the recasting, the European Commission is promoting the creation of a benchmarking system for the minimum requirements adopted in the different MS. The aim is to improve this system through a cross-country comparison, leading to greater transparency and effectiveness. It is also proposed that the threshold of 1000m^2 for imposing energy performance requirements on buildings that undergo major renovation be lowered. The current limit of 1000m^2 limits the application of the EPBD to about the 30% of the EU Building stock[29].

Some European countries have already developed integrated calculation methodologies and overseen their introduction and use. The EPBD 'integrated approach' has already been applied, under voluntary certification in France, the United Kingdom, the Netherlands and some Italian regions. Furthermore, the certification was already mandatory in Denmark. Here a calculation on the basis of 3.5 years of certification of 160,000 houses showed a total certification cost of about 25 MEUR and identified potential savings of about 125 MEUR. These measures reduced the energy costs for the consumers by 20 MEUR each year. In this particular case, certification, together with the implementation of the identified measures, provided a return on investment of greater than 13%[30].

Certification schemes for new and existing buildings on the basis of the above methodology

Art. 7 of the EPBD called on MS to ensure that when a building is constructed, sold or rented out an energy performance certificate is made available to the owner or by the owner to the buyer or tenant (with some building types excluded). The content and validity of the certification are defined as:

1. The certification shall contain reference values such as the current legal standards.
2. The certification shall include recommendations for cost effective energy saving measures.
3. The validity should not exceed 10 years.

The main objective of the certification, in line with the previous EU actions in this field[31], is to provide clear and reliable information to the tenant or owner in order to make him aware of the costs and the possible

29 Ecofys for Eurima, VII study 2007
30 MURE database, Measure A1 EU8 Energy Performance of Buildings (Directive 2002/91/EC)
31 Council Directive 93/76/EEC of 13 September 1993 to limit carbon dioxide emissions by improving energy efficiency (SAVE), article 2 'Member States shall draw up and implement programmes on the energy certification of buildings. Energy certification of buildings, which shall consist of a description of their energy characteristics, must provide information for prospective users concerning a building's energy efficiency. Whereas appropriate, certification may also include options for the improvement of these energy characteristics.'

savings that could be obtained with energy efficiency measures. In the rental market, the energy certification is an attempt to address the often conflicting interests of the renter who pays the energy bills and the owner who may not wish to invest in energy efficiency measures he will gain very little from.

The most innovative aspect of this provision is to make **the certification obligatory for all buildings.** Table 3-1 shows the obligation has been introduced by Member States at different time scales, depending on the application of minimum requirements and the type of buildings concerned. Article 7 also contains an obligation for buildings with a total useful area over 1000 m^2 and occupied by public authorities or institutions providing public services, to place the EP certificate in a prominent place clearly visible to the public. This measure represents a first action directed at public buildings, ensuring they play a ‘leading role’ promoting and supporting the EP of buildings. This ‘soft informative imposition’ of displaying the certificate together with the recommended/current indoor temperature and other climatic factors is under discussion with the EPBD recasting which aims to recognise a more active and exemplary role for public buildings.

The Directive allows considerable scope for Member States to regulate the procedures at national or regional levels, including the information and indicators to be used in the certification process (see Table 3-1). The European Commission has mandated the CEN to produce a set of standards[32] describing the possible different approaches for certification as well as three examples of certificate designs, although it is not mandatory to use these.

32 CEN PrEN1517217 ‘Energy Performance of buildings – methods for expressing energy performance and for energy certification of buildings’.

Table 3-1: Implementation of Energy Performance Certificates by Member State [33]

			DIRECTIVE 2002/91/EC art. 7 Mandatory energy efficiency certificates : deadline for transposition 1/2006 or 1/2009 (3-year extension allowed by the EPBD art. 15). country status reports updated 08/2006-01/2007		
		Mandatory energy efficiency certificates for new buildings	**Mandatory audits for public building (larger than 1.000)and/or renovated building (larger than 1,000 m)**	**Mandatory energy efficiency certificates for existing buildings (certification for selling/renting)**	**Mandatory audits in small residential buildings**
Austria	**U**	24/05/2006 and 04/2007 Obligation: 1/01/2008	24/05/2006 and 04/2007 Obligation: 1/01/ 2009 unless regional introduces it earlier	24/05/2006 and 04/2007 Obligation: 1/01/ 2009	24/05/2006 and 04/2007 Obligation: 1/01/ 2009
Belgium	**M**	**Flemish Region** 7/05/2004 and 2005. Obligation from 1/01/2006	Flemish Region Law 7/05/2005. Obligation should start from 2008	Flemish Region Law 7/05/2005. Obligation should start from 2008 (residential) 2009 (non residential)	Flemish Region Law 7/05/2005. Obligation should start from 2008 (residential) 2009 (non residential)
	M	**Brussels Capital Region**- 2007.2008	Brussels Capital Region- 2007.2008	Brussels Capital Region- 2007.2008	Brussels Capital Region- 2007.2008
	M	**Wallon Region** 19/04/2007. Orders under discussion.	Wallon Region 19/04/2007. Orders under discussion.Obligation should start from 2008-2009.	Wallon Region 19/04/2007. Orders under discussion.Obligation should start from 2008-2009.	Wallon Region 19/04/2007. Orders under discussion.Obligation should start from 2008-2009.
Bulgaria		03/2004 and 1/2005.	03/2004 and 1/2005.		
Cyprus		2006. Decree and law under discussion- should be transposed by 2009	2006. Decree and law under discussion- should be transposed by 2009	2006. Decree and law under discussion- should be transposed by 2009	2006. Decree and law under discussion- should be transposed by 2009
Czech Republic		02/2006 and 07/2006 Obligation after 1/01/2009.	29/02/2006 and 07/2006 Obligation after 1/01/2009.	29/02/2006 and 07/2006. Obligation from 1/01/2009 only if new or renovated after the 1/01/2009.	29/02/2006 Amendement to the Act on Energy Management. Obligation from 1/01/2009 only if new or renovated after the 1/01/2009.
Denmark	**U**	12/2005 and 06/2006. Obligation from 09/2006	06/2006 and 12/2005. Obligation from 09/2006	06/2006 and 12/2005. Obligation from 09/2006	06/2006 and 12/2005. Obligation from 09/2006
Estonia	**H**	27/09/2006 and orders under discussion. Obligation after 1/01/2009.	27/09/2006 and orders under discussion. Obligation should be from 1/01/2009.	27/09/2006 and orders under discussion. Obligation should be from 1/01/2009.	27/09/2006 and orders under discussion. Obligation should be from 1/01/2009.
Finland		04/2007. Obligation from 01/2008.		13/04/2007 The Act on Building Energy Certification. Obligation from 1/01/2009.	
France		2005 and 2006. Obligation after 1/07/2007	2005 and 2006. Obligation from 1/07/2007	2005 and 2006. Obligation from 1/11/2006 (selling) from 1/07/2007 (renting)	2005 and 2006. Obligation from 1/07/2007
Germany		2007. New Obligation from 10/2008	2002-2007. New Obligation from 10/2008	2002-2007. New Obligation from 10/2008	2002-2007. New Obligation from 10/2008
Greece		2007 Law and Order under discussion. Obligation should be from 1/01/2009.	2007 Law under discussion. Obligation should be from 1/01/2009.	2007 Law on discussion. Obligation should be from 1/01/2009.	
Hungary		2006 Order under discussion.			
Ireland	**H**	2006 EC Building Regulations. Obligation from 1/01/2007(residential building) and from 1//07/2008 (all)	2006. Obligation from 1/01/2009	2006. Obligation from 1/01/2009	2006. Obligation from 1/01/2009
Italy	**U**	2005-2006. Obligation from 2009.	2005-2006. Obligation from 07/2007 for buildings above 1000 m2.	2005 -2006. Obligation from 07/ 2007 below 1000 m2 (excluding single flats).	2005-2006. Obligation from 07/ 2009.
Latvia		Law under discussion			
Lithuania		17/11/2005. Obligation from 01/2007	17/11/2005. Obligation from 01/2009	17/11/2005. Obligation from 01/2009	17/11/2005. Obligation from 01/2009
Luxembourg		July 2006. Order under discussion	July 2006. Order under discussion	July 2006. Order under discussion	July 2006. Order under discussion
Malta		Law under discussion			
Netherlands	**L**	2006-2007. Order under discussion, obbligation should start in 2008.	2006-2007. Order under discussion, obbligation should start in 2008.	2006-2007. Order under discussion, obbligation should start in 2008.	2006-2007. Order under discussion, obbligation should start in 2008.

33 MURE Database based on the information available in the Country Status Report published by the EPBD Building Platform

(Table 3-1 continued)

Poland		2006 law under discussion. Obligation should have started 1/01/2008	Law under discusssion. Obligation should start 1/2009	Law under discusssion. Obligation should start 1/2009	Law under discusssion. Obligation should start 1/2009
Portugal	H	2006. . Obligation should have started after mid-2007.	2006.Obligation should start 2008/2009 (public building).	2006.. Obligation should start 01/2009.	2006. Obligation should start 01/2009.
Romania	U	2005 and 2007. Obligation after 01/ 2007.	2005 and 2007. Obligation from 01/ 2007.	2005 and 2007. Obligation from 01/ 2007 (non residential) and 1/2010 (residential)	2005 and 2007. Obligation from 01/ 2007 (non residential) and 1/2010 (residential)
Slovakia	H	2005-2006. Obligation from 01/2008	2005-2006. Obligation from 01/2008	2005-2006. Obligation from 01/2008	2005-2006. Obligation from 01/2008
Slovenia		2006. Order under discussion. Obligation should start 2008.	2006. Order under discussion. Obligation should start 2008.	2006. Order under discussion. Obligation should start 2009.	2006. Order under discussion. Obligation should start 2009.
Spain		2006-2007.Obligation from 10/2007.	2006-2007.Obligation should start in 2009.	2006-2007.Obligation should start in 2009.	2006-2007.Obligation should start in 2009.
Sweden	U	2007 Obligation from 01/2009	2007 Obligation from 12/2008	2007 Obligation from 01/2009	2007 Obligation from 01/2009
United Kingdom	H	**England and Wales** 2007.Obligation start from 07/2007- 10/2008	England and Wales 2007.Obligation start from 07/2007- 10/2008	England and Wales 2007.Obligation start from 07/2007- 10/2008	England and Wales 2007.Obligation start from 07/2007- 10/2008
	H	**Scotland** 2007.	**Scotland** 2007.	**Scotland** 2007.	**Scotland** 2007.
	H	**Northern Ireland** Law 2006- 2007Orders under discussion.			

The EP certificate issued for a building is based on measured or calculated ratings and must contain an easily understandable global indicator of the energy consumption level. The indicator[34] represents a weighted sum of all the energy delivered to the building and, depending on the weight chosen, the indicator can be represented by: (1) primary energy (2) CO_2 emissions (3) Total energy cost (4) A weighted sum of the net delivered energy, weighted by any other parameter defined by the national energy policy.

Two reference values are defined by the standard:

1. An **Energy performance regulation reference** that corresponds to typical values of the energy performance requirements for new buildings.
2. A **Building stock reference** that corresponds to the energy performance reached by approximately 50% of the national or regional building stock.

One of main challenges faced by the MS in enforcing this measure has been the recognition and the training of ‘independent experts’ able to assess a building’s energy performance according to the identified ‘integrated approach’ and to grant the required certification. Art. 10 of EPBD prescribes that the certification of buildings, the drafting of accompanying recommendations and the inspection of boilers and air conditioning systems must be carried out by independent, qualified and/or accredited experts leaving it to the MS to take responsibility for the identification of appropriate qualifications and to establish the conditions necessary to perform these tasks.

Specific inspection and assessment of heating/cooling installations

Art. 8 of the EPBD Directive requires MS to adopt for **heating installations** one of the following two options in order to reduce energy consumption and to limit carbon dioxide emissions:

A) Establish regular inspection of boilers fired by non renewable liquid or solid fuels of an effective rated output of 20 to 100 kW, and of boilers with an effective rated output of more than 100 kW without restriction to the fuel used. In the latter case, the inspection shall be carried out at least every 4 years for gas boilers and every 2 years for all other fuels. In the case of boilers with an effective rated power of more than 20 kW which are older than 15 years the MS shall establish one-off inspections of the whole heating installation in order to compare the boiler sizing with the heating requirement of the building and to provide advice on the replacement of the boilers.

34 ‘Energy performance certification procedures, present status’, EPBD Buildings Platform, Paper P03 of 15-06-2006.

B) Organise active policies/advice to the users that must achieve an overall equivalent impact of the measure foreseen in A).

For **cooling installations,** Art. 9 of EPBD requires MS to establish a regular inspection of air conditioning systems of an effective output of more than 12 kW for which an overall assessment of the air conditioning efficiency and the sizing compared to the cooling requirements of the building shall be provided as well as advice on possible improvement.

The application of these provisions has generally been delayed. Many MS elected to use the full transition period to 4th January 2009 to transpose these aspects into national legislation.

These articles are formulated in such broad terms that, at the moment, their impact is considered by the EC to be quite limited. In light of this shortcoming, the Directive's recasting is aiming to better regulate the inspection specifications, requirements and objectives.

Three main approaches have been adopted by MS regarding the inspection or the provision of advice for boilers [35]:

1. Countries such as Germany and Austria, where regular building checks were already functioning, have opted to enforce systematic inspections and advice to all end users, usually coupled with regular safety checks paid for by the user.
2. Countries like Sweden, distinguished by the political will of establishing long term national plans, have set up programmes funded by the government for offering advice, grant incentives for boiler replacement and conducting inspection on a voluntary basis.
3. Countries like Italy and Portugal have chosen to limit the inspection to critical cases which are identified from a heating system database. In order to set up and maintain the database, an obligation of boiler/equipment registration and periodical maintenance is imposed on the users.

In contrast to Art. 8, Art. 9 on air conditioning inspection does not propose implementation options on MS. However, they still have the obligation to regulate a number of aspects. As an example, the inspections might be aligned with operation and maintenance standards, combined with safety requirements or coordinated with other types of mandatory inspection of A/C installations[36].

With air conditioning systems disparities among MS are originating from the interpretation of ambiguous provisions. The reference to 'systems of an effective rated output of more than 12 kW' for example has been indeed considered by the MS as referring to:

- one single air conditioner of more than 12 kW,
- the sum of all air conditioning of a building,
- the sum of all units in one building that are owned by the same owner.

Most of the national legislation regarding A/C inspections has been recently approved, or is still being drafted. Therefore, a comparison and assessment of their impacts cannot be done.

35 EPBD Platform, Maecello Antinucci 'Article 8 of the EPBD: Inspection of boilers or provision of advice to users?'
36 R. Hithin, J. Adnot, M. Dupont 'Issues of the implementation of the EPBD article 9: how and why to inspect all air conditioning systems all over Europe?' http://www.energyagency.at/publ/pdf/auditac_aicarr06.pdf

3.2 Methodological approach and data context

3.2.1 Methodology for evaluation

The evaluation of the impacts of the EPBD, in the 10 case study countries, has been carried out by using the building routine of the MURE-Household and Tertiary Sector models. A detailed description of this model is provided in Annex B. Before entering into the details of the simulation methodology, it is important to underline that, given the fact that the application of this Directive is very recent and/or, in some parts, it is not yet implemented, it has been objectively impossible to carry out a real ex-post evaluation (according to Table 3-1 the first implementing measures started, for a few countries, in the years 2005-2006 and only to concern new buildings).

Furthermore, the impact of any building regulation on the total building stock is not immediate, but can only be detected in the energy consumption statistics some years after its issuing. The most recent Odyssee energy efficiency indicators (www.odyssee-indicators.org) based on statistical information, are for the year 2006/7 and it is thus not possible to detect from these data any kind of substantial impact of the EPBD. **Nevertheless, the development of an ex-post Tier 3 methodology can be simulated with the MURE building model. This simulation exercise is moreover useful to derive data requirements for the further development of the evaluation guidelines.** The most important hypothesis for the simulation exercise is that the latest national building regulations put in place after the introduction of the EPBD were strongly influenced by the EU Directive.

The simulation methodology: main settings

The following are the main settings applied to the simulation exercise:

- The time frame of this evaluation is 2004 – 2020
- The simulation has been carried out by applying to each country either the building regulation recently adopted or under discussion (*Art. 5&6*). These standards are applied to both existing and new buildings.
- Very strict building regulations, like those required for passive houses, have not been applied because it is out of the scope of the Directive.
- For the achievement of the Minimum Performance Standards (*Art 7*) a moderate but steady improvement of the heating systems has been considered by simulating the shift to highly efficient gas boilers, heat pumps and renewables. It should be emphasised that the impact on the heating systems has been considered for the household sector only. In fact, due to the lack of reliable data, the non-residential building section of the MURE simulation model only provides the impact of the building shell.
- The regular inspections (*Art. 8*) have been taken into account by simulating the spread of a regular maintenance practice for heating devices (again, only for the household sector).

The evaluation provides:

- The final energy trends and savings and the corresponding CO_2 emissions for the household heating uses. For the household sector the evaluation was carried out in two steps: first of all the energy demand trends were evaluated by estimating the penetration of the EPBD EE standards in the building stock of the different MS. Then the final energy consumption trends were calculated by estimating the impact of the Directive on the heating technologies.
- The energy demand trends and savings for the service sector. For the non-residential buildings the evaluation has been limited to the energy demand due to the lack of reliable data on the diffusion of heating technologies in the service sector.

a. Energy demand evaluation

The settings for the useful energy evaluation have been the following:

- Main energy consumption drivers: growth of the households stock and the dwelling size in m^2.
- <u>Baseline</u>: Unit energy consumption for both new and existing buildings frozen at 2004 but the new EE standards existing by 2004 penetrate and therefore new buildings have used the most recent national building regulation valid before the introduction of the EPBD (**this creates a possible counterfactual scenario if seen from the ex-post perspective of the year 2020**).
- <u>EPBD penetration</u>:

- *Existing buildings*: The EPBD modifies the real estate market, obliging building owners to reduce the building renewal interval from 40 to 30 years or less and to carry out insulation interventions together with standard rehabilitation and maintenance measures. In order to comply with the Directive articles, more stringent regulatory measures will be undertaken by the central and local authorities to refurbish their own buildings. In figures this implies: 25% of refurbished buildings by 2020 for the moderate climate/western countries (At, De, Dk, Fr, UK); 20% of refurbished buildings for warm climate/western countries (Es, It); 16% of refurbished buildings for moderate climate/eastern countries (Cz, Pl).
- *New buildings*: New standards implemented at national level in accordance with the requirements of the EPBD, that is: strong penetration of the EPBD EE standards starting from the year 2010. Moderate penetration of further tighter EE standards initiated by the EPBD from 2015. The EE standards penetration is fine-tuned for the different country groups according to historic observations.

- Similar criteria are adopted for the non-residential buildings, in particular, for the *existing stock*:
  - 30% of refurbished buildings by 2020 for the moderate climate/western countries, 25% of refurbished buildings for warm climate/western countries, 18% of refurbished buildings for moderate climate/eastern countries.

In the calculation of the energy demand trends we considered the fact that only part of the target group to which the Directive is addressed will comply with its requirements. This has led to apply a set of **Compliance Factors**[37] in accordance with the following criteria:

- Different compliance factors for existing and new buildings
- Compliance factors differentiated by country groups:
  - Western/moderate climate countries: 55% existing, 70% new (only 55% and 70% respectively comply with the regulation).
  - Western/warm climate countries: 50% existing, 70% new.
  - New EU Members/moderate to cold climate: 45%, 70% new.

The Compliance Factors reduce significantly the expected savings and a sensitivity analysis has been carried out to evaluate this barrier. **The certification mechanisms envisaged by the EPBD should reduce this barrier but ex-post controls of the quality of the certification are essential**. In any ex-post evaluation, data on non-compliance is important for the quality of the evaluation.

MURE breaks down the existing and new building stock by the building standards described in **Table 3-2**. **Table** 3-3 and the related Figure 3-3 show the estimated trends of penetration of the different building regulations in accordance with the MURE settings. In an ex-post evaluation these penetration ratios have to be established statistically.

37 Source: Wuppertal Institute based on Hjorth and Warren (2008), ESD Potential Study for DG TREN (to be published). The compliance factors are based on historic observations of non-compliance. However, there are no good statistical databases for most countries that cover non-compliance issues.

Table 3-2: Breakdown of the existing and new building stock by type of building standard

Existing buildings (by the time of the base year 2004 for the simulation)	**MURE code**
Buildings without refurbishment	W. Ref
Buildings refurbished with old (1980-2000) building regulation	Ref0
Buildings refurbished with recent building regulation (after 2000 but before the introduction of the EPBD)	Ref1
Buildings that will be refurbished with EPBD building regulation (new building regulation initiated/inspired currently by the EPBD)	Ref2
Buildings that will be refurbished with more stringent building regulation (more stringent building regulation initiated/inspired in the future by the EPBD, e.g. low energy consumption houses)	Ref3
New buildings (built starting from the base year 2004)	
Buildings that will be built applying recent building regulation (after 2000 but before the introduction of the EPBD)	New1
Buildings that will be built applying EPBD building regulation (new building regulation initiated/inspired currently by the EPBD)	New2
Buildings that will be built applying more stringent building regulation (more stringent building regulation initiated/inspired in the future by the EPBD, e.g. low energy consumption houses)	New3

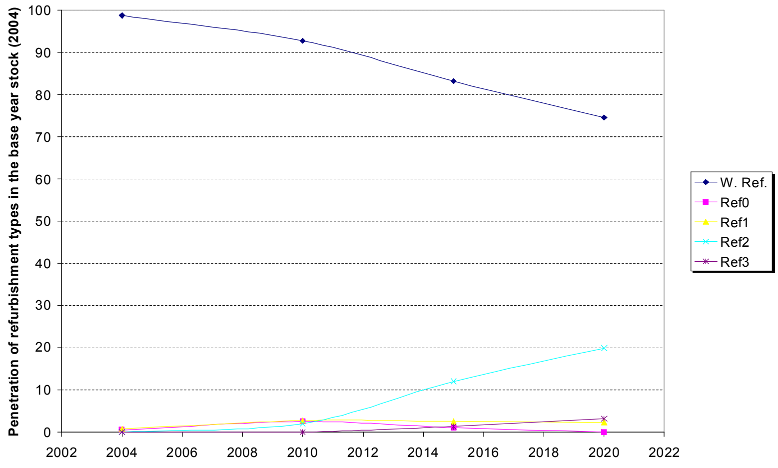
Note: The existing building EE standards Ref 1, 2 and 3 are equal to the new standards New1, 2 and 3. See Annex B for more details.

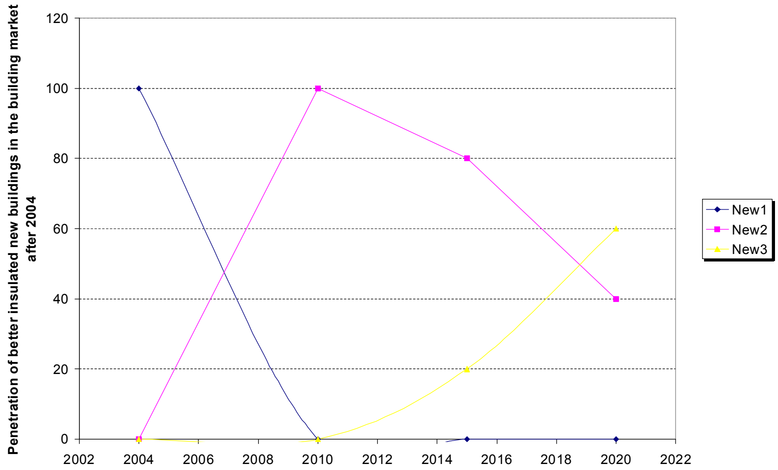
Table **3**-**3**: Penetration of the EPBD EE standards for existing and new buildings example for the Western/Moderate Climate Zone Countries)

Existing buildings [1]	**2004**	**2010**	**2015**	**2020**
Without Refurbishment (W. Ref.)	98.8	92.8	83.2	74.6
Old building regulation (Ref0)	0.5	2.5	1.0	0.0
Recent building regulation (Ref1)	0.7	2.7	2.5	2.3
EPBD building regulation (Ref2)	0.0	2.0	12.0	19.9
More stringent building regulation (Ref3)	0.0	0.0	1.3	3.2
New buildings [2]	**2004**	**2010**	**2015**	**2020**
Recent building regulation (New1)	100.0	0.0	0.0	0.0
EPBD building regulation (New2)	0.0	100.0	80.0	40.0
More stringent building regulation (New3)	0.0	0.0	20.0	60.0

Notes: [1] in % of the stock of buildings existing in 2004; [2] in % of the new building market

Figure 3-3 Penetration of the EPBD EE standards in existing buildings (upper graph) and new buildings (lower graph) (example of the Western/Moderate Climate Zone Countries)





Note: for the legend see Table 3-3

b. Final energy evaluation

The settings of the final energy evaluation are:

- Baseline: the heating technologies used in for both existing and new buildings are frozen in 2004. There is an energy efficiency increase for heating technologies independent from the EPBD due to the implementation of the EuP (Energy-using-Products) standards currently set up at EU level. It is important to note that in this way the impact of the EuP standards are not attributed to the EPBD; however they may be part of the ECCP and have to be evaluated separately. **Again this baseline constitutes an *anticipated* counterfactual scenario**.
- EPBD scenario: the energy efficiency increase of the heating technologies is the same as in the baseline scenario (except for the impact of the equipment maintenance required by the EPBD) and therefore the EE increment is only due to fuel shift, mainly:
  - Moderate shift to natural gas systems (from oil and coal-fired units).
  - Moderate penetration of renewable heating systems (especially in the southern countries).
  - Moderate penetration of heat-pumps (also caused by other measures such as White Certificate Schemes at national level).
  - For biomass and district heating systems the market share is frozen to the year 2004 for the existing stock (this may be a conservative assumption).

3.2.2 Data

Annex B provides a detailed description of the data used in the MURE household model. Here we report only the main input variables used by the MURE model and the corresponding sources (**Table** 3-4).

Table **3**-**4**: Main input variables used by the MURE model and corresponding data sources

Input variables	Data sources
Drivers: Trends in number of households	Primes database
Drivers: Trends in square metres	Wuppertal Institute and other specialised sources (see below)
Structural data for buildings	Odyssee database
Building EE standards	Wuppertal Institute and other specialised sources (see below) Odyssee database for calibration
Building EE penetration rates	Wuppertal Institute and other specialised sources (see below)
Heating technologies diffusion - reference year	EuP preparatory studies, LOT 1
Heating technologies diffusion - forecast	ISIS – FhG/ISI assumptions

The most important sources of data used to set up the input variables are:

- *The Odyssee* database that provides detailed energy efficiency data and indicators for the EU-27 members and Norway as. Among others, the database provides important information on the construction of dwellings, single and multi-family dwellings (new and existing) and detailed information about the average square metres for new/existing single/multi-family dwellings. The data covers the years 1990 to 2006/7 (as of 2008).
- Statistical publications such as "Housing Statistics in the European Union 2004" from *Boverket and MMR*[38] (2005) give a detailed overview of the housing development and living conditions in the European Union. It is the 10th edition and, for the first time, it covers the EU-25. The database for the quality of the housing stock is of special interest. It concentrates on the average living area and the age of the EU-building stock as well as on the distribution of building types such as single and multi-family buildings. The last update of the Housing Statistics, by the *Italian Ministry of Infrastructure and Italian Housing Federation* (MIIR) has been used to refresh this data.
- The PRIMES model gives an overview of the projections of household numbers for each country of the European Union by 2030. Also, detailed values of the current and future energy use and CO_2 emission trends to 2030 are given.
- The study "Cost-effective Climate Protection in the EU-Building Stock" carried out by *ECOFYS* for *EURIMA*[39] (2005) analyses the energy saving potential of the building stock in the countries studied, and the energy saving potential that could be realised by further tightening the requirements of the *Energy Performance of Buildings Directive (EPBD)*. Additionally, the recent study *U-values – For better energy performance of buildings*, from November 2007, was used to refresh data.
- The EuP study on Central Heating Boilers, LOT 1 V.H Kemna and others.

3.3 Step 1: Mapping of the ECCP measure

3.3.1 Overview

Table 3-5 maps the different policies that may interact with the EPBD. As outlined in section 3.2, even if it is not possible to provide an ex-post impact analysis of the interaction of these measures with the EPBD, or to design a counterfactual scenario, it is conceivable to anticipate some possible interactions and synergies (see Table 3-6).

38 Boverkert - National Board of Housing, Building and Planning, Sweden; MMR - Ministry for Regional Development of the Czech Republic.
39 European Insulation Manufacturers Association (EURIMA).

Table 3-5: EPBD Measure interaction map

MEASURE	TARGET	GOAL FOR TOP-DOWN IMPACT
ECCP Directive on the Energy Performance of Buildings (EPBD) EuPs Standards (heating equipment) **Complementary national measures** Independent building regulation issuing at national level Support schemes for renovation works and heating equipment replacement White Certificates (heating equipment and insulation) Information and awareness campaigns	Final energy, GHG emissions Final energy, GHG emissions	20% improvement in energy efficiency 20% improvement in CO_2 emissions

Table 3-6: Interactions and synergies of the national policies with the EPBD

MEASURES	ASSUMPTION OF THE POSSIBLE INTERACTIONS

Independent and parallel building regulation (those issued in the years 2004 – 2007)	• These regulatory measures have been generally issued in the framework of the Building Directive and are, in some way, part of it.
	• Some regulations can go beyond the Directive purposes because of national policies and culture. For example the Dutch and French national targets are notably more ambitious than the simple targets achievable by the Directive:
	  o For the Netherlands, new houses target: 85 kWh/m^2 in 2006, 60 kWh/m^2 in 2011, 40 kWh/m^2 in 2015
	  o For France:
	    (1) In 2010, 50 kWh/m^2 per year for all public and tertiary buildings
	    (2) In 2012, 50 kWh/m^2 per year for all buildings (adjusted to the geography and latitude)
	    (3) In 2020, all new buildings should be passive buildings (<15 kWh/m^2 per year) or positive energy buildings.

Incentives and Subsidies	• Only applicable to existing buildings (except for incentives to new buildings to go beyond the prevailing thermal regulation) • In theory these measures should not interfere with existing buildings because they are only given beyond building regulation requirements. • The data available for existing buildings would generally not separate impacts of the incentives and of the EPBD. Issue of 'free riders', but difficult to identify.
White Certificates and EuP standards	• White Certificates: mechanisms in principle similar to subsidy schemes. Impact evaluation requires knowledge of technologies promoted (e.g. evaluation of the Energy Efficiency Commitment EEC in the UK) • The EuP standards should modify the heating equipment market independently from the Building Directive but, in the medium term, this should allow to better achieve the Minimum Performance Requirements

To complete the picture of the ECCP measures issued to improve the EE of the building sector an insight on the MS regulatory and facilitating measures in the building sector is provided in the following section.

3.3.2 MS regulatory and facilitating measures

The regulatory and facilitating measures issued by the MS to enhance the EE in the building sector cover a wide range of instruments varying from subsidies and incentives to EE standards:

- Energy efficiency standards and building codes are the most effective instruments to enhance the building energy performance. The compliance factors have to be monitored with care and their application to existing building is still difficult. This is mainly due to the investment barrier and other important obstacles like the conflict of interest between landlords and tenants (the latter should be increasingly tackled by the certification scheme foreseen in the EPBD).

- Direct subsidies for energy efficiency investments remain popular. They were often considered as costly and questionable, but are now better targeted. Subsidies are viewed as a temporary measure to mobilize consumers, to prepare for new regulations, or to promote energy efficient technologies by creating a larger market than would exist otherwise. The objective is ultimately a cost reduction for the subsidised energy efficient technologies.
- Fiscal incentives, such as tax credits, tax reductions and accelerated depreciation, are usually considered cheaper than direct subsidies, especially to households, as they have lower transaction costs. They can work well if the tax collection rate is sufficiently high: such measures usually perform poorly in an economy in recession or in transition.

Apart from the cost barrier, a further obstacle that hinders the penetration of the energy efficiency works in the buildings is the lack of information to consumers about what they can do. To address this issue, a large range of tools have been designed from a general information campaign, dwellings rating their energy performance, audits, local information centres and comparative information.

Annex A provides a rather deep insight of these instruments for some important MS. The wide range of facilitating measures that are enforced reflect the different challenges and difficulties faced by the Member States to foster the EE practices in existing buildings, as well as in implementing the EPBD Directive. These have justified rooting the Directive in the subsidiary principle.

3.4 Step 2: Compilation of quantitative evaluation evidence

As previously said there is still no evidence of the quantitative impact of the EPBD. This section therefore provides the past energy consumption trends of the building sector and the main relevant Odyssee energy efficiency indicators for buildings to analyse the impact of the regulatory and facilitating measures issued during the last decade. These measures have in some cases anticipated, or have been issued in parallel to, the Building Performance Directive. In general they have paved the way for its introduction, especially with respect to cultural and behavioural aspects.

3.4.1 Energy Use in Buildings

Figure 3-4 shows the total Energy consumption trend for space heating for some EU countries while

Figure 3-5 and Table 3-6 show the trend of the unitary energy consumption trends per m^2 [40]. All figures have been normalised with respect to annual climatic variations. The trend shown by these graphs suggests the following observations:

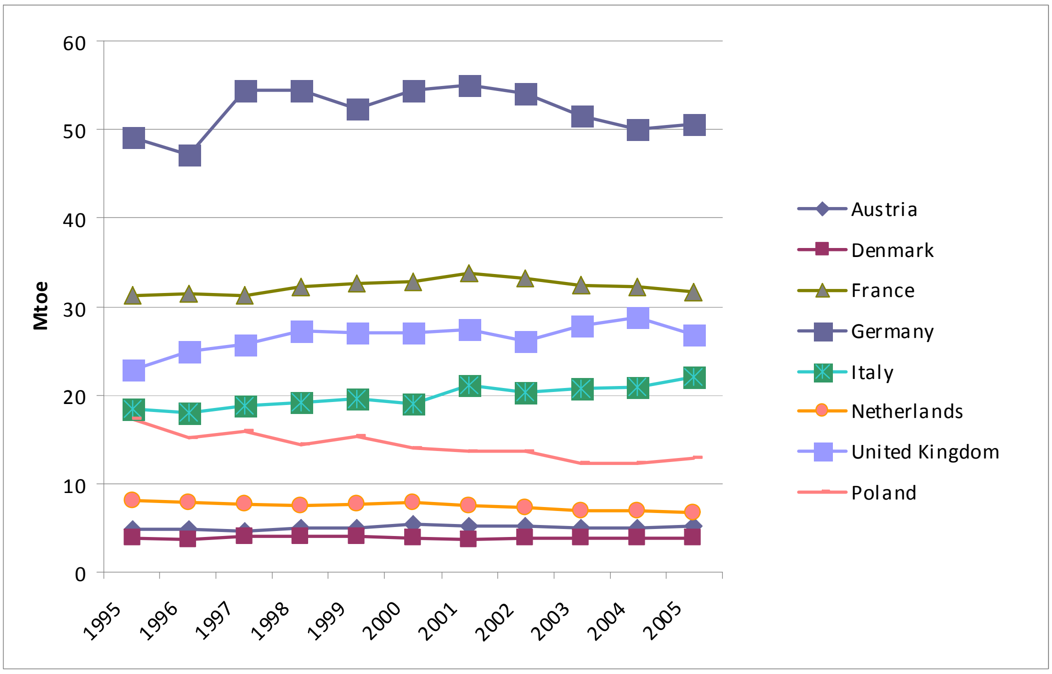
1. The energy savings provided by the set of measures put in place by the EU countries have barely counterbalanced the heating demand increase due to the growth of the number of households, the dwelling floor area and behaviour. The household energy consumption is predominantly driven by the growth in number of households, which in turn depends on population growth and the persons per household. The reduction in the average number of people per household is a main driver for energy consumption, as it increases the number of dwellings and appliances needed for the same population.
2. The building energy efficiency increment of the EU countries is rather differentiated. The overall EE increment for the EU 15 is around the 0.9% per year, in line with the expectation of the Energy Service Directive. Within this average, there are very efficient countries such as the Netherlands, fairly efficient countries like Ireland, Germany and France and inefficient countries such as Italy and Greece. The Eastern European countries have very different behaviour: in some countries there have been strong refurbishment programmes of the highly inefficient collective buildings of the 1950's and 1960's as in Poland, Slovenia and Romania (as well in the Czech Republic and in Hungary but the Odyssee database does still not have data for these latter countries). In other countries these refurbishment interventions have still to be enacted.

Apart from the Eastern EU countries, for which the EE increase is due to the vast state refurbishment programmes (but also to the abandoning of the old and inefficient district heating systems), for the majority of the EU15 countries, the EE increase is due to the penetration of the new buildings built in accordance with more stringent building codes and the heating equipment renewal. There is little evidence for the contribution to the EE increase of the existing buildings, with expert opinion being that it has been marginal so far.

The contribution of new buildings to the overall EE improvement of the EU15 countries can be roughly estimated. During the observed period (1997-2005) 17.640 new dwellings have been built corresponding to 11% of the total building stock in 2005 (source PRIMES). Assuming a demolition rate of 0.5% per year[41], and an average unit consumption for space heating in new buildings of 100 kWh/m^2 [42], on the basis of the data provided in the table below the new building stock provides 50% of the overall EE increment. The remaining 50% is thus provided by the replacement of new and more efficient heating equipment and the refurbishment of old buildings.

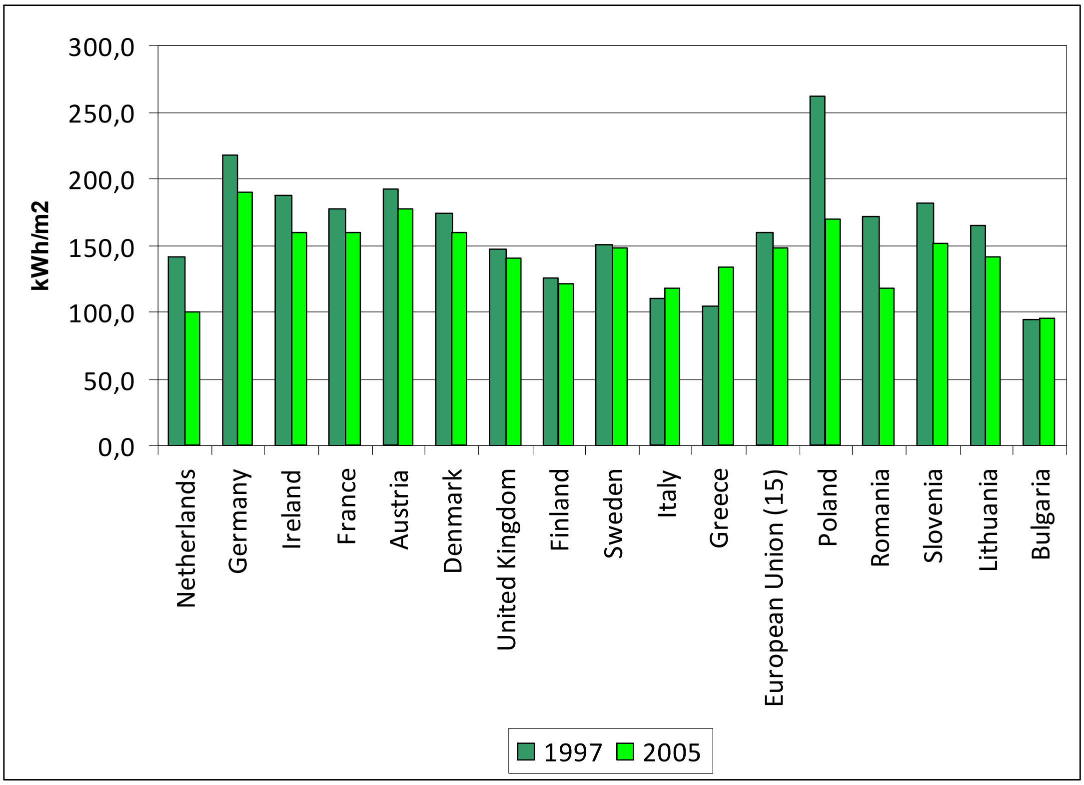
Figure **3**-**4** Energy consumption trend per dwelling for space heating with climatic correction

40 Data source of this paragraph: Odyssee database. Figure 3-5 starts at the year 1997 because this is the first year from which the unitary energy consumption per m^2 starts steadily declining for the majority of the EU countries.
41 Niklaus Kohler; Wei Yang, Long-term management of building stocks. University of Karlsruhe, Karlsruhe July 2007
42 Data taken from the ESD Potential Study (Fraunhofer-ISI, Wuppertal Institute, ISIS, ENERDATA 2008, to be published). The 100 kWh/m^2 figure takes into account a compliance factor of 70-50% according to the EU countries.



Source: Odyssee Database

Figure **3**-**5** Trends in space heating consumption per m2 with climatic correction



Source: Odyssee Database

The 50% improvement due to the enhanced of the energy efficiency conditions in the existing building stock corresponds to an increment of 5.4 kWh/m^2 in 8 years. This figure is rather disappointing when correlated to the huge EE potentials represented by this stock. Actually, the subsidy and incentive schemes enacted by several EU MS have not worked as expected or were not to the size.

It is nevertheless conceivable that the combined action of the facilitating measures and the building certification mechanisms envisaged in the EPBD would start to break down the numerous barriers that still impede the diffusion of the EE measures in the existing building stock. Also the incoming new EuP standards together with instruments like the White Certificates might be strong allies of the EPBD periodic inspections to the heating and cooling systems to achieve a substantial renewal of these devices.

Table 3-7: Trends in space heating consumption per m2 with climatic correction

Countries	kWh/m2		Annual Variation
	1997	2005	
Netherlands	141.5	100.2	-4.22%
Germany	217.8	189.4	-1.73%
Ireland	187.5	159.9	-1.97%
France	177.9	159.6	-1.35%
Austria	192.4	177.4	-1.01%
Denmark	174.4	159.5	-1.11%
United Kingdom	147.6	140.8	-0.59%
Finland	126.1	121.8	-0.43%
Sweden	151.1	148.1	-0.25%
Italy	110.4	118.4	0.88%
Greece	104.5	133.6	3.12%
EU 15	159.3	148.6	-0.87%
Poland	261.6	169.7	-5.27%
Romania	172.0	118.4	-4.56%
Slovenia	182.3	151.8	-2.26%
Lithuania	165.6	141.6	-1.94%
Bulgaria	94.3	95.9	0.22%

Source: Odyssee Database

3.4.2 The impact of the regulating and facilitating measures: two examples

Residential measures in the UK

Taking into account supplier obligations in the UK, the first phase of the Energy Efficiency Commitment (EEC1) took place between 2002 and 2005. The energy savings target was 62 TWh, equivalent to a 1% yearly reduction in CO_2 emissions from households. A second Energy Efficiency Commitment (EEC2) was then put in place from 2005 to 2008 which doubled the target (130 TWh) by including innovative measures. Today a Carbon Emissions Reduction Commitment (CERT) has started and will last up to 2011. This obligation focuses on a CO_2 reduction target, not an energy one. It has set an objective of 154 Mt CO_2 avoided, which is double that of the EEC2 target.

Another interesting measure is the so-called “Zero Carbon Homes” proposed by a government consultation which postulates that by 2016 all new homes built in England should be “zero carbon”, defined as:

- Over one year, net carbon emissions from all energy use in the home must be zero by:
    - Energy efficiency and renewables in individual homes or housing developments.
    - New planning framework including a Code for Sustainable Homes (star rating).

Initial estimates are that measures to bring zero carbon homes could deliver 1.1 – 1.2 Mt C per year by 2020, and by 2050 between 6.5 and 7 Mt C per year.

Table 3-8: Expected yearly energy and carbon savings from the UK Zero Carbon Homes measure

Policy	2010		2016		2020	
	TWh	MtC	TWh	MtC	TWh	MtC
Building a Greener Future – Towards zero carbon homes	0	0	4.2	0.2	22.6	1.2

Source: DCLG

Residential measures in France

In France the so-called "factor 4" official target of the Ministry of Sustainable Development introduced:

- The National Strategy for Sustainable Development (June 2003)
- The Climate Change Programme (July 2004)
- The Programme Law for Energy Policy Orientations ("POPE" July 2005).

The intention was to cut by a factor of 4 the total GHG emissions between 1990 and 2050. The objectives of the "Grenelle de l'Environnement" are to define this "factor 4" target and its implementation requirements, in order to rapidly commit France toward sustainable development.

Today the French building sector is characterised by a 40% share of final energy consumption and a 25% share in GHG emissions. Therefore the measure target for buildings is to reduce to 38% the energy consumption by 2020.

The program for new buildings is characterised by the following goals:

- In 2010: Very High Energy performance VHEP label (-20% compared with the 2005 regulation) and 50 kWh/m^2 yearly consumption for all public and tertiary buildings (low consumption building)
- In 2012: 50 kWh/m^2 yearly consumption for all buildings (adjusted to geography and latitude)
- In 2020: all new buildings should have passive house standard (<15 kWh/m^2 yearly consumption) or should be "positive energy houses".

For existing buildings, the measure is to launch an unprecedented thermal retrofitting programme consisting of:

- Energy improvement for every private housing property transfer and study for a retrofitting obligation (class B or C)
- Retrofitting of 400'000 housings per year
- Market exclusion of all obsolete components or technologies for electric appliances
- New public buildings conformed with the best energy efficiency standards
- Thermal retrofitting (-20%) of all state buildings (120 million of m^2)
- Launching of a large professional training plan (100,000 professionals trained in 10 years)
- Financial instruments (reduced rate loans, zero rate loans)
- Improvement of the Energy Performance Diagnostic (DPE)
- Reinforcement of the White Certificates (CEE) objective by between 2 and 10 times
- Renewable energies development (national plan of solar panels and 60,000 professionals trained in 10 years).

3.5 Step 3: Screening

The following remarks can be made with respect to the screening of the policies, to identify the more important policy drivers:

- ➢ The main national measures interacting with the EPBD directive are (and will be) the national support measures, which are mainly subsidies and incentives. In practice the building certificates and the

support measures are expected to mutually and beneficially interact but only future experience will show if this occurs.
- The national regulatory EE standards for new and existing buildings are a de facto part of the EPBD itself.
- White Certificate schemes are relevant so far only for the UK, France and Italy. The greatest level of impact was observed in the UK. The mechanism was, however, similar to a subsidy scheme, and hence has been included in the evaluation of national support schemes to the EPBD directive.

3.6 Step 4: Modelling step

3.6.1 Energy Savings

This section discusses the quantitative impacts calculated by using the MURE household model and applying the methodology described in section 3.2.1. **Figure 3-6** and **Figure** 3-7 illustrates the trends for the energy demand (useful energy) and the energy consumption for space heating (final energy) of residential buildings for the ten countries considered in this study. As outlined in section 3.2.1 the simulation takes into account the building codes compliance factors (CF). The dotted green lines in the graphs show what might be the energy consumption trend if the EPBD building standards are fully applied (that is, without applying the CFs).

Table 3-9 provides the total energy savings for households due to the foreseen impact of the Directive again including and excluding the CFs while Table 3-10 provides the same savings by country split by thermal and electricity end uses and taking into account the compliance factors.

The trend of energy demand for the non-residential buildings is shown in Figure 3-8, while Table 3-11 shows the achievable savings after the implementation of the EPBD in this specific market. These values also take into account the same compliance factors considered in the household sector. The total savings achievable by the non-residential buildings sector by 2020 reach 2,743 ktoe for the 10 countries investigated, which corresponds to 33% savings achievable in the household sector (8,320 ktoe, see **Figure** 3-10).

For residential buildings the overall results show that if one considers a large degree of non-compliance (40% of the EPBD target audience does not comply in the simulation), an energy saving impact of 9% compared to the counterfactual (i.e. without policy scenario) seems achievable by 2020. This corresponds to an annual rate of EE improvement of 0.6%. The impact may increase to 14% (more than 1% per year) if the envisaged building standards are rigorously applied by the Directive target audience. It is finally worth adding that these results reflect a rather conservative attitude in the settings of the main drivers for the impact evaluation of the EPBD: existing buildings are only refurbished when the building itself have to be renewed (even if the renewal interval is accelerated). The building codes are not extreme and it was not envisaged in the simulated evaluation strong actions to renew the heating device stock. The conservativeness if the approach is illustrated by the graph of Figure 3-9 which shows how the foreseen unitary energy consumption for space heating follows the past trend of the more conservative countries while, for the more efficient ones like the Netherlands or the UK, it would have been possible to be more daring with the simulation assumptions (but in this case it would be necessary to modify also the autonomous progress of these countries).

Finally **Figure** 3-10 shows the impact of the Directive in 2020 for residential buildings broken down by the type of intervention. For energy demand this takes into account the insulation measures (8,320 ktoe) and the final energy that includes the heating equipment improvement (18,934 ktoe). The savings attributable to new houses account for 22% of the energy demand and 18% for the final energy consumption.

Figure 3-6 EU 10 Countries – Useful energy trend with and without the compliance factor (CF) (residential sector)

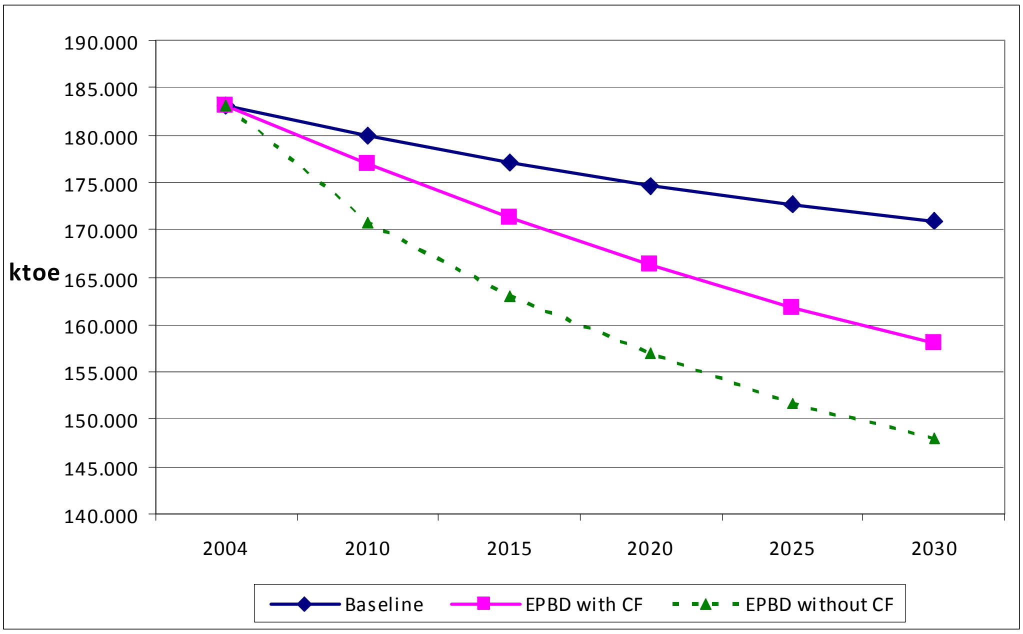


Figure **3**-**7** EU 10 Countries –Energy consumption trend for space heating with and without the compliance factor (residential buildings)

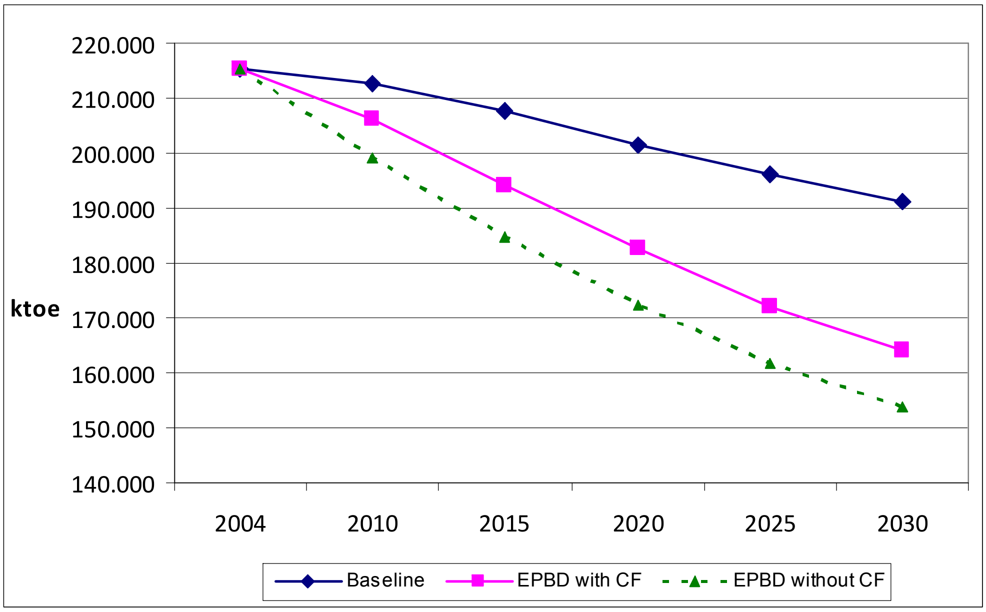


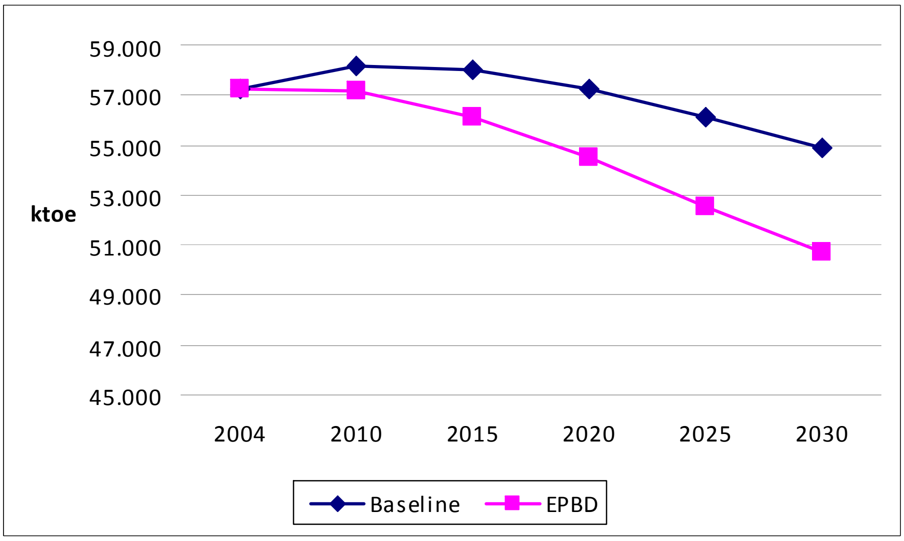
Table 3-9: EU 10 – Total Energy savings for space heating with and without the compliance factors (residential buildings)

		Total savings		
		2010	2015	2020
With Compliance Factors	ktoe	8,453	13,582	18,934
	%	3.9%	6.3%	9.1%
Without Compliance Factors	ktoe	15,409	22,796	29,155
	%	7.2%	10.6%	14.0%

Table 3-10: Energy savings for space heating by country (with the compliance factors) (residential sector)

ktoe	Savings from direct heating with fossil fuels			Savings from electric space heating			Total savings		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
AT	72	219	344	33	50	81	105	269	425
CZ	317	251	290	30	193	234	347	444	524
DE	2.451	3.920	5.498	723	969	1.302	3.173	4.889	6.800
DK	92	151	217	28	40	56	121	191	273
ES	542	798	995	135	189	253	677	987	1.247
FR	1.099	1.995	2.944	314	502	756	1.413	2.497	3.701
IT	780	1.235	1.634	181	270	388	961	1.505	2.022
NL	43	182	278	55	83	120	98	265	398
PL	572	931	1.322	74	113	165	646	1.044	1.487
UK	791	1.320	1.818	120	171	238	911	1.492	2.056
Total	6.760	11.002	15.340	1.693	2.581	3.594	8.453	13.582	18.934
Estimate Scaled to EU27[43]	8.381	13.641	19.019	2.099	3.200	4.456	10.481	16.840	23.475

Figure 3-8: EU 10 Countries – Non residential buildings, Useful energy trend (with the compliance factors)

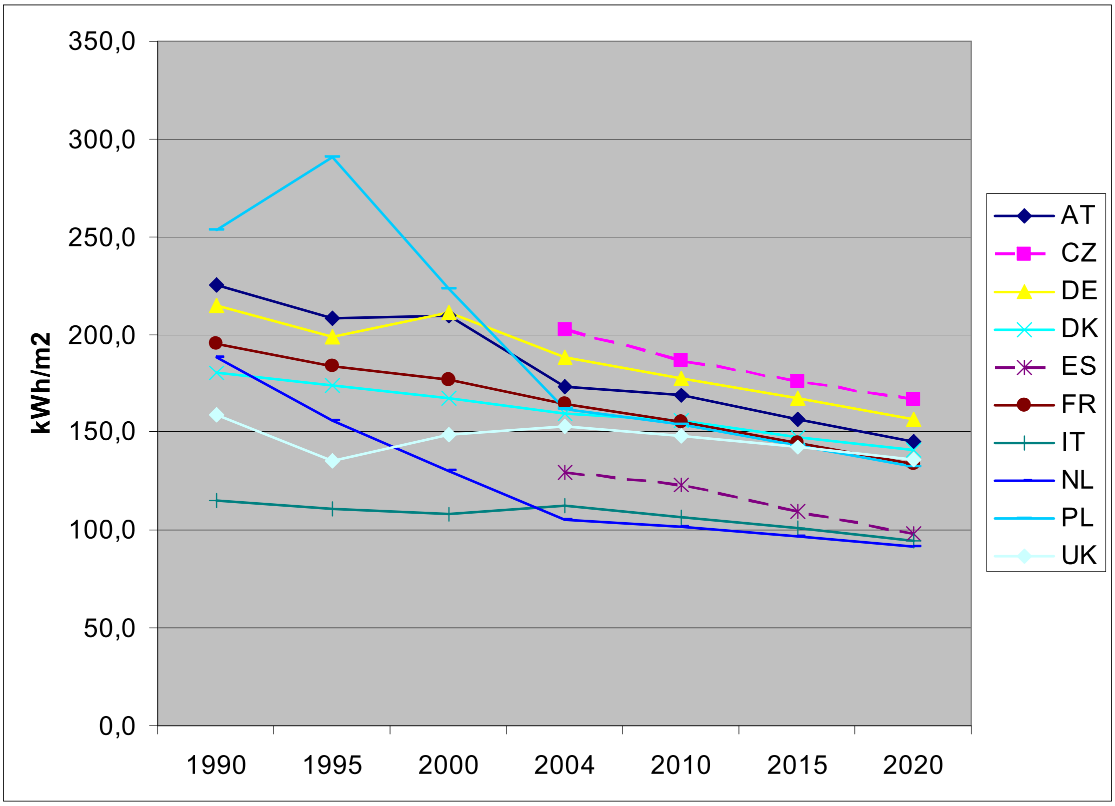


43 The scaling to EU 27 has been made with reference to the total household energy consumption.

Table 3-11: Non residential buildings, Useful energy savings by country (with the compliance factors)

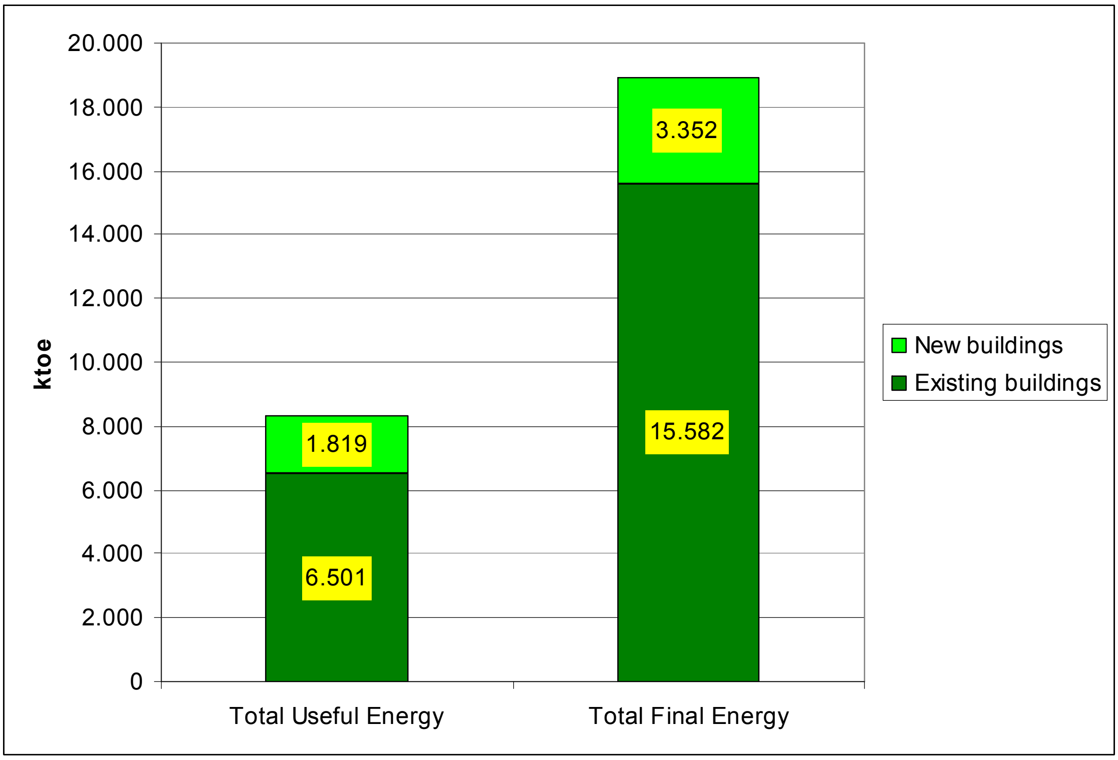
ktoe	Total savings		
	2010	**2015**	**2020**
AT	27.5	60.2	88.9
CZ	35.4	65.3	95.5
DE	227.8	475.7	694.0
DK	20.0	42.4	62.5
ES	112.7	193.5	271.9
FR	131.1	285.0	423.9
IT	173.8	275.2	370.5
NL	32.9	71.1	106.0
PL	103.9	192.8	287.1
UK	105.6	226.0	342.4
Total ktoe	970.8	1,887.3	2,742.7
Total %	1.7%	3.3%	4.8%
Estimate Scaled to EU27[44]	1,179.2	2,312.9	3,386.6

Figure 3-9 Unit consumption per m2 for space heating with climate correction (historical data and impact simulation) (residential sector)



44 The scaling to EU 27 has been made with reference to the total energy consumption of the non-residential buildings.

Figure **3**-**10** EU 10 – Energy savings due to the EPBD impact by type of intervention and building age (residential sector)



3.6.2 CO_2 Savings

The CO_2 emissions considered in this section refer to household space heating uses and have been calculated from energy savings according to the following procedure:

- The fuel, district heating and electricity coefficients have been averaged on the basis of the heating technology mixes by country (sources for the base year: EuP studies, Odyssee database).
- For electricity, as in the study on the appliances directive, we have assumed the average fossil fuel emission coefficient of the power sector of the selected countries (as a proxy for hourly simulations of the emission coefficient); see Table 3-12.
- For district heating we have assumed the fuel mix coefficients according to the data available in the MURE database.

Table **3**-**12**: Average emission coefficient of the power sector of selected EU countries (including all fossil plants) according to PRIMES

	AT	CZ	DE	DK	ES	FR	IT	NL	PL	RO	UK	EU-27	EU-15
t/MWh	0.84	1.29	0.96	0.90	0.71	0.70	0.64	0.66	1.22	1.27	0.71	0.86	0.79

By multiplying the total energy savings presented in the previous section with the emission coefficients calculated for each country in accordance with the method outlined above, the total emission reductions can be calculated. The results of this are shown in **Table** 3-14 for the residential sector and in

Table 3-15 for the non-residential buildings together with the emission coefficients used (Table 3-13) and the summary of the CO_2 savings scaled to the EU27.

Table 3-13: Average CO_2 emission coefficients per country (residential sector)

kt CO_2/ktoe	2004	2010	2015	2020	2025	2030
AT	1.94	1.92	1.89	1.83	1.76	1.70
CZ	2.52	2.34	2.32	2.30	2.25	2.21
DE	2.48	2.33	2.24	2.12	2.03	2.04
DK	1.52	1.46	1.47	1.46	1.47	1.45
ES	1.33	1.50	1.53	1.55	1.58	1.61
FR	1.61	1.72	1.77	1.87	1.98	1.83
IT	2.16	2.12	2.11	2.09	2.04	1.99
NL	2.37	2.34	2.34	2.32	2.31	2.27
PL	2.07	1.98	2.00	2.03	2.00	2.10
UK	2.35	2.34	2.38	2.38	2.39	2.36

Table 3-**14**: (Direct and indirect) CO2 savings from space heating in the residential sector by country with/without compliance factors CF

kt CO_2	**CO_2 emissions with CF (partial compliance with regulation)**				**CO_2 emissions without CF (full compliance with regulation)**			
	2004	**2010**	**2015**	**2020**	**2004**	**2010**	**2015**	**2020**
AT	0	202	508	780	0	608	1,001	1,293
CZ	0	813	1,032	1,207	0	1,445	1,994	2,374
DE	0	7,404	10,953	14,420	0	11,815	16,259	19,813
DK	0	175	282	398	0	329	479	612
ES	0	1,012	1,508	1,933	0	1,684	2,397	2,875
FR	0	2,430	4,427	6,918	0	4,587	7,165	9,963
IT	0	2,035	3,177	4,227	0	4,178	6,363	7,965
NL	0	229	619	925	0	657	1,152	1,496
PL	0	1,280	2,085	3,018	0	2,782	4,366	5,776
UK	0	2,132	3,554	4,897	0	4,053	6,009	7,553
Total	0	17,714	28,145	38,722	0	32,139	47,185	59,719
Scaled to EU 27	0	21,963	34,896	48,011	0	39,848	58,503	74,044

Table 3-15: (Direct) CO_2 savings from the non residential sector by country (with the CFs)

kt CO_2	**CO_2 emissions with CF**			
	2004	**2010**	**2015**	**2020**
AT	0	53	116	168
CZ	0	89	153	222
DE	0	565	1,110	1,555
DK	0	30	62	92
ES	0	150	289	415
FR	0	211	490	752
IT	0	375	583	782
NL	0	78	166	248
PL	0	215	382	573
UK	0	248	529	816
Total	0	2,016	3,879	5,623
Scaled to EU 27	0	2,448	4,754	6,943

3.7 Step 5: Impact delimitation

The impact delimitation in Step 5 is supposed to correct for, among others, the treatment of:

- independent national measures aiming at the same target;
- autonomous progress;
- the impact of energy price variations

The issue of autonomous progress has been discussed in the introduction, and the methodology set at a building efficiency frozen at the base year. The efficiency of heating equipment is, on the contrary, not fixed at the reference year because its improvement will depend mainly on the incoming new EuP eco-design standards. A variant of this approach would be to determine the autonomous progress from the development of the building sector consumption per m^2 before the entrance of the directive (see step 2). A risk with this procedure is the overlap of the Directive with the application of the national building codes that many countries have issued in parallel or in conjunction with the Directive itself.

The impact of the Directive would then be defined in terms of the 'rate of acceleration' in the existing building stock's energy efficiency (this rate should be frozen in the autonomous progress scenario) and the renewal of the heating equipment.

To take into account the issues above, the following points must be considered with care, to try to understand the impact of the Directive with respect to the other measures:

- If the building certificates alone are enough to convince the EPBD target audience of the need to improve the EE of the existing building stock, i.e. in the absence of incentives and subsidies;
- If, in the presence of the building certificates, it is still possible to speak of the 'free riders' effect.
- If, or to what extent, the White Certificate mechanism will interfere (in positive terms) with the heating and cooling system controls and a buildings energy performance itself.

Energy price increase has been limited over the past 10 years, with the exception of the last two years. Moreover, there is not a clear correlation between building energy consumption and a Member State's purchasing power (contrary to what happened in the case of the electric appliances, see the report on the Labelling Directives for Large Appliances) due to the obvious influence of the climate on this type of consumption. However the energy prices for heating have been increasing due to increased fuel input prices. Once the present economic instability is over, energy prices are expected to follow their established trend of showing a steady increase. This will likely favour the adoption of EE investments and practices, but the balance between the energy price and the disposable family income is also an issue. Mechanisms like the White Certificates and Third Party Financing could help to achieve the EPBD targets.

3.8 Results – Tier 1, Tier 2, Tier 3 approach

Results for case study Member States

Table 3-16 illustrates the CO_2 emission[45] savings for Tier 1 and 2 for the selected MS and the EU15/EU27 respectively (period 2002-2006). The table documents also Tier 3 results (2004-2020). Overall results differ quite substantially for all three methods. Results from Tier 1/2 methodologies indicate annual average savings in the range of 16-31 Mt CO_2 for 2002-2006 in the residential sector with the higher results for the Tier 2 methodology. The Tier 3 results are not directly comparable with Tier 1/2 results because this methodology is looking at a different time period and into the future. With full compliance with the regulation, the residential sector savings may reach 74 Mt CO_2 by 2020.

45 Other GHG have been neglected in this analysis but may be considered in future evaluations. However, their contribution is small.

Table 3-16 (Direct and indirect) CO2 Savings for the EPBD in Tier 1/2 methodologies for the residential and the Commercial/Institutional sectors (2002-2006) and in Tier 3 methodologies (2004-2020)

Tier 1 Analysis (Based on average member state fuel mix; EU emission factors)

	Savings per year MtCO2					Cumu-	Average
Residential Sector	**2002**	**2003**	**2004**	**2005**	**2006**	**lative**	**annual**
EU-27	3,9	14,0	20,4	21,9	17,4	77,6	15,5
EU-15	-0,4	2,0	8,6	9,2	9,3	28,8	5,8
Service Sector							
EU-27	2,7	-3,0	-0,7	2,8	4,4	6,2	1,2
EU-15	2,2	-4,0	1,2	1,8	3,5	4,7	0,9

Tier 2 Analysis (Based on average member state fuel mix; MS emission factors)

	Savings per year MtCO2					Cumu-	Average
Residential Sector	**2002**	**2003**	**2004**	**2005**	**2006**	**lative**	**annual**
EU-27	11,3	31,6	37,6	40,3	35,8	156,5	31,3
EU-15	4,3	16,9	22,0	25,3	19,2	87,8	17,6
Service Sector							
EU-27	-	-	-	-	-	0,0	-
EU-15	0,2	-10,2	-7,5	-12,6	-13,6	-43,6	-8,7

Tier 3 Analysis (Based on detailed simulation of building stocks)

	Savings per year MtCO2							
Mt CO2	**CO2 emissions with Compliance Factors (partial compliance with regulation)**				**CO2 emissions without Compliance Factors (full compliance with regulation)**			
Residential Sector	**2004**	**2010**	**2015**	**2020**	**2004**	**2010**	**2015**	**2020**
Total 10 countries investigated	0,0	17,7	28,1	38,7	0,0	32,1	47,2	59,7
EU-27	0,0	22,0	34,9	48,0	0,0	39,8	58,5	74,0
Service Sector	**2004**	**2010**	**2015**	**2020**	**2004**	**2010**	**2015**	**2020**
Total 10 countries investigated *	0,0	2,0	3,9	5,6	-	-	-	-
EU-27 (useful energy only)*	0,0	2,4	4,8	6,9	-	-	-	-
EU-27 (esimate with heating systems included)*	0,0	7,3	11,6	16,0	0,0	13,3	19,5	24,7

* only from savings on the building envelope (useful energy). Data on heating systems are not included due to data gaps. In useful energy terms service sector savings present 33% of residential savings on useful energy. Hence they may also present 33% of the residential sector emissions including savings on the heating systems if one assumes similar heating efficiencies for the service sector.

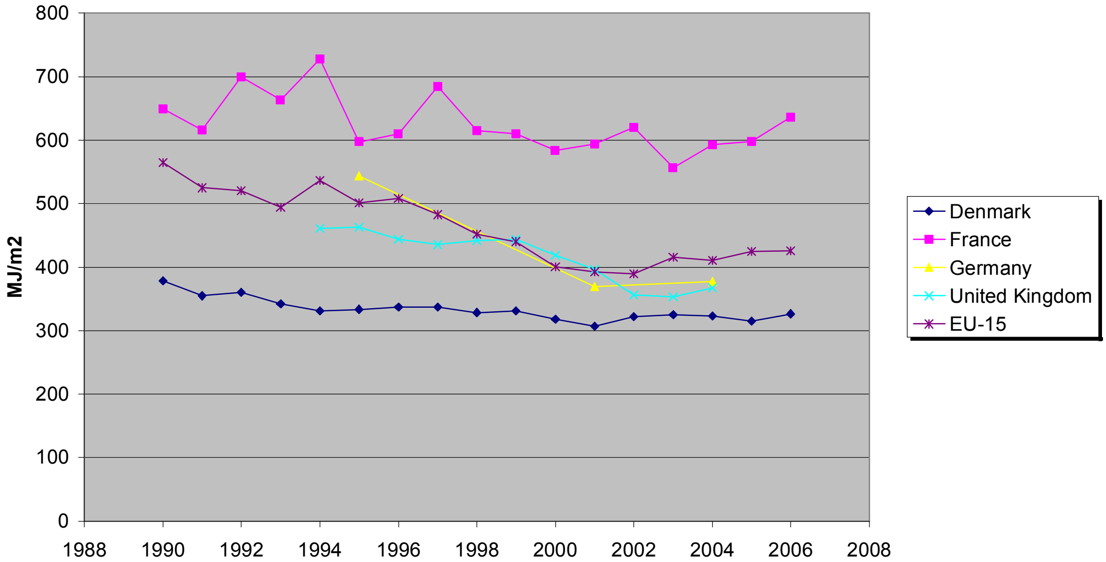
Note: Negative values represent in theory "dis-savings". In practice they imply structural changes which are not separated. In the Tier 1 methodology this is for example the increase in the size of residential buildings.

The results for the service sector are not very significant given the size of the savings obtained, roughly 1 Mt CO_2 at EU27-level in Tier 1 methodology, see

Table **3-16**. The relatively poor quality for this sector and the fact that the aggregate data used did not allow the separation of some structural changes occurring in the sector. It is for this reason that the results obtained with the Tier 2 methodology do not indicate any savings at all. It is difficult to explain, for example surfaces are saturating in the EU15 in the Commercial/Institutional sector, while energy use for space heating is still increasing. This leads to a specific energy consumption per m^2 which is increasing (Figure 3-11). The spaces needing to be heated / cooled, used in this approach are much more uncertain than employees. The space heating categories in this sector are poorly understood in many countries, based on samples and estimates.

In the Tier 3 approach, due to a lack of information on heating systems in the Commercial/Institutional sector, only energy demand savings could be calculated. The total savings on energy demand achievable by the non-residential buildings sector in the 10 countries investigated could reach 2,743 ktoe by 2020 (assuming partial compliance with the building regulation) compared to a 33% energy demand reduction achievable in the household sector (8,320 ktoe). Thus, if savings for heating systems are similar to residential boilers, CO_2 savings in the service sector in 2020 may be around 25 Mt CO_2 at the EU27-level, assuming full compliance with the regulation.

Figure 3-11: Space heating consumption Commercial/Institutional sector (climate corrected)



Source: Odyssee Database 2008

Differences between Tier 1, 2 and 3 results are explained by:

- Assumptions on the start of the EPBD: Tier 1 and Tier 2 methodologies assume that the EPBD already had an influence at a national level from its enforcement at EU level in 2002, despite the fact that even today formally in many countries part of the EPBD is still in the phase of being transposed into national law. Tier 3 does not make this assumption and introduces the regulations when they became valid or can be expected to be valid in the future, i.e. after 2006 as the earliest year.
- Structural factors: The Tier 1 methodology does not allow for the trend towards larger heated spaces in residential buildings. It delivers smaller savings because technical savings are compensated for by increasing heating and cooling demands.
- The treatment of autonomous progress and pre-EPBD policies: The Tier 3 methodology models explicitly the penetration of pre-EPBD thermal regulations, while Tier 1 and 2 methodologies handle this in a progress factor derived from the period 1990-2002. However, the current impact of high energy prices on changes in autonomous insulation measures has not been included but must be considered in a high-price environment as has been experienced over the last two years.

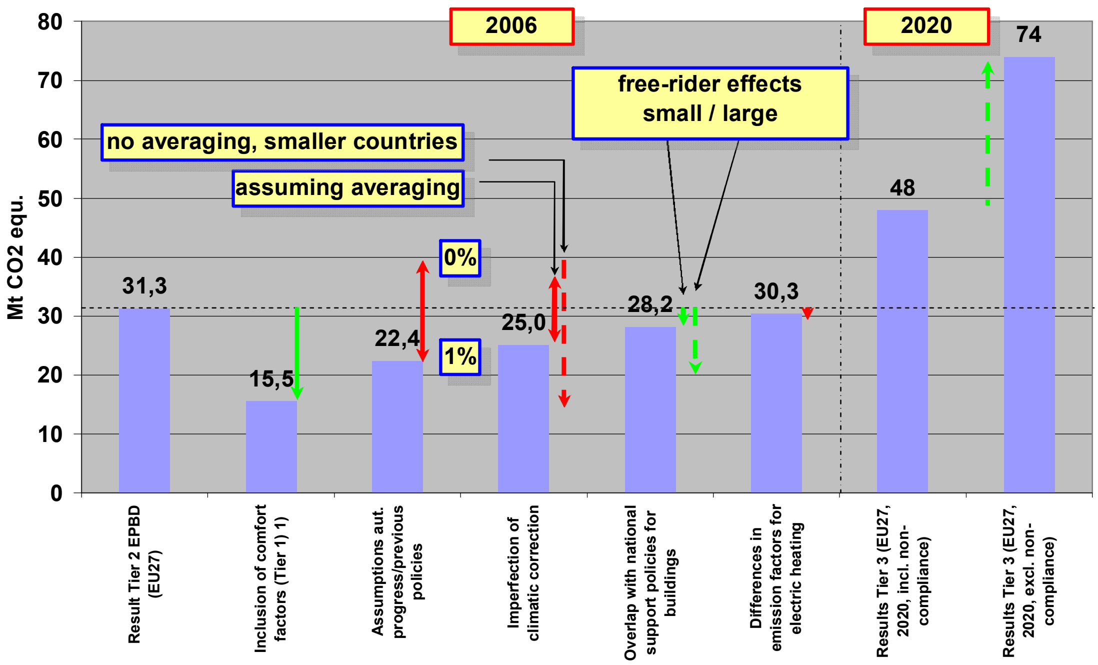
Corrections of climatic variations: in principle this is a well-established method, however in practice it has its has its limitations. In Tier 1 and 2 methodologies, the savings are established as a relatively small difference difference between the counterfactual and the policy scenario, especially in the earlier years when the the penetration of the EPBD is still small. Imperfect corrections of climatic variations may induce quite large large fluctuations in the savings, which may be reduced by taking averages over several years. In

- **Table 3-16** the averages have been calculated over several years. Climatic variations occur due to behaviour change: when a year is colder people tend to be more careful to avoid drafts, while if a winter is warmer, windows and doors are opened more frequently and with less care. In addition rooms may be overheated, demonstrated by the fact that energy consumption for space heating does not correlate fully linearly with temperature changes.
- Differences in the emission factors used: EU-wide versus national emission factors (mainly an issue for electric heating and district heating). See the debate on this issue in the section on appliance labelling.
- The treatment of overlapping EU policies and national promotion policies for the thermal improvement of buildings: in Tier 1 and 2 methodologies national measures cannot be separated from the impacts of the EPBD. Tier 3 methodology allows two effects to be modelled separately (such as the impact of the Energy-using-Product EuP Directive, another ECCP policy, on heating and cooling appliances). National subsidy schemes for insulation installation into existing buildings or for new low-energy buildings/passive houses do not in principle overlap if the subsidy goes only to insulation exceeding the regulation. In practice, however, there will be an overlap and 'free-rider' effects need to be determined separately.

3.9 Sensitivity analysis

In Figure 3-12 the results of a sensitivity analysis are shown. This tests the impact of using specific methodological assumptions, and the influence of data uncertainties, upon the overall results. The solid arrows show the influence of the specific factors, as calculated within this study. The dashed arrows are used to highlight the significant uncertainty in the factors themselves, and the potential range in the results that can arise from alternative assumptions.

Figure 3-12 Sensitivity analysis of the impacts of the EPBD



Note: Variations due to methodological choices are in red. Variations due to data issues are in green in the figure.e.g. increase m^2/dwelling included

It can be seen that a variety of factors may have substantial impacts mainly linked to data uncertainties. In particular these are:

- Inclusion of comfort factors such as increased square metres per building (Tier 1 approach), compared to Tier 2 and 3 approaches which make the comfort increase explicit and do not include the factors in the impact estimate.
- Overlap with national support policies for buildings: small in case free-rider effects can be well controlled
- Non-compliance issues are included automatically in Tier 1 and 2 approaches while non-compliance with building regulation is made explicit in the Tier 3 approach.

Other factors are linked to methodological choices. In particular these are:

- Assumptions on autonomous progress/previous policies: In the Tier 3 approach autonomous progress/previous policies are modelled explicitly by considering the penetration of buildings conforming to previous building regulations. For Tier 1 or 2 approaches this is included by assuming a progress factor. For the residential sector, the value of 0.5% annual improvement was chosen as it correlates with the period 1990-2002.
- Assumptions on the start of the policy impacts: Tier 1 and 2 approaches assume immediate commencement of improvements in 2002, the year when the EPBD was accepted. (There are some arguments in favour of this: the EPBD is an important EU policy and had some effects on national legislation before it was translated by all MS into national regulation). The Tier 3 approach takes into account the implementation delays and thus models the EPBD impacts only in the period 2004-2020, assuming that the main impacts of the EPBD are still in the future.
- Imperfection of climatic correction: In the Tier 1 and 2 approach, given that this is a statistical approach that does not contain averaging over several years, in smaller countries and in the early stages of implementation, when savings are still small, the fluctuations in the impact results may reach significant levels.
- Differences in emission factors for electric heating: This is only important for countries with a high proportion of electric space heating or a high proportion of district heating

3.10 Synthesis and interpretation of results

3.10.1 Comparison of results from the different methods

The three different methods of Tier 1, Tier 2, Tier 3 provide results which are diverging for the reasons mentioned above. Tier 1 and 2 diverge for the residential sector due to Tier 2 disaggregating comfort factors such as the increase in m^2 per dwelling. For the Commercial/Institutional sector the savings calculated are not significant. The Tier 3 methodology is based on the detailed modelling of the building stock used as inputs for the MURE simulation model, investigated in the form of a simulation for an ex-post impact evaluation in the period 2004-2020. This method is more precise and less subject to annual fluctuations. The Tier 1 or 2 approaches suffer from imperfect climatic corrections, which are amplified by considering the difference between the counterfactual and the actual development.

Using the Tier 3 methodology and the MURE simulation model gives a good evaluation scheme, at least for the residential sector. The main weak point of the assessment is insufficient data on the compliance levels with building regulations. In order to improve the quality of the evaluation in the future such information must be provided by sampling. For the Commercial/Institutional sector, there is still a lack of basic data, especially on heated spaces and the types of heating systems if a reliable Tier 3 evaluation is to be carried out.

3.10.2 Comparison of impacts across Member States

The impact of the Labelling Directive across Member States differs significantly in the different methods adopted (Table 3-18 to Table 3-20). Generally, in Tier 1 and 2 methodologies the impact of imperfect correction for climatic variations becomes larger, the smaller the geographic region, given the slow path with which more efficient buildings are penetrating to building stock. Averaging the results over several years in order to smooth out the fluctuations becomes more important. Only after 10-15 years, when the cumulated impacts are larger will Tier 1 and 2 methodologies will be less influenced by such fluctuations.

Table 3-17 CO_2 Savings in Tier 1 methodologies for the EPBD (2002-2006)

Tier 1 Analysis (Based on average member state fuel mix; EU emission factors)

	Savings per year MtCO2					Cumu-	Average
Residential Sector	**2002**	**2003**	**2004**	**2005**	**2006**	**lative**	**annual**
EU-27	3,9	14,0	20,4	21,9	17,4	77,6	15,5
EU-15	-0,4	2,0	8,6	9,2	9,3	28,8	5,8
Austria	-0,18	-0,40	0,59	0,32	0,53	0,9	0,2
Czech Republic	0,61	0,59	0,73	1,75	-0,37	3,3	0,7
Denmark	-0,05	0,11	0,24	0,35	0,43	1,1	0,2
France	-2,66	-0,32	0,28	2,54	0,50	0,3	0,1
Germany	-0,54	3,49	9,11	7,36	0,26	19,7	3,9
Italy	1,45	5,48	3,73	6,87	8,15	25,7	5,1
Netherlands	0,35	0,70	1,13	1,24	1,16	4,6	0,9
Poland	1,24	3,87	3,78	1,35	-1,49	8,8	1,8
Romania	-0,60	-0,77	-1,03	-0,92	-0,96	-4,3	-0,9
Spain	-0,44	-0,72	-0,50	-0,80	-1,13	-3,6	-0,7
UK	-0,48	-1,10	-1,83	1,17	2,85	0,6	0,1
Service Sector							
EU-27	2,7	-3,0	-0,7	2,8	4,4	6,2	1,2
EU-15	2,2	-4,0	1,2	1,8	3,5	4,7	0,9
Austria	-0,30	-0,85	0,42	0,67	0,55	0,49	0,03
Czech Republic	-0,01	-0,68	-0,81	0,02	0,56	-0,92	-0,05
Denmark	-0,02	-0,07	-0,07	-0,05	-0,07	-0,29	-0,02
France	0,88	-1,65	-0,35	-0,35	0,49	-0,98	-0,06
Germany	1,61	0,62	1,68	2,96	1,79	8,66	0,51
Italy	0,56	-1,23	0,25	-1,12	-2,88	-4,41	-0,26
Netherlands	-0,35	-0,68	-0,25	0,89	-0,33	-0,71	-0,04
Poland	-1,80	-2,36	-2,07	-1,44	-1,19	-8,86	-0,52
Romania	0,46	0,13	-0,45	-0,40	-1,22	-1,47	-0,09
Spain	-0,08	0,94	1,24	0,94	1,91	4,95	0,29
UK	0,64	1,23	0,43	1,08	1,46	4,84	0,28

Note: Negative values represent in theory “dis-savings”. In practice they imply structural changes which are not separated. In the Tier 1 methodology this is for example the increase in the size of residential buildings.

Table 3-18 CO_2 Savings in Tier 2 methodologies for the EPBD (2002-2006)

Tier 2 Analysis (Based on average member state fuel mix; MS emission factors)

	Savings per year MtCO2					Cumu-	Average
Residential Sector	**2002**	**2003**	**2004**	**2005**	**2006**	**lative**	**annual**
EU-27	11,3	31,6	37,6	40,3	35,8	156,5	31,3
EU-15	4,3	16,9	22,0	25,3	19,2	87,8	17,6
Austria	0,18	0,59	1,76	1,57	1,88	6,0	1,2
Czech Republic	1,14	2,13	3,12	4,41	3,12	13,9	2,8
Denmark	-0,29	0,07	0,29	0,59	0,61	1,3	0,3
France	0,96	3,66	4,77	6,23	8,76	24,4	4,9
Germany	0,63	11,18	17,08	15,76	8,54	53,2	10,6
Italy	0,93	1,26	2,18	-0,38	-1,79	2,2	0,4
Netherlands	0,34	1,19	1,41	1,78	2,06	6,8	1,4
Poland	7,07	12,36	12,75	9,70	5,81	47,7	9,5
Romania	0,41	1,12	1,89	2,27	2,28	8,0	1,6
Spain	-	-	-	-	-	0,0	-
UK	5,14	3,25	1,05	7,25	11,17	27,9	5,6
Service Sector							
EU-27	-	-	-	-	-	0,0	-
EU-15	0,2	-10,2	-7,5	-12,6	-13,6	-43,6	-8,7
Austria	-	-	-	-	-	0,0	-
Czech Republic	-	-	-	-	-	0,0	-
Denmark	-0,10	-0,10	-0,09	-0,01	-0,10	-0,4	-0,1
France	-1,32	2,24	0,94	0,46	-1,40	0,9	0,2
Germany	-	-	-0,23	-	-	-0,2	-0,2
Italy	-	-	-	-	-	0,0	-
Netherlands	-	-	-	-	-	0,0	-
Poland	-	-	-	-	-	0,0	-
Romania	-	-	-	-	-	0,0	-
Spain	-	-	-	-	-	0,0	-
UK	2,37	2,48	1,76	-	-	6,6	2,2

Note: Negative values represent in theory "dis-savings". In practice they imply structural changes which are not separated. In the Tier 2 methodology this is for example the increase in internal room temperature and the length of the heating period due to comfort increase.

Table **3**-**19** (Direct and indirect) CO2 Savings in Tier 3 methodologies for the EPBD (2004-2020; only residential sector)

Tier 3 Analysis (Based on detailed simulation of building stocks)								
Savings per year MtCO2								
Mt CO2	CO2 emissions with Compliance Factors (partial compliance with regulation)				CO2 emissions without Compliance Factors (full compliance with regulation)			
Residential Sector	**2004**	**2010**	**2015**	**2020**	**2004**	**2010**	**2015**	**2020**
AT	0,0	0,2	0,5	0,8	0,0	0,6	1,0	1,3
CZ	0,0	0,8	1,0	1,2	0,0	1,4	2,0	2,4
DE	0,0	7,4	11,0	14,4	0,0	11,8	16,3	19,8
DK	0,0	0,2	0,3	0,4	0,0	0,3	0,5	0,6
ES	0,0	1,0	1,5	1,9	0,0	1,7	2,4	2,9
FR	0,0	2,4	4,4	6,9	0,0	4,6	7,2	10,0
IT	0,0	2,0	3,2	4,2	0,0	4,2	6,4	8,0
NL	0,0	0,2	0,6	0,9	0,0	0,7	1,2	1,5
PL	0,0	1,3	2,1	3,0	0,0	2,8	4,4	5,8
UK	0,0	2,1	3,6	4,9	0,0	4,1	6,0	7,6
Total 10 countries investigated	0,0	17,7	28,1	38,7	0,0	32,1	47,2	59,7
EU-27	0,0	22,0	34,9	48,0	0,0	39,8	58,5	74,0
Service Sector	**2004**	**2010**	**2015**	**2020**	**2004**	**2010**	**2015**	**2020**
AT	0,0	0,1	0,1	0,2	-	-	-	-
CZ	0,0	0,1	0,2	0,2	-	-	-	-
DE	0,0	0,6	1,1	1,6	-	-	-	-
DK	0,0	0,0	0,1	0,1	-	-	-	-
ES	0,0	0,2	0,3	0,4	-	-	-	-
FR	0,0	0,2	0,5	0,8	-	-	-	-
IT	0,0	0,4	0,6	0,8	-	-	-	-
NL	0,0	0,1	0,2	0,2	-	-	-	-
PL	0,0	0,2	0,4	0,6	-	-	-	-
UK	0,0	0,2	0,5	0,8	-	-	-	-
Total 10 countries investigated *	0,0	2,0	3,9	5,6	-	-	-	-
EU-27 (useful energy only)*	0,0	2,4	4,8	6,9	-	-	-	-
EU-27 (esimate with heating systems included)*	0,0	7,3	11,6	16,0	0,0	13,3	19,5	24,7

* only from savings on the building envelope (useful energy). Data on heating systems are not included due to data gaps.
In useful energy terms service sector savings present 33% of residential savings on useful energy. Hence they may also present 33% of the residential sector emissions including savings on the heating systems if one assumes similar heating efficiencies for the service sector.

3.11 Conclusions

The different tiered methodologies discussed in this chapter deliver results for the sum of the residential and service sector in the EU27 which differ substantially among each other. These differences are explained by methodological differences and data issues:

- Assumptions on the start of the policy impacts: Tier 1 and 2 approaches assume an immediate start of the impacts in 2002, the year when the EPBD was accepted. (There are some arguments in support of this: the EPBD is an important EU policy and had some effect on national legislation before it was translated into all MS to national regulation). The Tier 3 approach takes into account the implementation delays and thus models the EPBD impacts only in the period 2004-2020, assuming that the main impacts of the EPBD are still in the future.
- Inclusion of comfort factors: Factors such as increased square metres per building (Tier 1 approach), compared to Tier 2 and 3 approaches which make the comfort increase explicit and do not include them into the impact estimate.
- Overlap with national support policies for buildings
- Non-compliance issues: These are included automatically in Tier 1 and 2 approaches while non-compliance with building regulation is made explicit in the Tier 3 approach.

- Assumptions on autonomous progress/previous policies: In the Tier 3 approach autonomous progress/previous policies are modelled explicitly by considering the penetration of buildings complying with the previous building regulation. For Tier 1 or 2 approaches this is included by assuming a progress factor. For the residential sector an annual improvement of 0.5% was chosen for the period 1990-2002.
- Imperfection of climatic correction: Tier 1 and 2 use a statistical approach that doesn't use averaging over several years. Therefore for smaller countries and in early stages of implementation when savings are still small, the fluctuations in the impact results may be considerable.
- Differences in emission factors for electric heating: This factor is only important for countries with a high proportion of electric space heating or a high proportion of district heating.

The size of the possible CO_2 savings indicates that by 2020 the EPBD could be one of the largest impacts to ECCP policies if its implementation is enforced.

3.12 Recommendations

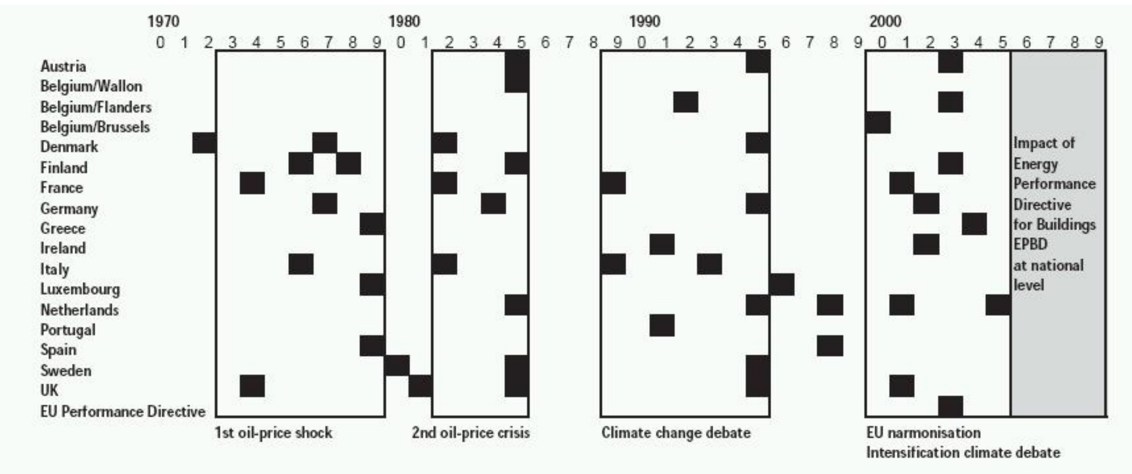
The evaluation has shown three important points for further evaluations:

1 Decisions have to be made as to whether **comfort increasing factors** such as m^2 per dwelling are to be included in the impact evaluation result (as in Tier 1) or excluded from the results (as in Tier 2 or 3). We believe that it is more appropriate to exclude them from the result but to explain them separately. However, a variety of comfort factors such as increasing internal room temperatures are difficult to separate, due to a lack of appropriate data.

2 **The supposed start of the impacts due to the EPBD** has a large influence on the final results. Tier 1 and 2 approaches suppose an immediate impact even if the regulation is formally delayed, as in many MS. Tier 3 assumes that the observed delays are important for the final impacts. Both approaches have arguments in their favour (see Figure 3-13).

3 **Non compliance** is a critical factor for the results and consideration of how knowledge and information on this factor can be improved, and how non-compliance in many MS (evident from the scarce data available) can be reduced through further tightening of the EPBD.

Figure 3-13: What drives the tightening of building regulations?



Note: Each black square represents a national building regulation
Source: ADEME (2005), MURE Database (www.mure2.com)

3.13 Next steps

The next steps to carry out, to improve the evaluation methodologies for the EPBD are:

- The **data available for the evaluation of the Directive** in the service sector is poor in many of the EU27 countries. Approaches to improve this situation exist, mainly in the form of suitable surveys of buildings in this sector. In Germany for example, such an approach is followed every 3 years in combination with private market research institutes like GfK. The lack of data especially hampers the more detailed Tier 3 approach.

- **Non-compliance with building regulations** has a large impact on the evaluation results but is largely unknown for both the residential and the service sector. This issue deserves to be investigated more carefully in field studies to improve knowledge.
- The issue of **data averaging for the Tier 1 and 2 approaches**, which is necessary due to imperfect corrections for climatic variations, must be further investigated.

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Annex A: Examples of EPBD facilitating measures[46]

COUNTRY	TITLE	DATE EFFECTIVE	DESCRIPTION
AUSTRIA	Federal Promotion of Extraordinary Efficiency in Buildings	26 January 2006	In January 2006, Austria's federal and state governments announced a program to reduce the climate impacts of housing. Under the deal, residential buildings must clearly exceed regulatory standards to qualify for state funding. The agreement includes an initial insulation standard of 65kWh per square meter, falling to 25-45 kWh/m2 by 2010. It also introduces new incentives for use of renewable heating systems. Total funding available is to remain at 1.78 billion. The program is expected to generate 10,000 additional jobs.
	Quick-Check Online Household Energy Efficiency Calculator	23 February 2006	In February 2006, the Austrian Energy Agency launched Quick-Check, an online energy efficiency calculator for household products.
AUSTRIA	Energy Efficient Housing Programs - Constitutional Treaty Between Austrian Federation and Länder	January 2007	The Länder (federal provinces) administer subsidies of more than 2 billion ? annually for housing support programmes. Therefore, a majority of dwellings is constructed or renovated with public support. The financial support allocated to housing support schemes is guaranteed by the Financial Distribution Act (allocating federal tax revenues to executive bodies on federal, provincial and municipal level) for the years 2005?2008 and needs to be re-negotiated for periods thereafter. The large amount of public money involved in the housing sector is of significant relevance for heating related energy demand and CO2 emissions. Specific schemes can give relevant incentives for more sophisticated energy solutions, like solar heating systems, optimized thermal insulation or even “zero-energy-houses”. Therefore, the Environment Minister, representing the federal government, entered into a constitution based treaty (according to Art. 15a of the Federal Constitution) with the Länder aiming at optimizing the use of subsidies for housing schemes by introducing minimum standards with respect to energy profiles. This type of treaty is legally binding and needs to be implemented in legal terms by the Parties until January 2007. The agreement provides for: shift of subsidies from construction of new dwelling to thermal renovation of existing dwellings; high quality standards for thermal renovation, including the whole building shell (exterior walls, windows and doors, ceilings and roof);|maximum energy performance codes for newly constructed buildings that go well beyond standards that are foreseen in general construction codes; replacement of old fossil fuel heating systems by highly efficient systems based on renewable energy (solar or biomass) or natural gas.

46 Table based on the information available in the MURE Database ‘ Household’ http://www.isis-it.com/mure/index.htm.asp (EU15).

COUNTRY	TITLE	DATE EFFECTIVE	DESCRIPTION
	KeepCool: Promotion of Sustainable Cooling in the Service Building Sector	January 2005 – February 2007	A joint venture between eight European countries: Austria, Germany, Italy, Lithuania, Portugal, Spain, Sweden and the United Kingdom, KeepCool operates under the auspice of the Austrian Energy Agency. To disseminate knowledge about strategies and available technologies of sustainable summer comfort, KeepCool lists several objectives: Improve the policy framework of sustainable cooling, specifically by expanding the number of implemented cooling laws; Facilitate the market diffusion of existing technologies and tools of "sustainable summer comfort"; Drive investment; Promote the cooperation of technology suppliers; Enhance know-how transfer between different European regions on benefits, costs, risks and opportunities of sustainable cooling. Involving participants in each member nation, KeepCool advises local building owners and planners on sustainable summer cooling. The Program supports at least five pilot projects. In addition, KeepCool develops toolkits for building owners: General toolkit on sustainable summer comfort; Toolkit for communication with planners, cooling experts and other professionals; Toolkit for communication with tenants; Toolkit for communication with operation and maintenance staff; Tools to assess efficacy, suitability and costs of different cooling technologies and tools to structure the planning process are integrated into this toolkit.
BELGIUM	Buildings Energy Performance Regulations - Wallonia & Flanders	January 2006	On 7 May 2004, the Government of Flanders introduced the Energy Performance Decree which provides the legal basis for the implementation of minimum energy performance requirements and energy certificates for buildings. On 26 November 2004, the Government of Flanders approved in a second stage the minimum energy performance and internal climate requirements. From 1 January 2006, these requirements will be obliged for new buildings and for conversions, for which an application for an urban development license must be submitted. The Walloon region is also seriously considering legislation in this area, and, in particular, introducing "as built" dossiers to make the sector more aware of its energy performance.
	Sustainable Energy Use in Federal Administrations	2004	An environmental management system will become compulsory for all federal agencies by the end of 2005. For this purpose, "sustainable development cells" will be implemented in each federal agency.
	Third Party Financing for energy efficiency investments 2005 - TPF	2004	The Belgian Government established the Belgian Energy Service Company (ESCO) to promote energy efficiency, mainly in public buildings. ESCO starts with 1.5 million euro of government capital from the Kyoto Fund and will find 5 million euro of private funding. ESCO will invest in projects where energy reduction is profitable, but the investment cost for the owner or building administrator is too high. The savings on the energy bill first pay back the investment to ESCO, and then benefit the client.
FRANCE	White Certificate Trading	2006	Under the French program of White Certificates Trading, suppliers of energy (electricity, gas, heating oil, LPG, heat, refrigeration) must meet government-mandated targets for energy savings achieved through the suppliers' residential and tertiary customers. Suppliers are free to select the actions to meet their objectives, such as informing customers how to reduce energy consumption, running promotional programs, providing incentives to customers and so on. A list of ratified activities was ratified to help the various actors to facilitate the operations. Those exceeding and undercutting their objectives can trade energy savings certificates as required for common compliance. Energy suppliers who do not meet their obligation over the period (2006-2008) must pay a penalty of euro 0,02 per kWh. Lump evaluation of energy savings are established for each process, expressed in kWh of final energy, cumulated and present-worthed over the life of the product. The first, experimental phase of the scheme will run for three years from 1 July 2006 to 30 June 2009. It is intended that during this time, the scheme will result in 54TWh of cumulated energy savings.
	Défi Pour la Terre/Challenge for the Earth	2005	Défi Pour la Terre presents a youth-oriented guide to simple techniques for energy efficiency. The website offers a personal carbon dioxide emissions calculator, guides to home and business efficiency techniques, and information on climate change and sustainable development to be used both by businesses and classrooms.

COUNTRY	TITLE	DATE EFFECTIVE	DESCRIPTION
FRANCE	Requirements for Real Estate Energy Efficiency Diagnoses	1 July 2006	As of July 2006, real estate developers and property managers must conduct energy efficiency analyses for all new construction. Under the new law, developers and property managers will inform potential buyers of a property's energy consumption patterns in an "energy efficiency diagnoses." The document, to be included as an annex to all property sales, will also detail additional measures to limit energy use and reduce associated emissions. From 1 July 2007, property owners and management companies will be obliged to provide similar documentation to potential renters as an annex to rental leases. This "legal simplification law" aims to reduce greenhouse gas emissions from residential and commercial properties, currently accounting for one-third of France's total emissions.
	Tax Credit for Energy-Saving Home Renovations	9 February 2005	In 2005, the government recalibrated the tax credits for purchases of equipment for primary residences (Article 200 of the General Tax Code) to promote both sustainable development and energy conservation. Tax credits: - 15% for purchases of low-temperature boilers; - 25% for purchases of condensation boilers, thermal insulation and heating regulation devices; - 40% for energy production equipment using renewable energy and heat pumps devoted primarily to heat production. For purchases made before 31 December 2009, including those taxes paid for the 2006, the tax credit increases to include: - 40% - 50% for energy production equipment using renewable energy and heat pumps devoted primarily to heat production; - 25% - 50% for condensation boilers and thermal insulation, with the double condition that the material and equipment be installed in a home constructed before 1 January 1977 and that this installation occur before the 31 December of the second year of the home's acquisition by its present owners. Finally, to encourage the development of renewable energy, the purchase of equipment and heating systems drawing the majority of their power from cogeneration or renewable energy sources qualifies for a tax credit of 25%.
	Tax Reduction for Investment in Energy Efficiency Residential Buildings	2006	As announced on 23 March 2005, amendments to the French tax law's Robien Mechanism will require rental property built after 1 January 2006 to reduce energy consumption by 8-15% over existing standards to qualify for tax relief. Since 2003, the Robien Mechanism has enabled individual investors in new rental property to deduct up to 65% of total costs - including the initial purchase price, interest and fees on loans, property management costs and various property taxes - from rental income over a 15-year period.
	Tax Credit in favour of Sustainable Development and Energy Efficiency	1 January 2005 – 31 December 2009	The French government has put in place a tax credit in favour of house equipment following eligible performance standards. The tax credit is fixed at 15% for the purchase of low temperature boilers, at 25% for the purchase of condensing boilers, thermal isolating materials, and heaters, and at 40% for renewable energy sources. For a household, the amount of credits cannot exceed 8000€ for a single person, and 16000€ for a couple between 1 January, 2005 and 31 December, 2009.
GERMANY	Blue Angel Ecolabel: Hot Water Tank	2 June 2006	Germany's Blue Angel eco-labelling scheme has launched a label for highly insulated hot water tanks, among labels for several other products of household heat production. Consumers who buy hot water tanks meeting the standard could reduce their energy costs for heating water by up to 10%, according to the German environment ministry. The labeling criteria also specify that manufacturers accept and recycle used tanks.
	Heat Pump Labeling	28 January 2005	Germany's Blue Angel eco-labeling program now includes gas-powered heat pumps in its portfolio of over 90 product groups. Heat pumps of up to 70 kilowatts output can qualify for the emissions label, given to those products meeting high standards for the use of refrigerants, energy efficiency, and emissions of nitrous oxides and carbon dioxide.

COUNTRY	TITLE	DATE EFFECTIVE	DESCRIPTION
GERMANY	KfW-Programme Producing Solar Power		This program, introduced in 2005, offers low-interest loans for small investments in solar PV generation. Private investors are the main beneficiary as only projects with an overall investment up to 50 ,000 are supported. 100% of the investment cost can be financed. The Reconstruction Loan Corporation (KfW) runs the program and provides interest rates between 3.6% and 4.15% p.a. Credit terms may vary between ten and twenty years with a redemption-free initial phase of two to three years. The program is running successfully. As of July 2006, more than 25,000 loans had been provided, for a total amount of 784 million and a capacity of 199 MWp in photovoltaic systems.
	Solarthermie 2000Plus	2004	"Solarthermie2000Plus" is a research program with an annual volume of about 4 million aiming to optimize solar thermal systems in terms of cost, solar coverage rate and level of system utilization. It will assist new technical developments for solar-assisted, combined potable water heating and room heating systems, solar-assisted heating networks, and cost-effective and efficient storage concepts for centralized long-term storage, incorporation of solar thermal installations into district heating networks, solar-assisted air conditioning. Research projects at universities, public research institutes and industry, collaborative projects between universities/research institutes and industry, and cluster projects (joint research by several industrial companies at the pre-competitive stage in collaboration with research institutes) will be considered for project selection. Grants are depending on the kind of applicant body, they vary from 50 to 90% of the investment costs.
ITALY	Financial Law 2008	2007	This measure allows the owners of dwelling units (including houses and flats) to deduct as much as 55% of the expenses incurred for energy saving interventions. Interventions concerning common areas of collective buildings are not eligible. Eligible interventions are as follows: a. insulation of the building shell (provided it yields a reduction of yearly energy needs of at least 10%). b. Double glazing is applicable only for climatic zones D, E and F (Northern Regions). As far as piping insulation is concerned, the eligible investment only refers to the cost of the insulation material and its installation (excluding therefore masonry work). c. heating/air conditioning systems and sanitary hot water heating using flat solar panels; d. photovoltaic systems for electricity production; e. geothermal heating systems with low enthalpy; f. CHP heat generators. From 2010 onwards selling appliances with energy labeling lower than A class and class 3 electric motors will be forbidden. From 2011 the commercialization of incandescent lamps and electric appliances without power switch will be forbidden.
	Regional Measures for Energy Efficiency: Val d'Aosta	24 January 2006	In January 2006, the Val d'Aosta launched a program to offer financing and credit for the installation of systems for: - the rational use of energy - energy efficiency improvements in buildings - use of renewable energy sources
ITALY	The so-called "White Certificates"	2005	In Italy energy saving targets have been set by law for energy distributors for the period 2005-9. A tradable certificate scheme has been launched in order to minimize the reduction costs. During the first year of application the amount of "white certificates" presented to the Authority of Energy represented an energy saving quantity larger than the 156.000 toe target. Most of the 500 projects (87%) presented in 2005 have been proposed by ESCos. Many projects have been concentrated in the cheapest areas of intervention, like the Cfl or public lighting. In this contest, the actions to save energy in buildings had a marginal role. The situation has changed in the next years with the introduction of more ambitious reduction targets (2,9 Mtoe in 2009) and with the increase of the value recognized to the "white certificates" (in 2005 100 €/toe for 5 years, extended to 8 years in case of energy retrofit of buildings). However the real challenge of achieving the 2007 goal has not been achieved.

COUNTRY	TITLE	DATE EFFECTIVE	DESCRIPTION
THE NETHERLANDS	Compass (Kompas)	2006	The Compass Program is a comprehensive program covering the whole built environment, aimed at reaching the CO2-reduction goals as set in the Kyoto agreement. Projects focus on development and implementation of instruments to enable target groups to conserve energy and reduce greenhouse gas emissions. The program can be divided into government instruments and supporting instruments. Government instruments include: Energy Performance in Buildings Directive; Energy Performance Advice for existing non-residential buildings and Housing and energy label; Energy Performance Coefficient, adjustment for non-residential buildings and housing adjustment. Supporting instruments include: Energy Saving Monitor; Model Quality Profiles for existing buildings. These instruments are fully described on the website.
	Implementation of EU Energy Performance of Buildings Directive (EPBD): Energy Performance Certificate and Energy Labeling	2006	The Netherlands government has taken a number of measures to transpose the EU Directive on the Energy Performance of Buildings (EPBD). It instituted a building labeling scheme designed to encourage property buyers to choose property using relatively less fossil energy - either through integrated renewable energy generation or the building's energy efficiency. This scheme was further reviewed in 2007, such that from 1 January 2008, it is compulsory for energy labels to be produced during the construction, sale or lease of residential and non-residential buildings. This label offers the new users information about the building's energy consumption. Housing corporations need only satisfy this requirement by 1 January 2009, on the condition that they provide energy labels for their entire building stock.
	Housing Energy Subsidies	2005	The Dutch Government has proposed a new subsidy scheme to cut housing carbon emissions, with a stronger emphasis than previously on economic efficiency. The existing scheme went €96m into the red in 2003, its last year of operation, as householders rushed to apply for fixed subsidies to fit solar panels. The Government now views the approach as having been inefficient. The new scheme, to be operational from 2005, will not be open to households but will target bigger building projects via architects, housing associations and local councils. Applicants will have to submit tenders for the carbon dioxide reductions they propose to make. The program's budget is to be €34.5m in 2005. The government wants to cap CO2 emissions from housing at 28m tons per year by 2010.

COUNTRY	TITLE	DATE EFFECTIVE	DESCRIPTION
SPAIN	Building Technical Code - Solar Panel Requirements / Implementation of the Energy Performance of Buildings Directive	January 2006	A package of minimum construction standards, Spain's Building Technical Code (CTE - Código Técnico de la Edificación) will require all new or renovated buildings to install solar power systems capable, at a minimum, of heating water. Specifically, the CTE plans to promote solar energy by recommending public subsidies, tax benefits and interest-free loans for construction companies to install solar panels. Though nationally-applicable, theses subsidies are likely to differ in amount from region to region. The CTE supports Spain's goal to install 5 million square meters of thermal panels with 143MW capacity by 2010. Upon its publication in the EU Official Journal on 4 January 2003, the EU Directive on the Energy Performance of Buildings (EPBD) entered into EU law. Member States, including Spain, were granted until 4 January 2006 to transpose the EPBD into domestic law. The Directive's principal objectives are: - To promote the improvement of the energy performance of buildings within the EU through cost effective measures; - To promote the convergence of building standards towards those of Member States which already have ambitious levels. Measures include: - Methodology for calculating the energy performance of buildings; - Application of performance standards on new and existing buildings; - Certification schemes for all buildings; - Regular inspection and assessment of boilers/heating and cooling installations. To complement the incorporation of these standards into its national law, Spain further required all new or renovated buildings to install solar power systems capable, at a minimum, of heating water.
	Mandatory Solar Panels on New Houses	2005	In November 2004, the Ministry of Industry announced that from 1 January 2005, any plans for new housing must include solar panels.
SWEDEN	Energy declaration of Buildings Act- Incentives for Investment on Lower – Energy Buildings	1 October 2006	Sweden's National Program for Energy Efficiency and Energy-smart Construction (Govt Bill 2005/06:145) proposes an Energy Declaration of Buildings Act to harmonize domestic legislation with the EPBD. Under Swedish legislation, buildings will be subject to inspections, and certain information about a building's energy use and indoor environment will be certified in an energy declaration when buildings are constructed, sold or rented out. The building owner will be able to reduce the costs of energy use through the measures proposed in the energy declaration. The Act aims to promote energy efficiency and a good indoor environment in buildings. Under the proposal, the Act will come into force on 1 October 2006. Under proposed transitional provisions, energy declarations for premises used for public activities (known as special buildings) and multi-dwelling buildings (apartment blocks) must be carried out by the end of 2008. Energy declaration of other buildings will begin on 1 January 2009. Support for purchase of energy-efficient windows and biomass boilers is set at 30% of the cost exceeding Skr 10 000; support capped at Skr 15 000.
	Anglo-Swedish Initiative for Greener Buildings	June 2005	The Swedish and UK governments have launched a joint initiative to share best practices in sustainable building. Citing the role of buildings in carbon dioxide emissions generation, representatives of each nation founded the initiative to promote sustainable construction. The initiative centres on a public information campaign targeting contractors and a website.
SWEDEN	Tax Credits for Household Fuel-Switching	20 September 2005	The 2006 Bill outlines tax relief of SEK 2 billion over the 2006 - 2010 period for energy consumers switching from heating with oil or unsustainably-generated electricity to heating with more climate-friendly power. As approved by the Swedish Parliament on 20 December 2005, households switching to bio-fuel, solar power, heat pumps and/or direct heating systems will qualify for 30% reduction in installation costs, up to an overall ceiling of SEK 400 million each year.

COUNTRY	TITLE	DATE EFFECTIVE	DESCRIPTION
	Tax Reduction for Environmental and Energy Investments in Public Buildings	2004	In the spring of 2004, the Government presented a proposal for a limited time subsidy for certain investments focused on energy efficiency and renewable energy in public buildings. The support takes the form of a tax credit corresponding to 30% of the total cost of approved projects, rising to 70% to support the cost of installation of solar cells. The scheme will be in force from 1 January 2005 until 30 June 2006 except for the support for solar cells, which will continue until 31 December 2007. The total volume of the support is estimated at 2 000 million SEK. The support for solar cells accounts for 100 million SEK out of this total.
	Tax Reduction for Installation Costs of Biomass Heating Systems and Energy Efficient Windows	1 January 2004	A new measure introduced for 2004-2006 offers an income tax reduction as an incentive to house owners to fit high-performance windows in existing houses, or to install a bio-fuel-fired heating system in new houses. The tax reduction accounts for 30% of the costs over 10 000 SEK with a maximum of 10 000 for windows and 15 000 for heating systems. This law on tax reductions (2003:1204) entered into force on 1 January 2004.
UK	Climate Change and Sustainable Energy Act	2006	On 21 June 2006, the UK government approved the Climate Change and Sustainable Energy Act, which placed an obligation on Defra to report to parliament on greenhouse gas emissions in the UK and action taken by government to reduce these emissions. The first report was put to the UK parliament on 26 July 2007. If the Climate Change Bill 2007 is eventually adopted, this reporting procedure will continue under that legislation. The legislation also establishes a scheme to promote national targets micro-generation; provides for reporting on the energy efficiency of residential accommodation; the promotion of community energy projects; and provides for a green certificate scheme for electricity from renewable sources (see separate database entries).
	Low Carbon Buildings Program	1 April 2006	On 1 April 2006, the UK government launched a GBP 30 million funding package for small-scale power generation within the context of energy-efficient buildings. The Low Carbon Building Program (LCPB) aims to reduce carbon emissions from buildings by funding the installation of small-scale renewable power generators like micro-turbines, solar panels and air source heat pumps and general energy efficiency measures. The program will fund single installations and large-scale developments in the public and private sectors. Potential beneficiaries include schools, community centres and buildings and villages isolated from the electricity grid. Under Phase One of the DTI's Low Carbon Buildings Program, grants totalling £10.5 million will be available to householders and community organizations for micro-generation technology.
UK	Micro-generation Strategy	28 March 2006	On 28 March 2006, the Government launched its Micro-generation Strategy, aiming to create conditions under which micro-generation becomes a realistic alternative or supplementary energy generation source for the householder, communities and small businesses. The government provides grant funding for installation of micro-generation technologies under the Low Carbon Buildings Program (LCBP). This replaces Clear Skies and the Major PV Demonstration Program and is currently structured in two 'phases: - Phase 1 was launched in April 2006. £28.5 million has been made available to support projects in households, community organizations, housing associations, public sector and private businesses. This phase was opened for private sector applications under the Low Carbon Building Program. - Phase 2 takes forward the Chancellor of the Exchequer's 2006 Budget commitment of an additional £50m of capital grant funding for the installation of micro-generation technologies in the public and charity sectors (social housing, libraries, hospitals, schools etc).
	Anglo-Swedish Initiative for Greener Buildings	June 2005	The Swedish and UK governments have launched a joint initiative to share best practices in sustainable building. Citing the role of buildings in carbon dioxide emissions generation, representatives of each nation founded the initiative to promote sustainable construction. The initiative centres on a public information campaign targeting contractors and a website.

COUNTRY	TITLE	DATE EFFECTIVE	DESCRIPTION
	Code for Sustainable Homes	2006	Building Regulations set out minimum performance standards for new homes. But the UK wants to encourage house-builders and developers to go beyond compliance with minimum requirements. Building on the recommendations of the Sustainable Buildings Task Group, the Code for Sustainable Homes has been developed to support a step change in the building of sustainable new homes. The Code provides a single national standard to guide industry in the design and construction of sustainable homes, considering not just energy but also water, materials, waste and ecology. Developers will be able to obtain a 'star rating' for any new home that will demonstrate its environmental performance. It will provide valuable information to home buyers, and offer builders a tool with which to differentiate themselves in sustainability terms. This is intended as a means of driving continuous improvement, greater innovation and exemplary achievement in home building. The Code provides a clear picture of what will be required to meet future Building Regulations. There are six levels of the Code, with mandatory minimum standards for energy efficiency and water efficiency at each level. For example, Code Level 1 represents a 10% improvement in energy efficiency over the 2006 Building Regulations. Code Level 6 would be a completely zero carbon home (heating, lighting, hot water, and all appliances). Improvements in the energy efficiency of new homes of more than 25% compared to 2006 regulations (Level 3 of the code) would probably require some form of low or zero carbon energy generation, either by individual buildings (e.g. dedicated solar water heating) or, by whole developments sharing a source of low carbon generation (e.g. wind turbines). Development beyond level 3 of the code will not only improve energy efficiency but encourage the deployment of low carbon technologies and encourage greater distributed forms of energy generation. While the Code is voluntary for private sector housing, the UK Government is considering whether, from April 2008, all new homes should be required to have a rating against the Code. The UK Government will use the Code to support housing developments which are under our own control. For example, it will ensure that all new Government funding for homes built by registered social landlords and other developers will now make it a condition that they comply with level 3 of the Code for Sustainable Homes.

Annex B: Details on the MURE simulation model

The MURE –Household Model

To understand the way the impact simulation has been carried out it is important to shortly describe how the building section of the MURE household model has been structured and how it works. To this end it is important to understand: a. the structure of the database, b. the simulation mechanisms.

a. the MURE – Household Building database

The database contains the building unitary consumption (kWh/m2), that constitute the main building technological attributes, split by age and building type.

There are three classes of age: old, that is the buildings builds before 1975, intermediate, concerning those built from 1976 to 2004 and the future ones, that is the forecast of the buildings built from the year 2005 up to the year 2030. The age classes are then further divided by single and multi family houses and the old and the future building stocks are in turn further split by energy efficiency (EE) classes (or building codes):

- the old buildings are divided in five EE classes: not refurbished (W. Ref), already refurbished, with old building code standards (1975 - 2003, Ref 0), refurbished by using the most recent building codes (2003 – 2006, Ref 1), refurbished with more advanced standards which are assumed to be promoted by the EPBD and by other national standards like, i.e., the German Energy Saving Directive (Ref 2); refurbished with EE standards equivalent to the new low consumption buildings (Ref 3)
- the future buildings are in turn characterized by four EE classes, New 1 up to New 4. The energy standards New1 corresponds to REF 1, New 2 to Ref 2 and New 3 to Ref3. The EE class New 4 is an improved standard and comparable to the Passive Houses.

It is worth noting that the intermediary stock is not further split by EE classes as it is supposed that no refurbishing interventions will be carried out on this stock during the analysed time frame.

Figure B. 1 shows the structure of the MURE household building database in accordance with the brief description outlined above.

Besides the building unitary consumption data and to allow the calculation of the energy demand at country level, the MURE database also contain figures concerning the average square meter trends per building type, the total household number trends and the households number split by age and building type.

b. the simulation mechanisms

To generate the energy demand of a given scenario, that is, of a given hypothesis on the energy efficiency evolution of the building stock of a country, MURE uses the following set of data:

the building unitary energy consumption figures broken down by EE classes as shown in

- Figure B. 1;
- the penetration rate of the EE classes within their corresponding markets.

The unitary consumption data are thus provided while penetration rates of the EE building classes vary along the simulation period and by scenario

The simulation scenarios containing the different hypotheses of EE class penetration rates are prepared exogenously. Once the scenarios are ready, the model calculates the energy demand by scenario for each of them and provides the corresponding energy savings. It is worth noting that, in this case, the calculated energy demand corresponds to the useful energy of the building. The final heating demand is then calculated by a separated procedure in which the building energy useful demand is divided by the energy efficiencies of the considered heating technologies.

Data

Currently MURE household provides the unitary consumption figures of each EE class for the 27 EU MS plus 4 EEA countries (Norway, Iceland, Lichtenstein and Croatia). These countries have been divided by climate zones classes and to each of these zone has been attributed the same U values (Wm2-K) split by building components and building age. Table B. 1 shows how these country have been classified by climate zones (the figure between parenthesis shows the average DD) while

Table B. 2 shows the U values that have been considered to calculate the final unitary consumption data. These last data have been firstly calculated by climatic zone and then recalibrated by country taking into account the total heating demand as provided by external data sources like Kemna et al. (2007), Odyssee (2007) and PRIMES. Finally

Table B. 3 shows an overview of the average unitary energy consumption of single and multifamily buildings by climate classes before the country calibration.

Table B. 1: Country classification by climate zones

Cold	Moderate	Warm
Estonia (4420) Finland (5823) Iceland (4977) [1] Latvia (4243) Norway (5423) [1] Sweden (5423)	Austria (3569) Belgium (2882) Croatia (3044)[1] Czech Republic (3559) Denmark (3479) France (2494) Germany (3244) Hungary (2917) Ireland (2916) Liechtenstein (3569)[1] Lithuania (4017) Luxemburg (3216) the Netherlands (2905) Poland (3605) Romania (2917)[1] Slovakia (3440) Slovenia (3044) United Kingdom (3354)	Bulgaria (2101) [1] Cyprus (787) Greece (1698) Italy (2085) Malta (564) Portugal (1302) Spain (1856)

Source: Eurostat (2006), Wuppertal Institute calculations for the DG-TREN-ESD study

Table B. 2: Energy standard of building components by climate zone and construction period of building

U-values in Wm^2K										
	Old buildings		Int. build.	Refurbished buildings			New Buildings			
	W. Ref.	Ref 0		Ref 1	Ref 2	Ref 3	New1	New2	New3	New 4
Cold Climate Zone										
Roof	0.50	0.20	0.18	0.15	0.13	0.11	0.15	0.13	0.11	0.10
Façade	0.50	0.30	0.25	0.18	0.17	0.15	0.18	0.17	0.15	0.10
Floor	0.50	0.20	0.19	0.18	0.17	0.15	0.18	0.17	0.15	0.10
Windows	3.00	1.60	1.60	1.42	1.33	1.03	1.42	1.33	1.03	0.78

U-values in Wm^2K										
	Old buildings		Int. build.	Refurbished buildings			New Buildings			
	W. Ref.	Ref 0		Ref 1	Ref 2	Ref 3	New1	New2	New3	New 4
Moderate Climate Zone										
Roof	1.50	0.50	0.45	0.25	0.23	0.16	0.25	0.23	0.16	0.10
Façade	1.50	1.00	0.75	0.41	0.38	0.20	0.41	0.38	0.20	0.10
Floor	1.20	0.80	0.65	0.44	0.41	0.28	0.44	0.41	0.28	0.10
Windows	3.50	2.00	2.75	1.84	1.68	1.30	1.84	1.68	1.30	0.60
Warm Climate Zone										
Roof	2.46	1.00	0.65	0.50	0.43	0.30	0.50	0.43	0.30	0.10
Façade	1.97	1.40	0.90	0.59	0.48	0.25	0.60	0.48	0.25	0.10
Floor	2.50	1.00	0.68	0.55	0.48	0.33	0.55	0.48	0.33	0.10
Windows	4.70	3.50	3.85	3.04	2.71	1.26	3.04	2.71	1.26	0.60

Source: Wuppertal Institute calculations for the DG-TREN-ESD study based on EURIMA, ECOFYS (2005b); WI (2000); IWU (1994); ISIS

Table B. 3: Average unitary energy consumption of single and multifamily buildings

Average unitary energy consumption of a Single Family Building in kWh/m^2			
Building standard	**Cold**	**Moderate**	**Warm**
Old w/o ref	**197**	**269**	**272**
Old, already ref.	**158**	**225**	**212**
Intermediate	**165**	**219**	**188**
REF 1	**157**	**182**	**167**
REF 2	**154**	**178**	**159**
REF 3	**147**	**160**	**143**
New 1	**144**	**159**	**144**
New 2	**140**	**153**	**134**
New 3	**130**	**131**	**115**
New 4	**97**	**99**	**83**
Average unitary energy consumption of a Multi Family Building in kWh/m^2			
Building standard	**Cold**	**Moderate**	**Warm**
Old w/o ref.	**142**	**177**	**168**
Old, already ref.	**122**	**150**	**126**
Intermediate	**117**	**125**	**112**
REF 1	**115**	**122**	**106**
REF 2	**109**	**110**	**97**
REF 3	**107**	**109**	**91**
New 1	**106**	**108**	**92**
New 2	**99**	**93**	**76**
New 3	**96**	**91**	**72**
New 4	**69**	**66**	**53**

Source: Wuppertal Institute calculations based on WI (2001); WI (2000)

To have an idea of the difference between the average figures shown in

Table B. 3 and those resulting through the comparison with the Odyssee/Primes databases, it resulted that the energy demand for countries like Belgium, Luxemburg, Finland, France, Latvia and Estonia was higher than calculated. In contrast to this, the useful energy demand for Spain, Portugal, Italy, Poland, Bulgaria, Slovakia, Lithuania, Denmark, the Netherlands and United Kingdom was lower than expected. Table B. 4 shows the final calibrated EE standards used for this case study.

Figure B. 1: Household sector: structure of the building section

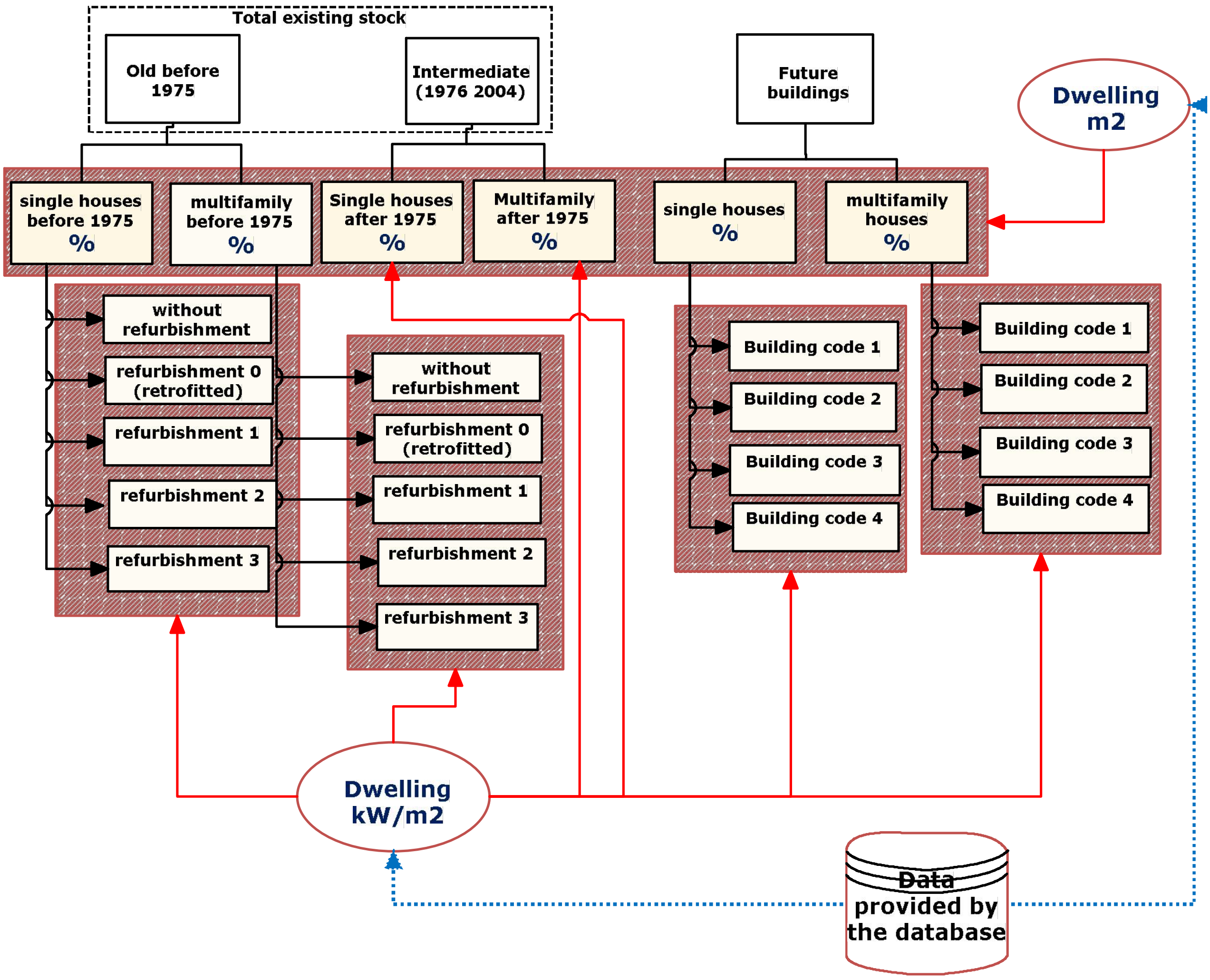


Table B. 4 Final calibrated Energy Efficiency standards

EE Standards	AT		CZ		DE		DK		ES		FR		IT		NL		PL		UK	
	Ind.	Coll.	Ind.	Coll.	Ind.	Coll.	Ind.	Coll.	Ind.	Coll.	Ind.	Coll.	Ind.	Coll.	Ind.	Coll.	Ind.	Coll.	Ind.	Coll.
Existing Buildings kWh/m2																				
Without Refurbishment	312,5	201,5	311,6	200,9	284,0	183,1	198,0	127,7	171,7	100,7	251,1	161,9	158,7	93,1	150,1	96,8	265,1	170,9	196,1	126,4
Old buildings codes	228,4	147,6	227,7	147,2	207,6	134,2	144,7	93,5	108,9	58,4	183,5	118,6	100,6	54,0	109,7	70,9	193,8	125,3	143,3	92,6
Recent buildings codes	131,4	91,2	131,0	90,9	119,4	82,9	128,1	57,8	74,2	42,6	91,8	63,7	68,5	35,8	88,2	40,8	132,7	77,4	119,5	68,7
EPBD building codes	85,5	45,5	122,3	67,5	111,4	61,5	119,5	42,9	63,7	42,6	85,7	47,3	58,9	28,7	82,3	30,3	123,8	68,4	111,5	61,6
New Buildings kWh/m2																				
Recent building codes	131,4	91,2	131,0	90,9	119,4	82,9	128,1	57,8	74,2	42,6	91,8	63,7	68,5	35,8	88,2	40,8	132,7	77,4	119,5	68,7
EPBD building codes	85,5	45,5	122,3	67,5	111,4	61,5	119,5	42,9	63,7	28,5	85,7	47,3	58,9	28,7	82,3	30,3	123,8	68,4	111,5	61,6
More stringent building codes	50,0	26,0	86,0	63,9	78,4	58,3	84,1	40,6	43,9	24,3	60,3	44,8	40,5	24,5	57,9	28,7	87,1	64,7	78,5	58,3

4 European Emission Trading Scheme (EU ETS)

The purpose of this chapter is to describe an example “Tier 3” approach for the ex-post evaluation of the EU ETS taking into account the interaction of this measure with other measures aiming at the same target, including national measures. The main accent is on the description of the methodology given the fact that the interactions of the EU ETS with other policies are multiple and that many effects, simultaneously with the EU ETS, impact on the emissions of the installations concerned.

The analysis is carried out according to the following five steps after a general discussion of the methodology and the data context:

- Step 1 Mapping of GHG measures in the context of the ECCP: This is the qualitative description of the "measure network" which may include EU-ECCP measures, EU-pre-ECCP measures, ECCP-triggered national measures as well as independent national measures aiming at the same target.
- Step 2 Compilation of quantitative evaluation evidence: This consists of the compilation of quantitative evaluation evidence such as in-depth national bottom-up evaluations, estimates from top-down impact indicators or simple estimates.
- Step 3 Screening step: This consists of the exclusion of unimportant national measures and pre-ECCP measures from the measure map, reducing the measure map to a simpler picture that can be modelled more easily.
- Step 4 Modelling step: The model-based harmonised evaluation of the simplified measure map provides an evaluation of impacts under harmonised assumptions.
- Step 5 Impact Delimitation: The impacts obtained in the previous step are in general “gross impacts”. Further treatment of issues such as independent national measures aiming at the same target, autonomous progress, the impact of market energy price changes etc. may be necessary.

As the EU ETS consists of two rather distinct types of participants, the power sector and the large industrial emitters, the evaluation methodology makes a distinction between these two types where necessary.

The Tier 3 approach to the EU ETS described here proposes therefore two different methodologies:

- One for the **electricity sector** which represents the most relevant part of the energy transformation sector. This approach reposes on a detailed description of the power sector on a plant by plant level, as well as on a high time resolution (modelling on an hourly basis). This shows the effects of the ETS on the dispatching of the fossil power plants, which are the most important **short term** effects and the most relevant ones for an ex-post analysis at the present level. For this purpose the PowerAce model was used which represents the renewables power generation units with an hourly resolution. At the **longer term, investment decisions** may be influenced by the EU ETS, however this is beyond the short historic time period 2005/2006 assessed here. For this purpose results from the Green-X model are provided. This issue is discussed further in this report.
- One for the **industry sector** based on an econometric approach. The econometric approach was chosen, because the industrial sector is far from having the same degree of detail as the electricity sector concerning the different installations. Even from the emission registers only the CO2 emissions are known by installation, neither the fuel mix nor the production levels are known. The econometric approach is therefore the most appropriate one for the **shorter term impacts**. Most models rely on assumed behaviour and the sector representation differs from the sectoral aggregation in the ETS. Hence, they cannot be directly linked to the information provided by the verified emissions tables. In contrast, econometric analyses are based on observed behaviour, and the econometric approach may be directly linked with emissions from the verified emissions tables.

4.1 Introduction: Brief description of the measure

The European Emission Trading Scheme (EU ETS) is governed by the EU ETS Directive[47] and was launched in January 2005. The EU ETS covers around 11,000 large greenhouse gas emitting installations in the energy and industry sectors: combustion installations with a rated thermal input capacity of at least 20 Megawatts, as well as refineries, coke ovens, steel plants, and installations producing cement clinker, lime, bricks, glass, pulp and paper provided that they exceed the threshold production levels given in Annex 1 of the directive. The EU ETS is the world's largest emissions trading system, and the first international trading system for CO_2[48]. In total, the EU ETS covers about 50% of Europe's CO_2 emissions and 40% of its total greenhouse gas emissions. As the European Union's key climate policy instrument for the energy and industrial sectors, the EU ETS is expected to help the EU and the EU Member States reach their short- and long-term greenhouse gas emissions targets in a cost-efficient way[49]. The EU ETS is made up of consecutive trading periods. The first trading period – often considered to be a "learning phase" – lasted from 2005 to 2007 (phase 1); the second trading period coincides with the Kyoto commitment period from 2008 to 2012 (phase 2). According to the recent proposal by the European Commission, the third trading period (phase 3) will last from 2013 to 2020[50]. Also, the scope of the EU ETS will be extended to include additional installations (air traffic) extending those already referred to in Annex 1 of the Directive[47]. On the other hand, small emitters (with emissions of less than 25.000 t CO_2 in a reference period) may opt out from the system.

For phase 1 and phase 2 individual Member States developed country-specific National Allocation Plans (NAPs). At the macro level, these NAPs define the cap, i.e. the total quantity of allowances available in each period (ET-budget). Thus, the size of the ET-budget indicates whether the EU ETS is environmentally effective in terms of reducing CO_2-emissions. At the micro level, NAPs determine how these allowances are allocated to individual installations. By the end of a particular period, operators must surrender the number of allowances equivalent to the amount of emissions caused by their installations during that period, otherwise sanctions have to be paid. Companies may emit more emissions than their initial allocation if they purchase extra allowances from others. In general, more stringent ET-budgets will lead to higher prices for European Union Allowances (EUAs) and thus greater incentives to improve carbon efficiency, ceteris paribus.

According to the Climate and Energy Package adopted by the EU in 2008[50,51], after 2013 the ET-budgets and allocation rules will no longer be set by individual Member States. The EU intends to reduce total greenhouse gas emissions by 20% compared to 1990 levels. In case other developed countries also decided to take on similar reduction targets within a Post-Kyoto framework, the EU would commit to a reduction of 30%. To achieve these targets the proposed size of the ET-budget corresponds to a reduction of 21% compared to 2005 emissions for the 20% target, and 38% compared to 2005 emissions for the 30% reduction target. The Climate and Energy Package also includes binding targets for renewables and energy efficiency. By 2020 the target share for renewables in final energy use is to be 20%. Finally, energy efficiency must be improved by 20% between 2005 and 2020 compared to the 'business as usual' development.

4.2 Methodological approach and data context

4.2.1 Data

For the installations covered under the EU ETS verified data on emissions are available from the Community Independent Transaction Log (CITL) from 2005 onwards. The European Commission publishes the verified emissions data once the companies' verified emission reports are approved by the Commission – typically in late April of the following year. While the EU ETS is designed to include – in principle – all six Kyoto greenhouse gases, in the first phase only CO_2-emissions were included. Neither the CITL nor the NAPs, however, provide information on production levels for these installations. When interpreting the data it has to be kept in mind, that in some countries (e.g.

47 CEC, 2003
48 Ellermann and Buchner, 2007
49 CEC, 2000
50 CEC, 2008a
51 CEC 2009

Germany), "installation" level data for industry installations may also include emissions from combustion installations since both types of installations operate under the same permit. Likewise, emissions data on activities in the CITL may not be sufficiently disaggregate to directly allow for sector specific analyses. For example, emissions from lime and cement productions are presented under the same activity number. Similarly, for a thorough analysis of emissions in the steel sector, one would have to identify installations with basic oxygen furnace technology from those with electric arc furnace technology. For many countries, this data is available from the NAPs. While the CITL provides verified installation-specific emission data for 2005 and beyond, no such data is generally available for earlier years. Likewise, generally, there is no installation-specific data available on output, neither for the years prior to the start of the EU ETS, nor for the years afterwards.

Historic data on emissions at the sectoral level may be obtained from the International Energy Agency statistics (based on energy balances) or from the national inventories from the UNFCCC, but sectoral aggregation in these data is usually not consistent with Annex 1 of the original Directive (CEC, 2003) or the revised Directive from December 2008. Likewise, data on energy-related emissions may have to be combined with data on process-related emissions from several sources. Production level data is often available from national statistical offices or ministries, and from industry associations at the national level, EU level, or at the international level (e.g. the International Iron and Steel Institute).

4.2.2 Methodological aspects

Since the EU ETS differs in nature from the other measures under the ECCP it is worthwhile focussing on some methodological aspects for the evaluation of its impacts first. When developing a methodology to evaluate the EU ETS the following aspects have to be taken into account.

Direct versus indirect carbon cost effects

The EU ETS provides direct and indirect incentives to save emissions. First, direct incentives exist for installations directly covered by the EU ETS. Saving emissions through organisational measures or investment in carbon-saving technologies reduces the costs under the EU ETS since fewer allowances have to be surrendered. Indirect effects result from the price effects of the EU ETS on product prices: higher product prices usually result in lower demand, lower production, and lead thus to lower emission levels. Most notably, the EU ETS results in an increase in power prices, the extent of which depends on the pass through of carbon costs to the customers (see for example Sijm et al. 2005, 2006). These customers include operators of installations covered by the EU ETS which use electricity (e.g. paper production, electric arc furnace steel) as well as power users in other sectors including industry (e.g. aluminium smelters), the tertiary(service sector) and the household sector. In general the pass through may vary regionally because, for example, of differences in the marginal power producer (e.g. coal in Germany versus natural gas in the UK). It may further vary with market structure, with demand/load types and, in particular, with the elasticity of demand. The more sensitive demand is to price increases, the stronger would be the decrease in demand in response to a price increase. Thus, the EU ETS generates additional incentives for power users to save electricity through such indirect effects. Since the scope of the EU ETS is limited to installations located in the EU higher output prices may result in competitiveness distortions for certain carbon and energy intensive companies in the EU. In extreme cases, affected companies may choose to migrate to regions where regulations are less stringent or investors may decide to launch new investments in these regions rather than in the EU. Producers in sectors which export to, or import from, less regulated regions but which do not migrate away, may suffer losses in market shares and profits. These competitive disadvantages may translate into higher overall emissions and hence undermine the environmental integrity of the EU ETS (carbon leakage).

From a macroeconomic perspective, additional "general economic" effects on for example, on long-term competitiveness, and levels of available income, may also feed back into changes in carbon emissions.

Conclusions: Direct and indirect effects of the EU ETS should be taken into account when impacts of the EU ETS are evaluated. In particular, the impacts of direct and indirect effects on output prices and demand need to be taken into account. To account for leakage effects one would have to know in which region carbon leakage occurs as well as the carbon-intensity of the production process in this region. More general economic effects would have to be addressed via macro-economic models, and may be neglected at this point of the analysis.

ETS-induced direct emission reductions

Operators of installations covered by the EU ETS may reduce emissions via organisational measures, by fuel switch from carbon intensive fuels like coal to less carbon intensive fuels like gas, renewables or nuclear, by investments to improve efficiency for existing installations, or by investing in new, less carbon-intensive processes. In the short run, feasible measures to reduce carbon output include primarily organisational measures and – in particular in the power sector – fuel switch (via dispatching). This issue will be exemplified with the calculation of the impact of the EU ETS on dispatching in Germany (see Section 4.6) based on a simulation with the PowerACE model. CO_2 savings from dispatching, however, may easily be reversed, once the price signal diminishes. Incentives for these measures are provided by the existing and expected future price levels for allowances (in relation to the costs for internal abatement measures) as well as by existing and expected allocation rules for new projects.

<u>Conclusions</u>: Ideally, the price of carbon needs to be taken into account for the evaluation (see also discussion of price effects of first phase above).

Autonomous technological change

Because of *technological change* that is unrelated to policy or price incentives, the carbon performance of installations covered by the EU ETS is expected to change and, taken by itself, is likely to reduce emissions in these sectors.

<u>Conclusions</u>: Autonomous emission reductions resulting from autonomous technological change have to be taken into account. Otherwise the effects of the EU ETS on emissions will be overstated if these autonomous effects result in lower emissions.

Structural change

Changes in demand due to changing industrial structures may also lead to changes in production and hence in greenhouse gas emissions. Such changes may or may not be triggered by the EU ETS. In many cases they are changes triggered by autonomous changes in the industrial structures.

<u>Conclusions</u>: Effects of structural change should only be taken into account if the implications are judged to be of significance. For example, for steel production, a shift in production shares between electric arc furnace steel and basic oxygen steel would have significant implications in terms of direct greenhouse gas emissions. Failing to account for a shift towards electric arc furnace steel would lead to inflated estimates of ETS-induced emission reductions.

Price-induced changes in emissions

Increasing fuel prices (relative to labour or capital costs) or changes in relative fuel prices can also be expected to lead to lower emissions. An increase in fuel prices may render existing abatement technologies more profitable and would also provide incentives for R&D in new energy-saving technologies leading to lower carbon emissions in the future. Likewise, an increase in the price of coal compared to gas would make the use of gas rather than coal more profitable, and would lead to lower emissions.

<u>Conclusions</u>: Fuel price-induced technological change needs to be taken into account. The effects of relative fuel prices are particularly relevant for the power sector, where fuel switch may be achieved with greater ease and with less lag time than in industry sectors.

Policy-induced changes in emissions (policy interaction/policy mapping)

In principle, all policies and measures affecting supply and demand of the output produced by installations covered by the EU ETS interact with the EU ETS. The mutual influence appears as rather complex and not only of economic nature.

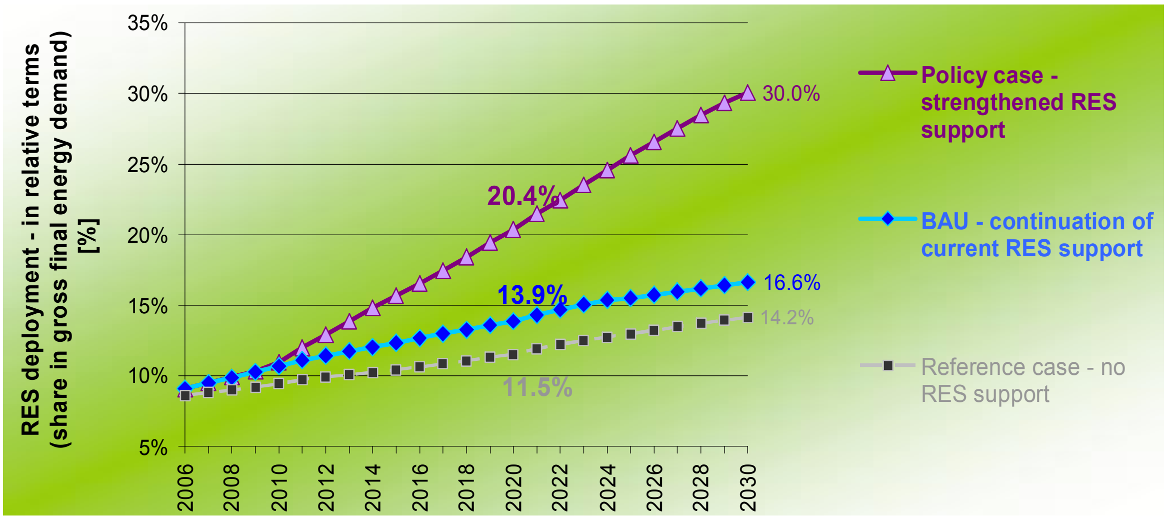
The impact of direct and indirect measures is taken into account to some extent when deciding on the size of the ET-budget (and on the size of the greenhouse gas budgets of the Non-ETS sectors). For example, the estimated impact of targeted support measures for renewable energy sources (such as feed-in tariffs) or demand-side energy efficiency measures which reduce supply from installations covered under the EU ETS would, in principle, have to be taken into account when deciding on the ET-budget. Once this cap is set, however, and if these other measures turned out to be more effective than estimated when setting the cap, they would not lead to additional emission reductions because emissions replaced by carbon-free technologies beyond the assumed success would open more room for fossil emission, hence lead to a reduced price signal.

On the other hand, since the EU ETS results in an increase in power prices, rendering energy-efficient measures and technologies more profitable, the EU ETS complements the effectiveness of other measures. Similarly, by increasing the costs for carbon-intensive supply side technologies, carbon-free technologies become more profitable. The impact of the ETS can therefore be seen as complementary to other policies because it makes the continuation of those instruments easier as it reduces the need for direct subsidies. On the other hand, the ETS benefits from the presence of those instruments due to the volatility of prices for CO_2 allowances. Without the steady frame of the present promotion schemes for renewable energy sources far less renewables would be installed given the high uncertainties and high volatility around the carbon price. It has to be realised that once the cap has been set, taking into account impacts of energy efficiency and renewables policies, any additional increase in the share of renewables or energy efficiency leads to a replacement of other options.

This interaction is exemplified with the policies for renewables: The RES target in EU Member States is reached by quantity based mechanisms (e.g. quotas) or price based mechanisms (e.g. fixed feed-in tariffs or feed-in premiums). Generally these systems should be designed to reach the RES target independently of the ETS price, which is clearly the case for a quota system and a fixed feed-in system. In the case of a premium system the level of the premium needs to be adjusted according to the ETS price.
Figure 4-1 shows that in the absence of RES support (but including EU ETS) the RES share would reach 11.5% by 2020, while with the continuation of present RES policies nearly 14% would be reached by 2020.

The policy costs for the RES support will depend on the ETS price (according to the impact assessment of the Climate package 45 €/MWh with ETS and 56 €/MWh without ETS, see Table 4-1) but the level of target achievement of the RES targets will not depend on the ETS price as these targets exist separately. The figures in 2020 from the EU impact assessment, established with the PRIMES model differ from the Green-X projections as they show a considerably larger impact of the EU ETS in the absence of renewables policies. There may be methodological differences in the model that explain these differences but this discussion shows that the interactions are not easy to determine and require further analytical work.

Figure 4-1: Comparison of the overall RES share in final (gross) energy consumption up to 2030 within the European Union (EU-27) excluding/including targeted RES support



Investigated cases: Reference case (including EU ETS, no RES support), Business as Usual BAU (including in addition continuation of the current level of policy support, policy case with strengthened RES support. Please note that the graph refers to all renewables, including non-electric renewables. Calculations have been made with the Green-X model for renewables run by TU Vienna.

Source: Fraunhofer ISI (2009)

Table 4-1: Ex-ante impact of stand alone and combined RES and GHG policies on the share of renewables, and CO2 and GHG emissions in 2020, without access to JI/CDM

	2020		
	RES share final energy consumption	Compared to 1990	
		CO2 emissions from energy	Total GHG emissions
Baseline projections	12.5%	5.1%	-1.5%
20% RES achieved	20.0%	-5.8%	-9.3%
20% GHG achieved	15.8%	-15.8%	-20.0%
20% RES and GHG achieved	20.0%	-16.7%	-20.0%

Source: EC (2008c)

Conclusions: The impact of the most relevant policies needs to be taken into account when developing the counterfactual for greenhouse gas emissions, in particular for the power sector.

Counterfactual climate policy

If the EU ETS had not been implemented, some Member States may have implemented other climate policy instruments (e.g. domestic trading systems, carbon taxes, energy taxes). Likewise, upon the introduction of the EU ETS some MS may have abandoned existing policies. The latter may also include policies which MS had implemented to prepare companies in their states for participating in the EU ETS. For example, domestic carbon trading systems were in place in the UK and in Denmark prior to the introduction of the EU ETS.

Conclusions: Since it is rather hypothetical which alternative new policies would have been in place in the absence of the EU ETS, they may be neglected. Because global warming reflects a global externality, it is doubtful that any meaningful climate policy would have been implemented unilaterally by individual MS. In cases where the EU ETS replaced existing policies which are not related to the introduction of the EU ETS, they would have to be captured in the counterfactual.

Impact of trading allowances and using project-based credits

To comply with provisions of the EU ETS directive, operators may reduce emissions internally (e.g. via abatement or output reduction), purchase allowances (EUAs) and – according to the so-called "Linking Directive[52] – also use (a limited amount of) credits (Certified Emission Reductions CERs or Emission Reduction Units ERUs) from Clean Development Mechanism (CDM)- or Joint Implementation (JI)-projects. While internal measures show up as emission reductions within a particular sector, purchasing EUAs, CERs or ERUs do not. Since the total ET budget is fixed, however, purchasing EUAs by one operator will not increase overall emissions within the EU ETS. In contrast, the purchase of CERs and ERUs increases the amount of greenhouse gas emissions within the EU ETS (while reducing emissions outside the EU ETS). In the future the category of "community-level projects" which is foreseen in the proposal for a new directive (CEC, 2008a), would link the EU ETS sector to the non-EU ETS sectors within EU countries. In any case, rational companies are expected to reduce emissions internally, if abatement costs are lower than the price for EUAs, CERs and ERUs.

Conclusions: Constructing a counterfactual argument and comparing it to the observed emissions of a sector, only allows conclusions to be drawn for this particular sector. To assess the overall effect of the EU ETS, the counterfactuals of all sectors (covering all EU ETS installations) would need to be calculated and then related to the size of the ET budget. In-Credits from projects would have to be added to the contribution of the EU ETS since they correspond to emission savings outside[53] the system[54]. However, to avoid double-counting of emission reductions when evaluating the impact of the EU ETS, one must take into account whether so-called *set-asides* (e.g. JI-Reserves) have been created in the NAPs for approved or planned JI/CDM projects taking place in ETS installations (e.g. Poland, Hungary or Bulgaria for phase 2). Otherwise no CERs or ERUs could be issued for reductions of limitations of greenhouse gases which take place in installations covered by the EU ETS or impact emissions in these installations.[55]

Banking and Borrowing

Companies may transfer unused allowances into future years within trading periods (banking) and across periods. Only banking from phase 1 into phase 2 was prohibited. The opposite of banking, i.e. borrowing, is also feasible within periods, but not across periods. As a consequence, companies may choose to reduce more in present periods, if they expect future prices for EUAs to rise significantly. Hence, current abatement efforts also reflect expectations about future EUA prices, and banking may induce early abatement.

Conclusions: When interpreting the results for phase 1, one needs to take into account that the ban on banking – together with the generous allocation – resulted in the low prices in phase 1 of the EU ETS. The ban on banking also dampened incentives for early emission reductions, since unused allowances could not be carried over to phase 2.

52 CEC, 2004

53 In the discussion process for the development of the methodology the argument was advanced that the impacts of CDM and JI should also be attributed to EU ETS, even if they take place elsewhere. In our view this is too far reaching an interpretation of the flexibility instrument ETS by allocating the impacts of the CDM to the ETS. This is seen by the fact that CDM may be used by countries that have no ETS. This clearly shows that the CDM is an instrument per se. The question would then be rather in how far the ETS by its presence enhances the uptake of CDM projects. Further discussion of the issue is certainly necessary.

54 Hence, to adequately address this issue, information on the use of credits from JI and CDM projects would have to be available in due time. Credit from CDM projects are expected to be particularly relevant after 2013, when a Post-Kyoto agreement involving ambitious emission targets for other developed countries will be reached. In this case, companies in the ETS sector may use up to 50% of the additional emission reductions required. In addition, companies may transfer CERs from phase two into the third phase.

55 See Article 3(1) of Decision 2006/780/EC37 (Commission Decision 2006/780/EC of 13 November 2006 on avoiding double counting of greenhouse gas emission reductions under the Community emissions trading scheme for project activities under the Kyoto Protocol pursuant to Directive 2003/87/EC of the European Parliament and of the Council, OJ L 316/12, 16.11.2006; also see the so-called "Linking Directive" EU Linking Directive (2004/101/EC).

4.2.3 Methodology for evaluation

Evaluation of the EU ETS based on the Tier 3 approach may be conducted using models covering all sectors, using models covering single sectors, or by carrying out econometric analyses. Such models tend to rely on assumed behaviour and the sector representation differs from the sectoral aggregation in the ETS. Hence, they cannot be directly linked to the information provided by the verified emissions tables. In contrast, econometric analyses are based on observed behaviour, and – as will be illustrated below – the econometric approach may be directly linked with emissions from the verified emissions tables.

a) Evaluation based on models for the power and the industry sectors

Models which allow for a sectoral disaggregation of the sectors covered by the EU ETS may be used for evaluation. Models suitable for the task include those capturing several sectors such as the PRIMES model, or models for single sectors such as the PowerACE model (a model developed by Fraunhofer ISI for the power sector). While the former allow for an analysis of the effects on all sectors in all countries combined (including interactions), sector-specific models tend to be better suited to capture technological and country-specific details including interactions with other policies.

In principle, the evaluation would consist of the subsequent steps:

Step (i): Run model with observed prices for EUAs in period t and include other economic variables as actually observed in period 1 (energy prices, sector growth, supply of renewables, policies, etc.) as much as possible (without compromising the logic and internal consistency of the model) (*Policy run*).

Step (ii): Run model from Step (i) but set price for EUAs at zero and – if possible – model counterfactual national climate policy (*Counterfactual*).

Step (iii): Take the difference in emissions between Step (ii) and Step (i) and relate result (e.g. growth rate in emissions) to verified emissions (*Calibration*).

This approach implicitly assumes that the models are able to capture the actual technological and economic environment, including agents' behaviour sufficiently well. Unless the models also capture changes in demand in response to the EU ETS – e.g. because of higher electricity prices – this approach may underestimate the effects of the EU ETS on greenhouse gas emissions.

This procedure will be exemplified with the calculation of the impact of the EU ETS on dispatching in Germany (see Section 4.6) based on a simulation with the PowerACE model. Due to the long lead times for the planning and construction of new power plants it can be safely assumed that the ETS had no impact on the structure of the power plant portfolio itself in the first period. Therefore the central impact of ETS in the power sector in the first period is the change in plant dispatch caused by higher generation cost for CO_2-intensive generation technologies. The PowerACE model is capable of simulating plant dispatch on an hourly level for an entire year. It combines detailed data on power plants, renewable electricity generation, fuel prices and CO_2 prices to calculate plant dispatch, market prices and CO_2 emissions. As hourly plant dispatch is crucial for the calculation of emissions in the electricity sector the high level of detail is necessary in order to obtain reliable results. In addition the model proceeds through a multi-agent simulation which allows the market behaviours of actors to be modeled on the electricity markets. At present no models exist at that level of detail at the European level. This is why the impact evaluation with PowerACE is limited to Germany. Models currently used for the ex-ante impact assessment of the EU ETS such as PRIMES are only calculating at five-year intervals. In the longer term, investment decisions need to be included in the evaluation. In order to carry out such an integrated analysis it is advisable to combine several models: A plant dispatch model (e.g. PowerACE), a model for the diffusion of renewable electricity generation (e.g. PowerACE RESINVEST or GreenX) and a model the development of the conventional power plant portfolio (e.g. Balmorel, TIMES, MARKAL...). The combination of these model types could provide additional insights into the interaction of renewable support schemes and ETS over different time scales.

b) Econometric approach for the industry sector[56]

Using econometric techniques, the EU ETS may be evaluated based on observed (rather than implied or imposed) behaviour. An econometric approach should only be used if sufficient data is available and if the regression equations are well specified. In particular, misspecification tests should be conducted to assess the appropriateness of the underlying econometric model from a statistical perspective. This approach is best suited for the industrial sector. To estimate the savings in emissions associated with the EU ETS, the following steps would have to be carried out.

Step (i): Output Effect. Start with Verified Emission Table (VET) data from the CITL for year 't' for sector 'i' and multiply verified emissions with observed growth rate for t+1 of industry sector (implicitly assuming that growth in ETS installations is the same as in non-ETS installations within a particular sector.[57] Using observed growth and starting from VETs means that the data reflects the impact of all drivers on emissions. That is, the impact from other policies – including those on demand – is also taken into account). This yields the *counterfactual accounting for output changes* – see also Figure 4-2.

Step (ii): Demand-induced Emission Reduction Effect. If the EU ETS resulted in an increase in product prices (because of direct and indirect effects on costs) demand would decrease in response to higher prices, resulting in lower greenhouse gas emissions in the sector considered.[58] There are several reasons why demand declines including

(a) substitution by other products (substitutes) within the EU,
(b) substitution by the same products produced outside the EU, or
(c) a lower demand in general because of efficiency improvements or because the product is no longer needed (sufficiency argument).

Note that only (c) would actually lead to a full reduction in emissions, while (a) may result in higher emissions in other sectors within the EU ETS or outside the EU ETS, or in other regions (leakage). To capture the demand reduction effect, results from Step (i) need to be corrected for demand changes in response to higher output prices because of the EU ETS. For this adjustment, estimates for the price increase in the product due to the EU ETS (i.e. direct and indirect effects!) and for the price elasticity of demand for the product produced domestically would have to be available. Such estimates, however, are rarely at hand. As a first step one may rely on estimates from studies, such as IEA (2005)[59]. Besides, one needs to decide whether increases in average costs or marginal costs are most appropriate. Likewise, in the case of free allocation, the use of actual financial outlays or of opportunity costs would lead to quite different outcomes. From a theoretical perspective (and if markets were perfectly competitive), the appropriate measure for the price increase would be the increase in marginal costs (using the opportunity costs concept). In general though, the adequate measure is likely to depend on market structure, sectors and countries. Multiplying the price increase due to direct and indirect carbon cost effects (in percentage) by the price elasticity would then yield an estimate for the reduction in demand (in percentage). This step yields the *counterfactual accounting for demand-induced emission effects*.[60]

Step (iii): Autonomous Technical Change Effect. Adjust the outcome from Step (i) by autonomous technological change; in the econometric approach the impact of autonomous technological change will be derived from econometric analyses. In particular, we may estimate the following regression equation based on time series data for a particular sector:

$$(1) \quad emissions(t) = \beta_0 + \beta_1 TREND + \beta_2 production(t) + \sum_i \sum_j \beta_{3ij} fuelprice(i,t-j) + \varepsilon(t)$$

56 For the power sector, data requirements would be prohibitive. For example, VET data does not distinguish between particular power technologies. Likewise, it would be difficult to adequately reflect the impact of national policies, which are the main driver for the type of power generation in a country, based on time series analyses.
57 These figures may have to be adjusted across years, to reflect changes in the scope of the ETS Directive, also reflecting the opt-in and opt-out of installations (e.g. UK in phase 1).
58 We implicitly assume that production and demand are harmonized, i.e. produced quantities equal demand (no storage). Unlike for electricity, for industrial goods, this assumption may not always hold. Likewise, we abstract from "indirect effects" of higher product prices on emission elsewhere including in other domestic sectors or abroad (e.g. carbon leakage).
59 It should be recognised though, that estimates on cost increases and demand elasticities vary across regions and methods applied and that obtaining reliable estimates may be challenging.
60 Since in the short run, demand tends to be less responsive than in the long run, short-run elasticities are usually lower (in absolute terms) than long-run elasticities. Hence, using short-run elasticities may underestimate the effectiveness of the EU ETS.

where *emissions(t)* stands for the level of emissions at time 't'. TREND reflects a trend and is supposed to capture autonomous changes in emissions. The variable *production(t)* stands for the production level in that particular sector at time t, $fuelprice(i,t-j)$ captures the impact of the price of fuel type 'i' at time t-j and hence price induced changes in emissions (including fuel switch). In general, since companies may not be able to react instantaneously to changes in fuel prices, lags of length j may be included, provided there are sufficient observations available (i.e. sufficient degrees of freedom). To the extent that fuel prices include energy taxes, the impact of energy taxes is captured. Finally, ε is an error term usually added in econometric analyses, capturing non-systematic effects. In the simplest case, there is only one type of fuel used in the sector[61]. If the depend and the explanatory variables – except for TREND - enter equation (1) in logarithmic form, the parameter estimates may conveniently be interpreted as elasticities. That is, they capture the percentage change in emissions, if the explanatory variable changes by one percent.

Alternatively, the following equation may be estimated, which captures the development of carbon-intensity in a particular sector[62]:

$$(2) \quad specificemissions(t) = \alpha_0 + \alpha_1 TREND + \alpha_2 specificemissions(t-1) + \sum_i \sum_j \alpha_{3i} fuelprice(i,t-j) + \mu(t)$$

where *specificemissions* is just the ratio of emissions to output at time t in a particular sector. Now, TREND reflects autonomous effects on specific emissions, and *fuelprice* reflects all changes in specific emissions related to changes in fuel prices. Including the lagged endogenous (i.e. left-hand-side variable) as an explanatory variable (right-hand-side variable) captures the fact that because of technological (and possibly other) constraints, actual specific emissions may be explained by the level of specific emissions of the previous year. Specification (2) allows distinguishing between short-run and long-run effects. More specifically, short-run effects of fuel i are captured by α_{3i}, while long-run effects are calculated by dividing short-run elasticities by 1-α_2,

If data on emissions or on specific emissions was not available, data on fuel use, which is available, e. g. from the IEA, may be used as a proxy instead.

The parameter estimate on TREND may be applied to correct for the impact of autonomous technological change, which then yields the *counterfactual accounting for technological change*.

Alternatively, or when lack of data prevents an econometric approach, an estimate for autonomous technological change may be obtained from judgements by technology and sector experts.

Step (iv): Effects of other policies. To account for the impact of other (domestic) policies leading to lower carbon emissions in the sector (e.g. fuel taxes; subsidies for audit programs) the carbon impact of these measures would have to be subtracted. Otherwise, the impact of the EU ETS would be overstated. This step yields the *counterfactual accounting for policy linkage effects*.

Step (v): *Fuel Cost Effect*. Adjust outcome from Step (iv) to account for the impact of fuel prices on carbon intensity. To do so, the actual values for fuel prices need to be plugged into equation (1) or (2). For example, using a log-log specification of equation (2), the percentage change in carbon intensity attributable to the effect of the price of fuel i with lag 0, would then be obtained by first multiplying the growth rate in the fuel price by the parameter estimate for α_{i0} and then multiplying this product by the outcome of Step (iv). The outcome of this step may be termed *counterfactual accounting for fuel cost effects*, where the term only refers to actual abatement measures compared to emission savings induced by demand reductions as outlined in Step (ii). To get an estimate for the savings attributable to abatement measures induced by the EU ETS, observed emissions from the verified emissions table (VET) for the year t need to be subtracted from the *counterfactual accounting for fuel cost effects.*

Alternatively, the Step (v): Fuel Cost Effect. Compare actual VET data for t+1 with result from Step (vi) (*counterfactual*). The difference between both figures may be explained by changes in energy costs

61 For parsimony, and if the time series is limited, it may be useful to confine the set of fuel prices to the type of fuel used most intensively in the industry sector. If such data is not available, the oil price may be used as a rough proxy, keeping in mind that the development of the price of oil and of other fuels may not always be aligned.
62 Using specific emissions saves degrees of freedom, which – given the short time series – may be an important aspect.

and carbon costs, i.e. by the impact of the EU ETS. One rule for dividing up this difference would be the relative cost share of energy costs versus carbon costs[63]. The latter may be calculated by multiplying VET emissions by the average price of EUAs (i.e. using the concept of opportunity costs concept). Also, indirect effects of the ETS on energy costs via higher electricity prices would have to be taken into account.

To sum up, the methodology for calculating the counterfactual consists of the following building blocks:

(1) growth rate in sector production (*output effect*)

(2) demand reduction in response to increased output prices induced by EU ETS (*demand-induced emission reduction effect*)

(3) change in carbon intensity unrelated to policy or input price effects (*autonomous technical change effect*)

(4) change in emissions resulting from other policies (*policy linkage effect)*

(5) change in carbon intensity induced by fuel costs (*fuel cost effect*).

Using growth rates, the development of the counterfactual to calculate the demand-induced emission reductions, respectively, may be expressed as:

$$\text{(3a)} \quad \begin{aligned} &\textit{counterfactual emissions for demand effect} = \\ &\quad (VET - emissions) \\ &\quad *(1 + demand - induced\ emission\ reduction\ effect) \\ &\quad *(1 + autonomous\ technical\ change\ effect) \\ &\quad *(1 + policy\ linkage\ effect) \\ &\quad *(1 + fuel\ cost\ effect) \end{aligned}$$

The demand-induced emission reduction effect (indirect effect) may then be calculated as the difference between the counterfactual in (3a) and the counterfactual accounting for output growth. Ideally, the difference should be corrected for the effects of autonomous technical change, policy linkage and fuel costs, since the demand-induced emission changes would have been subject to these effects.

And for the counterfactual emissions to calculate the direct effect:

$$\text{(3b)} \quad \begin{aligned} &\textit{counterfactual emissions for direct effect} = \\ &\quad *(VET - emissions) \\ &\quad *(1 + output\ growth) \\ &\quad *(1 + autonomous\ technical\ change\ effect) \\ &\quad *(1 + policy\ linkage\ effect) \\ &\quad *(1 + fuel\ cost\ effect) \end{aligned}$$

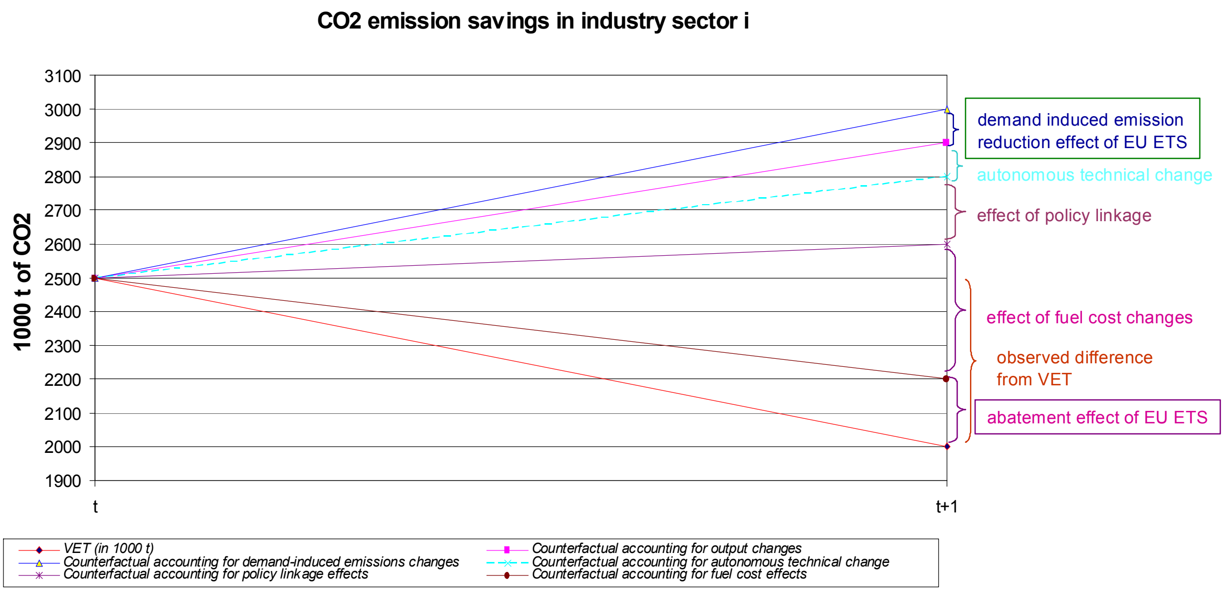
Results: The *direct effects* of the EU ETS in the year t may then be quantified by comparing the counterfactual with emissions in the VET. An estimate for the *indirect effects* of the EU ETS may be obtained by multiplying the change in demand from Step (ii) (in terms of the growth rate) with the *counterfactual*.[64] It should be pointed out again, when using the econometric approach, particular care needs to be given to the model specification. Findings need to be interpreted in the light of data availability and the quality of econometric results.

Further, since the proposed methodology calculates the direct effects of the EU ETS as a residual, it implicitly assumes that all other mechanism resulting in a reduction of greenhouse gases have been

63 Alternatively, rather than using absolute cost levels, the difference may also be split according to changes in energy versus carbon-related costs. However, this approach may fail, if energy or carbon prices drop.
64 If reliable data was available, actual carbon intensity in t may be multiplied by the change in production induced by the demand effect to quantify the demand effect in terms of emissions.

captured. Also, the approach primarily accounts for measures which quickly translate into greenhouse gas emission reductions, in particular fuel switch. The effect of abatement measures which – because of lead times – result in lower future emissions would then also show up as emission savings attributed to the EU ETS in the future.

Figure 4-2: General methodology for the econometric approach for the industry sector



4.3 Step 1: Mapping of the ECCP measure EU ETS

Table 4-2 maps the different policies that may interact with the EU ETS. As described above and as evident from the table, there are many interactions with policies which cannot be reasonably described in detail individually. This is the main reason to design procedures as described above which combine such policy interactions into the counterfactual.

In principle, all policies and measures affecting supply and demand of the output produced by installations covered by the EU ETS interact with the EU ETS. This interaction may be direct or indirect. Direct interaction refers to policies directed at the same installations as those covered by the EU ETS (double regulation). Examples are energy/carbon taxes, voluntary/negotiated agreements or support mechanisms for CHP. Indirect measures reduce demand for products from ETS installations and thus indirectly lead to lower emissions in the ETS sector. Of particular relevance are policies affecting final energy demand such as the Energy Efficiency and Energy Services Directive or the EU labelling scheme for household appliances, but also energy taxation. In principle, the (estimated) impact of these policies on ETS installations via direct or indirect interaction would have to be taken into account when deciding on the size of the ET-budget. Since the EU ETS only covers energy installations exceeding a certain threshold, not all power producers would be affected from a tax on electricity, for example. Likewise, ambitious standards for thermal insulation would only be relevant to the extent that demand of district heating from instillations covered by the EU ETS is reduced. Support schemes for renewable energy sources may have similar effects. For example, under the German Renewable Energy Act (employing feed-in tariffs), grid operators are forced to feed the electricity generated by certain RES-E technologies into the power grid and to remunerate it at preferential tariffs. Hence production from other installations, notably from fossil fuel-based installations is crowded out, resulting in lower carbon emissions from power generation. In the future, some RES-E technologies may directly compete with fossil-fuel power technologies, if production costs for RES-E continue to decrease and if carbon prices are sufficiently high.

Table 4-2: Measure mapping of the EU ETS

MEASURE	TARGET	GOAL FOR TOP-DOWN IMPACT
ECCPx		
EU ETS Phase 1 (2005-2007) Phase 2 (2008-2012) Phase 3 (2013-2020) (proposed)	**GHG emissions of large installations from energy and industry**	-21% compared to verified emissions in 2005 by 2020 (more ambitious if international Post Kyoto agreement can be achieved)
Complementary financial measures		
Energy taxes	**primary/final energy use**	
Support schemes for renewables (power and heat)	**deployment of RES**	
Support schemes for CHP	**deployment of CHP**	
Subsidised credits for energy efficiency measures (SMEs)	**final energy**	
White certificate trading schemes	**final energy**	
Command and control Technology standards Building codes		
Technology promotion R&D networks R&D subsidies		
Informational measures Labelling Subsidies for energy audits (SMEs) Climate tables / networks Information and awareness campaigns		
Voluntary agreements Industry association and national government/EU		

4.4 Step 2: Compilation of quantitative evaluation evidence

In the first phase, incentives to reduce emissions were low since the ET-budgets turned out to be rather lenient, resulting in low prices for EUAs. Until the verified emissions for 2005 of the installations participating in the EU ETS were made public in April/May 2006, the price for EUAs was up to around 30 € per EUA but afterwards crashed down to almost zero towards the end of phase 1[65]. According to Kettner et al. (2008), the market was long, with 95 (50) million tonnes in 2005 (2006), corresponding to 4.5% (2.4%) of the allocated allowances.[66] Since the emission level in the absence of the EU ETS cannot be determined (it is counterfactual), the real extent of possible over-allocation cannot be determined. Ellerman and Buchner[48] tentatively suggest that a substantial part of the surplus may have resulted from abatement activities. According to a survey conducted among participants by Point Carbon (2007), 65% of respondents initiated internal abatement projects in 2006. Nevertheless, the surplus of EUAs and the correspondingly low price provided little additional incentive to improve energy and carbon efficiency in phase 1. Together with high uncertainty about governments' commitment to long-term targets, this meant that firms were not strongly motivated to develop energy-efficient and low-carbon technologies and services in phase 1. For phase 2, emission budgets turned out to be significantly tighter, but only because the European Commission decided to apply more stringent criteria for the size of the ET budgets[67]. Forward prices for phase 2 ranged around 25 € per EUA until the early Autumn of 2008. In the wake of the current economic crisis, forward prices dropped to under 10 € per EUA in 2009.

65 EUAs had no value at the end of phase 1 since they were not allowed to be transferred in phase 2 (i.e. no banking).
66 Estimates are based on installations where data on both allocated EUAs and verified emissions were available for both years.
67 Betz et al. 2006

4.5 Step 3: Screening

In the procedures described above the screening step is not relevant given the fact the concurrent measures are not modelled individually but as the sum of their impacts.

4.6 Step 4: Modelling step

In this step procedure a) is exemplified by an analysis with the PowerACE model of the impact of dispatching in the German power sector as a consequence of the EU ETS price signals. Procedures b) and c) as outlined above will be exemplified for the German cement sector, respectively clinker production.

a) Evaluation based on the PowerACE model for the power sector in Germany (impact of dispatching)

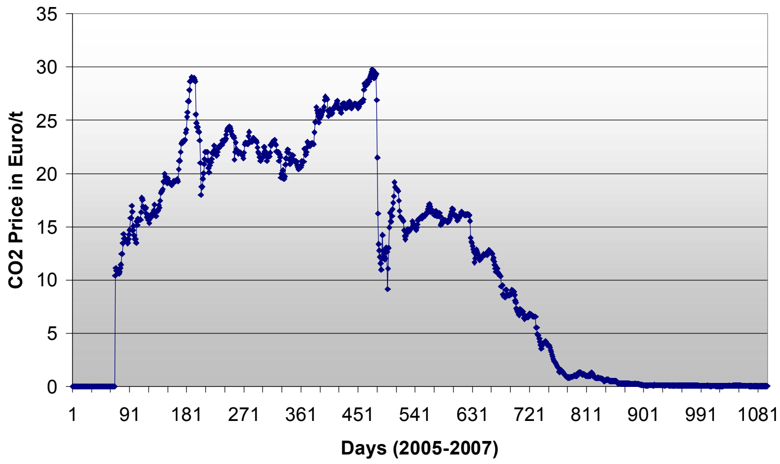
Methodology:

- PowerACE Simulation platform
- Dispatch according to variable cost and start up cost
- CO_2 price is included into variable generation cost for all fuels

Simulation with CO_2 price of zero and the actual daily CO_2 price (

- Figure 4-3)

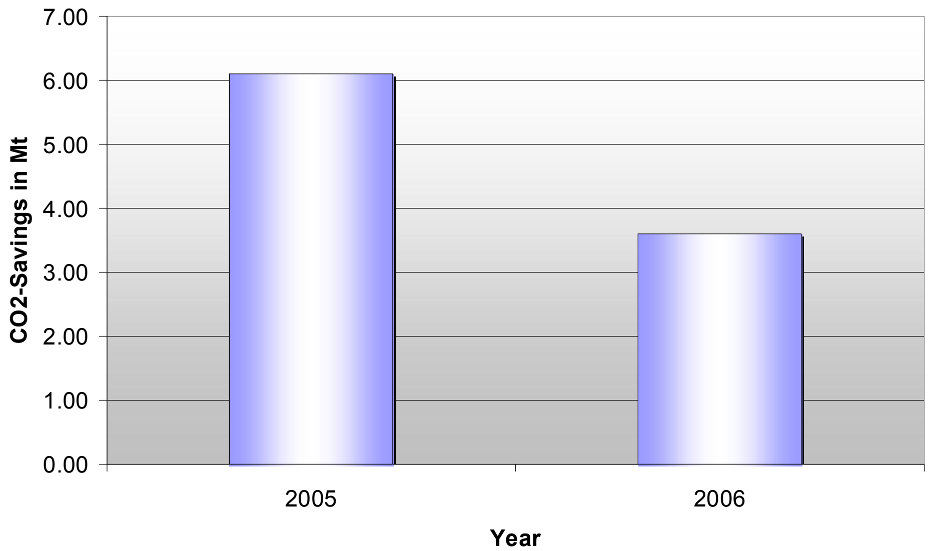
Figure 4-3: Development of EU ETS prices used for the simulation with PowerACE



Results of the PowerACE model for Germany:

- Savings: 2005 max. 6.1 Mt
- Savings: 2006 max. 3.6 Mt

Figure 4-4: Impacts of the EU ETS on the power sector in Germany



Source: Own calculations with PowerACE

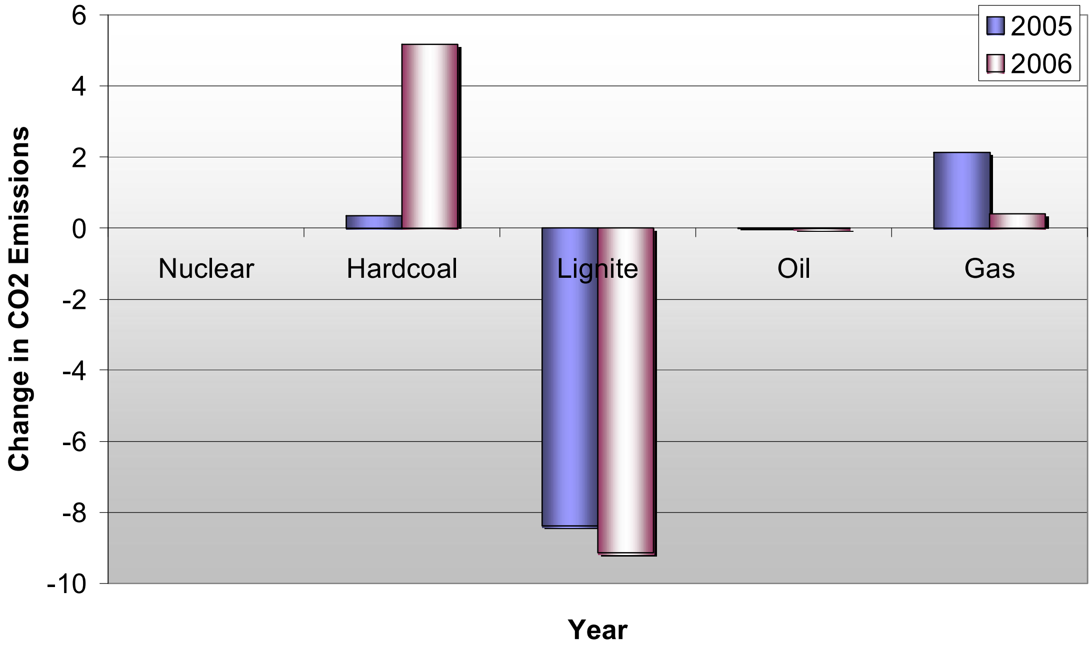
Analysis of the fuel switch:

- 2005: Mainly switch to gas

2006: Mainly switch lignite to hard coal (Reason: Increasing gas prices in 2006, slight decrease in hard decrease in hard coal prices in 2006, see

- Figure 4-5)

Figure 4-5: Change in CO_2 emissions from the power sector in Germany 2005 and 2006 due to the EUETS (in Mt CO_2)



Source: Own calculations with PowerACE

b) Econometric approach for cement sector in Germany

<u>Step (i):</u>
To calculate the *counterfactual accounting for output change* for 2006 we multiply observed emissions from the verified emissions tables (VET) for clinker production in 2005 (i.e. around 20,066 kt of CO_2) with the observed growth rate of 2.62% for clinker production in Germany (provided by the annual report of the German association for the cement industry, BDZ Jahresbericht 2006-2007). Accordingly, clinker production increased from 24,315 kt in 2005 to 24,952 kt in 2006, i.e. yielding a matching growth rate of 2.62%. Neglecting other factors such as fuel-price and ETS-effects, projected emissions from ETS clinker production for 2006 would then have been 20,591 kt of CO_2. (= 20,066*1.0262). See also Figure 4-7 and the results in Table 4-3.

<u>Step (ii):</u>
To calculate the impact of the carbon costs on demand, we use the figures provided by IEA 2005. There, the increase in direct and indirect costs for the production of cement is estimated at 18.6 % for a price of 10 Euro per EUA. Since average prices for EUAs in 2006 were around 15 Euro[68], the resulting increase in average price would be 28%[69]. Using the figure for the price elasticity of -0.27[70],

68 Using transaction volume weighted settlement prices for 2006 from the EEX spot market or from the ECX market, the average price for EUA in 2006 is just slightly under 16 Euro per EUA. Of course, participants may react to daily prices or to future prices of EUA rather than to average annual prices. Once banking is allowed, though, difference between future and current prices should only differ by the „cost of carry“
69. Compared to marginal production costs, the percentage increase for the given EUA price would be significantly higher. Estimates reported in Graichen et al. (2008), Smale (2006) or Ponssard and Walker (2008) range around 70-80%.

and assuming that the industry passes through the entire cost increase, demand would decrease by 7.53%. Rather than assuming a 100% pass through of additional costs, we use a figure of 50%, which translates into a reduction in demand of -3.77 percent. Hence, without the partial cost pass through, demand for clinker would have been 3.77 % higher in 2006. Clearly, the higher the pass through rate and the higher the elasticity of demand (in absolute terms) the larger are demand induced reductions in greenhouse gases due to the EU ETS. In terms of emissions, the *counterfactual accounting for demand induced emissions changes* is then 21,367 kt of CO_2 (= 20,591*1.0377). **It should be highlighted, however, that both the figures for the price elasticities and the assumptions on the cost pass through are highly uncertain due to a lack of empirical data**. **As the issue is highly sensitive (delocalisation of industrial companies from Europe; carbon leakage issues), the results need to be carefully debated and presented**. However, not accounting for these indirect effects, may underestimate the impact of the ETS.

In the absence of empirical data, one important element to judge on the possibilities of companies to react is the competitive position of the respective branch as well as the possibility to pass on CO_2 prices to the market. This issue is briefly touched upon in the next section.

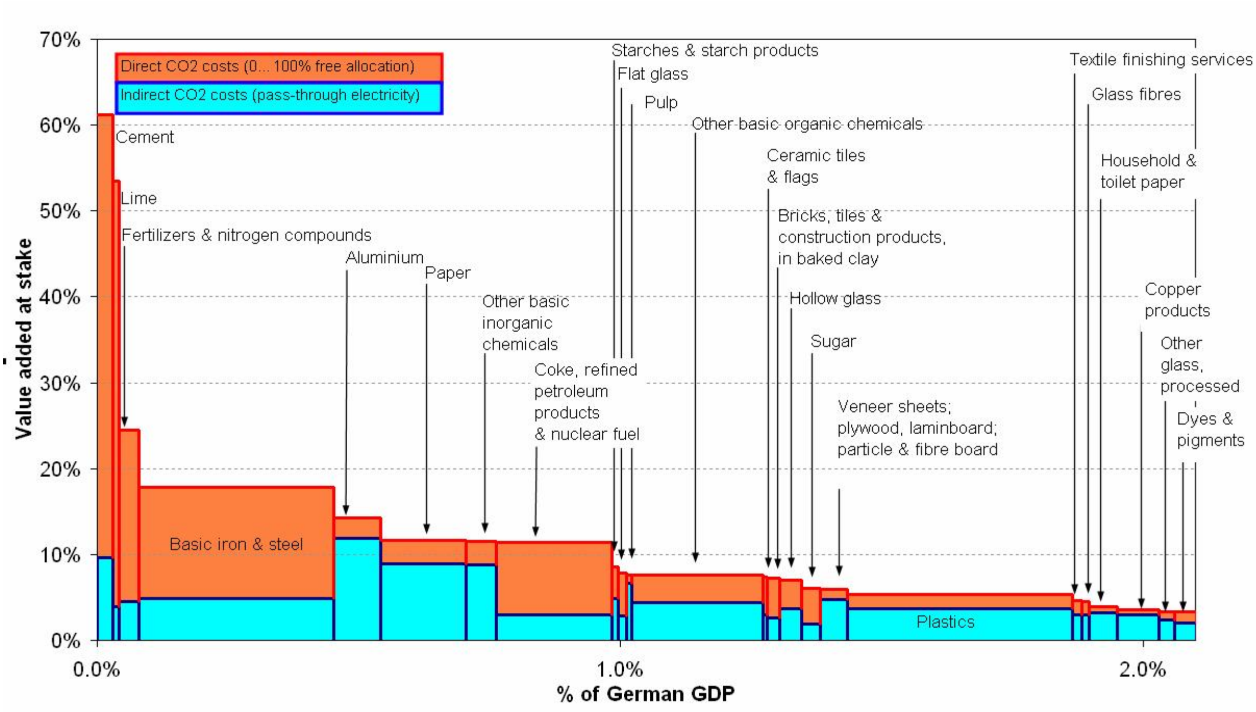
Figure 4-5 shows the impact of CO_2 prices on the value at stake in different branches. The sector with the highest impact on the production cost is the cement sector followed by oxygen steel, electric steel some chemicals and the refineries. In order to judge on the results it is also important to realise that the Dollar/Euro parity has changed by 40% between 1998-2005, i.e. the exchange rate can have a much larger impact on the international competitiveness than the Emission Trading Scheme. Another way to look at the international competitiveness context is the trade intensity (Figure 4-6).

Possible measures to impede carbon leakage are discussed, among others, in Öko Institut, Fraunhofer Institute, DIW (2008) and are summarised here briefly:

- Adjustment measures at the border: hard to implement in practice, raise opposition in other industries within EU (e.g. manufacturing sector), WTO compatibility? Developing countries' reaction?
- Free allocation for direct carbon effects: does not address indirect effects of carbon costs; only effective for new projects; subsidy;
- Free allocation for indirect emissions: need acceptable country-specific rules, reduces transparency of the EU ETS, at odds with fundamental principle of EU ETS; only effective for new projects; subsidy;
- Free allocation to power producers for long-term supply contracts in return for lower power prices to industry customers; splits the power market; consistent with EU electricity market objectives? Reduces transparency because country-specific rules to determine the amount of free allocation needed; enforcement costs; not necessarily in power producers' best interest;
- Direct compensation for indirect (and also direct) carbon costs based on hardship rule: reverses burden of proof; state aid issues?
- Most measures may only be implemented at sectoral/sub-sectoral level (intra-sectoral distortions?);
- No perfect measures; what is the real driver for political debate: carbon leakage or competitiveness?

70 This figure is provided by La Cour and Mollgaard (2002) and is based on data for the Danish cement industry. Primarily because reliable estimates for elasticities are rare, this figure has usually been used in the literature, including IEA (2005) or Ponssard and Walker (2008). Smale et al. (2008) use an estimate of 0.8 for the demand elasticity of cement in the UK. Since compared to the UK only a relatively small portion of the cement production is subject to leakage (only few sites are close to a port), a rather low value for the demand elasticity may be reasonable. Also, cement is not traded very heavily in Germany (see e.g. Graichen et al. 2008).

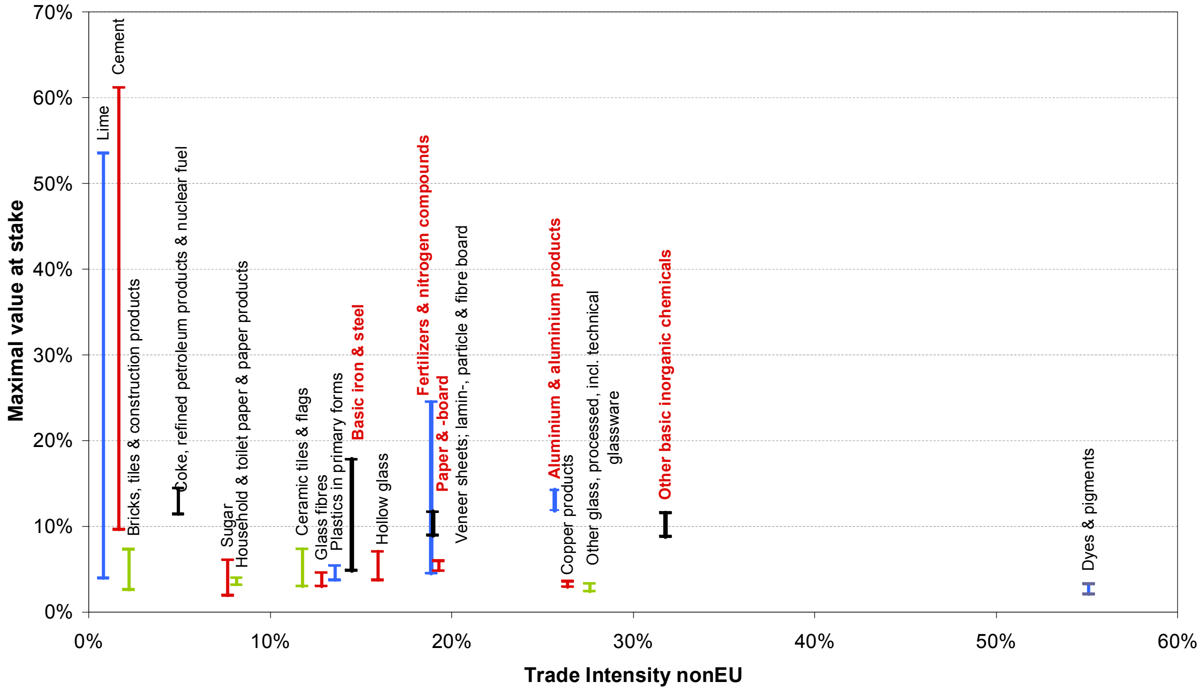
Figure 4-6: Impact of Emissions Trading on value at stake – Germany



Price increase assumptions: 20 €/t CO2; ca. 20 €/MWh

Source: Öko Institut, Fraunhofer Institute, DIW

Figure 4-7: Trade intensity and value at stake – Germany



Source: Öko Institute, Fraunhofer Institute, DIW

Step (iii):

To quantify the effects from autonomous technological change and from fuel-price induced developments, several econometric analyses are conducted. To explore the robustness of the results we varied the independent variables and also the sets or explanatory variables. For all regressions presented, specification tests (e.g. for autocorrelation, normality) did not indicate specification problems. In the first regression, the dependent variable is the sum of energy-related and process-related specific CO_2 emissions in t CO_2/t clinker. Results of the regression are displayed in Table 4-3).

Table 4-3: Estimation results for specific total CO_2-emissions in clinker production in Germany (standard errors below parameter estimates)

Log-log	Specific CO2-emissions (total)
	Prais-Winsten
Trend	-0.010 **
	0.004
Oilprice (t)	-0.128 *
	0.062
Constant	0.516 *
	0.286
Adjusted R^2	0.65
Sample size	15
F-value	14.11
Durbin-Watson	1.61

*** indicates statistical significance at 1% level
** indicates statistical significance at 5% level
* indicates statistical significance at 10% level

Data on energy-related emissions was taken from the ENERDATA database, and process-related emissions were taken from the UNFCCC inventory for cement. Explanatory variables are the price of light sulphur oil for industry (in 2000 Euros per t). Oil prices were taken from the IEA ENERGY PRICES & TAXES (several volumes) and deflated by the producer price index for manufacturing provided by the OECD. Since the data on oil prices includes the impact of mineral oil taxes (including the eco tax), the impact of the major policy interaction in Germany for the industry sector is accounted for. Sales taxes are not included since companies get reimbursed for those. The dependent variable and oil price variables enter in log form, hence parameter estimates reflect elasticities. Id est, a one percent increase in the (tax included) price of oil leads to a decrease in specific fuel emissions of 0.128%.[71] The parameter estimate for the trend suggests that autonomous technological change results in an annual decrease in specific emissions of 1.0%.[72]

In the second regression the lagged oil price is included as an additional regressor. Compared to the first regression the goodness of fit – as reflected by the (adjusted) R^2 has improved – but the trend and contemporaneous oil prices are no longer statistically significant at conventional levels, the signs however are, as expected, negative.

[71] This approach also implies that lower fuel prices would then result in higher emissions. In practice, this may be quite likely when it comes to fuel switch in the cement sector, it would not be comprehensible for measures involving high investments and long lead times. Once a technology is implemented, it will not be reversed in response to (potentially temporary) changes in fuel cost (i.e. asymmetric response to fuel costs is realistic)..
[72] Including only a trend variable in their analysis Böhringer and Frondel (2002) estimate annual improvements in energy efficiency as 0.63 %.

Table 4-4: Estimation results for specific CO_2-emissions in clinker production in Germany (standard errors below parameter estimates)

Log-log	Specific CO2-emissions (total)
	Prais-Winsten
Trend	-0.007
	0.005
Oilprice (t)	-0.132
	0.073
Oilprice (t-1)	-0.092 *
	0.071
Constant	0.961 **
	0.428
Adjusted R^2	0.76
Sample size	14
F-value	14.77
Durbin-Watson	1.72

*** indicates statistical significance at 1% level
** indicates statistical significance at 5% level
* indicates statistical significance at 10% level

Finally, since coal (rather than oil) is the main fossil fuel input in cement clinker production in Germany, we ran a third regression, using real coal prices (available from the Federal German Ministry of Economics) rather than oil prices as explanatory variables. Also, we used specific fuel input rather than total emissions as the dependent variable. To capture technological sluggishness, we also included the lagged values of the independent variable as regressors. Results of this third regression are presented in Table 4-5[73]. Accordingly, annual autonomous technological change reduces specific fuel consumption by about 2%. In terms of total CO_2-emissions however, this would only amount to about 0.5%, since coal prices may only affect fuel-related emissions, which only account for about ¼ of total carbon emissions in the production of cement clinker in Germany. About ¾ stem from process-related emissions. Since – unlike oil prices – coal prices decreased in 2006 compared to 2005, it seems more appropriate to use regression results based on the prices of the fossil fuel input actually used primarily in clinker production, i.e. coal.

To sum up, in light of these results it seems reasonable to assume that autonomous technological change results in annual specific emission reductions of about 0.5% to 1%.

73 Regressions using specific emissions did not pass specification tests.

Table 4-5: Estimation results for specific fuel use in clinker production in Germany (standard errors below parameter estimates)

Log-log	Specific fuel consumption
	Prais-Winsten
Trend	-0.021 *
	0.247
Spec_fuel (t-1)	0.681 **
	0.247
Coalprice	-0.155
	0.230
Constant	-0.123
	0.811
Adjusted R^2	0.85
Sample size	15
F-value	28.47

*** indicates statistical significance at 1% level
** indicates statistical significance at 5% level
* indicates statistical significance at 10% level

Using the conservative value of 0.5% for annual autonomous technological change, *the counterfactual accounting for technical change* then amounts to 20,488 kt of CO_2. (=20,591*(1-0.005)).

Step (iv): Other policies affecting greenhouse gas emissions in the production of clinker in Germany could not be identified.

Step (v):
To adjust the outcome from Step (iii) for the impact of fuel prices on carbon intensity we first multiply the (negative) growth rate in the carbon price by our estimate for the (short-run) carbon price elasticity of fuel intensity, i.e. by 0.155.[74] We use the coal prices for industry in Germany in 2005 and 2006 provided by the Federal German Ministry of Economics. Accordingly, the percentage change in carbon intensity attributable to fuel price changes is 1.27 percent[75]. We then divide this figure by four, since fuel-related emissions only account for about ¼ of total carbon emissions in clinker production in Germany. This outcome is then multiplied by the counterfactual emissions from Step (iii). Hence, the resulting *counterfactual accounting for fuel cost effects* is then 20,548 kt of CO_2. (=20,488*(1+0.31)).

An alternative approach to distinguish fuel-price effects from carbon-price effects is presented below.

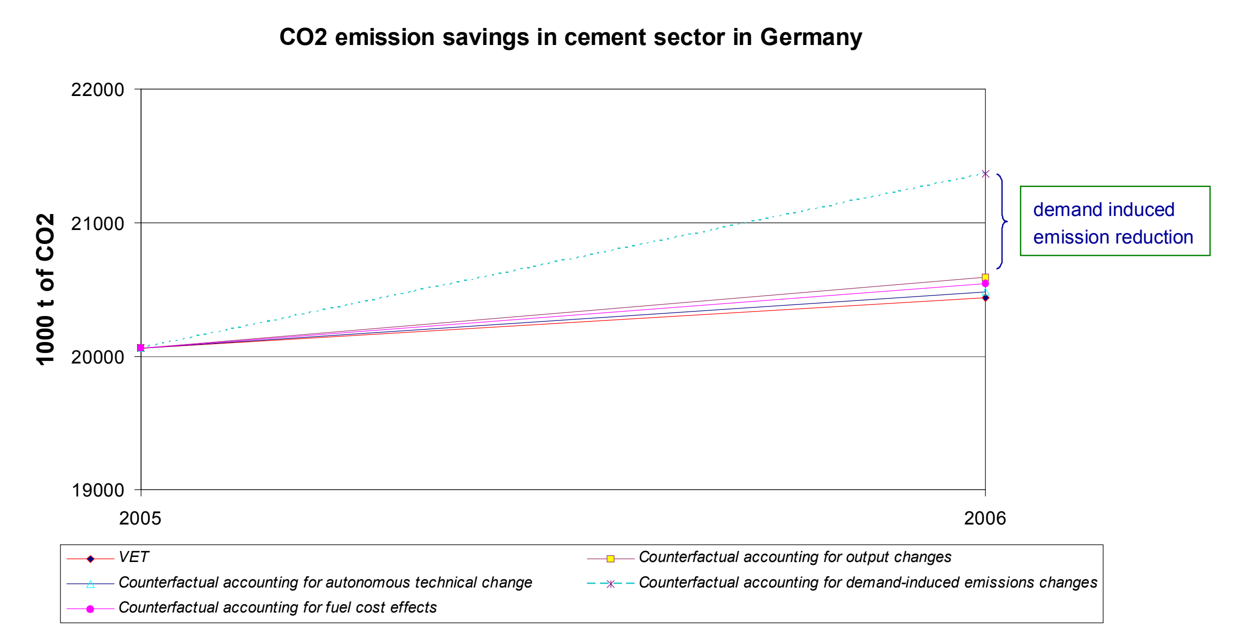
Results
Finally, subtracting the *counterfactual accounting for fuel cost effects* from VET data for 2006, the implied direct savings from the ETS are calculated as 115 kt of CO_2 corresponding to 0.56% (compared to counterfactual).[76]

74 The long-run coal price elasticity would be $\frac{0.155}{(1-0.681)} = 0.486$

75 Note that the sign is positive, since coal prices in Germany were lower in 2006 than in 2005.
76 It should be noted though that in principle, this approach may also lead to calculated negative direct emission reductions", in particular if the regression results imply large autonomous change or fuel price effects.

The indirect effects are estimated to be 774 kt of CO_2 corresponding to 3.64% of the counterfactual[77]. Thus, the indirect effects of the EU ETS on carbon emissions in the cement sector are estimated to be substantially higher than the direct effects. This can also be seen in Figure 4-8.

Figure 4-8: CO_2 emission savings in the cement sector in Germany due to the EU ETS



77 To calculate this figure, the effects of autonomous technological change and of fuel costs were taken into account. Otherwise, the demand-induced emission reduction effect would be (slightly) overstated.

Table 4-6: Results for the impact of the EU ETS for the German clinker production

		Unit	2004	2005	2006
Step (i)	**Emissions from Verified Emissions Tables**	1000t		**20066**	**20433**
	Observed growth rate in emissions	%			1.83%
	Clinker production	1000t		24315	24952
	Output growth rate	%			2.62%
	Counterfactual accounting for output changes				**20591**
Step (ii)	Price elasticity of cement demand	%			-27.00%
	Increase in costs for cement (opportunity costs)	%			27.90%
	Change in demand (full pass through)	%			-7.53%
	"Realistic" pass through	%			50.00%
	Change in demand (realistic pass through)	%			-3.77%
	Counterfactual accounting for demand induced emission re	1000t			**21367**
Step (iii)	Autonomous technological change	%			-0.51%
	Counterfactual accounting for technical change	1000t			**20485**
Step (v)	Change in fuel intensity (fuel cost induced)	%			1.27%
	Change in carbon intensity (fuel cost induced)	%			0.31%
	Typical share of carbon costs to sum of fuel and carbon costs	%			
	Counterfactual				**20548**
Results	**Implied savings from direct ETS effects**	**1000t**			**115**
	as share of counterfactual	%			0.56%
	Implied savings from indirect ETS effects	**1000t**			**774**
	as share of counterfactual	%			3.64%

Aside: Alternative approach to distinguishing fuel price effects from the cost effects induced by the EU ETS.

Alternative Step (v): To separate the effects on emissions induced by fuel costs and carbon costs, the difference between *counterfactual gross of policy/fuel price induced changes* from Step (iii) and emissions from the VET are split according to relative cost share of fuel costs versus carbon costs. For the German cement sector, estimates for these figures are taken from UBA (2007), which in turn also relies on data from IEA (2005). Accordingly, using the average price for EUAs in 2006 of about 15 Euro, the share of carbon costs would be about 45%. Hence, the difference is split at a ratio of 45 to 55.

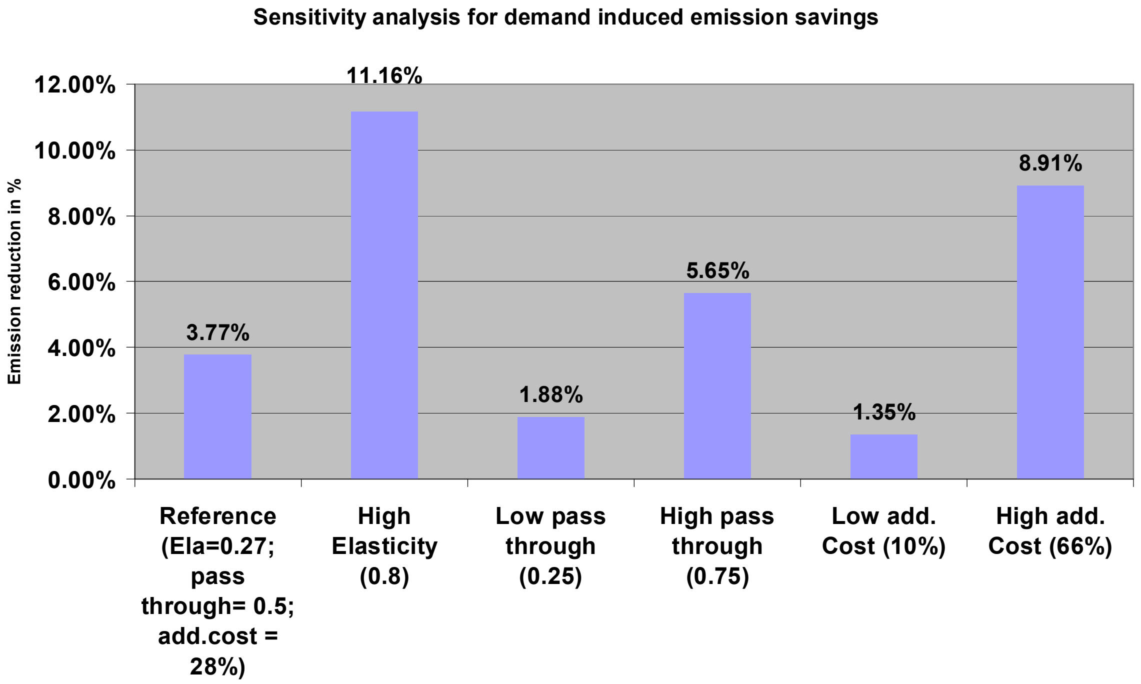
Alternative Results

Finally, subtracting the *counterfactual without ETS induced savings* from VET data for 2006, the implied direct savings from the ETS are calculated as 25 thousand tons of CO_2 corresponding to 0.12% (compared to counterfactual). The indirect effects are estimated to be 772 thousand tons of CO_2 corresponding to 3.63% of the counterfactual. Thus, the direct effects using procedure c) are somewhat lower than those calculated based on procedure b), but overall results are quite similar (Table 4-6) and appear "realistic" given that prices for EUAs were high only until May 2006. Thus, in response to these prices, companies are likely to have carried out carbon saving measures, in particular fuel switch (i.e. burning biomass rather than coal). Likewise, the observed savings may – at least to some extent – also be the result of measures induced by the EU ETS, which were decided on during 2005 but which have only become effective in late 2005 or in 2006.

Sensitivity analyses

To illustrate the impact of the various blocks on indirect (i.e. demand-induced) and direct emission reductions, the values for the key parameters are varied. Figure 4-9 shows the results compared to the reference case presented in Table 4-6. Figure 4-9 shows the elasticity of demand is high (i.e. 0.8 rather than 0.27), when pass through is at 25% or 75% of the additional (average) costs passed through to consumers (rather than 50 percent), and when this cost increase is 10% and 66% (rather than 28%).

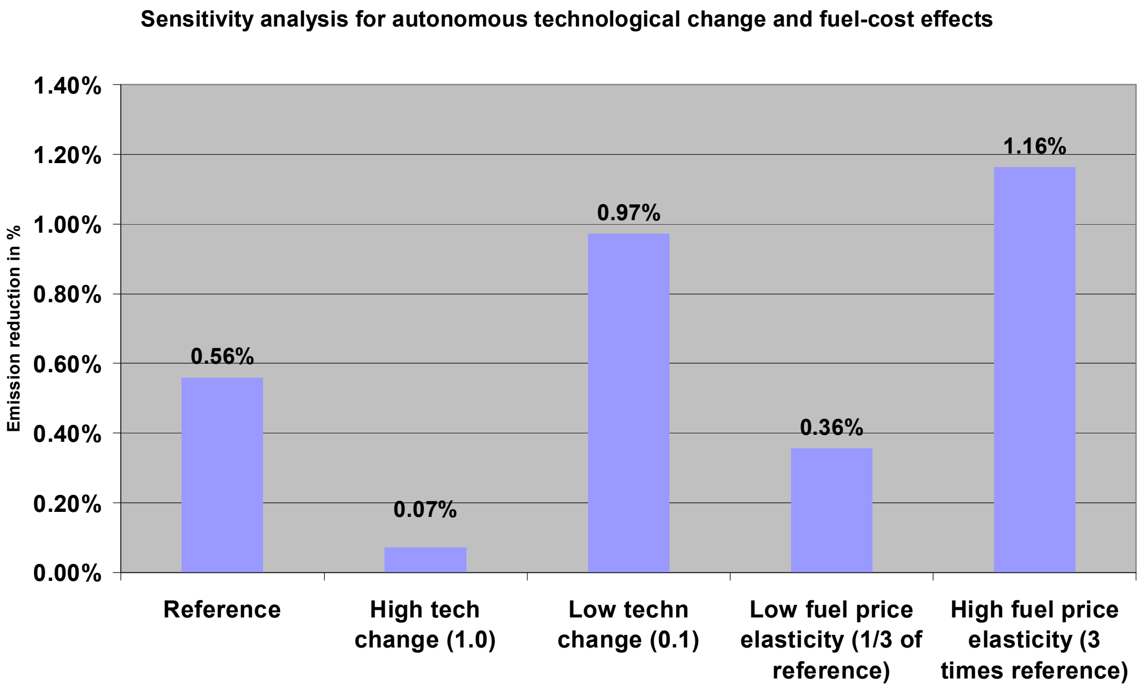
Figure 4-9: Sensitivity analyses for demand induced emissions savings in the German clinker production



In Figure 4-10 the results of selected sensitivity analyses are presented. Here autonomous technological change has been taken as high, i.e. fuel efficiency improves by 1.0% per year, or low (0.1%) rather than 0.5% as in the reference case. In addition the elasticity of fuel intensity with respect to coal price changes is assumed to be 1/3 and three times the value used in the reference case[78].

78 Note that a higher coal price elasticity results in higher direct emissions savings because coal prices in 2006 were lower than in 2005.

Figure 4-10: Sensitivity analyses for direct effect of EU ETS on emissions savings in the German clinker production



4.7 Step 5: Impact Delimitation

The impact delimitation step 5 is an integral part of the above described procedures, which corrects among others for the:

- treatment of independent national measures aiming at the same target;
- treatment of autonomous progress;
- treatment of the impact of energy price variations

4.8 Comparison with Tier 1/2 approaches

Tier 1/2 methodologies

The Tier 1 approach proposed is based on emission intensity trends and based upon EU wide values:

- First, the sector definition in the Value Added (VA) and emission statistics needs to be matched with the ETS participants. In Tier 1, the correction factors for adjusting the statistics sector definition to match the ETS system boundary (one for sectors, one for gases) are set at 0.
- Second, the historic trend in VA and emissions for the appropriate system boundary is determined for the 5 years preceding the implementation of the Directive.
- Third, the historic annual development in emission intensity is assumed to continue in the baseline in absence of the ETS Directive and needs to be combined with the value added in the year of evaluation to determine the baseline emissions.
- Fourth, the emissions from the baseline must be corrected for the impact of actual energy prices that are different than those occurring in the past. For Tier 1, the correction factor is assumed to be 0.

- Fifth, the effect of the RES-E directive on emissions needs to be assessed (as described in the corresponding guideline). The baseline data need to be adjusted to reflect the effect of the RES-E directive, by adding the emissions associated with the additional renewable electricity production as determined under the previous step.
- Six, the effect of the ETS Directive is estimated by subtracting the actual verified emissions in the ETS sectors from the corrected baseline data determined in the previous step.
- Finally, the estimated effect of the Directive needs to be corrected for the JI projects hosted in the Member States, by adding the amount of emissions equivalent to the amount of ERUs generated within the Member States from the JI reserve. (Note: This refers to JI projects realised (=hosted) in the respective Member State, not to JI or CDM credits that a Member State purchases from projects realised abroad.)

The Tier 2 approach is similar to the Tier 1 approach, except for:

- Correcting the statistics sector definition with a country-specific correcting factor to match the ETS system boundaries.
- Assessing the effect of the RES-E Directive according to the Tier 2 approach for that Directive.
- Correcting the effect for energy prices that are different from historic trends.

For the concrete Tier 1 calculations carried out the emissions were based on the emission inventories and the EU ETS was approximated as:

- Emissions from fuel combustion in the energy sector
- Emissions from fuel combustion in the manufacturing and construction sector
- Process emissions from cement production
- Process emissions from lime production
- Process emissions from limestone and dolomite use
- Process emissions from soda ash production
- Process emissions from nitric acid production
- Process emissions from adipic acid production.

The value added had to be approximated in a quite crude manner in the Tier 1 approach as:

- Energy, gas and water supply
- Mining and quarrying
- Manufacturing
- Construction.

Comparison with the Tier 1/2 Approach

Given the complexity of the different factors intervening in the EU ETS, it is not surprising, that simple approaches do not provide good estimates. The Tier 1/2 approach which is based on a projection of CO_2 intensities for the counterfactual, generally does not provide convincing results. The savings appear as too large or negative savings may appear (Table 4-7). The reasons for this are mainly the fluctuations in the value added used for the projections which do not correlate well with the development of the part of the inventories that have been chosen to represent the EU ETS. This may be due to the fact that the total manufacturing sector was chosen as a proxy for the industrial part of the EU ETS. But even tests with the energy sector only, which is a better match to one part of the EU ETS does not capture the impacts well. The aggregate value added simply contains too many influencing factors that are not well defined.

This advocates the use of more refined approaches at the Tier 3 level.

Table 4-7: Results from the Tier 1 Approach (Intensity Approach) and comparison with a direct impact evaluation from a projection of inventory data

Intensity approach

		Mt CO2 eq
Tier 1		**2005**
Geographical entity	Germany	18,24
	France	-0,62
	Spain	- 15,45
	Italy	16,74
	UK	30,96
	Denmark	9,14
	Austria	0,85
	Netherland	- 10,77
	Poland	41,02
	Czech	- 11,61

Direct projection of inventory data

		Mt CO2 eq.
Tier 1		**2005**
Geographical entity	Germany	13,56
	France	-2,42
	Spain	- 7,63
	Italy	6,18
	UK	-0,86
	Denmark	7,14
	Austria	1,28
	Netherland	4,00
	Poland	1,34
	Czech	- 0,93

4.9 Synthesis and interpretation of results

4.9.1 Comparison of results from the different methods

The Tier 1/2 approach as explored in this evaluation provides results which are not realistic. In general the impact estimates are far too high. This confirms the view that assessing the impacts of the EU ETS is rather complex. Refinements may be possible on the Tier 1/2 approach but in order to achieve realistic results it is most likely that so many corrections have to be applied that one would have gone half way to a Tier 3 approach.

The Tier 3 approach has delivered realistic results for the two examples chosen here: the dispatching in the power sector and the impacts in the cement sector in Germany. The calculations are, however, fairly complex and require a substantial amount of additional data. In particular, to the extent that demand-induced effects are to be accounted for, reliable data for demand elasticities and cost pass through rates would be required. Further work is needed in both areas. Given the fact that the EU ETS is a major instrument within the ECCP however, there is no way of developing a more refined approach. Current models, such as PRIMES are not well adapted to capture a multitude of effects. So more dedicated models need to be developed such as an hourly dispatching model for the European power sector exemplified here with the PowerAce model for Germany, as well as econometric approaches in the case of industrial sectors. These models need to be gauged to the CO_2 registries which provide more and more information over time.

4.9.2 Comparison of impacts across Member States

The Tier 1/2 approach does not provide sufficiently reliable results in order to allow for a comparison. The Tier 3 approach could, for the time being, only be exemplified for Germany concentrating on the power sector and the cement sector. Therefore a complete cross-country comparison is not possible at this stage.

4.9.3 Comparison with alternative estimates

For the first period (2005-2007), total emission allowances available to the EU ETS installations (emissions trading budget) exceeded verified emissions by about 3% (EEA 2007, EEA 2008). Since the emission level in the absence of the EU ETS cannot be determined (it is counterfactual), the real extent of possible over-allocation cannot be determined. Ellerman and Buchner (2006) tentatively suggest that a substantial part of the surplus may have resulted from abatement activities. As a consequence of the apparent surplus though, the price for EUA, which was relatively high in 2005 and for parts of 2006 (as long as information on actual emissions was not known), eventually dropped to almost zero towards the end of 2007. Hence, incentives to immediately reduce emissions (e.g. via fuel switch / dispatching) were only high in the beginning of the first period. However, since most measures to reduce emissions are long-term measures, it is the expected price for EU allowances (EUAs) rather than the current price which drives companies' investment behaviour.

4.9.4 Comparison with ex-ante results

Ex ante (and rather imperfect) estimates for the effect of the EU ETS in phase 2 may be obtained by comparing the size of the emissions trading budget for phase 2 with verified emissions in phase 1. Accordingly, for the EU-15 the EU ETS will provide a reduction in greenhouse gas emissions of approximately 139 Mt CO_2 (or 3.3%) (EEA 2008). For the EU-12 however, this method would result in a net increase of emissions by 12 Mt CO_2. Qualitatively, Schleich et al. (2008) come to a similar conclusion. Comparing projected emissions (by Member States) with the size of the emission trading budget, the estimated savings would be considerably larger.

4.9.5 Cost effectiveness

The arguments in favour of market-based instruments such as tradable allowances to generate a strong carbon price signal are well-known and need only be summarised here:

- They use market forces and all the information at the disposal of economic agents to improve the allocation of scarce resources;
- They can provide firms with flexibility to meet regulatory requirements;
- By allowing greater flexibility they ensure better efficiency through lower compliance costs;
- In the longer-term they encourage innovation and technological development.

The Council of the European Union (2008)[79] concludes that market-based instruments, such as the EU ETS and environmental taxes, as well as more 'clean' technologies, should be the "centrepiece of Europe's efforts to reduce its greenhouse gas emissions". However, much depends on the design options of the system in order to provide the carbon signal to the energy consumer while keeping in mind competitiveness and carbon leakage issues.

4.10 Conclusions

The Tier 1 and Tier 2 approaches do not, currently, provide a sufficiently reliable estimate of the policy impacts. This means that a Tier 3 approach is required for this policy. It should, however, be investigated whether improvements are possible to the Tier 1 and Tier 2 methodologies, following experience from the further development and application of the Tier 3 methodology.

The Tier 3 approach could only be exemplified, in the current study, for two sectors (power sector and the cement sector) in Germany. The main uncertainties in the methodology are the assumed demand elasticities (which are used to characterise indirect effects) and the assumed cost pass-through behaviour of the energy sector and the industrial sector. Further work is required to advance the understanding of the factors further.

4.11 Recommendations

The EU ETS is a very complex and new instrument. For this reason we would like to highlight the explorative character of the methodology applied as part of this study and especially for the Tier 3 approach. The current approach seems to work for the German power sector and the German cement sector; produces "reasonable" results; however, the results depend crucially on some key parameters and assumptions about cost increases, pass through rates, and demand responses. These parameters need more empirical foundation than they have currently.

79 Council of the European Union (2008): Report on the efficiency of economic instruments for energy and climate change. Brussels, 5 February 2008, 5850/08, ECOFIN 33, ENV 51. http://register.consilium.europa.eu/pdf/en/08/st05/st05850.en08.pdf

In considering the impacts on the power sector, future evaluations would benefit from the development of European models that represents:

1) short-term dispatching induced by the EU ETS (which requires hourly resolution and detailed information on the use and characteristics of power plants)
2) long-term investment effects in the power sector. This would, in particular, reflect the interlinkage between targeted renewables and energy policies and the ETS.

In considering the impacts on the industrial sector a full econometric analysis of the industrial activities as described in the Tier 3 report for the EU ETS is necessary. It is further necessary, to conduct misspecification tests to assess the appropriateness of the underlying econometric model from a statistical perspective. Although some regressions test have been carried out in this study, the results should be considered as exemplary and could be improved further when longer time periods are available in the future from the allowance registries.

The issue of CDM/JI projects interacting with the EU ETS needs to be further explored. In the current approach it is assumed that in the absence of JI projects, the corresponding emission reductions would not have taken place in the EU ETS. In part, however, the emission reduction measures comprising the JI project could also be incentivised by the carbon price instituted by the EU allowance price. The extent to which this occurs will depend on the differential in the EU allowance price and the ERU price and the period over which that differential is (expected to be) maintained. This effect is not taken into account here. In the discussion process for the development of the methodology the argument was advanced that the impacts of CDM and JI should also be attributed to EU ETS, even if they take place elsewhere. In our view this is too far reaching. This view is supported by the fact that CDM may be used by countries that have no ETS. This clearly shows that the CDM is an instrument per se. The question would then be rather in how far the ETS by its presence enhances the uptake of CDM projects. Further discussion of the issue is certainly necessary.

In case further sectors and gases are added to the system (N_2O for some processes is already envisaged for some industrial processes), additional steps in the methodology may be needed, especially in terms of data sources and system boundaries (e.g. aviation or shipping).

When domestic offset projects become feasible within the scheme, additional steps in the methodology will be needed, adding the effects of domestic offset projects on emissions in non-ETS sectors to the estimated effect of the ETS Directive.

In terms of data, the quality of ex-post analyses of the EU ETS would be greatly enhanced if verified output data was available at installation level, similar to the emission data available in the verified emissions tables. Likewise, data quality could be improved, if data on installations covered by the EU ETS would be collected and displayed in a consistent way across Member States and would clearly allow identification of the types of installations (rather than conglomerates of various types of installations, as is often the case).

4.12 Next steps

The most important next steps are:

- The development of a European model to capture the short-term ETS-induced changes (dispatching) in the power sector;
- Develop further test applications of the econometric method developed for the industrial sector (for other years, for other Member States and for other sectors);
- Further analysis of the main uncertainties in the methodology (demand elasticities to characterise indirect effects and the cost pass-through behaviour of the energy sector and the industrial sector for the CO_2 signals).
- Further work on identifying pass through
- Further analytical work required to understand better the interaction between ETS and targeted policies for renewables and energy efficiency as well as CDM in order to settle on allocating possible impacts between those policies. At present there are still wide spreads in the allocation of impacts to either instrument.

- The outcome of the discussion process on the interlinkage of targeted policies with the ETS could be linked back to the Tier 1 and 2 approaches in the form of simplified correction factors.

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5 RES-E Directive

5.1 Introduction

Electricity generated from renewable energy sources (RES) in the EU has increased significantly in recent years, contributing not only to reductions in GHG emissions but also to enhanced energy security and employment. National promotion strategies triggered by the RES-E Directive (2001/77/EC) on renewable energy in the electricity sector are the major reason for this development.

The RES-E Directive entered into force in September 2001 and was transposed into national law by October 2003. The directive defines indicative targets for the share of renewable electricity in gross electricity consumption for all Member States. Furthermore it contains requirements on the implementation of national support schemes; it asks for a reduction of administrative and grid barriers and regulates the issuing of guarantees of origin for renewable electricity. According to the Directive "*Member States shall publish, for the first time not later than 27 October 2003 and thereafter every two years, a report which includes an analysis of success in meeting the national indicative targets taking account, in particular, of climatic factors likely to affect the achievement of those targets and which indicates to what extent the measures taken are consistent with the national climate change commitment*."

All EU Member States have introduced policies to support the market introduction of RES-E and most of them have started to improve the corresponding administrative framework conditions (e.g. planning procedures, grid connection). The market diffusion of new renewable energy sources has increased significantly since the RES-E Directive was adopted. The existing policies encompass feed-in tariffs, quota-based tradable green certificates (TGCs), investment grants, tender procedures and tax measures. Up to now, these policies have been implemented exclusively on a national level with the primary aim of meeting the national targets set in the RES-E directive. However, it is very likely that the RES-E targets will not be met based on the performance to date of the current policies (COM (2004) 366) and (COM (2006) 849). One important reason for this is that the RES-E support systems in most EU countries are still not designed in an appropriate way, see Ragwitz (2004). In some Member States, growth to date has only been moderate since investments in renewables are associated with high risks due to uncertainties associated with the policy instruments. Furthermore, certain identified barriers to enhanced RES-E deployment which are administrative, financial, and social in nature, as well as insufficient electricity grid capacity, are not being appropriately addressed by national authorities. Altogether, the effectiveness of the present RES-E policy environment in most EU countries is still limited and shows a rather uneven distribution across the EU.

5.2 Methodological approach and data context

The model used for the evaluation of the RES-EE Directive is the Green-X model, the structure of which is presented in **Figure 5-1**.

Green-*X *model:

The ***Green-*X** model has been developed for the detailed assessment of the future deployment of renewable energies in the European Union. The ***Green-*X** model is a well known software tool with respect to forecasting the deployment of RES in a real-world policy context. The tool has been successfully applied within a number of projects, including FORRES 2020, see Ragwitz (2004).

It covers geographically the EU-25 plus Bulgaria, Romania and Croatia, and can easily be extended to other countries such as Turkey and Norway. It allows an investigation of the future deployment of RES, the impact of RES on GHG emissions, as well as the accompanying costs – comprising capital expenditures, additional generation cost (of RES compared to conventional options), transfer costs due to applied supporting policies, etc. – at country- and technology-level on a yearly basis. The time-horizon is currently extended to the year 2030. The modelling approach to describe supply-side generation technologies is to derive dynamic cost-resource curves by RES option, allowing besides the formal description of potentials and costs, a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Besides the detailed depiction of RES deployment and cost the model also allows to investigate the impact of applying different energy policy instruments (e.g. quota obligations based on tradable green certificates, feed-in tariffs, tax incentives, investment subsidies) at country or at the European level. Sensitivity investigations can easily be derived for key input parameters such as non-economic barriers (influencing the technology diffusion), conventional energy prices or energy demand developments. In this respect the effect of the main policy instruments implemented in the EU Member States for the promotion of RES-E are simulated. An example of the most relevant policies for the promotion of RES-E in Germany is given in Table 5-1.

In addition to the detailed modelling of RES deployment, a variant of this tool, focussing on the power sector, can be applied to assess the impacts of RES development on the conventional power sector (due to an enhanced RES penetration).

Green-*X *database:

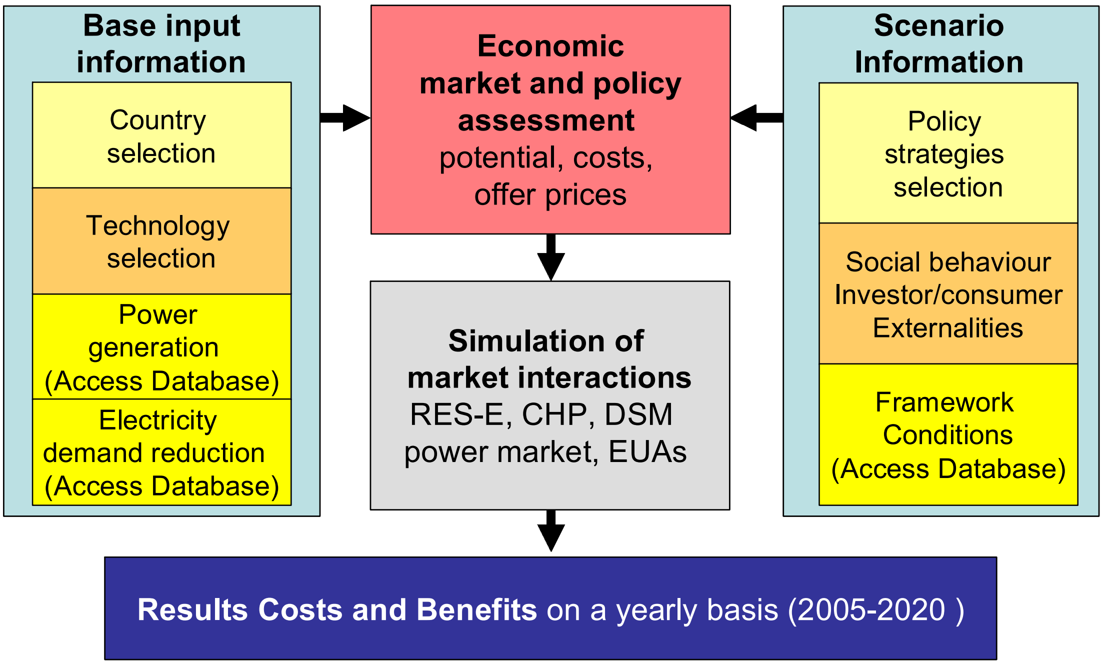
The input database of the Green-X model provides a detailed depiction of the past and present development of the individual RES technologies - in particular with regard to costs and penetration in terms of installed capacities or actual & potential generation. This database is build on the most recent data from EUROSTAT, IEA and national statistical offices as well as from sector organisations, e.g. EWEA and independent international data providers, e.g. ObservER.

Table 5-1 Example for most relevant policies for the promotion of RES-E in Germany (2000-2008)

MS	National Policy	Evaluation period [1]	Base year for savings	Annual savings (MtCe/ yr)
DE	Feed-in Tariffs implemented Renewable Energy Act	2000 - 2008	2008	
	Low interest loans for renewable energy investments			
	Investment incentives for Photovoltaics provided by the 100.000 roof programme			
	Total	**2000 - 2004**	**2004**	

[1] Reflects the evaluation period for the overall climate change programme. The evaluation period for individual policies and measures may differ.

Figure 5-1 Main features of the Green-X model for the evaluation of the RES-EE Directive



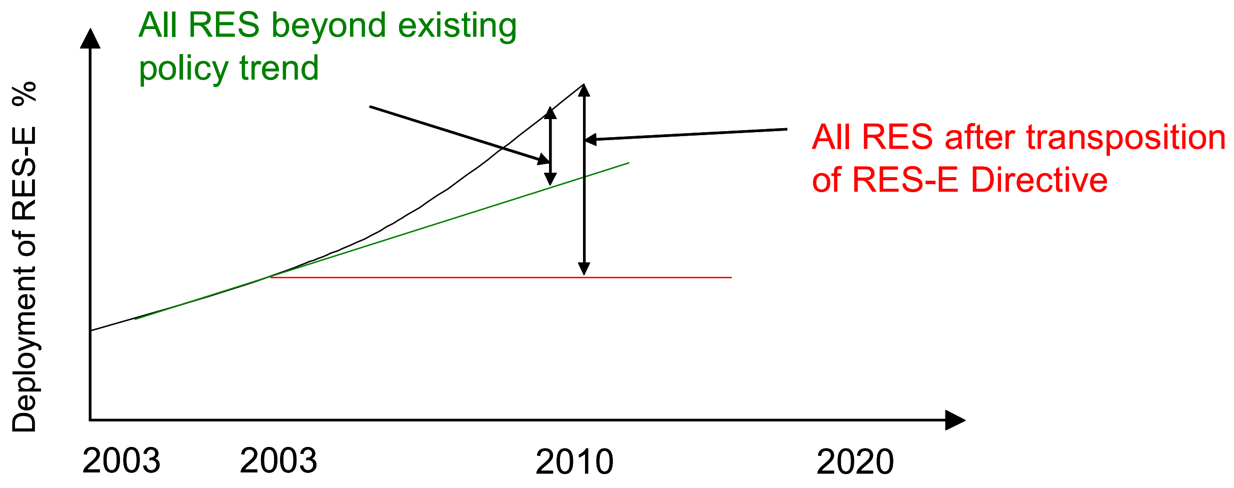
In order to evaluate the impacts of the RES-E Directive a number of methodological choices have to be made with respect to:

- approaches to account for the impact of the RES-E Directive as compared to pre-existing national policies
- approaches to calculate the avoided emissions based on different concepts of national emission coefficients

Three general methodological approaches can be pursued **to account for the impact of the RES-E Directive on the national renewable energy deployment**. These are:

- **Account for all new renewable energies installed after transposition of the Directive:** In this approach all new RES-E, which is installed after the date of the national transposition of the RES-E Directive and has received policy support, is assumed to be an outcome of the RES-E Directive. Therefore, any renewables that would have been cost-effective without any policy support (i.e. would have been installed anyway) are not assumed to be an outcome of the Directive.
- **Account for renewable implementation beyond the existing policy trend:** In this approach all new RES-E, which goes beyond the linear trend of the national RES-E development, after the date of the transposition of the Directive, is assumed to be an outcome of the RES-E Directive. Therefore, the short-run trend in RES-E deployment is assumed to continue in the absence of the Directive.
- **Expert judgement of the impact of the RES-E Directive on national measures:** In this approach one would specify, based on an expert judgement, whether a measure for the promotion of RES-E was introduced only for reasons of national policy priorities, e.g. security of supply, or whether the RES-E Directive was the main driver for the implementation of a national instrument.

Figure 5-2 Accounting methods for the impact of the RES-E Directive



Four general methodological approaches can be pursued **to account for different emission coefficients**. These are:

- **Average EU emission factor:** This approach assumes that renewable electricity production is replacing the average European fossil fuel mix of the EU-27 of public and auto producers[80].
- **Average national emission factor:** This approach assumes that renewable electricity production is replacing the average domestically applied fuel mix of public and auto producers[13].
- **Emission factors based on marginal power plant in terms of Short Term Marginal Costs (STMC):** This approach assumes that the marginal power plant along the merit order curve is replaced as reflected by the short term marginal generation cost of the plants. That means that the operation of the power system is optimised in a way that the most expensive fossil and nuclear plants are replaced by renewable electricity.
- **Emission factors based on marginal power plant in terms of Long Term Marginal Costs (LTMC):** This approach assumes that the marginal power plant along the merit order curve is replaced as reflected by the long term marginal generation cost of the plants. That means that the investments into the power system are optimised in a way that the most expensive fossil and nuclear plants are replaced by renewable electricity.

5.3 Step 1: Mapping of the ECCP measure

The key ECCP measure to promote renewable electricity is the RES-E Directive (2001/77/EC), which has triggered a variety of national measures for the promotion of renewable electricity. The main national measures currently implemented in EU Member States can be divided into price-driven (e. g. Feed-in-Tariffs FITs) and quantity-driven (e. g. Tradable Green Certificate (TGC)-based quotas) strategies, which are defined in the following.

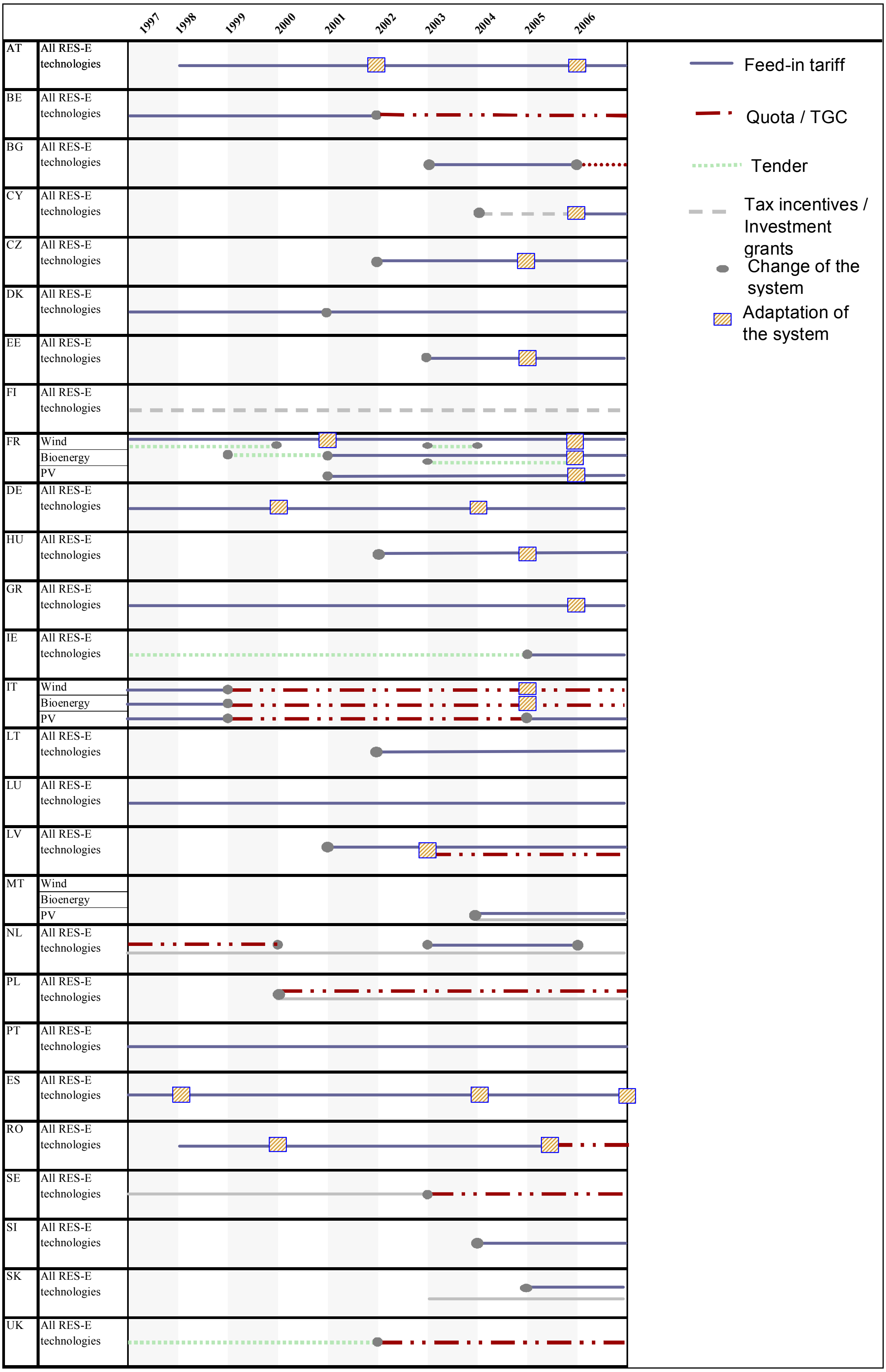
Feed-in tariffs (FITs) are generation-based, price-driven incentives. The price that a utility or supplier or grid operator is legally obligated to pay for a unit of electricity from RES-E producers is determined by the system. Thus, a federal (or regional) government regulates the tariff rate. It usually takes the form of either a fixed amount of money paid for RES-E production, or an additional premium on top of the electricity market price paid to RES-E producers. Besides the level of the tariff, its guaranteed duration represents an important parameter when evaluating the actual financial incentive. FITs allow technology-specific promotion and acknowledge future cost-reductions by applying dynamically decreasing tariffs.

[80] Nuclear plants have been excluded because their operation was not influenced by renewables in the past.

Quota obligations based on Tradable Green Certificates (TGCs) are generation-based, quantity-driven instruments. The government defines targets for RES-E deployment and obliges a particular party of the electricity supply-chain (e. g. generator, wholesaler or consumer) with their fulfilment. Once defined, a parallel market for renewable energy certificates is established and their price is set following demand and supply conditions (forced by the obligation). Hence, for RES-E producers, financial support may arise from selling certificates in addition to the revenues from selling electricity on the power market. In principle, technology-specific promotion is also possible in TGC systems. But it should be noted that separate markets for different technologies will lead to much smaller and less liquid markets.

Figure 5-3 shows the evolution of the main support instrument for each country of the EU-27. Only 8 of the 25 countries regarded did not experience a major policy shift during the period 1997-2006. The current discussion within EU Member States focuses on the comparison of two opposed systems, the FIT system and the quota regulation in combination with a TGC-market. The latter have replaced existing policy instruments in some European countries such as Belgium, Italy, Sweden, the UK, Poland and Romania. Other policy instruments such as tender schemes are no longer used in any European country as the dominating policy scheme. However, there are instruments like production tax incentives and investment incentives which are frequently used as supplementary instruments. Only Finland and Malta apply them as their main support scheme.

Figure 5-3: Evolution of the main policy support schemes in EU-15 Member States



All of the main instruments act on an increased deployment of renewable electricity. Therefore the main indicator to measure the impact of the instrument is the generation of renewable electricity in MWh.

These instruments can be associated to the RES-E Directive although some of them have also been implemented before the date on implementation of the Directive.

Besides the national measures for the promotion of RES-E other community wide ECCP measures may interact with the Directive 2001/77/EC. Such an ECCP measure is the EU ETS. In principle, all policies and measures affecting supply and demand of the output produced by installations covered by the EU ETS interact with the EU ETS. This interaction may be direct or indirect:

- Direct interaction refers to policies directed at the same installations as those covered by the EU ETS (double regulation). Examples for policies falling under this category among the RES-E policies are co-firing of biomass in fossil power plants. Indirect interaction occurs through the impact of the ETS on electricity prices and the impact of renewable energy policies on the demand for conventional electricity. The first effect leads to a lower support level that has to be given to renewable electricity hence lowering the policy costs for RES-E. Therefore it increases indirectly the acceptance for RES-E policies and the demand for RES-E.
- The second effect is based on the fact that based on the increased RES-E generation the production from other installations, notably from fossil fuel-based installations is crowded out, resulting in lower carbon emissions from power generation. In the future, some RES-E technologies may directly compete with fossil-fuel power technologies, if production costs for RES-E continue to decrease and if carbon prices are sufficiently high.

Further interactions of support schemes for renewable electricity exist with respect to energy taxes and support schemes for CHP. The measure mapping of the measures potentially relevant for the promotion of RES-E is provided in

Table 5-2.

Table 5-2: Measure mapping of the RES-E Directive

MEASURE	TARGET	GOAL FOR TOP-DOWN IMPACT
ECCP **Support schemes for renewable electricity**	**deployment of RES**	
RES-E Directive		**21% RES-E by 2010 in EU**
National support schemes		**national RES-E targets**
EU ETS		**-21% compared to verified emissions in 2005 by 2020 (more ambitious if international Post Kyoto agreement can be achieved)**
Phase 1 (2005-2007) Phase 2 (2008-2012) Phase 3 (2013-2020) (proposed)	**GHG emissions of large installations from energy and industry**	
Complementary financial measures Energy taxes Support schemes for CHP	**primary/final energy use** **deployment of CHP**	
Command and control Technology standards Building codes		
Technology promotion R&D networks R&D subsidies		
Informational measures Labelling Subsidies for energy audits (SMEs) Information and awareness campaigns		
Voluntary demand for RES-E Industry association and national government/EU		

5.4 Step 2: Compilation of quantitative evaluation evidence

There is significant experience with respect to the quantitative assessment of the impact of renewable electricity policies on the deployment of RES-E technologies as well as on GHG reductions. In particular with respect to a prospective assessment of the future emission reductions of renewable energy sources various studies exist, e.g. Ragwitz (2004), Ragwitz (2006). However, less evaluation exists with respect to the historic impact of renewable electricity on GHG avoidance on the EU level. Individual national studies exist in this respect, in particular in Germany substantial effort was made to quantify the impact of RES-E on the GHG balance. These studies evaluated the emission reductions due to renewable electricity generation based on the average or marginal emissions of the power system, see Lux (1999), Nitsch (2000), Klobasa (2005).

As stated above a wide literature of the assessment of ex-ante impacts of renewable energy policies exist. For the year 2020 it was estimated in the "Renewable Energy Road Map Renewable energies in the 21st century: building a more sustainable future COM(2006)848" that 700 Mt of CO_2 will be saved based on the 20% target for renewable electricity. These figures are derived based on a bottom-up assessment of emission reductions by renewables in the electricity, heat and transport sector. One general difference between the ex-post and the ex-ante assessment is that ex-ante assessments should be based on the replacement of the marginal power plant with respect to long term marginal costs (LTMC), whereas for the ex-post assessment the marginal plant with respect to short term marginal costs (STMC) are relevant. Due to this important principal the results of ex-ante and ex-post evaluations are not easily compara

5.5 Step 3: Screening

Among the measures for the promotion of renewable electricity given in Table 5-1 the direct national support instruments are by far most important. Other instruments such as the ETS have no or only an indirect effect on the development of renewable energy sources. For example the effectiveness of the quota systems as well as of feed-in systems is independent of the ETS. Ecological or energy tax measures need to be considered only if renewable energies are exempted from such payments. This is for example the case in the UK (Climate Change Levy) but not in most countries, e.g. for the German ecological tax. Therefore the most relevant measures to include in the assessment are the quota systems and feed-in tariffs implemented in 25 EU Member States.

Many of these national instruments could in general be classified as pre-ECCP measures as they have been introduced already before the transposition of the RES-E Directive. However, as the Directive is one of the main motivations for maintaining and fine-tuning these national measures, they should be considered, when evaluating the impact of the RES-E Directive.

5.6 Step 4: Modelling step

In this step the different methodological approaches outlined in section 5.2 will be shown using the situation in Germany as an example.

Step (i): Assess the electricity generation from renewables in the year of the transposition of the Directive and in the following years

In a first step the electricity generation by renewable energy sources is assessed in the base year, i.e. the year of the transposition of the RES-E Directive, and in the following years. This assessment contains the actual figures of RES-E generation. However, this has to be normalised with respect to the meteorological variability in a next step. The RES-E generation for the years 2003, 2004 and 2005 is shown for the example of Germany in Table 5-3.

Table 5-3 Actual electricity generation by renewable energy sources in Germany

Year		2003	2004	2005
Biogas	TWh	2.97	3.26	4.71
Solid biomass	TWh	2.78	3.90	4.65
Biowaste	TWh	2.16	2.12	3.04
Geothermal electricity	TWh	0.00	0.00	0.00
Hydro large-scale	TWh	11.30	12.70	11.62
Hydro small-scale	TWh	7.97	8.38	7.96
Photovoltaics	TWh	0.33	0.56	1.28
Solar thermal electricity	TWh	0.00	0.00	0.00
Tide & Wave	TWh	0.00	0.00	0.00
Wind on-shore	TWh	18.86	25.51	27.23
Wind off-shore	TWh	0.00	0.00	0.00
RES-E total	**TWh**	**46.36**	**56.42**	**60.49**

Step (ii): Assess the normalised electricity generation from renewables in the year of the transposition of the Directive and in the following years

In a next step the RES-E generation is normalised with respect to the meteorological variability of hydropower and wind energy. This adjusts for annual variations in renewable output arising from e.g. lower rainfall, or wind speeds. In this way the generation capacity of renewable electricity sources are multiplied by a long term average of the capacity factor for hydropower and wind energy measured for each Member State. The normalised RES-E generation for the years 2003, 2004 and 2005 is shown for the example of Germany in Table 5-4.[81]

Table 5-4 Normalised electricity generation by renewable energy sources in Germany

Year		2003	2004	2005
Biogas	TWh	2.97	3.26	4.71
Solid biomass	TWh	2.78	3.90	4.65
Biowaste	TWh	2.16	2.12	3.04
Geothermal electricity	TWh	0.00	0.00	0.00
Hydro large-scale	TWh	13.34	13.34	13.37
Hydro small-scale	TWh	8.08	8.18	8.97
Photovoltaics	TWh	0.33	0.56	1.28
Solar thermal electricity	TWh	0.00	0.00	0.00
Tide & Wave	TWh	0.00	0.00	0.00
Wind on-shore	TWh	24.10	27.44	30.41
Wind off-shore	TWh	0.00	0.00	0.00
RES-E total	**TWh**	**53.76**	**58.79**	**66.42**

Step (iii): Assess the additional normalised electricity generation from renewables during the years after the transposition of the Directive

Based on the normalised generation in each year the additional normalised generation as compared to the base year - the year of the transposition of the RES-E Directive - is calculated. The resulting additional normalised generation in the years 2004 and 2005 are shown for the example of Germany in Table 5-5.

81 For hydro and wind power the normalisation rules according to Annex II of the renewable energy Directive for 2020 with a normalisation period of 15 years has been used.

Table 5-5 Additional normalised electricity generation by renewable energy sources in Germany

Year		2003 - 2004	2003 - 2005
Biogas	TWh	0.30	1.74
Solid biomass	TWh	1.13	1.87
Biowaste	TWh	-0.05	0.88
Geothermal electricity	TWh	0.00	0.00
Hydro large-scale	TWh	0.00	0.03
Hydro small-scale	TWh	0.10	0.89
Photovoltaics	TWh	0.22	0.95
Solar thermal electricity	TWh	0.00	0.00
Tide & Wave	TWh	0.00	0.00
Wind on-shore	TWh	3.33	6.30
Wind off-shore	TWh	0.00	0.00
RES-E total	**TWh**	**5.04**	**12.66**

Step (iv): Assessment of the additional normalised electricity generation from renewables during the years after the transposition of the Directive, which needed policy support

In the next step any autonomous deployment of renewables (i.e. renewables that would also have been implemented if no government policies would have been in place) should be subtracted from the additional generation realised after 2003. In the case of Germany all plants added after the year 2003, and therefore all additional generation shown in Table 5-5, received policy support by means of the feed-in tariff. Therefore this step does not alter the figures shown in Table 5-5.

Step (v): Determination of emission coefficient based on the average fossil fuel mix - accounting method I

In a next step the emission coefficient of the average fossil generation is determined according to the data provided by EUROSTAT. It has been assumed that the operation of nuclear power has not been affected in a significant manner, in any of the EU countries, by the additional renewable generation. Therefore, only the fossil power generation is taken into account in the calculation. The result of this procedure is shown for Germany in Table 5-6. Generally the emission factor determined in this way is a weighted average of gas and oil plants, hard coal plants and lignite plants. In particular in countries with a small share of renewables and a large share of gas plants in the conventional portfolio, one could argue that mainly gas would be avoided and the average might lead to an overestimation of the coefficient. However, very often a significant share of coal plants is replaced by renewables for the following reasons: first during night times gas plants are often not operated but base-load lignite plants dominate the market. Therefore during these times coal plants are replaced in many countries. Secondly many gas power plants are coupled with CHP or industrial processes and can not easily turned off. This is a second reason, why coal plants are frequently replaced by renewable generation. See also the following Step (vi) for the justification of this approach with the detailed hourly calculation of the emission coefficient.

Table 5-6 Average emission coefficient of the German power sector (including all fossil plants) according to PRIMES

		2000	2001	2002	2003	2004	2005
emission coefficient	$tCO2/MWh_{out}$	0.975	0.971	0.968	0.964	0.961	0.957

Step (vi): Determination of emission coefficient based on marginal power plant in terms of the short term marginal costs (STMC) of the power sector - accounting method II

Alternatively to step (v) the emission coefficient can also be determined based on the operation of the power sector, where renewables would replace the marginal power plant in terms of the short term marginal costs (STMC) of the power sector. In this approach the renewable generation replaces the most expensive power plant along the merit order curve in every hour of the year. In this way the plants characterised by high fuel costs (i.e. first oil and gas fired plants, secondly hard coal fired plants, thirdly lignite fired power plants) and low efficiencies are replaced first. It has to be considered however, which part of the power plants is not dispatchable, e.g. due to cogeneration heat. This procedure leads for Germany to an emission coefficient of **0.929 tCO2/ MWh** for the years 2004 and 2005 (according to AGESTAT). As compared with Table 5-6 which shows the average fossil emission coefficient it is seen that that the average fossil emission coefficient is a much better approximation in the case of Germany than the assumption of a gas-fired power plant would have been.

Step (vii): Determination of the total emission reductions

By multiplying the total additional RES-E generation, which received policy support, with the emission coefficients determined under step (vi) and step (vii) the total emission reductions can be calculated. The results of this are shown in Table 5-7 when using the average emission coefficient of the power sector and in Table 5-8 when using the emission coefficients of the marginal plants replaced by renewable electricity. Therefore the impact on the emission reductions in the German power sector amounts to 4.7 - 4.8 Mt CO_2 in the year 2004 and to 11.8 - 12.1 Mt CO_2 in the year 2005.

Table 5-7 Total emission reductions in Mt CO_2 due to renewable electricity in Germany installed after 2003 - accounting method I (emission factor based on average fossil fuel mix)

Year		2004	2005
total reductions	Mt	4.84	12.11

Table 5-8 Total emission reductions in Mt CO_2 due to renewable electricity in Germany installed after 2003 - accounting method II (emission factor based on hourly calculations)

Year		2004	2005
total reductions	Mt	4.68	11.76

5.7 Step 5: Impact Delimitation

The impact delimitation step 5 corrects for, among other things, the treatment of independent national measures aiming at the same target. The possible approaches have been described previously. Specifically, approach 2 (Accounting for renewable implementation beyond the existing policy trend) and approach 3 (Expert judgement of the impact of the RES-E Directive on national measures) are most relevant. For some countries with strong pre-existing policies for renewable energy sources (e.g. in Denmark, Germany or Spain) both approaches lead to a strong reduction of the above CO2 savings associated with the ECCP, while especially for many Eastern countries where renewables were mainly triggered by the ECCP little change will occur.

Other corrections may be introduced for the impact of energy price variations of the fossil fuels in competition with the renewable energy sources.

5.8 Synthesis and interpretation of results

5.8.1 Comparison of results from the different methods

The results of the Tier 3 approach can be compared with the results from the more simplistic Tier 1 and Tier 2 methods. These results are presented in Table 5-9. In all cases the impact is shown without the contribution of large hydropower, as this technology can be typically classified as autonomous development, which would have taken place even without RES-E Directive.

The different emission factors are shown for all countries covered in this analysis. It can be seen that emission factors differ significantly between the countries depending on the conventional power system in each country. In the Tier 1 approach the emission factor of the EU-27 is used for all Member States. The average EU emission factor is strongly influenced by the low coefficient in France, due to the high share of nuclear power in this country. Therefore the average EU-27 emission coefficient is lower for all countries compared to the national value, except for France. The highest emission reductions could be achieved in Germany followed by Spain, Italy and the United Kingdom. This relative order is the same for all three approaches although the absolute figures of emission reductions can differ significantly. In the Tier 3 approach the results for all countries represent the approximated short term marginal cost approach whereas for Germany the results are also shown for the calculation of the exact short term marginal cost approach. For the case of Germany it can be seen that the approximation of the short term marginal cost approach gives rather good approximation of the exact figures.

Table 5-9 Total emission reductions in Mt CO_2 due to renewable electricity installed after 2003

Tiers 3			AT	CZ	DE	DK	ES	FR	IT	NL	PL	RO	UK	EU-27	EU-15
emission factor approximated short term average		t/MWh	0.84	1.29	0.96	0.90	0.71	0.70	0.64	0.66	1.22	1.27	0.71	0.86	0.79
emission reduction (normalised)	2004	Mt	0.59	0.29	4.82	0.39	3.64	0.36	2.53	0.74	0.66	-0.09	1.26	20.55	17.80
emission reduction (normalised)	2005	Mt	1.44	0.41	12.09	0.71	5.88	0.96	3.44	1.25	2.01	-0.07	3.66	40.34	34.08
emission factor short term average		t/MWh			0.93										
emission reduction (normalised)	2004	Mt			4.68										
emission reduction (normalised)	2005	Mt			11.74										
Tiers 2			AT	CZ	DE	DK	ES	FR	IT	NL	PL	RO	UK	EU-27	EU-15
emission factor MS avarage		t/MWh	0.84	0.88	0.67	0.90	0.54	0.08	0.64	0.63	1.22	1.07	0.56	0.55	0.49
emission reduction (normalised)	2004	Mt	0.59	0.20	3.36	0.39	2.78	0.04	2.53	0.71	0.66	-0.07	0.99	13.13	11.05
emission reduction (normalised)	2005	Mt	1.44	0.28	8.42	0.71	4.48	0.12	3.44	1.20	2.01	-0.06	2.90	25.79	21.16
Tiers 1			AT	CZ	DE	DK	ES	FR	IT	NL	PL	RO	UK	EU-27	EU-15
emission factor EU average		t/MWh	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
emission reduction (normalised)	2004	Mt	0.39	0.12	2.77	0.24	2.83	0.28	2.18	0.62	0.30	-0.04	0.97	13.13	12.41
emission reduction (normalised)	2005	Mt	0.95	0.17	6.96	0.43	4.57	0.76	2.96	1.05	0.91	-0.03	2.83	25.79	23.75

Sensitivity analysis

A sensitivity analysis has been applied to test the impact of using specific methodological assumptions upon the results. This would include, as a minimum, the impact of using marginal versus average emissions factor but potentially other parameters also.

In the Figure 5-4 the results of the sensitivity analysis are shown. This shows the impact of using specific methodological assumptions, and the influence of data uncertainties, upon the overall results. The arrows show the relative variability in the results depending upon the particular assumptions that are used. The solid arrows show the influence of the specific factors, as calculated within this study. The dashed arrows are used to highlight the significant uncertainty in the factors themselves, and the potential range in the results that can arise from alternative assumptions.

A further differentiation is made between sensitivities that relate to methodological choices and those that relate to data issues.

The relative influence of the different sensitivities is as follows:

- The impact of the normalisation according to the weather conditions (i.e. normalisation of the specific year under investigation to a long term average) can amount to about plus/minus 10% of the total emission savings calculated, depending of the specific RES-E portfolio of a country.

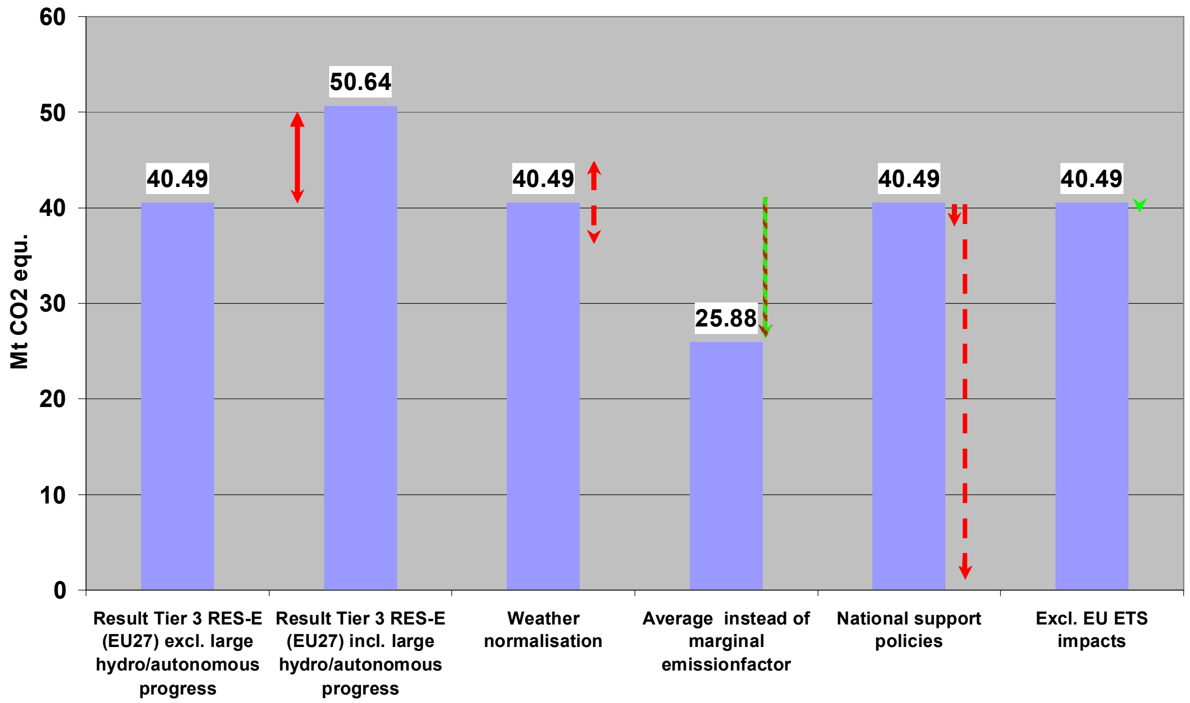
- The impact of using an average emission factor instead of a marginal one can be substantial. For the EU-27 this impact amounts to about one third of the total emissions. This is a very important factor which explains the different results that are achieved from the different Tier methods.

- The extent to which the change in emissions is attributed to the RES-E Directive or to "independent" national policies can be crucial. In the extreme case where all of the emissions impacts from RES-E are attributed to the national policies the effect of the RES-E Directive would be zero.

- The impact of excluding the contribution of large hydropower - as a way to account for autonomous progress - is substantial and amounts to about 20% of the total emission reductions at EU-27 level.

- The EU ETS had in the past no impact on the emission reductions by the RES-E Directive since additional support had to be given in all countries in order to develop renewable electricity generation using specific support schemes.

Figure 5-4 Sensitivity analysis of the impacts of the RES-E Directive



Note: Variations due to methodological choices are in red. Variations due to data issues are in green in the figure.

5.8.2 Comparison of impacts across Member States

The impact of the RES-E Directive across Member States differs significantly and scales directly with the induced growth of renewable electricity in the Member States and with the carbon intensity of the power system. Countries, which have introduced successful instruments like Denmark, Germany, Spain, UK and have a coal based generation system at the same time show significant emission reductions due to the impact of the RES-E Directive. In some countries like Poland and the Czech Republic the very large value of the emission coefficient due to a high contribution of inefficient coal power plants is particularly significant.

5.8.3 Cost effectiveness

Generally, increasing renewable energy sources has resulted in additional generation costs as compared to conventional alternatives since the RES-E Directive was adopted. Therefore, financial support schemes had to be introduced at Member State level. These support schemes can now be evaluated regarding their policy costs. Such evaluations have been performed in different communications of the European Commission, e.g. SEC(2008)57, COM(2005)627. One general conclusion from these evaluations is that technology specific support schemes, which give long term price guarantees for investors, tend to be more cost effective than technology neutral instruments. Although this has not been an issue studied in this project, the additional generation costs of renewable energy sources triggered by the RES-E Directive can be estimated at the order of 1 billion € in 2005 for the EU-27. It has to be emphasised, however, that renewable energy sources also bring additional benefits such as increased security of supply.

5.9 Conclusions

The Tier 1 approach does not provide sufficiently detailed results in order to allow for an evaluation of the performance of the RES-E Directive at Member State level, since the emission coefficients differ largely among countries. The Tier 2 is better since it gives a differentiation among Member States, but as the Tier 1 approach it tends to largely underestimate the emission reductions, since nuclear power is considered to be replaced by renewable energy. Since typically this is not the case, i.e. the generation from nuclear power is largely unaffected by renewable energy sources, the Tier 3 approach seems to be superior.

In this paper a fully detailed Tier 3 approach, which models the avoided emissions based on the hourly dispatch of the power sector (using the PowerACE model), has been performed for Germany as an illustrative example. For all other Member States the approach to calculate the emission reductions based on marginal power plant with respect to the short term marginal costs had to be approximated. The case of Germany indicated that this approximation can be done with good agreement.

5.10 Recommendations

The RES-E Directive is a new instrument and the impact of renewable energy sources on the power sector are rather complex. Although approximations to such a detailed calculation may result in reasonable estimates, as has been shown for Germany, the level of accuracy and the robustness of the results may increase significantly by using a detailed model of the power market (as used in the Tier 3 approach presented here). In this respect the evaluation requires the development of full European models representing on one hand the short-term dispatching induced by RES-E (which requires hourly resolution like in the PowerAce model for Germany and detailed information on the use and characteristics of power plants) and on the other hand the long-term investment effects in the power sector. Such a model may at the same time also be very useful to evaluate the impacts of the EU ETS.

5.11 Next steps

The most important next concrete steps to be carried out are:

- The development of a European model to capture the short-term RES-E-induced changes (dispatching) in the power sector;
- Test the results of such a model against simplified approximation methods for more EU countries;
- Develop more sophisticated approximation methods to "imitate" detailed power market modelling by econometric approaches.

5.12 References

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6 Biofuels Directive

Disclaimer: The analysis of the Biofuels Directive has been prepared by Fraunhofer ISI. The final presentation of the results from the Biofuels Directive does, however, not reflect the views of Fraunhofer ISI.

The purpose of this section is to describe a “Tier 3” approach for the evaluation of the Biofuels Directive, taking into account the interaction of this measure with other measures aimed at the same target, including national measures. The main focus is on the description of the methodology.

The approach to developing the Tier 3 methodology has followed five sequential steps. These are:

- Step 1 Mapping of GHG measures in the context of the European Climate Change Programme (ECCP): This is the qualitative description of the "measure network" which may include EU-ECCP measures, EU-pre-ECCP measures, ECCP-triggered national measures as well as independent national measures aimed at the same target.
- Step 2 Compilation of quantitative evaluation evidence: This consists of the compilation of quantitative evaluation evidence such as in-depth national bottom-up evaluations, estimates from top-down impact indicators or simple estimates.
- Step 3 Screening step: This consists of the exclusion of unimportant national measures and pre-ECCP measures from the measure map, reducing the measure map to a simpler picture that can be modelled more easily.
- Step 4 Modelling step: The model-based harmonised evaluation of the simplified measure map provides an evaluation of impacts under harmonised assumptions.
- Step 5 Impact Delimitation: The impacts obtained in the previous step are in general “gross impacts”. Further treatment of issues such as independent national measures aiming at the same target, autonomous progress, the impact of market energy price changes etc. may be necessary.

Each of these steps is described further below, following a more general discussion of the methodology and the data context.

6.1 Introduction

Biofuels production and consumption from renewable sources, mainly biomass and agricultural feedstock, have increased considerably in the last few years. The interest in biofuels started gathering momentum in the 1990’s in several Member States and more attention has been given since 2000, with legislation such as the Directive on the promotion of the use of biofuels and other renewable fuels for transport (2003/30/EC, from here onwards referred to as 'Biofuels Directive') adopted in 2003.

The Biofuels Directive required Member States to set national indicative targets on the basis of energy content of all gasoline and diesel fuels consumption. For 2005 an interim 2% biofuels target was agreed followed by the 5.75% target for 2010. All Member States have introduced policies to support the penetration of biofuels, ranging from biofuel production quotas and blending obligations through to tax exemptions in accordance with Article 16 of the Energy Taxation Directive (2003/96/EC). To date, these policies have been implemented at a national level with the aim to meet the national targets set in the Biofuels directive.

Since 2005, 13 Member States have received state aid approval for biofuels tax exemption, while at least eight Member States have plans or are implementing Biofuels blending obligations. However, the proposed 2005 targets were not met and it is likely that the 2010 targets will not be met either, according to the progress report on Biofuels (COM (2006) 845).

The diffusion of biofuels into the European market has increased from 0.3% of the transport fuels market in 2001 to approximately 2.6% at the end of 2007. Although initially this figure appears impressive, progress has been uneven across Member States. By the end of 2006, Germany and Sweden were the only two Member States that had reached their targets.

In addition there are important challenges to the future development of the biofuels market with respect to biofuels and food competition, expected increases in imports and the requirement to meet sustainability criteria.

6.2 Methodological approach and data context

The methodological approach and data context for evaluating this measure is presented in this section. This evaluation identifies approaches that account for the impact before and after the implementation of the Directive at national levels.

Historical levels of biofuel production are available from statistics at an EU and Member State level in either tons or litres (and translated into energy units) and are used as an indicator of the effect of the transposition of the Directive in these Member States, taking into account the year in which the Directive has been applied. Biofuel production figures as an impact indicator are complemented with data on the biofuels consumed during the period before and after the Directive has been transposed to national law. Estimates on biofuels imports/exports have been carried out as they are not currently collected in EU or Member States statistics[82].

Biofuel production across the EU before the time of adoption of the Directive into national law is initially accounted as autonomous development in combination with the identification of the national policies in place for biofuels. It is important to remark that most biofuels technologies (1st and 2nd generation) remain until now non-competitive without subsidies when compared to their fossil fuels counterparts, namely gasoline and diesel fuels. These options are capable of entering the markets only through political and economic support. The autonomous development therefore is assumed to be insignificant without the existence of the Directive in the ex-post perspective.

Delays in the implementation of the Directive into national law play a minor role in hindering the deployment of biofuels (from production, to distribution, trade and sale) in the markets. In view of the approval of the Directive, biofuels market actors across Member States started activities with the certainty that at national level policies to support the market (e.g. tax exemptions and quotas) would soon be put in place. On this basis, any delays in implementing the Directive are not considered to have a major effect on the biofuels development at Member State level.

The impact on GHG emission reductions of the Biofuels directive is modelled with the following well-established accounting methods:

1. the direct CO_2 emission reductions achieved through the substitution of gasoline and diesel in energy terms (**gross impact**) and
2. CO_2 and GHG emission reductions achieved through biofuels consumption after the Directive entered into force, taking into account emissions factors that reflect the complete life cycle emissions across the whole supply chain for biofuels and their fossil fuel comparators (**net impact excluding land-use change**)

The accounting methods are explained in detail in Step 4.

6.3 Step 1: Mapping of the ECCP measure

The key ECCP measure to promote biofuels in the EU is the Biofuels Directive (2003/30/EC) adopted in May 2003, which indicated that a variety of national measures for the promotion of alternative fuels for transport were to be implemented in the Member States not later than 31st December 2004. Every year, Member States are required to submit a report presenting the level of achievement of the aims assumed in the directive referring to the level of use of biofuels for transport and support instruments used to promote the production and the use of biofuels.

The Directive also specifies a target for biofuels and other renewable fuels for all EU Member States currently adopted as:

[82] We are aware that data on biodiesel and ethanol imports may be available for certain EU sources. However, we were unable to access this data for use in this study. This issue therefore needs further investigations in follow-up studies to improve the methodology.

- 2% share of renewable sources in the total energy market until 31st December 2005.
- 5.75% share of renewable sources[83] in the total energy market until 31st December 2010.

The renewable energy Directive from 2008 contains a 10 % target for fuels from renewable sources for 2020.

The main national measures implemented in EU Member States are:

- **Full or partial tax exemptions:** Tax exemptions are the most popular policy measure adopted by Member States to promote biofuels from 2004 to 2008. Tax exemptions or tax reductions for biofuels are also regulated by Directive 2003/96/EC on taxation for energy allowing Member States to establish measures – under strict conditions – for a maximum period of 6 consecutive years, without the unanimous approval by other Member States. Such tax exemptions support the development of a European production and consumption market for biofuels. However the proposed targets for 2005 were not achieved by these measures and only in countries with important exemptions such as Germany and Sweden, were the targets met. Tax exemptions also exhibit important drawbacks as they are costly instruments resulting in over-compensation to producers of lower-cost biofuels. In addition, if tax exemptions are not granted under stable and multi annual programs, they may not provide sufficient investor certainty (Vannini et. al., 2006). Tax exemptions may be granted partially to limited biofuels volumes. Member States that have opted for tax exemptions include: Belgium, Denmark, Estonia, Finland, Hungary, Latvia, Luxembourg, Malta, The Netherlands, Poland, Slovakia, Spain and Sweden.

- **Mandatory biofuel blending (low blends) in conventional fuels:** Biofuel mandatory blending obligations consist of requiring fuel suppliers to place a specified quota of biofuels in the market, generally calculated as a blending percentage (e.g. B5 or E5) of the total fuel they place in the market. This instrument is gaining increasing attention among Member States as it represents a least cost measure. Future approaches and proposals suggest that this combined with other promotion measures such as tradable certificates or tax exemptions has the advantages of cost-efficiency (it gives incentive to lower the cost of bio-fuel production) and investor certainty depending on the time limits set. Biofuel obligations are used in Austria, Italy, Lithuania, Slovenia, Germany and Czech Republic (where the introduction of biofuel obligations has been announced for 2007), while they have been proposed in the United Kingdom for 2008. A number of Member States use tax exemptions in combination with mandatory blending obligations (Austria, Lithuania, Slovenia, Germany and Czech Republic). Finally, four Member States grant tax exemptions to limited amounts of bio-fuel production, namely France, Ireland, Italy and Portugal.

According to the EU Commission, infringement procedures against nine Member States (Denmark, Finland, Greece, Hungary, Ireland, Italy, Luxembourg, Poland, and the United Kingdom) were launched as targets that were too low were set without providing adequate justification or for not having taken further actions to implement Directive 2003/30/EC.

The costs incurred by EU Member States depend on the selected promotion policies for biofuels and the scope of support for this sector. The following are some of the most frequently supported branches along the biofuels supply chain including: agricultural production, processing and distribution and mobility[84].

Member States with considerable agricultural capacities for production of raw materials in the first phase supported the agricultural sector with subsidies for crops intended for energy purposes. In addition investments and tax relieves for producers and distributors of biofuels were granted. Most EU Member States have declared the importance of biofuels for climate change and energy security, and therefore strong emphasis has been put on the stimulation of biofuels demand and social acceptance. The implementation of the Biofuels Directive at national levels shows that other sectors are also involved in support measures besides the direct instruments of biofuel production or consumption promotion. Among the most important are:

83 The Directive does not explicitly specify that biofuels are to be used for this purpose but mentions rather renewables more generally.
84 The Biomass Action Plan from December 2005 indicated further conditions and possibilities for promotion measures for renewable energy sources including transport among them the possibility to use second generation biofuels. It also considered free trade in bioethanol in the European Union countries. In 2006, the Biofuels Strategy underlined further possibilities to use biofuels, but also puts an emphasis on the developing countries where production of biofuels on macro scale can contribute to the improvement and to the economic profitability of these countries.

1. Agricultural production
   a) Subsidies for the production of energy crops (CAP Reform)
   b) Use of compulsorily set-aside land for energy crops (Command and Control).
2. Production of Biofuels
   a) Expenditures on Research and Development (R&D for second generation Biofuels)
   b) Loans and subsidies for investments in the production of biofuels
   c) Tax incentives for producers of biofuels / excise relief
   d) Mandatory blending system for producers of biofuels.
3. Distribution of Biofuels
   a) Obligation to use biofuels by the distributors, quality aspects of biofuels for fuel standards
   b) Quota system for distributors, allowing the introduction of a specific quantity of biofuels to the market with tax relief
   c) Subsidies for construction or modernisation of petrol stations designated for sale of biofuels.
4. Marketing of biofuels and support for end recipients
   a) Incentives for users of biofuels
   b) Use of vehicles powered by pure biofuels in public fleets
   c) Information campaigns and Governmental plans and strategies.

Table 6-1 Examples of most relevant policies for Biofuels promotion in Germany (2000-2008)

MS	National Policy	Implementation Date	Evaluation period [1]	Base year for savings
DE	Mineral Oil Tax exemption	1992 – 2004	2004-2007	2004
	Energy Tax Act (EnergieStG) – Tax Exemption	01.08.2006		
	Biofuels Obligatory Quota Act (BiokrafstoffQuotenG)	01.01.2007		
	R& D Program for Biomass	2007	2000 - 2004	2004-2005
	Sustainability Decree (Nachhaltigkeits VO)	2007 – 2008	n.a.	n.a.

Taking Germany as an example, Table 6-1 shows a series of promotional measures and policies that relate to Biofuels and Biomass promotion including a mineral oil tax exemption existing before the implementation of the Directive 2003/30 into national law. This law has been updated and changed to the Energy Tax Act, entering into force on 1st August 2006 and introducing a partial tax on biodiesel of 9 cents per litre for pure biodiesel and 15 cents per litre for added biodiesel. These rates took account of the overcompensation detected in comparison with fossil fuels. A further measure was the Biofuel Quota Act which entered into force on 1st January 2007 and replaced the exemption from petroleum tax for biofuels with a regulation with amendments to the Tax Law (*Steuerrecht*) and the Emission Control Act (*Immissionsschutzrecht*). The key aspects of the Quota Act are summarized as follows:

- Companies marketing fuels are obliged from 2007 onwards to market a legally-prescribed minimum percentage (quota) in the form of biofuels in their transport fuels portfolio. The compliance of the quota requirement may be delegated to third parties.
- The quota is fixed in relation to the energy content from 2007 at 4.4% for diesel and 1.2% for gasoline. The quota for gasoline increases to 2.0% in 2008, 2.8% in 2009 and 3.6% in 2010.
- A combined quota of 6.25% will be introduced for both fuels from 2009 which will gradually be raised to 8% in 2015 [85]. The minimum rates for gasoline and diesel biofuels blending continue to apply.
- The tax incentives are continually reduced for a transitional period, until the end of 2009, for pure vegetable oil and pure biodiesel not included in the blending quotas. The tax relief before the Energy Tax Act was adopted was limited to the end of 2009.

85 On 22 Oct 2008 the German Federal Cabinet decided, on the initiative of the German Environment Minister, on a new foundation for the promotion of biofuels in Germany. The aim is to avoid competition for the cultivation of biofuels and food and to orient the expansion of biofuels more strongly as in the past towards an effective reduction of GHG emissions. The quote of 6.25% foreseen for the beginning of 2009 will be delayed by one year, for 2009 the quota is fixed at 5.25% (in energy contents). After 2010 the quota of 6.25% will be frozen until 2014. In 2011 the quota will be reviewed in particular with respect to the question of sustainable production of biofuels. The law will also allow to take bio methane from biogas into the quota if certain criteria are fulfilled during the production processes in order to achieve a positive climate impact. Taxes on pure Biodiesel will be lowered in 2009 by 3 Cent per Litre (from 21 to 18 Cents per Litre) as compared to the present regulation. Starting from 2015 the quota will not be established any more on an energetic basis but considering the net contribution to GHG reduction. This includes also the emissions for the production of biofuels. This aims to promote second generation biofuels that might have a considerably better climate impact than the first generation (BMU 22/10/2008), http://www.bmu.bund.de/pressemitteilungen/aktuelle_pressemitteilungen/pm/42433.php).

– Second-generation biofuels, biogas and pure bioethanol (E85) are granted a descending tax incentive until 2015 but overcompensation will be analysed. No tax is currently levied on such fuels.

The following table show the tax rates for biodiesel and vegetable oil in cents per litre according to the German progress report to the EU Commission on the Biofuels Directive.

Table 6-2 Tax rates for pure biodiesel and vegetable oil in Germany from 2006 onwards[86]

Support for biofuels is coupled with compliance with fuel standards cover materials such as fatty acid methyl esters (FAME, biodiesel) which are considered to be biofuels only if they meet at least the requirements of DIN EN 14214 and bioethanol which is considered to be biofuel only if it meets at least the requirements of draft DIN EN 15376 (as of May 2006). Biofuels produced wholly or partially from either animal oil or fat will, from 2012 onwards, no longer be taken into account for meeting the quota requirement.

Furthermore, a wide variety of R&D programs, measures and grants are allocated for biofuel production focusing on biodiesel quality and second generation biofuels such as biomass to liquids technologies (BTL) as well as issues related to biomass availability, logistics and environmental impacts and protection. Further research projects relate to biofuels and bioenergy certification including raw materials used for production in order to guarantee sustainable practices.

At EU level tax exemptions are applied as displayed in Table 6-3. This table shows the tax exemptions granted for biofuels across the selected Member States for bioethanol and biodiesel in €/1000 L.

Table 6-3 Tax Exemptions and other fuel taxes across the selected Member States for Biofuels

	Petrol	Bioethanol Relief	Diesel	Biodiesel Relief
	€/1000 l	Amount of relief in €/1000 l	€/1000 l	€/1000 l
AT	452.55	Full	375.00	Full
DE	663.50	Full (E85)	475.20	Full (B100)
DK	537.60	EUR 30	364.08	Full
FR	606.90	EUR 340	428.40	EUR 178.9
CZ	418.55	Trials	351.74	Full
PL	415.83	Full; not less than EUR 3	321.15	Full
UK	759.99	EUR 289	806.61	EUR 290
SE	542.24	Full	425.32	Full
IT	564.00	EUR 289	423.00	EUR 245
ES	426.95	EUR 371	302.00	Full

Source: Wisniewski et al. (2008)

In addition to the national measures for the promotion of Biofuels, community wide ECCP and non-ECCP measures interact with Directive 2003/30/EC. These measures are the CAP Reform, the reform on the Directive for Taxation of energy products 2003/96/EC and regulations for fuel quality among others. The measures mapping for the promotion of Biofuels is summarised in Table 6-4.

86 See footnote 85 for the modifications introduced recently in taxation.

Table 6-4: Measure mapping of the Biofuels Directive

MEASURE	TARGET	GOAL FOR TOP-DOWN IMPACT
Support schemes for Biofuels		
Biofuel Directive	**5.75 % Biofuels in 2010 – Proposal 10% in 2020 (discussion)**	**Increase share of biofuels and other renewable fuels for transport**
National support schemes	**Tax exemptions, quotas**	**Reaching national targets**
Complementary financial measures		
Energy taxes	**primary/final energy use**	**Incentive for production**
Support for Agricultural Land (CAP Reform)	**Subsidies for energy crops**	**Incentive for cultivation**
Command and control		
Fuel standards (Fuel Standards for Biofuels)	**Assure fuel quality.**	
Technology promotion		
R&D (1st and 2nd generation, BTL, Logistics, Sustainability)	**Increase efficiency, technology diffusion**	
Informational measures and voluntary demand		
Information and awareness campaigns and Industry and MS Governments/EU	**Awareness raising, social acceptance, create markets**	

6.4 Step 2: Compilation of quantitative evaluation evidence

There is already considerable experience on the quantitative assessment of the impact of biofuels policies on the deployment of biofuels technologies as well as on GHG reductions in the future at EU level. In particular with respect to a prospective assessment of the future emission reductions of biomass, including biofuels and renewable energy sources various studies exist, such as Ragwitz (2004), EEA (2006), REFUEL (2008), VIEWLS (2006).

Consideration of the historic impact of biofuels on GHG avoidance at an EU level has been evaluated in the Biofuel Directive from the EU Commission (Jan. 2007). No further studies have been identified In Germany various studies exist with respect to the analysis of climate change policies and measures at national level, including analysis on prospective investments and expected CO_2 and GHG emissions such as the Integrated Energy and Climate Program (IEKP 2008) study as well as the Policy Scenarios IV and V from 2008 and the study on Investments for a Climate Friendly Germany (June 2008). In the framework of the discussions for the Sustainability Act for Biofuels, the study from IFEU (Dec. 2007) reviews the GHG Balances for the German Biofuels Quota Act as well as the Review on GHG savings calculations from the Renewables Fuel Agency in the UK from June 2008. These studies evaluated the emission reductions due to biofuels generation based on the LCA emissions of the biofuels from production to end use.

A recent ex-ante estimate for the EU is presented in RFA (2008). The savings resulting from the European Union 10% (by energy content) target are estimated to be approximately 54 – 68 million tonnes CO_{2eq}. The following assumptions were made:

- The feedstock mix was based on the impact analysis carried out by the European Commission[87] - details are provided in the table below.
- The GHG saving achieved by a biofuel chain was based on the best performing feedstock / origin default value from the UK Renewable Transport Fuel Obligation RTFO default values. The lower estimate assumes that there is no improvement over time in the GHG saving of first generation biofuels, while the higher estimate assumes that there will be a 20% improvement.

87 See http://ec.europa.eu/agriculture/analysis/markets/biofuel/impact042007/text_en.pdf

These ex-ante estimates scale rather well with the results found in this study when LCA factors were used, because those factors are already well established.

Table 6-5: Ex-ante GHG impact projections by RFA (2008) for the 10 % biofuels target

Fuel chain	Quantity of biofuel	Low GHG saving	High GHG saving	Low GHG saving	High GHG saving
	Mtonne	kg CO2e / GJ	kg CO2e / GJ	Mt CO2e	Mt CO2e
Bioethanol from cassava	0.0	34.4	44.5	0	0
Bioethanol from wheat	12.4	25.6	37.4	8	12
Bioethanol from sugar beet	0.2	34.4	44.5	0	0
Bioethanol from sugar cane	2.0	60.0	64.9	3	3
Bioethanol from sorghum	0.0	60.0	64.9	0	0
Bioethanol from maize	4.5	35.6	45.4	4	6
Biodiesel from soya beans	3.4	38.8	48.3	5	6
Biodiesel from palm	0.6	39.6	48.9	1	1
Biodiesel from sunflower	1.3	41.2	50.2	2	2
Biodiesel from jatropha	0.0	39.6	48.9	0	0
Biodiesel from rapeseed oil	19.9	41.2	50.2	31	37
Lignocellulosic ethanol from bagasse	0.0	68.9	68.9	0	0
Lignocellulosic ethanol from wood residues	0.0	68.9	68.9	0	0
Lignocellulosic ethanol from agricultural residues	0.0	68.9	68.9	0	0
FT (or syn) diesel from bagasse	0.0	83.5	83.5	0	0
FT (or syn) diesel from wood residues	0.0	83.5	83.5	0	0
FT (or syn) diesel from Agricultural residues	0.0	83.5	83.5	0	0
TOTAL	**44.3**	**-**	**-**	**54**	**68**

Source: RFA (2008)

6.5 Step 3: Screening

The screening of various measures has already been partially carried out in the mapping section. Among the measures for the promotion of biofuels given in the Directive, by far the most important national support instruments are tax exemptions and the recently implemented mandatory quotas in combination with tax exemptions. Other instruments such as the RES-E Directive have no or only indirect effects on the development of biofuels for transport. Future legislation aimed at Ecological and Sustainable developments will have an indirect effect on production and imports, however, the methodologies and GHG measures will affect the direct promotion of biofuels. These measures were still under discussion in 2008. Other non-ECCP measures such as R&D as well as Fuel Standards and payments for energy crops cultivation under the Common Agricultural Policy have an indirect effect on the promotion of biofuels.

6.6 Step 4: Modelling step

In this step the different methodological approaches outlined in Section 6.2 will be shown for the case of Germany and the EU.

6.6.1 Biofuels production

Sub-step (i): Assess biofuel production, consumption and imports before and in the year of the transposition of the Directive as well as in the following years.

In a first sub-step the production and consumption of biofuels is assessed from 1995 until 2007 including the base year, i.e. the year of the transposition of the Biofuels Directive at national level (2004-2005). Assumptions with respect to imports/exports of biodiesel and bioethanol were made as these are not included in any statistical review at EU or national level. Import figures are obtained through the difference between production and consumption per year. In the case of Biodiesel in 2005, the difference in consumption and production could be interpreted as possible exports, however, part of the biodiesel produced could also have been used for electricity generation in diesel plants or exported to other EU countries, corresponding to data uncertainties and there are no records on one or the other use. For this assessment it has been assumed that the biodiesel produced is used for electricity generation rather than exported outside the EU as costs and prices are higher in the EU than in other world regions. Biofuel consumption values are registered for the EU from 2005 onwards after the implementation of the Directive at national level. Stock changes may also be an additional element to be considered but no information is available on this yet.

These figures play an important role later in the quantification of the CO_2 and GHG emission reductions. The production and consumption figures as shown in Table 6–6 and Table 6-7 for the EU and Germany are converted into energy units from physical units (e.g. tonnes or litres) of production for biodiesel and bioethanol.

Table 6-6 Actual Biofuel production, consumption and share in the EU (1995-2007)

Year	BE-Prod. [Mtoe]	BD-Prod. [Mtoe]	BF-Prod. [Mtoe]	BE-Cons. [Mtoe]	BD-Cons. [Mtoe]	BF-Cons. [Mtoe]	BE-Imports [Mtoe]	BD-Imports [Mtoe]	Share BF in transport fuels [%]
1995	0.03	0.35	0.38	n.a.	n.a.	0.20	n.a.	n.a.	0.08
2000	0.08	0.74	0.82	n.a.	n.a.	0.63	n.a.	n.a.	0.24
2001	0.12	0.75	0.87	n.a.	n.a.	0.74	n.a.	n.a.	0.28
2002	0.13	1.12	1.25	n.a.	n.a.	1.03	n.a.	n.a.	0.39
2003	0.20	1.49	1.69	n.a.	n.a.	1.37	n.a.	n.a.	0.51
2004	0.26	1.93	2.19	n.a.	n.a.	2.02	n.a.	n.a.	0.69
2005	0.46	3.18	3.64	0.56	2.25	2.99	0.10***	-0.93*	1.10
2006	0.80	4.88	5.68	0.87	4.07	5.60	0.07***	-0.81*	1.90
2007	0.89	5.70	6.59	1,17	5,77	7.7**	0,28***	0,07*	2.60

BE: Bioethanol – BD: Biodiesel – BF: Biofuel – Prod: Production – Cons.: Consumption

* Calculated by difference from production and consumption. See comments above -

** Includes other biofuels

*** Calculated by difference from production and consumption. Other figures indicate that approximately 0.4 to 0.6 Mtoe of ethanol was imported to EU but the end uses for the imports are unclear with respect to transport use or chemical use. It could be expected that the import figure is higher and consumed later as well. For the calculation a figure of 0.07 Mtoe was initially adopted.

Biofuel production at EU level grew slightly from 1.3 Mtoe in 2002 to 1.69 Mtoe in 2003 after the Directive was adopted. National programmes entered into effect only from the end of 2004 when production had already grown to 2.2 Mtoe. Production had increased threefold by the end of 2007. In consumption terms the demand for biofuels has increased almost four times between 2004 and 2007, as demonstrated by biofuels imports.

Table 6-7 Actual Biofuel (Bioethanol and Biodiesel) Production, Consumption and Share in Germany (1995-2007)

Year	BE-Prod. [Mtoe]	BD-Prod. [Mtoe]	BF-Prod. [Mtoe]	BE-Cons. [Mtoe]	BD-Cons. [Mtoe]	BF-Cons. [Mtoe]	BE-Imports [Mtoe]	BD-Imports [Mtoe]	Share BF [%]
1995	0.00	0.04	0.04	n.a.	n.a.	0.03	n.a.	n.a.	0.06
2000	0.00	0.22	0.22	n.a.	n.a.	0.22	n.a.	n.a.	0.39
2001	0.00	0.29	0.29	n.a.	n.a.	0.31	n.a.	n.a.	0.56
2002	0.00	0.39	0.39	n.a.	n.a.	0.49	n.a.	n.a.	0.88
2003	0.00	0.62	0.62	n.a.	n.a.	0.71	n.a.	n.a.	1.34
2004	0.01	0.90	0.91	n.a.	n.a.	0.98	n.a.	n.a.	1.84
2005	0.08	1.46	1.54	0.15	1.55	1.94*	0.07	0.09*	3.87
2006	0.22	2.33	2.55	0.30	2.53	3.48*	0.08	0.20*	6.30
2007**	0.20	2.52	2.72	0.29	2.96	4.00*	0.09	0.44*	n.a.

BE: Bioethanol – BD: Biodiesel – BF: Biofuel – Prod: Production – Cons.: Consumption

* Difference in total consumption and BE and BD consumption due to other biofuels such as vegetable oil

** Not confirmed by the EU Commission until end of 2008

Germany is the Member State with the strongest increase in production and consumption for biofuels across the EU since the adoption of the Directive and transposition into national law from 2004 onwards. Here biofuel production grew from roughly 1 Mtoe in 2004 to 2.7 Mtoe in 2007. Consumption on the other hand increased strongly amounting 3.5 Mtoe in 2006. Figures for 2007 are being reviewed and will be confirmed later this year.

6.6.2 Gross GHG Savings

Sub-step (ii): Direct GHG emissions accounting for all new biofuel consumption after transposition of the Directive and National Law that substitute fossil petrol and diesel by end use (gross impact).

In this approach all GHG emission reductions due to biofuel consumption from 2004 is accounted for in the selected Member States. This consumption substitutes a certain amount of fossil fuel (gasoline or diesel) based on the energy content. Its corresponding emission reductions are calculated with the following Well-to-Wheel (WTW) emission factors for gasoline and diesel.

Table 6-8 Emission factors for Gasoline and Diesel[88]

Emission factors	WTW t CO_2/TJ	TTW t CO_2/TJ
Gasoline	85	73.3
Diesel	86.2	73.2

Source: CONCAWE 2006

88 There is critics about the use of constant 2005 base values (85g $CO_{2\text{-eq}}$/MJ for gasoline and 86.2g $CO_{2\text{-eq}}$/MJ for Diesel) for the reference system. In future the CO_2 expenditure for the winning of fossil fuels may increase drastically.

Table 6-9 Gasoline/Diesel replaced by biofuels and the corresponding gross emission reductions[89] for Biofuels after transposition of the Biofuels Directive into National Law (2004-2007)

	Gasoline Replaced [Mtoe]	Diesel Replaced [Mtoe]	Emission Reductions G – BE [$MtCO_2$]	Emission Reductions D – BD [$MtCO_2$]	Total Gross Emission Reductions [$MtCO_2$]
EU					
2004		2.0		7,39	7,4
2005	0.6	2.3	2,01	8,23	10,2
2006	0.9	4.1	3,13	14,89	18,0
2007	1.2	5.8	4,19	21,13	25,3
DE					
2004	n.a.	1.0		3,59	3,6
2005	0.2	1.6	0,54	5,67	6,2
2006	0.3	2.5	1,08	9,26	10,3
2007	0.3	3.0	1,05	10,82	11,9

This approach is however not complete as it does not consider the life cycle emissions from the biofuels, but it has been included here to allow comparison. The following sub-step takes this effect into account.

6.6.3 GHG Savings taking into account Lifecycle Assessment

Sub-step (iii): Assessment of GHG Emission Reductions (CO_{2-eq}) accounting for all new biofuel consumption after transposition of the Directive taking into account Life Cycle Emissions from biofuel production to consumption.

In the selected Member States, a survey of the biofuels produced is made by identifying the production quantities for biofuels, differentiated by the type of biofuel produced (biodiesel or bioethanol), the feedstock and the processes used (see step (i)). The GHG reduction quantification in this case is calculated with emission factors determined by Life Cycle Emissions Assessment (LCA from Well-to-Wheel) for complete biofuels supply chains, taking into account the emissions and fuel uses along the whole production process from cultivation, transport, production, delivery to the refineries and to end users. The following emissions factors are adopted for the assessment from the WTW analysis of the EU (CONCAWE and REFUEL 2008) for these calculations.

Table 6-10 WTW Emissions factors for Biofuels Production Chains[90]

GHG emissions data	tCO_2-eq. / TJ Biofuel
Biodiesel	
Biodiesel Rapeseed	49.2
Biodiesel Sunflower	26.2
Biodiesel Used Fats	42.2
Biodiesel Palm Oil	42.2
Bioethanol	
Bioethanol Wheat	59.9
Bioethanol Sugar beet	58.4
Bioethanol Sorghum	11.5
Bioethanol Rye	60.9
Bioethanol Maize	60.3
Bioethanol imported	11.5

Source: REFUEL Project 2008, CONCAWE WTW Assessment

89 An alternative calculation would be to use not the WTW (well-to-wheel) emission factors but rather the TTW (tank-to-wheel) emission factors for the gross savings. In 2007 the total would be 21.3 Mt CO2 instead of 25.3 Mt CO_2.

90 Most of these factors are in line with the emission factors mentioned in Article 17 (Calculation of the greenhouse gas impact of biofuels and other bioliquids) and Annex VII of the Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources COM(2008) 30 final, Brussels, 23.1.2008, (http://ec.europa.eu/energy/climate_actions/doc/2008_res_directive_en.pdf) although there are some differences in detail

The emission reductions are calculated in first instance for bioethanol and biodiesel using their Well-to-Wheel emissions as illustrated in Table 6-10 (Source: REFUEL EU Project 2008, CONCAWE WTW Assessment). For 2004, the Biofuels consumption in Europe and in Germany was all assumed to be Biodiesel as figures for bioethanol consumption were not recorded in the statistics. Table 6-12 illustrates the allocations assumed for biodiesel and bioethanol with respect to the type of feedstock used (e.g. rapeseed, sunflower, imported etc.) for Europe and Germany.

Table 6-11 Assumed allocations (in percentage) for Biodiesel and Bioethanol for Europe and Germany according to the type of feedstock used or imports (2005-2006)

	Allocation Share EU (2005) - [%]	Allocation Share DE (2005) - [%]	Allocation Share EU (2006) - [%]	Allocation Share DE (2006) - [%]
Biodiesel				
Biodiesel Rapeseed	60	80	60	80
Biodiesel Sunflower	35	15	35	15
Biodiesel Used Fats	5	5	5	5
Bioethanol				
Bioethanol Wheat	40	45	40	50
Bioethanol Sugar beet	20	10	22	10
Bioethanol Sorghum	10	10	10	11
Bioethanol Rye	10	10	10	11
Bioethanol Maize	10	5	10	11
Bioethanol imported	10	20	8	7

With these allocations and the corresponding emissions factors mentioned before, the emission reductions were calculated for biodiesel and bioethanol first and then the net emissions where deducted from the avoided emissions calculated in sub-step (ii) (column Net Emission Reductions). The total emissions considering WTW emissions from Biofuels reduced the impacts to roughly half as compared to the gross emission reduction calculated in sub-step (ii) (Table 6-12). The allocations for 2006 are used for 2007 calculations.

Table 6-12 Net emission reductions for Biofuels Consumption for EU and Germany after the Biofuels Directive transposition (2004-2007)

	BE-Cons. [Mtoe]	BD-Cons. [Mtoe]	Emissions BE [$MtCO_2$]	Emissions BD [$MtCO_2$]	Net Emiss. Reductions BE [$MtCO_2$]	Net Emiss. Reductions BD [$MtCO_2$]	Total Em. Reductions [$MtCO_2$]
EU							
2004		2.02		3.45		3.94	3.94
2005	0.56	2.25	1.17	3.84	0.84	4.39	5.23
2006	0.87	4.07	1.86	6.95	1.27	7.94	9.21
2007	1.17	5.77	2.49	9.86	1.70	11.27	12.96
DE							
2004	n.a.	0.98		1.86		1.72	1.72
2005	0.15	1.55	0.28	2.95	0.25	2.73	2.98
2006	0.30	2.53	0.64	4.81	0.43	4.45	4.88
2007	0.29	2.96	0.63	5.62	0.42	5.20	5.62

BE: Bioethanol – BD: Biodiesel

At EU level nearly 13 million tons CO_{2eq} of net savings (excluding land use change) are observed in 2007, three times as much as in 2004, with bioethanol imports largely from Latin America, reaching 8% of the total consumed at EU level in 2006 (10% of the total consumed at EU level in 2005). For Germany, emission reductions in 2006 were almost 5 million tonnes CO_{2eq} with bioethanol imports close to 7% in 2006, a dramatic reduction from almost 27% in 2005. The imports assumed for Germany are adjusted and are not all coming from Latin America (between 7 to 20% only) but from other EU countries.

It is currently being discussed whether, in addition to the consideration of LCA emissions for biofuels across the whole production and distribution chain, assessment of emission reductions should be extended to cover the effects from land use changes (direct and indirect). There is currently insufficient evidence to enable these impacts to be quantified within a reasonable level of accuracy. However, this issue should be captured within future evaluations. Further discussion on this issue is provided below.

6.6.4 Issues related to land-use change

Land-use change occurs when the cultivation of feedstock (e.g. soybean for biodiesel) results in the conversion of the land from a prior land-use (e.g. forest), thereby generating possible changes in the carbon stock of that land. However, these changes do not necessarily imply a negative effect. Conversion of forest, wetlands, and grasslands to cropland usually results in a net emission of carbon from biomass and soils to the atmosphere. However, cropland established on previously sparsely vegetated, highly disturbed lands and some grasslands can result in a net gain in both biomass and soil carbon. Moving from a long-term (20 years) cultivated system to a shifting cultivation can reduce the loss of carbon. Shifting cultivation means that the land is set-aside for a certain period, allowing the soil to partially recover from intense agricultural use. These effects are well studied and default values of GHG emission factors are available. Nevertheless, GHG emissions from land-use change have only recently been included in LCAs of biofuels.

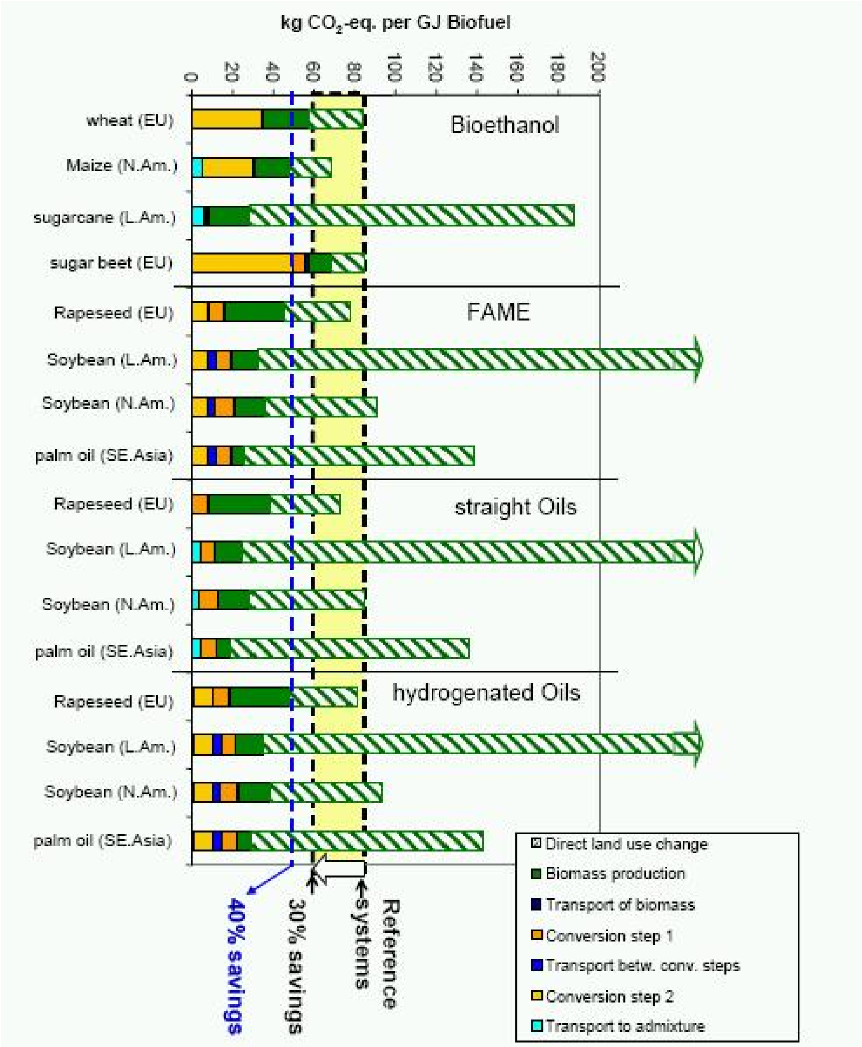
For period covered by this study (2004 and 2007) the effect of land use changes at EU Level is considered to be small after the adoption and transposition of the Biofuels Directive. In 2007, approximately 30% of EU biofuels consumption was imported. Of the remainder produced in the EU, those that were produced on recently abandoned agricultural land or land that would otherwise have been abandoned can be assumed to not result in any land use change. In addition, the biofuel co-products (see later) will have replaced other agricultural commodities, leading to a saving of land elsewhere. These considerations should be taken into account when evaluating the land use change effects of this policy.

Whilst, for the reasons described above, the impact on GHG emissions associated with biofuel imports is not relevant for the current study, it is potentially important for considering the future impacts of biofuel policies. In certain developing countries with important biofuel potential and production capacities, land-use changes for feedstock production may occur, replacing land with important carbon stocks. Biofuel export prospects can have an important influence on the conversion of such areas for cultivating biofuel feedstock. However, there are neither quantitative assessments in this respect nor registers of these changes with statistical data in the countries in question. The sustainability criteria for biofuels laid down in the Fuel Quality Directive and the Renewable Energy Directive define certain categories of land that should not be considered for biofuels production, and include the greenhouse gas emissions from direct land use change in the lifecycle calculation of the greenhouse gas emissions from biofuels. Further, the Renewable Energy Directive requires monitoring of the impacts of the policy, including impacts on land use.

More details on emission factors including direct land-use change for 1st generation biofuels are included in the German Biomasse Sustainability Ordinance BSO (see Annex 1). When combined with the requirement of minimum savings as compared to the fossil reference system in order to allow for a margin, very few of the first generation biofuels may qualify for GHG savings (

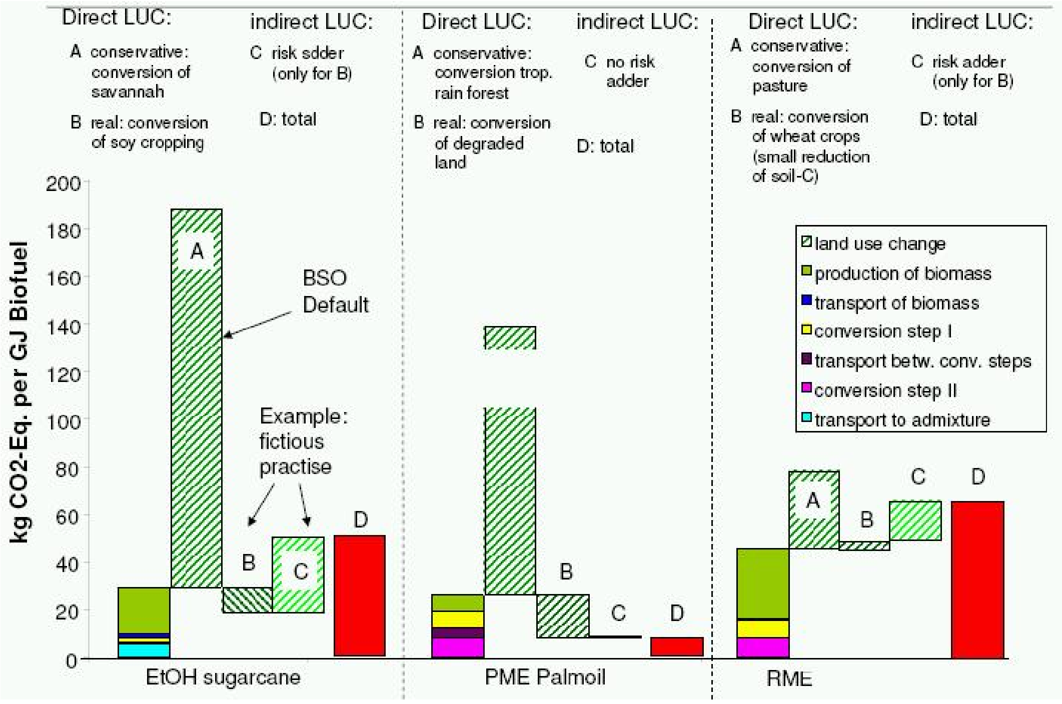
Figure 6-1). It must be recognised that the default values in the BSO are – on purpose - conservative in nature and represent quite negative cases in order to provide incentives to directly determine the correct emission factors and to spur innovation; see the comparison of default values (column A in Figure 6-2) with more typical cases (column B). This might even lead to increased savings in some cases due to higher storage of carbon in the new land-use. Second generation fuels may have more favourable GHG impacts according to the EU legislation but interestingly, the Gallagher report (2008) points in its recommendations to the fact that second generation biofuels using feedstock grown on existing agricultural land may cause greater net land-use change than first generation biofuels that also produce co-products that avoid land use.

Figure 6-1 Conservative default values for emission factor taking direct land-use change into account



Source: UBA (2008)

Figure 6-2 Comparison of the conservative default values for direct LUC impacts in the German BSO (column A) with more typical cases (column B)



Source: Fritsche 2008

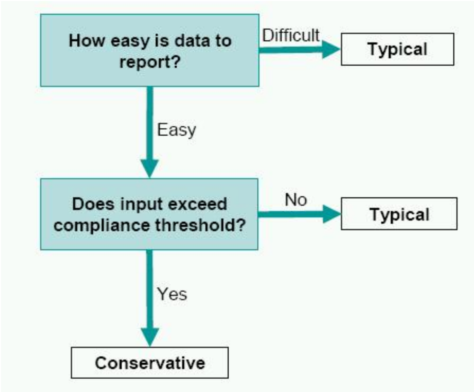
RFA (2008) debates how far default values, if used, should be conservative and enumerates pros and cons. In terms of the cons, according to RFA (2008) there are clearly risks associated with setting default values at a level which is too conservative:

- Reporting of actual data and the uptake of fuels with low carbon intensity would be encouraged, but the compliance costs for industry would potentially be high.
- A biofuel's carbon intensity would be overestimated if it was based purely on default values, making them appear to achieve lower GHG savings than they actually do. This could lead to a lack of support for biofuels policies because the GHG savings are not thought to be worthwhile.
- The industry might be reluctant to use the methodology and may attempt to develop alternative schemes.

In terms of pros RFA (2008) argues, if default values were not conservative enough:

- There would be little or no incentive for companies to report actual data and the supply of fuels with a low carbon intensity would not be encouraged.
- A biofuel's carbon intensity could be underestimated, possibly making them appear to achieve better GHG savings than they do.
- There would be considerable uncertainty about the actual carbon savings of the policy.
- There would be a risk to both industry and Government that biofuels would lose credibility as an environmentally friendly fuel if a third party (e.g. an environmental NGO) demonstrates that the methodology overestimated GHG savings.

Figure 6-3: Approach suggested by RFA (2008) to selecting appropriate magnitude for input level default values



Source: RFA (2008)

RFA (2008) concluded that if default values are set conservatively then the policy objective of complete carbon reporting is more likely to be achieved. In addition, it would be easier to manage the public perception risks if default values were on the conservative side – the apparent overestimation could be more easily explained and would have more resonance with the public than the reverse. RFA (2008) adds two important arguments to the debate to make the approach of default values more reliable and more flexible (Figure 6-3):

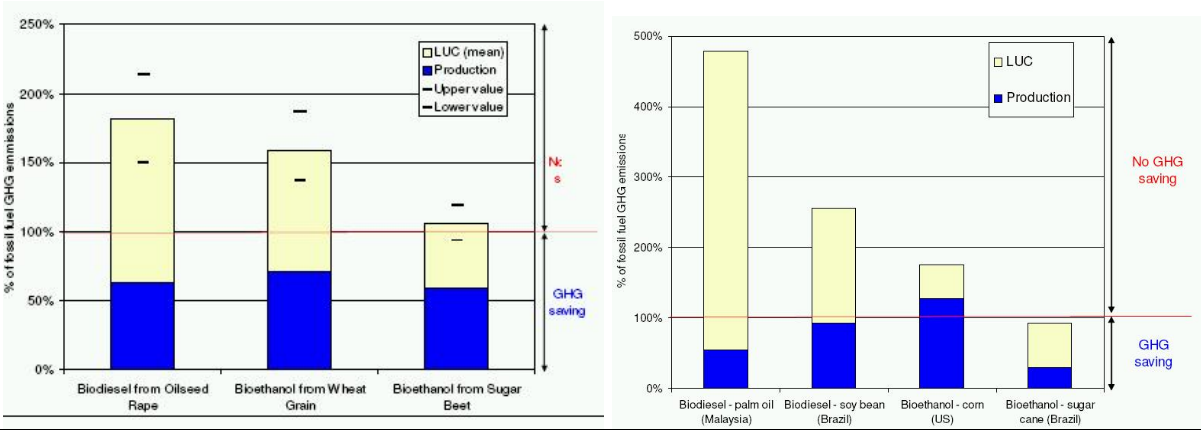
(1) For some data inputs it would be relatively easy for companies to report actual data – for example, a biofuel producer should be able to report on the yield, the energy efficiency and the fuel mix used at its plants. However, some data is scientifically more difficult to collect – for example, N_2O emissions from soils are difficult to measure because emissions vary between fields on the basis of soil type, daily climate, cultivation techniques, the rates and timing of fertiliser application and the crop grown (JEC, 2007). Therefore, it would be appropriate to set single default values for which it is "difficult" to report actual data, at a magnitude representative of typical practice rather than at a conservative magnitude.

(2) Most biofuel chains have approximately five major sources of GHG emissions, with the remainder made up of a large number (e.g. 15 – 20) of sources which contribute less than 5% individually. If a company wanted to report actual data on their fuel chain rather than relying on single default values they would optimise their efforts on the basis of impact (in terms of reducing the carbon intensity for their fuel chain) and cost of reporting. The sensitivity of the overall fuel chain result to an input which only contributes 5 percent is low – if it were technically possibly to halve this source of emissions, it would still only decrease the carbon intensity of the entire fuel chain by 2.5%.

Similar aspects to the German Biomasse Sustainability Ordinance BSO are discussed in the report *Review of Indirect Effects of Biofuels* by AEA Technology (2008). This estimates the net carbon loss rates from grassland conversion in the UK (ADAS, 2008) to grow biofuels feedstocks would in many cases negate the emissions savings from biofuel use (Figure 6-4 left). The impact of GHG emissions associated with land use conversions overseas, gives (Figure 6-4 right) a similar conclusion. For land uses where the carbon stored is very high, e.g. peatland rainforest, conversion can lead to extremely high emissions compared to conventional petrol or diesel.

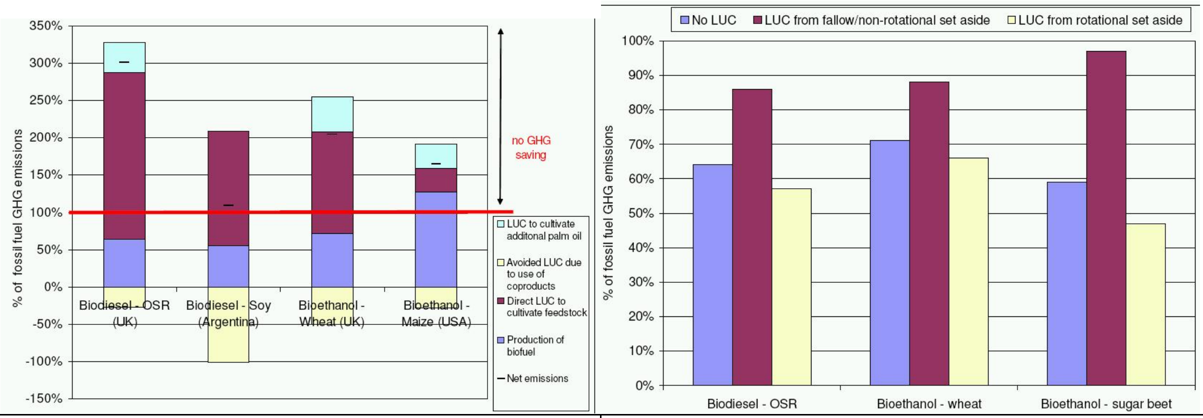
This report further discusses the potential reduction in land use change that might arise from the utilisation of co-products (e.g. Dried Distillers Grains with Solubles DDGS) as animal feed. A simple estimate of the avoided GHG emissions from this avoided land use change is shown in Figure 6-5 (left). It is clear from this that if the use of co-products prevents land use change, then this should be included in the overall estimate of GHG emissions from biofuels production, as it may be significant. North Energy also considered the specific case for the conversion of fallow land, non-rotational set-aside land and rotational set-aside land in the UK for production of the biofuels feedstocks Oil Seed Rape OSR or wheat. Figure 6-5 (right) shows the increase in biofuel GHG emissions if OSR or wheat are cultivated on non-maintained fallow or set aside land, compared to a standard case where cultivation is on land which is already cropped. The increase in GHG emissions is due to emissions of carbon from the soil when it is cultivated. These subsequently decline and, in the longer term, GHG emissions are less than the standard case due primarily to avoided soil N_2O emissions from the set-aside/fallow land. This suggests that in the UK biofuels are best grown on rotational rather than permanent set aside or fallow land.

Figure 6-4: Impact of direct LUC in the case of conversion of unfertilised grassland in UK (left) and overseas biofuels production (right)



Sources and assumptions: AEA Technology 2008, original source North Energy (2008) assuming unfertilised grassland, default values from the RFA methodology for production emissions, and allowing for net carbon loss, methane loss and change in N2O emissions.	Sources and assumptions: AEA Technology 2008, original source North Energy (2008); assumes conversion from tropical rainforest for palm oil production, from grassland cerrado for soybean production, central grassland for maize production and wooded cerrado for bioethanol production, and values for LUC GHJG emissions from Fargione et al, 2008 and Smeets et al, 2007.

Figure 6-5: Impact of allowing for avoided LUC from co-product production on GHG emissions (left) and short term increase in biofuel emissions when fallow or set aside land is converted (right)



Sources and assumptions: AEA Technology 2008, original source Calculated by AEA based on avoided land use change for co-product production calculated by Ecofys and CE Delft study teams, and assuming production of co-products avoids conversion from grassland.	Sources and assumptions: AEA Technology 2008, original source North Energy (2008). Results are shown for the short term (i.e. less than 20 years); in the longer term (after 100 years) the release of soil carbon from previously fallow land plateaus out in the long term as soil carbon reaches a new equilibrium level, and the long term increase is zero.

Indirect land-use change occurs as a result of additional demand for agricultural commodities, when pressure on agriculture, due to the displacement of previous activity or use of the biomass, induces land-use changes on other lands. The environmental effects of indirect land-use change can be described as leakage i.e. the result of an action occurring in a system that induces effects, indirectly, outside the system boundaries but that can be attributed to the action occurring within the system. The displacement of current land-use to produce biofuels can generate land-use change elsewhere. In order to meet an increased demand of biofuel a certain amount of feedstock is needed. These feedstock quantities can be obtained by:

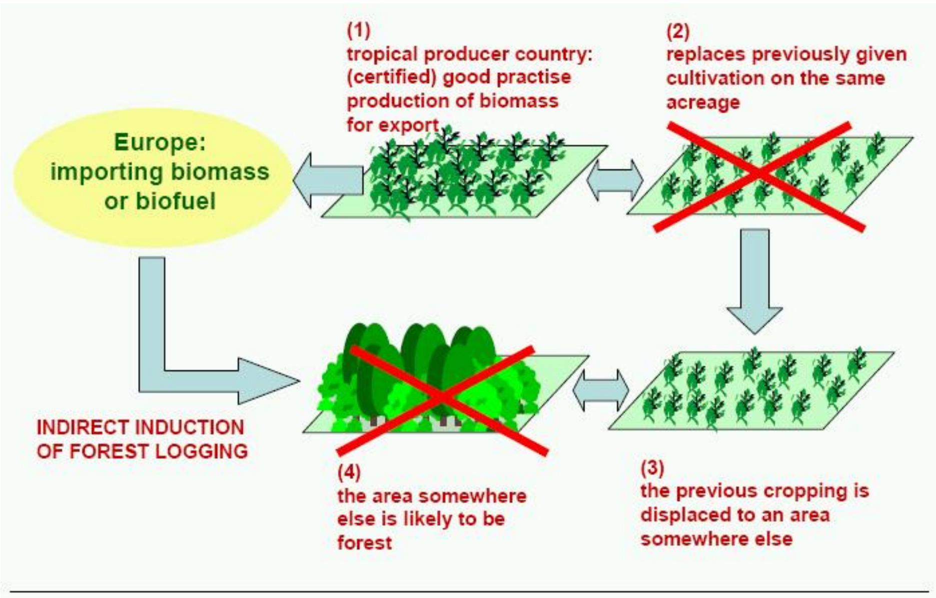
a) feedstock use substitution,
b) crop area expansion,
c) yield increase on the same land, and
d) shortening the rotation length.

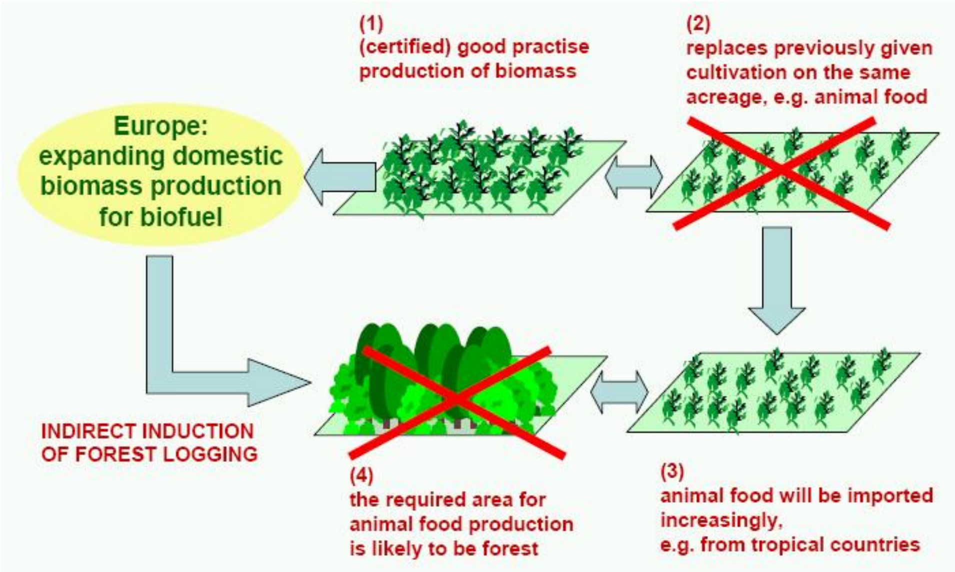
Apart from option c) (and if only the additional production resulting from yield increases is used for biofuels) all the other strategies may result in indirect land-use effects. In case a), this would be due to the decreasing of feedstock quantities for other purposes. This may have consequences on land-use dynamics of the impacted commodities somewhere else. Option b) may result in direct land-use changes due to the replacement of existing activities on other land, and option d) will result in reducing the production of the alternative crops and consequently may imply a relocation of the associated activities. The magnitude of this impact will depend on how the displaced activities/uses are relocated.

Some have claimed that GHG emissions from indirect land-use change are overall more important than emissions from direct land-use change. Despite the high uncertainty, some authors have produced a range of values to show the magnitude of this effect. They conclude that if temperate grasslands and tropical forests are converted to croplands, the GHG emissions of most biofuel pathways are higher than those of the fossil reference. For example, shifting corn-soybean to produce only corn for ethanol may induce soybean expansion into forest in other soybean producing regions. This could result in GHG emissions six times higher than those of petrol.

Figure 6-6 shows two possible mechanisms of displacement by increased use of bioenergy in Europe (UBA 2007). The upper diagram refers to an increase of biomass imported from the tropics. In the producing country good practice and absence of direct land use change may be certified. But the area now used by the new crop is no longer available for the previous crop, for which the demand is unchanged. That crop will therefore be displaced to other areas, which eventually will lead to the conversion of new land (with potentially high carbon stock or biodiversity value) for agricultural use. The lower diagram of Figure 6-6 shows that an increased biomass production in Europe may also indirectly induce forest conversion. In fact, the location of the feedstock cultivation for biofuels is not relevant. Commodity markets are global and global area for agriculture is limited. Therefore, eventually it is always the area with the cheapest and easiest development for agricultural use that will be used, and that will in many cases be forest or similar natural areas. It has to be underlined here that these examples don't take into account possible yield increases or the fact that the final expansion might take place in non-forested land.

Figure 6-6: Two examples of indirect land use change





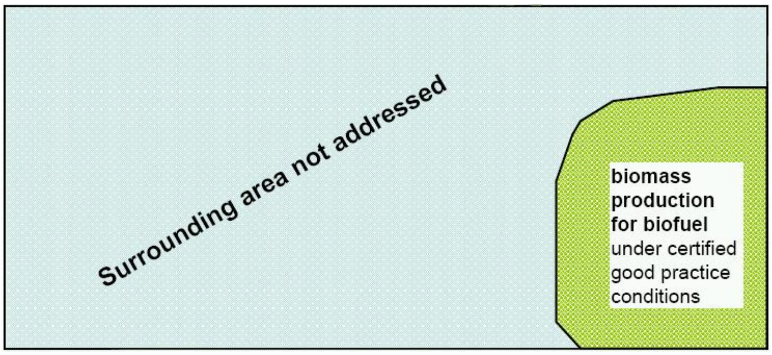
Source: UBA 2007

These examples suggest that limiting the analysis to the actual production area of the feedstock, the 'direct impact' (upper part of Figure 6-7) may not be sufficient (UBA 2007), because the implications outside of those boundaries are not considered. The middle diagram of Figure 6-7 shows the mechanism induced by using land for biomass feedstock production where land was previously allocated to other uses. The pressure may originate from expanding settlements and increasing, or at least constant, need of food crops requiring agricultural land. This would put pressure on areas of high carbon stock and biodiversity. The report 'Sustainable Use of Bioenergy on a Global Scale', authored by UBA (2008), states that it is up to the sovereignty of each country to address these issues and concludes that a certification system for sustainable biomass production cannot be expected to influence national responsibilities. On the other hand, sustainability cannot be attested to a production system placed in a country where clear and enforced regulation of land rights is absent. This leads to a fundamental conclusion: Certification of sustainable production of biomass requires land use regulation. Binding objectives have to be codified. How much land is needed for what purpose and to what nature quality level? The lower diagram of Figure 6-7 illustrates how politically announced land use objectives can take shape within a (national) allocation plan. According to UBA (2008) the following elements are necessary to put such a goal into practice:

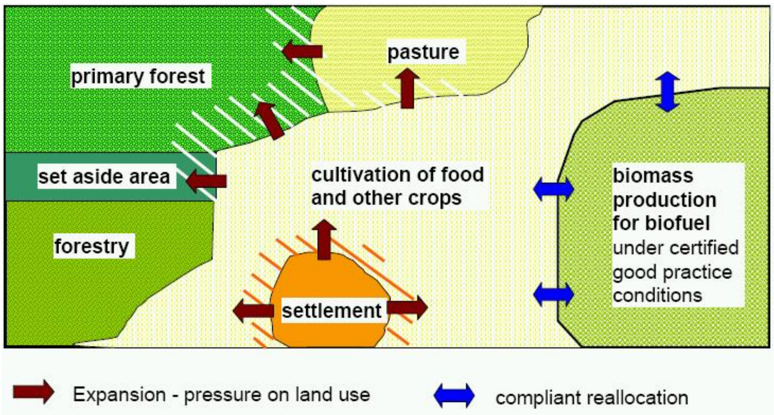
- setting up an area-wide status quo inventory of land use activities
- giving precise objectives in terms of percentages or absolute numbers
- installing a monitoring system (e.g. satellite monitoring)
- granting transparency and disclosure on the achievement of objectives.

Figure 6-7: Single view on biofuels impact or integrated assessment of land-use?

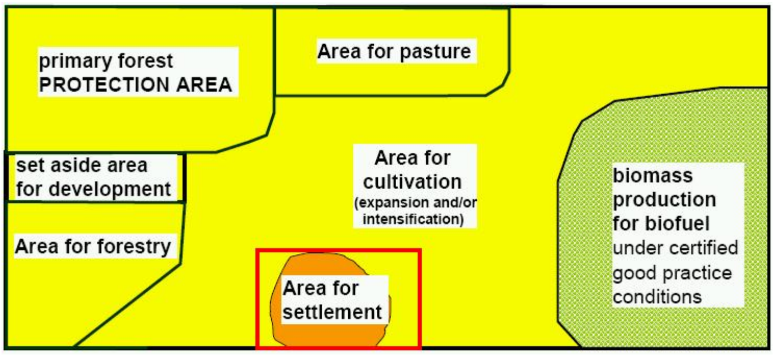
Effectiveness of land allocation for biomass production; analysis limited to the actual biomass production area



Effectiveness of land allocation for biomass production; considering dynamic effects of land use expansion by several forces



Consolidation of defined land use areas and land use objectives within an (national) allocation plan



Source: UBA (2008)

Such an integrated approach would have consequences in terms of impact monitoring and would imply that other policies considered as relevant for the ECCP such as the CAP reform and the Nitrate Directive need to be considered in an integrated manner with the Biofuels Directive. This requires setting up reference systems against which the impacts that are considerably outside the boundaries of the biofuels system can be measured.

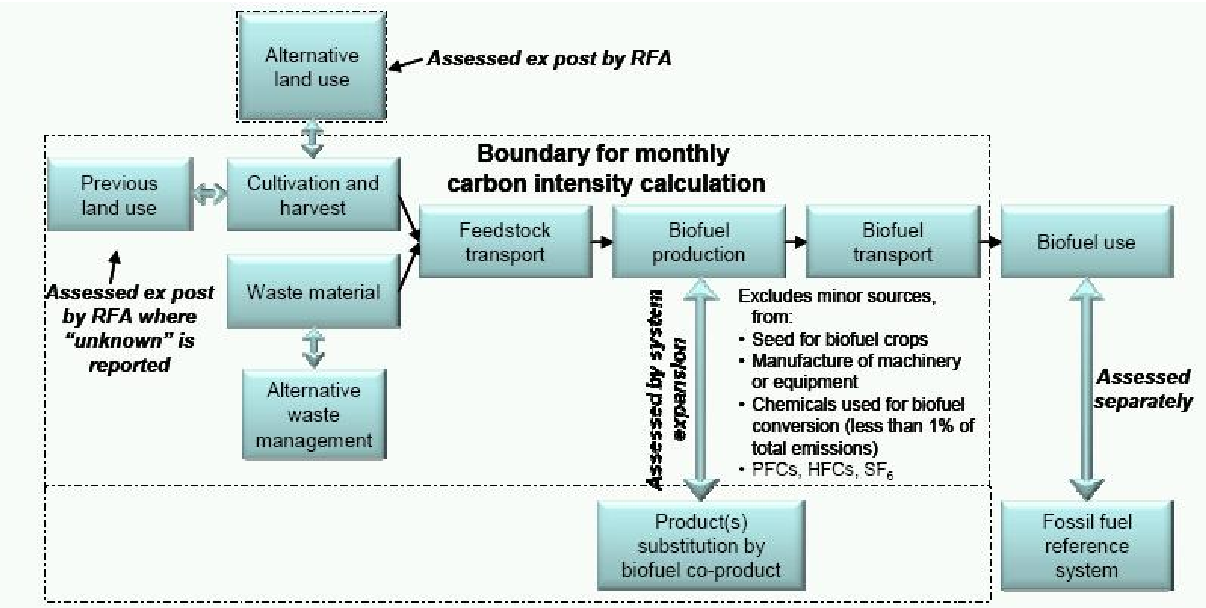
RFA (2008) discusses reference systems that could be included as part of the boundary of the biofuel carbon intensity calculation to account for emissions or avoided emissions resulting from systems displaced due to biofuel production. The following reference systems need to be considered in defining the boundaries of the carbon intensity calculation (see Figure 6-8):

- Alternative land use reference systems: used to determine the emissions (or avoided emissions) that would have occurred had the biofuel not been grown and the land had been used for an alternative. This includes the impact of displacing biomass production from that land to another area, e.g. sugarcane replaces soya bean farming, which is displaced to another area.
- Previous land use reference system: used to determine emissions (or avoided emissions) that have occurred due to land use change, e.g. forest or grass land that has been converted to energy crops.
- Residue and waste use reference system: used to determine emissions (or avoided emissions) that would have occurred due to an alternative use of the residue or disposal system for the waste, e.g. waste is now used for the creation of biofuel when previously would have been landfilled.

There are two other situations where reference systems are considered in relation to biofuel production activities:

- The boundaries of the biofuel carbon intensity calculation could be extended to include emissions or avoided emissions from products substituted by co-products of biofuel production activities. The issue of co-products is discussed in a separate section below.
- Fossil fuel reference systems are used to calculate the net GHG emissions resulting from the displacement of fossil fuels by biofuels in transport applications. This calculation is strictly outside the boundary of the biofuel carbon intensity calculation, but is required in order to establish the net GHG impact biofuels policy (see the default values discussed previously).

Figure 6-8: Boundaries for the carbon intensity calculation suggested by RFA (2008)



RFA recommend in their work that (see Figure 6-8):

- Carbon intensity is to be calculated including any GHG impact of direct land use change. The Renewable Energy Directive and the Fuel Quality Directive include such a requirement.
- Indirect land use change should be monitored, ex-post, in all countries which export biofuels (or their feedstocks) to the EU. The EU sustainability criteria for biofuels include a requirement for the Commission to work on the issue of indirect land use change.

6.6.5 Treatment of Co-products

Almost all biofuel chains produce co-products – e.g. glycerine from conventional biodiesel, dried distillers grains with soluble (DDGS) from cereal derived bioethanol and so on. Within lifecycle analysis theory there are two fundamentally different interpretations of how to treat the existence of co-products:

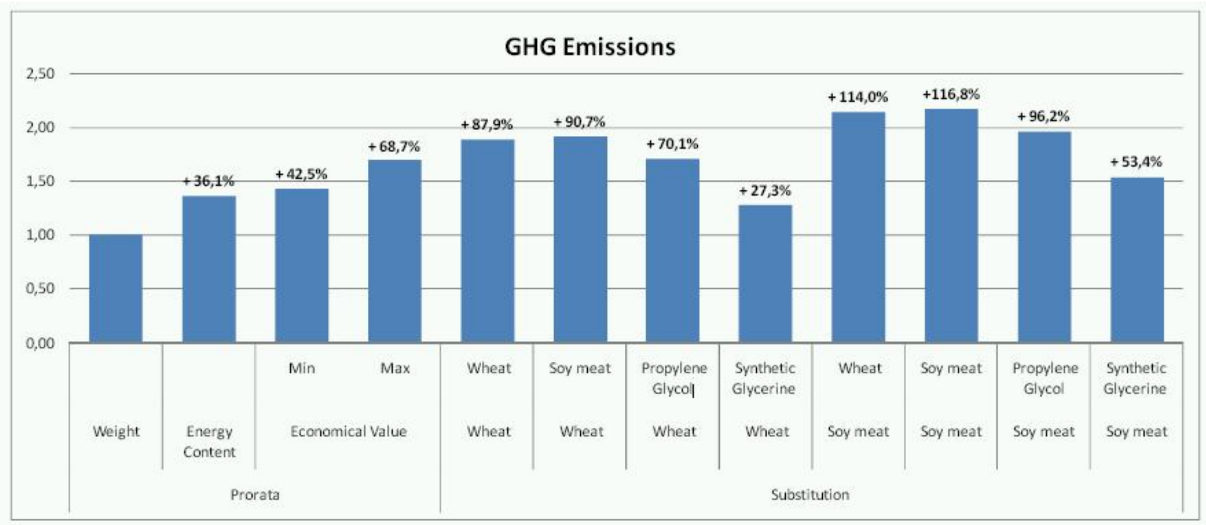
(1) system expansion
(2) allocation.

In terms of impact evaluation methodologies both interpretations may lead to rather different results. The Fuel Quality Directive and the Renewable Energy Directive indicate that the issue of co-products should be treated following an allocation method, based on energy content, for regulatory purposes. Recital 71 of the Renewable Energy Directive and recital 12 of the Fuel Quality Directive explain this choice as follows:

In the calculation of greenhouse gas emissions from the production and use of fuels, co-products should be accounted for. For policy analysis purposes the substitution method is appropriate. For regulatory purposes concerning individual operators and individual consignments of transport fuels, the substitution method is not appropriate. In these cases the energy allocation method is the most *appropriate method to use, because it is easy to apply, predictable over time, minimises counter-productive incentives and gives results that are generally comparable with the range of results given by the substitution method. For policy analysis purposes the Commission should also, in its reporting, give results using the substitution method*.

This recognises that policy analysis may make use of a more refined method than the allocation one used for practical purposes. Nevertheless, both methods need to be checked in the future for contradictory results.

Figure 6-9: Example: variations of GHG emissions according to the methodology considering co-products for rapeseed biodiesel



Source: DGPEI / ADEME / MEDAD / ONIGC / IFP / Cabinet BIO Intelligence Service (2008)

RFA (2008) debates the implications of the substitution/displacement method (designated as system expansion method). The system expansion method is based on the principle that a biofuel should be attributed with any consequences of a marginal increase in demand, such as increased or avoided GHG emissions. Therefore, if increased demand for a biofuel results in increased supply of a co-product any impact this co-product has on GHG emissions should be included within the boundaries of the biofuel's carbon intensity. A co-product could influence GHG emissions in any of the following ways:

- Displacement – if there is a market for the co-product, it will have displaced a product or co-product which would have incurred some GHG emissions in its production. For example, a rapeseed to biodiesel chain will have rapemeal as a co-product (from the seed crushing process). Rapemeal could be sold as a protein feed for animals, in which case it is likely to displace some soya meal from the animal feed market. Soya meal production would have resulted in some GHG emissions (e.g. from cultivation, fertiliser manufacturer, oil extraction etc.), since the soya meal is displaced out of the market these emissions will no longer occur.
- Intermediate processing – it may be necessary to carry out some additional processing on a co-product, which is not part of the biofuel production process, but which adds value to the co-product in some way. For example, DDGS is produced by drying wet distiller's grains to produce DDGS, a more valuable animal feed.

A crucial step in the system expansion method is establishing whether increased demand for a biofuel (or a biofuel feedstock) alone will lead to an increase in the supply of the biofuel (or feedstock) and its co-products. If this is the case, then the biofuel is known as the "determining co-product". Where the biofuel (or biofuel feedstock) is the determining co-product, its carbon intensity is to be evaluated by:

- Quantifying the emissions from the biofuel process (1)
- Adding the emissions from all upstream processes (2)
- Subtracting the emissions which would have been caused in the production of the displaced product (the marginal production route currently supplying this market) (3)

This is done because an increase in demand for the biofuel will result in an increase in supply (since it is determining). This will result in an increase of GHG emissions from (1) and (2) and a decrease in emissions from (3).

The alternative definition is that the biofuel is a “dependent co-product”. Where this is the case:

- Upstream emissions and emissions from the production process are allocated to the determining product A – i.e. NOT to the biofuel.
- The carbon intensity of the biofuel is equal to the emissions which would have been caused in the production of the displaced product

This is done because, the biofuel is not the determining co-product, so an increase in demand for it will not be met by an increase in the production volume of the main product (and hence there will be no increase in emissions from it). Instead, the increase in demand will be met by the marginal production route. Further explanation of the system expansion approach is given in Weidema (2001).

Table 6-13: Arguments provided by RFA (2008) for and against using different co-product treatment approaches

	Arguments for	**Arguments against**
System expansion	The most accurate method for assessing the consequences of a co-product. In particular system expansion is able to accurately assess any impacts a co-product has had outside the normal system boundaries of the calculation (i.e. through displacement of another product). This has proved to be crucial for maintaining the credibility of the methodology.	This approach can be expensive to carry out in practice, because it requires detailed information and analysis – e.g. to determine exactly which products are displaced and to establish their GHG impact. If the necessary analysis is not undertaken system expansion methods can introduce significant uncertainty into the final carbon intensity result.
Allocation	The information needed to carry out allocation tends to be easy to collect and does not require detailed calculations or analysis.	Allocation ignores the impact a co-product can have outside the boundaries of analysis (i.e. through product displacement). Allocation factors are based on parameters which vary in a way that bears no relationship to changes in the GHG impact of a co-product.
Market value	“Arguments for” given above in main Allocation row, and: Price allocation provides a link to the incentives which drive business decision making	“Arguments against” given above in main Allocation row, and: Price information alone does not always provide a clear indication of which products can influence the volume of production Even if market prices are averaged over time (e.g. 2-3 years) they can still vary significantly Use of international market prices can overcome spatial variation and improve comparability. However, there may be no international market price available for a product
Mass	“Arguments for” given above in main Allocation row, and: Mass allocation produces results which do not change over time, thus providing stability for decision makers The mass of a co-product can be easily determined	“Arguments against” given above in main Allocation row
Energy content	“Arguments for” given above in main Allocation row, and: Energy allocation produces results which do not change over time The energy content of a co-product can be easily determined	“Arguments against” given above in main Allocation row

Source: RFA (2008)

6.6.6 N_2O Emissions from the production of biofuels

Nitrous oxide (N_2O) is a GHG with a very strong global warming potential (296 times that of CO_2). The agricultural sector is one of the leading emitters of nitrous oxide in the atmosphere, as a consequence of the use of nitrogen fertilizers. There are two types of (N_2O) emissions:

- Direct emissions: emissions from the soils to which nitrogen is directly added.
- Indirect emissions: emissions from NH_3 and NO_x that volatilise from the farmed soils, and from the washing of nitrogen from the farmed soils, mainly under the form of NO^{3-}.

Various methods exist to quantify these atmospheric emissions. The result is a definition of an emission factor representing the percentage of the nitrogen applied on a parcel of land that is emitted into the atmosphere in the form of N_2O after several chemical reactions and processes have occurred. These emission factors (including direct and indirect emissions) vary from less than 1% up to 5%, depending on the source. Given the important influence they may have on the final results in terms of avoided emissions by biofuels, more work is necessary to narrow down the range.

6.7 Overall results Tier 3

Sub-Step (v): Determination of the total emission reductions

Table 6-14 summarizes the CO_2 and GHG emission reductions from sub-step (ii) and (iii) for the case of Biofuels in EU and Germany. As mentioned before, method II is incomplete, but it is used to obtain the net emissions in the accounting method III and is included as the grey figures in Table 6-17. When LCA emissions for biofuels are taken into account as in step (iii), emission reductions for the period between 2004-2007 amount to 31.3 Mt CO_{2-eq} for the EU while for Germany the figure is 15.2 Mt CO_{2eq}.

Table 6-14 Total emission reductions in Mt CO_{2-eq} due to Biofuels for Transport in EU and Germany after 2004 –accounting methods II and III

	Gross savings Tier 3	Net savings Tier 3 (incl. LCA; excl. iLUC)
	Sub-step (ii) - method I	Sub-step (iii) – method II (0% iLUC)
	Emission Reductions Total [$MtCO_2$]	BF Net Emission Reductions Total [$MtCO_{2-eq}$]
EU		
2004	6,2	3,9
2005	8,6	5,2
2006	15,1	9,2
2007	21,3	13,0
Total 2004-2007	51,2	31,3
DE		
2004	3,0	1,7
2005	5,2	3,0
2006	8,7	4,9
2007	10,0	5,6
Total 2004-2007	26,9	15,2

For the determination of the total emission reductions for Biofuels, the calculations from step (iii) are currently considered to be the most accurate impact assessment results for the Biofuels Directive. However, the result is only valid if direct or indirect land-use change may be excluded from the considerations. Otherwise, it is not possible to know at present what the greenhouse gas savings would be, if any.

6.8 Sensitivity analysis

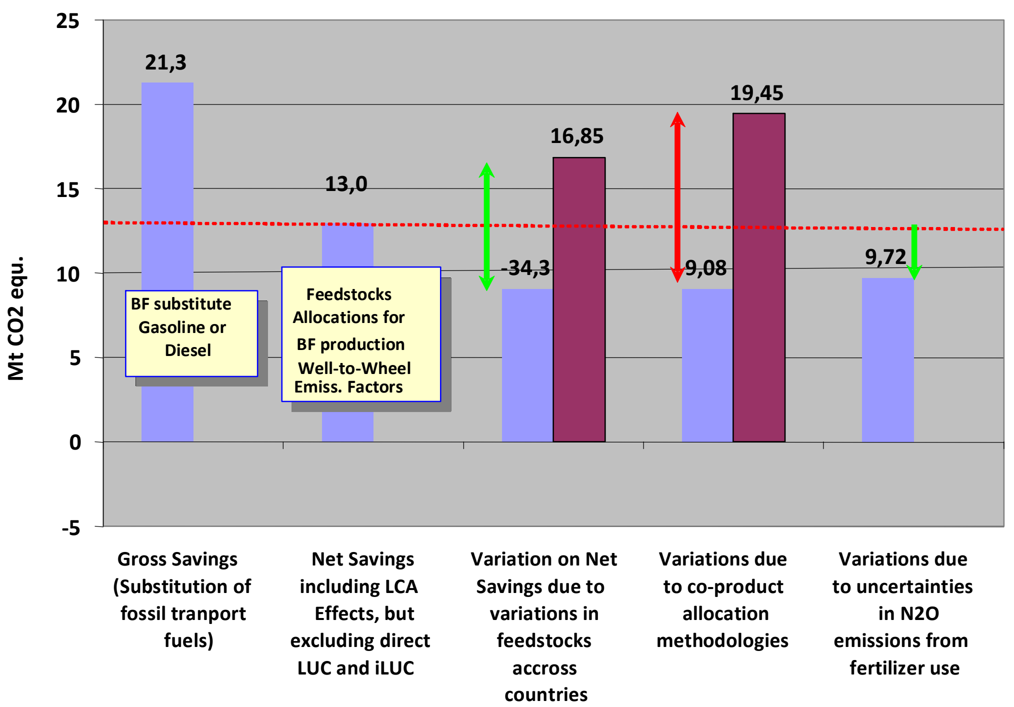
6.8.1 Overview

The following factors have been examined as part of the Tier 3 sensitivity analysis to determine the impact of changes in methodological assumptions on the results:

- feed stocks across countries
- co-product allocation methodologies
- N_2O emissions from fertiliser use

The results are shown in
Figure 6-10. This shows the impact of using specific methodological assumptions, and the influence of data uncertainties, upon the overall results. This shows the impact of using specific methodological assumptions, and the influence of data uncertainties, upon the overall results. The arrows show the relative variability in the results depending upon the particular assumptions that are used. The solid arrows show the influence of the specific factors, as calculated within this study. The sensitivities shown represent the historic importance of the different factors. This does not necessarily mean that the factors will have the same importance in the future.

Figure **6-10** Sensitivity analysis of the impacts of the Biofuels Directive, EU-27



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

It can be seen that a variety of factors may have substantial impacts mainly linked to data uncertainties. These are in particular:

- Uncertainties in country-wise feedstock composition and feedstock composition of imports;
- Uncertainties in N_2O emissions from the use of fertilisers;

Other factors are rather linked to methodological choices.

6.9 Synthesis and interpretation of results

6.9.1 Comparison of results from the different methods

Figure 6-10 and

Figure 6-12 illustrate the net GHG emission savings for Tier 1, Tier 2 and Tier 3 for Europe and Germany respectively. These three approaches are distinguished from each other in the following manner:

- Tier 1 approach: calculates impacts based on the total biodiesel and bioethanol consumption and uses EU average default emission factors for each of the two main groups.
- Tier 2 approach: calculates impacts based on the total biodiesel and bioethanol consumption and uses Member State average default emission factors for each of the two main groups.
- Tier 3 approach: calculates impacts based on specific feedstock /type of biofuel at Member State level. However due to a lack of data on feedstocks for most of the Member State (except for Germany) currently the refined calculation could only be carried out for Germany.

For Europe, all three Tiers result in positive GHG savings. The differences between the Tier 1, 2 and 3 results is explained by the assumed feedstock allocations used for Tier 3 and the use of average EU or Member State well to wheel (WTW) emission factors for Tier 1 and Tier 2.

The cumulated net GHG savings for Tier 1 and 2 amounts to roughly 30 Mt $CO_{2\text{-eq}}$ between 2004 and 2007 for Europe (EU-27). The results of the Tier 3 methodology are similar. For comparison, the cumulative gross savings of over 60 Mt $CO_{2\text{-eq}}$ are reported in the figures. The German figures represent roughly half these values.

Figure 6-11 Net GHG Savings for all Biofuels for Europe – 2004-2007 and Total GHG Savings in Mt $CO_{2\text{-eq}}$ – all accounting methods

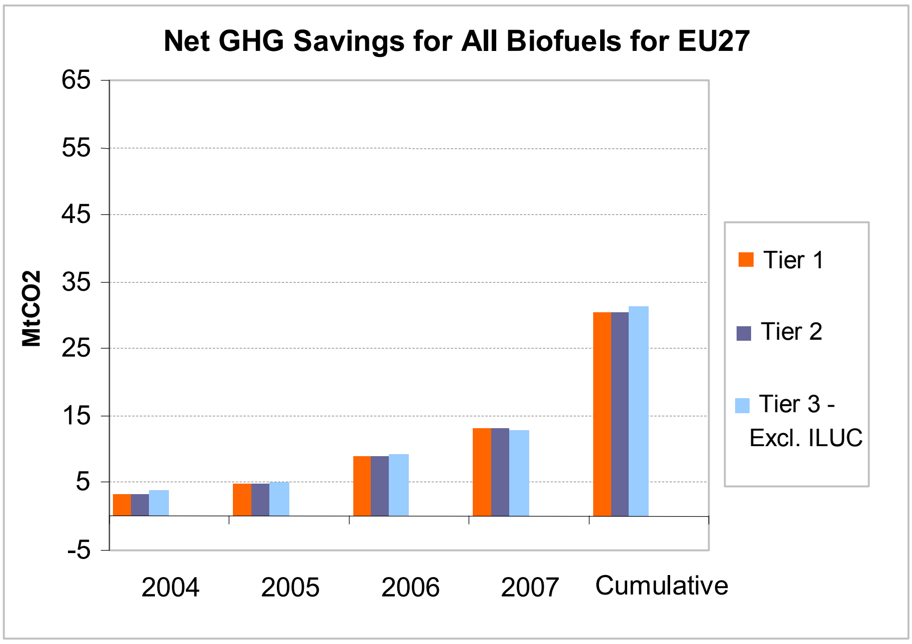
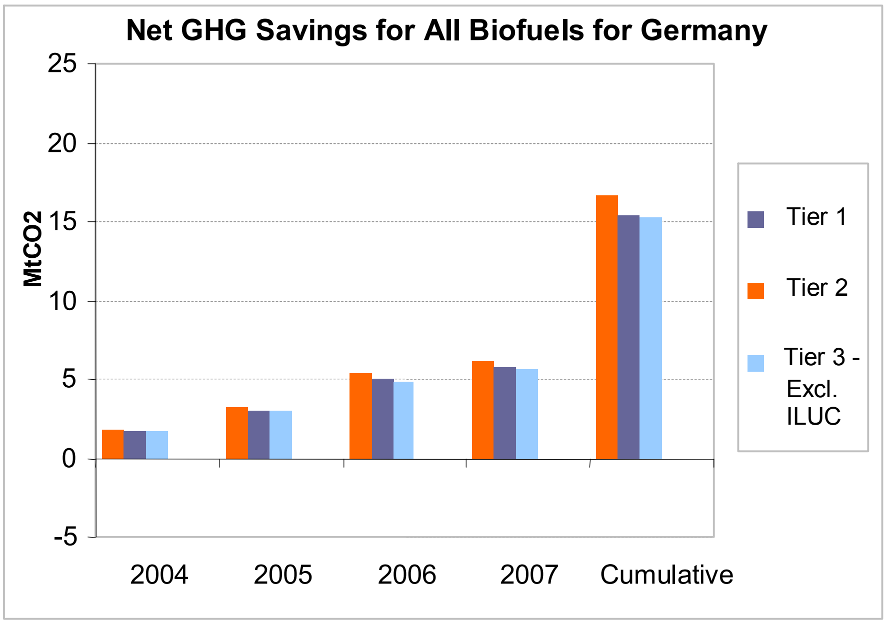


Figure 6-12 Net GHG Savings for all Biofuels for Germany – 2004-2007 and Total GHG Savings in Mt $CO_{2\text{-eq}}$ – all accounting methods



6.9.2 Comparison of impacts across Member States

The impact of the Biofuels Directive across Member States differs significantly (

Table 6-15. If the share in biofuels production in 2007 is taken as a proxy for the share in impacts, Germany has the lead with more than half of the impacts, followed by France with around 19%. Other countries with substantial shares are Austria, Spain, UK, Sweden, Portugal and Italy - totalling 22%). These differences are linked to the different promotion schemes introduced in the various countries for biofuels.

Table 6-15: Shares of different EU MS countries in biofuels production (2007)

Countries	Biofuels consumption (toe)	% of total
Germany	4.002.748	52%
France	1.434.214	19%
Austria	389.023	5%
Spain	373.220	5%
UK	348.690	5%
Sweden	281.251	4%
Portugal	158.853	2%
Italy	139.350	2%
Bulgaria	112.496	1%
Poland	100.680	1%
Belgium	91.260	1%
Greece	80.840	1%
Lithuania	52.600	1%
Luxembourg	34.963	0%
Czech Rep.	32.840	0%
Slovania	13.787	0%
Slovakia	13.262	0%
Hungary	9.180	0%
The Netherlands	8.670	0%
Ireland	8.374	0%
Denmark	6.025	0%
Latvia	1.740	0%
Malta	0	0%
Finland	0	0%
Cyprus	0	0%
Estonia	0	0%
Romania	0	0%
Total EU	**7.694.067**	**100%**

Source: Observ'er (http://www.energies-renouvelables.org/observ-er/stat_baro/comm/baro185.asp)[91]

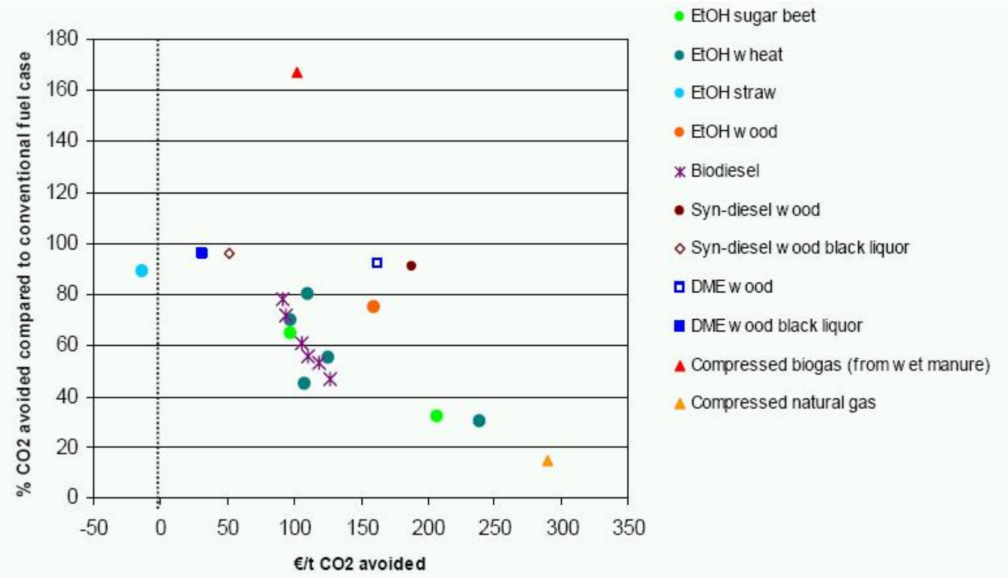
6.9.3 Cost effectiveness

In general the production of biofuels has been more expensive than conventional transport fuels, since the Biofuels Directive was adopted. Therefore financial support schemes had to be introduced at Member State level. In the Concawe/Eucar/JRC (2007) study the costs of biofuels have been assessed. Even in the "high" oil price scenario of 50$/bbl, few options were under the 100 €/t CO_2 mark, considerably higher than the current value of CO_2 at 15-25 €/t (Figure 6-13). However this cost is in the range of, or lower than, other alternatives for reducing GHG emission and oil dependency in the transport sector, with the exception of energy efficiency options for vehicle technologies, which in net terms generally lead to negative net costs.

According to the EU impact assessment of biofuels (2007) current estimates of costs show that second generation feedstock are 30% (second generation bioethanol) to 70% (BTL) more expensive than respective production of first generation fuels under present conditions and prices in the EU(2007), but deliver higher GHG saving performances.

91 The Eurobarometer data is not official and probably not consolidated (some differences with Eurostat data). Therefore, in future evaluations reliance should be made on Eurostat data. Biofuel produced is also used for electricity and heat generation, i.e. not counting for the biofuels targets. With Eurostat data on 2007 are the most up-to-date available. Data on 2005 are also relevant for the assessment of the intermediate target.

Figure 6-13 Biofuels: Cost vs. potential for CO2 avoidance (Oil price scenario: 50€/bbl)



Source: Concawe/Eucar/JRC (2007)

6.10 Conclusions and outlook for future work

The Gallagher Report (2008) reviews the uncertainties in the current methodologies to determine emission factors for biofuels. It points, among other things, to the uncertainty surrounding N_2O soil emissions and the impact this has on biofuel emissions and emissions from land use change.

Consequently, further analysis is needed on the following aspects:

- The well-to-tank GHG emissions of the biofuel (this is currently part of the emission factors and is widely accepted, although individual parts of the LCA such as N_2O release from fertilisers are subject to a high variation);
- Emissions arising from land-use change. A methodology will be proposed by the Commission in the frame of the Renewables Directive.

Such extensions of the methodology are vital for the GHG impact evaluation described here, given the fact that the method relying on LCA default factors may deliver reliable results only if indirect or direct land-use change can be ruled out based on sustainability criteria. Advances on the methodology can be expected during the next one or two years, making the assessment more reliable but a number of issues like the construction of a reference system to evaluate indirect land-use change may be subject to debate for quite some time.

At a policy level a variety of issues are subject to debate and are briefly discussed here as they may influence the final evaluation methodologies:

- A crucial question is whether the additional land required due to the demand for biofuels is considered to be on an equal footing with additional land required for other uses such as food. It may be the case that food production is considered to be more important and the land demand for biofuels is considered in addition to that. This decision, which is surely a political one, has an impact on how one assesses the emissions. If all increases in demand for land are considered equal, then it would be necessary to understand all increases in demand and then average the land use change emissions over all uses. If food is considered to be the priority it would only be necessary to understand the increases in demand for land from biofuels and apply these to biofuel production.
- The above issue is also linked with the question of whether comparable approaches are desirable in other sectors. It can be argued that since biofuels policy is put in place to achieve a GHG reduction, we actually need to know what the effect of that policy is on top of other

demands for land use. Alternatively it can be argued that since in the long run we will need to look for ways of reducing GHG emissions in all sectors, we should put in place an approach that treats all sectors equally (this could mean for example that thresholds for GHG emissions comparable to those under discussion for biofuels could be enacted in other sectors). Another factor to be borne in mind is that if an approach is followed that treats all land uses equally, while there are only GHG constraints in one sector, there will be massive leakage from that sector as essentially much of its emissions will be allocated to other sectors with no carbon constraint. This raises interesting questions in the frame of the overall evaluation of the ECCP and shows possible limitations to what is feasible in terms of quantitative impact evaluation of the Biofuels Directive in the short term.

- Once the further development of the methodological frame of emission factors for biofuels, as described in the previous section, has been tackled, it will be necessary to investigate the foundations for fixing the frame of the quantification of iLUC. The next steps to be carried out are:
  - Understanding the mechanisms that cause indirect land use change;
  - Determination of the scale of indirect land use change;
  - Determination of the scale of indirect land use change emissions;
  - Debate on methodological questions of how to attribute iLUC to biofuels, in isolation of other factors that impact on land-use change.

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Annex 1: Default values for direct land-use change proposed in the German Biomasse Sustainability Ordinance (BSO)

Table A1-1: Determination the default values for (direct) land use change for seven cases of generating biofuels for the proposed German Biomasse Sustainability Ordinance BSO

		wheat Europe	Maize / corn N. America	Sugar cane tropics (L.America)	Sugar beet Europe	Rapeseed Europe	soybean tropics (L. America)	soybean America	Palm oil South East Asia
Previous use		**grassland**	**grassland**	**Savannah**	**grassland**	**grassland**	**Savannah**	**grassland**	**trop. rain forest**
Change of C-storage									
biomass total	**t C/ha**	**70,0**	**70,0**	**134,0**	**70,0**	**70,0**	**134,0**	**70,0**	**265,0**
above ground	t C/ha	6,3	6,3	66,0	6,3	6,3	66,0	6,3	165,0
below ground	t C/ha			21,0			21,0		40,0
Soil	t C/ha	63,0	63,0	47,0	63,0	63,0	47,0	63,0	60,0
Use		cultivated land	cultivated land	cultivated land	cultivated land	cultivated land	cultivated land	cultivated land	plantation
biomass total	**t C/ha**	**55,0**	**55,0**	**55,0**	**55,0**	**55,0**	**53,0**	**55,0**	**110,0**
above + below ground	t C/ha	5,0	5,0	7,5	5,0	5,0	5,0	5,0	50,0
Soil	t C/ha	50,0	50,0	47,5	50,0	50,0	48,0	50,0	60,0
Change	t C/ha	-15,0	-15,0	-79,0	-15,0	-15,0	-81,0	-15,0	-155,0
time span	a	20	20	20	20	20	20	20	20
	t C/(ha*a)	0,75	0,75	3,95	0,75	0,75	4,05	0,75	7,75
Result (Emission)	**t CO_2/(ha*a)**	**2,75**	**2,75**	**14,5**	**2,75**	**2,75**	**14,9**	**2,75**	**28,4**
required area									
co-products not allocated	ha/GJ	0,0174	0,0131	0,0121	0,0089	0,02	0,0607	0,0632	0,0079
co-products allocated	ha/GJ	0,0095	0,0072	0,0107	0,0057	0,0107	0,0168	0,019	0,0038
Emissions referring to biofuels									
co-products not allocated	kg CO_2-eq./GJ	47,9	36,0	175,2	24,5	55,0	901,4	173,8	224,5
co-products allocated	kg CO_2-eq./GJ	26,1	19,8	155,0	15,7	29,4	249,5	52,3	108,0

a) Negative values are given in case of a loss of carbon storage
b) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

Source: UBA (2008)

Table A1-2: Set of proposed default values with allocation of co-products for examples of bioethanol and FAME; all figures given in kg CO2-equivalents per Gigajoule

Biofuel	Ethanol				Biodiesel (FAME)			
Biomass	**Wheat**	**Maize** (corn)	**Sugarcane**	**Sugar beet**	**Rapeseed**	**Soybean**		**Palm oil**
origin	Europe	North America	Latin America	Europe	Europe	Latin America	North America	Southeast Asia
step of production chain								
direct land use change [a) b)]	26,2	19,8	158,8	15,6	32,8	289,6	54,5	112,8
production of biomass	22,3	17,8	19,5	11,3	29,1	12,9	15,2	6,6
transport of biomass	0,7	0,7	1,5	1,7	0,4	0,5	0,5	0,1
conversion step I	-	-	0,8	6,6	7,6	7,3	9,2	6,9
transport between conversion steps	-	-	-	-	0,2	3,8	3,4	4,3
conversion step II	34,3	25,0	1,0	48,9	7,6	7,7	7,7	7,7
transport to fuel storage for admixture	0,4	4,8	5,5	0,4	0,3	0,3	0,3	0,3
Total without LUC	**57,7**	**48,2**	**28,3**	**68,8**	**45,3**	**32,4**	**36,3**	**25,9**
Total with direct LUC [a) b)]	**83,9**	**68,0**	**187,1**	**84,4**	**78,1**	**322,0**	**90,7**	**138,7**

a) Worst case situation, contradicts generally criteria for sustainability (conversion of areas with high C storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.
b) co-products allocated
All figures given in kg CO_2-equivalents per GJ

Source: BSO (2008)

Table A1-3: Set of proposed default values with allocation of co-products for examples of straight and hydrogenated vegetable oils; all figures given in kg CO2-equivalents per Gigajoule

Biofuel	Straight vegetable oil				Hydrogenated vegetable oil			
Biomass	Rapeseed oil	Soybean oil		Palm oil	Rapeseed oil	Soybean oil		Palm oil
origin	Europe	North America	Latin America	Europe	Europe	Latin America	North America	Southeast Asia
step of production chain								
direct land use change [a) b)]	34,2	298,8	56,2	117,4	33,2	293,4	55,2	114,3
production of biomass	30,4	13,1	15,5	6,9	29,5	13,0	15,4	6,7
transport of biomass	0,5	0,6	0,6	0,1	0,4	0,8	0,5	0,1
conversion step I	7,6	6,9	9,0	7,4	7,3	6,8	8,6	7,2
transport between conversion steps	-	-	-	-	0,2	3,8	3,5	4,3
conversion step II	-	-	-	-	9,7	9,7	9,7	9,7
transport to fuel storage for admixture	0,2	3,9	3,5	4,4	0,7	0,7	0,7	0,7
Total without LUC	**38,6**	**24,5**	**28,5**	**18,8**	**47,9**	**34,8**	**38,3**	**28,7**
Total with direct LUC [a) b)]	**72,8**	**323,3**	**84,7**	**136,2**	**81,1**	**328,2**	**93,5**	**143,1**

a) Worst case situation, contradicts generally criteria for sustainability (conversion of areas with high C storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.
b) co-products allocated
All figures given in kg CO_2-equivalents per GJ

Source: BSO (2008)

AEA group
The Gemini Building
Fermi Avenue
Harwell International Business Centre
Didcot
OX11 0QR

Tel: 0870 190 6474
Fax: 0870 190 6318

AEA