Factors Underpinning Future Action – Phase III

Evaluation of the 2020 Climate targets for EU Member States

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EXECUTIVE SUMMARY

In this report, Ecofys presents an approach to share some of the energy and climate related targets between EU Member States simultaneously. In an earlier report, Ecofys prepared an analysis that illustrated how the EU's greenhouse gas (GHG) emission reduction target, -20% in 2020 compared to 1990 levels, and -30% if other countries make a comparable effort, can be shared between the Member States. This earlier report did not account for the various other targets and systems that the EU has agreed – such as the 20% renewable target by 2020, 20% improvement in energy efficiency by 2020, a biofuel target, CO2 levels from cars, and the EU Emission Trading Scheme (EU ETS).

General methodology

We take a look at how a set of these targets, the renewable energy targets and the energy efficiency target, each alone then combined, contribute to the GHG emission reductions until the year 2020 and how these can be shared among the member states. To do so we use a bottom-up approach. We created an excel spreadsheet that contains data on energy consumption/ production, emissions and further indicators for each of the 27 member states of the EU. Within this excel spreadsheet, which includes historical data as well as a BAU scenario, an effort sharing scenario was created to appropriately take account of the targets.

Sharing the renewable target

The renewable energy (RE) target was shared using three different sharing approaches – namely:

- an equal progress approach, where each country is assumed to increase its renewable energy share by 13 percentage points from 2005 until 2020,
- an equal share approach, where all countries are assumed to have a 20% share of renewable energy in 2020, and
- a least cost approach, assuming that the options with the lowest costs across Europe will be used first.

Additionally, the different economic situations of the countries can be taken into account by including a GDP adjustment factor. The equal progress approach with a GDP adjustment factor is used as the default approach in this report.

Sharing the energy efficiency target

The energy efficiency (EE) target is shared here in two different ways. It is assumed that

- all Member States equally improve their energy efficiency or that
- the energy efficiency of all Member States converges until 2020.

The default approach used here is the convergence approach.

Additionally to these two targets we assumed GHG emission reductions in sectors that are not covered by these targets as it is likely that these will contribute as well. We look at the overall emission reductions that can be achieved, those that can be achieved under the Kyoto Protocol and, in a simplified manner by assuming that all of the energy industry equals the EU ETS sector, at those that can be achieved under the EU ETS.

Results

The emission reductions in the Member States resulting from the default sharing approaches vary greatly among countries and considered targets (vertical bars as shown in Figure 1). Figure 1 also shows the emission change from 1990 to 2005 (horizontal bar).

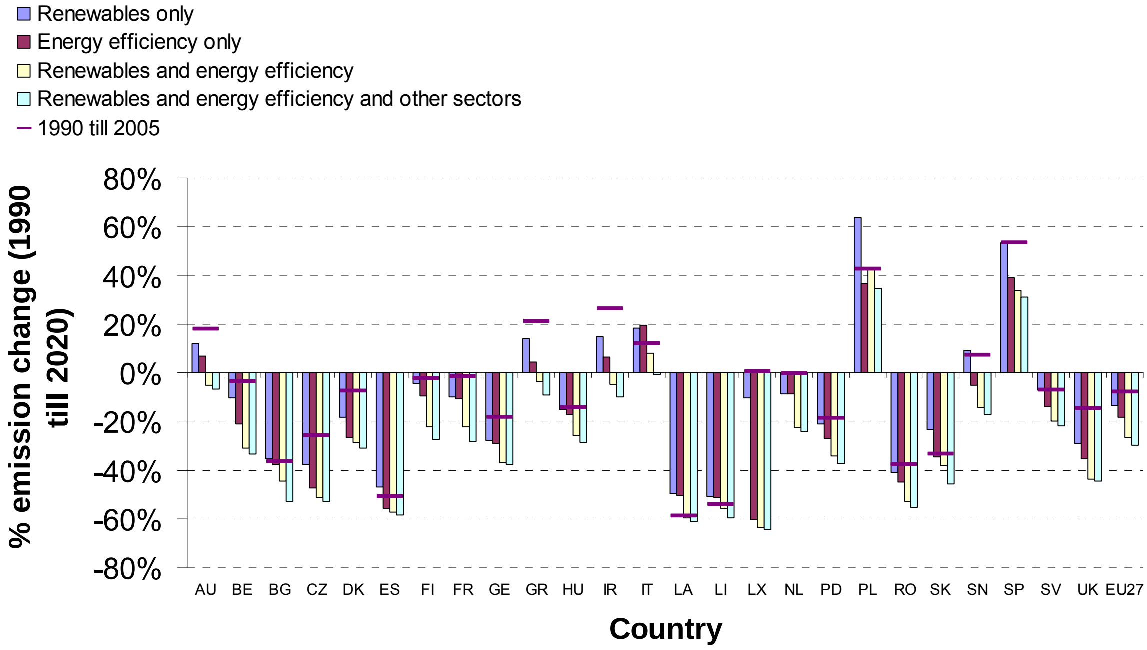

Figure 1: Change in emission allowances for sectors covered by the Kyoto protocol until 2020 (base year 1990) across 25 EU countries (excluding Malta and Cyprus) for default cases

For all countries emission cuts below baseline projections are achieved. Due to very high baseline projections, some countries are able to increase their emissions above 1990 levels. Emission changes when applying the renewable target only are usually less stringent compared to the case applying the efficiency target only. Emission changes in the two combined target scenarios always lead to yet more reductions.

The change in greenhouse gas emission in the Kyoto Protocol sectors between 1990 and 2020 across the EU 25 (Malta and Cyprus are excluded due to a lack of data) sharing only the renewables target is -14%. Applying only the EE sharing approach, the emission change is -18%. Combining the RE *and* EE sharing approach gives -26% (excluding other sectors). We assumed that the additional 4 percentage points are achieved by the sectors not covered by the first two targets leading to an overall reduction of -30% (including the other sectors).

Conclusions

From our analysis we draw the following conclusions:

- For the EU 27 the combined renewable and energy efficiency target base-case leads to a GHG emission reduction of 26% on 1990 levels by 2020. This implies that the meeting the sub-targets for renewable energy and energy efficiency is more than sufficient to meet the overall 20% GHG emission reduction target for the EU27.
- Relative emission reductions within the EU ETS sectors are higher than for the economy as a whole. If EU GHG emissions are reduced by 30% between 1990 and 2020 under a multilateral agreement then emissions in the EU ETS are reduced by 42% in our case. This has to be taken into account when allocating emission reduction across sectors, as equal reductions in all sectors would have the potential risk of over-allocating the EU ETS.
- Assuming that energy efficiency in all countries will converge when sharing the energy efficiency improvements leads to very diverse GHG reductions between the Member States. As a consequence national targets would have to be very different from country to country.
- For sharing the renewable energy target the GDP adjustment has a smaller effect on the distribution between the countries than using another distribution method such as least cost or equal share.
- The overall split of necessary reductions between EU ETS sectors and other sectors according to our approach is very similar to that chosen in the proposal by the European Commission of 23 January 2008 (European Commission 2008a, 2008b). Our results can therefore give an indication how the reductions within the EU ETS could be shared among member states, which is not included in the Commission’s proposal. For the emissions outside of the EU ETS, the commission assigns reductions solely on GDP/capita, while we mostly consider reduction potential. Consequently, our method assigns more ambitious reductions to the Eastern European States and less ambitious reductions to the wealthier nations.
- This analysis and the Commission’s Proposal start sharing the reduction on the basis of 2005 emissions and neglect the Kyoto targets. Consequently they are less stringent to those countries that are likely to not meet their Kyoto targets (as agreed within the EU), such as Austria, Denmark, Italy, Ireland, Portugal and Spain.

CONTENTS

1. INTRODUCTION

This report is the output from the third phase of the Ecofys project on ‘Factors underpinning future action’, carried out by Ecofys on behalf of the Department for Environment, Food and Rural Affairs (Defra).

Ecofys prepared an analysis illustrating how to share the EU’s greenhouse gas (GHG) emission reduction target between Member States in March 2007 (Höhne and Moltmann 2007). This analysis was based only on the GHG emissions targets and did not take into account the other targets and systems that the EU has now agreed to:

- 20% renewable energy target by 2020
- 20% improvement in energy efficiency by 2020
- Biofuels targets
- CO_2 levels from cars
- EU Emissions Trading Scheme (EU ETS)

This third phase of the project focuses on the interaction between different targets and policies and implications for EU GHG emissions effort-sharing.

This document addresses the following questions:

- How do the EU’s targets on renewable energy, energy efficiency and GHG emissions reductions relate to each other in a conceptual manner? (Chapter 2)
- What are the options for effort-sharing both the 20% energy efficiency improvement target and the 20% renewable energy target? How could these two targets be shared in an integrated way? (Chapter 3)
- What would meeting these two targets mean in terms of GHG reductions for the EU 27 as a whole? What does this imply for the EU ETS? (Chapter 4)

This report also contains details on the methodology (Chapter 3) and the results of the analysis (Chapter 4).

2. UNDERSTANDING THE EU’S TARGETS

The EU has a range of targets and policies in place that either directly tackle climate change or have significant climate change co-benefits. How these targets and policies relate to different sectors of the EU economy is summarised in Figure 2.

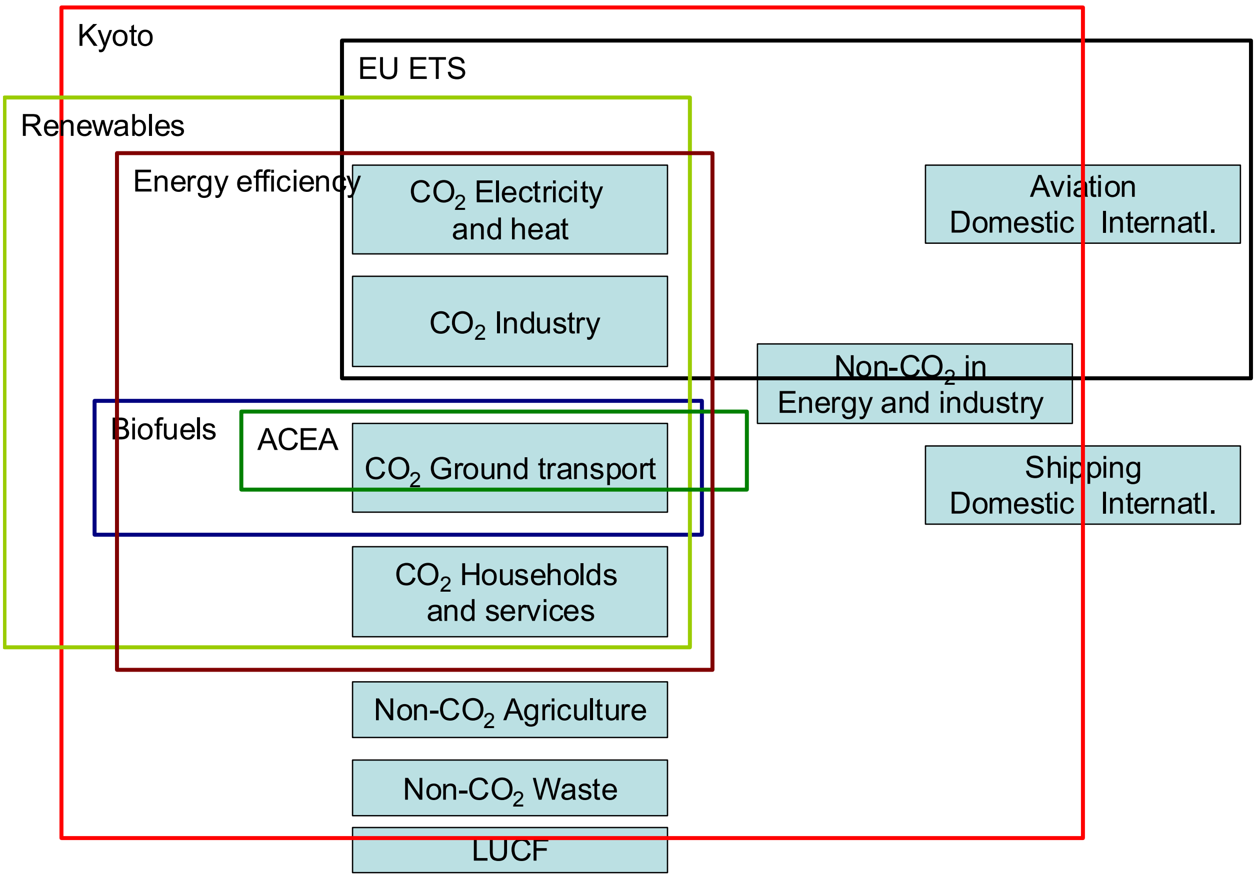

Figure 2 Overlap of EU targets and policies. The blue shaded boxes represent emissions sectors. The coloured squares encompass the sectors (or parts of sectors) which are included in the scope of a particular target.[1]

The figure shows that there is a great deal of overlap among the targets with the emissions from some sectors being covered by a number of targets. For example, some emissions from industry are covered by the EU ETS, renewables, energy efficiency and Kyoto Protocol targets. Deliveries of these targets are likely to have a strong knock-on effect for the delivery of the overall Kyoto greenhouse gas reduction target. However, it is also clear that non-CO_2 gases are largely omitted from current legislation and therefore the potential for greenhouse gas reductions in these sectors should be considered important where targets are particularly stringent for other sectors. The targets are briefly described in the following sections.

2.1. THE GREENHOUSE GAS TARGET[2]

The European Council Conclusions in March 2007 agreed that the EU and its Member States should propose a 30% reduction in GHG emissions by developed countries by 2020 as part of a wider international agreement aimed at limiting global climate change to 2°C above pre-industrial levels. Until an international agreement is concluded the EU should already now

[1] Some sectors (boxes) are only treated in part by a target or policy. In such cases the lines go through a box.

[2] Limiting Global Climate Change to 2 degrees Celsius: The way ahead for 2020 and beyond COM(2007) 2 final (European Commission 2007c)

take on a firm independent commitment to achieve at least a 20% reduction of GHG emissions by 2020 compared to 1990.

2.2. THE RENEWABLE ENERGY TARGET[3]

The EU aims to reach a renewable energy target of 20% of renewable energy sources in gross inland consumption by 2020[4]. The effort in reaching this target is to be shared in an appropriate way between Member States. There is also a binding target for *each* Member State to achieve a 10% share by energy content of biofuels in petrol and diesel by 2020 subject to certain sustainability criteria.

Different scenarios for reaching 20% renewable energy in 2020 have been suggested. The target can be achieved by different combinations of renewable deployment in the electricity, heat and transport sectors. Four possible combinations are detailed below.

The European Commission's renewable energy road map suggests that Europe's 2020 target could be made up from:

- 34% of overall electricity consumption, of which 12 percentage points would come from wind,
- 18% renewable heat – mostly from biomass and
- 14% of transport fuels[5].

This scenario is referred to in the renewable energy road map as a 'balanced' scenario, which aims to ensure a comparatively similar effort between sectors[6]. This is not a least-cost scenario. However, it aims to take into account that it may be more cost effective in the long term to develop a portfolio of technologies across the sectors.

Other scenarios, which should achieve the 20% renewable target, suggest different splits between electricity, heat and transport. These alternates are given in Table 1.

[3] Renewable Energy Road Map. Renewable energies in the 21st century: building a more sustainable future COM(2006) 848 final (European Commission 2006c)

[4] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0001:FIN:EN:PDF (European Commission 2007b)

[5] Note that this figure is different from the Green-X modelling report which assumes 12% of transport fuels

[6] Effective and efficient policies are implemented in all the sectors

Table 1 Comparison of different scenarios for meeting the renewable energy target

	Renewable Energy Road Map (balanced)[3]	PRIMES - combined high renewables and energy efficiency scenario[3]	Green-X least cost[3]	Pöyry least cost [7]
Electricity consumption	34%	43%	43%	41%
Heating and cooling	18%	16%	16%	16%
Transport fuels	14%	15%	11%	10%

The last three estimates are broadly consistent and provide useful indicators of the level of effort necessary across the electricity, heat and transport sectors to achieve an overall 20% renewable energy target. These estimates are used as inputs in this analysis.

2.3. THE ENERGY EFFICIENCY TARGET

The 2005 Green Paper on energy efficiency[8] outlines the EU ambition to reduce energy consumption by 20% compared to projections for 2020 on a cost-effective basis. The projections for the EU are for 1900 million tonne of oil equivalent (Mtoe) gross inland consumption in 2020 compared with 1725 Mtoe energy consumption in 2005.

The 2006 Action Plan for energy efficiency[9] is more concrete in that it outlines a framework of policies and measures for realising the energy savings potential, estimated at over 20% of EU annual primary energy consumption by 2020. While the green paper includes gross energy consumption or total consumption, the Action Plan is based on primary energy consumption. Thus, the major difference is that gross energy consumption covers only all final energy consumed, i.e. does not cover potential energy efficiency improvements in conversion of primary energy to final energy (e.g. electricity generation), while primary energy consumption includes all primary energy. Table 2, taken from the Action Plan, identifies a theoretical energy saving potential in final energy consumption in the energy consuming sectors. For example, there is a theoretical energy saving of 63 Mtoe in commercial buildings in 2020, this represents 30% of the business-as-usual (BAU) energy consumption in 2020. Details on the derivation of these theoretical potentials are not given in the Action Plan (i.e. on the costs of reaching the identified potential). If this theoretical potential is realised in all sectors, the total savings would be higher than 20% of total energy consumption in the considered sectors. It does not cover the whole potential, because the supply side (electricity, heat and other fuel production) is not included but gives an indication of a possible distribution of savings across energy consuming sectors.

Table 2 Final energy consumption and possible saving potential (European Commission 2006a)

[7] Greetham 2007

[8] Green Paper on Energy Efficiency or Doing More With Less COM(2005) 265 final (European Commission 2005)

[9] Action Plan for Energy Efficiency: Realising the Potential COM(2006) 545 final (European Commission 2006a)

Sector	Energy consumption 2020 BAU Mtoe	Energy saving potential 2020 Mtoe	Energy saving potential relative to BAU energy use in 2020 %
Household	338	91	27%
Commercial buildings	211	63	30%
Transport	405	105	26%
Manufacturing industry	382	95	25%

2.4. ACEA AGREEMENT

Negotiated self-commitments are an important element of the EU's strategy to improve fuel economy and reduce CO_2 emissions from passenger cars. Commitments have been concluded with the European (European Automobile Manufacturers' Association - ACEA), the Japanese (Japan Automobile Manufacturers' Association - JAMA) and Korean (Korean Automobile Manufacturers' Association - KAMA) automobile industries.

All three commitments are have the following main features:

- **The CO_2 emission objective**: The three commitments contain the same quantified CO_2 emission objective for the average of new passenger cars sold in the European Union, i.e. 140 grams carbon dioxide per kilometre (gCO_2/km) (to be achieved by 2009 by JAMA and KAMA and by 2008 by ACEA).
- **Means of achievement**: ACEA, JAMA and KAMA have to achieve the CO_2 target 'mainly' by technological developments and market changes linked to these developments.

According to latest communication on progress to these targets[10] the average for new vehicles in the EU 15 in 2004 was 163 g CO_2/km, compared to 186 g CO_2/km in 1995. Estimates of the mitigation potential if the agreement is met are 75-80 million tonnes of carbon dioxide ($MtCO_2$) by 201011.

In addition, the EU’s strategy to reduce CO_2 emissions from passenger cars aims for a longer-term target with a figure for passenger cars newly registered from 1 January 2012 in the Community of 120 g CO_2/km.

2.5. FUEL QUALITY DIRECTIVE

The proposal for amendment[12] of the fuel quality Directive[13] includes the obligation for mineral oil companies to reduce the specific GHG balance of their traded fuels by 1% per year between 2011 and 2020. Apart from improvements in the production chain, blending with biofuels would be one of the most important options to achieve this goal. Therefore, the amendment of the fuel quality directive could have significant implications on the expansion of biofuels. Depending on the required emissions reductions and the development of the greenhouse gas balance of fossil and biofuels, the demand for biofuels could increase and might even exceed the 10% target of the Renewable Energy Road Map. So far the influence of this Directive cannot be estimated but should be kept in mind.

[10] http://ec.europa.eu/environment/co2/pdf/com_2006_463_en.pdf (European Commission 2005)

[11] Fourth National Communication of the EU to the UNFCCC http://unfccc.int/resource/docs/natc/eunce4add.pdf (European Commission 2006b)

[12] Directive of the European Parliament and of the Council COM(2007)18, 31 January 2007 (European Commission 2007a)

[13] Directive 98/70/EC (European Commission 1998)

2.6. OVERLAPS BETWEEN THE TARGETS

As already discussed earlier, there is substantial overlap between the emissions covered by the targets described above (see Figure 2). For a more detailed illustration of which gases are covered by which targets see Figure 3 below. For example, CO_2 from electricity and heat, together with CO_2 from industry are addressed by the renewables, energy efficiency, Kyoto Protocol and the EU ETS targets. The EU ETS includes in addition some of the non-CO_2 emissions in industry, as well as emissions from domestic and international aviation (as of 2012). The Kyoto Protocol currently only covers the domestic part of aviation. It seems unlikely to us that it will include international aviation in 2020 given the history of the negotiations on this topic. The renewables and energy efficiency targets also include ground transport and households and services. Transport is also addressed by the ACEA agreement and the biofuels agreement. The Kyoto Protocol target includes in addition non-CO_2 from agriculture and waste and parts of emissions from land use, land-use change and forestry (LULUCF).

	Kyoto Protocol	EU ETS	Renewables directive	Energy efficiency	ACEA	Biofuels
CO_2 electricity and heat		Part				
CO_2 industry		Part				
CO_2 gases domestic						
CO_2 gases commercial						
Land transport emissions					Part (cars)	
Air and marine transport emissions	Domestic	Part (air from 2012)				
Non CO_2 electricity and heat						
Non CO_2 industry		Part				
Non CO_2 gases domestic						
Non CO_2 gases commercial						
Other Non CO_2						
LULUCF						

fully covered
partly covered
not covered

Figure 3 Overlap of gases and sectors included between the considered EU targets.

Whether part of the renewables targets could be achieved outside of the EU is under discussion. If such flexibility were allowed as part of a CDM project, it would account towards meeting the renewables target and the Kyoto Protocol emissions target. However if such flexibility were allowed without a CDM project it would account towards the renewables target but not towards the Kyoto Protocol emissions target.

2.7. WHAT CAN THE ENERGY EFFICIENCY AND RENEWABLE ENERGY TARGETS DELIVER IN TERMS OF GHG EMISSIONS REDUCTIONS?

In the preparation of our own modelling, we have considered four preliminary estimates of the possible impact of the renewables and energy efficiency targets on GHG emissions for the aggregate EU 27. The Primes and the Green-X scenario are the same as those already mentioned in Section 2.2.

2.7.1. PRIMES

The PRIMES model is a macroeconomic approach to energy projections which provides results to 2030. For this analysis we used already available data (Mantzos and Capros 2006). In addition to a baseline assessment of energy use, there are several scenarios incorporating the various climate-change-related targets:

a) The energy efficiency case: This scenario assumes full implementation of existing EU legislation on energy efficiency, as well as increased uptake of cogeneration and an increased uptake of energy efficient options by end-use consumers.

b) The high renewables case: This scenario ensures Europe's renewable energy target for 2020 is reached – further incentives are introduced so that 12% of gross energy consumption is sourced from renewables by 2010, and 20% by 2020.

c) The combined high renewables and energy efficiency case (Combined HR and EE): This scenario combines the two aforementioned scenarios and includes any synergies and trade-offs necessary in meeting the two targets.

The PRIMES data can provide a preliminary insight into the relationship of the targets and GHG emissions, from a macroeconomic perspective. Table 3 shows the percentage change from the baseline scenario for a number of different variables e.g. in the high renewables scenario final energy demand in energy intensive industry is 0.7% higher than in the baseline.

Table 3 PRIMES energy data for the EU 27 in 2020 under different policy scenarios

EU-27	**Source: PRIMES 2005**			
Figures are given here for 2020				
		Scenario		
		High renewables	*Energy efficiency*	*Combined HR and EE*
CO2 emissions index	1990=100	90.9	89.3	78.2
Gross Inland Consumption	% change from baseline scenario	-1	-11.9	-13.3
Gross Inland Consumption - Renewable energy forms		81.9	-10.3	64.6
Final energy demand by sector				
Energy intensive industry		0.7	-2.9	-2.1
Other industrial sectors		0.5	-3.6	-2.9
Residential		0.4	-17.1	-17.7
Tertiary		-0.8	-21.9	-23
Transport		0	-9.4	-9.4

"Tertiary" is the commercial or services sector

Achievement of renewable energy and energy efficiency targets:

- To achieve the 2020 renewable target (high renewables scenario), gross inland consumption from renewable energy forms increases by 81.9% compared to the baseline. In the combined case the increase is only 64.6% because of reduced energy consumption. In the energy efficiency scenario, Gross Inland Energy Consumption is decreased by roughly 10% below baseline, Gross Inland Energy Consumption of renewable energy is also decreased by 10% below baseline. Energy efficiency policies alone do not encourage the uptake of renewables.
- The PRIMES energy efficiency scenario does not include an implicit assumption that the energy efficiency target for 2020 is met, but includes measures that are assumed possible to increase energy efficiency. It results in an 11.9% decrease in gross inland consumption of energy in 2020 for the EU-27, as compared to the PRIMES baseline scenario. Under the high renewables target, gross inland energy consumption only decreases by 1% on the baseline scenario, again indicating little co-benefits. The combined scenario shows some, but little, synergistic effect.

CO_2 reductions:

- Under the high renewables scenario, there is a CO_2 reduction of 9.1% on 1990 levels across the EU-27 by 2020; under the energy efficiency scenario the decrease is 10.7%. As expected the overall CO_2 reductions result from implementing both sets of policies is greater – resulting in a 21.8% reduction in CO_2 on 1990 levels by 2020. This indicates that **energy efficiency policies and renewables policies, if implemented successfully, should deliver, with CO_2 alone, at least the first of the Council's two greenhouse gas reduction targets**.
- As indicated above, the modelled energy efficiency is significantly short of the 20% target. This suggests that extending energy efficiency efforts should reduce greenhouse gas emissions further, coming closer to the 30% reduction target in 2020. However, the PRIMES modelling approach as described appear to already make optimistic assumptions about the delivery of existing energy efficiency policies. Therefore, in policy terms delivery in terms of energy efficiency would need to be based on new policies and measures. For the analysis in this paper, other data sets e.g. those given in the energy efficiency action plan and shown in Table 2 above are used.

Overall conclusions from PRIMES

The combination of the existing renewables target and energy efficiency target should deliver the 20% greenhouse gas reduction target in 2020. A full achievement of the energy efficiency target is likely to require additional policies beyond those already in place, however, should the energy efficiency target be achieved in 2020, the 20% greenhouse gas reduction target is likely to be exceeded and may come close to the 30% target. The PRIMES modelling discussed above, implies that fully implementing existing energy efficiency policy would involve only a relatively small effort from the EU ETS sectors (considered heavy industry) as compared to other sectors.

2.7.2. International Energy Agency Data:

We also used energy projections data from the IEA World Energy Outlook (IEA 2006) to understand the impact a change in energy generation could have on GHG emissions. An order-of-magnitude estimate of the CO_2 savings that could be achieved from the renewables target is obtained using the following methodology[14]:

- The IEA publishes projections for 2015 and 2030, but not 2020. To obtain 2020 projections, the 2015 projections were extrapolated using the annual percentage growth rate between 2015 and 2030;
- Assume the proportion of renewables in each sector is as in the balanced scenario for the Renewables Energy Road Map (i.e. 34% in electricity demand, 21% in heat demand and 14% in transport);
- Assume that the use of biofuels in transport displace only oil; and
- Assume that the renewable fuels in electricity and heat displace coal and gas in the proportion 59% coal and 41% gas. These assumptions are derived from the Green-X modelling but because of the difficulty of comparing the two sources of data there are only broad estimates.

With this methodology, CO_2 emissions from fossil fuel consumption in 2020 would be 1% below the 1990 level in 2020 or 9% below BAU level in 2020.

To add in the effect of the energy efficiency target the methodology is as follows:

- Calculate the percentage saving in each sector from Table 3 to give 20% overall;
- Apply that percentage to the final consumption figures for those sectors from the IEA. It is assumed that all fuels (including renewables) are reduced by the same amount;
- Calculate the energy and carbon saving – the energy saving applying this methodology is 19% and the carbon saving 22% compared to the baseline; and
- For the renewable energy calculation described above, reduce the transport oil demand and the electricity generation by the percentage determined in the energy efficiency calculation.

This brings emissions in 2020 to 12% below 1990 levels or 18% below BAU emissions for 2020.

2.7.3. Green-X model:

The Green-X model uses a bottom-up approach based on renewable energy potentials and costs in EU Member States; the baseline is the PRIMES energy efficiency case. Under the Green-X model least-cost assessment of achieving the 20% renewables target, the additional renewable energy deployed will reduce annual CO_2 emissions in the range 600-900 $MtCO_2$ in 2020. This gives a CO_2 emission **reduction of between 15-23% compared to 1990 levels**.

2.7.4. EVOC tool

We used the EVOC tool (Höhne et al. 2007) to estimate the effect of the renewables target, using the 2020 sectoral renewable shares from Green-X: a 34% share of renewable energy in total electricity generation, 21% renewables for heat and 12% for transport fuels, which is in line with the other calculations made in this chapter. Due to the restrictions of the EVOC

[14] The data provided by the IEA is at a high level of aggregation. We had to make a number of broad assumptions, for example regarding conversion of delivered heat to primary energy.

model, we considered heat and transport together as a 15% reduction. EVOC calculates a 2020 GHG emissions reduction for the EU 27 of about 17% compared to 1990 levels. As this scenario does not assume any emission reductions from energy efficiency it is **likely that the 20% GHG emission reduction target would be exceeded** if the energy efficiency target is also met.

2.7.5. Summary

Table 4 provides an overview of the greenhouse gas emission reductions achieved by implementing the renewable energy and the energy efficiency targets as calculated with the various methods described above. The spread of reductions is large due to the use of various independent models with their different datasets. We however conclude that the combined implementation of the renewable energy target and the energy efficiency target leads to an emission reduction of more than 20% below the 1990 level by 2020.

Table 4 Preliminary estimates of GHG emissions reductions in 2020 compared to 1990 levels under different models and targets

Model / Targets	PRIMES	Based on IEA data	GreenX least-cost model	EVOC tool
RE target	9.1 %	1 %*	-	17 %
EE target	10.7 %**	-	-	-
RE +EE target	21.8 %**	12 %*	15 - 23 %	-

Note: GHG savings from different models for the same target (e.g. only RE or RE & EE) differ because of various reasons: different data and assumptions as well as different calculation methods

*: Reductions apply to energy related CO_2 emissions only.

**: EE improvement over baseline is 11%, not 20%

3. AN INTEGRATED WAY TO SHARE THE EFFORTS

To deliver the EU-wide targets for energy efficiency (EE), renewables (RE) and GHG emissions, an agreement of Member State responsibilities is necessary. Several options for sharing these three targets exist. The GHG emission target can be shared directly among the Member States in several ways. They were discussed and applied in the second phase of *Factors Underpinning Future Action* (FUFA II, Höhne et al. 2007) analysis. Here, we only look at methods for sharing the RE and the EE targets. Sharing these two targets among the Member States leads to a certain GHG emission reduction, thus making the method applied here an indirect way to share the GHG emission target. The problem of this indirect manner of sharing is that the achieved GHG emission reductions do not necessarily equal the desired overall emission reductions. To achieve this, the RE and the EE targets would have to be adjusted or further emission reduction potential would have to be identified. Alternatively a combination of the indirect sharing methods with a direct sharing method could be used. This would need a more complex analysis that is beyond the scope of this project.

Here we first describe the general options for sharing the RE and the EE target. We then describe the method used here for effort-sharing in an integrated way. In a last step (Section 3.1 and Section 0), we describe the individual options and how they were applied in a spreadsheet in greater detail. This excel spreadsheet includes historic data and future target sharing options for all EU 27 countries. It includes all results described in this report at a very high level of detail.

There are several possible approaches for **sharing the effort of the renewables target**. Those considered in this assessment are:

a) **Equal progress 1**: All Member States increase the current share of renewables in their gross inland consumption by 13 percentage points by 2020. This will take the European average from the current 7% to the needed 20%. This method prescribes only the share of total renewables, the progress per sector (renewable electricity, heat and transport fuels) can differ between countries. Some have suggested adjusting this “equal progress” at the margins – upwards for countries with higher GDP per capita, downwards for countries with lower GDP per capita (see also option f).

b) **Equal progress 2**: All Member States increase the current share of renewables in the energy consumption by the same percentage for each sector (electricity, heat and transport) so that the EU renewable share adds up to a 20%. In this method we fix the progress per sector, while in “equal progress 1” we fixed the progress per country.

c) **Equal share**: All countries aim to have a 20% share of renewables in gross inland consumption by 2020. This option seems easy, but currently Member States have very different starting positions ranging from 1% (Belgium) to 20% (Austria). The equal share of 20% is therefore more of a theoretical than a likely option.

d) **Least cost**: The European target is shared across the Member States by choosing the least cost options – for example using the Green-X model.

Further effort-sharing options that could be considered include:

e) Low-carbon generation: An effort-sharing approach that is based upon equal sharing of the target, as described in (b) but takes into account existing low-carbon generation (i.e. nuclear that is already in place) and therefore, by definition, integrates an element of the GHG reduction target into the renewables target.

f) Ability to pay: This approach compares GDP across the EU and in this manner incorporates the ability of countries to pay for investments in renewables into their targets.

Options a and d were identified the most relevant for this study at the project meeting held on 15 August 2007. A combination of methods could also be used – e.g. equal progress for part of the 13 percentage point gap and least costs for the remainder.

The **energy efficiency target** can be shared in two principal manners:

a) Equal % reduction: It is assumed that all Member States equally improve the energy efficiency. Consequently all Member States have to make the same effort starting from a given point.

b) Convergence: Under this approach it is assumed that the energy efficiency of the Member States converge, so that all Member States are equally energy efficient.

To integrate the EU 27 energy efficiency target and the renewables target it is necessary to combine some of the approaches mentioned above. In doing so the key concept is to share the targets on a sector basis. In this way the targets that apply only to some sectors can be considered appropriately and the impact on EU ETS sectors can be studied. We defined rules for each sector that are applied to all countries in the same manner. The parameters are set so that all the different targets are satisfied. We distinguished among the following sectors (see also Figure 2):

- 1 Energy industry
- 2a Industry (energy related emissions)
- 2b Industry (non-energy related emissions)
- 2c Other energy industry (fugitive emissions)
- 3a Domestic transport
- 3b International transport

- 4 Residential and services
- 5 Non-CO_2 agriculture
- 6 LUCF
- 7 Waste

We followed a three-stage approach to share the targets:

1. Share the renewables target according to one of the three approaches mentioned above (*equal progress*, *equal share*, *least cost*). For *equal share* and *equal progress 2* the 20% target is split between the electricity, heat and transport sectors based on model studies, see section 2.7. For *equal progress 1* the 13% increase in RE penetration is applied to each country and is then split between the sectors using the least cost method. For *least cost* the split across Europe is determined by the least cost optimisation.
2. Apply the energy efficiency improvements on a sector level. The first option, as described above is to apply the same percentage for all countries and all sectors. However this does not take into account starting positions and reduction potentials. The second method is to assume convergence of energy efficiency. This requires indicators on energy efficiency in each sector (e.g. energy efficiency in electricity production, energy efficiency index in industry, heating per m^2, fuel consumption/km in transport). The results will be checked with the reductions required under the EU ETS in its second phase and with the ACEA agreement to ensure that the limits in 2020 are lower than already agreed for 2008-2012.
3. Apply common rules, based on the overall GHG reduction target, for reducing GHG emissions in the remaining sectors (e.g. non-CO_2 in agriculture and waste are each reduced by 20%).

Parts 1 and 2 show how the renewables and energy efficiency targets affect GHG emissions. Including part 3 gives the full impact on GHG emissions. Parameters in part 3 can be set in a way that the EU 27 reduces its emissions by the 30% target.

3.1. SHARING THE RENEWABLES TARGET

Using the spreadsheet model, the current share of renewable energy in gross inland consumption in the EU 27 was calculated to be 7%.[15] This aggregate figure is made from renewable energy shares in the different sectors of: electricity 15%, heat in industry 0%, heat in households and services 11%, and transport 1%.

The 20% renewables target is shared over the electricity, heat and transport sectors using the three approaches described above:

3.1.1. Equal progress 1

We assume that each Member State increases the share or renewables by the same number of percentage points. This overall renewables share is then split up into the sectors using the least cost method described in Section 3.1.4., except only at the country level. As there are only costs for the electricity and the heat sectors in the cost curve we use, and since RE transport costs are generally higher than these two, we assume the BAU share of RE in the transport sector. In the case that the country does not have enough RE potential in the other 2 sectors available, we increase the RE share in the transport sector so that the overall RE target of the country is met.

[15] The share of renewables in our tool differs to that cited by the commission, as we have used different energy statistics.

We also add a variant where the percentage point increases for each member state is adjusted to the Gross Domestic Product: If the GDP per capita for a Member State in 2005 is higher than the EU average GDP per capita, their percentage point increase is higher than the EU average and vice versa. While the EU wide percentage increase does not change this way, individual member states have higher or lower percentage point increases. Technically this is achieved using the following equation.

Equation 1: GDP adjustment of a member states' (MS) RE share

$$RE_{MS\_2020} = RE_{MS\_2005} + (RE_{EU\_2020} - RE_{EU\_2005}) * \left[GDP_{adj} * Diff_{GDP\_MS-EU} + (1 - GDP_{adj}) \right]$$

RE_{MS_2020}	Targeted Share of renewable energy in 2020 in a given Member State (MS)
RE_{MS_2005}	Share of renewable energy in 2005 in a given Member State (MS)
RE_{EU_2020}	Targeted Share of renewable energy in 2020 in the EU 27
RE_{EU_2005}	Share of renewable energy in 2020 in the EU 27
GDP_{adj}	GDP adjustment factor
$Diff_{GDP\_MS-EU}$	Difference in per capita GDP between given MS and EU 27 average

Assuming a GDP adjustment factor of 50 % therefore means that, for a given MS, 50% of the EU27 wide percentage point increase is adjusted by the difference in per capita GDP between the EU27 and the MS.

3.1.2. Equal progress 2

We assume that each Member State increases its share in a particular sector by the same number of percentage points. We first choose parameters for electricity, heat and transport on the EU level so that the aggregated increase corresponds to an overall share of renewable energy of 20% in 2020:

- the share of renewable electricity is increased from 15% in 2005 to 33% in 2020, i.e. 18 percentage points,
- the share of renewable heat in industry is increased from 0% in 2005 to 10% in 2020, i.e. 10 percentage points,
- the share of renewable heat in households and services is increased from 11% in 2005 to 18% in 2020, i.e. 7 percentage points,
- the share of renewable fuels in transport is increased from 1% in 2005 to 14% in 2020, i.e. 13 percentage points.

Note that this split is broadly similar to the review of model analyses presented in chapter 2.2.

We then apply these percentage point increases to individual Member States. For example the UK with an X% share of renewable electricity in 2005 increases this by 20 percentage points to (X+20) %.

Analogous to the equal progress 1 case, we also add a variant where the percentage point increases are adjusted to the Gross Domestic Product: If the GDP per capita for a Member State in 2005 is higher than the EU average GDP per capita, their percentage point increase is higher than the EU average (see 3.1.1).

3.1.3. Equal share

We assume that all countries increase their share in renewable electricity, heat and transport to the same level. We first choose parameters for electricity, heat and transport on the EU level so that this increase corresponds to an overall share of renewable energy of 20% in 2020:

- the share of renewable electricity is increased from 15% in 2005 to 33% in 2020,
- the share of renewable heat in industry is increased from 0% in 2005 to 9% in 2020,
- the share of renewable heat in households and services is increased from 11% in 2005 to 15% in 2020,
- the share of renewable fuels in transport is increased from 1% in 2005 to 12% in 2020.

We apply these shares to each Member State only if the current value is smaller than in the reference case. Since some Member States already have higher percentages than those stated above, the values for equal share are different to those under equal progress.

3.1.4. Least Costs

The basis for the parameters used in our least-cost analysis are EU-wide cost curves for renewable energy from Pöyry (Greetham 2007)[16]. The cost curves include renewable energy options in the heat and electricity sectors. For the transport sector it is assumed that the 10% biofuels target is met, but no more than that as the Green-X model results indicate that renewable energy in the transport sector is a more expensive option than in other sectors.

To determine the additional amount of renewable energy that needs to be installed in the electricity and the heat sectors between 2005 and 2020 ($RE_{add.\ heat/el}$) the total additional production of RE ($RE_{add.,total}$) has to be calculated first. This is done by subtracting the total production of RE installed in 2005 from the total production of RE installed in 2020, which is determined by multiplying the 20% renewable energy share in 2020 by the forecasted total energy production. In a next step the additional production of renewable energy in the transport sector is determined analogue to the total additional production of energy. This figure is then subtracted from the above mentioned overall additional production of renewable energy.

$RE_{add.\ heat/el}$ is then used to determine the total production of RE options out of the least-cost curve described above. A restriction that applies when using this method is that the total renewable energy production in a given sector (heat or electricity) in a given country cannot exceed the total production of energy production in the same. In case this happens the options in the given sector in the given country have to be reduced and options in other countries have to be added (see Figure 4). This is done until the restriction does not apply anymore.

The options are then redistributed to the sectors in the countries and the share of renewable energy is determined. This is straightforward in the electricity sector. We add the additional renewable electricity to the already existing one (2005) and divide it by the total electricity production in that country (see Equation 2). It is not as straightforward in the heat sector as it is subdivided into four subsectors. These four subsectors are the energy industry sector, which produces heat from combined heat and power (CHP) and district heating units and exports it to the other three sectors, the industry sector, the residential sector and the agricultural sector. These latter three sectors also produce and consume heat autonomously. The increase in the share of renewables in a given heat sector is determined through first determining the increase of the share of renewable in the whole heat sector in a given country. Then this increase of the share of renewables in the whole sector is added to the existing

[16] The data is based on the 2003 baseline of the Primes model

share of renewable heat in each of the four heat subsectors (see Equation 3: Determination of renewable heat share in 2020 in a given country). Here, another restriction applies, as the share of renewable heat in a given sector cannot be more than 100%. To prevent this from happening, it is assumed that the share of a sector with technically more than 100% is 100% and that the production of renewables over 100% is redistributed among the remaining sectors. This has to be repeated until none of the four subsectors have a renewables share of more than 100%. (see Figure 4)

This approach is iterated until the share of renewable energy in the four heat subsectors and the electricity sector is determined.

Equation 2: Determination of renewable electricity share in 2020 in a given country

$$\%_{RE,2020,EL} = \frac{RE_{2005,EL} + RE_{add.,EL}}{D_{2020,EL}}$$

$\%_{RE,2020,EL}$	Share of renewable electricity in 2020
$RE_{2005,EL}$	Renewable electricity production in a given country in 2005
$RE_{add.,EL}$	Additional renewable electricity production until 2020 in a given country (determined by the MAC Curves)
$D_{2020,EL}$	Electricity demand in 2020 in a given country

Equation 3: Determination of renewable heat share in 2020 in a given country

$$\%_{RE,2020,heat(\sec)} = \%_{RE,add.,heat} + \%_{RE,2005,heat(\sec)}$$

$$\%_{RE,add.,heat} = \%_{RE,2020,heat} - \%_{RE,2005,heat}$$

$$\%_{RE,2020,heat} = \frac{RE_{2005,heat} + RE_{add.,heat}}{D_{2020,heat}}$$

$\%_{RE,2020,heat(\sec)}$	Share of renewable heat in 2020 in a given sector in a given country
$\%_{RE,add.,heat}$	Additional heat share from 2005 till 2010 determined using the least cost method
$\%_{RE,2005,heat(\sec)}$	Share of renewable heat in 2005 in a given sector in a given country
$\%_{RE,2020,heat}$	Share of renewable heat in 2020 in a given country
$RE_{2005,heat}$	Renewable heat production in a given country in 2005
$RE_{add.,heat}$	Additional renewable heat production until 2020 in a given country (determined by the MAC Curves)
$D_{2020,heat}$	Heat demand in 2020 in a given country

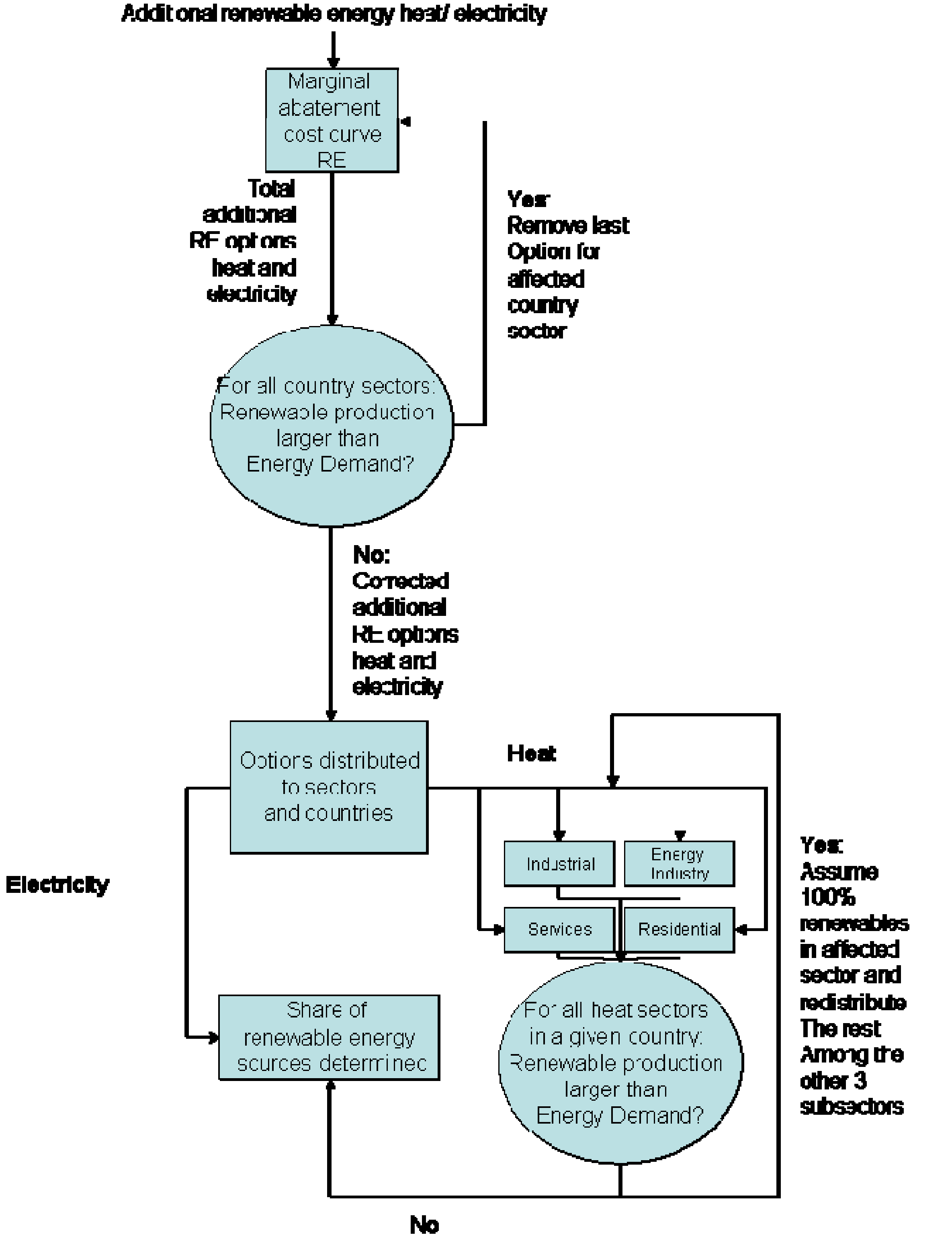

Figure 4: Overview determination share of renewables under the least cost scenario

3.2. SHARING THE ENERGY EFFICIENCY TARGET

The energy efficiency target requires reduction of the primary energy consumption by 20% in 2020 compared to BAU. Analogous to the above mentioned renewable target distribution we have implemented two options: (1) apply the same percentage for all countries and all sectors and (2) convergence of energy efficiency.

3.2.1. Equal energy efficiency improvements

We apply the same percentage improvement (i.e. 20%) over BAU to all relevant sectors in all Member States. As this method does not take starting positions or sector reduction potentials into account it is an unlikely option; but is a good reference point.

3.2.2. Convergence of energy efficiency

The second method is to assume convergence of energy efficiency in each of the energy sectors. For each sector we need to define a meaningful indicator that depicts the current energy efficiency and is available for all Member States. We also need to define the level to which each indicator converges. The indicators, their EU average in 2005 and exemplary convergence values are given in Table 5.

Table 5: EU sector-wise energy efficiency indicators (2005 and assumed convergence values)

Energy Sectors and Energy Efficiency indicator	EU average 2005 values	Convergence values in 2020
Energy Industry (elec.) : Energy efficiency improvements in fossil fuel power plants [%-point improvement over BAU in 2020]	n.a.	3%
Industry (heat): Energy Efficiency Index (EEI) [-]	1.5	1.1
Transport (passenger): Energy per passenger km [ktoe/Gpkm]	39	30
Transport (freight): Energy per tonne freight km [ktoe/Gtkm]	52	38
Households (heat): Energy for heating and cooling per m² [ktoe/Gtkm]	0.022	0.013
Households (elec.): Energy for electrical appliance. per person [toe/ million cap]	74	40
Services (heat): Energy for heating and cooling per employee [toe/cap]	4.27	3
Services (elec.): Energy for electrical appliances. per employee [toe/cap]	1.08	0.8

In the energy industry, we assumed an improvement in energy efficiency over BAU, as initial efficiencies of electricity production in fossil power plants are not easily available[17]. For industry, the Energy Efficiency Index (EEI) was used as the indicator. This index compares the energy conversion efficiency in the sector against a best practice reference value. Where the energy conversion efficiency of a Member State equals the current best practice reference value, the EEI is one. An index of 1.1 means, that the country is using 10% more energy than best practice.

The remaining indicators are derived from the data available, namely energy and an indicator of the activity in a sector. Progress in the passenger transport sector is measured using en-

[17] When calculating the Energy Efficiency CHP was takes account of through a constant correction factor

ergy per person km[18]. For freight transport energy consumption per tonne km is chosen. These indicators can be reduced through energy efficiency improvements but also by modal shifts. For the households sector, energy efficiency improvement related to heating and cooling consumption can be evaluated using energy consumption per m² of floor space. Energy efficiency of electrical appliances can be evaluated by breaking it down to the per capita level for domestic use and per employee for the services sector. For the Services sector, heating and cooling demand is also measured per employee.

Table 5 depicts the EU average values for the indicators in 2005 as well as the convergence parameters. The latter are chosen to result in an overall energy efficiency improvement of 20% for the EU27 total. The choice was made based on the authors expert judgements of what seems reasonably achievable in the sectors. Since this is connected with a high degree of uncertainty, and consequently there are alternative sets of parameters that would also lead to an overall improvement of 20%, sensitivity analysis through using other factors is performed in chapter 4.4.

3.3. OTHER SECTORS

The above mentioned energy efficiency improvements do not cover all the efficiency improvements that can be achieved and that lead to a reduction in resource consumption. Firstly, there are energy related emissions that are not included in the energy efficiency target. These include emissions from international transport, also excluded from the Kyoto protocol, and fugitive emissions of CH_4 from for example pipeline leaks. Second, there are those emissions that are not energy related. These occur in the agriculture, land-use change and forestry and waste sectors.

Assumptions need to be made for these other sectors on how much emissions can be reduced relative to BAU. These assumptions are based on expert judgement so that balanced efforts are needed across sectors. We assume that non-energy emissions in industry (e.g. CO_2 from cement production or N_2O from chemical production) can also be reduced by 20%. For fugitive emissions in the energy industry, the assumption is that technical measures to reduce leaks could reduce emissions by 50%. CH_4 from coalmines can also be recovered and used for energy purposes. Overall international transport emissions will be growing intensively under the BAU scenario (+126% from 2005 to 2020) and energy efficiency improvements of 30% over the BAU scenario, reducing this growth to 58%, seem to be possible. For non-CO_2 agriculture there is a smaller potential as this depends very much on what fertilizers will be used in the future and the consumer choices, soft factors that are difficult to influence. The emissions per capita for waste are assumed to converge to the value listed in Table 6.

[18] The ACEA agreement uses g/km as an indicator. In our scenarios 2005 values roughly correspond to 177g/km in and the 2020 values to 138g/km. The average g/km value therefore equals roughly that of new cars in the ACEA agreement.

Table 6: Overview of other sector indicators

Non - Energy Sectors and Efficiency indicators	EU average 2005 values	Necessary values in 2020
Non-energy in industry: Reduce emissions from 2005 by at least	0%	20%
Other energy industries (fugitive emissions): Reduce emissions from 2005 by at least	0%	50%
International transport: Reduction below BAU in 2020		30%
Non-CO_2 Agriculture: Reduction below BAU in 2020		10%
LUCF: At least do not increase emissions / decrease removals from 2005		
Waste: Converge emissions per capita to [tCO_2eq/cap]	0.31	0.2

These sectors are used to achieve a given overall GHG emission reduction by closing the gap between the emission reductions achieved through RE and EE and the target overall GHG emission reductions. Therefore the numbers for the “Reduction over BAU” listed in Table 6 can be only seen as a reference and were adjusted slightly to achieve the desired emission reductions.

3.4. INPUT DATA

Sources of data for energy production and consumption, emissions and indicators for specific sectors (e.g. number of households in the residential sector) and modifications and calculations to derive all the necessary indicators are described in this section.

Energy production/ energy consumption

Most of the input energy data used for the spreadsheet is taken from the “frozen technology” scenario developed by Ecofys and based on PRIMES data from the year 2007. The data sets were available for the years 2000 and 2005 (historical values) as well as 2010, 2015 and 2020 (BAU projections).[19]

In the following we lay out data groups that were available and describe some further calculations made to include additional useful indicators (marked in yellow in the spreadsheet) such as for energy efficiency and to derive our Effort Sharing Scenario. For a better understanding of this section it is advised to read alongside the spreadsheet model.

For energy production data was available for all electricity producing options in a given country. This data included fuel input data where appropriate[20], as well as energy output data split up by electricity production options and steam consumptions by sector. Additionally, fuel input and energy output data could be used to determine the energy efficiency for most power plants. However, CHP plants produce both heat and electricity so assumptions have to be made on how much of the energy input is used to produce heat. To do so it is assumed that to the electricity production (output) side 17.5% of the CHP heat production is added in the calculation of the energy efficiency. This is a common method for integrating CHP in efficiency calculations. (see Equation 4).

[19] In the excel spreadsheet the cells containing energy or emissions for the historical values and the BAU projections from the “frozen technology” scenario are coloured in light pink.

[20] For RE sources other than biomass no fuel input is necessary

Equation 4: Determination of thermal energy efficiency

$$E_{eff} = \frac{E_{End,El.} + E_{End,heat} * 0.175}{E_{Prim}}$$

E_{eff}	Energy Efficiency thermal power plants
$E_{End,El.}$	Energy output energy industry (electricity)
$E_{End,heat}$	Energy output energy industry (heat)
E_{Prim}	Primary Energy input

For the **effort sharing scenario**, in order to determine the electricity production, we used the consumption that is derived from the demand in the consuming sectors (transport, residential, industry, Service and Agriculture). Shares of distribution losses, internal consumption and imports are kept constant at the BAU values. The share of renewables is given by the renewables sharing approach. Share of energy production from nuclear reactors is kept constant, as under BAU. The remaining electricity production, if any, is shared across the fossil fuels, assuming the same share as under BAU. Conversion efficiency is provided by energy efficiency sharing approach.

Demand for heat provided through district heating and CHP units is given by the total amount of heat demand in the industrial, residential and services sector[21]. Of that total heat, the share that is provided by CHP units is assumed to be dependent on the electricity production from thermal power plants. Since there is no data available on how much heat is produced from CHP plants nor the number of CHP installations, the electricity/heat ratio of the BAU scenario, for which data was available, was applied to the effort sharing scenario. The residual heat demand not covered by CHP is provided for by district heating units. The share of renewables in district heating is determined through the RE sharing approach. The remaining heat production from district heating is distributed among other fuels in same proportion as under BAU.[22]

In all other sectors, data for energy demand were sufficiently detailed to evaluate the indicators for the historical and the BAU data. For the effort sharing scenario first the heat and the electricity demand are determined for each sector. These two have to be supplied by the energy industry (see above[23]). Electricity consumption is determined from the BAU Scenario by applying an indicator that reflects assumed energy efficiency improvements in the corresponding sector. Heat supplied through the Energy industry and consumed in the sector, is assumed to be the same proportion of electricity production as in the BAU scenario, assuming that the share of CHP plants in total electricity production stays constant. In a next step the share of renewables is determined by using the RE sharing approach. Once the RE production/consumption is known, the residual energy demand in the sectors is split between the other fuels, assuming the same proportional distribution as under the BAU Scenario.

[21] This total heat demand includes only the heat produced in the energy industry sector.

[22] In the approach taken, it can happen, that all heat will be supplied through CHP power plants and none through district heating units. In that case, in order to reach the RE share given by the RE sharing approach

[23] Electricity/ heat production in the energy industry is determined through the electricity/ heat consumption in the four other sectors

Emission data

Emission data are used from three sources:

- National greenhouse gas inventories reported to the UNFCCC (1990 to 2005),
- Energy data (see above) multiplied by standard emission factors (1990 to 2020),
- Projections in national communications (1990 to 2020 for most countries).

For the period where the datasets overlap, they contain different values and are not always available in the sectoral split needed here. We chose to take UNFCCC emissions for the historical values until 2005. To derive future energy related emissions, we used growth rates of the emissions derived from our energy data and applied this growth rate to the latest available year for the emissions from the national inventories reported to the UNFCCC. We compared this result with the projections from countries and found good agreement. For non-energy related sectors, we used growth rates of the projections of countries and applied this growth rate to the latest available year of the emissions from the national inventories reported to the UNFCCC. Table 7 shows the sector definition and UNFCC source categories.

Table 7: Sector definition

Our sector definition	UNFCCC source categories
1 Energy industry	1.A.1 Energy Industry
2a Industry (energy related emissions)	1.A.2 energy industry manufacturing. + construction Industry]
2b Industry (non-energy related emissions)	2 Industrial Processes, 3 Solvents
2c Other energy industry (fugitive emissions)	1.B fugitive emissions
3a Domestic transport	1.A.3 Transport
3 a International transport	International transport reported separately
4 Residential and services	1.A.4 Residential, Commercial, Agriculture, 1.A.5 Non-specified from fuel combustion, e.g. military
5 Non-CO_2 in agriculture	4 Agriculture
6 Land use change and forestry	5 LULUCF
7 Waste	6 Waste

Other indicator data

Other indicators used in the analysis, such as the average useful floor area per dwelling in m², are derived from various sources, all of which are laid out in the spreadsheet under the “source” column, or were calculated using the available data. They are among those cells marked yellow in the spreadsheet.

4. RESULTS

In this section results from the spreadsheet model are presented. First the renewable energy and the energy efficiency targets are examined independently to give an insight into how the assumptions on the sharing in Section 3.1 and Section 0 affect the model output. The effect of the different sharing methods on the renewables energy share in each EU Member State is illustrated in Section 4.1. The different effort sharing methods are evaluated as to how they affect the energy efficiency in Section 4.2. This leads to the selection of two references cases: the *equal progress case for renewable energy* and the *convergence case for energy efficiency*. Then, in a second step, the combined effect of the EU-wide RE target and the EE target on Member State emissions is examined for the two reference cases (Section 4.3). Sensitivity analysis on these results is performed in Section 4.4, and the results are compared to the previous GHG effort-sharing analysis in FUFA II (Section 4.5).

4.1. SHARING RENEWABLE ENERGY TARGET ONLY

This section compares the results from sharing only the renewable energy target. We assume zero energy efficiency improvement over BAU and that GHG emissions in the other sectors are equal to the BAU levels. Table 6 shows the parameters for the electricity, heat and transport sectors for the three effort-sharing approaches for EU as a whole. Figure 3 shows Member State shares for the three cases and the 2020 base case compared to the 2005 share of renewables, the data is in Annex 3.

Table 8: Distribution of Renewable energy across sectors under the three effort-sharing methods for the EU 27

Parameter	2005	2020	2020	2020	2020	2020
Method	Historical Values	Equal progress 1 (+13%) [24]	Equal progress 2 (+13%)	Equal share (20%)	Least cost[24]	BAU / UNFCCC projections
$\%_{RE}$ Electricity	15.4%	41.2%	33.0%	31.0%	33.0%	
$\%_{RE}$ heat in industry	0.0%	17.0%	11.0%	10.0%	16.0%	
$\%_{RE}$ heat for space heating	11.0%		18.0%	15.0%		
$\%_{RE}$ transport	0.9%	7.2%	14.0%	13.0%	14.0%	
$\%_{RE}$ total	6.5%	20.0%	20.0%	20.0%	20.0%	11.3%

[24] For the equal progress and the least cost scenario the RE shares for heat and electricity is the output of the calculations, for all other scenario calculations the RE shares are the input for the calculation

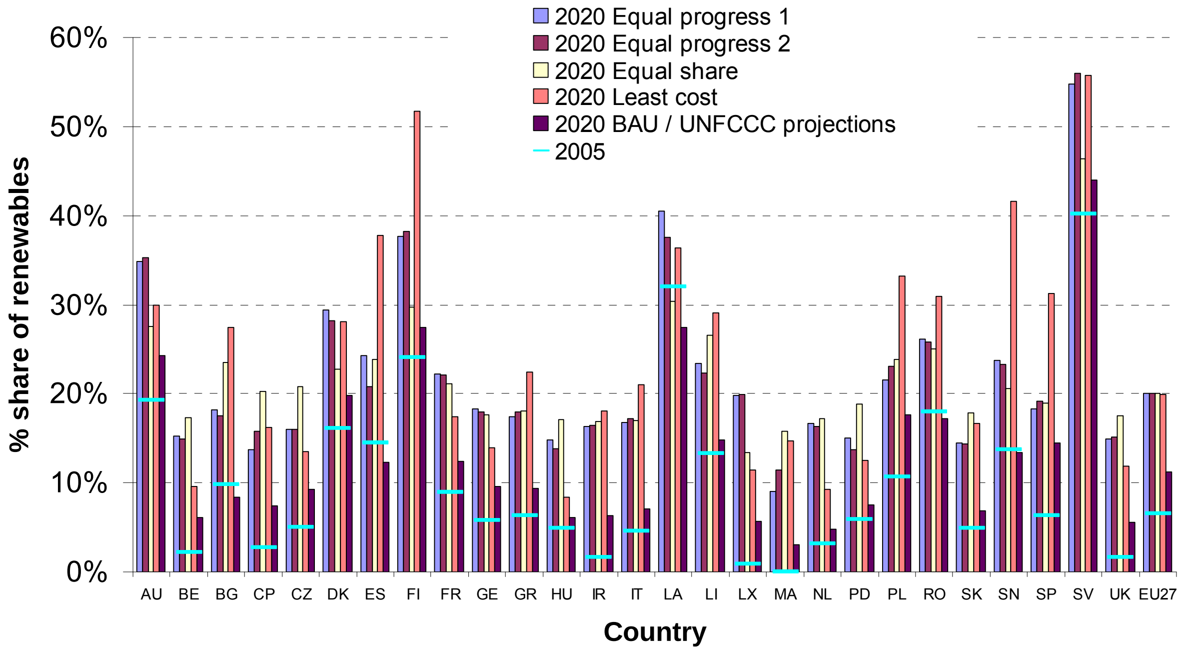

Figure 5: Total renewable energy share in 2020 for the EU 27 and each Member State under different effort sharing assumptions compared to the base case and 2005 levels (for values see Annex 3).

Figure 5 shows how the renewable energy effort-sharing approach influences the distribution of the overall 20% target among the Member States. While the overall share of renewables in the EU is constrained at 20%, the contribution varies from country to country and from case to case. All Member States must increase their share of renewable energy for all three effort-sharing approaches compared to BAU. As well as the variation in the 2020 share within each Member State for different effort-sharing methods, there is also wide variation across Member States.

The base scenario is the **equal progress 1 scenario**. The Figure shows how under this scenario the countries have to contribute equally based on their current situation – Member States that start with a higher RE share remain higher than average. Under this scenario, the country that has the highest share of RE installed is Sweden, reaching a share of 55 % of RE installed, followed by Latvia with just over 40% of RE installed. On the lower side lie Malta (9%) as well as Belgium, Cyprus, Hungary, Poland, Slovakia and the UK (14-15%).

Under the **equal progress 2 scenario** the trend is similar to the equal progress 1 scenarios. In this scenario, we applied the increase for each of the three sectors (electricity, heat and transport) and therefore the increase per country is not necessarily 13% in total. Under this scenario, the country that has the highest share of RE installed is Sweden, reaching a share of 56 % of RE installed followed by Latvia with a share of app. 40% of RE installed. On the lower side lie Malta (12%) as well as Belgium, Hungary, Slovakia and the UK (14-15%).

The **equal share** case leads to a situation where there is less difference in the distribution of RE between different Member States. Because the equal share is not assumed for the overall renewables but instead for the heat, electricity and transport sectors separately, and because some countries lie above these equal shares already in the base line, the overall RE share for each country does not always equal 20%. Yet the low variability among countries is reflected by the fact that 19 countries have a share of RE between 20% and 30% while only 3 lie above this range and 5 beneath. The only country that has a share of RE above 40% in this case is Sweden.

The **least cost scenario** attributes the effort to the Member States that have the most readily available and least expensive resources. This is generally the case in northern European countries, especially Finland and Sweden, but also Latvia and Lithuania. Other countries that contribute more under this scenario are Estonia and Slovenia. In contrast, some countries such as the Netherlands, Poland or Hungary would have to contribute less. The variability in the increase of renewable energy share between 2005 and 2020 between Member States is the highest using the least cost method, which reflects the uneven distribution of the economical RE potential across Europe. Under least cost the UK RE share would be 11.8%.

A variation to the reference case is to account for difference in the wealth among the countries. This variation is to reflect the fact that some countries have a higher ability to pay for installation of renewables. How this affected the outcome can be seen in Figure 6, where this case is compared to the case were GDP per capita adjustment is not included. For the variation case we assumed that those Member States with GDP per capita 10% above the EU average have to contribute 5% more renewables and that those that have a GDP per capita 10% below the EU average have to contribute 5% less renewables. Since the EU deviation from the EU average per capita GDP is used, this leads to a situation where the EU wide per capita renewables share does not change and therefore the overall RE share in the EU. This adjustment changed the results slightly, but not more than the difference between the other approaches.

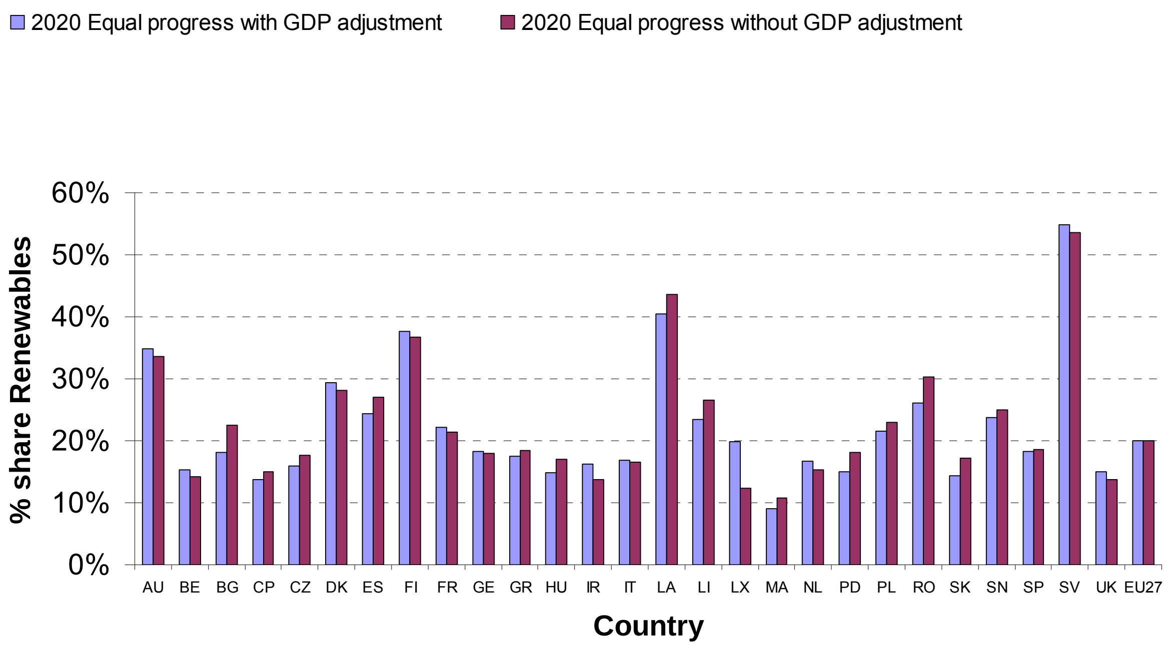

Figure 6: Renewable energy in 2020 share under equal progress 1 scenario with and without ability to pay (GDP per capita) adjustment

4.2. SHARING ENERGY EFFICIENCY ONLY

In this section, we analyse the energy efficiency target only. For this purpose, we leave the RE target aside and assume the BAU RE share. To determine the energy efficiency improvement, the total primary energy demand in the effort-sharing scenario is compared with that of the BAU scenario. The convergence case explained in Section 3.2.2 is used to distribute the energy efficiency target among the Member States.

Since the sectoral distribution of the overall energy efficiency improvement is not specified[25], different assumptions can be made on how the target is reached. **Table 9** gives the convergence case from Table 5 as well as three other cases: Case 1 assumes that the energy efficiency target in the energy industry and industry sectors will be relatively low, with Member States only reaching the EU average in the industry sector and achieving no efficiency improvement in the energy industry sector. To reach 20% overall, more effort is required in the other sectors, especially the transport sector. Case 2 assumes that energy industry and industry sectors contribute the major share towards achieving the goal and the other sectors less. Case 3 assumes that once again the energy industry and industry sectors have to contribute less than in the base case, but instead of the transport sector the main contributions come from the households and services sectors. The range of the three cases is represented by the error bars in Figure 7.

[25] In Section 3.2.2 we listed the different indicators for different sectors that reflect how energy efficiency improvements can be reached.

Table 9: Energy efficiency parameters for 2005 and different "sharing energy efficiency only" assumptions for 2020

Parameter	2005	2020 Base Case[26]	2020 Case 1	2020 Case 2	2020 Case 3
Energy Industry (elec.) : Energy efficiency improvements in fossil fuel power plants [%-point improvement over BAU in 2020]	0%	3%	0%	5%	0%
Industry (heat): Energy Efficiency Index (EEI) [-]	1.5	1.1	1.5	0.9	1.5
Transport (passenger): Energy per passenger km [ktoe/Gpkm]	39	30	22	39	39
Transport (freight): Energy per tonne freight km [ktoe/Gtkm]	52	38	26	52	52
Households (heat): Energy for heating and cooling per m² [ktoe/Gtkm]	0.022	0.013	0.01	0.013	0.0044
Households (elec.): Energy for electrical appliance. per person [toe/ million cap]	74	40	35	74	20
Services (heat): Energy for heating and cooling per employee [toe/cap]	4.27	3	2.1	4.27	0.8
Services (elec.): Energy for electrical appliances. per employee [toe/cap]	1.08	0.8	0.6	1.08	0.4
Resulting total reduction below BAU:	0%	-20%	-20%	-20%	-20%

Figure 7 depicts the energy efficiency improvements that need to take place under the base case scenario in the different countries to achieve the targeted EU wide 20% efficiency improvement over the BAU. It can be observed that the variability between the countries is high: Some countries, such as Eastern European States and Ireland have to achieve a significant decrease, while others such as Italy or Sweden only have to make minor efficiency improvements. This results from the different levels of energy efficiency already reached in different countries (Table 9).

[26] Convergence case from Table 5

Table 10: Energy efficiency input parameters for 2005 for different countries

	Efficiency of fossil fuel power plants (CHP corrected)	Industry: EEI	Transport: Energy per pkm (in ktoe/Gpkm)	Transport: Energy per tkm (in ktoe/Gpkm)	Households: Energy for heating and cooling (incl. cooking) per m² (toe/m²)	Households: Energy for electric appliances per cap (toe/ mio cap)	Services: Energy for heating and cooling per employee (toe/cap)	Services: Electric appliances and lighting per employee (toe/cap)
AU	36.6%	1.2	39.60	59.00	0.019	74.83	0.78	0.106
BE	38.3%	1.5	46.78	48.01	0.024	76.59	0.87	0.126
BG	25.5%	2.5	32.25	65.68	0.010	46.65	0.26	0.031
CP	33.0%	1.5	56.79	261.28	0.014	66.12	0.70	0.121
CZ	29.2%	1.9	32.32	54.34	0.018	62.22	0.65	0.113
DK	38.2%	2.3	40.21	75.79	0.013	141.45	0.65	0.129
ES	31.7%	1.5	30.48	18.85	0.024	94.22	0.56	0.119
FI	38.6%	1.2	34.20	44.47	0.021	182.16	0.89	0.241
FR	31.6%	1.3	32.71	76.85	0.017	86.89	0.74	0.178
GE	35.4%	1.3	40.74	35.30	0.017	77.55	0.75	0.103
GR	33.6%	1.6	35.84	101.49	0.014	70.65	0.34	0.118
HU	33.0%	1.5	34.82	39.16	0.017	68.69	0.86	0.098
IR	38.8%	1.5	70.72	111.24	0.017	87.51	0.78	0.101
IT	40.0%	1.3	30.63	54.00	0.012	56.07	0.48	0.177
LA	26.9%	1.5	33.85	17.47	0.026	54.81	0.58	0.067
LI	29.4%	1.5	26.81	17.32	0.016	51.29	0.32	0.115
LX	51.9%	3.6	[27]172.38	[27]144.59	0.027	54.76	0.24	0.118
MA	31.1%	1.5	65.05	167.65	0.004	53.48	0.52	0.122
NL	41.8%	1.5	51.28	39.61	0.012	114.03	1.15	0.225
PD	30.5%	1.8	24.42	39.45	0.017	43.13	0.32	0.112
PL	41.3%	1.3	42.42	63.82	0.007	87.76	0.29	0.147
RO	28.0%	2.8	30.65	30.70	0.016	26.57	0.25	0.029
SK	25.7%	2.1	29.75	22.68	0.015	49.04	0.62	0.145
SN	29.0%	1.5	46.19	42.66	0.019	70.21	0.53	0.063
SP	41.0%	1.3	44.70	61.09	0.009	51.25	0.33	0.142
SV	28.9%	1.4	40.94	44.62	0.017	139.45	0.54	0.364
UK	39.3%	1.9	46.78	59.78	0.017	94.84	0.47	0.184

In the base case, 13 of the countries have to achieve an efficiency improvement of 20% to 30%, 12 have to make efforts between 10% and 20% and 2 have to make efforts greater than 30% , with an average contribution (non-weighted) of 24.5% between the countries. Since the convergence case was used, the results in Figure 7 reflect the historical situation in the countries represented by the figures in Table 10.

Among the countries with the lowest contribution is Italy, which has a relatively efficient power plant structure and industry due to the only recent economic development as well as a low energy demand in households due to the moderate climate. The spread for Italy is also low, since it is efficient in all sectors. Although the climate is not as moderate, Finland's contribution is also well below the average, due to a very efficient industry. Only if reductions are

[27] Value is high, due to fuel tourism

over-proportionally high for industry, Finland has to reduce significantly (case 2). Concerning the countries with a larger contribution, the high numbers for Luxemburg are due to the inaccuracy of the data (especially transport, see Table 10). The small countries of Malta and Cyprus[28] have relatively inefficient power plants and industries and so does Romania.

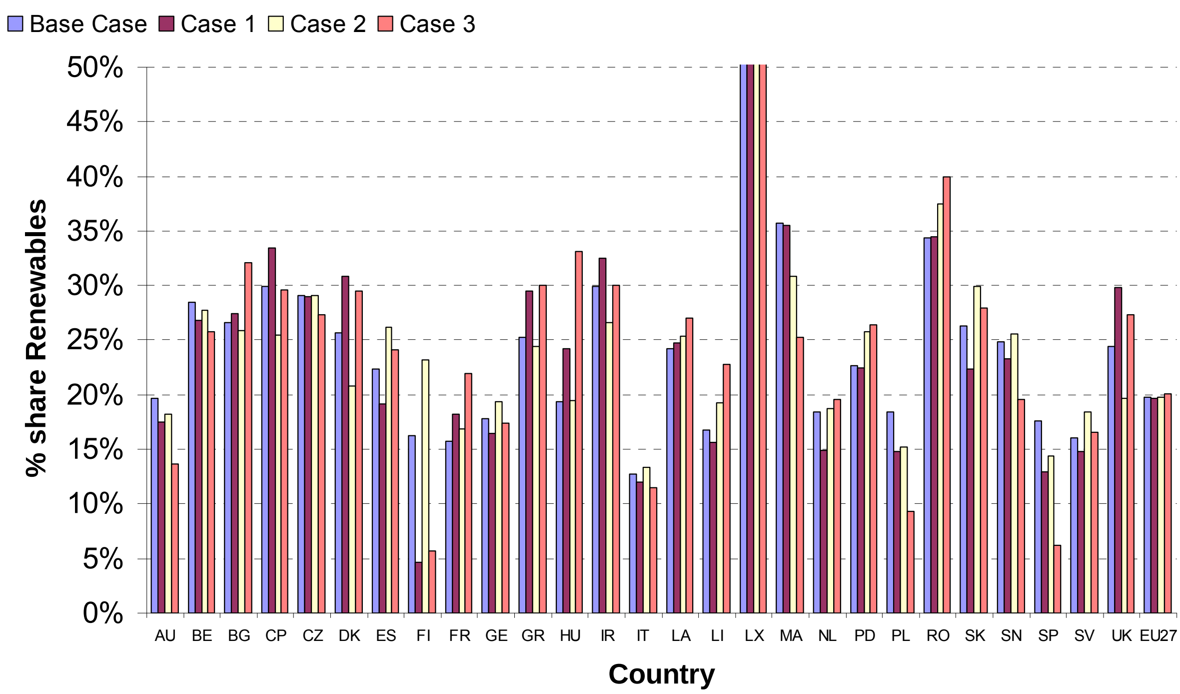

Figure 7: Energy efficiency improvements in 2020 over BAU under sharing energy efficiency (see Table 9)

4.3. COMBINED EFFECT OF ALL TARGETS

Sections 4.1 and 1.1 present the results from separately analysing the renewables and the energy efficiency targets. In this section we present the results when the both targets are met at the same time. The combination analysed included the base case for the energy efficiency target and the equal progress 1 case with GDP adjustment[29] for the renewables. The renewable target case was selected following discussions at the EU level on options for sharing the target prior to their official announcement on 23 January 2008.

[28] Data was sufficiently available for these two countries here, in contrast to other calculations

[29] It is chosen to have a 50% GDP adjustment.

Table 11: GHG Emission reductions below 1990 level with sharing renewable energy only (equal progress with GDP per capita adjustment); energy efficiency only (convergence case); and a combined RE and EE case.

Total EU 27 GHG emissions reductions below 1990:	Renewables only	Energy efficiency only	Renewables and energy efficiency	Renewables and energy efficiency and other sectors
All sectors and gases	-11%	-15%	-24%	-29%
Kyoto total (excl. LUCF, excl. int. transport)	-14%	-18%	-26%	-30%
ETS total (only energy industry and industry)	-28%	-27%	-42%	-42%

Table 11 shows the 2020 GHG emission reductions compared to 1990 levels assuming the effort-sharing of the renewable energy (first column) and energy efficiency targets (second column) separately and when they are combined including (third column) and excluding other sectors (last column). Results are shown for the six gases covered by the Kyoto Protocol and separately for the energy industry and industry sectors included in the EU (Figure 8 and Figure 9).

The emission reductions from the RE only case and the EE only case do not add up for the combined cases since there are synergies between the two measures. E.g. an increase in energy efficiency will lead to a reduction in the absolute RE installations necessary to achieve the RE target. Consequently the emission reductions achieved by the renewables are lower when energy efficiency is added compared to the case when it is not.

Generally it can be observed, that the emission reductions needed in the ETS sectors relative to 1990 are higher than the overall figures. This does not imply though, that the *effort* that has to be made in these sectors is disproportionate compared to the other sectors. A major share of these emission reductions through energy efficiency improvement in the EU ETS (-27%) is not achieved through energy efficiency measures *in* the ETS sector, but through reduced demand for electricity by energy efficiency efforts in other sectors.

Besides, renewable energy which has a significant impact on the emissions in the EU ETS (-28%) is supported by separate renewable energy policies, which also lead to emission reductions that do not have to be supported through the EU ETS. In Table 11 the emission reduction of -42% achieved when the two targets are combined can therefore only be partially attributed to efficiency measures taken in the ETS sector.

Taking greenhouse gases as a whole, the RE only case corresponds to a small percentage decrease (-14%) as only CO_2 emissions are reduced by renewable energy. For energy efficiency the emission reductions in the sectors covered under the Kyoto protocol are slightly higher (-18%). When combining both the renewables and the energy efficiency target, we find a decrease in Kyoto emissions of 26% and when including also the other sectors of -30%. For the EU ETS an overall emission reduction of -42% can be observed.

This leads to the following conclusions:

- The combined effect of the renewable energy and energy efficiency targets leads to EU GHG reductions in 2020 of more than 20% compared to 1990 levels (here -26%). The system is over-constrained and the unilaterally agreed GHG reduction of 20% is only meaningful if one of the other targets is *relaxed*. This would be regarded as a step backwards, with consequent political implications.
- If the EU reduces all emissions covered by the Kyoto Protocol by 30% from 1990 to 2020 while fulfilling the renewable and energy efficiency targets at the same time, the ETS sectors will reduce more (here 42% from 1990 to 2020, from already 10% below

1990 in 2005). ETS sectors will reduce GHG emissions both due to their own efficiency improvements, as well due to the reduced production consequent from demand reduction in electricity and heat. The reductions of the ETS sectors therefore have to be stronger than 30% below 1990.

The distribution of the combined target scenarios (renewables and energy efficiency) for the EU Member States is shown in Figure 8. For all countries the scenario leads to emission cuts below baseline projections. Due to very high baseline projections, some countries are able to increase their emissions above 1990 levels (Latvia, Portugal and Spain). For Germany, which just announced it wants to cut overall GHG emission in 2020 by 40%, the chosen scenario achieves approximately that (c.a. 37% reduction). All in all six countries will experience emission increases, 15 countries will experience emission cuts between 0 and 40% and another 6 between 40% and 70% percent (including also the other sectors).

Emission changes in the two combined target scenarios always lead to an emission reduction compared to the level of emissions in 2005. In the two single target cases this is not always the case. In particular in the "sharing renewables only" case, emissions for some countries are higher than they were in 2005.

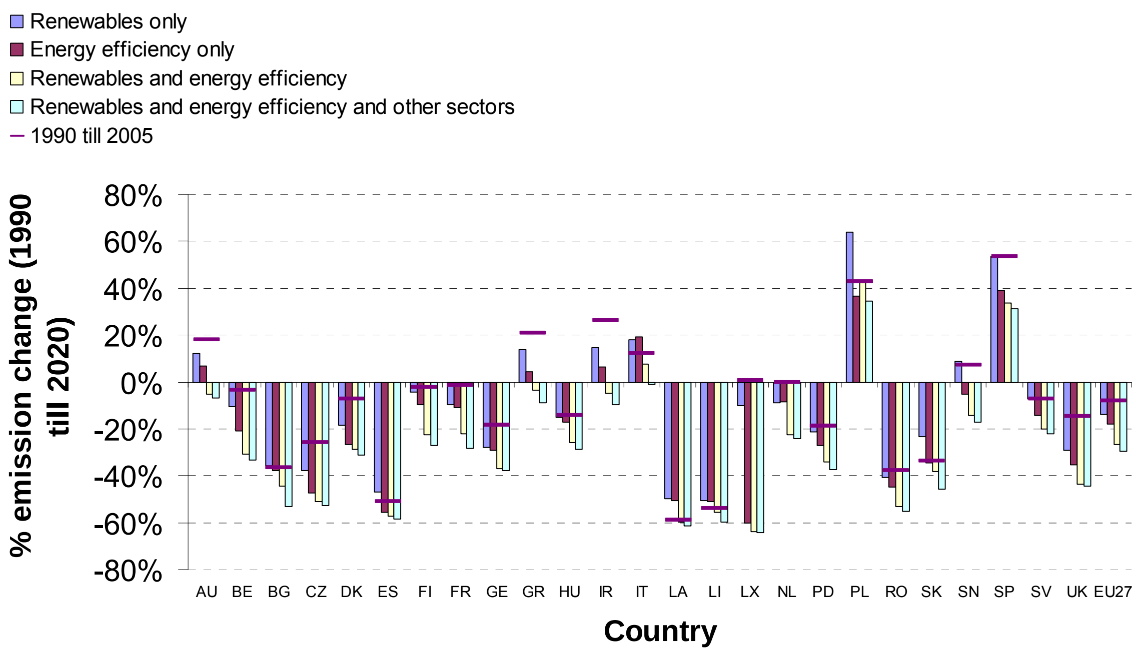

Figure 8: GHG emission change between 1990 and 2020 across 25 EU countries (excluding Malta and Cyprus) for the cases in Table 11[30] (for values see Annex 3)

Figure 9 shows the change of the emissions that are covered by the EU ETS until the year 2020. The percentagewise EU wide emission reductions are higher than they are for the Kyoto sectors as discussed earlier. This also translates to the countries: the relative emissions reductions between 1990 and 2020 are, in all but five cases, higher in EU ETS sectors than they are in the Kyoto sectors.

[30] The increase observable in Portugal (PL) from the EE only scenario to the RE & EE scenario over the EE only scenario can be explained by different RE substitution effects. While under the RE & EE scenario heat is substituted, electricity is substituted in the EE only case. This leads to a lower emission decrease in the RE & EE scenario than in the EE scenario, although the absolute RE share is higher under the RE & EE scenario.

An interesting case is France, where the share of fossil fuels in electricity generation is currently low, due to extensive use of nuclear power. Introduction of renewable energy in electricity replaces almost all fossil fuel produced electricity, leading to high percentage reductions in emissions of the ETS sectors.

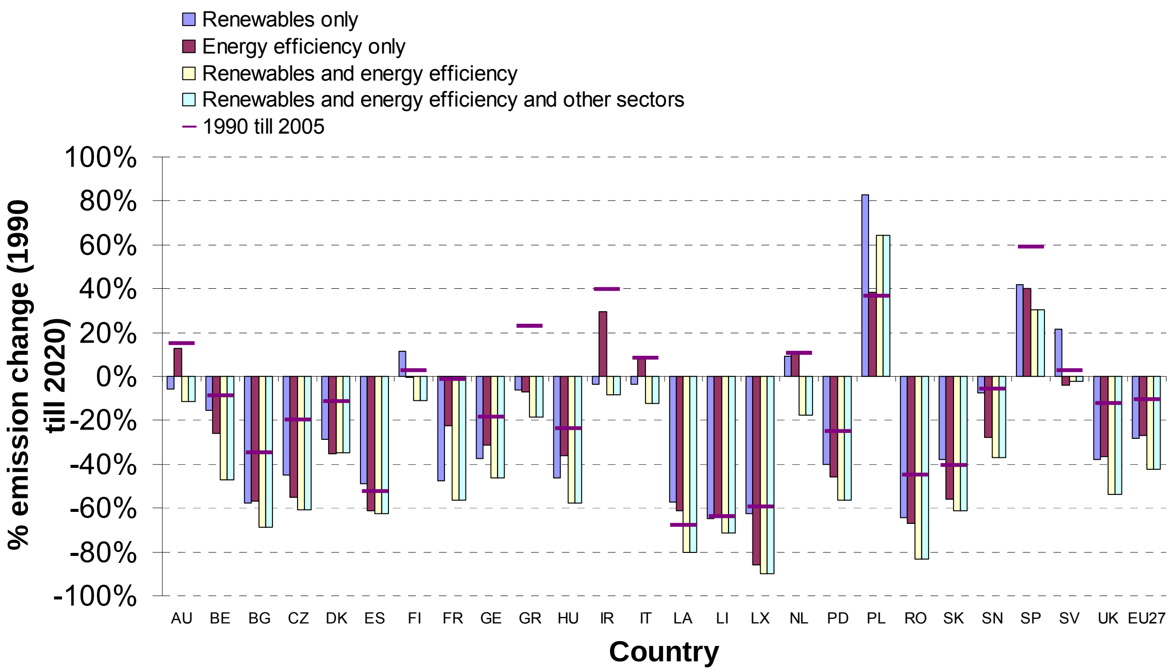

Figure 9: Emission change under the EU ETS until 2020 (base year 1990) across the countries (excluding Malta and Cyprus) for all cases mentioned in Table 11 (for values see Annex 3)

The figures below show how the emission reductions are spread across sectors for all sectors (Figure 10), for the Kyoto sectors only (Figure 11), and for the EU ETS sectors (Figure 12), the data is tabulated in Annex 3. The biggest share of emission reductions is realised by the energy industry sectors followed by domestic transport, industry and in residential, services and agriculture.

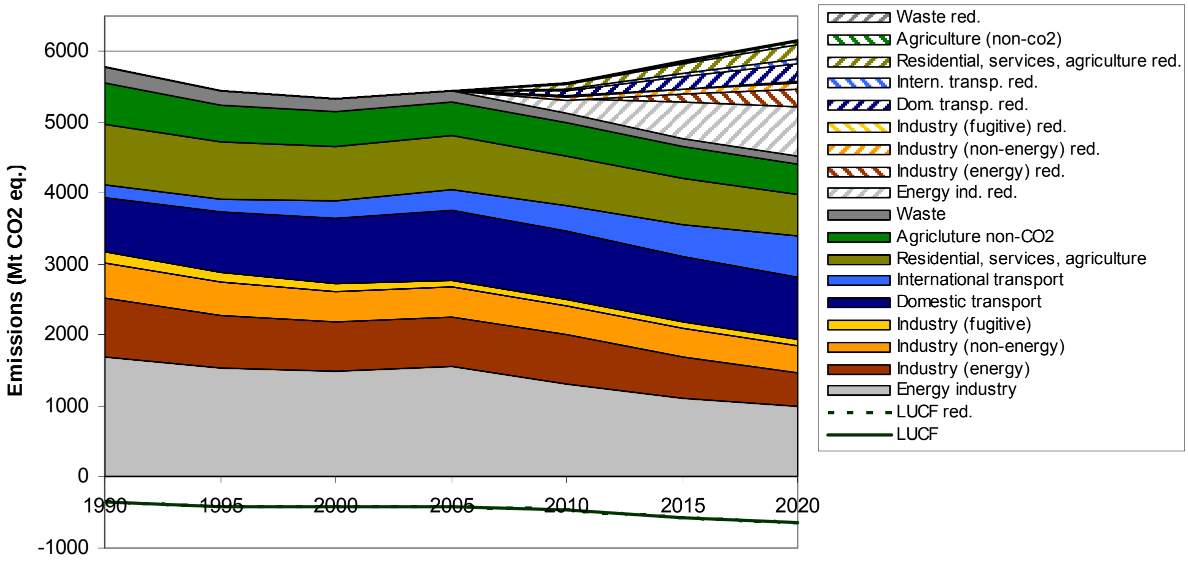

Figure 10: Emission reductions of all sectors over BAU (for renewables, energy efficiency and other sectors case)

Figure 10 shows the emissions of all sectors in a stacked graph. As the sector Land use change and forestry is removing CO_2 on a net basis, it is included as separate line and not added to the other emissions. The striped areas show the reductions below reference for the different sectors.

Historically, energy industry has the largest share in emissions and also contributes most to the reduction (largest striped wedge). These reductions also include those through reduced energy demand in the other sectors. Reductions in industry, domestic transport and residential, services & agriculture contribute reductions equally.

Figure 11 provides the same picture as Figure 10, but excludes LUCF and international transport to depict the Kyoto total. International transport is a sector with high projected growth. Excluding this sector leads to an emission level in the reference scenario in 2020 below the 1990 (Figure 11) as opposed to above the 1990 level (Figure 10).

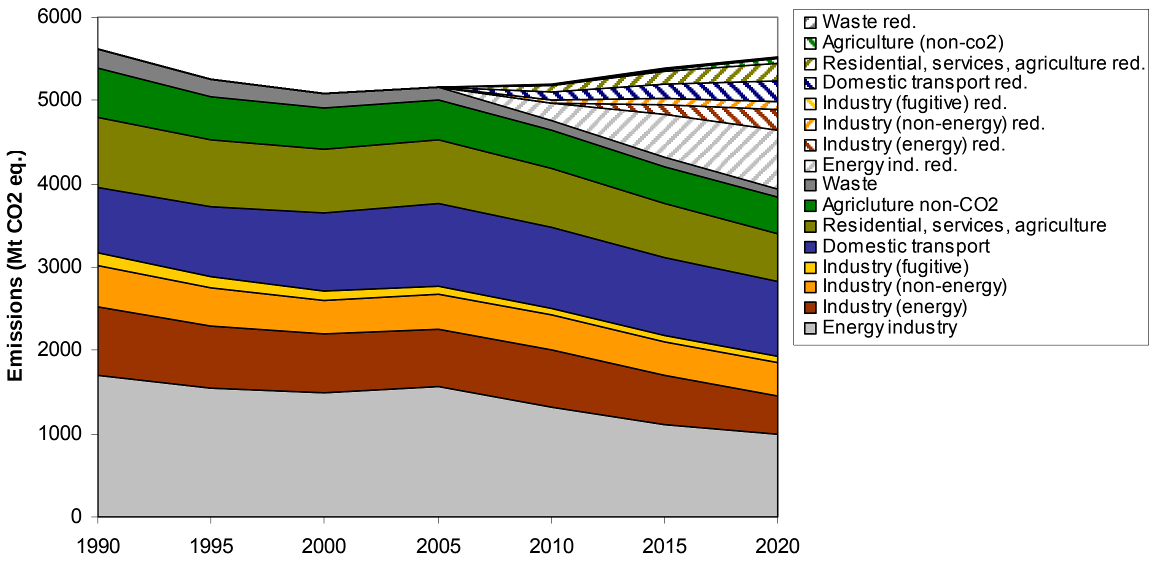

Figure 11: Emission Reductions of Kyoto total over BAU (for renewables,

energy efficiency and other sectors case)

Figure 12 shows the same information as above but only the sectors that are covered by the EU ETS. These sectors' emissions are greatly reduced, as they also include reductions in energy use as a result of energy efficiency measures in the other sectors.

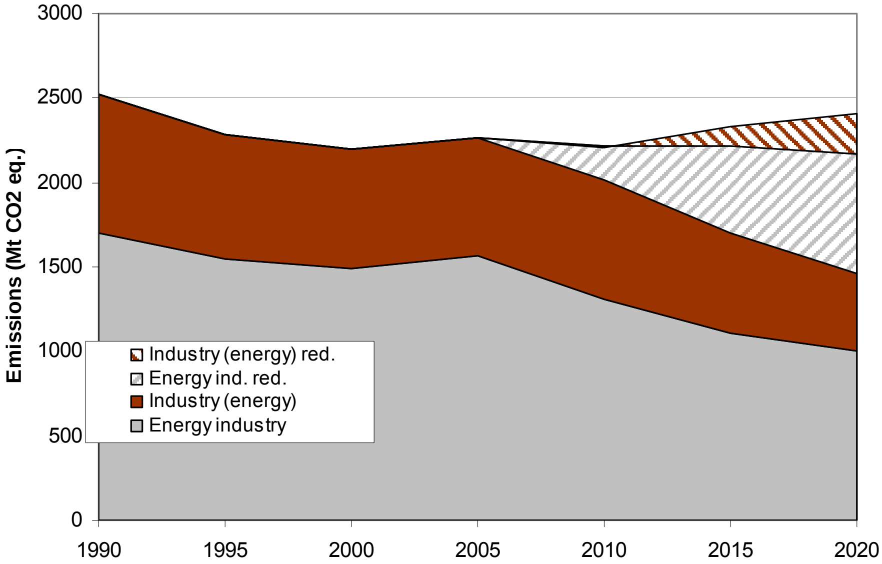

Figure 12: Emission Reductions of EU ETS sectors over BAU (for Renewables, energy efficiency and other sectors case)

4.4. SENSITIVITY ANALYSIS

In this part sensitivity analysis is applied to the results mentioned in the last section. Six cases are calculated that all achieve an emission reduction below 1990 levels for the emissions included in the Kyoto agreement[31] till the year 2020 of -30%. They differ on the details of how this emission reduction is achieved. For the renewable target, we assume alternatively the equal progress scenario and the least cost scenario, while always assuming the renewable penetration rate to be 20%. For the energy efficiency, the convergence and the equal reduction cases are taken, each reaching -20% and -15%. Emissions reductions in the other sectors are adjusted to give an overall emission reduction of 30%. Their emission reduction rate therefore depends on the other two factors and how much they contribute towards achieving the target. The EU wide emission reduction in these sectors ranges from -20% to -42% below BAU (**Table 12**).

Table 12: Input parameters for the sensitivity analysis

	Renewable Target	Energy Efficiency	Other sectors emission reduction below BAU	Total Emission reduction under Kyoto
Case 1	Equal progress 1, 50% GDP adjust., 20%	Convergence to -20%	- 23%	-30 %
Case 2	Equal progress 1 50% GDP adjust. , 20%	Equal %reduction to -20%	- 21%	-30 %
Case 3	Equal progress 1, 50% GDP adjust. , 20%	Convergence to -15%	- 42%	-30 %
Case 4	Equal progress 1 50% GDP adjust. , 20%	Equal %reduction to -15%	- 42 %	-30 %
Case 5	Least cost, 20%	Convergence to -20%	-35%	-30 %
Case 6	Least cost, 20%	Equal %reduction to -20%	-31%	-30 %

Figure 13 and Figure 14 depict the resulting emission reductions under the Kyoto protocol and the EU emission trading scheme (respectively) for the above mentioned sensitivity cases. Between the six cases the overall variability that can be observed in the emission trading sector is higher than that of all the emissions covered under the Kyoto protocol. Except for one country, the standard deviation for each country across the six cases is higher for the emissions covered by the EU ETS than that for the emissions covered under the Kyoto protocol. This can be explained partly by the higher average emission reductions under the EU ETS.

For the Kyoto emissions (Figure 13) it can be observed generally that the variability across the cases is relatively low. This means that the different sharing methods regarded here do not lead to a very different allocation of the targets across the countries. Larger variability is only observed for a few countries such as Luxemburg, Sweden or Slovenia. For the latter two and some further countries, the variability can be explained by the fact that the countries have a large potential for low cost renewable energy that is not exploited if an equal progress sharing approach is taken. The opposite is the case for instance for France and also in part

[31] In the following referred to as „Kyoto emissions"

for the UK (although not as pronounced). Here higher emissions can be observed for those scenarios including the least cost case for renewables, as the low costs potentials are not high enough to cover the RE share allocated. What can also be observed is that under the least cost case, larger countries such as the UK, Germany or France have to contribute less to the reduction of the Kyoto gases. Since, in terms of population they are the largest countries, this reflects the relatively larger share of renewable potential in some of the smaller countries. One last point of interest to mention here, is that it does not seem to be of high importance whether the emissions reductions are reached through the sectors covered by the energy efficiency target (Section 0) or through the other sectors (Section 3.3) (compare cases 1 & 2 with cases 3 & 4). The alternating bars suggest that it is more important how the energy efficiency target is achieved: through convergence or equal % reductions.

For the 6 cases all emission reductions until 2020 are higher than the emission reductions achieved until 2005. In contrast, this is not always the case in the BAU scenario.

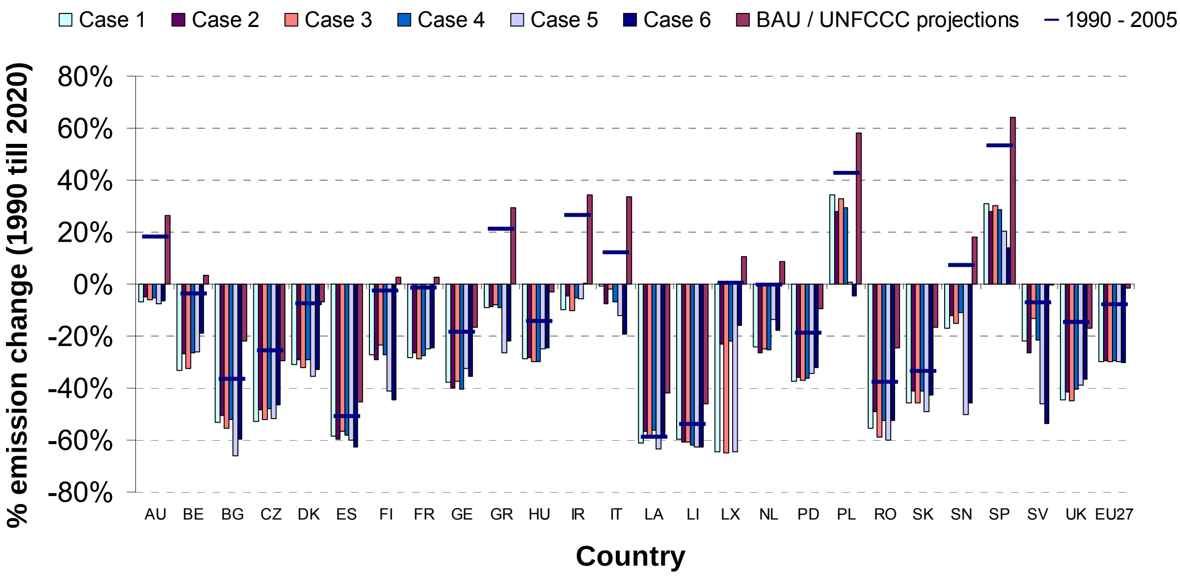

Figure 13: Sensitivity analysis of emission change under Kyoto until 2020 (base year 1990) across the countries for all cases mentioned in Table 12 **(for values see Annex 3)**

For the EU ETS sectors (Figure 14) similar observations can be made as for the emissions under the Kyoto target. First and foremost the variability across the cases is relatively low and there are only a few countries that stand out. Their variability can be explained by the same reasoning as was already brought up for the emission reductions towards the Kyoto target. The other observations made above also hold largely true.

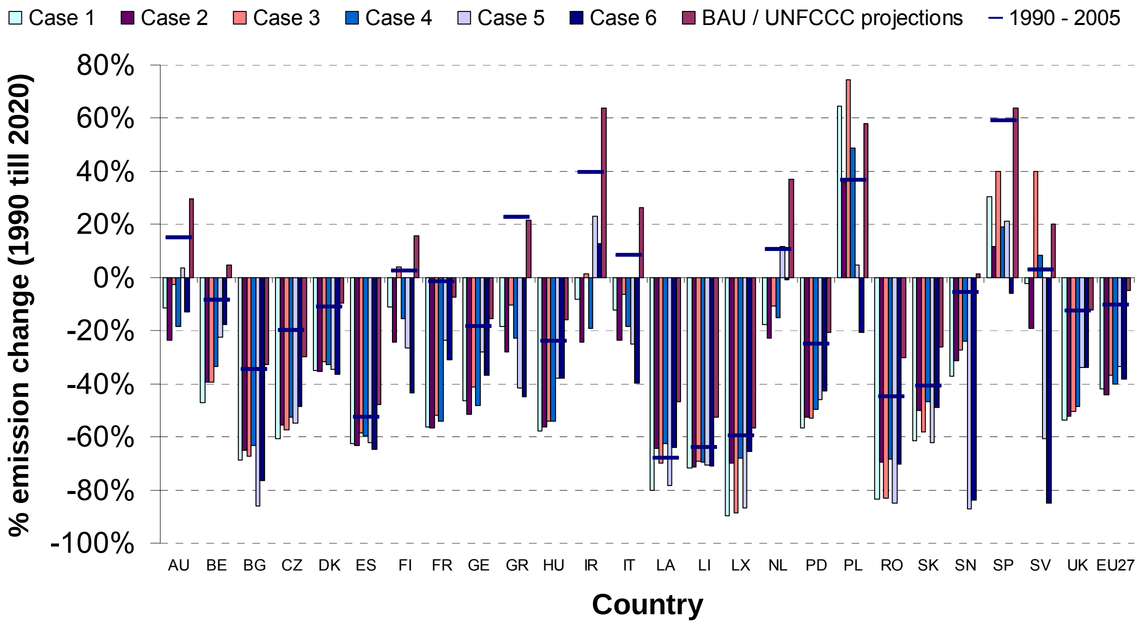

Figure 14: Sensitivity analysis of emission change under EU ETS until 2020 (base year 1990) across the countries for all cases mentioned in Table 12 **(for values see Annex 3)**

4.5. COMPARISON WITH PROPOSAL BY THE EUROPEAN COMMISSION

On 23 of January 2008 the EC proposed a package of measures for climate change mitigation. Among the proposals included in this package were a proposal for a directive on the improvement and extension of the emissions trading system (COM (2008) 16 final) (European Commission 2008b) and a proposal for an effort sharing directive for those emissions not covered under the emission trading scheme (COM(2008) 17 final)(European Commission 2008a). The first proposed directive (COM (2008) 16 final) states an EU wide target for the installations covered under the emission trading scheme until the year 2020. The second decision (COM (2008) 17 final) includes a table with specific emission reductions per country to be achieved until 2020.

Here we compare the mentioned targets with the results of our analysis. We can only consider the 30% overall emission reduction from 1990 to 2020, because we did not find a consistent solution for all targets for the 20% reduction case. To do so, a 30% emission reduction until 2020 has to be calculated from the figures listed in the two EU documents. While the two documents only explicitly mention emission reduction targets for an EU wide reduction target of 20%, they give a basic principle that states how to calculate the 30% reduction figures from the 20% figures. This method is briefly described the following way: “Targets for both the EU ETS and for sectors not covered by the ETS will be adapted in a manner that is proportional to their share of total emissions in 2020.” (MEMO/08/34[32]). The resulting emission reduction targets for 2020 for an EU wide target of -30% that are used here are summarized in Annex III in Table 24.

The European Commission proposal is based on a simple approach to assign reductions based on the countries’ GDP per capita. For the 20% greenhouse gas reduction target 1990 to 2020, the country with the lowest GDP per capita is allowed to increase the emissions

[32] Accessed through http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/08/34&format=HTML&aged=0&language=EN&guiLanguage=en on 07/04/2008

above 2005 level by 20%, the country with the highest GDP per capita needs to reduce by 20% below 2005 level, countries in between receive intermediate targets according to a simple but not linear formula. We scaled these results downwards to achieve the overall 30% reduction.

In Figure 15 the results of our comparison are summarized. The figure shows the proposal by the Commission as well as the results of this study (FUFA III analysis). The European commission proposed an overall cap for the sectors that are covered by the EU ETS and did not differentiate these per country. Therefore the figure shows only the reduction in emissions of the sectors that are not covered be the EU ETS. For the FUFA III analysis the emission reductions under the EU ETS until 2020 were subtracted from the overall emission reduction achieved in the Kyoto protocol sectors until 2020 for each and every member state as well as the overall EU. Using the sectors mentioned in the Kyoto protocol implies that we assume that a future climate agreement will cover only those. It is possible though, that sectors such as LULUCF will be added. In that case, the 30% emission reduction would also apply to these sectors. As we can only speculate on what a future climate agreement will include, it seems reasonable to only use the Kyoto sectors.

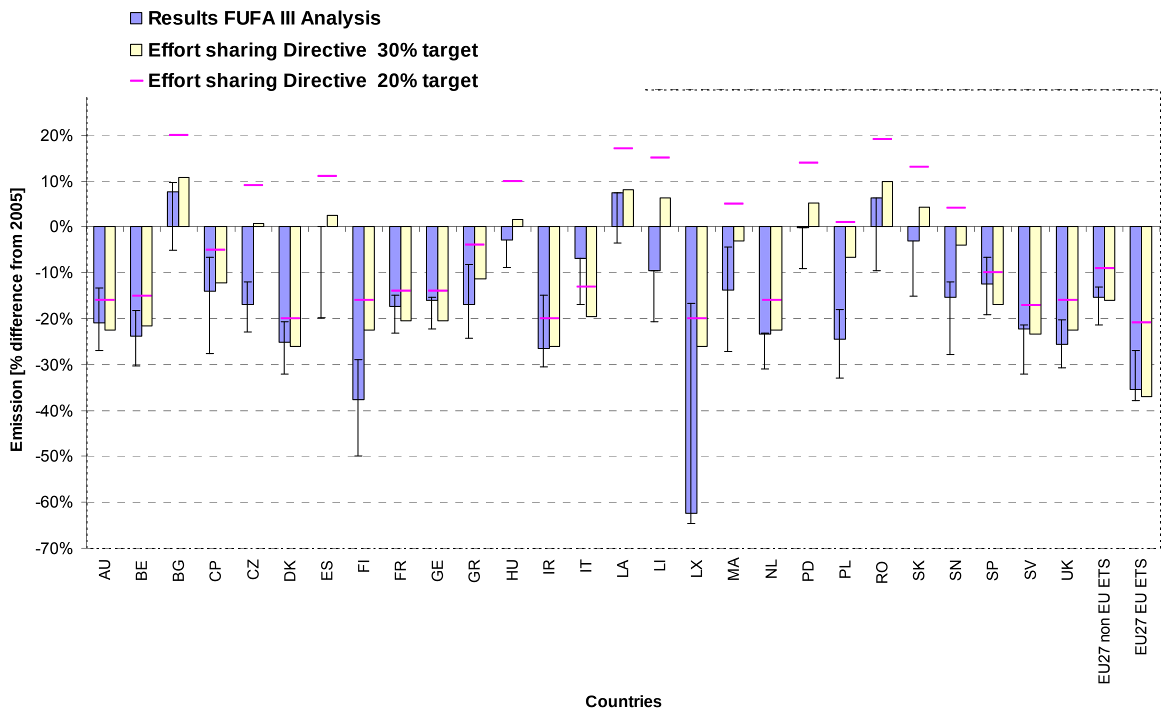

Figure 15: Emission reduction from 2005 to 2020 for the Kyoto Protocol sectors that are not included in the EU ETS for the Member States and the cap on the sectors covered by the EU ETS. Comparison of results with EU targets mentioned in COM (2008) 16 final and COM (2008) 17 final. Error bars represent the cases analysed in the sensitivity analysis in Section 1.1

Figure 15 shows the base case used in this analysis and also the sensitivity cases from Section 1.1. For the non-EU ETS sectors the targets split up into the countries as well as the overall EU figure is shown, for the EU ETS sectors only the overall EU figure is shown.

A first observation that can be made is that the overall EU figures for EU ETS and non-EU ETS of the EU documents lie within the range of the FUFA Analysis. The base case of the

FUFA III analysis differs only marginally. This verifies the results of this report for the 30% reduction case.

Our analysis also gives an idea of how the emission reduction in the sectors covered by the EU ETS could be shared among the member states. The EU commission proposal does not include the split of these emissions among member states. The results of our analysis give a range of what the effort sharing among the member states could possibly look like, since we use approximately the same cap for the EU ETS sectors. In this context, especially the results from the least cost method for reaching the renewable target[33] are valuable, as they also ignore country borders and assume the emission reductions to occur where they are cheapest, see Figure 14.

For most countries the Commission's proposal is within the sensitivity range of our approach, but for some countries we find substantially different results for the required reductions in the non EU ETS sectors. The differences can be explained by the different methods used to share among the member states:

The EU commission used only the differences in the GDP as input, we shared the renewable target according to an assumption of equal progress of the share of RE installed in the MS (+13%) with an assumption of a GDP adjustment of 50% (i.e. that 50% of the RE installations are shared according to the GDP difference) and the energy efficiency target according to the assumption that the energy efficiency in all EU countries will converge. Therefore only a small share of the emission reductions is actually shared according to the GDP difference, the rest is shared by methods that are largely independent of the GDP difference. Consequently, our method assigns more ambitious reductions to the Eastern European States. For the Czech Republic, Hungary, Lithuania, Poland and Slovenia, the Commission proposal is well outside of our sensitivity range. Our method results in less ambitious reductions to the wealthier nations, e.g. France, Germany and Italy but are largely within the same range.

4.6. COMPARISON TO RESULTS OF THE EARLIER ANALYSIS

The model used in this report is based on particular assumptions, methods and data availability. A comparison of this work with results from earlier analysis (FUFA II, Höhne and Moltmann 2007) is made in this section to judge validity of these new results.

In the earlier analysis, possible ways for sharing an EU-wide greenhouse gas target directly among the EU27 Member States were analysed. The methodology used to derive the results is explained in the first output of that project (Höhne et al. 2007). Three levels of EU-wide emission reduction ambitions compared to 1990 were analysed (-30%, -20% and -15%); only the -30% target will be regarded here. The earlier analysis allocated the emission reductions directly (while in this report the emission reductions are allocated indirectly through sharing the RE and EE target). The sharing methods applied were:

1. Equal percentage reduction of absolute emissions
2. GHG intensity targets
3. Convergence of emissions per GDP
4. Convergence of emissions per capita
5. The Brazilian historical responsibility proposal
6. Triptych

The earlier analysis assumed that the Kyoto targets are at least achieved in 2010 and are the basis for future burden sharing until 2020. For countries that are likely to overachieve their Kyoto targets (mostly Eastern European States), the earlier analysis assumes the reference scenario as the basis in 2010. The new analysis does not consider the Kyoto targets. This has implications especially for those countries that are likely to exceed their Kyoto targets.

[33] Note that the least cost method only applies to emission reductions through RE energy and not to those achieved through EE

Figure 16 and Figure 17 show the comparison of the GHG emissions reductions between 1990 and 2020 for base case (Case 1 in **Table 12**) and the earlier FUFA analyses.

Figure 16 and Figure 17 shows that the required emission reductions may for some countries vary substantially between the two reports. Some countries that have approximately the same emissions changes in both reports (e.g. Germany, Poland, Slovenia). Others that experience a higher emission decrease in the present analysis (especially larger countries such as the UK or France).

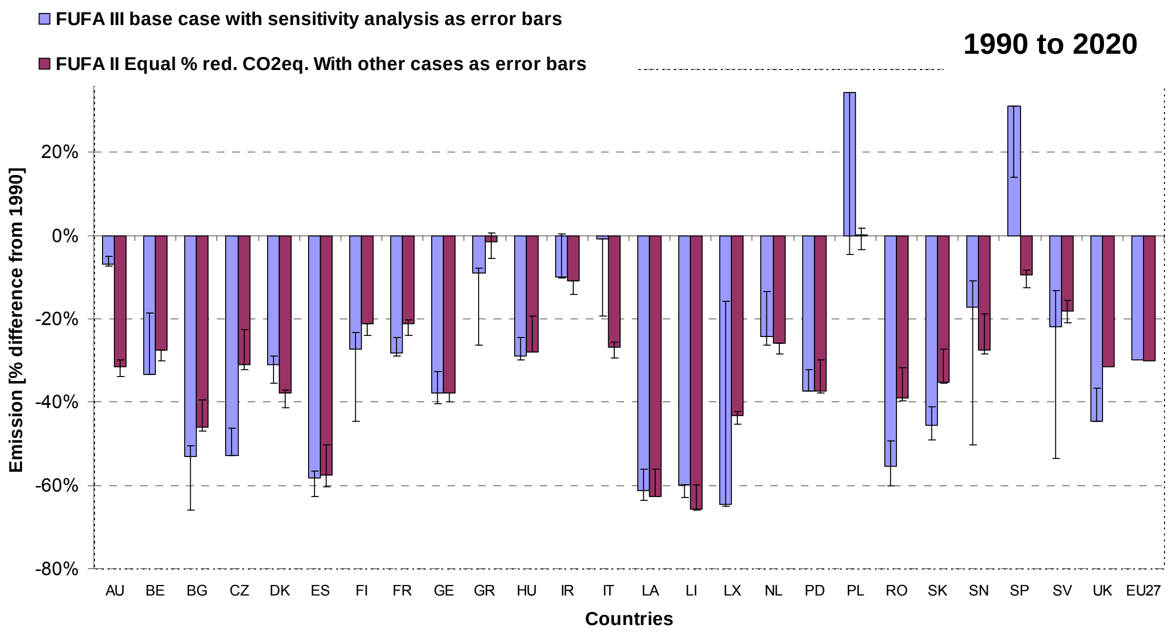

Figure 16: Comparison of emission reductions in the Kyoto sectors until 2020 for the base case of this report (left columns, error bars show the spread of the sensitivity analysis) and the earlier report FUFA II (right columns, Equal %red. CO_2 eq case, error bars show the spread of other cases) (for values see Annex 3)

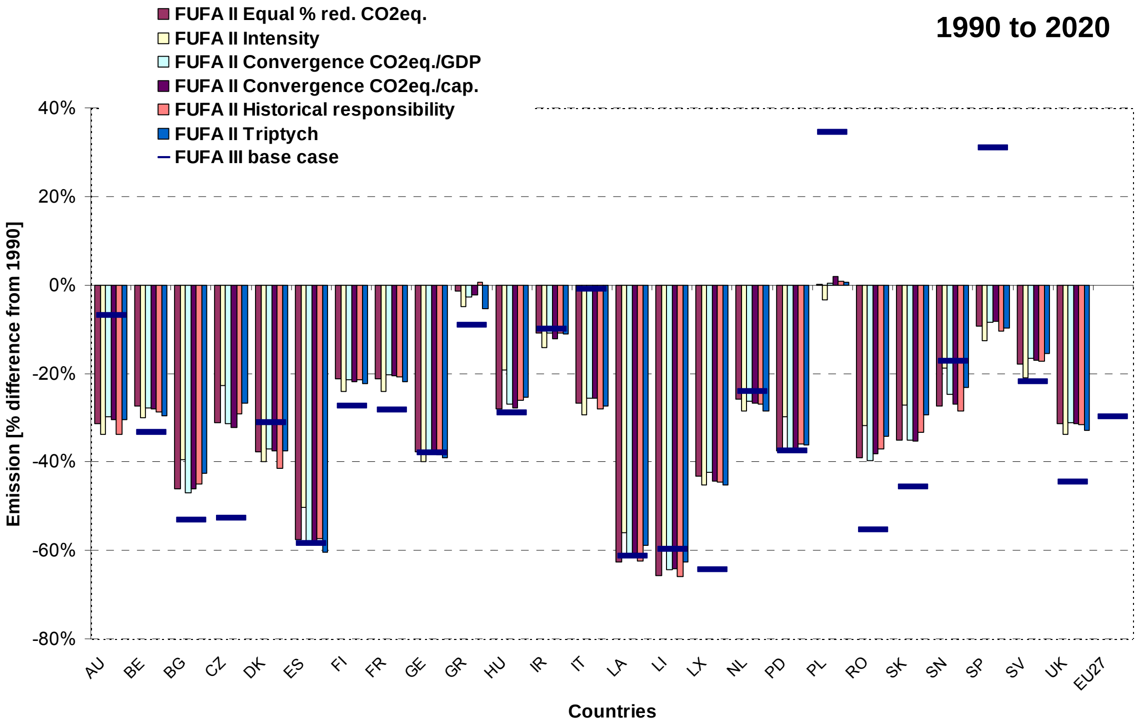

Figure 17: Comparison of base case of this report (blue line) with FUFA II cases (s.a.) for emission reductions in the Kyoto sectors until 2020 (for values see Annex 3).

There are several reasons that can explain the differences between the two results. One of the most important ones is the fact that the FUFA II analysis assumes that the 2010 Kyoto targets (and those agreed upon under the EU burden sharing) are at least reached by the respective countries. If a country over achieves its Kyoto target in the BAU scenario, then emission reductions achieved in the BAU scenario are used instead of the Kyoto values.

The FUFA III analysis does not consider the Kyoto targets. Assumed levels below 1990 in *2010* are provided in Figure 18. The present analysis assumes that several countries exceed their Kyoto targets in 2010 (Austria, Denmark, Ireland, Portugal and Spain). This explains that this analysis is less stringent in 2020 for Austria, Denmark, Portugal and Spain (Figure 16 and Figure 17). Some are likely to over achieve their Kyoto targets substantially (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and UK). This has no influence, as they are treated the same in both studies.

Another reason for differences is the fact that the earlier analysis is more based on approaches of "what should be done", while the present analysis considers "what could be done" by looking at a higher degree of detail and at energy efficiency and renewable energy.

Last but not least, the difference between the two analysis compared here can be explained by the fact that the 1990 emissions are not the same in both cases. Differences as observable in

Table 14 can largely be explained by the fact that for FUFA II international aviation emissions were *included* and for FUFA III they were *excluded*.

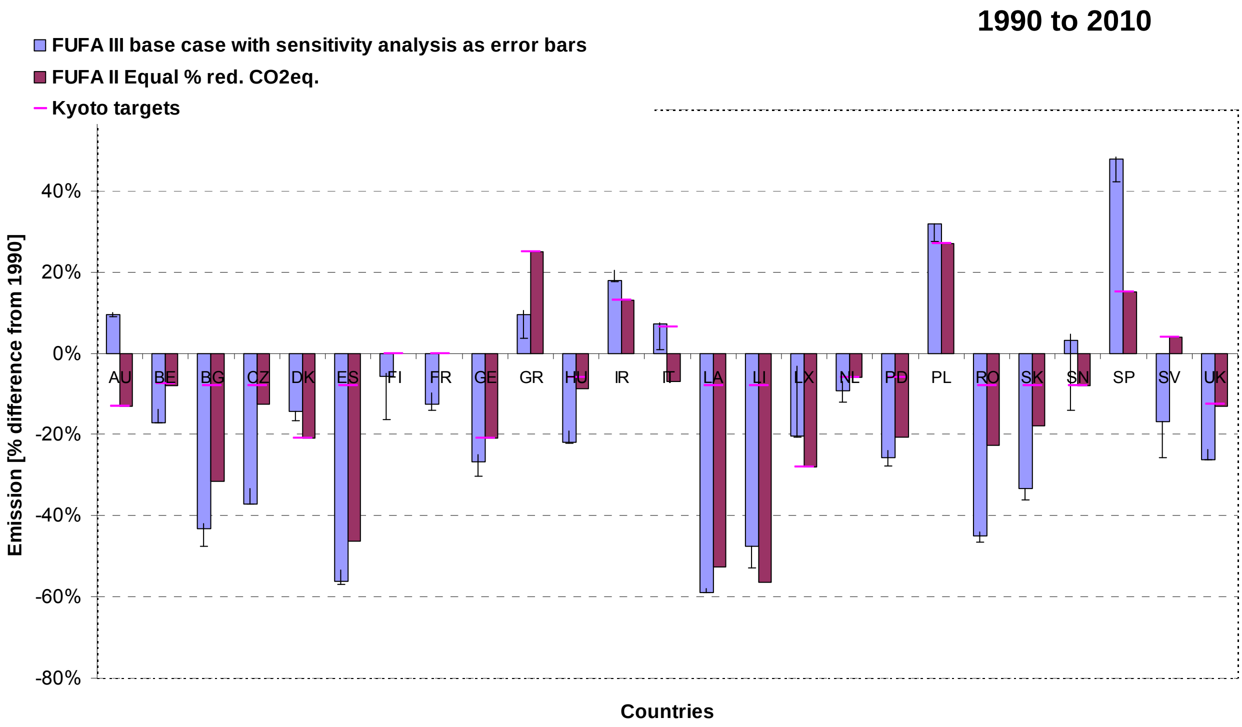

Figure 18: Comparison of emission reductions achieved in the Kyoto sectors until *2010* between FUFA II analysis (Kyoto targets) and the base case of this report

As the difference between the two scenarios for some countries such as the UK is pronounced, a more detailed look is taken here at the reasons for this. To do so the case of the UK is examined. Table 13 gives an overview of the emission reductions achieved in the UK between 1990 and 2010 in both analyses. The first two figures are the same as those represented in Figure 18. The difference between the two scenarios is 14 percentage points. If we include international transport into the FUFA III analysis, the difference shrinks to 9.5 percentage points.

In FUFA III we based our calculation on a different BAU scenario. For the UK, the BAU scenario of FUFA III gives already a reduction in emissions until 2010 of 17%, which is already 4.5 percentage points more stringent than under the FUFA II analysis. One could argue now, that there is only 5 percentage points of emission reductions left that need to be explained. These can largely be explained by the difference in the approach taken. As already mentioned the “what could be done” approach was taken in the FUFA III analysis, neglecting the Kyoto target and “what should be done”.

Table 13: Resulting emission reductions in the UK from the FUFA III and FUFA II analysis between 1990 and 2010

	Emission reductions 1990 - 2010
Emission reductions in FUFA II analysis (assumed to reach Kyoto target)	-12.5 %
Emission reductions in FUFA III analysis base case, Kyoto sectors	-26.5 %
Emission reductions in FUFA III analysis base case, Kyoto sectors plus international transport	-22 %
Emission reductions in FUFA III BAU scenario	-17 %

Table 14: Comparison of base year emissions (mostly 1990) used in the FUFA II (including international transport) and FUFA III analysis (excluding international transport).

	FUFA II [Mt CO_2eq.]	**FUFA III [Mt CO_2eq.]**
Austria	80.32	79.05
Belgium	162.27	148.29
Bulgaria	116.34	112.12
Czech Republic	197.23	196.20
Denmark	74.01	69.04
Estonia	42.64	42.62
Finland	73.56	71.00
France	592.20	567.30
Germany	1252.79	1227.86
Greece	120.21	111.10
Hungary	104.34	96.84
Ireland	56.82	55.37
Italy	533.66	516.85
Latvia	27.84	26.44
Lithuania	52.54	49.37
Luxembourg	12.98	12.71
Netherlands	260.34	212.96
Poland	565.50	484.45
Portugal	63.20	59.92
Romania	233.68	247.76
Slovakia	73.67	72.05
Slovenia	18.65	19.19
Spain	309.03	287.37
United Kingdom	788.83	771.42[34]

[34] International transport emissions are 22.6 $MtCO_{2eq}$, therefore explaining the difference.

5. CONCLUSIONS

In this report, we present an approach to share the various energy and climate related targets of the EU simultaneously. The targets include:

- Reducing greenhouse gas emissions in 2020 by 20% compared to 1990 levels, and by 30% if other countries make a comparable effort;
- Reach 20% renewable energy by 2020;
- Improve energy efficiency by 20% below BAU in 2020;
- Implement an effective Emissions Trading Scheme.

We draw the following conclusions from this analysis:

- For the EU 27 the combined renewable and energy efficiency target base-case leads to a GHG emission reduction of 26% on 1990 levels by 2020. This implies that the meeting the sub-targets for renewable energy and energy efficiency is more than sufficient to meet the overall 20% GHG emission reduction target for the EU27.
- Relative emission reductions within the EU ETS sectors are higher than for the economy as a whole. If EU GHG emissions are reduced by 30% between 1990 and 2020 under a multilateral agreement then emissions in the EU ETS are reduced by 42% in our case. This has to be taken into account when allocating emission reduction across sectors, as equal reductions in all sectors would have the potential risk of over-allocating the EU ETS.
- Assuming that energy efficiency in all countries will converge when sharing the energy efficiency improvements leads to very diverse GHG reductions between the Member States. As a consequence national targets would have to be very different from country to country.
- For sharing the renewable energy target the GDP adjustment has a smaller effect on the distribution between the countries than using another distribution method such as least cost or equal share.
- The overall split of necessary reductions between EU ETS sectors and other sectors according to our approach is very similar to that chosen in the proposal by the European Commission of 23 January 2008 (European Commission 2008a, 2008b). Our results can therefore give an indication how the reductions within the EU ETS could be shared among member states, which is not included in the Commission’s proposal. For the emissions outside of the EU ETS, the commission assigns reductions solely on GDP/capita, while we mostly consider reduction potential. Consequently, our method assigns more ambitious reductions to the Eastern European States and less ambitious reductions to the wealthier nations.
- This analysis and the Commission’s Proposal start sharing the reduction on the basis of 2005 emissions and neglect the Kyoto targets. Consequently they are less stringent to those countries that are likely to not meet their Kyoto targets (as agreed within the EU), such as Austria, Denmark, Italy, Ireland, Portugal and Spain.

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ANNEX 1: DESCRIPTION OF SELECTED PARAMETERS

This section describes how some of the most important parameters were determined. The parameters are described in the order they appear in the spreadsheet from the top to the bottom. The number in front of the Parameter refers to the row in the spreadsheet.

16 Efficiency of fossil fuel power plants (CHP corrected) (BAU and Historical)

$$\%_{el,fossil} = \frac{E_{el,fossil} + E_{heat,CHP,fossil} * 0{,}175}{F_{input,thermal,solids}}$$

$\%_{el,fossil}$	Electrical Efficiency of fossil fuel power plants (CHP corrected)
$E_{el,fossil}$	Net Electricity generation from fossil fuels
$E_{heat,CHP,fossil}$	Net heat generation from fossil fuels in CHP power plants
$F_{input,thermal,solids}$	Fuel input of solids in thermal power plants (in ktoe)

30: Efficiency of biomass and geothermal heat power plants (CHP corrected) (BAU and Historical)

$$\%_{el,biomass/geo} = \frac{E_{el,biomass/geo} + E_{heat,CHP,biomass/geo} * 0{,}175}{F_{input,thermal,biomass/geo}}$$

$\%_{el,biomass/geo}$	Electrical Efficiency of biomass and geothermal heat power plants (CHP corrected)
$E_{el,biomass/geo}$	Net Electricity generation from biomass and geothermal heat
$E_{heat,CHP,biomass/geo}$	Net heat generation from biomass and geothermal heat
$F_{input,thermal,biomass/geo}$	Fuel input of biomass & waste, Geothermal heat in thermal power plants (in ktoe)

29: Energy branch / Transmission and distribution losses (in GWh): ***(Effort sharing)*** can be determined by assuming the same share of energy losses in the Effort sharing as in the BAU.

$$E_{heat,losses} = (E_{industrial,heat} * \frac{E_{industrial,heat,BAU,energyindustry}}{E_{industrial,heat,BAU}} + E_{residential,heat} + E_{services,heat}) * \frac{E_{heat,losses,BAU}}{E_{heat,total,BAU}}$$

$E_{heat,losses}$	Net Heat Energy branch/ transmission and distribution losses in the Energy Industry (Effort Sharing)
$E_{heat,total,BAU}$	Net heat generation in the energy industry sector (BAU Scenario)
$E_{industrial,heat}$	Net heat consumption in the industrial sector (Effort Sharing Scenario)
$E_{industrial,heat,BAU,energyindustry}$	Net heat generation in the energy industry sector (BAU Scenario)
$E_{industrial,heat,BAU}$	Net heat consumption in the industrial sector (Effort Sharing Scenario)
$E_{residential,heat}$	Net heat consumption in the residential sector (Effort Sharing Scenario)

$E_{services,heat}$	Net heat consumption in the services sector (Effort Sharing Scenario)
$E_{heat,losses,BAU}$	Net Heat Energy branch/ transmission and distribution losses in the Energy Industry (BAU Scenario)

31: Steam supply (in GWh): ***(Effort sharing)*** equals the sum of all heat demand minus the heat that is not accounted for since it is not sold. This share is calculated by assuming the same share of non-accounted for heat in the industry as in the BAU.

$$E_{heat,total} = E_{industrial,heat} * \frac{E_{industrial,heat,BAU,energyindustry}}{E_{industrial,heat,BAU}} + E_{residential,heat} + E_{services,heat} + E_{heat,losses}$$

$E_{heat,total}$	Net heat generation in the energy industry sector
$E_{industrial,heat}$	Net heat consumption in the industrial sector (Effort Sharing Scenario)
$E_{industrial,heat,BAU,energyindustry}$	Net heat generation in the energy industry sector (BAU Scenario)
$E_{industrial,heat,BAU}$	Net heat consumption in the industrial sector (Effort Sharing Scenario)
$E_{residential,heat}$	Net heat consumption in the residential sector (Effort Sharing Scenario)
$E_{services,heat}$	Net heat consumption in the services sector (Effort Sharing Scenario)
$E_{heat,losses}$	Net Heat Energy branch/ transmission and distribution losses in the Energy Industry (Effort Sharing)

For the industrial heat share it has to be taken account of the heat share that is not paid for.

32: CHP power plants production: ***(Effort sharing)*** Heat in the CHP sector is supplied through the thermal power stations. Assuming the same heat/electricity ratio as in the BAU, the heat from CHP thermal power plants can be determined through multiplying this ratio with the available electricity output from the thermal power plants. In case this supplies more heat than is demanded for, only the heat will be made available from CHP that is demanded for. This change in the operation mode of the power plant, which usually brings an improvement of the electrical efficiency with it, is not taken account of.

33: District Heating (DH) units production: ***(Effort sharing)*** Is simply determined through subtracting the two parameters above. This can be 0 in case the CHP power plants already supply too much heat. It can be the case that there is no heat demanded from the DH units, and consequently this row is 0, but heat supplied from RE (Row *107*:). This has to do with the RE goal which cannot be reached in the CHP sector and therefore needs additional RE heat in the DH sector, although there is demand in the DH sector or the demand is too low. (see below)

37: Renewables: (Effort sharing) determined by assuming the given share of renewables from electricity.

41: Biomass & waste and ***42: Geothermal (all other electricity renewables): (Effort sharing)*** determined by assuming the same share of the total renewables electricity as in the BAU scenario.

65: Fuel input in thermal power plants (in ktoe): (Effort sharing) is determined with the help of ***75: Biomass & waste:*** and by solving ***16: Efficiency of fossil fuel power plants (CHP corrected) (BAU and Historical)*** for fuel input of solids

$$F_{input,thermal,total} = F_{input,thermal,biomass/geo} + F_{input,thermal,solids}$$

$$F_{input,thermal,solids} = \frac{E_{el,fossil} + E_{heat,CHP,fossil} * 0{,}175}{\%_{el,fossil}}$$

$F_{input,thermal,total}$	Total Fuel input in thermal power plants
$F_{input,thermal,solids}$	Fuel input of solids in thermal power plants
$F_{input,thermal,biomass/geo}$	Fuel input of biomass & waste, Geothermal heat in thermal power plants
$E_{el,fossil}$	Net Electricity generation from fossil fuels
$E_{heat,CHP,fossil}$	Net heat generation from fossil fuels in CHP power plants
$\%_{el,fossil}$	Electrical Efficiency of fossil fuel power plants (CHP corrected)

75: Biomass & waste: (Effort sharing) solved equation in ***30: Efficiency of biomass and geothermal heat power plants (CHP corrected)*** for Biomass and waste output

$$F_{input,thermal,Biomass/geo} = \frac{E_{el,Biomass/geo} + E_{heat,CHP,Biomass/geo} * 0{,}175}{\%_{el.,biomass/geo}}$$

$$E_{heat,CHP,Biomass/geo} = (\%_{el,thermal,Biomass/geo} * E_{heat,CHP,total})$$

$F_{input,thermal,biomass/geo}$	Fuel input of biomass & waste, Geothermal heat in thermal power plants
$E_{el,biomass/geo}$	Net Electricity generation from biomass and geothermal heat
$E_{heat,CHP,biomass/geo}$	Net heat generation from biomass and geothermal heat
$\%_{el,biomass/geo}$	Electrical Efficiency of biomass and geothermal heat power plants (CHP corrected)
$E_{heat,CHP,total}$	Net heat generation from combined heat and power (CHP)
$\%_{el,thermal,Biomass/geo}$	Share of Biomass and Geothermal heat of the electricity generation

81: Fuel input in district heating units (in ktoe): (Effort sharing) By assuming the same conversion efficiency of District heating units as in the BAU 2020 scenario, the Fuel input in district heating units can be determined out of ***33: District Heating units production***

85: Biomass and waste (ignoring Geothermal): (Effort sharing) The renewable heat from biomass and waste is determined by solving ***88: share of renewables from energy industry heat production (BAU and Historical)*** for the percentage of biomass and geo fuel in the district heating fuel input. The share is then multiplied by the total district heating fuel input

$$F_{input,DH,Biomass/geo} = \frac{\%_{heat,Biomass/geo} * E_{heat,total} - E_{heat,CHP,total} * \%_{el,thermal,Biomass/geo}}{E_{heat,DH,total}} * F_{input,DH,total}$$

.

$F_{input,DH,Biomass/geo}$	Fuel input of biomass & waste, Geothermal heat in district heating units
$\%_{heat,Biomass/geo}$	Share of heat from biomass and geothermal heat
$E_{heat,total}$	Net heat generation in the energy industry sector
$E_{heat,CHP,total}$	Net heat generation thermal power plants (CHP)
$\%_{el,thermal,Biomass/geo}$	Share of Biomass and Geothermal heat of the electricity generation
$E_{heat,DH,total}$	Net heat generation in the district heating sector
$F_{input,DH,total}$	Total Fuel input in district heating units

88: share of renewables from energy industry heat production (BAU and Historical)

The share of renewables of the heat production of the energy industry is determined the following way:

$$\%_{heat,Biomass/geo} = \frac{E_{heat,CHP,total} * \%_{el,thermal,Biomass/geo} + E_{heat,DH,total} * \%_{Fuel,DH,Biomass/geo}}{E_{heat,total}}$$

$\%_{heat,Biomass/geo}$	Share of heat from biomass and geothermal heat
$E_{heat,CHP,total}$	Net heat generation thermal power plants (CHP)
$\%_{el,thermal,Biomass/geo}$	Share of Biomass and Geothermal heat of the electricity generation
$E_{heat,DH,total}$	Net heat generation in the district heating sector
$\%_{Fuel,DH,Biomass/geo}$	Share of heat from biomass and geothermal heat in the fuel input of district heating units
$E_{heat,total}$	Net heat generation in the energy industry sector

Doing so it is assumed

1. that for CHP the share of renewables of the total thermal electricity production is the same as the share of renewables of the total CHP heat production.
2. that for district heating the share of renewables in the fuel input is the same as the share of renewables of the fuel output.

This equation reflects the incompleteness of the data, as for the Industry, Residential, Services and Transport Sector there are no primary energy demand numbers available and instead the end energy numbers have to be used mostly. For all four sectors only the primary energy numbers for the energy that is supplied through the energy industry are available.

109: share of renewables industry (excl. electricity): (BAU and Historical)

$$\%_{RE,industry} = \frac{E_{industrial,RE}}{E_{industrial} - E_{industrial,heat} - E_{industrial,el.}}$$

$\%_{RE,industry}$	Share of renewables in the industry (excl. electricity and heat)
$E_{industrial,RE}$	Net consumption stemming from renewable energy in the industrial sector (Effort Sharing Scenario)
$E_{industrial}$	Net energy consumption in the industrial sector (Effort Sharing Scenario) (including heat and electricity from the energy industry)
$E_{industrial,heat}$	Net heat consumption in the industrial sector (Effort Sharing Scenario)
$E_{industrial,el.}$	Net electricity consumption in the industrial sector (Effort Sharing Scenario)

392: Total energy GIC (ktoe): The gross inland consumption is determined with by using the following equation.

$$E_{GIC} = E_{industrial} + E_{residential} + E_{services} + E_{transport} + E_{el,losses} + E_{heat,losses}$$

$$E_{el,losses} = E_{el,losses,transmission} + E_{el,losses,energybranch}$$

E_{GIC}	Gross inland consumption
$E_{industrial}$	Net energy consumption in the industrial sector (Effort Sharing Scenario) (including heat and electricity from the energy industry)
$E_{residential}$	Net energy consumption in the residential sector (Effort Sharing Scenario) (including heat and electricity from the energy industry)
$E_{services}$	Net energy consumption in the services sector (Effort Sharing Scenario) (including heat and electricity from the energy industry)
$E_{transport}$	Net energy consumption in the transport sector (Effort Sharing Scenario) (including electricity from the energy industry)
$E_{el,losses}$	Net electricity losses in the energy industry
$E_{el,losses,transmission}$	Net transmission electricity losses in the energy industry
$E_{el,losses,energybranch}$	Net energy branch electricity losses in the energy industry
$E_{heat,losses}$	Net heat losses in the energy industry

393: Total share of renewables of GIC:

$$\%_{RE,GIC} = \frac{E_{GIC,RE}}{E_{GIC} - imports + \exp orts}$$

$$E_{RE,GIC} = E_{industrial,RE} + E_{residential,RE} + E_{services,RE} + E_{transport,RE} + E_{el.,RE} + E_{heat,RE}$$

$$E_{el.,RE} = E_{el.,RE,w/olosses} + \frac{E_{el.,RE,w/olosses}}{E_{el.,total,w/olosses}} * E_{el,losses}$$

$$E_{heat,RE} = \%_{heat,RE} * (E_{heat,total} + (E_{industrial,heat} - E_{industrial,heat,energyindustry}))$$

$\%_{RE,GIC}$	Total share of renewables of the GIC
$E_{GIC,RE}$	Gross inland consumption of renewable energy
E_{GIC}	Gross inland consumption
$E_{industrial,RE}$	Net consumption stemming from renewable energy in the industrial sector (Effort Sharing Scenario)
$E_{residential,RE}$	Net renewable energy consumption in the residential sector
$E_{transport,RE}$	Net renewable energy consumption in the transport sector
$E_{el,RE}$	Net Electricity generation from renewable energy
$E_{heat,RE}$	Net heat generation from renewable energy
$E_{el.,RE,w/olosses}$	Net electricity generation from renewable energy without energy losses
$E_{el,losses}$	Net electricity losses in the energy industry
$E_{el.,total,w/olosses}$	Total Net electricity generation from without energy losses
$E_{heat,total}$	Net heat generation in the energy industry sector
$E_{industrial,heat,Energyindustry}$	Net industrial heat generation in the energy industry sector (does not include all the heat generated in the energy industry, only the one that is being sold)
$E_{industrial,heat}$	Net heat consumption in the industrial sector (Effort Sharing Scenario)

The total share of RE is calculated by dividing the GIC of RE by the total GIC minus net imports.

Although expectably the share of RE of the GIC should be the same as the 20% RE target, this is not the case. The difference can be explained by the share of CHP power plants.

394: Total energy PED (ktoe): The demand for primary energy is determined using the following equation.

$$PED = E_{industrial,w/oel.,heat} + E_{residential,w/oel.,heat} + E_{services,w/oel.,heat} + E_{transport,w/oel.} + F_{input,DH,total} + F_{input,thermal,total}$$
$$+ E_{el,RE\,Rest,w/losses} + F_{input,nuclear}$$

$$E_{industry,w/oel.,heat} = E_{industrial} - E_{industrial,el.} - E_{industrial,heat}$$

$$E_{residential,w/oel.,heat} = E_{residential} - E_{residential,el.} - E_{residential,heat}$$

$$E_{services,w/oel.,heat} = E_{services} - E_{services,el.} - E_{services,heat}$$

$$E_{transport,w/oel.} = E_{transport,passenger} - E_{transport,el.,passenger} + E_{transport,goods} - E_{transport,el.,goods}$$

$$E_{el.,RE\,Rest,w/losses} = E_{el.,RE} - E_{el.,biomass/geo} + E_{el.,RE\,Rest,losses}$$

PED	Primary Energy Demand
$E_{industrial,w/oel.,heat}$	Net energy consumption in the industrial sector without heat and electricity
$E_{residential,w/oel.,heat}$	Net energy consumption in the residential sector without heat and electricity
$E_{services,w/oel.,heat}$	Net energy consumption in the services sector (excluding heat and electricity from the energy industry)
$E_{transport,w/oel.}$	Total energy consumption in the transport sector without electricity.
$F_{input,DH,total}$	Total Fuel input in district heating units
$F_{input,nuclear}$	Total Fuel input in nuclear power plants
$E_{industrial}$	Net energy consumption in the industrial sector (including heat and electricity from the energy industry)
$E_{industrial,el.}$	Net electricity consumption in the industrial sector
$E_{industrial,heat}$	Net heat consumption in the industrial sector
$E_{residential}$	Net energy consumption in the residential sector (including heat and electricity from the energy industry)
$E_{residential,el.}$	Net electricity consumption in the residential sector
$E_{residential,heat}$	Net heat consumption in the residential sector
$E_{services}$	Net energy consumption in the services sector (including heat and electricity from the energy industry)
$E_{services,el.}$	Net electricity consumption in the services sector
$E_{services,heat}$	Net heat consumption in the services sector
$E_{transport,passenger}$	Net energy consumption in the passenger transport sector (including electricity from the energy industry)
$E_{transport,el.,passenger}$	Net electricity consumption in the passenger transport sector
$E_{transport,goods}$	Net energy consumption in the goods transport sector (including electricity from the energy industry)
$E_{transport,el.,goods}$	Net electricity consumption in the goods transport sector
$E_{el,RE}$	Net Electricity generation from renewable energy

$E_{el,biomass/geo}$	Net Electricity generation from biomass and geothermal heat
$E_{el,RE\,\mathrm{Re}st,losses}$	Net electricity losses of RE in the energy industry, excluding Biomass & Waste and Geothermal Heat

ANNEX 2: EXPLANATIONS THE EFFORT SHARING SCENARIO

Share of renewables does not equal 20%

The difference in the determined share of renewables and the given share or renewables in the equal progress and the least cost scenarios can be explained by the existence of CHP. In our calculations we have to assume that the heat/electricity ratio in the thermal plants section, that includes plants with and without CHP, stays the same in our effort sharing scenarios as it is in the BAU scenario and that the share of renewables in the heat production from CHP and electricity production (in general) is the same. This simply has to be done since there is no data available on the CHP RE heat production.

On the other hand, there are two different targets for electricity and heat (i.e. there are two different shares of renewables for these two sectors). If we assume this, it can happen that the share of new RE thermal power plants (Biomass and Geothermal) increases a lot, leading to a situation that we can supply more heat from RE by CHP plants alone than is demanded for. In this case heat will be lost. Another situation is where there is heat supplied through CHP and a certain share of this is through renewables, but there remains a demand for RE heat that cannot be covered by the available DH units. In this case the CHP units are not " green" enough and supply a heat that is too much supplied through fossil energy and the heat produced by RE has to be vented into the air as well.

Summarizing it can be said that the problem is that CHP interferes with both heat and electricity, yet the model looks at heat and electricity separately and has separate targets for them.

BAU scenario (effort sharing) is not always 0% efficiency improvement over BAU

This has to do with the fact that the BAU numbers do not add up in all the countries. That is, the final energy demand is not the same as the sum of all the energy (electricity and heat) consumed in the different sectors.

ANNEX 3 TABLES FOR FIGURES

Table 15: Table for Figure 5: Total renewable energy share in 2020 for the EU 27 and each Member State under different effort sharing assumptions compared to the base case and 2005 levels (for values see Annex 3).

	2020 Equal progress 1	2020 Equal progress 2	2020 Equal share	2020 Least cost	2005	2020 BAU / UNFCCC projections
AU	34.90%	35.24%	27.57%	29.95%	19.24%	24.26%
BE	15.26%	14.94%	17.30%	9.63%	2.14%	6.15%
BG	18.18%	17.56%	23.55%	27.46%	9.76%	8.34%
CP	13.70%	15.78%	20.25%	16.22%	2.72%	7.37%
CZ	15.98%	15.96%	20.77%	13.46%	4.99%	9.29%
DK	29.44%	28.23%	22.72%	28.14%	16.11%	19.79%
ES	24.30%	20.76%	23.88%	37.81%	14.53%	12.27%
FI	37.73%	38.20%	29.72%	51.69%	24.08%	27.48%
FR	22.26%	22.12%	21.14%	17.39%	8.89%	12.46%
GE	18.35%	17.92%	17.68%	13.93%	5.80%	9.59%
GR	17.44%	17.98%	18.11%	22.47%	6.30%	9.33%
HU	14.84%	13.78%	17.09%	8.36%	4.87%	6.06%
IR	16.31%	16.45%	16.87%	18.09%	1.65%	6.35%
IT	16.80%	17.17%	17.01%	20.98%	4.57%	7.09%
LA	40.51%	37.61%	30.33%	36.35%	32.00%	27.45%
LI	23.41%	22.36%	26.58%	29.05%	13.28%	14.76%
LX	19.87%	19.93%	13.40%	11.47%	0.86%	5.67%
MA	9.08%	11.46%	15.83%	14.75%	0.00%	3.07%
NL	16.70%	16.32%	17.25%	9.26%	3.16%	4.84%
PD	15.02%	13.69%	18.82%	12.56%	5.84%	7.48%
PL	21.53%	23.10%	23.85%	33.26%	10.64%	17.65%
RO	26.14%	25.76%	25.03%	30.91%	18.00%	17.15%
SK	14.45%	14.40%	17.83%	16.68%	4.94%	6.91%
SN	23.79%	23.28%	20.58%	41.57%	13.73%	13.36%
SP	18.33%	19.15%	18.94%	31.25%	6.37%	14.51%
SV	54.77%	55.98%	46.43%	55.80%	40.16%	44.04%
UK	14.94%	15.11%	17.49%	11.82%	1.63%	5.54%
EU27	20.04%	19.99%	20.03%	19.98%	6.48%	0.112604

Table 16: Table for Figure 7: Energy efficiency improvements in 2020 over BAU under sharing energy efficiency (see Table 9**)**

	Base Case	Case 1	Case 2	Case 3
AU	19.65%	17.47%	18.25%	13.67%
BE	28.45%	26.78%	27.73%	25.77%
BG	26.62%	27.45%	25.93%	32.13%
CP	29.88%	33.48%	25.46%	29.60%
CZ	29.12%	28.96%	29.14%	27.33%
DK	25.64%	30.82%	20.84%	29.55%
ES	22.38%	19.19%	26.22%	24.09%
FI	16.29%	4.70%	23.18%	5.69%
FR	15.73%	18.21%	16.86%	21.96%
GE	17.80%	16.46%	19.41%	17.38%
GR	25.24%	29.48%	24.48%	30.00%
HU	19.39%	24.27%	19.42%	33.08%
IR	29.87%	32.47%	26.63%	30.02%
IT	12.69%	12.04%	13.33%	11.52%
LA	24.17%	24.72%	25.41%	26.99%
LI	16.76%	15.68%	19.28%	22.77%
LX	67.36%	70.72%	63.53%	64.80%
MA	35.68%	35.54%	30.90%	25.27%
NL	18.44%	14.86%	18.75%	19.52%
PD	22.65%	22.50%	25.78%	26.40%
PL	18.41%	14.76%	15.20%	9.30%
RO	34.36%	34.45%	37.51%	39.98%
SK	26.33%	22.39%	29.93%	27.93%
SN	24.89%	23.26%	25.58%	19.59%
SP	17.64%	12.90%	14.44%	6.23%
SV	16.04%	14.77%	18.44%	16.61%
UK	24.46%	29.80%	19.69%	27.35%
EU27	19.74%	19.65%	19.76%	20.07%

Table 17: Table for Figure 8: GHG emission change between 1990 and 2020 across 25 EU countries (excluding Malta and Cyprus) for the cases in Table 11 (for values see Annex 3)

	Renewables only	Energy efficiency only	Renewables and energy efficiency	Renewables and energy efficiency and other sectors	1990 till 2005
AU	12.08%	6.88%	-5.15%	-6.93%	18.00%
BE	-10.51%	-20.90%	-30.95%	-33.31%	-3.67%
BG	-35.56%	-37.89%	-44.64%	-53.07%	-36.68%
CZ	-37.64%	-47.52%	-51.19%	-52.76%	-25.79%
DK	-18.28%	-26.57%	-28.69%	-31.03%	-7.37%
ES	-46.78%	-55.65%	-57.36%	-58.31%	-50.88%
FI	-4.34%	-9.57%	-22.35%	-27.27%	-2.48%
FR	-9.82%	-10.84%	-22.19%	-28.29%	-1.57%
GE	-27.88%	-29.01%	-36.89%	-37.90%	-18.44%
GR	14.03%	4.21%	-3.54%	-9.09%	21.01%
HU	-15.23%	-17.14%	-25.79%	-28.84%	-14.41%
IR	14.69%	6.54%	-4.68%	-9.91%	26.31%
IT	18.16%	19.32%	7.83%	-0.89%	12.13%
LA	-49.81%	-50.47%	-59.57%	-61.25%	-58.85%
LI	-50.85%	-51.21%	-55.57%	-59.76%	-54.06%
LX	-10.30%	-60.36%	-63.77%	-64.42%	0.42%
NL	-8.73%	-8.62%	-22.60%	-24.15%	-0.39%
PD	-21.26%	-27.24%	-34.21%	-37.43%	-18.72%
PL	63.87%	36.66%	42.63%	34.48%	42.75%
RO	-40.90%	-44.85%	-53.00%	-55.39%	-37.77%
SK	-23.50%	-34.45%	-38.18%	-45.59%	-33.57%
SN	8.97%	-5.31%	-14.46%	-17.15%	7.20%
SP	53.41%	38.96%	33.85%	31.06%	53.34%
SV	-7.34%	-14.11%	-19.86%	-21.95%	-7.25%
UK	-29.10%	-35.54%	-43.59%	-44.62%	-14.78%
EU27	-13.66%	-18.19%	-26.47%	-29.73%	-8.03%

Table 18: Table for Figure 9: Emission change under the EU ETS until 2020 (base year 1990) across the countries (excluding Malta and Cyprus) for all cases mentioned in Table 11 (for values see Annex 3)

	Renewables only	Energy efficiency only	Renewables and energy efficiency	Renewables and energy efficiency and other sectors	1990 till 2005
AU	-5.80%	12.92%	-11.64%	-11.64%	15.11%
BE	-15.47%	-25.93%	-47.24%	-47.24%	-8.64%
BG	-57.75%	-56.76%	-68.94%	-68.94%	-34.68%
CZ	-44.85%	-54.94%	-60.75%	-60.75%	-19.99%
DK	-28.65%	-35.28%	-34.98%	-34.98%	-11.27%
ES	-48.84%	-61.28%	-62.71%	-62.71%	-52.54%
FI	11.48%	-0.50%	-11.16%	-11.16%	2.63%
FR	-47.42%	-22.64%	-56.29%	-56.29%	-1.43%
GE	-37.31%	-31.32%	-46.31%	-46.31%	-18.46%
GR	-6.00%	-7.09%	-18.43%	-18.43%	22.76%
HU	-46.14%	-36.29%	-57.65%	-57.65%	-23.84%
IR	-3.56%	29.44%	-8.27%	-8.27%	39.44%
IT	-3.34%	9.13%	-12.38%	-12.38%	8.36%
LA	-57.15%	-61.30%	-80.07%	-80.07%	-68.00%
LI	-64.87%	-63.66%	-71.58%	-71.58%	-63.83%
LX	-62.55%	-85.85%	-89.65%	-89.65%	-59.53%
NL	9.09%	10.56%	-17.54%	-17.54%	10.56%
PD	-40.12%	-45.89%	-56.60%	-56.60%	-24.98%
PL	82.89%	38.22%	64.49%	64.49%	36.70%
RO	-64.26%	-67.11%	-83.47%	-83.47%	-44.73%
SK	-37.74%	-56.08%	-61.35%	-61.35%	-40.68%
SN	-7.43%	-27.71%	-37.08%	-37.08%	-5.51%
SP	41.67%	39.97%	30.28%	30.28%	59.12%
SV	21.44%	-4.01%	-2.27%	-2.27%	2.83%
UK	-37.91%	-36.66%	-53.56%	-53.56%	-12.39%
EU27	-28.31%	-26.65%	-42.10%	-42.10%	-10.48%

Table 19: Table for Figure 13: Sensitivity analysis of emission change under Kyoto until 2020 (base year 1990) across the countries for all cases mentioned in Table 12 **(for values see Annex 3)**

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	1990 - 2005
AU	-6.93%	-5.03%	-5.88%	-5.28%	-7.42%	-6.36%	18.00%
BE	-33.31%	-26.71%	-32.37%	-26.55%	-26.10%	-18.69%	-3.67%
BG	-53.07%	-50.51%	-55.50%	-52.06%	-65.96%	-59.69%	-36.68%
CZ	-52.76%	-48.39%	-52.04%	-48.03%	-51.65%	-46.25%	-25.79%
DK	-31.03%	-28.97%	-32.17%	-28.92%	-35.36%	-32.97%	-7.37%
ES	-58.31%	-59.73%	-56.66%	-58.21%	-59.92%	-62.67%	-50.88%
FI	-27.27%	-29.05%	-23.35%	-27.00%	-41.32%	-44.70%	-2.48%
FR	-28.29%	-26.59%	-28.80%	-27.60%	-24.93%	-24.49%	-1.57%
GE	-37.90%	-40.09%	-37.21%	-40.46%	-32.55%	-35.64%	-18.44%
GR	-9.09%	-8.74%	-7.84%	-9.10%	-26.40%	-22.05%	21.01%
HU	-28.84%	-28.42%	-29.71%	-29.83%	-25.02%	-24.53%	-14.41%
IR	-9.91%	-4.40%	-10.10%	-5.23%	-5.76%	0.31%	26.31%
IT	-0.89%	-7.53%	-1.76%	-6.64%	-11.93%	-19.36%	12.13%
LA	-61.25%	-56.53%	-58.25%	-56.16%	-63.58%	-58.72%	-58.85%
LI	-59.76%	-60.63%	-60.89%	-61.98%	-62.71%	-62.83%	-54.06%
LX	-64.42%	-22.99%	-64.91%	-21.90%	-64.37%	-15.80%	0.42%
NL	-24.15%	-26.24%	-24.93%	-25.39%	-13.46%	-17.62%	-0.39%
PD	-37.43%	-35.91%	-37.14%	-36.28%	-34.16%	-32.22%	-18.72%
PL	34.48%	27.92%	32.87%	29.53%	0.64%	-4.47%	42.75%
RO	-55.39%	-49.20%	-58.79%	-52.62%	-59.98%	-52.51%	-37.77%
SK	-45.59%	-41.18%	-45.58%	-41.31%	-49.18%	-42.75%	-33.57%
SN	-17.15%	-12.21%	-14.91%	-10.82%	-50.32%	-45.55%	7.20%
SP	31.06%	27.85%	30.02%	28.55%	20.44%	13.89%	53.34%
SV	-21.95%	-26.55%	-13.30%	-21.50%	-45.94%	-53.43%	-7.25%
UK	-44.62%	-41.58%	-44.72%	-40.25%	-38.75%	-36.60%	-14.78%
EU27	-29.73%	-29.55%	-29.75%	-29.52%	-29.87%	-30.16%	-8.03%

Table 20: Table for Figure 14: Sensitivity analysis of emission change under EU ETS until 2020 (base year 1990) across the countries for all cases mentioned in Table 12 **(for values see Annex 3)**

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	1990 - 2005
AU	-11.64%	-23.60%	-2.69%	-18.62%	3.55%	-12.99%	15.11%
BE	-47.24%	-39.50%	-39.35%	-33.47%	-22.57%	-17.85%	-8.64%
BG	-68.94%	-65.18%	-67.37%	-63.25%	-86.14%	-76.52%	-34.68%
CZ	-60.75%	-55.43%	-57.28%	-52.71%	-54.66%	-48.46%	-19.99%
DK	-34.98%	-35.42%	-31.61%	-32.73%	-34.61%	-36.50%	-11.27%
ES	-62.71%	-63.25%	-58.60%	-59.74%	-62.32%	-64.66%	-52.54%
FI	-11.16%	-24.45%	3.96%	-15.65%	-26.70%	-43.59%	2.63%
FR	-56.29%	-56.79%	-51.83%	-54.24%	-23.46%	-31.07%	-1.43%
GE	-46.31%	-51.54%	-41.30%	-48.24%	-28.08%	-36.88%	-18.46%
GR	-18.43%	-27.92%	-10.42%	-22.88%	-41.68%	-44.80%	22.76%
HU	-57.65%	-56.22%	-53.97%	-53.93%	-37.97%	-37.96%	-23.84%
IR	-8.27%	-24.27%	1.27%	-19.01%	22.92%	12.65%	39.44%
IT	-12.38%	-23.44%	-6.44%	-18.35%	-25.21%	-39.74%	8.36%
LA	-80.07%	-64.37%	-69.90%	-62.59%	-78.46%	-63.98%	-68.00%
LI	-71.58%	-71.19%	-69.20%	-69.42%	-70.64%	-70.85%	-63.83%
LX	-89.65%	-69.94%	-88.56%	-67.96%	-86.64%	-65.61%	-59.53%
NL	-17.54%	-23.03%	-10.85%	-15.05%	11.84%	-0.85%	10.56%
PD	-56.60%	-52.76%	-52.86%	-49.57%	-46.16%	-42.67%	-24.98%
PL	64.49%	35.98%	74.33%	48.62%	4.82%	-20.80%	36.70%
RO	-83.47%	-69.39%	-83.15%	-68.52%	-85.06%	-70.37%	-44.73%
SK	-61.35%	-49.98%	-58.10%	-46.80%	-62.26%	-48.84%	-40.68%
SN	-37.08%	-31.14%	-27.25%	-24.01%	-87.25%	-83.86%	-5.51%
SP	30.28%	11.49%	39.91%	19.18%	21.30%	-6.05%	59.12%
SV	-2.27%	-19.16%	40.10%	8.44%	-60.74%	-84.93%	2.83%
UK	-53.56%	-52.27%	-50.36%	-48.75%	-33.79%	-33.80%	-12.39%
EU27	-42.10%	-44.29%	-36.90%	-40.18%	-33.65%	-38.14%	-10.48%

Table 21: Table for Figure 16: Comparison of emission reductions in the Kyoto sectors until 2020 for the base case of this report (left columns, error bars show the spread of the sensitivity analysis) and the earlier report FUFA II (right columns, Equal %red. CO_2 eq case, error bars show the spread of other cases) (for values see Annex 3)

	FUFA III base case with sensi-tivity analysis as error bars	plus	minus	FUFA II Equal % red. CO_2eq. With other cases as error bars	plus	minus
AU	-6.93%	1.91%	0.48%	-31.41%	1.65%	2.45%
BE	-33.31%	14.61%	0.00%	-27.47%	0.00%	2.59%
BG	-53.07%	2.57%	12.89%	-46.09%	6.59%	0.86%
CZ	-52.76%	6.51%	0.00%	-31.09%	8.43%	1.11%
DK	-31.03%	2.11%	4.33%	-37.72%	0.61%	3.72%
ES	-58.31%	1.65%	4.35%	-57.57%	7.31%	2.84%
FI	-27.27%	3.92%	17.43%	-21.16%	0.00%	2.82%
FR	-28.29%	3.80%	0.51%	-21.16%	0.82%	2.82%
GE	-37.90%	5.34%	2.56%	-37.72%	0.00%	2.23%
GR	-9.09%	1.25%	17.31%	-1.46%	1.98%	3.91%
HU	-28.84%	4.31%	0.99%	-28.01%	8.71%	0.00%
IR	-9.91%	10.21%	0.19%	-10.92%	0.13%	3.19%
IT	-0.89%	0.00%	18.47%	-26.68%	1.12%	2.62%
LA	-61.25%	5.09%	2.32%	-62.62%	6.57%	0.00%
LI	-59.76%	0.00%	3.07%	-65.64%	5.87%	0.23%
LX	-64.42%	48.62%	0.48%	-43.24%	0.99%	2.03%
NL	-24.15%	10.69%	2.09%	-25.89%	0.00%	2.65%
PD	-37.43%	5.21%	0.00%	-37.46%	7.67%	0.35%
PL	34.48%	0.00%	38.95%	0.12%	1.77%	3.58%
RO	-55.39%	6.18%	4.59%	-38.95%	7.18%	0.77%
SK	-45.59%	4.41%	3.59%	-35.17%	7.91%	0.21%
SN	-17.15%	6.33%	33.18%	-27.47%	8.66%	1.06%
SP	31.06%	0.00%	17.17%	-9.34%	1.07%	3.24%
SV	-21.95%	8.65%	31.48%	-18.01%	2.53%	2.93%
UK	-44.62%	8.02%	0.10%	-31.41%	0.36%	2.45%
EU27	-29.73%	0.20%	0.43%	-30.00%		

Table 22: Table for Figure 17: Comparison of base case of this report (blue line) with FUFA II cases (s.a.) for emission reductions in the Kyoto sectors until 2020 (for values see Annex 3).

	FUFA III base case with sensitivity analysis as error bars	FUFA II Equal % red. CO_2eq. With other cases as error bars	FUFA II Equal % red. CO_2eq.	FUFA II Intensity	FUFA II Convergence CO_2eq./GDP	FUFA II Convergence CO_2eq./cap.	FUFA II Historical responsibility	FUFA II Triptych
AU	-6.93%	-31.41%	-31.41%	-33.87%	-29.77%	-30.49%	-33.81%	-30.52%
BE	-33.31%	-27.47%	-27.47%	-30.06%	-27.73%	-28.10%	-28.73%	-29.55%
BG	-53.07%	-46.09%	-46.09%	-39.49%	-46.95%	-46.02%	-45.02%	-42.51%
CZ	-52.76%	-31.09%	-31.09%	-22.66%	-31.38%	-32.20%	-29.23%	-26.81%
DK	-31.03%	-37.72%	-37.72%	-39.95%	-37.11%	-37.58%	-41.44%	-37.40%
ES	-58.31%	-57.57%	-57.57%	-50.26%	-57.90%	-57.99%	-57.35%	-60.41%
FI	-27.27%	-21.16%	-21.16%	-23.98%	-21.51%	-21.79%	-21.40%	-22.37%
FR	-28.29%	-21.16%	-21.16%	-23.98%	-20.34%	-20.55%	-20.66%	-21.77%
GE	-37.90%	-37.72%	-37.72%	-39.95%	-37.74%	-37.84%	-38.47%	-39.04%
GR	-9.09%	-1.46%	-1.46%	-4.98%	-2.72%	-2.22%	0.52%	-5.37%
HU	-28.84%	-28.01%	-28.01%	-19.29%	-26.85%	-27.83%	-26.11%	-25.37%
IR	-9.91%	-10.92%	-10.92%	-14.10%	-10.79%	-12.08%	-10.79%	-10.98%
IT	-0.89%	-26.68%	-26.68%	-29.30%	-25.56%	-25.69%	-27.98%	-27.29%
LA	-61.25%	-62.62%	-62.62%	-56.05%	-60.89%	-60.64%	-62.45%	-58.78%
LI	-59.76%	-65.64%	-65.64%	-59.77%	-64.31%	-64.21%	-65.88%	-62.68%
LX	-64.42%	-43.24%	-43.24%	-45.27%	-42.25%	-44.31%	-44.60%	-45.18%
NL	-24.15%	-25.89%	-25.89%	-28.54%	-26.23%	-26.64%	-27.01%	-28.39%
PD	-37.43%	-37.46%	-37.46%	-29.79%	-37.81%	-37.79%	-35.95%	-36.11%
PL	34.48%	0.12%	0.12%	-3.46%	0.44%	1.89%	0.78%	0.69%
RO	-55.39%	-38.95%	-38.95%	-31.77%	-39.72%	-38.25%	-37.13%	-34.12%
SK	-45.59%	-35.17%	-35.17%	-27.27%	-35.17%	-35.38%	-33.29%	-29.30%
SN	-17.15%	-27.47%	-27.47%	-18.82%	-24.79%	-27.02%	-28.53%	-23.11%
SP	31.06%	-9.34%	-9.34%	-12.58%	-8.36%	-8.27%	-10.35%	-9.67%
SV	-21.95%	-18.01%	-18.01%	-20.94%	-16.65%	-17.08%	-17.20%	-15.48%
UK	-44.62%	-31.41%	-31.41%	-33.87%	-31.05%	-31.43%	-31.64%	-32.96%
EU27	-29.73%	-30.00%						

Table 23: Table for Figure 18: Comparison of emission reductions achieved in the Kyoto sectors until *2010* between FUFA II analysis (Kyoto targets) and the base case of this report

	FUFA III base case with sensitivity analysis as error bars	FUFA II Equal % red. CO2eq./ Kyoto targets	Error bars FUFA III	Error bars FUFA III
AU	10.16%	-13.00%	0.24%	0.77%
BE	-15.36%	-7.50%	2.89%	0.00%
BG	-41.24%	-8.00%	0.00%	4.34%
CZ	-34.41%	-8.00%	2.05%	0.00%
DK	-11.10%	-21.00%	0.00%	4.86%
ES	-55.85%	-8.00%	2.65%	0.68%
FI	-3.07%	0.00%	0.00%	7.59%
FR	-11.07%	0.00%	2.47%	1.59%
GE	-26.37%	-21.00%	2.05%	3.43%
GR	10.40%	25.00%	0.84%	5.83%
HU	-20.73%	-6.00%	2.49%	0.83%
IR	19.27%	13.00%	1.40%	0.85%
IT	8.34%	6.50%	0.00%	6.43%
LA	-57.89%	-8.00%	0.45%	0.10%
LI	-46.64%	-8.00%	0.11%	5.65%
LX	-17.25%	-28.00%	14.82%	0.48%
NL	-7.18%	-6.00%	2.74%	3.71%
PD	-24.73%	-6.00%	1.82%	2.46%
PL	33.70%	27.00%	0.00%	4.14%
RO	-43.26%	-8.00%	0.00%	1.86%
SK	-32.29%	-8.00%	0.00%	3.40%
SN	5.89%	-8.00%	0.83%	16.91%
SP	49.74%	15.00%	0.00%	5.46%
SV	-12.77%	4.00%	0.00%	10.44%
UK	-24.33%	-12.50%	2.30%	1.25%
EU27	-15.01%		0.46%	1.89%

Table 24: Overview Emission reduction targets in COM (2008) 16 final and COM (2008) 17 final for a 20% reduction target, and calculated figures for a 30% reduction target. Country figures refer to targets under COM (2008) 17 (effort sharing non EU ETS)

	2005 emissions [MT CO_2]	20% reduction in 2020 (in % to 2005)	20% reduction in 2020 (absolut)	30% reduction in 2020 (in % to 2005)	30% reduction in 2020 (absolut)
AU	59.34	-16.00%	49.84	-22.39%	46.05
BE	83.48	-15.00%	70.95	-21.47%	65.56
BG	29.30	20.00%	35.16	10.87%	32.49
CP	4.88	-5.00%	4.63	-12.23%	4.28
CZ	63.06	9.00%	68.74	0.71%	63.51
DK	37.34	-20.00%	29.87	-26.08%	27.60
ES	8.01	11.00%	8.89	2.56%	8.21
FI	35.41	-16.00%	29.74	-22.39%	27.48
FR	412.15	-14.00%	354.45	-20.54%	327.49
GE	510.37	-14.00%	438.92	-20.54%	405.53
GR	66.72	-4.00%	64.05	-11.30%	59.18
HU	52.75	10.00%	58.02	1.63%	53.61
IR	47.40	-20.00%	37.92	-26.08%	35.03
IT	350.94	-13.00%	305.32	-19.62%	282.10
LA	8.02	17.00%	9.39	8.10%	8.67
LI	16.03	15.00%	18.43	6.25%	17.03
LX	10.65	-20.00%	8.52	-26.08%	7.87
MA	1.46	5.00%	1.53	-2.99%	1.42
NL	127.74	-16.00%	107.30	-22.39%	99.14
PD	189.99	14.00%	216.59	5.33%	200.12
PL	47.94	1.00%	48.42	-6.68%	44.73
RO	82.75	19.00%	98.48	9.95%	90.99
SK	20.84	13.00%	23.55	4.41%	21.76
SN	11.67	4.00%	12.14	-3.91%	11.21
SP	243.35	-10.00%	219.02	-16.85%	202.36
SV	44.90	-17.00%	37.27	-23.31%	34.43
UK	369.51	-16.00%	310.39	-22.39%	286.78
EU 27 non EU ETS	2935.99	-9.14%	2667.53	-16.05%	2464.63
EU 27 EU ETS	2177.22	-21.00%	1720.00	-36.87%	1374.45
EU27 total	5113.21	-14.19%	4387.53	-24.92%	3839.09

ANNEX 4 HOW TO USE THE EXCEL MODEL

Parameter Sheet

The parameter sheet is the basic input sheet for the model. This is the sheet where changes should be made and where the target sharing method can be chosen. Generally the sheet is divided into four sections. Section 1 through 3 represent the RE target sharing, EE target sharing and the other sector reductions respectively. Section 4 represents the overall emission reductions achieved in the EU under the given effort sharing assumptions.

When the “Equal progress 2” scenario or the “least cost” scenario are chosen care has to be taken. When a change is made anywhere in the parameter sheets, the buttons in the parameter sheet assigned to the scenarios should be used when the change is finalized. These two effort-sharing methods are implemented in the excel model using macros.

Pivot table sheet

For the full use of the excel spreadsheet a txt file is needed. This txt file is used for the pivot table to view the results in a compact manner. Once you have decided on a setting in the parameter sheet, you can go to the Pivot table sheet where you can press the button “Refresh pivot data table”. There you are prompted t to append or not. Pressing ‘yes’ will append the txt file, which is the basis for the table. The new data can be accessed through the scenarios where they are shown as Effort sharing X scenarios (X increases the more often you append). If you chose not to append, the whole txt file content will be deleted and overwritten.

The txt file must be copied in the same folder as the scenario, so that it can be found by the macro.