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Preparatory Signal Detection for the EU-25 Member States under EU Burden Sharing/Advanced Monitoring Including Uncertainty (1990-2004)

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IIASA Interim Report
November 2008

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Interim Report **IR-08-036**

Preparatory Signal Detection for the EU-25 Member States Under EU Burden Sharing—Advanced Monitoring Including Uncertainty (1990–2004)

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4 November 2008

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Corrigendum

Table 9 contained numerical misprints (the δ_{KP} values had not been multiplied with (-14/20)) and is now updated.

21 March 2011

Foreword

This report is the first of two reports coauthored by Khrystyna Hamal, a first-year Ph.D. student in Applied Mathematics from Ukraine's Lviv National Polytechnic University, during her participation in IIASA's Young Scientists Summer Program 2007. It serves as the scientific basis for her second report *Reporting Greenhouse Gas Emissions: Change in Uncertainty and its Relevance for the Detection of Emission Changes*.

This report continues and updates IIASA's annual emissions change-versus-uncertainty monitoring of the greenhouse gas emissions reporting of the European Union (EU) and its 25 Member States. It builds on the concept of preparatory signal detection, which addresses the question of how well we need to know net emissions if we want to detect a specified emission change (also termed emission signal) after a given time, and the strictest signal analysis technique available, the so-called combined undershooting and verification time (Und&VT) concept. The Und&VT concept is applied in a standard mode referring to the Member States' agreed emission targets in 2008–2012, and in a monitoring mode referring to linear path emission targets between base year and commitment year. Here, the intermediate year of reference is 2004. (Note: The EU officially releases updates of its historical emissions since 1990 with a time lag of two years and more.)

Preparatory signal detection allows generating useful information beforehand as to how great uncertainties can be depending on the level of confidence of the emission signal, or the signal one wishes to detect, and the risk one is willing to tolerate in not meeting an agreed emission limitation or reduction commitment. It is this knowledge of the required quality of reporting versus uncertainty that one wishes to have at hand before negotiating international environmental treaties such as the Kyoto Protocol.

This monitoring report updates and perpetuates exactly this knowledge. It follows a standard template to facilitate easy assessment of the countries' year-to-year emission changes, while applying the aforementioned emissions change-versus-uncertainty analysis technique. Whether or not changes in the year-to-year assessments become visible depends on the relative uncertainty intervals that are applied. The ones favored for this monitoring exercise prove to be fairly robust as they compensate 'small' changes in the country assessments. The Excel database behind this monitoring report is available free of charge.

Contents

Abstract

This study follows up IIASA Interim Report IR-04-024 (Jonas *et al.*, 2004a), which addresses the preparatory detection of uncertain greenhouse gas (GHG) emission changes (also termed emission signals) under the Kyoto Protocol. The question probed was *how well do we need to know net emissions if we want to detect a specified emission signal after a given time?* The authors used the Protocol's Annex B countries as net emitters and referred to all Kyoto GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) excluding CO_2 emissions/removals due to land-use change and forestry (LUCF). They motivated the application of preparatory signal detection in the context of the Kyoto Protocol as a necessary measure that should have been taken prior to/in negotiating the Protocol. The authors argued that uncertainties are already monitored and are increasingly made available but that monitored emissions and uncertainties are still dealt with in isolation. A connection between emission and uncertainty estimates for the purpose of an advanced country evaluation has not yet been established. The authors developed four preparatory signal analysis techniques and applied these to the Annex B countries under the Kyoto Protocol. The frame of reference for preparatory signal detection is that Annex B countries comply with their agreed emission targets in 2008–2012. The emissions path between base year and commitment year/period is generally assumed to be a straight line, and emissions prior to the base year are not taken into consideration.

This study applies the strictest of these techniques, the combined undershooting and verification time (Und&VT) concept to advance the monitoring of the GHG emissions reported by the 25 Member States of the European Union (EU). In contrast to the earlier study, the Member States' agreed emission targets under EU burden sharing in compliance with the Kyoto Protocol are taken into account, however, still assuming that only domestic measures will be used (i.e., excluding Kyoto mechanisms). The Und&VT concept is applied in a standard mode, i.e., with reference to the Member States' agreed emission targets in 2008–2012, and in a new mode, i.e., with reference to linear path emission targets between base year and commitment year. Here, the intermediate year of reference is 2004.

To advance the reporting of the EU, uncertainty and its consequences are taken into consideration, i.e., (i) the risk that a Member State's true emissions in the commitment year/period are above its true emission limitation or reduction commitment (true emission target); and (ii) the detectability of the Member State's agreed emission target. This risk can be grasped and quantified although true emissions are unknown by definition (but not necessarily their ratios). Undershooting the agreed EU, or EU-compatible but detectable, target can decrease this risk. The Member States' potential linear path undershooting opportunities as of 2004 are contrasted with their actual

emission situation in that year, which is captured by the distance-to-target indicator (DTI) previously introduced by the European Environment Agency.

In 2004, eleven EU-25 Member States exhibit a negative DTI and thus appear as potential sellers: Czech Republic, Estonia, France, Germany, Hungary, Latvia, Lithuania, Poland, Slovakia, Sweden, and the United Kingdom. However, expecting that all of the EU Member States will eventually exhibit relative uncertainties in the range of 5–10% and above rather than below (excluding LUCF and Kyoto mechanisms), the Member States require considerable undershooting of their EU-compatible, but detectable, targets if one wants to keep the said risk low ($a \approx 0.1$) that the Member States' true emissions in the commitment year/period fall above their true emission targets. As of 2004, these conditions can only be met by eight (seven new and one old) Member States (ranked in terms of credibility): Latvia, Lithuania, Estonia, Poland, Hungary, Slovakia, Czech Republic, and the United Kingdom; while three old Member States, Germany, Sweden, and France, can only act as potential sellers with a higher risk (Germany: $\alpha \approx 0.25$; Sweden and France: $\alpha = 0.5$). The other EU-25 Member States do not meet their linear path (base year–commitment year) emission targets as of 2004 (i.e., they overshoot their intermediate targets), or do not have Kyoto targets at all (Cyprus and Malta).

The relative uncertainty matters with which countries report their emissions. For instance, with relative uncertainty increasing from 5 to 10%, the linear path 2008/12 emission signal of the old EU-15 as a whole (which has jointly approved, as a Party, an 8% emission reduction under the Kyoto Protocol) switches from detectable to non-detectable, indicating that the negotiations for the Kyoto Protocol were imprudent because they did not take uncertainty and its consequences into account.

It is anticipated that the evaluation of emission signals in terms of risk and detectability will become standard practice and that these two qualifiers will be accounted for in pricing GHG emission permits.

Acknowledgments

Khrystyna Hamal would like to thank Matthias Jonas of IIASA's Forestry Program, who was my supervisor during the summer of 2007, for many useful discussions, comments and guidance. I would also like to thank the YSSP Team (Tanja Huber, Barbara Hauser and Serge Medow) and all the YSSP 2007 participants for making my stay at IIASA pleasurable.

About the Authors

Khrystyna Hamal graduated (M.Sc.) from Lviv National Polytechnic University, Ukraine, in Applied Mathematics in 2006 and is now a Ph.D. student at the same university. This study is a result of her participation in IIASA's 2007 Young Scientist Summer Program, supervised by Matthias Jonas who is a Research Scholar in IIASA's Forestry Program.

Preparatory Signal Detection for the EU-25 Member States Under EU Burden Sharing—Advanced Monitoring Including Uncertainty (1990–2004)

Khrystyna Hamal and Matthias Jonas

1 Background and Objective

This study follows up IIASA Interim Report IR-04-024 (Jonas *et al.*, 2004a). It applies the strictest of the preparatory signal analysis techniques developed in this report,[1] the combined undershooting and verification time (Und&VT) concept,[2] to advance the monitoring of the greenhouse gas (GHG) emissions reported by the 25 Member States of the European Union (EU) under EU burden sharing in compliance with the Kyoto Protocol. Here, 'emissions' refer to all Kyoto GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) excluding CO_2 emissions/removals due to land-use change and forestry (LUCF). The Member States' emissions are evaluated relative to the EU's linear path target as of 2004 and in terms of their positive and negative contributions to this target.[3] This monitoring process is illustrated in Figures 1 and 2 and Table 1. The figures and the table provide details, for each Member State and the EU-25 as a whole, of trends in emissions of GHGs up to 2004. The EU-15 as a whole is shown separately, as it was the old EU Member States that have jointly approved, as a Party, the Kyoto Protocol to the United Nations Framework on Climate Change (EU Official Journal, 2002: Annex II). Figure 1 follows the total emissions of the EU over time since 1990, while the distance-to-target indicator (DTI) introduced in Figure 2, based on the country data listed in Table 1 (and their updates referred to in caption to Table 1), is a measure for how much the Member States' actual (2004) GHG emissions deviate from their linear target paths between 1990 and 2008–2012, assuming that only domestic measures will be used (i.e., excluding Kyoto mechanisms). A negative DTI means that in 2004 a Member State is below its linear path target; a positive DTI means that in 2004 a Member State is above its linear path target (EEA, 2006a: Table ES.1; EEA, 2006b: Table A7.1; update: EEA, 2006c: Annex 1: Table ES.1).[4] As Figures 1 and 2 only present relative information of the kind 'must buy versus can sell', Figure 3 is added which translates this information into absolute numbers based on the Member States' emission changes as of 2004 and their linear path targets for that year (Table 1). Figure 3 facilitates understanding the 2004 situation of the EU in quantitative terms.

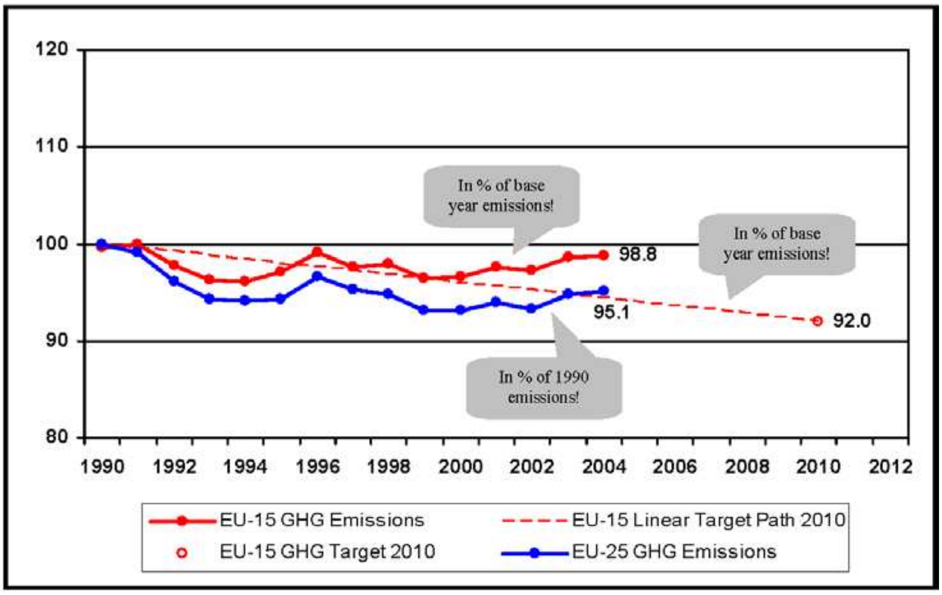

Figure 1: EU-25 GHG emissions for 1990–2004 (excluding LUCF and Kyoto mechanisms) with 1990 emissions as reference. The corresponding EU-15 GHG emissions and linear target path 1990–2008/12, with base-year emissions as reference, are shown for comparison. Sources: EEA (2006a: Figures ES.1, ES.2); update: EEA (2006c: Annex 1: Figures ES.1, ES.2); reproduced with the help of original data provided by Ritter (2007).

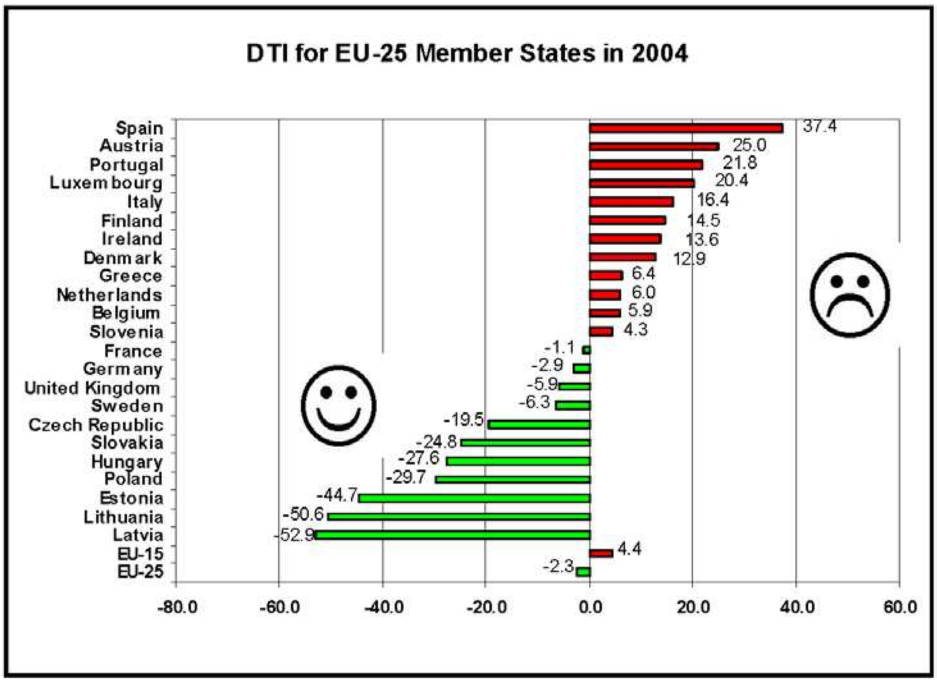

Figure 2: Distance-to-target indicator (DTI) for EU-25 as a whole and its Member States in 2004 under the Kyoto Protocol and EU burden sharing (excluding LUCF and Kyoto mechanisms). The DTI for the EU-15 as a whole is shown for comparison.

Table 1: Distance-to-target indicator (DTI) for EU-25 as a whole and its Member States in 2004 under the Kyoto Protocol and EU burden sharing (including and excluding LUCF and Kyoto mechanisms; see last column). 2nd and 3rd columns: base year and 2004 GHG emissions (excluding LUCF and Kyoto mechanisms; in CO_2 equivalents); 4th and 5th columns: 2003–2004 and base year–2004 emission changes (in %); 6th and 7th columns: 2008–2012 emission targets under the Kyoto Protocol and EU burden sharing (in % and CO_2 equivalents). Values for the EU-15 as a whole are shown for comparison. Sources: EEA (2006b: Table A7.1); updates: EEA (2006c: Annex 1: Table ES.1), Ritter (2007).

	Base-year (Mt CO_2)	GHG emissions 2004 (Mt CO_2)	Change 2003–2004 (in %)	Change 2004 relative to base-year (in %)	EU burden-sharing or Kyoto target (in %)	EU burden-sharing or Kyoto target (Mt CO_2)	Distance to target indicator (index points)*
Austria	78.9	91.3	− 1.3 %	+ 15.7 %	− 13.0 %	68.68	+ 17.9 (+ 24.8)
Belgium	146.9	147.9	+ 0.2 %	+ 0.7 %	− 7.5 %	135.87	+ 1.8 (+ 5.9)
Cyprus	6.0	8.9	− 3.0 %	+ 48.2 %	No target	No target	No target
Czech Republic	196.3	147.1	− 0.3 %	− 25.1 %	− 8.0 %	180.58	− 19.9 (− 19.5)
Denmark	69.3	68.1	− 8.1 %	− 1.8 %	− 21.0 %	54.77	+ 7.9 (+ 12.9)
Estonia	42.6	21.3	+ 0.7 %	− 50.0 %	− 8.0 %	39.23	− 44.4
Finland	71.1	81.4	− 4.9 %	+ 14.5 %	0.0 %	71.10	+ 13.1 (+ 14.5)
France	567.1	562.6	+ 0.3 %	− 0.8 %	0.0 %	567.09	− 1.2 (− 0.8)
Germany	1 230.0	1 015.3	− 0.9 %	− 17.5 %	− 21.0 %	971.67	− 2.8
Greece	111.1	137.6	+ 0.3 %	+ 23.9 %	+ 25.0 %	138.82	+ 6.4
Hungary	122.2	83.1	− 0.2 %	− 32.0 %	− 6.0 %	114.89	− 27.8
Ireland	55.8	68.5	+ 0.1 %	+ 22.7 %	+ 13.0 %	63.03	+ 6.5 (+ 13.6)
Italy	519.6	582.5	+ 0.9 %	+ 12.1 %	− 6.5 %	485.83	+ 9.9 (+ 16.7)
Latvia	25.9	10.7	+ 0.4 %	− 58.5 %	− 8.0 %	23.82	− 52.9
Lithuania	50.9	20.3	+ 17.9 %	− 60.1 %	− 8.0 %	46.86	− 54.5
Luxembourg	12.7	12.7	+ 11.3 %	+ 0.3 %	− 28.0 %	9.14	+ 3.3 (+ 19.9)
Malta	2.2	3.2	+ 4.2 %	+ 45.9 %	No target	No target	No target
Netherlands	214.3	217.8	+ 1.1 %	+ 1.6 %	− 6.0 %	201.45	− 0.7 (+ 5.8)
Poland	565.3	386.4	+ 1.0 %	− 31.6 %	− 6.0 %	531.34	− 27.4
Portugal	60.0	84.5	+ 1.0 %	+ 41.0 %	+ 27.0 %	76.15	+ 14.6 (+ 22.1)
Slovakia	73.2	51.0	− 0.1 %	− 30.3 %	− 8.0 %	67.36	− 24.7
Slovenia	20.2	20.1	+ 2.0 %	− 0.8 %	− 8.0 %	18.60	− 1.0 (+ 4.8)
Spain	289.4	427.9	+ 4.8 %	+ 47.9 %	+ 15.0 %	332.79	+ 31.2 (+ 37.4)
Sweden	72.5	69.9	− 1.5 %	− 3.6 %	+ 4.0 %	75.35	− 8.4 (− 6.4)
United Kingdom	767.9	659.3	+ 0.2 %	− 14.1 %	− 12.5 %	671.90	− 5.8 (− 5.4)
EU-15	4 266.4	4 227.4	+ 0.3 %	− 0.9 %	− 8.0 %	3925.11	+ 2.3 (+ 4.7)
EU-25	5 371.3	4 979.6	+ 0.4 %	− 7.3 %	No common target	No common target	No common target

* In brackets: excluding Kyoto mechanisms and sinks

Notes: The base-year emissions reported in this table are the latest data available from national greenhouse gas inventories (6 June 2006). Final data will be available in the report on the EU's assigned amount (pursuant to Article 3, Paragraphs 7 and 8 of the Kyoto Protocol) under the UNFCCC, due end of 2006.

For fluorinated gases, the EU-15 base-year emission is the sum of 15 Member States' base-year emissions. A total of 13 Member States have indicated they will select 1995 as base-year under the Kyoto Protocol; Finland and France indicate that it will use 1990. Therefore, the EU-15 base-year estimates for fluorinated gas emissions are the sum of 1995 emissions for 13 Member States and 1990 emissions for Finland and France.

For Austria, Belgium, Czech Republic, Denmark, Finland, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Slovenia, Spain, Sweden, the United Kingdom and the EU-15, the effect of Kyoto mechanisms and carbon sinks were included in the calculations of the distance to target indicator (DTI). For these countries, the values in brackets give the DTI without Kyoto mechanisms and sinks.

The overall objective of the study is to advance the reporting of the EU by taking uncertainty and its consequences into consideration, i.e., (i) the risk that a Member State's true emissions in the commitment year/period are above its true emission limitation or reduction commitment (true emission target); and (ii) the detectability of the Member State's agreed emission target. This risk can be grasped and quantified although true emissions are unknown by definition (but not necessarily their ratios). Undershooting the agreed EU, or EU-compatible but detectable, target can decrease this risk. Here, the intermediate year of reference in the focus of attention is 2004, i.e., the linear target path 1990–2008/12 is evaluated with respect to this year.

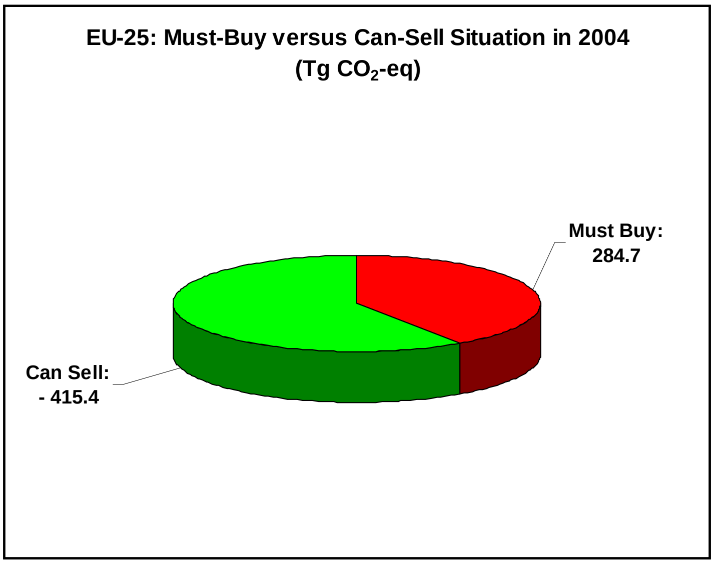

Figure 3: Figure 2 presented in absolute terms. Potential buyers in 2004: AT, BE, DK, ES, FI, GR, IE, IT, LU, NL, PT, SI; potential sellers in 2004: CZ, DE, EE, FR, HU, LT, LV, PL, SE, SK, UK. Member States not considered: CY, MT. See ISO Country Code for country abbreviations and text for underlying assumptions.

Uncertainties are reported and extracted from the national inventory reports of the Member States. However, a connection between emission and uncertainty estimates for the purpose of an advanced country evaluation has not yet been established. A recent compilation of uncertainties has been presented by EEA (2006a: Tab. 1.15) and is reproduced as Table 2. This compilation makes available quantified uncertainty estimates from 18 of the 25 EU Member States (extracted from their National Inventory Reports 2004, 2005, and 2006). From the remaining Member States, national inventory reports were available but without uncertainty estimates, or national inventory reports were not provided. The listed uncertainty estimates refer to a confidence of 95%[5] and exclude, with the exception of a few Member States, CO_2 emissions/removals due to land-use change and forestry (LUCF). France, Poland and the United Kingdom report (CO_2 or combined) uncertainties that include LUCF emissions/removals.

Taking uncertainty into account in combination with undershooting is important because the amount by which a Member State undershoots its EU, or its EU-compatible but detectable, target can be traded. Towards installing a successful trading regime, Member States may want to price the risk associated with this amount. We anticipate that the evaluation of emission signals in terms of risk and detectability will become standard practice.

Section 2 recalls the methodology of the Und&VT concept, which is applied in Section 3 with the above objective in mind. Results and conclusions are presented in Section 4.

Table 2: Uncertainty estimates available from EU-25 Member States excluding LUCF (with the exception of France, Poland and the United Kingdom) and Kyoto mechanisms.[6] Source: EEA (2006a: Table 1.15).

Member State	Austria		Belgium		Cyprus	Czech Republic		Denmark		Estonia		Finland		France		Germany	
Citation	Austrian NIR 2006, p. 39–43		Belgian NIR 2006, p. 15–22		No NIR provided	Czech NIR 2006, p. 22–23		Danish NIR 2006 p. 53–54		No information provided		Finnish NIR 2006 p. 24–26, Annex 1 (Table A)		French NIR 2006, Chpater A.4		German NIR 2006, p. 67–71, Annex 7	
Method used	Tier 1, Tier 2		Tier 1			Tier 1		Tier 1				Tier 1, Tier 2		Tier 1, Tier 2		Tier 1	
Documen-tation available in NIR (according to Table 6.1 of GPG)	Yes		Yes			Yes: Table 1.3		Yes				Yes: Annex 1 (Table A)		Yes		Yes: Annex [Anhang] 7 (not according to Table 6.1 of GPG)	
Years and sectors included	Tier 1: base year and 2004 — Key sources Tier 2: 1990, 1997 (from year 1999) — All sectors		2003 — All sectors except LULUCF; for Flanders, a complete uncertainty study was conducted both on Tier 1 and Tier 2 level			1990, 2004 — All sources (key sources and 'others')		1990, 2004 — The sources included in the uncertainty estimate cover 99.9 % of the total Danish greenhouse gas emission (CO_2 eq., without CO_2 from LUCF)				1990, 2004 — All sectors Tier 2 uncertainty results below are for the year 2004; information for 1990 is available in the Finnish NIR		1990, 2004) — Tier 1 all sources, Tier 2 only Road transportation		1990, 2002 - nearly complete estimation for sources 1A, 2A1, 2A2, 2C1, 2C3, 4A (2002 only), 5A (2002 only)	
Uncertainty (%)	Tier 1	Tier 2	Tier 1	Tier 2		Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
CO_2	Base year: 0.9 % 2004: 0.9 %	1990: 2.3 % 1997: 2.1	1.9 %	-				2.3 %					+/- 40 % (with LULUCF) +/- 3 % (without LULUCF)	-	-	-	-
CH_4	Base year: 13.1 % 2004: 11.6 %	1990: 48.3 % 1997: 47.4 %	24.0 %	-				23 %					+/- 22 %	-	-	-	-
N_2O	Base year: 24.6 % 2004: 26.8 %	1990: 89.6 % 1997: 85.9 %	27.0 %	-				40 %					– 30 to + 130 %	-	-	-	-
F-gases	Base year: 33.5 % 2004: 32.8 %	-	100	-				48 %					– 10 to + 20 %	-	-	-	-
Total	Base year: 2.42 % 2004: 1.81 %	1990: 9.8 % 1997: 8.9 %	7.5 %	-		7.0 %		5.2 %					+/– 30 % (with LULUCF) – 5 to +6 % (without LULUCF)	21 %	-	5.60 %	-
Uncertainty in trend (%)	Tier 1	Tier 2	Tier 1	Tier 2		Tier 1	Tier 2	Tier 1	Tier 2			Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
CO_2	-	-	-	-				1.9 %				-	–	-	-	-	-
CH_4	-	-	-	-				10.4 %				-	–	-	-	-	-
N_2O	-	-	-	-				11 %				-	–	-	-	-	-
F-gases	-	-	-	-				58 %				-	–	-	-	-	-
Total	2.97 %	-	2.7 %	-		2.9 %		2.1 %					– 160 to + 270 % (with LULUCF) – 90 to + 70 % (without LULUCF)	3.90 %	-	4.30 %	-

Table 2: continued.

Member State	Greece		Hungary	Ireland		Italy		Latvia		Lithuania		Luxembourg		Malta		Netherlands	
Citation	Greek Short — NIR 2006, p. 17–18.		Hungarian NIR 2006, p. 15 to 16	Irish NIR 2006, p. 14–15, 18–19 (Tab. 1.8)		Italian NIR 2004, p. 18, Annex 1		Latvian NIR 2006, p. 16. Annex 2		Lithuanian NIR 2006		Luxembourg NIR 2006		No NIR provided		Dutch NIR 2006, p. 1–12 to 1–13, Annex 7	
Method used	Tier 1		Tier 1?	Tier 1		Tier 1		Tier 1								Tier 1	
Documentation available in NIR (according to Table 6.1 of GPG)	No			Yes: Table 1.4		Yes (Table A1.2)		Yes		No		No				Partially (Annex 7)	
Years and sectors included	1990, 2004 — All sources			1990, 2004 — All sources		1990, 2002 — All sources		1990–2004, All sources								1990/95, 2004 — All sources	
Uncertainty (%)	Tier 1	Tier 2	Tier 1?	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
CO_2	3.7 % (witout LULUCF) 5 % (with LULUCF)	–	+/– 2 to 4 %	1.2	–	–	–	4								2.7 %	–
CH_4	32.9 %	–	+/– 15 to 25 %	2.13	–	–	–	16								16.20 %	–
N_2O	103.5 %	–	+/– 80 to 90 %	6.19	–	–	–	27								35.50 %	–
F-gases	113.7 %	–		0.1	–	–	–									20.30 %	–
Total	11.3 % (without LUCF)	–	< 10 %	6.66 %	–	2.5 %	–	5								5 %	–
Uncertainty in trend (%)	Tier 1	Tier 2		Tier 1	Tier 2	Tier 1	Tier 2	Tier 1								Tier 1	Tier 2
CO_2	–	–		1.8	–	–	–	2								+/– 3 %	–
CH_4	–	–		1.8	–	–	–	2								+/– 12 %	–
N_2O	–	–		2.3	–	–	–	8								+/– 15 %	–
F-gases	–	–		0.2	–	–	–									+/– 8 %	–
Total	9.7 %	–		3.4	–	2.4 %	–	12								+/– 3 %	–

Table 2: continued.

Member State	Poland		Portugal		Slovakia		Slovenia		Spain		Sweden		United Kingdom	
Citation	Polnish NIR 2006. p. 13. Annex 5. 6		Portuguese NIR 2006. p. 8		Slovakian NIR 2006. p. 12–13; Coverletter 2005 (Data of greenhouse gas emissions): Table on Tier 1 uncertainty calculation and reporting		Sovenian NIR 2006. p. 21. Annex 7		Spanish NIR 2005. p. 46–55		Swedish NIR 2006. p. 37–39		UK NIR 2006. p. 78. Annex 7	
Method used	Tier 1						Tier 1		Tier 1		Tier 1		Tier 1. Tier 2	
Documentation available in NIR (according to Table 6.1 of GPG)	Partially		No		No		No. Partially		Yes: Table 5.5.2 and 5.5.3		Partially (Annex 2)		Yes: Tables in Annex 7 (no composite table on references included)	
Years and sectors included	1998–2004 — All sources						1986. 2002. 2003		2001. 2002 (from year 2005) — All sources (key sources and 'other emission sources')		1990 and 2004 for all sectors and gases		1990. 2004 — All sources	
Uncertainty (%)	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
CO_2	7.5 %								–	–	2.3 %	–	2.00 %	
CH_4	20.9 %								–	–	2.1 %	–	19 % (2004) 25 % (1990)	
N_2O	47.7 %								–	–	5.0 %	–	221 %	
F-gases	HFC 46.5 % PFC 20 % SF6 150 %									–	0.3 %	–	HFC 21 PFCs 13 SF6 16	
Total							1986: 12 % 2002: 13.1 % 2003: 12 %		2001 +/- 17 % 2002 +/- 15.8 %	–	5.8 %	–	14 %	
Uncertainty in trend (%)					Tier 1	Tier 2	Tier 1		Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
CO_2									–	–	–	–	3– 8 %	–
CH_4									–	–	–	–	37 %(2204) 62 % (1990)	–
N_2O									–	–	–	–	19–76 %	–
F- gases									–	–	–	–	HFC 22 % PFCs 75 % SF6 9 %	–
Total			13.3				2002: 4 % 2003: 3 %		2001 +/- 2.65 % 2002 +/- 3.95 %	–	–	–	14 %	–

2 Methodology

The applied Und&VT concept is described in detail in Jonas *et al.* (2004a). With the help of δ_{KP}, the normalized emission change under EU burden sharing in compliance with the Kyoto Protocol,[7] and δ_{crit}, the critical (crit) emission limitation or reduction target, the four cases listed in Table 3 and shown in Figure 4 are distinguished. The Member States' δ_{crit} values can be determined knowing the relative (total) uncertainty (ρ) of their net emissions (see Eq. (32a, b) in Jonas *et al.*, 2004a):

$$\delta_{crit} = \begin{cases} \dfrac{\rho}{1+\rho} & x_2 < x_1 \, (\delta_{KP} > 0); \\ & \textit{for} \\ -\dfrac{\rho}{1-\rho} & x_2 \geq x_1 \, (\delta_{KP} \leq 0), \end{cases} \tag{1a,b}$$

where ρ is assumed to be symmetrical and, in line with preparatory signal detection, constant over time, i.e., $\rho(t_1) = \rho(t_2)$ with t_1 referring to 1990 as base year[8] and t_2 to 2010 as commitment year (as the temporal mean over the commitment period 2008–2012). The Member States' best estimates of their emissions at t_i are denoted by x_i.

Table 4 assembles the nomenclature that is required for recalling Cases 1–4.

Table 3: The four cases that are distinguished in applying the Und&VT concept (see also Figure 4).

Emission Reduction: $\delta_{KP} > 0$	**Case 1**	$\delta_{crit} \leq \delta_{KP}$	Detectable EU/Kyoto target	
	Case 2	$\delta_{crit} > \delta_{KP}$	Non-detectable EU/Kyoto target: An initial or obligatory undershooting is applied so that the Member States' emission signals become detectable (before the Member States are permitted to make economic use of excess emission reductions)	
Emission Limitation: $\delta_{KP} \leq 0$	**Case 3**	$\delta_{crit} < \delta_{KP}$	Non-detectable EU/Kyoto target	As in Case 2, an initial or obligatory undershooting is applied unconditionally for all Member States (their emission reductions, not increases, must become detectable)
	Case 4	$\delta_{crit} \geq \delta_{KP}$	Detectable EU/Kyoto target[a]	

[a] Detectability according to Case 4 differs from detectability according to Case 1. The reason for this is that countries agreed to emission reduction ($\delta_{KP} > 0$) and emission limitation ($\delta_{KP} \leq 0$) exhibit an over/undershooting dissimilarity (see Jonas *et al.*, 2004a: Sections 3.1, 3.2 for details).

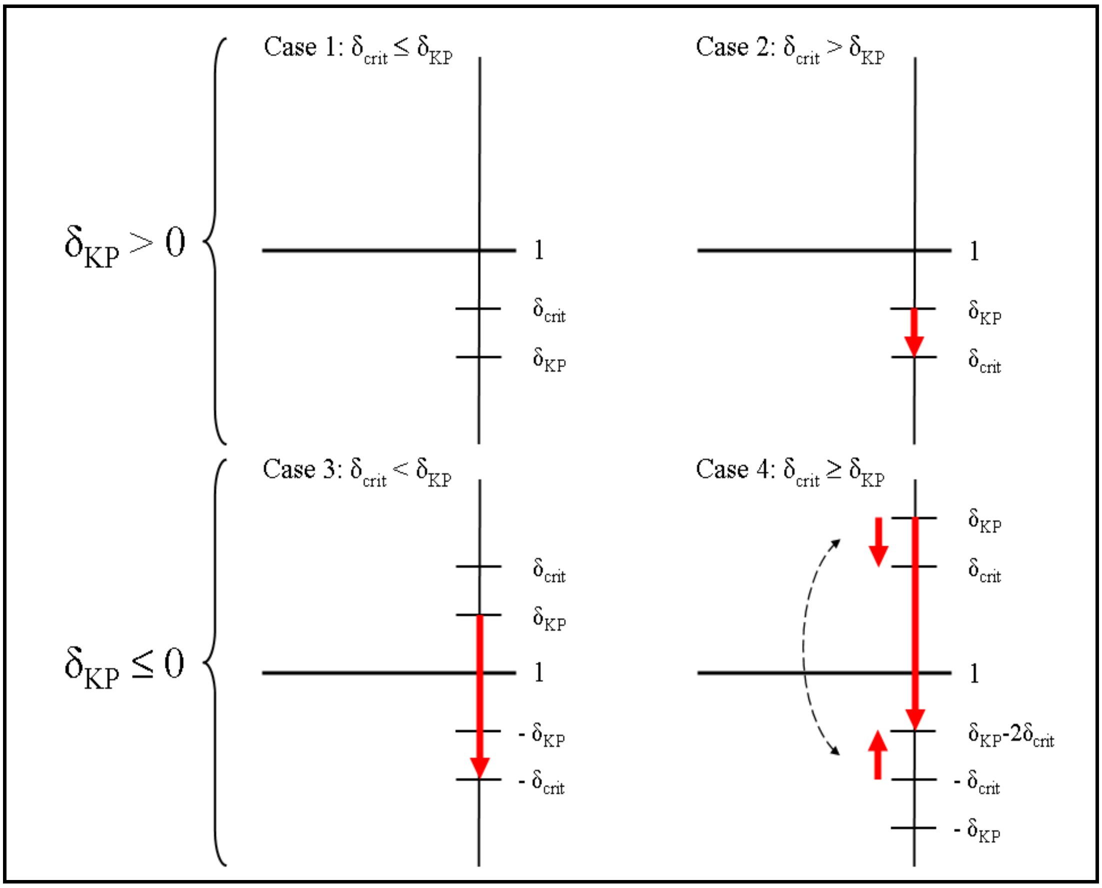

Figure 4: The four cases that are distinguished in applying the Und&VT concept (see also Table 3). Emission reduction: $\delta_{KP} > 0$; emission limitation: $\delta_{KP} \leq 0$.

Case 1: $\delta_{KP} > 0 : \delta_{crit} \leq \delta_{KP}$. Here, use is made of Eq. (43a), (B1), (D1), (B3) and (D2) of Jonas *et al.* (2004a: App. D):

$$\frac{x_1}{x_2} \leq (1-\delta_{KP})\frac{1}{1+(1-2\alpha)\rho} = 1-\delta_{\text{mod}}, \qquad (2), (3)$$

where

$$\delta_{\text{mod}} = 1-(1-\delta_{KP})\frac{1}{1+(1-2\alpha)\rho} = \delta_{KP} + U \qquad (4), (5)$$

$$U = (1-\delta_{KP})\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}. \qquad (6)$$

Case 2: $\delta_{KP} > 0 : \delta_{crit} > \delta_{KP}$. Here, use is made of Eq. (45a), (B1), (D3a,b), (D4) and (42b) of Jonas *et al.* (2004a: App. D):

$$\frac{x_1}{x_2} \le (1-\delta_{crit})\frac{1}{1+(1-2\alpha)\rho} = 1-\delta_{\text{mod}} \ , \qquad (7), (3)$$

where

$$\delta_{\text{mod}} = 1-(1-\delta_{crit})\frac{1}{1+(1-2\alpha)\rho} = \delta_{KP} + U \qquad (8), (5)$$

$$U = U_{gap} + (1-\delta_{crit})\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}. \qquad (9)$$

with

$$U_{gap} = \delta_{crit} - \delta_{KP}. \qquad (10)$$

Table 4: Nomenclature for Cases 1–4.

Known or Prescribed:	
x_i	A Member State's net emissions (best estimate) at t_i
α	The risk that a Member State's true emissions in the commitment year/period fall above its true emission limitation or reduction commitment (true emission target) Note: In Jonas *et al.* (2004a: Section 3.4 and App. D) α is replaced by α_v (where 'v' refers to 'verifiable') in Cases 2–4, which is not done here
δ_{KP}	A Member State's normalized emission change agreed under EU burden sharing in compliance with the Kyoto Protocol
ρ	The relative (total) uncertainty of a Member State's net emissions
Derived:	
U	Undershooting Note: In Jonas *et al.* (2004a: Section 3.4 and App. D) U is replaced by U_v (where 'v' refers to 'verifiable') in Cases 2–4, which is not done here
U_{Gap}	Initial or obligatory undershooting
δ_{crit}	A Member State's critical emission limitation or reduction target or, equivalently, its 'detectability reference' for undershooting (Case 2: δ_{crit}; Case 3: $-\delta_{crit}$; Case 4: $-\delta'_{crit} = \delta_{KP} - 2\delta_{crit}$)
δ_{mod}	A Member State's modified emission limitation or reduction target
Unknown:	
$x_{t,i}$	A Member State's true emissions at t_i The said risk α (e.g., the $x_{t,2}$-greater-than-$(1-\delta_{KP})x_{t,1}$ risk in Case 1) can be grasped and quantified although true emissions are unknown by definition (but not necessarily their ratios)

Case 3: $\delta_{KP} \le 0 : \delta_{crit} < \delta_{KP}$. Here, use is made of Eq. (50a), (B1), (D7a,b), (D8) and (52) of Jonas *et al.* (2004a: App. D):

$$\frac{x_1}{x_2} \le (1+\delta_{crit})\frac{1}{1+(1-2\alpha)\rho} = 1-\delta_{\mathrm{mod}} \;, \tag{11), (3}$$

where

$$\delta_{\mathrm{mod}} = 1-(1+\delta_{crit})\frac{1}{1+(1-2\alpha)\rho} = \delta_{KP} + U \tag{12), (5}$$

$$U = U_{gap} + (1+\delta_{crit})\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}. \tag{13}$$

with

$$U_{gap} = -(\delta_{crit} + \delta_{KP})\,. \tag{14}$$

Case 4: $\delta_{KP} \le 0 : \delta_{crit} \ge \delta_{KP}$. Here, use is made of Eq. (55a), (B1), (D11a,b), (D12), (57) and (58) of Jonas *et al.* (2004a: App. D):

$$\frac{x_1}{x_2} \le (1+\delta'_{crit})\frac{1}{1+(1-2\alpha)\rho} = 1-\delta_{\mathrm{mod}} \;, \tag{15), (3}$$

where

$$\delta_{\mathrm{mod}} = 1-(1+\delta'_{crit})\frac{1}{1+(1-2\alpha)\rho} = \delta_{KP} + U \tag{16), (5}$$

$$U = U_{gap} + (1+\delta'_{crit})\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}. \tag{17}$$

with

$$U_{gap} = -2\delta_{crit} \tag{18}$$

$$-\delta'_{crit} = \delta_{KP} - 2\delta_{crit}\,. \tag{19}$$

It is recalled that emission reductions are measured positively ($\delta_{KP} > 0$) and emission increases negatively ($\delta_{KP} < 0$), which is opposite to the emissions reporting for the EU (see Section 1). However, this can be readily modified by introducing a minus sign when reporting results.

3 Results

The evaluation procedure encompasses two steps. In the first step the Und&VT concept is applied with reference to the time period base year–commitment year. With the knowledge of ρ, the relative (total) uncertainty with which a Member State reports its net emissions and which is assumed here to take on one of the values listed in Table 5 (excluding LUCF and Kyoto mechanisms), Eq. (1) can be used to determine δ_{crit}, the Member State's critical emission limitation or reduction target.

Comparing δ_{crit} and δ_{KP}, the Member States' 2008–12 targets under EU burden sharing in compliance with the Kyoto Protocol (see Table 1), allows to identify which case applies to which Member State, that is, the conditions that underlie the emissions reporting of a particular Member State and the EU-25 as a whole (see Tables 3 and 6).

Table 7 lists the Member States' modified emission limitation or reduction targets δ_{mod} (Eq. (4), (8), (12) and (16)), where the (Case 1: '$x_{t,2}$-greater-than-$(1-\delta_{KP})x_{t,1}$'; Cases 2 and 3: '$x_{t,2}$-greater-than-$(1-|\delta_{crit}|)x_{t,1}$'; Case 4: '$x_{t,2}$-greater-than-$(1-(\delta_{KP}-2\delta_{crit}))x_{t,1}$') risk α is specified to be 0, 0.1, …, 0.5. Table 8 lists the undershooting U (Eq. (6), (9), (13) and (17)) contained in the modified emission limitation or reduction targets δ_{mod} listed in Table 7.

As explained by Jonas *et al.* (2004a: Section 3.3), it is the sum of δ_{KP} and U, i.e., the modified emission limitation or reduction target δ_{mod} (see Eq. (5)) that matters initially because it describes a Member State's overall burden. However, once Member States have agreed on δ_{KP} targets, it is the undershooting U which then becomes important. Therefore, only U is considered in the second step of the evaluation, where the focus is on the Member States' emissions as of 2004.

The results are interpreted in Section 4, which also contains the conclusions that are drawn from this monitoring exercise.

Table 5: Critical emission limitation or reduction targets (δ_{crit}) derived with the help of Eq. (1) for a range of relative uncertainty values (ρ), covering the uncertainty estimates of the EU-25 Member States (cf. Table 2).

	$\delta_{KP}>0$	$\delta_{KP}\le 0$		$\delta_{KP}>0$	$\delta_{KP}\le 0$
ρ %	δ_{crit} %	δ_{crit} %	ρ %	δ_{crit} %	δ_{crit} %
0.0		0.00	15.0	13.04	-17.65
2.5	2.44	-2.56	20.0	16.67	-25.00
5.0	4.76	-5.26	30.0	23.08	-42.86
7.5	6.98	-8.11	40.0	28.57	-66.67
10.0	9.09	-11.11			

In the second step, the U values reported in Table 8 are multiplied with the factor $(-14/20)$. The minus sign ensures compliance with the emissions reporting for the EU, which measures emission reductions negatively and emission increases positively (see Section 1). The factor $(14/20)$ establishes the linear path (base year–commitment year) emission targets and undershooting opportunities for the year 2004 (see Table 9).

Table 6: The conditions (in the form of Cases 1–4) that underlie the emissions reporting of a particular EU-25 Member State (MS) and the EU-15 as a whole (which has approved, as a Party, the Kyoto Protocol to the United Nations Framework on Climate Change). Green: Detectable EU/Kyoto target under emission reduction (Case 1). Orange: Detectable EU/Kyoto target under emission limitation (Case 4). Red: Non-detectable EU/Kyoto Target under emission reduction (Case 2) or emission limitation (Case 3). Blue: Member States having no Kyoto target.

MS	δ_{KP} **%**	**Case Identification for ρ =**								
		0%	**2.5%**	**5%**	**7.5%**	**10%**	**15%**	**20%**	**30%**	**40%**
AT	**13.0**	Case 1	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2
BE	**7.5**	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2
CY	**-**									
CZ	**8.0**	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2
DK	**21.0**	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2
EE	**8.0**	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2
FI	**0.0**	Case 4	Case 3	Case 3	Case 3	Case 3	Case 3	Case 3	Case 3	Case 3
FR	**0.0**	Case 4	Case 3	Case 3	Case 3	Case 3	Case 3	Case 3	Case 3	Case 3
DE	**21.0**	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2
GR	**-25.0**	Case 4	Case 4	Case 4	Case 4	Case 4	Case 4	Case 4	Case 3	Case 3
HU	**6%**	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2	Case 2
IE	**-13.0**	Case 4	Case 4	Case 4	Case 4	Case 4	Case 3	Case 3	Case 3	Case 3
IT	**6.5**	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2	Case 2
LV	**8.0**	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2
LT	**8.0**	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2
LU	**28.0**	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 2
MT	**-**									
NL	**6.0**	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2	Case 2
PL	**6.0**	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2	Case 2
PT	**-27.0**	Case 4	Case 4	Case 4	Case 4	Case 4	Case 4	Case 4	Case 3	Case 3
SK	**8.0**	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2
SI	**8.0**	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2
ES	**-15.0**	Case 4	Case 4	Case 4	Case 4	Case 4	Case 3	Case 3	Case 3	Case 3
SE	**-4.0**	Case 4	Case 4	Case 3	Case 3	Case 3	Case 3	Case 3	Case 3	Case 3
UK	**12.5**	Case 1	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2
EU-15	**8.0**	**Case 1**	**Case 1**	**Case 1**	**Case 1**	**Case 2**	**Case 2**	**Case 2**	**Case 2**	**Case 2**

Table 7: The Und&VT concept applied to the EU-25 Member States (MS) and the EU-15 as a whole. The table lists the 2008–2012 modified emission limitation or reduction targets δ_{mod} (Eq. (5) in combination with Table 8), where the (Case 1: ‘$x_{t,2}$-greater-than-$(1-\delta_{KP})x_{t,1}$’; Cases 2 and 3: ‘$x_{t,2}$-greater-than-$(1-|\delta_{crit}|)x_{t,1}$’; Case 4: ‘$x_{t,2}$-greater-than-$(1-(\delta_{KP}-2\delta_{crit}))x_{t,1}$’) risk a is specified to be 0, 0.1, …, 0.5.

MS	δ_{KP} %	a 1	**Modified Emission Limitation or Reduction Target δ_{mod} in % for ρ =** 0%	2.5%	5%	7.5%	10%	15%	20%	30%	40%
AT	**13.0**	0.0	13.0	15.1	17.1	19.1	20.9	24.4	30.6	40.8	49.0
		0.1	13.0	14.7	16.3	17.9	19.4	22.4	28.2	38.0	45.9
		0.2	13.0	14.3	15.5	16.7	17.9	20.2	25.6	34.8	42.4
		0.3	13.0	13.9	14.7	15.5	16.3	18.0	22.8	31.3	38.4
		0.4	13.0	13.4	13.9	14.3	14.7	15.6	19.9	27.4	33.9
		0.5	13.0	13.0	13.0	13.0	13.0	13.0	16.7	23.1	28.6
BE	**7.5**	0.0	7.5	9.8	11.9	14.0	17.4	24.4	30.6	40.8	49.0
		0.1	7.5	9.3	11.1	12.7	15.8	22.4	28.2	38.0	45.9
		0.2	7.5	8.9	10.2	11.5	14.2	20.2	25.6	34.8	42.4
		0.3	7.5	8.4	9.3	10.2	12.6	18.0	22.8	31.3	38.4
		0.4	7.5	8.0	8.4	8.9	10.9	15.6	19.9	27.4	33.9
		0.5	7.5	7.5	7.5	7.5	9.1	13.0	16.7	23.1	28.6
CZ	**8.0**	0.0	8.0	10.2	12.4	14.4	17.4	24.4	30.6	40.8	49.0
		0.1	8.0	9.8	11.5	13.2	15.8	22.4	28.2	38.0	45.9
		0.2	8.0	9.4	10.7	12.0	14.2	20.2	25.6	34.8	42.4
		0.3	8.0	8.9	9.8	10.7	12.6	18.0	22.8	31.3	38.4
		0.4	8.0	8.5	8.9	9.4	10.9	15.6	19.9	27.4	33.9
		0.5	8.0	8.0	8.0	8.0	9.1	13.0	16.7	23.1	28.6
DK	**21.0**	0.0	21.0	22.9	24.8	26.5	28.2	31.3	34.2	40.8	49.0
		0.1	21.0	22.5	24.0	25.5	26.9	29.5	31.9	38.0	45.9
		0.2	21.0	22.2	23.3	24.4	25.5	27.5	29.5	34.8	42.4
		0.3	21.0	21.8	22.5	23.3	24.0	25.5	26.9	31.3	38.4
		0.4	21.0	21.4	21.8	22.2	22.5	23.3	24.0	27.4	33.9
		0.5	21.0	21.0	21.0	21.0	21.0	21.0	21.0	23.1	28.6
EE	**8.0**	0.0	8.0	10.2	12.4	14.4	17.4	24.4	30.6	40.8	49.0
		0.1	8.0	9.8	11.5	13.2	15.8	22.4	28.2	38.0	45.9
		0.2	8.0	9.4	10.7	12.0	14.2	20.2	25.6	34.8	42.4
		0.3	8.0	8.9	9.8	10.7	12.6	18.0	22.8	31.3	38.4
		0.4	8.0	8.5	8.9	9.4	10.9	15.6	19.9	27.4	33.9
		0.5	8.0	8.0	8.0	8.0	9.1	13.0	16.7	23.1	28.6
FI	**0.0**	0.0	0.0	4.9	9.8	14.5	19.2	28.4	37.5	56.0	76.2
		0.1	0.0	4.5	8.9	13.3	17.7	26.5	35.3	53.9	74.7
		0.2	0.0	4.0	8.0	12.1	16.1	24.4	33.0	51.6	73.1
		0.3	0.0	3.5	7.1	10.8	14.5	22.3	30.6	49.0	71.3
		0.4	0.0	3.0	6.2	9.5	12.9	20.0	27.9	46.1	69.1
		0.5	0.0	2.6	5.3	8.1	11.1	17.6	25.0	42.9	66.7
FR	**0.0**	0.0	0.0	4.9	9.8	14.5	19.2	28.4	37.5	56.0	76.2
		0.1	0.0	4.5	8.9	13.3	17.7	26.5	35.3	53.9	74.7
		0.2	0.0	4.0	8.0	12.1	16.1	24.4	33.0	51.6	73.1
		0.3	0.0	3.5	7.1	10.8	14.5	22.3	30.6	49.0	71.3
		0.4	0.0	3.0	6.2	9.5	12.9	20.0	27.9	46.1	69.1
		0.5	0.0	2.6	5.3	8.1	11.1	17.6	25.0	42.9	66.7

Table 7: continued.

DE	**21.0**	0.0	21.0	22.9	24.8	26.5	28.2	31.3	34.2	40.8	49.0
		0.1	21.0	22.5	24.0	25.5	26.9	29.5	31.9	38.0	45.9
		0.2	21.0	22.2	23.3	24.4	25.5	27.5	29.5	34.8	42.4
		0.3	21.0	21.8	22.5	23.3	24.0	25.5	26.9	31.3	38.4
		0.4	21.0	21.4	21.8	22.2	22.5	23.3	24.0	27.4	33.9
		0.5	21.0	21.0	21.0	21.0	21.0	21.0	21.0	23.1	28.6
GR	**-25.0**	0.0	-25.0	-16.9	-9.0	-1.2	6.6	22.0	37.5	56.0	76.2
		0.1	-25.0	-17.5	-10.1	-2.6	4.8	19.9	35.3	53.9	74.7
		0.2	-25.0	-18.1	-11.1	-4.1	3.0	17.7	33.0	51.6	73.1
		0.3	-25.0	-18.7	-12.2	-5.6	1.2	15.4	30.6	49.0	71.3
		0.4	-25.0	-19.3	-13.3	-7.2	-0.8	12.9	27.9	46.1	69.1
		0.5	-25.0	-19.9	-14.5	-8.8	-2.8	10.3	25.0	42.9	66.7
HU	**6.0**	0.0	6.0	8.3	10.5	-17.5	-13.6	-6.6	-0.4	9.8	18.0
		0.1	6.0	7.8	9.6	-18.8	-15.2	-8.6	-2.8	7.0	14.9
		0.2	6.0	7.4	8.7	-20.0	-16.8	-10.8	-5.4	3.8	11.4
		0.3	6.0	6.9	7.8	-21.3	-18.4	-13.0	-8.2	0.3	7.4
		0.4	6.0	6.5	6.9	-22.6	-20.1	-15.4	-11.1	-3.6	2.9
		0.5	6.0	6.0	6.0	-24.0	-21.9	-18.0	-14.3	-7.9	-2.4
IE	**-13.0**	0.0	-13.0	-5.2	2.4	10.0	17.5	28.4	37.5	56.0	76.2
		0.1	-13.0	-5.8	1.5	8.7	15.9	26.5	35.3	53.9	74.7
		0.2	-13.0	-6.3	0.5	7.4	14.4	24.4	33.0	51.6	73.1
		0.3	-13.0	-6.8	-0.5	6.0	12.7	22.3	30.6	49.0	71.3
		0.4	-13.0	-7.3	-1.5	4.6	11.0	20.0	27.9	46.1	69.1
		0.5	-13.0	-7.9	-2.5	3.2	9.2	17.6	25.0	42.9	66.7
IT	**6.5**	0.0	6.5	8.8	11.0	13.5	17.4	24.4	30.6	40.8	49.0
		0.1	6.5	8.3	10.1	12.2	15.8	22.4	28.2	38.0	45.9
		0.2	6.5	7.9	9.2	11.0	14.2	20.2	25.6	34.8	42.4
		0.3	6.5	7.4	8.3	9.7	12.6	18.0	22.8	31.3	38.4
		0.4	6.5	7.0	7.4	8.4	10.9	15.6	19.9	27.4	33.9
		0.5	6.5	6.5	6.5	7.0	9.1	13.0	16.7	23.1	28.6
LV	**8.0**	0.0	8.0	10.2	12.4	14.4	17.4	24.4	30.6	40.8	49.0
		0.1	8.0	9.8	11.5	13.2	15.8	22.4	28.2	38.0	45.9
		0.2	8.0	9.4	10.7	12.0	14.2	20.2	25.6	34.8	42.4
		0.3	8.0	8.9	9.8	10.7	12.6	18.0	22.8	31.3	38.4
		0.4	8.0	8.5	8.9	9.4	10.9	15.6	19.9	27.4	33.9
		0.5	8.0	8.0	8.0	8.0	9.1	13.0	16.7	23.1	28.6
LT	**8.0**	0.0	8.0	10.2	12.4	14.4	17.4	24.4	30.6	40.8	49.0
		0.1	8.0	9.8	11.5	13.2	15.8	22.4	28.2	38.0	45.9
		0.2	8.0	9.4	10.7	12.0	14.2	20.2	25.6	34.8	42.4
		0.3	8.0	8.9	9.8	10.7	12.6	18.0	22.8	31.3	38.4
		0.4	8.0	8.5	8.9	9.4	10.9	15.6	19.9	27.4	33.9
		0.5	8.0	8.0	8.0	8.0	9.1	13.0	16.7	23.1	28.6
LU	**28.0**	0.0	28.0	29.8	31.4	33.0	34.5	37.4	40.0	44.6	49.0
		0.1	28.0	29.4	30.8	32.1	33.3	35.7	37.9	41.9	45.9
		0.2	28.0	29.1	30.1	31.1	32.1	33.9	35.7	39.0	42.4
		0.3	28.0	28.7	29.4	30.1	30.8	32.1	33.3	35.7	38.4
		0.4	28.0	28.4	28.7	29.1	29.4	30.1	30.8	32.1	33.9
		0.5	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.6
NL	**6.0**	0.0	6.0	8.3	10.5	13.5	17.4	24.4	30.6	40.8	49.0
		0.1	6.0	7.8	9.6	12.2	15.8	22.4	28.2	38.0	45.9
		0.2	6.0	7.4	8.7	11.0	14.2	20.2	25.6	34.8	42.4
		0.3	6.0	6.9	7.8	9.7	12.6	18.0	22.8	31.3	38.4
		0.4	6.0	6.5	6.9	8.4	10.9	15.6	19.9	27.4	33.9
		0.5	6.0	6.0	6.0	7.0	9.1	13.0	16.7	23.1	28.6

Table 7: continued.

PL	**6.0**	0.0	6.0	8.3	10.5	13.5	17.4	24.4	30.6	40.8	49.0
		0.1	6.0	7.8	9.6	12.2	15.8	22.4	28.2	38.0	45.9
		0.2	6.0	7.4	8.7	11.0	14.2	20.2	25.6	34.8	42.4
		0.3	6.0	6.9	7.8	9.7	12.6	18.0	22.8	31.3	38.4
		0.4	6.0	6.5	6.9	8.4	10.9	15.6	19.9	27.4	33.9
		0.5	6.0	6.0	6.0	7.0	9.1	13.0	16.7	23.1	28.6
PT	**-27.0**	0.0	-27.0	-18.9	-10.9	-3.1	4.7	20.3	35.8	56.0	76.2
		0.1	-27.0	-19.5	-12.0	-4.5	3.0	18.1	33.6	53.9	74.7
		0.2	-27.0	-20.1	-13.1	-6.0	1.2	15.9	31.3	51.6	73.1
		0.3	-27.0	-20.7	-14.2	-7.6	-0.7	13.5	28.7	49.0	71.3
		0.4	-27.0	-21.3	-15.3	-9.1	-2.7	11.0	26.0	46.1	69.1
		0.5	-27.0	-21.9	-16.5	-10.8	-4.8	8.3	23.0	42.9	66.7
SK	**8.0**	0.0	8.0	10.2	12.4	14.4	17.4	24.4	30.6	40.8	49.0
		0.1	8.0	9.8	11.5	13.2	15.8	22.4	28.2	38.0	45.9
		0.2	8.0	9.4	10.7	12.0	14.2	20.2	25.6	34.8	42.4
		0.3	8.0	8.9	9.8	10.7	12.6	18.0	22.8	31.3	38.4
		0.4	8.0	8.5	8.9	9.4	10.9	15.6	19.9	27.4	33.9
		0.5	8.0	8.0	8.0	8.0	9.1	13.0	16.7	23.1	28.6
SI	**8.0**	0.0	8.0	10.2	12.4	14.4	17.4	24.4	30.6	40.8	49.0
		0.1	8.0	9.8	11.5	13.2	15.8	22.4	28.2	38.0	45.9
		0.2	8.0	9.4	10.7	12.0	14.2	20.2	25.6	34.8	42.4
		0.3	8.0	8.9	9.8	10.7	12.6	18.0	22.8	31.3	38.4
		0.4	8.0	8.5	8.9	9.4	10.9	15.6	19.9	27.4	33.9
		0.5	8.0	8.0	8.0	8.0	9.1	13.0	16.7	23.1	28.6
ES	**-15.0**	0.0	-15.0	-7.2	0.5	8.1	15.7	28.4	37.5	56.0	76.2
		0.1	-15.0	-7.7	-0.5	6.8	14.1	26.5	35.3	53.9	74.7
		0.2	-15.0	-8.2	-1.4	5.5	12.5	24.4	33.0	51.6	73.1
		0.3	-15.0	-8.8	-2.4	4.1	10.8	22.3	30.6	49.0	71.3
		0.4	-15.0	-9.3	-3.4	2.7	9.0	20.0	27.9	46.1	69.1
		0.5	-15.0	-9.9	-4.5	1.2	7.2	17.6	25.0	42.9	66.7
SE	**-4.0**	0.0	-4.0	3.5	9.8	14.5	19.2	28.4	37.5	56.0	76.2
		0.1	-4.0	3.1	8.9	13.3	17.7	26.5	35.3	53.9	74.7
		0.2	-4.0	2.6	8.0	12.1	16.1	24.4	33.0	51.6	73.1
		0.3	-4.0	2.1	7.1	10.8	14.5	22.3	30.6	49.0	71.3
		0.4	-4.0	1.6	6.2	9.5	12.9	20.0	27.9	46.1	69.1
		0.5	-4.0	1.1	5.3	8.1	11.1	17.6	25.0	42.9	66.7
UK	**12.5**	0.0	12.5	14.6	16.7	18.6	20.5	24.4	30.6	40.8	49.0
		0.1	12.5	14.2	15.9	17.5	19.0	22.4	28.2	38.0	45.9
		0.2	12.5	13.8	15.0	16.3	17.5	20.2	25.6	34.8	42.4
		0.3	12.5	13.4	14.2	15.0	15.9	18.0	22.8	31.3	38.4
		0.4	12.5	12.9	13.4	13.8	14.2	15.6	19.9	27.4	33.9
		0.5	12.5	12.5	12.5	12.5	12.5	13.0	16.7	23.1	28.6
EU-15	**8.0**	**0.0**	**8.0**	**10.2**	**12.4**	**14.4**	**17.4**	**24.4**	**30.6**	**40.8**	**49.0**
		0.1	**8.0**	**9.8**	**11.5**	**13.2**	**15.8**	**22.4**	**28.2**	**38.0**	**45.9**
		0.2	**8.0**	**9.4**	**10.7**	**12.0**	**14.2**	**20.2**	**25.6**	**34.8**	**42.4**
		0.3	**8.0**	**8.9**	**9.8**	**10.7**	**12.6**	**18.0**	**22.8**	**31.3**	**38.4**
		0.4	**8.0**	**8.5**	**8.9**	**9.4**	**10.9**	**15.6**	**19.9**	**27.4**	**33.9**
		0.5	**8.0**	**8.0**	**8.0**	**8.0**	**9.1**	**13.0**	**16.7**	**23.1**	**28.6**

Table 8: The Und&VT concept applied to the EU-25 Member States (MS) and the EU-15 as a whole. The table lists the undershooting U (Eq. (6), (9), (13) and (17)) contained in the modified emission limitation or reduction targets δ_{mod} listed in Table 7.

MS	d_{KP}	*a*	Undershooting U in % for *r* =								
	%	1	0%	2.5%	5%	7.5%	10%	15%	20%	30%	40%
AT	**13.0**	0.0	0.0	2.1	4.1	6.1	7.9	11.4	17.6	27.8	36.0
		0.1	0.0	1.7	3.3	4.9	6.4	9.4	15.2	25.0	32.9
		0.2	0.0	1.3	2.5	3.7	4.9	7.2	12.6	21.8	29.4
		0.3	0.0	0.9	1.7	2.5	3.3	5.0	9.8	18.3	25.4
		0.4	0.0	0.4	0.9	1.3	1.7	2.6	6.9	14.4	20.9
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	3.7	10.1	15.6
BE	**7.5**	0.0	0.0	2.3	4.4	6.5	9.9	16.9	23.1	33.3	41.5
		0.1	0.0	1.8	3.6	5.2	8.3	14.9	20.7	30.5	38.4
		0.2	0.0	1.4	2.7	4.0	6.7	12.7	18.1	27.3	34.9
		0.3	0.0	0.9	1.8	2.7	5.1	10.5	15.3	23.8	30.9
		0.4	0.0	0.5	0.9	1.4	3.4	8.1	12.4	19.9	26.4
		0.5	0.0	0.0	0.0	0.0	1.6	5.5	9.2	15.6	21.1
CZ	**8.0**	0.0	0.0	2.2	4.4	6.4	9.4	16.4	22.6	32.8	41.0
		0.1	0.0	1.8	3.5	5.2	7.8	14.4	20.2	30.0	37.9
		0.2	0.0	1.4	2.7	4.0	6.2	12.2	17.6	26.8	34.4
		0.3	0.0	0.9	1.8	2.7	4.6	10.0	14.8	23.3	30.4
		0.4	0.0	0.5	0.9	1.4	2.9	7.6	11.9	19.4	25.9
		0.5	0.0	0.0	0.0	0.0	1.1	5.0	8.7	15.1	20.6
DK	**21.0**	0.0	0.0	1.9	3.8	5.5	7.2	10.3	13.2	19.8	28.0
		0.1	0.0	1.5	3.0	4.5	5.9	8.5	10.9	17.0	24.9
		0.2	0.0	1.2	2.3	3.4	4.5	6.5	8.5	13.8	21.4
		0.3	0.0	0.8	1.5	2.3	3.0	4.5	5.9	10.3	17.4
		0.4	0.0	0.4	0.8	1.2	1.5	2.3	3.0	6.4	12.9
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	7.6
EE	**8.0**	0.0	0.0	2.2	4.4	6.4	9.4	16.4	22.6	32.8	41.0
		0.1	0.0	1.8	3.5	5.2	7.8	14.4	20.2	30.0	37.9
		0.2	0.0	1.4	2.7	4.0	6.2	12.2	17.6	26.8	34.4
		0.3	0.0	0.9	1.8	2.7	4.6	10.0	14.8	23.3	30.4
		0.4	0.0	0.5	0.9	1.4	2.9	7.6	11.9	19.4	25.9
		0.5	0.0	0.0	0.0	0.0	1.1	5.0	8.7	15.1	20.6
FI	**0.0**	0.0	0.0	4.9	9.8	14.5	19.2	28.4	37.5	56.0	76.2
		0.1	0.0	4.5	8.9	13.3	17.7	26.5	35.3	53.9	74.7
		0.2	0.0	4.0	8.0	12.1	16.1	24.4	33.0	51.6	73.1
		0.3	0.0	3.5	7.1	10.8	14.5	22.3	30.6	49.0	71.3
		0.4	0.0	3.0	6.2	9.5	12.9	20.0	27.9	46.1	69.1
		0.5	0.0	2.6	5.3	8.1	11.1	17.6	25.0	42.9	66.7
FR	**0.0**	0.0	0.0	4.9	9.8	14.5	19.2	28.4	37.5	56.0	76.2
		0.1	0.0	4.5	8.9	13.3	17.7	26.5	35.3	53.9	74.7
		0.2	0.0	4.0	8.0	12.1	16.1	24.4	33.0	51.6	73.1
		0.3	0.0	3.5	7.1	10.8	14.5	22.3	30.6	49.0	71.3
		0.4	0.0	3.0	6.2	9.5	12.9	20.0	27.9	46.1	69.1
		0.5	0.0	2.6	5.3	8.1	11.1	17.6	25.0	42.9	66.7

Table 8: continued.

DE	**21.0**	0.0	0.0	1.9	3.8	5.5	7.2	10.3	13.2	19.8	28.0
		0.1	0.0	1.5	3.0	4.5	5.9	8.5	10.9	17.0	24.9
		0.2	0.0	1.2	2.3	3.4	4.5	6.5	8.5	13.8	21.4
		0.3	0.0	0.8	1.5	2.3	3.0	4.5	5.9	10.3	17.4
		0.4	0.0	0.4	0.8	1.2	1.5	2.3	3.0	6.4	12.9
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	7.6
GR	**-25.0**	0.0	0.0	8.1	16.0	23.8	31.6	47.0	62.5	81.0	101.2
		0.1	0.0	7.5	14.9	22.4	29.8	44.9	60.3	78.9	99.7
		0.2	0.0	6.9	13.9	20.9	28.0	42.7	58.0	76.6	98.1
		0.3	0.0	6.3	12.8	19.4	26.2	40.4	55.6	74.0	96.3
		0.4	0.0	5.7	11.7	17.8	24.2	37.9	52.9	71.1	94.1
		0.5	0.0	5.1	10.5	16.2	22.2	35.3	50.0	67.9	91.7
HU	**6.0**	0.0	0.0	2.3	4.5	7.5	11.4	18.4	24.6	34.8	43.0
		0.1	0.0	1.8	3.6	6.2	9.8	16.4	22.2	32.0	39.9
		0.2	0.0	1.4	2.7	5.0	8.2	14.2	19.6	28.8	36.4
		0.3	0.0	0.9	1.8	3.7	6.6	12.0	16.8	25.3	32.4
		0.4	0.0	0.5	0.9	2.4	4.9	9.6	13.9	21.4	27.9
		0.5	0.0	0.0	0.0	1.0	3.1	7.0	10.7	17.1	22.6
IE	**-13.0**	0.0	0.0	7.8	15.4	23.0	30.5	41.4	50.5	69.0	89.2
		0.1	0.0	7.2	14.5	21.7	28.9	39.5	48.3	66.9	87.7
		0.2	0.0	6.7	13.5	20.4	27.4	37.4	46.0	64.6	86.1
		0.3	0.0	6.2	12.5	19.0	25.7	35.3	43.6	62.0	84.3
		0.4	0.0	5.7	11.5	17.6	24.0	33.0	40.9	59.1	82.1
		0.5	0.0	5.1	10.5	16.2	22.2	30.6	38.0	55.9	79.7
IT	**6.5**	0.0	0.0	2.3	4.5	7.0	10.9	17.9	24.1	34.3	42.5
		0.1	0.0	1.8	3.6	5.7	9.3	15.9	21.7	31.5	39.4
		0.2	0.0	1.4	2.7	4.5	7.7	13.7	19.1	28.3	35.9
		0.3	0.0	0.9	1.8	3.2	6.1	11.5	16.3	24.8	31.9
		0.4	0.0	0.5	0.9	1.9	4.4	9.1	13.4	20.9	27.4
		0.5	0.0	0.0	0.0	0.5	2.6	6.5	10.2	16.6	22.1
LV	**8.0**	0.0	0.0	2.2	4.4	6.4	9.4	16.4	22.6	32.8	41.0
		0.1	0.0	1.8	3.5	5.2	7.8	14.4	20.2	30.0	37.9
		0.2	0.0	1.4	2.7	4.0	6.2	12.2	17.6	26.8	34.4
		0.3	0.0	0.9	1.8	2.7	4.6	10.0	14.8	23.3	30.4
		0.4	0.0	0.5	0.9	1.4	2.9	7.6	11.9	19.4	25.9
		0.5	0.0	0.0	0.0	0.0	1.1	5.0	8.7	15.1	20.6
LT	**8.0**	0.0	0.0	2.2	4.4	6.4	9.4	16.4	22.6	32.8	41.0
		0.1	0.0	1.8	3.5	5.2	7.8	14.4	20.2	30.0	37.9
		0.2	0.0	1.4	2.7	4.0	6.2	12.2	17.6	26.8	34.4
		0.3	0.0	0.9	1.8	2.7	4.6	10.0	14.8	23.3	30.4
		0.4	0.0	0.5	0.9	1.4	2.9	7.6	11.9	19.4	25.9
		0.5	0.0	0.0	0.0	0.0	1.1	5.0	8.7	15.1	20.6
LU	**28.0**	0.0	0.0	1.8	3.4	5.0	6.5	9.4	12.0	16.6	21.0
		0.1	0.0	1.4	2.8	4.1	5.3	7.7	9.9	13.9	17.9
		0.2	0.0	1.1	2.1	3.1	4.1	5.9	7.7	11.0	14.4
		0.3	0.0	0.7	1.4	2.1	2.8	4.1	5.3	7.7	10.4
		0.4	0.0	0.4	0.7	1.1	1.4	2.1	2.8	4.1	5.9
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
NL	**6.0**	0.0	0.0	2.3	4.5	7.5	11.4	18.4	24.6	34.8	43.0
		0.1	0.0	1.8	3.6	6.2	9.8	16.4	22.2	32.0	39.9
		0.2	0.0	1.4	2.7	5.0	8.2	14.2	19.6	28.8	36.4
		0.3	0.0	0.9	1.8	3.7	6.6	12.0	16.8	25.3	32.4
		0.4	0.0	0.5	0.9	2.4	4.9	9.6	13.9	21.4	27.9
		0.5	0.0	0.0	0.0	1.0	3.1	7.0	10.7	17.1	22.6

Table 8: continued.

PL	**6.0**	0.0	0.0	2.3	4.5	7.5	11.4	18.4	24.6	34.8	43.0
		0.1	0.0	1.8	3.6	6.2	9.8	16.4	22.2	32.0	39.9
		0.2	0.0	1.4	2.7	5.0	8.2	14.2	19.6	28.8	36.4
		0.3	0.0	0.9	1.8	3.7	6.6	12.0	16.8	25.3	32.4
		0.4	0.0	0.5	0.9	2.4	4.9	9.6	13.9	21.4	27.9
		0.5	0.0	0.0	0.0	1.0	3.1	7.0	10.7	17.1	22.6
PT	**-27.0**	0.0	0.0	8.1	16.1	23.9	31.7	47.3	62.8	83.0	103.2
		0.1	0.0	7.5	15.0	22.5	30.0	45.1	60.6	80.9	101.7
		0.2	0.0	6.9	13.9	21.0	28.2	42.9	58.3	78.6	100.1
		0.3	0.0	6.3	12.8	19.4	26.3	40.5	55.7	76.0	98.3
		0.4	0.0	5.7	11.7	17.9	24.3	38.0	53.0	73.1	96.1
		0.5	0.0	5.1	10.5	16.2	22.2	35.3	50.0	69.9	93.7
SK	**8.0**	0.0	0.0	2.2	4.4	6.4	9.4	16.4	22.6	32.8	41.0
		0.1	0.0	1.8	3.5	5.2	7.8	14.4	20.2	30.0	37.9
		0.2	0.0	1.4	2.7	4.0	6.2	12.2	17.6	26.8	34.4
		0.3	0.0	0.9	1.8	2.7	4.6	10.0	14.8	23.3	30.4
		0.4	0.0	0.5	0.9	1.4	2.9	7.6	11.9	19.4	25.9
		0.5	0.0	0.0	0.0	0.0	1.1	5.0	8.7	15.1	20.6
SI	**8.0**	0.0	0.0	2.2	4.4	6.4	9.4	16.4	22.6	32.8	41.0
		0.1	0.0	1.8	3.5	5.2	7.8	14.4	20.2	30.0	37.9
		0.2	0.0	1.4	2.7	4.0	6.2	12.2	17.6	26.8	34.4
		0.3	0.0	0.9	1.8	2.7	4.6	10.0	14.8	23.3	30.4
		0.4	0.0	0.5	0.9	1.4	2.9	7.6	11.9	19.4	25.9
		0.5	0.0	0.0	0.0	0.0	1.1	5.0	8.7	15.1	20.6
ES	**-15.0**	0.0	0.0	7.8	15.5	23.1	30.7	43.4	52.5	71.0	91.2
		0.1	0.0	7.3	14.5	21.8	29.1	41.5	50.3	68.9	89.7
		0.2	0.0	6.8	13.6	20.5	27.5	39.4	48.0	66.6	88.1
		0.3	0.0	6.2	12.6	19.1	25.8	37.3	45.6	64.0	86.3
		0.4	0.0	5.7	11.6	17.7	24.0	35.0	42.9	61.1	84.1
		0.5	0.0	5.1	10.5	16.2	22.2	32.6	40.0	57.9	81.7
SE	**-4.0**	0.0	0.0	7.5	13.8	18.5	23.2	32.4	41.5	60.0	80.2
		0.1	0.0	7.1	12.9	17.3	21.7	30.5	39.3	57.9	78.7
		0.2	0.0	6.6	12.0	16.1	20.1	28.4	37.0	55.6	77.1
		0.3	0.0	6.1	11.1	14.8	18.5	26.3	34.6	53.0	75.3
		0.4	0.0	5.6	10.2	13.5	16.9	24.0	31.9	50.1	73.1
		0.5	0.0	5.1	9.3	12.1	15.1	21.6	29.0	46.9	70.7
UK	**12.5**	0.0	0.0	2.1	4.2	6.1	8.0	11.9	18.1	28.3	36.5
		0.1	0.0	1.7	3.4	5.0	6.5	9.9	15.7	25.5	33.4
		0.2	0.0	1.3	2.5	3.8	5.0	7.7	13.1	22.3	29.9
		0.3	0.0	0.9	1.7	2.5	3.4	5.5	10.3	18.8	25.9
		0.4	0.0	0.4	0.9	1.3	1.7	3.1	7.4	14.9	21.4
		0.5	0.0	0.0	0.0	0.0	0.0	0.5	4.2	10.6	16.1
EU-15	**8.0**	0.0	0.0	2.2	4.4	6.4	9.4	16.4	22.6	32.8	41.0
		0.1	0.0	1.8	3.5	5.2	7.8	14.4	20.2	30.0	37.9
		0.2	0.0	1.4	2.7	4.0	6.2	12.2	17.6	26.8	34.4
		0.3	0.0	0.9	1.8	2.7	4.6	10.0	14.8	23.3	30.4
		0.4	0.0	0.5	0.9	1.4	2.9	7.6	11.9	19.4	25.9
		0.5	0.0	0.0	0.0	0.0	1.1	5.0	8.7	15.1	20.6

Table 9: The undershooting U (as well as the Member States' agreed δ_{KP} values) listed in Table 8 multiplied with the factor $(-14/20)$ to reconcile the Und&VT concept with the emissions reporting for the EU and to establish the linear path emission targets and undershooting opportunities for 2004.

MS	d_{KP_04}	a	**Undershooting U in % for** r =								
	%	1	**0%**	**2.5%**	**5%**	**7.5%**	**10%**	**15%**	**20%**	**30%**	**40%**
AT	**-9.1**	0.0	0.0	-1.5	-2.9	-4.2	-5.5	-8.0	-12.3	-19.5	-25.2
		0.1	0.0	-1.2	-2.3	-3.4	-4.5	-6.6	-10.6	-17.5	-23.0
		0.2	0.0	-0.9	-1.8	-2.6	-3.4	-5.1	-8.8	-15.3	-20.6
		0.3	0.0	-0.6	-1.2	-1.8	-2.3	-3.5	-6.9	-12.8	-17.8
		0.4	0.0	-0.3	-0.6	-0.9	-1.2	-1.8	-4.8	-10.1	-14.6
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	-2.6	-7.1	-10.9
BE	**-5.3**	0.0	0.0	-1.6	-3.1	-4.5	-6.9	-11.8	-16.1	-23.3	-29.0
		0.1	0.0	-1.3	-2.5	-3.7	-5.8	-10.4	-14.5	-21.3	-26.9
		0.2	0.0	-1.0	-1.9	-2.8	-4.7	-8.9	-12.7	-19.1	-24.4
		0.3	0.0	-0.6	-1.3	-1.9	-3.6	-7.3	-10.7	-16.7	-21.6
		0.4	0.0	-0.3	-0.6	-1.0	-2.4	-5.7	-8.7	-14.0	-18.5
		0.5	0.0	0.0	0.0	0.0	-1.1	-3.9	-6.4	-10.9	-14.8
CZ	**-5.6**	0.0	0.0	-1.6	-3.1	-4.5	-6.5	-11.5	-15.8	-23.0	-28.7
		0.1	0.0	-1.3	-2.5	-3.6	-5.5	-10.1	-14.1	-21.0	-26.5
		0.2	0.0	-1.0	-1.9	-2.8	-4.4	-8.6	-12.3	-18.8	-24.1
		0.3	0.0	-0.6	-1.3	-1.9	-3.2	-7.0	-10.4	-16.3	-21.3
		0.4	0.0	-0.3	-0.6	-1.0	-2.0	-5.3	-8.3	-13.6	-18.1
		0.5	0.0	0.0	0.0	0.0	-0.8	-3.5	-6.1	-10.6	-14.4
DK	**-14.7**	0.0	0.0	-1.3	-2.6	-3.9	-5.0	-7.2	-9.2	-13.9	-19.6
		0.1	0.0	-1.1	-2.1	-3.1	-4.1	-5.9	-7.6	-11.9	-17.4
		0.2	0.0	-0.8	-1.6	-2.4	-3.1	-4.6	-5.9	-9.7	-15.0
		0.3	0.0	-0.5	-1.1	-1.6	-2.1	-3.1	-4.1	-7.2	-12.2
		0.4	0.0	-0.3	-0.5	-0.8	-1.1	-1.6	-2.1	-4.5	-9.0
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.5	-5.3
EE	**-5.6**	0.0	0.0	-1.6	-3.1	-4.5	-6.5	-11.5	-15.8	-23.0	-28.7
		0.1	0.0	-1.3	-2.5	-3.6	-5.5	-10.1	-14.1	-21.0	-26.5
		0.2	0.0	-1.0	-1.9	-2.8	-4.4	-8.6	-12.3	-18.8	-24.1
		0.3	0.0	-0.6	-1.3	-1.9	-3.2	-7.0	-10.4	-16.3	-21.3
		0.4	0.0	-0.3	-0.6	-1.0	-2.0	-5.3	-8.3	-13.6	-18.1
		0.5	0.0	0.0	0.0	0.0	-0.8	-3.5	-6.1	-10.6	-14.4
FI	**0.0**	0.0	0.0	-3.5	-6.8	-10.2	-13.4	-19.9	-26.3	-39.2	-53.3
		0.1	0.0	-3.1	-6.2	-9.3	-12.4	-18.5	-24.7	-37.7	-52.3
		0.2	0.0	-2.8	-5.6	-8.4	-11.3	-17.1	-23.1	-36.1	-51.2
		0.3	0.0	-2.5	-5.0	-7.5	-10.2	-15.6	-21.4	-34.3	-49.9
		0.4	0.0	-2.1	-4.3	-6.6	-9.0	-14.0	-19.5	-32.3	-48.4
		0.5	0.0	-1.8	-3.7	-5.7	-7.8	-12.4	-17.5	-30.0	-46.7
FR	**0.0**	0.0	0.0	-3.5	-6.8	-10.2	-13.4	-19.9	-26.3	-39.2	-53.3
		0.1	0.0	-3.1	-6.2	-9.3	-12.4	-18.5	-24.7	-37.7	-52.3
		0.2	0.0	-2.8	-5.6	-8.4	-11.3	-17.1	-23.1	-36.1	-51.2
		0.3	0.0	-2.5	-5.0	-7.5	-10.2	-15.6	-21.4	-34.3	-49.9
		0.4	0.0	-2.1	-4.3	-6.6	-9.0	-14.0	-19.5	-32.3	-48.4
		0.5	0.0	-1.8	-3.7	-5.7	-7.8	-12.4	-17.5	-30.0	-46.7

Table 9: continued.

DE	**-14.7**	0.0	0.0	-1.3	-2.6	-3.9	-5.0	-7.2	-9.2	-13.9	-19.6
		0.1	0.0	-1.1	-2.1	-3.1	-4.1	-5.9	-7.6	-11.9	-17.4
		0.2	0.0	-0.8	-1.6	-2.4	-3.1	-4.6	-5.9	-9.7	-15.0
		0.3	0.0	-0.5	-1.1	-1.6	-2.1	-3.1	-4.1	-7.2	-12.2
		0.4	0.0	-0.3	-0.5	-0.8	-1.1	-1.6	-2.1	-4.5	-9.0
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.5	-5.3
GR	**17.5**	0.0	0.0	-5.6	-11.2	-16.7	-22.1	-32.9	-43.8	-56.7	-70.8
		0.1	0.0	-5.2	-10.5	-15.7	-20.9	-31.4	-42.2	-55.2	-69.8
		0.2	0.0	-4.8	-9.7	-14.6	-19.6	-29.9	-40.6	-53.6	-68.7
		0.3	0.0	-4.4	-8.9	-13.6	-18.3	-28.3	-38.9	-51.8	-67.4
		0.4	0.0	-4.0	-8.2	-12.5	-17.0	-26.5	-37.0	-49.8	-65.9
		0.5	0.0	-3.6	-7.4	-11.4	-15.6	-24.7	-35.0	-47.5	-64.2
HU	**-4.2**	0.0	0.0	-1.6	-3.1	-5.2	-7.9	-12.9	-17.2	-24.4	-30.1
		0.1	0.0	-1.3	-2.5	-4.4	-6.9	-11.5	-15.5	-22.4	-27.9
		0.2	0.0	-1.0	-1.9	-3.5	-5.8	-10.0	-13.7	-20.2	-25.5
		0.3	0.0	-0.7	-1.3	-2.6	-4.6	-8.4	-11.8	-17.7	-22.7
		0.4	0.0	-0.3	-0.7	-1.6	-3.4	-6.7	-9.7	-15.0	-19.5
		0.5	0.0	0.0	0.0	-0.7	-2.2	-4.9	-7.5	-12.0	-15.8
IE	**9.1**	0.0	0.0	-5.4	-10.8	-16.1	-21.3	-29.0	-35.4	-48.3	-62.4
		0.1	0.0	-5.1	-10.1	-15.2	-20.3	-27.6	-33.8	-46.8	-61.4
		0.2	0.0	-4.7	-9.5	-14.3	-19.2	-26.2	-32.2	-45.2	-60.3
		0.3	0.0	-4.3	-8.8	-13.3	-18.0	-24.7	-30.5	-43.4	-59.0
		0.4	0.0	-4.0	-8.1	-12.4	-16.8	-23.1	-28.6	-41.4	-57.5
		0.5	0.0	-3.6	-7.4	-11.4	-15.6	-21.5	-26.6	-39.1	-55.8
IT	**-4.6**	0.0	0.0	-1.6	-3.1	-4.9	-7.6	-12.5	-16.8	-24.0	-29.7
		0.1	0.0	-1.3	-2.5	-4.0	-6.5	-11.1	-15.2	-22.0	-27.6
		0.2	0.0	-1.0	-1.9	-3.1	-5.4	-9.6	-13.4	-19.8	-25.1
		0.3	0.0	-0.6	-1.3	-2.2	-4.3	-8.0	-11.4	-17.4	-22.3
		0.4	0.0	-0.3	-0.6	-1.3	-3.1	-6.4	-9.4	-14.7	-19.2
		0.5	0.0	0.0	0.0	-0.3	-1.8	-4.6	-7.1	-11.6	-15.5
LV	**-5.6**	0.0	0.0	-1.6	-3.1	-4.5	-6.5	-11.5	-15.8	-23.0	-28.7
		0.1	0.0	-1.3	-2.5	-3.6	-5.5	-10.1	-14.1	-21.0	-26.5
		0.2	0.0	-1.0	-1.9	-2.8	-4.4	-8.6	-12.3	-18.8	-24.1
		0.3	0.0	-0.6	-1.3	-1.9	-3.2	-7.0	-10.4	-16.3	-21.3
		0.4	0.0	-0.3	-0.6	-1.0	-2.0	-5.3	-8.3	-13.6	-18.1
		0.5	0.0	0.0	0.0	0.0	-0.8	-3.5	-6.1	-10.6	-14.4
LT	**-5.6**	0.0	0.0	-1.6	-3.1	-4.5	-6.5	-11.5	-15.8	-23.0	-28.7
		0.1	0.0	-1.3	-2.5	-3.6	-5.5	-10.1	-14.1	-21.0	-26.5
		0.2	0.0	-1.0	-1.9	-2.8	-4.4	-8.6	-12.3	-18.8	-24.1
		0.3	0.0	-0.6	-1.3	-1.9	-3.2	-7.0	-10.4	-16.3	-21.3
		0.4	0.0	-0.3	-0.6	-1.0	-2.0	-5.3	-8.3	-13.6	-18.1
		0.5	0.0	0.0	0.0	0.0	-0.8	-3.5	-6.1	-10.6	-14.4
LU	**-19.6**	0.0	0.0	-1.2	-2.4	-3.5	-4.6	-6.6	-8.4	-11.6	-14.7
		0.1	0.0	-1.0	-1.9	-2.9	-3.7	-5.4	-7.0	-9.8	-12.5
		0.2	0.0	-0.7	-1.5	-2.2	-2.9	-4.2	-5.4	-7.7	-10.1
		0.3	0.0	-0.5	-1.0	-1.5	-1.9	-2.9	-3.7	-5.4	-7.3
		0.4	0.0	-0.3	-0.5	-0.7	-1.0	-1.5	-1.9	-2.9	-4.1
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4
NL	**-4.2**	0.0	0.0	-1.6	-3.1	-5.2	-7.9	-12.9	-17.2	-24.4	-30.1
		0.1	0.0	-1.3	-2.5	-4.4	-6.9	-11.5	-15.5	-22.4	-27.9
		0.2	0.0	-1.0	-1.9	-3.5	-5.8	-10.0	-13.7	-20.2	-25.5
		0.3	0.0	-0.7	-1.3	-2.6	-4.6	-8.4	-11.8	-17.7	-22.7
		0.4	0.0	-0.3	-0.7	-1.6	-3.4	-6.7	-9.7	-15.0	-19.5
		0.5	0.0	0.0	0.0	-0.7	-2.2	-4.9	-7.5	-12.0	-15.8

Table 9: continued.

PL	**-4.2**	0.0	0.0	-1.6	-3.1	-5.2	-7.9	-12.9	-17.2	-24.4	-30.1
		0.1	0.0	-1.3	-2.5	-4.4	-6.9	-11.5	-15.5	-22.4	-27.9
		0.2	0.0	-1.0	-1.9	-3.5	-5.8	-10.0	-13.7	-20.2	-25.5
		0.3	0.0	-0.7	-1.3	-2.6	-4.6	-8.4	-11.8	-17.7	-22.7
		0.4	0.0	-0.3	-0.7	-1.6	-3.4	-6.7	-9.7	-15.0	-19.5
		0.5	0.0	0.0	0.0	-0.7	-2.2	-4.9	-7.5	-12.0	-15.8
PT	**18.9**	0.0	0.0	-5.7	-11.3	-16.8	-22.2	-33.1	-44.0	-58.1	-72.2
		0.1	0.0	-5.3	-10.5	-15.7	-21.0	-31.6	-42.4	-56.6	-71.2
		0.2	0.0	-4.9	-9.7	-14.7	-19.7	-30.0	-40.8	-55.0	-70.1
		0.3	0.0	-4.4	-9.0	-13.6	-18.4	-28.3	-39.0	-53.2	-68.8
		0.4	0.0	-4.0	-8.2	-12.5	-17.0	-26.6	-37.1	-51.2	-67.3
		0.5	0.0	-3.6	-7.4	-11.4	-15.6	-24.7	-35.0	-48.9	-65.6
SK	**-5.6**	0.0	0.0	-1.6	-3.1	-4.5	-6.5	-11.5	-15.8	-23.0	-28.7
		0.1	0.0	-1.3	-2.5	-3.6	-5.5	-10.1	-14.1	-21.0	-26.5
		0.2	0.0	-1.0	-1.9	-2.8	-4.4	-8.6	-12.3	-18.8	-24.1
		0.3	0.0	-0.6	-1.3	-1.9	-3.2	-7.0	-10.4	-16.3	-21.3
		0.4	0.0	-0.3	-0.6	-1.0	-2.0	-5.3	-8.3	-13.6	-18.1
		0.5	0.0	0.0	0.0	0.0	-0.8	-3.5	-6.1	-10.6	-14.4
SI	**-5.6**	0.0	0.0	-1.6	-3.1	-4.5	-6.5	-11.5	-15.8	-23.0	-28.7
		0.1	0.0	-1.3	-2.5	-3.6	-5.5	-10.1	-14.1	-21.0	-26.5
		0.2	0.0	-1.0	-1.9	-2.8	-4.4	-8.6	-12.3	-18.8	-24.1
		0.3	0.0	-0.6	-1.3	-1.9	-3.2	-7.0	-10.4	-16.3	-21.3
		0.4	0.0	-0.3	-0.6	-1.0	-2.0	-5.3	-8.3	-13.6	-18.1
		0.5	0.0	0.0	0.0	0.0	-0.8	-3.5	-6.1	-10.6	-14.4
ES	**10.5**	0.0	0.0	-5.5	-10.9	-16.2	-21.5	-30.4	-36.8	-49.7	-63.8
		0.1	0.0	-5.1	-10.2	-15.3	-20.4	-29.0	-35.2	-48.2	-62.8
		0.2	0.0	-4.7	-9.5	-14.3	-19.2	-27.6	-33.6	-46.6	-61.7
		0.3	0.0	-4.4	-8.8	-13.4	-18.1	-26.1	-31.9	-44.8	-60.4
		0.4	0.0	-4.0	-8.1	-12.4	-16.8	-24.5	-30.0	-42.8	-58.9
		0.5	0.0	-3.6	-7.4	-11.4	-15.6	-22.9	-28.0	-40.5	-57.2
SE	**2.8**	0.0	0.0	-5.3	-9.6	-13.0	-16.2	-22.7	-29.1	-42.0	-56.1
		0.1	0.0	-4.9	-9.0	-12.1	-15.2	-21.3	-27.5	-40.5	-55.1
		0.2	0.0	-4.6	-8.4	-11.2	-14.1	-19.9	-25.9	-38.9	-54.0
		0.3	0.0	-4.3	-7.8	-10.3	-13.0	-18.4	-24.2	-37.1	-52.7
		0.4	0.0	-3.9	-7.1	-9.4	-11.8	-16.8	-22.3	-35.1	-51.2
		0.5	0.0	-3.6	-6.5	-8.5	-10.6	-15.2	-20.3	-32.8	-49.5
UK	**-8.8**	0.0	0.0	-1.5	-2.9	-4.3	-5.6	-8.3	-12.6	-19.8	-25.5
		0.1	0.0	-1.2	-2.4	-3.5	-4.5	-6.9	-11.0	-17.8	-23.4
		0.2	0.0	-0.9	-1.8	-2.6	-3.5	-5.4	-9.2	-15.6	-20.9
		0.3	0.0	-0.6	-1.2	-1.8	-2.4	-3.8	-7.2	-13.2	-18.1
		0.4	0.0	-0.3	-0.6	-0.9	-1.2	-2.2	-5.2	-10.5	-15.0
		0.5	0.0	0.0	0.0	0.0	0.0	-0.4	-2.9	-7.4	-11.3
EU-15	**-5.6**	0.0	0.0	-1.6	-3.1	-4.5	-6.5	-11.5	-15.8	-23.0	-28.7
		0.1	0.0	-1.3	-2.5	-3.6	-5.5	-10.1	-14.1	-21.0	-26.5
		0.2	0.0	-1.0	-1.9	-2.8	-4.4	-8.6	-12.3	-18.8	-24.1
		0.3	0.0	-0.6	-1.3	-1.9	-3.2	-7.0	-10.4	-16.3	-21.3
		0.4	0.0	-0.3	-0.6	-1.0	-2.0	-5.3	-8.3	-13.6	-18.1
		0.5	0.0	0.0	0.0	0.0	-0.8	-3.5	-6.1	-10.6	-14.4

4 Interpretation of Results and Conclusions

To interpret the results for 2004, the following are displayed:

(I) U by ρ with a as a parameter;
i.e., the Member States' undershooting U that matches the relative uncertainty r in the intervals $[0,5[$, $[5,10[$, $[10,20[$ and $[20,40[$%, while the risk α takes on the values 0, 0.1, …, 0.5.

(II) U by a with ρ as a parameter;
i.e., the Member States' undershooting U that matches the risk $\alpha = 0.5$ and α in the intervals $[0.4,0.5[$, $[0.3,0.4[$, $[0.2,0.3[$, $[0.1,0.2[$ and $[0,0.1[$, while the relative uncertainty r takes on the values 5, 10, 20 and 40%.

With respect to ρ, Jonas and Nilsson (2001: Section 4.1.3) recommend the application of relative uncertainty classes as a common good practice measure. The classes constitute a robust means to get an effective grip on uncertainties in light of the numerous data limitations and intra and inter-country inconsistencies, which do not justify the reporting of exact relative uncertainties. The procedure with respect to a is similar.

The DTIs displayed in Figure 2 are always shown to contrast the Member States' linear path emission targets and undershooting opportunities for the year 2004 with their actual emission situation in that year.

<u>*(I) U by ρ with α as a parameter.*</u> Figure 5 displays U by ρ for $a = 0.5$. For this α value, U equals zero (Case 1: Eq. (6)) or $U_{Gap} > 0$ (Cases 2–4: Eq. (9), (13) and (17) in which U_{Gap} is > 0 because Eq. (9), (13) and (17) have not yet been multiplied with the factor $(-14/20)$). U_{Gap} is the initial or obligatory undershooting that is required to achieve detectability before the Member States are permitted to make economic use of any excess emission reductions.

U_{Gap} is a function of δ_{crit} (Eq. (10), (14) and (18)) and thus of ρ (Eq. (1)). This explains the different initial or obligatory undershooting that Member States have to fulfill in dependence of the relative uncertainty with which they report their emissions. Of interest here are the eleven countries that exhibit a negative DTI: CZ, DE, EE, FR, HU, LV, LT, PL, SE, SK and the UK (Figure 2). Given $a = 0.5$, LV, LT, EE, PL, HU, SK and CZ are the best potential sellers followed by DE, the UK, SE and FR (Figure 5). LV, LT, EE, PL, HU, SK and CZ can report with a relative uncertainty > 40% and still exhibit a detectable signal; while DE and the UK must report within the 20–40% relative uncertainty class (more exactly: up to 34% and 26%, respectively), and both SE and FR within the 0–5% relative uncertainty class (more exactly: up to 4.8% and 1.6% respectively).[9]

Figures 6–10 display U by ρ for $a = 0.4,...,0.0$. These figures can be interpreted similarly to Figure 5, bearing in mind that U increases in absolute terms with decreasing a. For $a = 0.0$ (Figure 10), LV, LT, and EE can still report with a relative uncertainty

> 40%; while PL, HU, SK and CZ must report within the 20–40% relative uncertainty class (more exactly: up to 39%, 35%, 33% and 25%, respectively); the UK within the 10–20% relative uncertainty class (more exactly: up to 11%); DE within the 5–10% relative uncertainty class (more exactly: up to 6%); and both SE and FR within the 0–5% relative uncertainty class (more exactly: up to 3% and 0.8%, respectively).[10]

<u>*(II) U by a with ρ as a parameter.*</u> Figure 11 displays U by a for $r = 5\%$. For this r value, a white bar or, equivalently, a $U_{Gap} < 0$ (i.e., > 0 if the factor $(-14/20)$ is disregarded) appears only for Member States that agreed to emission limitation (ES, FI, FR, GR, IE, PT and SE; see Table 1). A $U_{Gap} < 0$ satisfies the demand for detectable signals. As it becomes obvious, the white bars represent the major part of U. Their length is equivalent to the length of the green bars in Figure 5.

With increasing r (Figures 12–14), an increasing number of Member States that agreed to emission reduction also exhibit a $U_{Gap} < 0$, for $r = 40\%$ eventually all of them (Figure 14). For $r = 10\%$, the length of the white bars is equivalent to the combined length of the green and yellow bars in Figure 5; and so on until Figure 14 ($r = 40\%$), where the length of the white bars is equivalent to the combined length of the green, yellow, orange and red bars in Figure 5. In general, Figures 12–14 resolve U_{Gap} better than the remainder of U.

Here, interpretation I (U by r with a as a parameter; Figures 5–10) is preferred over interpretation II (U by a with r as a parameter; Figures 11–14), as the use of a instead of r as a parameter appears to be more readily acceptable. Nevertheless, Figures 11–14 are well suited to quickly survey U_{Gap} and analyze which Member State with a negative DTI meets U_{Gap} for a given r. (The UK, e.g., meets U_{Gap} for $r = 20\%$ but not any more for $r = 40\%$; Figures 13 and 14.)

The following four conclusions emerge from this study:

(1) Jonas *et al.* (2004a) motivated the application of preparatory signal detection in the context of the Kyoto Protocol as a necessary measure that should have been taken prior to/in negotiating the Protocol. To these ends, the authors have applied four preparatory signal analysis techniques to the Annex B countries under the Kyoto Protocol. The frame of reference for preparatory signal detection is that Annex B countries comply with their agreed emission targets in 2008–2012. By contrast, in this study one of these techniques, the Und&VT concept, is applied to the old and new Member States of the European Union under EU burden sharing in compliance with the Kyoto Protocol, but with reference to the linear path (base year–commitment year) emission targets as of 2004. The exercise shows that preparatory signal detection can also be applied in connection with intermediate emission targets.

(2) To advance the reporting of the EU, uncertainty and its consequences are taken into consideration in addition to the DTI, i.e., (i) the risk that a Member State's true emissions in the commitment year/period are above its true emission limitation or reduction commitment (true emission target); and (ii) the detectability of the

Member State's agreed emission target. It is anticipated that the evaluation of emission signals in terms of risk and detectability will become standard practice and that these two qualifiers will be accounted for in pricing GHG emission permits.

(3) In 2004, eleven EU-25 Member States exhibit a negative DTI and thus appear as potential sellers: CZ, DE, EE, FR, HU, LT, LV, PL, SE, SK, and the UK (Figure 2). However, expecting that all of the EU Member States will eventually exhibit relative uncertainties in the range of 5–10% and above rather than below excluding LUCF and Kyoto mechanisms (cf. Table 2: quantified uncertainty estimates are only available from thirteen old and five new EU-25 Member States), the Member States require considerable undershooting of their EU-compatible, but detectable, targets if one wants to keep the risk low ($\alpha \approx 0.1$) that the Member States' true emissions in the commitment year/period fall above their true emission targets. These conditions are met differently: Potential low-risk sellers (cf. Figure 9: ranked in terms of credibility) are LV, LT, EE and PL which can even report with a relative uncertainty > 40% and still exhibit a detectable signal; while HU, SK and CZ, and the UK can still report within the 20–40% and 10–20% relative uncertainty class, respectively. In contrast, DE, SE and FR can only act as potential sellers with a higher risk: DE only with $\alpha \approx 0.25$ within the 10–20% relative uncertainty class (Figures 7, 8); and SE and FR only with $\alpha = 0.5$ within the 0–5% relative uncertainty class (Figure 5). The other EU-25 Member States exhibit positive DTIs, i.e., they do not meet their linear path (base year–commitment year) emission targets as of 2004, or do not have Kyoto targets at all (CY and MT).

(4) The Und&VT concept requires detectable signals. Measuring emission reductions negatively and emission increases positively (i.e., in line with the reporting for the EU), it can be stated that the greater the agreed emission limitation or reduction targets d_{KP} and the greater the relative uncertainty ρ, with which Member States report their emissions, the smaller the initial or obligatory undershooting U_{Gap} is (i.e., increasingly negative) to achieve detectability. That is, for $r = 5\%$ only the Member States agreed to emission limitation (ES, FI, FR, GR, IE, PT and SE) require a $U_{Gap} < 0$. For these Member States, U_{Gap} represents the major part of the undershooting U (Figure 11). For $r = 10\%$, BE, IT, the NL, SI as well as the EU-15 also require a $U_{Gap} < 0$ (Figure 12 with the focus on Member States with $U_{Gap} < \mathrm{DTI}$), indicating that somewhere within the 5–10% relative uncertainty range non-detectability will become a problem also for these Member States. The maximal (critical) relative uncertainties, with which they can report their emissions without compromising detectability, can be determined (Jonas *et al.*, 2004a: Section 3.1); these are, in absolute terms and with reference to 2010, 8.1% (BE), 7.0% (IT), 6.4% (NL) and 8.7% (SI and EU-15), respectively, assuming that the emission limitation or reduction targets are met under EU burden sharing in compliance with the Kyoto Protocol. From these numbers it becomes clear that the negotiations for the Kyoto Protocol were imprudent because they did not consider the consequences of uncertainty.

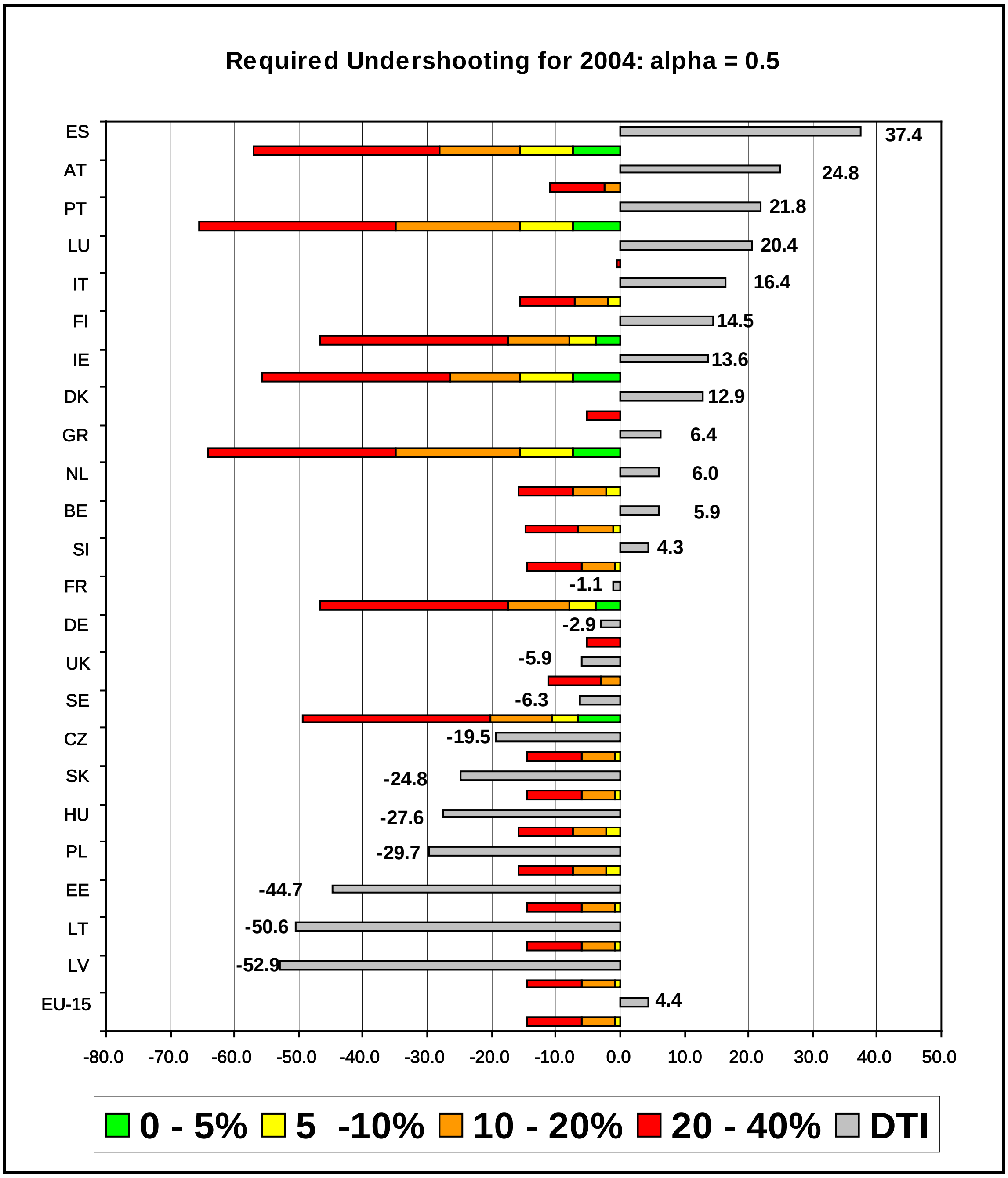

Figure 5: U by r (see intervals) for $a = 0.5$ in addition to the DTI.

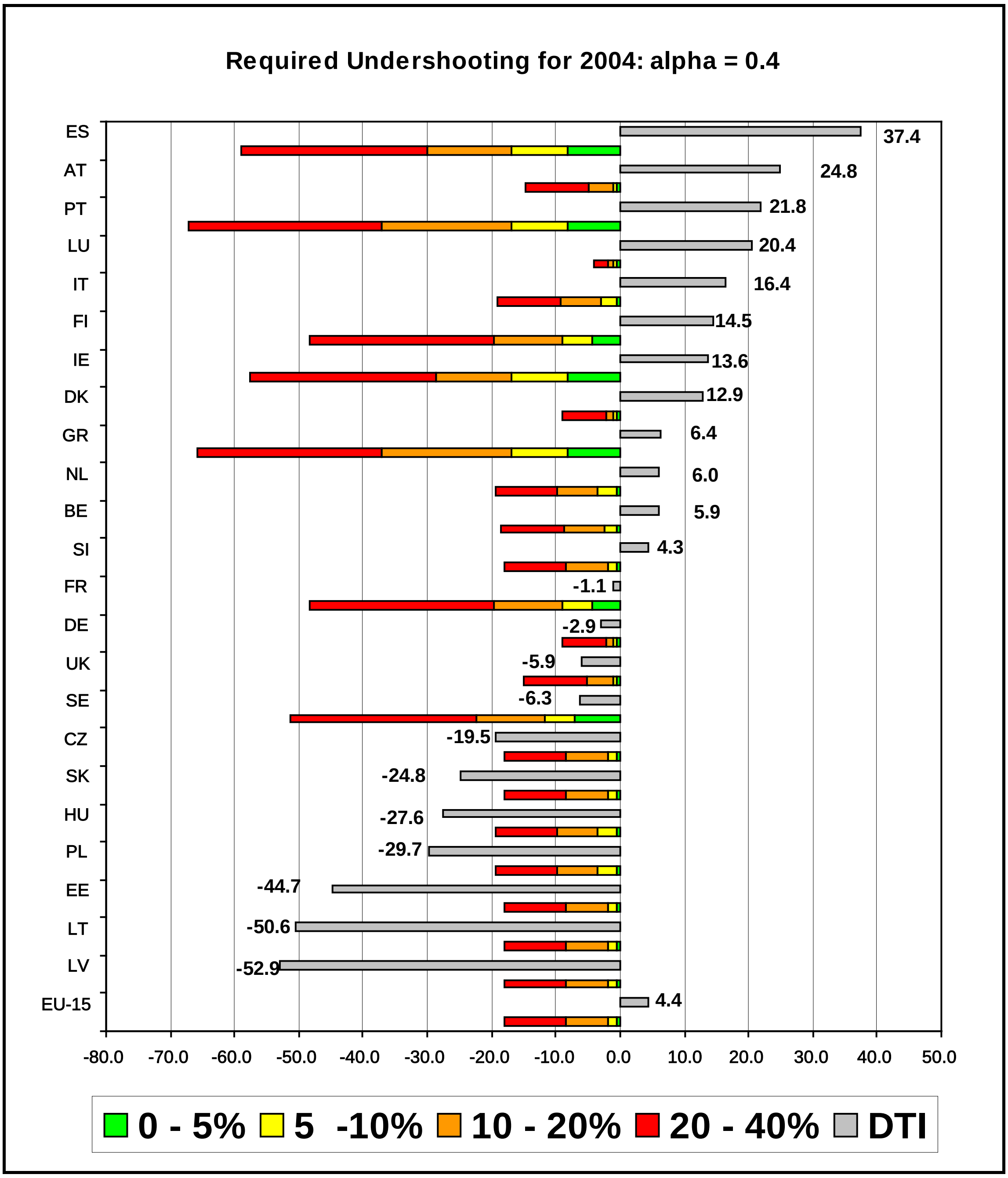

Figure 6: U by r (see intervals) for $a = 0.4$ in addition to the DTI.

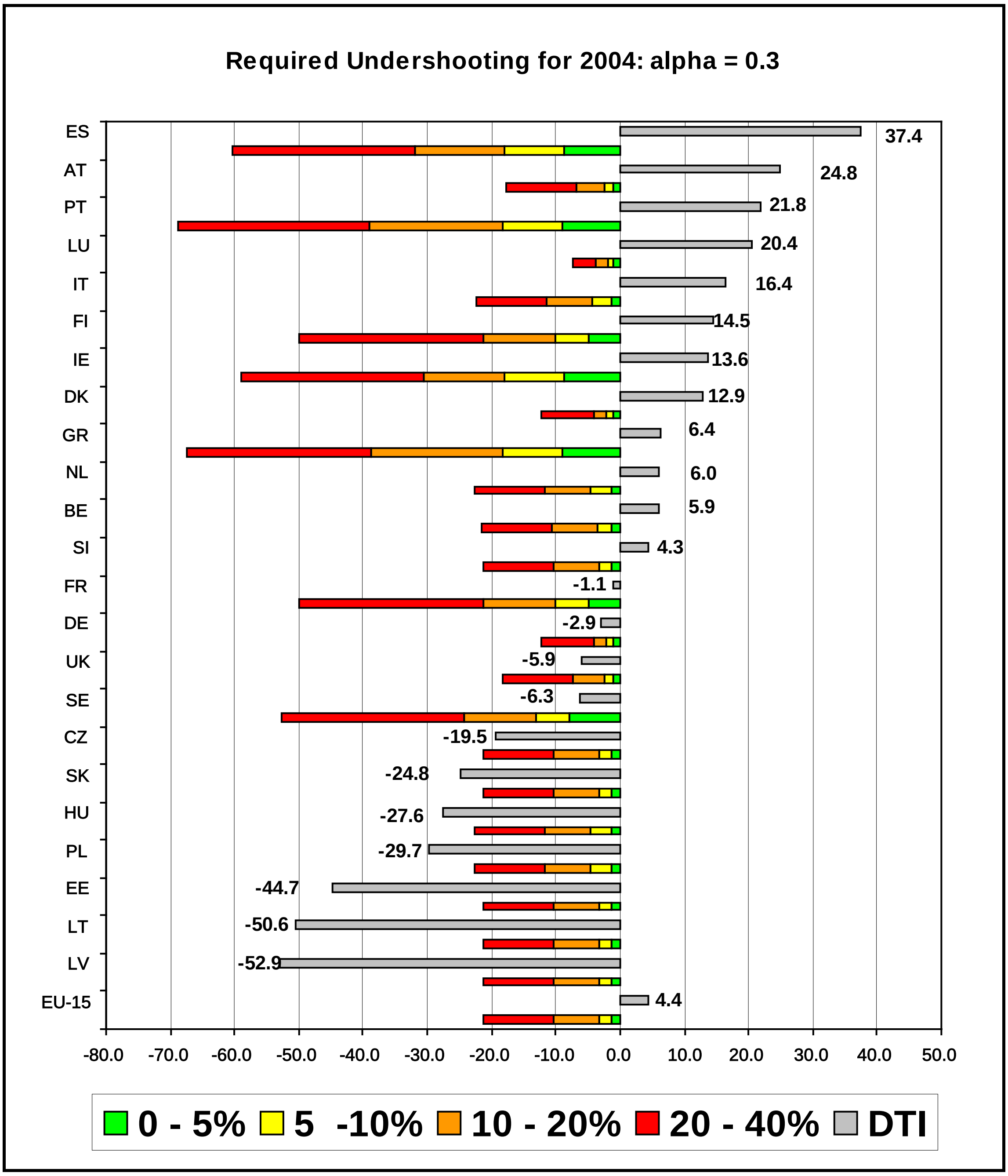

Figure 7: U by r (see intervals) for $a = 0.3$ in addition to the DTI.

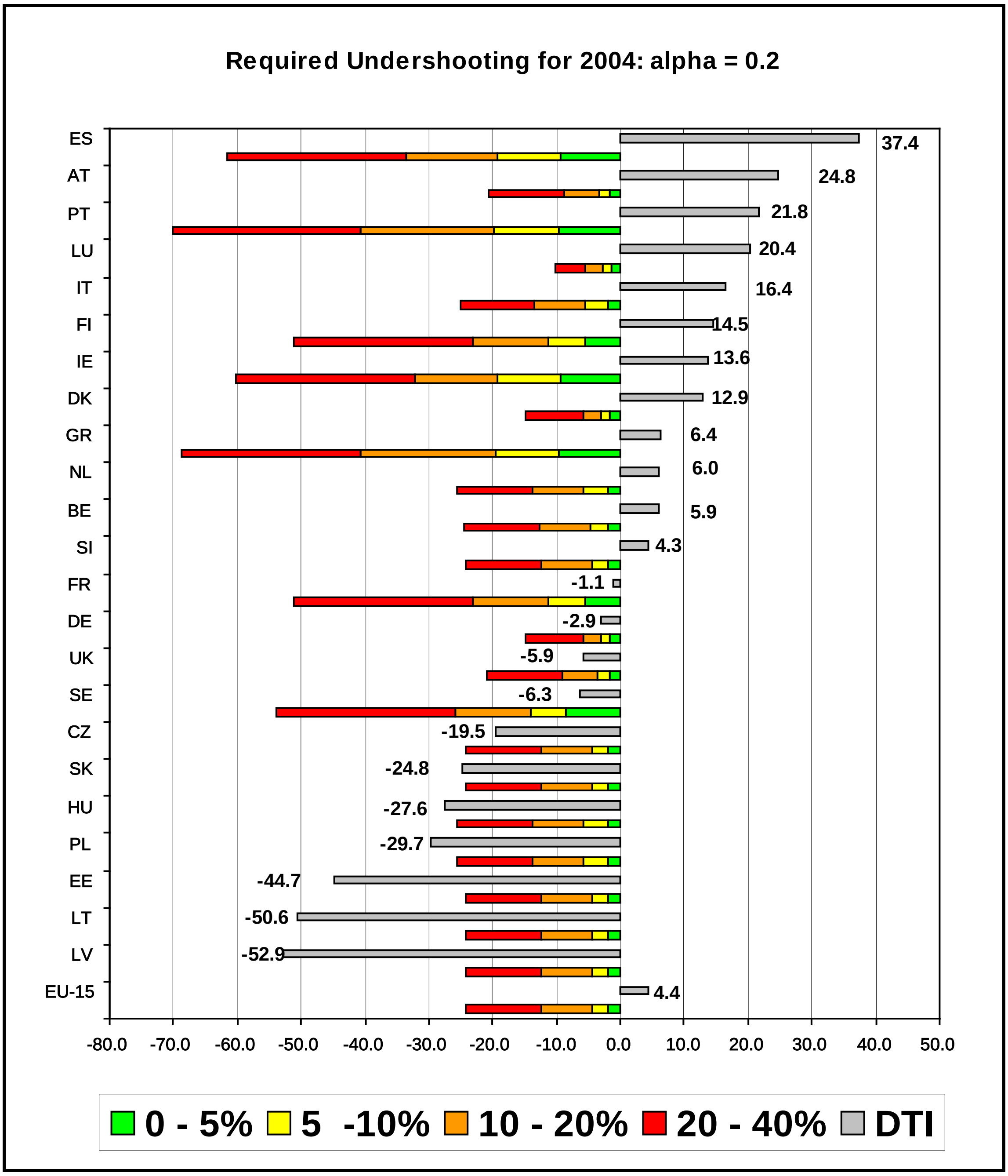

Figure 8: U by r (see intervals) for $a = 0.2$ in addition to the DTI.

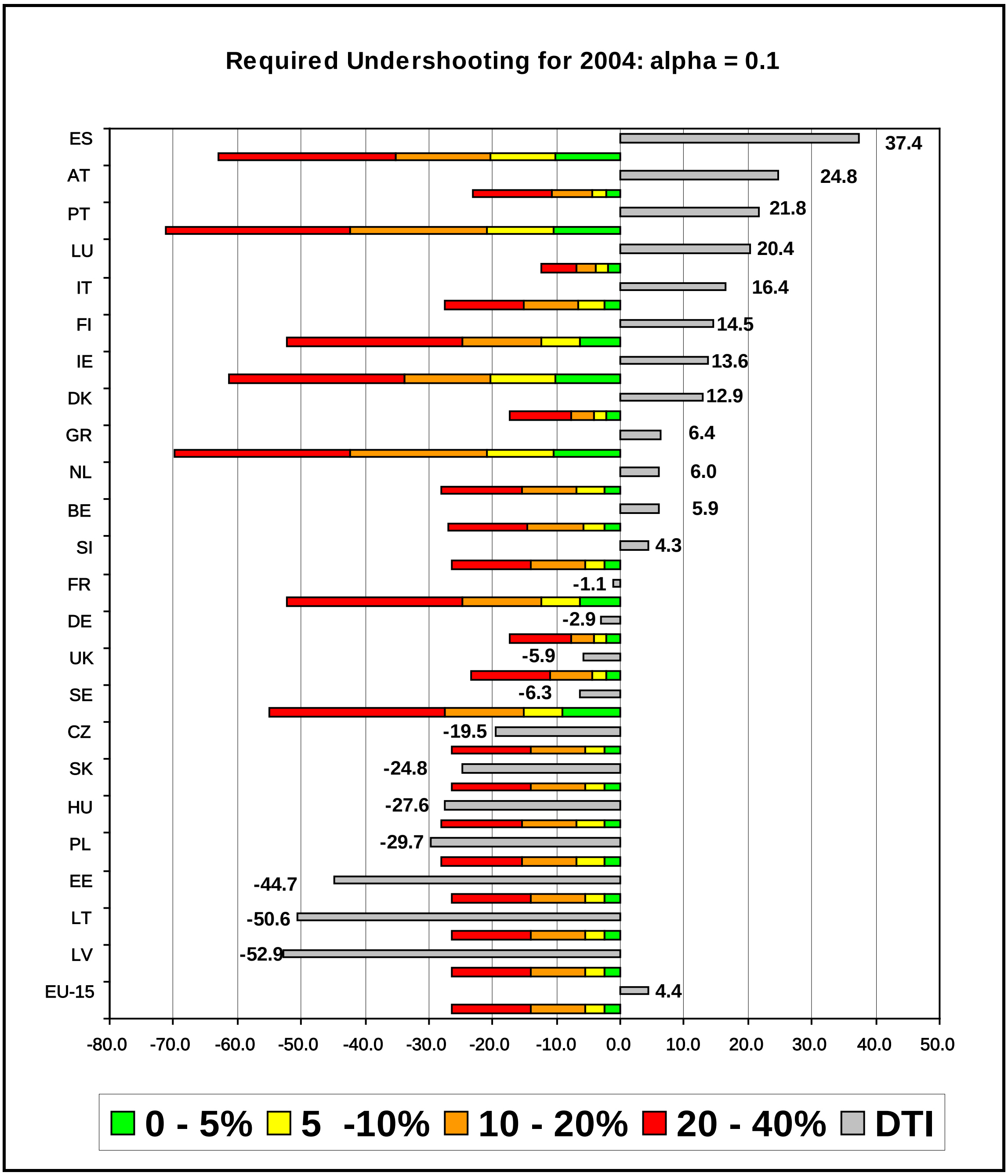

Figure 9: U by r (see intervals) for $a = 0.1$ in addition to the DTI.

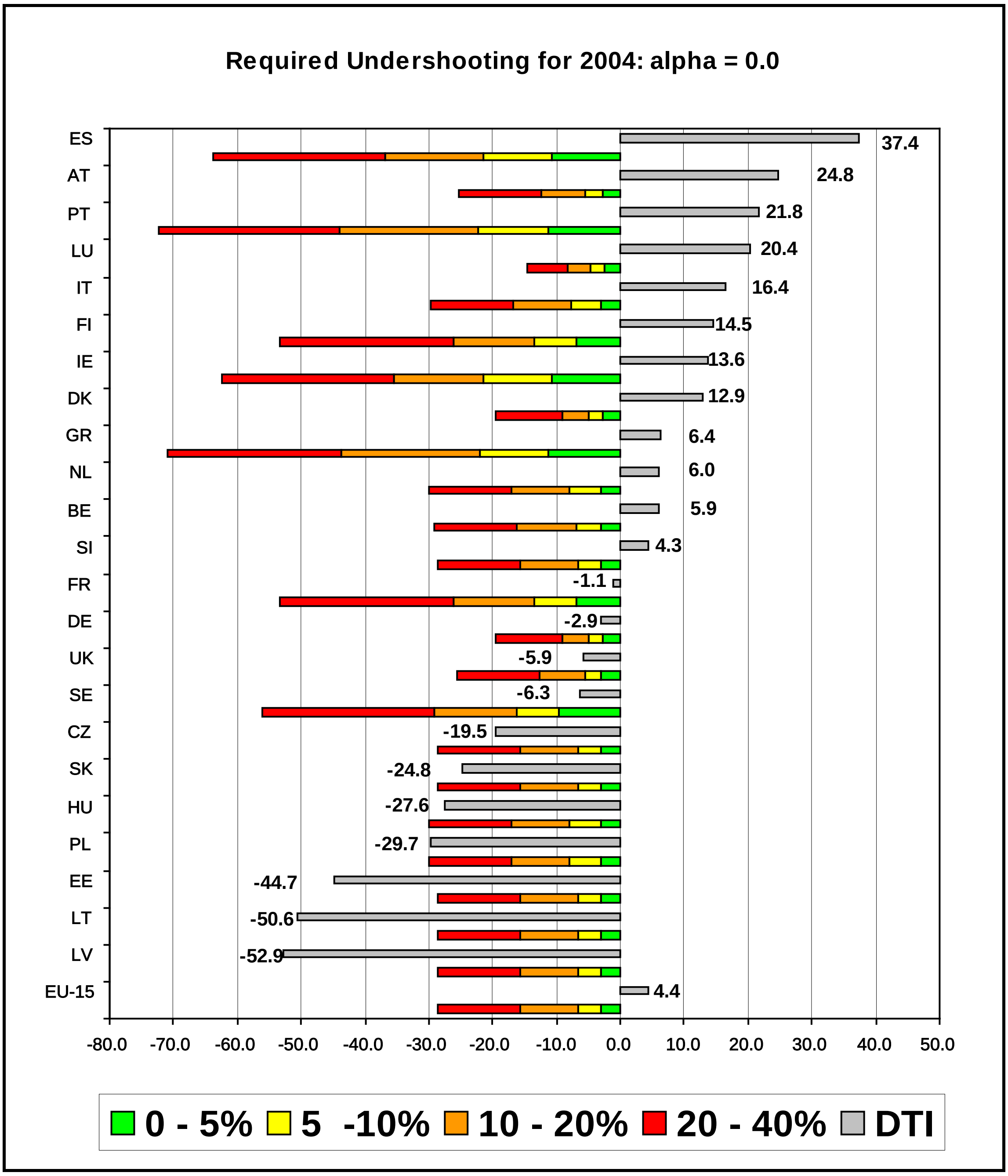

Figure 10: U by r (see intervals) for $a = 0.0$ in addition to the DTI.

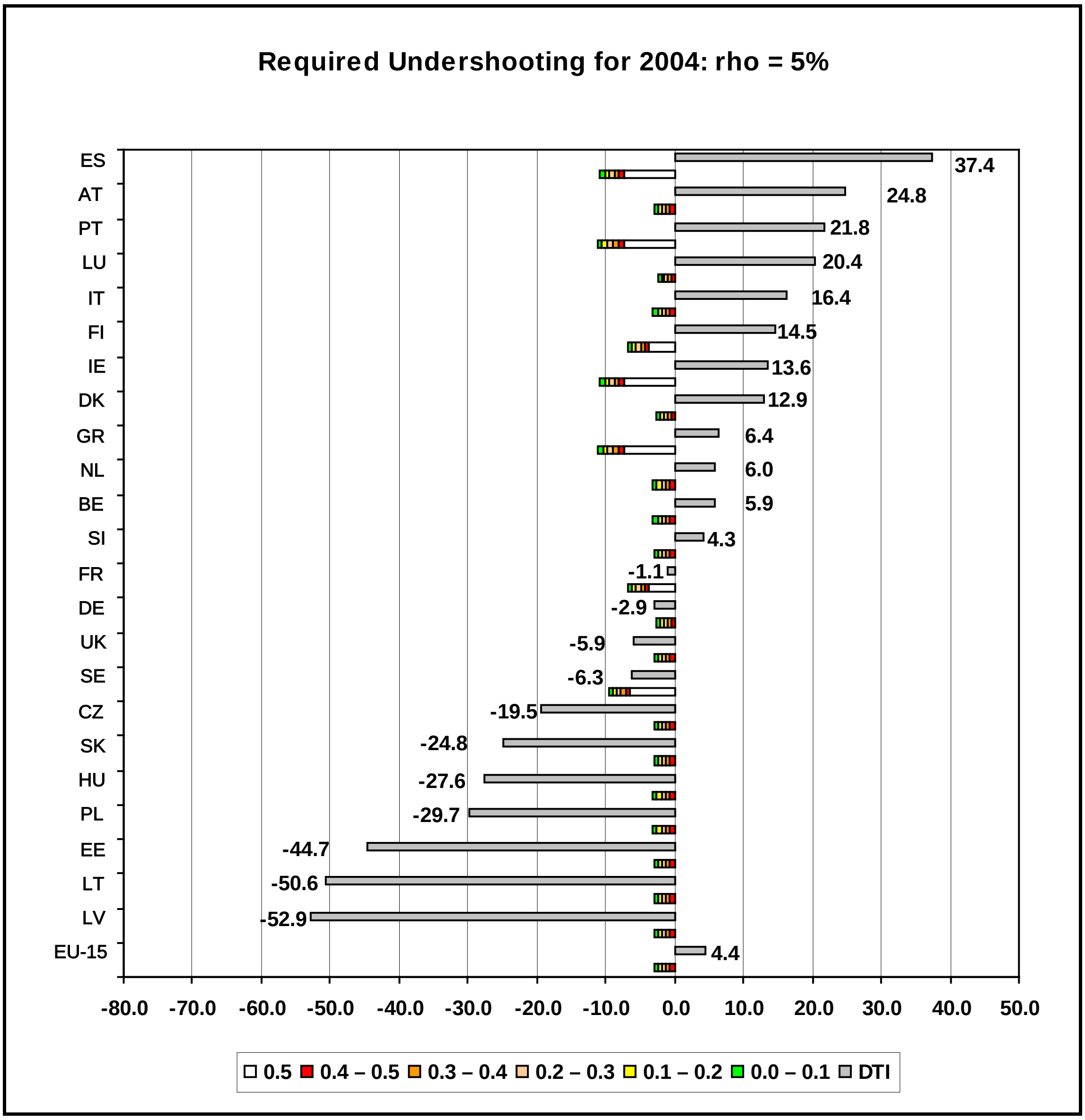

Figure 11: U by a (see value and intervals) for $r = 5\%$ in addition to the DTI.

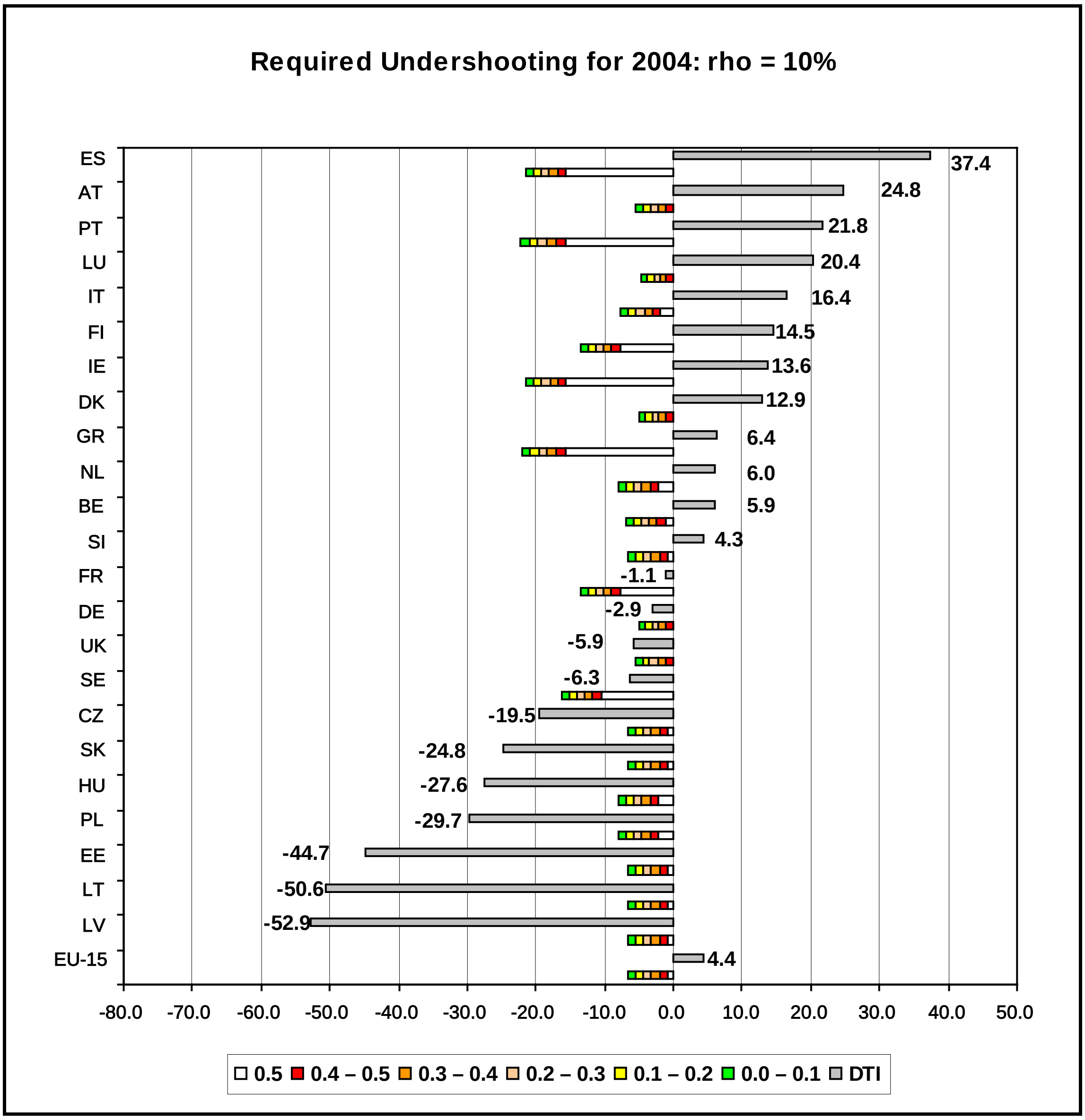

Figure 12: U by a (see value and intervals) for $r = 10\%$ in addition to the DTI.

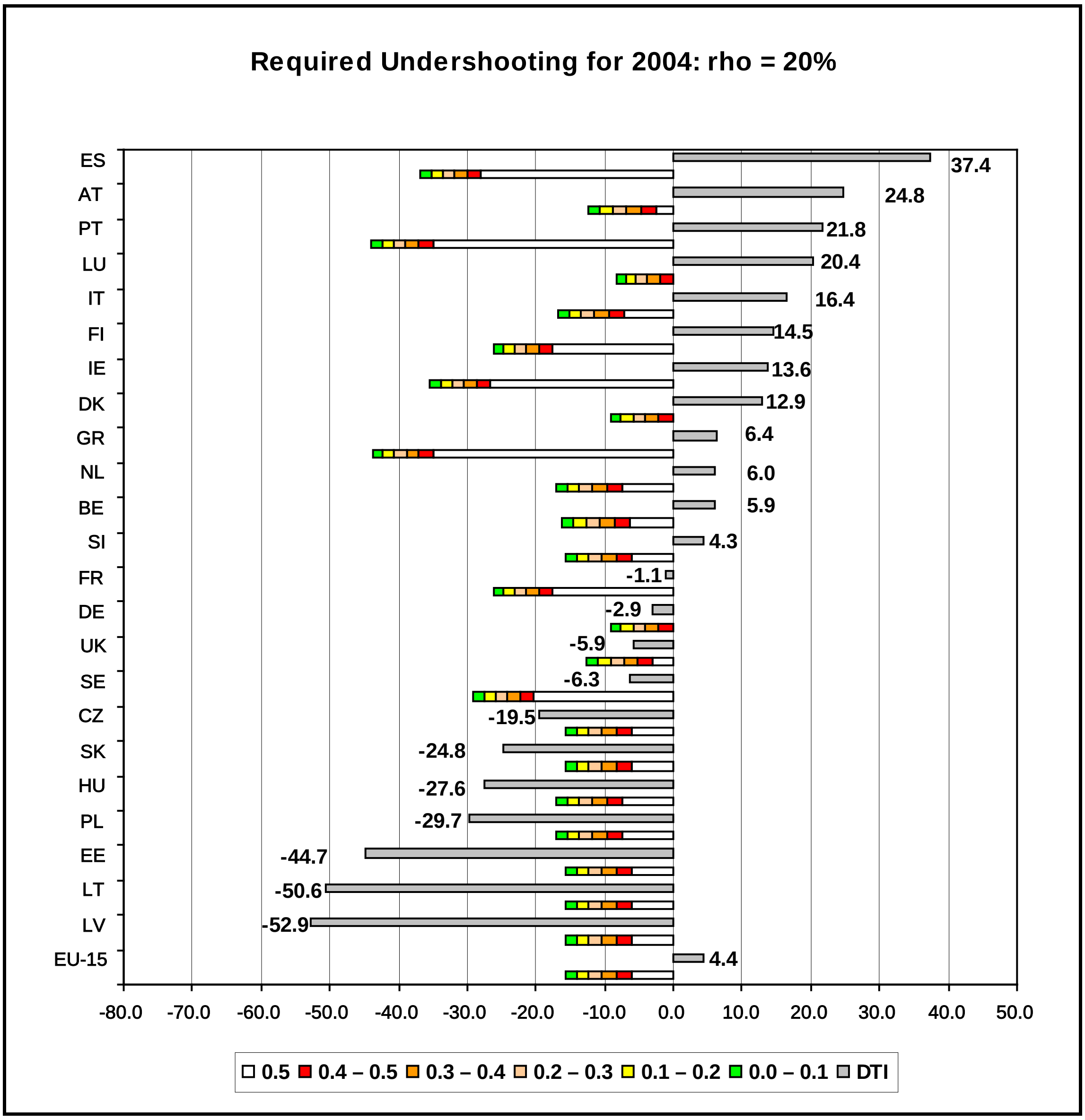

Figure 13: U by a (see value and intervals) for $r = 20\%$ in addition to the DTI.

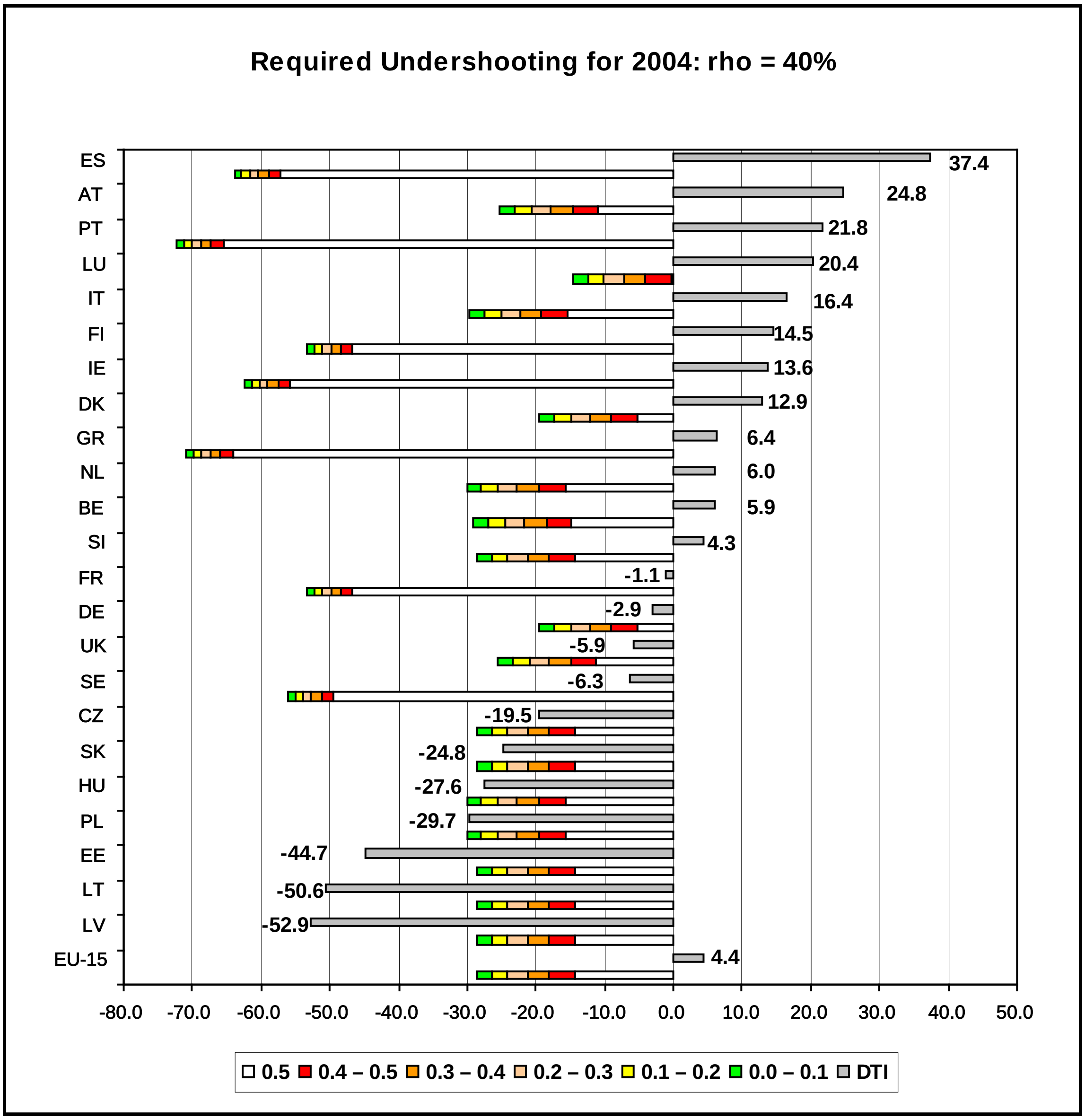

Figure 14: U by a (see value and intervals) for $\rho = 40\%$ in addition to the DTI.

References

Bun, A. and M. Jonas (2006a). Preparatory Signal Detection for the EU-15 Member States Under EU Burden Sharing—Advanced Monitoring Including Uncertainty (1990–2003). Interim Report IR-06-053, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 30. Available at: http://www.iiasa.ac.at Publications/Documents/IR-06-053.pdf.

Bun, A. and M. Jonas (2006b). Preparatory Signal Detection for the EU-25 Member States Under EU Burden Sharing—Advanced Monitoring Including Uncertainty (1990–2003). Interim Report IR-06-054, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 39. Available at: http://www.iiasa.ac.at Publications/Documents/IR-06-054.pdf.

EEA (2006a). Annual European Community Greenhouse Gas Inventory 1990–2004 and Inventory Report 2006. Technical Report No. 6, European Environment Agency (EEA), Copenhagen, Denmark, pp. 429, ISBN: 92-9167-879-1. Available at: http://reports.eea.europa.eu/technical_report_2006_6/en.

EEA (2006b). Greenhouse Gas Emission Trends and Projections in Europe 2006. Report No. 9, European Environment Agency (EEA), Copenhagen, Denmark, pp. 63, ISBN: 92-9167-885-6. Available at: http://reports.eea.europa.eu/eea_report_ 2006_9/en.

EEA (2006c). Annual European Community's Initial Report under the Kyoto Protocol. Technical Report No. 10, European Environment Agency (EEA), Copenhagen, Denmark, pp. 38, ISBN: 92-9167-914-3. Available at: http://reports.eea.europa.eu/ technical_report_2006_10/en.

EU Official Journal (2002). Council Decision as 25 April 2002. OJ L 130, 15 May 2002, pp. 20. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do? uri=OJ:L:2002:130:0001:0020:EN:PDF.

IPCC (1997a, b, c). *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1: Greenhouse Gas Inventory Reporting Instructions; Volume 2: Greenhouse Gas Inventory Workbook; Volume 3: Greenhouse Gas Inventory Reference Manual*. Intergovernmental Panel on Climate Change (IPCC) Working Group I (WG I) Technical Support Unit, IPCC/OECD/IEA, Bracknell, United Kingdom. Available at: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html.

Jonas, M. and S. Nilsson (2001). The Austrian Carbon Database (ACDb) Study—Overview. Interim Report IR-01-064, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 131. Available at: http://www.iiasa.ac.at/ Research/FOR/acdb.html.

Jonas, M., S. Nilsson, M. Obersteiner, M. Gluck and Y. Ermoliev (1999). Verification Times Underlying the Kyoto Protocol: Global Benchmark Calculations. Interim Report IR-99-062, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 43. Available at: http://www.iiasa.ac.at/Publications/ Documents/IR-99-062.pdf.

Jonas, M., S. Nilsson, R. Bun, V. Dachuk, M. Gusti, J. Horabik, W. Jęda and Z. Nahorski (2004a). Preparatory Signal Detection for Annex I Countries under the Kyoto Protocol—A Lesson for the Post-Kyoto Policy Process. Interim Report IR-04-024, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 91. Available at: http://www.iiasa.ac.at/Publications/Documents/IR-04-024.pdf.

Jonas, M., S. Nilsson, R. Bun, V. Dachuk, M. Gusti, J. Horabik, W. Jęda and Z. Nahorski (2004b). Preparatory Signal Detection for the EU Member States Under EU Burden Sharing—Advanced Monitoring Including Uncertainty (1990–2001). Interim Report IR-04-029, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 29. Available at: http://www.iiasa.ac.at/Publications/Documents/IR-04-029.pdf.

Jonas, M., S. Nilsson, R. Bun, V. Dachuk, M. Gusti, J. Horabik, W. Jęda and Z. Nahorski (2004c). Preparatory Signal Detection for the EU Member States Under EU Burden Sharing—Advanced Monitoring Including Uncertainty (1990–2002). Interim Report IR-04-046, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 29. Available at: http://www.iiasa.ac.at/Publications/Documents/IR-04-046.pdf.

Penman, J., D. Kruger, I. Galbally, T. Hiraishi, B. Nyenzi, S. Emmanuel, L. Buendia, R. Hoppaus, T. Martinsen, J. Meijer, K. Miwa and K. Tanabe (eds.) (2000). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan. Available at: http://www.ipcc-nggip.iges.or.jp/public/gp/english/.

Ritter, M. (2007). Personal communication. Federal Environment Agency (Umweltbundesamt), Vienna, Austria, 23 April.

Acronyms and Nomenclature

EU	European Union
DTI	Distance-to-Target Indicator
GHG	Greenhouse Gas
KP	Kyoto Protocol
LUCF	Land-use Change and Forestry
MS	Member State
Und	Undershooting
Und&VT	Undershooting and Verification Time
VT	Verification Time

crit	critical
mod	modified
t	true

ISO Country Code

AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom

Endnotes

[1] Preparatory signal detection allows generating useful information beforehand as to how great uncertainties can be depending on the level of confidence of the emission signal, or the signal one wishes to detect, and on the risk one is willing to tolerate in not meeting an agreed emission limitation or reduction commitment. It is this knowledge of the required quality of reporting versus uncertainty that one wishes to have at hand before negotiating international environmental treaties such as the Kyoto Protocol. It is generally assumed that the emissions path between base year and commitment year/period is a straight line, and emissions prior to the base year are not taken into consideration.

[2] The term 'verification time' was first used by Jonas *et al.* (1999) and by other authors since then. Actually, a more correct term is 'detection time'. The detection of emission changes does not imply verification of emissions. The implicit thinking behind the continued use of 'verification time' is that signal detection should, in the long-term, go hand-in-hand with bottom-up/top-down verification (see Jonas *et al.*, 2004a: Section 2.3).

[3] So far, the same evaluation has been carried out for the EU-15 Member States and their linear path emission targets as of 2001, 2002 and 2003 (Jonas *et al.*, 2004b,c; Bun and Jonas, 2006a), and for the EU-25 Member States and their linear path emission targets as of 2003 (Bun and Jonas, 2006b).

[4] For example, Ireland is allowed a 13% increase from 1990 levels by 2008–2012, so its theoretical linear emission target for 2004 is a rise of no more than 9.1%. Its actual emissions in 2004 show an increase of 22.7% since 1990; hence, its DTI is 22.7 - 9.1, or 13.6 percentage points. Germany's Kyoto target is a 21% reduction, so its theoretical linear target for 2004 is a decrease of 14.7%. Its actual emissions in 2004 were 17.6% lower than in 1990; hence, Germany's DTI is (-17.6) - (-14.7), or -2.9 percentage points.

[5] The Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidelines suggest the use of a 95% confidence interval, which is the interval that has a 95% probability of containing the unknown true emission value in the absence of biases (and which is equal to approximately two standard deviations if the emission values are normally distributed) (Penman *et al.*, 2000: p. 6.6).

[6] Austria has, with reference to 1990, as the only EU-25 Member State carried out full carbon accounting (FCA; Jonas and Nilsson, 2001: Tab. 14). It served as a basis for extracting a partial carbon account which encompasses CH_4 and N_2O and which is in line with the IPCC Guidelines (IPCC, 1997a,b,c). The relative uncertainties (more exactly: the median values of the respective relative uncertainty classes) are 2.5% for CO_2; 30% for CH_4; >40% for N_2O; and 7.5% for $CO_2 + CH_4 + N_2O$.

[7] Here, δ_{KP} specifies the normalized emission change, to which a Member State agreed under the EU burden sharing. This change can be different from that agreed under the Kyoto Protocol. However, δ_{KP} is continued to be used to avoid additional indexing.

[8] The linear target path is established for all countries between 1990 and 2010, irrespective of whether or not 1990 is the base year for their CO_2-CH_4-N_2O emissions, the determining system gases (see Jonas *et al.*, 2004a: Section 3). We follow this common practice to be in agreement with the DTI reporting of the EU.

[9] The exact values are derived by demanding that U_{Gap} (as given by Eq. (10) of Case 2 for DE and the UK, and Eq. (14) of Case 3 for FR and SE) equals a Member State's DTI (multiplied with (-20/14)) and resolving the resulting equation for the relative uncertainty r.

[10] The exact values are derived by demanding that a Member State's DTI (multiplied with (-20/14)) is reproduced by using Eq. (9) of Case 2 for PL, HU, SK and CZ; Eq. (6) of Case 1 for the UK and DE; Eq. (17) of Case 4 for SE; and Eq. (13) of Case 3 for FR, respectively.