International Institute for
Applied Systems Analysis
IIASA www.iiasa.ac.at

Preparatory Signal Detection for the EU Member States under EU Burden Sharing - Advanced Monitoring Including Uncertainty (1990-2002)

Jonas, M., Nilsson, S., Bun, R., Dachuk, V., Gusti, M., Horabik, J., Jeda, W. and Nahorski, Z.

IIASA Interim Report
September 2004

International Institute for
Applied Systems Analysis
Schlossplatz 1
A-2361 Laxenburg, Austria

Tel: +43 2236 807 342
Fax: +43 2236 71313
E-mail: publications@iiasa.ac.at
Web: www.iiasa.ac.at

Interim Report **IR-04-046**

Preparatory Signal Detection for the EU Member States Under EU Burden Sharing — Advanced Monitoring Including Uncertainty (1990–2002)

Matthias Jonas (jonas@iiasa.ac.at)
Sten Nilsson (nilsson@iiasa.ac.at)
Rostyslav Bun (rbun@org.lviv.net)
Volodymyr Dachuk (dachuk@infocom.lviv.ua)
Mykola Gusti (kgusti@yahoo.com)
Joanna Horabik (joanna.horabik@ibspan.waw.pl)
Waldemar Jęda (waldemar.jeda@ibspan.waw.pl)
Zbigniew Nahorski (nahorski@ibspan.waw.pl)

Approved by

Leen Hordijk
Director, IIASA

15 September 2004

Contents

Abstract

This study follows up the authors' collaborative 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 I countries as net emitters and excluded the 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 (total) uncertainty estimates for the purpose of an advanced country evaluation has not yet been established. The authors developed four preparatory signal detection techniques and applied these to the Annex I countries under the Kyoto Protocol. The frame of reference for preparatory signal detection is that Annex I countries comply with their committed emission targets in 2008–2012.

In our study we apply one of these techniques, the combined undershooting and verification time (Und&VT) concept to advance the monitoring of the GHG emissions reported by the Member States of the European Union (EU). In contrast to the earlier study, we focus on the Member States' committed emission targets under the EU burden sharing in compliance with the Kyoto Protocol. We apply the Und&VT concept in a standard mode, i.e., with reference to the Member States committed emission targets in 2008–2012, and in a new mode, i.e., with reference to linear path emission targets between the base year and the commitment year (here for 2002).

To advance the reporting of the EU we take 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; and (ii) the detectability of its target. Undershooting the committed EU target or EU-compatible, but detectable, target can decrease this risk. We contrast the Member States' linear path undershooting targets for the year 2002 with their actual emission situation in that year, for which we use the distance-to-target indicator (DTI) introduced by the European Environment Agency.

In 2002 only four countries exhibit a negative DTI and thus appear as potential sellers: France, Germany, Sweden and the United Kingdom. However, expecting that the EU Member States exhibit relative uncertainties in the range of 5–10% and above rather than below, excluding emissions/removals due to LUCF, the Member States require

considerable undershooting of their EU-compatible, but detectable, targets if one wants to keep the associated risk low ($\alpha \approx 0.1$). These conditions can only be met by two Member States, Germany and the United Kingdom, while Sweden and France can only act as potential high-risk sellers (ranked in terms of creditability). In contrast, with relative uncertainty increasing from 5 to 10%, the emission signal of the EU as a whole 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.

We anticipate 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

This report follows up the research project Carbon Management — Uncertainty and Verification that was carried out for and funded by the Austrian Federal Ministry for Education, Science and Culture (Ref.: GZ 309.012/1-VIII/B-8a/2000). We particularly thank Gisela Zieger for her support during this project.

This report benefited greatly from complementary research that is or has been carried out in Poland and the Ukraine, in Poland under the project Uncertainty, Verification, and Risk Management under the Kyoto Protocol financially supported by the Polish State Committee for Scientific Research (Ref: 3 P04G 120 24) and in the Ukraine under the project Information Technologies for Greenhouse Gas Inventories and Prognosis of the Carbon Budget of Ukraine funded by the Science and Technology Center in Ukraine (Ref.: 1700).

The authors are especially indebted to Shari Jandl for her assistance on improving and finalizing the manuscript.

About the Authors

Matthias Jonas is a Research Scholar in IIASA's Forestry Program and Sten Nilsson is Deputy Director of IIASA as well as Leader of the Forestry Program.

Rostyslav Bun, Volodymyr Dachuk and Mykola Gusti are from the State Scientific and Research Institute of Information Infrastructure (SSRIII) in Lviv, Ukraine. Rostyslav Bun is Deputy Director of Science and Research and Leader of the Department of Information Technologies for Mathematical Modeling of Complex Systems and Phenomena. Volodymyr Dachuk and Mykola Gusti are Senior Research Scientists at the Department of Mathematical Modeling of Complex Systems and Phenomena.

Joanna Horabik, Waldemar Jęda and Zbigniew Nahorski are from the Systems Research Institute (SRI) of the Polish Academy of Sciences in Warsaw. Joanna Horabik is a research assistant in the Laboratory of Computer Modeling, Waldemar Jęda is an adjunct in the Laboratory of Computer Modeling at SRI as well as in the Warsaw School of Information Technology, Faculty of Computer Science, and Zbigniew Nahorski is Head of the Laboratory of Computer Models at SRI as well as Dean of the Department of Informatics at the Warsaw School of Information Technology.

Preparatory Signal Detection for the EU Member States Under EU Burden Sharing — Advanced Monitoring Including Uncertainty (1990–2002)

Matthias Jonas, Sten Nilsson, Rostyslav Bun, Volodymyr Dachuk,
Mykola Gusti, Joanna Horabik, Waldemar Jęda and Zbigniew Nahorski

1 Background and Objective

This study follows up the authors' collaborative IIASA Interim Report IR-04-024 (Jonas *et al.*, 2004a). It applies the strictest of the preparatory signal detection techniques developed in this report, the combined undershooting and verification time (Und&VT) concept, to advance the monitoring of the greenhouse gas (GHG) emissions reported by the Member States of the European Union (EU) under EU burden sharing in compliance with the Kyoto Protocol. Under current monitoring, the Member States' emissions are evaluated in relation to the EU's actual (here: 2002) target and in terms of their positive and negative contributions to this target.[1] This monitoring process is illustrated in Figures 1 and 2 and Table 1. They give details, for each Member State and the EU as a whole, of trends in emissions of GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, SF6) up to 2002.[2] 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, is a measure of the derivation of actual GHG emissions in 2002 from the linear target path between 1990 and the EU target for 2008–2012, assuming that only domestic measures will be used. A negative DTI means that a Member State is below its linear target path, a positive DTI that a Member State is above its linear target path (EEA, 2003, 2004; Gugele *et al.*, 2004)[3]. As Figures 1 and 2 only present relative information of the kind "can sell versus must buy", we add Figure 3, which translates this information into absolute numbers based on the Member States' emissions in 2002 (Table 1) and their DTIs for that year. Figure 3 helps us to understand the 2002 situation of the EU in quantitative terms.

---

[1] In a recent study, the authors evaluated the Member States' emissions in relation to the EU's 2001 target (Jonas *et al.*, 2004b).

[2] Emissions from international aviation and shipping, and emissions/removals due to land-use change and forestry (LUCF), are not covered (EEA, 2004).

[3] For example, Ireland is allowed a 13% increase from 1990 levels by 2008–2012, so its theoretical "linear target" for 2002 is a rise of no more than 7.8%. Its actual emissions in 2002 show an increase of 28.9% since 1990; hence, its "distance-to-target" is 28.9 − 7.8, or 21.1 percentage points. Germany's Kyoto target is a 21% reduction, so its theoretical "linear target" for 2002 is a decrease of 12.6%. Actual emissions in 2002 were 18.9% lower than in 1990; hence, its "distance-to-target" is (–18.9) – (–12.6), or –6.3 percentage points (EEA, 2003, 2004; Gugele *et al.*, 2004).

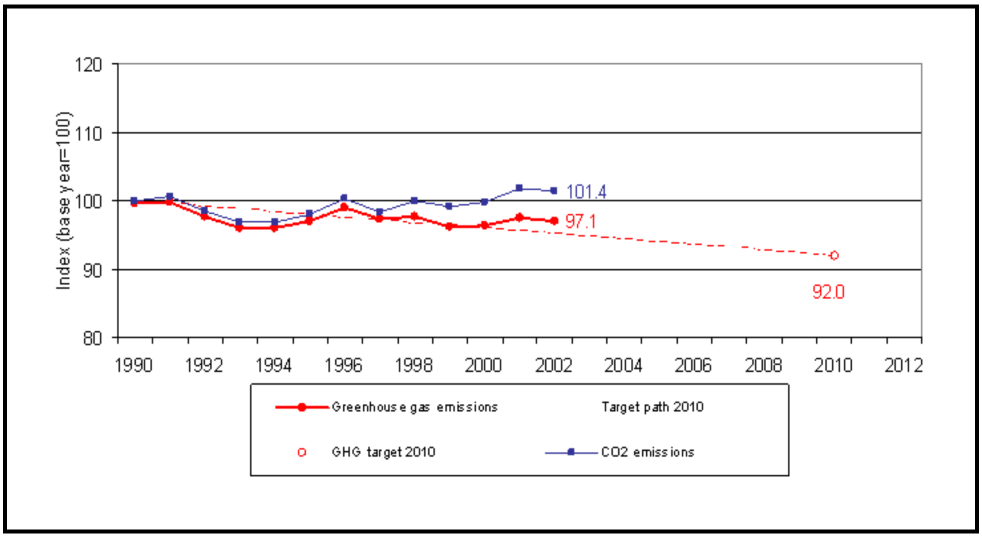
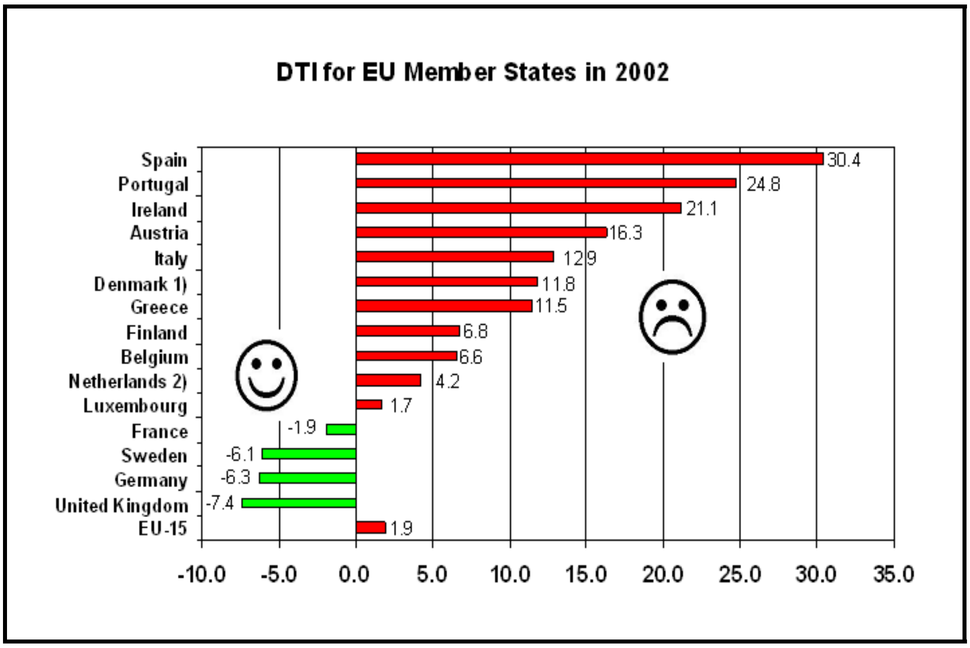


Figure 1: Total EU GHG emissions for 1990–2002 in relation to the Kyoto target for 2008–12. Source: EEA (2004:Figure 1).



[1)] Denmark's DTI is +3.5 percentage points if its emissions are adjusted for electricity trade in 1990.

[2)] The Dutch DTI is −1.4 percentage points, putting it on track to meet its Kyoto target, if anticipated emission savings from use of the Kyoto mechanisms are taken into account. The Netherlands is the only country that has provided detailed information on financial resources earmarked for using the mechanisms, specific projects and quantified emission reductions.

Figure 2: Distance-to-target indicator (DTI) for EU Member States in 2002 (in consideration of the EU burden sharing targets under the Kyoto Protocol). Source: Modified from EEA (2004:Figure 2).

Table 1: 2008–2012 targets for EU Member States under the Kyoto Protocol and EU burden sharing. Source: Modified from Gugele *et al.* (2004:Table ES.4).

Member State	Base Year[a] (million tonnes)	2002 (million tonnes)	Change 2001–2002 (%)	Change Base Year–2002 (%)	Targets 2008–12 under EU burden sharing (%)
Austria	78.0	84.6	0.3	8.5	-13.0
Belgium	146.8	150.0	0.5	2.1	-7.5
Denmark[b]	69.0	68.5	-1.2	-0.8 (-9.1)	-21.0
Finland	76.8	82.0	1.7	6.8	0.0
France	564.7	553.9	-1.4	-1.9	0.0
Germany	1253.3	1016.0	-1.1	-18.9	-21.0
Greece	107.0	135.4	0.3	26.5	25.0
Ireland	53.4	68.9	-1.6	28.9	13.0
Italy	508.0	553.8	-0.1	9.0	-6.5
Luxembourg	12.7	10.8	10.4	-15.1	-28.0
Netherlands	212.5	213.8	-1.1	0.6	-6.0
Portugal	57.9	81.6	4.1	41.0	27.0
Spain	286.8	399.7	4.2	39.4	15.0
Sweden	72.3	69.6	2.0	-3.7	4.0
United Kingdom	746.0	634.8	-3.3	-14.9	-12.5
EU-15	**4245.2**	**4123.3**	**-0.5**	**-2.9**	**-8.0**

[a] Base year for CO_2, CH_4 and N_2O is 1990; for the fluorinated gases 13 Member States have indicated to select 1995 as base year, whereas Finland and France indicate to choose 1990. As the EC inventory is the sum of Member States inventories, the EC base year estimates for fluorinated gas emissions are the sum of 1995 emissions for 13 Member States and 1990 emissions for Finland and France.
[b] For Denmark, data that reflect adjustments in 1990 for electricity trade (import and export) in 1990 are given in brackets. This methodology is used by Denmark to monitor progress towards its national target under the EC "burden sharing" agreement. For the EC emissions, total non-adjusted Danish data have been used.

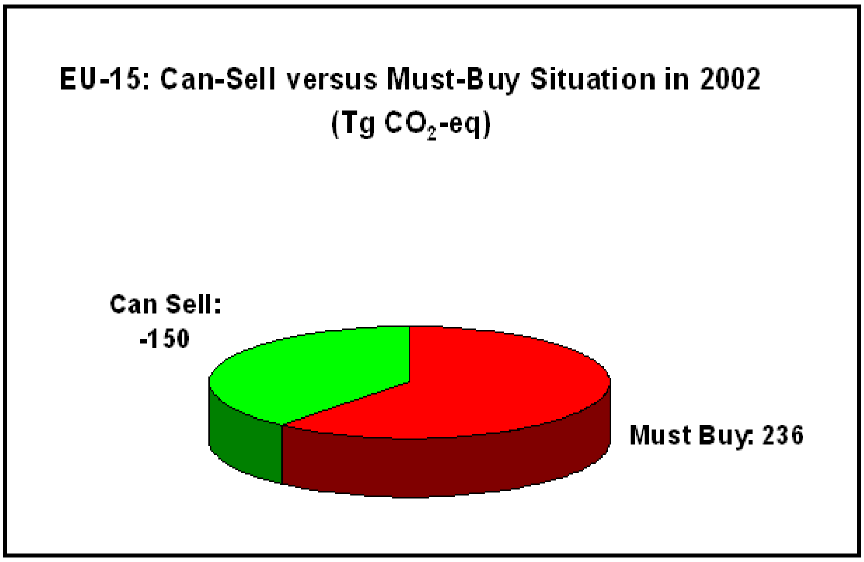


Figure 3: Figure 2 presented in absolute terms. Member States appearing as potential sellers in 2002: FR, DE, SE, UK; Member States appearing as potential buyers in 2002: AT, BE, DK, ES, FI, GR, IE, IT, LU, NL, PT. See ISO Country Code for country abbreviations and text for underlying assumptions.

The 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 (what we call the true EU reference line); and (ii) the detectability of its target. Undershooting the committed EU target or EU-compatible, but detectable, target can decrease the risk that the Member State's true emissions in the commitment year are above its true EU reference line. The year of reference shall be 2002, the last year of the EU monitoring (EEA, 2004; Gugele *et al.*, 2004).

Uncertainties are extracted from the national inventory reports of the Member States and are monitored separately. However, a connection between emission and (total) uncertainty estimates for the purpose of an advanced country evaluation has not yet been established. A recent compilation of uncertainties has been presented by Gugele *et al.* (2004:Table 8) (see Table 2). This compilation makes available quantified uncertainty estimates from thirteen Member States (extracted from their National Inventory Reports 2003 and 2004). In the case of Portugal, the national inventory report did not include a quantitative uncertainty analysis; and in the case of Luxembourg, a national inventory report was not available at all. The uncertainties refer to a 95% confidence interval[4] and neglect, with the exception of France and the United Kingdom, emissions/removals due to land-use change and forestry (LUCF).

Taking uncertainty into account in combination with undershooting is important because the amount, by which a Member State undershoots its EU target 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.

In Section 2 we recall the methodology of the Und&VT concept, which we apply in Section 3 with the above objective in mind. We interpret our results and present our conclusions in Section 4.

[4] 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 that is equal to approximately two standard deviations if the emission values are normally distributed) (Penman *et al.*, 2000: p. 6.6).

Table 2: Overview of uncertainty estimates available from Member States excluding LUCF (with the exception of France and the United Kingdom). Source: Modified from Gugele *et al.* (2004:Table 8).

Member State	**Austria**[a]		**Belgium**		**Denmark**		**Finland**		**France**		**Germany**	
Citation	Austrian NIR 2004, p. 28–30		Belgian NIR 2004, p. 13		Danish NIR 2004 p. 25–27		Finnish NIR 2004 p. 16, Annex 3 (Tables A–D)		French NIR 2003 p. 30–31		German NIR 2004, p. 1-32-35, Annex 7	
Method used	Tier 2		Tier 1		Tier 1		Tier 1, Tier 2		Tier 1		Tier 1	
Detailed documentation available in NIR (e.g., expert judgments according to Table 6.1 of GPG)	No		No		Yes: Table 1.2 (no reference to source information)		Yes: Annex 3		Yes: Annex 2 (no reference to source information)		Yes: Annex [Anhang] 7 (no source information)	
Years and sectors included	1990, 1997 (from year 1999) — All sectors		Some attempts have been made at determining the uncertainty of CO_2 emissions from fossil fuel combustion in the Flemish region (Tier 1) and Wallonia (Tier 1).		1990, 2002 (from year 2004) — The uncertainty estimates include stationary combustion plants, mobile combustion, agriculture and fugitive emissions from fuels (93% of total Danish GHG emissions)		1990, 2002 (from year 2004) — All sectors except agricultural soils and LULUCF		1990, 2002 (from year 2004) — All sources (key sources and "others")		1990, 2002 (from 2004) — nearly complete estimation for sources 1A, 1B2, 2A1, 2A2, 2C1, 2C3	
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
CO_2	-	2.3	-	-	2.0	-	-	-4 to +6	-	-	-	-
CH_4	-	48.3	-	-	15	-	-	+/-25	-	-	-	-
N_2O	-	89.6	-	-	407	-	-	-32 to +45	-	-	-	-
F-gases	-	-	-	-	-	-	-	-7 to +18	-	-	-	-
Total	-	8.9	-	-	46	-	+/-7	-5...+6	22.1	-	-	-
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
CO_2	-	-	-	-	1.7	-	-	-	-	-	-	-
CH_4	-	-	-	-	6.3	-	-	-	-	-	-	-
N_2O	-	-	-	-	32	-	-	-	-	-	-	-
F-gases	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	19	-	+/-6	+/-5	3.5	-	-	-

[a] Austria has, as the only Member State of the EU, carried out Full Carbon Accounting (FCA) for 1990. Jonas and Nilsson (2001:Table 14) constructed a full carbon account, which serves as a basis for extracting a partial carbon account that is extended by CH_4 and N_2O and that is in line with the IPCC Guidelines (IPCC, 1997a,b,c). The respective 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 $CO_2 + CH_4 + N_2O$.

Table 2: continued.

Member State	**Greece**		**Ireland**		**Italy**		**Netherlands**		**Spain**		**Sweden**		**United Kingdom**	
Citation	Greek NIR 2004, p. 15–15. Table VI.I		Irish NIR 2004, p. 8–9, 14–15		Italian NIR 2003, Annex 1		Dutch NIR 2004, p. 1–24 to 1–29 and A-6		Spanish NIR 2004, p.44–53		Swedish NIR 2004, p. 14–15		UK NIR 2004 (draft) Annex 7, Table A7.4	
Method used	Tier 1		Tier 1		Tier 1		Tier 1		Tier 1		Tier 1		Tier 1, Tier 2	
Detailed documentation available in NIR (e.g., expert judgments according to Table 6.1 of GPG)	No		Yes: Table 1.4 (no reference to source information)		Partially (Table A1.2): "IPCC GHG and expert judgment has been used, standard deviations have also been considered whenever measurements were available"		Partially p. 1–26		Partially, p. 44–48		No		Yes: Annex 7 (no composite table on references included)	
Years and sectors included	1990, 2002 (from year 2004) — All sources		1990, 2002 (from year 2004) — All sources (key sources and "others")		1990, 2001 (from year 2003) — All sources		1990, 2002 (from year 2004) — Key sources and "other" sources		1990. 2000, 2001 (from year 2004) — All sources (key sources and "other emission sources")		1990, 2002 (from year 2004) — All sources		1990, 2002 (from year 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	3.7	-	1.35	-	-	-	+/-3	-	-	-	3.2	-	-	2.1
CH_4	34.5	-	3.39	-	-	-	+/-25	-	-	-	1.8	-	-	13
N_2O	182.9	-	10.94	-	-	-	+/-50	-	-	-	6.2	-	-	231
F-gases	67.9	-	0.16	-	-	-	HFC +/-50 PFCs +/-50 SF_6 +/-50	-	-	-	0.3	-	-	HFC 25 PFCs 19 SF_6 13
Total	19.1	-	11.53	-	2.50	-	5	-	2000 +/-17.5 2001 +/-16.6	-	7.2	-	17.9	15
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	-	-	2.19	-	-	-	3	-	-	-	-	-	-	-
CH_4	-	-	2.31	-	-	-	6	-	-	-	-	-	-	-
N_2O	-	-	6.83	-	-	-	11	-	-	-	-	-	-	-
F-gases	-	-	0.18	-	-	-	9	-	-	-	-	-	-	-
Total	-	-	7.53	-	2.30	-	4	-	2000 +/-2.2 2001 +/-2.5	-	-	-	-	-

2 Methodology

We apply the Und&VT concept, which we have described in detail in Jonas *et al.* (2004a). With the help of δ_{KP}, the normalized emission change under the EU burden sharing in compliance with the Kyoto Protocol,[5] and δ_{crit}, the critical (crit) emission limitation or reduction target, we distinguish the four cases listed in Table 3 and shown in Figure 4. The Member States' δ_{crit} values can be determined knowing the relative (total) uncertainty (ρ) of their net emissions (see equation (32a,b) in Jonas *et al.*, 2004a):

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

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 the base year 1990[6] and t_2 to the commitment year 2010 (as the temporal mean of 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 we require 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: We apply an initial or obligatory undershooting so that the Member States' emission signals become detectable	
Emission Limitation: $\delta_{KP} \leq 0$	Case 3	$\delta_{crit} < \delta_{KP}$	Non-detectable EU/Kyoto target	We continue applying an initial or obligatory undershooting unconditionally for all Member States, before detectable reductions that Member States might have already realized (Case 4) are considered.
	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 committed 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 and 3.2 for details).

---

[5] Here, δ_{KP} specifies the normalized emission changes, to which the Member States committed themselves under the EU burden sharing and which are different from those under the Kyoto Protocol. However, we continue to use δ_{KP} to avoid additional indexing.

[6] We selected 1990 as the base year because it is determined by the "CO_2-CH_4-N_2O system of gases" (see Jonas *et al.*, 2004a:Section 3).

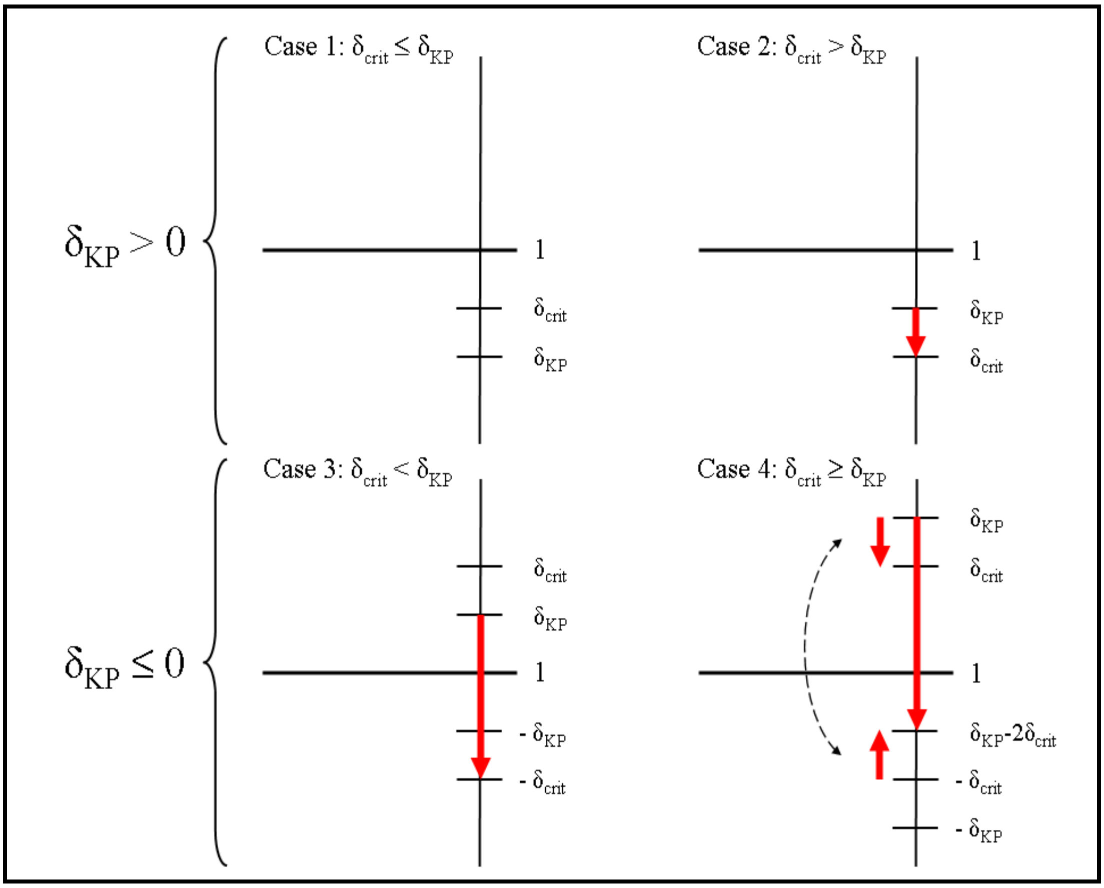


Figure 4: The four cases that are distinguished in applying the Und&VT concept (see also Table 3). Emission reduction: $\delta_{KP} > 0$; emission limitation: $\delta_{KP} \le 0$.

<u>*Case 1: $\delta_{KP} > 0$: $\delta_{crit} \le \delta_{KP}$.*</u> We make use of equations (43a), (B1), (D1), (B3) and (D2) of Jonas *et al.* (2004a:Appendix D):

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

where

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

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

<u>*Case 2: $\delta_{KP} > 0$: $\delta_{crit} > \delta_{KP}$.*</u> We make use of equations (45a), (B1), (D3a,b), (D4) and (42b) of Jonas *et al.* (2004a:Appendix D):

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

where

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

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

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 are above its true emission limitation or reduction commitment (true EU reference line) Note: In Jonas *et al.* (2004a:Section 3.4 and Appendix D) we replaced α by α_v (where "v" refers to "verifiable") in Cases 2–4, which we do not do here
δ_{KP}	A Member State's normalized emission change committed under the 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 Appendix D) we replaced U by U_v (where "v" refers to "verifiable") in Cases 2–4, which we do not do here
U_{Gap}	Initial or obligatory undershooting
δ_{crit}	A Member State's critical emission limitation or reduction target or, equivalently, its reference line 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 Nevertheless, we can grasp the risk α that $x_{t,2}$ is ≥ the true EU reference line (which is given, e.g., by $(1-\delta_{KP})x_{t,1}$ in Case 1)

Case 3: $\delta_{KP} \le 0$: $\delta_{crit} < \delta_{KP}$. We make use of equations (50a), (B1), (D7a,b), (D8) and (52) of Jonas *et al.* (2004a:Appendix D):

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

where

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

$$\text{U} = \text{U}_{\text{Gap}} + \left(1+\delta_{\text{crit}}\right)\frac{\left(1-2\alpha\right)\rho}{1+\left(1-2\alpha\right)\rho} \tag{13}$$

with

$$\text{U}_{\text{Gap}} = -\left(\delta_{\text{crit}} + \delta_{\text{KP}}\right) \ . \tag{14}$$

Case 4: $\delta_{KP} \le 0$: $\delta_{crit} \ge \delta_{KP}$. We make use of equations (55a), (B1), (D11a,b), (D12), (57) and (58) of Jonas *et al.* (2004a:Appendix D):

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

where

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

$$\text{U} = \text{U}_{\text{Gap}} + \left(1+\delta'_{\text{crit}}\right)\frac{\left(1-2\alpha\right)\rho}{1+\left(1-2\alpha\right)\rho} \tag{17}$$

with

$$\text{U}_{\text{Gap}} = -2\delta_{\text{crit}} \tag{18}$$

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

We recall that we measure emission reductions positively ($\delta_{\text{KP}} > 0$) and emission increases negatively ($\delta_{\text{KP}} < 0$), which is opposite to the emission reporting for the EU (see Section 1). However, this can be readily rectified by introducing a minus sign when we report our results.

3 Results

We proceed in two steps. In the first step we apply the Und&VT concept 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 we assume here to take on one of the values listed in Table 5 (excluding LUCF), we can make use of Equation (1) and determine δ_{crit}, the Member State's critical emission limitation or reduction target.

Knowing δ_{crit} and δ_{KP}, the Member States' 2008–12 targets under the EU burden sharing in compliance with the Kyoto Protocol (see Table 1), we can now compare the two and identify which Case applies to which Member State, that is, we identify the conditions that underlie the emission reporting of a particular Member State (and the EU as the whole) (see Table 6).

Table 7 lists the Member States' modified emission limitation or reduction targets δ_{mod} (equations (4), (8), (12) and (16)), where the (Case 1: "$x_{t,2}$-greater-than-$(1-\delta_{\text{KP}})x_{t,1}$"; Cases 2 and 3: "$x_{t,2}$-greater-than-$(1-|\delta_{\text{crit}}|)x_{t,1}$"; Case 4: "$x_{t,2}$-greater-than-$(1-(\delta_{\text{KP}}-2\delta_{\text{crit}}))x_{t,1}$") risk α is specified to be 0, 0.1, …, 0.5. Table 8 lists the undershooting U (Equations (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 Equation (5)) that matters initially because it describes a Member State's overall burden. However, once Member States have agreed upon their δ_{KP} targets, it is the undershooting U which then becomes solely important. Therefore, we will only consider the undershooting U in our 2nd-step investigation of the Member States' emission situation as of 2002.

In this second step, we take the U values reported in Table 8 and multiply them with the factor $(-12/20)$. The minus sign brings us in line with the emission reporting for the EU, which measures emission reductions negatively and emission increases positively (see Section 1). The factor $(12/20)$ establishes the base year–commitment year linear path undershooting targets for the year 2002 (see Table 9).

We interpret the results in the next section, together with our conclusions that we draw from this interpretation.

Table 5: The Member States' critical emission limitation or reduction targets (δ_{crit}) for assumed values of relative uncertainty (ρ), with which Member States report their net emissions (equation (1)).

	$\delta_{KP} > 0$	$\delta_{KP} \leq 0$		$\delta_{KP} > 0$	$\delta_{KP} \leq 0$
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			

Table 6: Identification of the conditions that underlie the emission reporting of a particular Member State (MS) and the EU as a whole in terms of Cases 1–4. Green: Detectable EU/Kyoto target (emission reduction). Orange: Detectable EU/Kyoto target (emission limitation). Red: Non detectable EU/Kyoto Target (emission limitation or reduction).

MS	δ_{KP} %	**Case Identification for** $\rho =$								
		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
DK	**21.0**	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	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
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
LU	**28.0**	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 1	Case 2
NL	**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
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
EC	**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 Member States (MS). The table lists the 2008–2012 modified emission limitation or reduction targets δ_{mod} (equations (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.

MS	δ_{KP}	α	Modified Emission Limitation or Reduction Target δ_{mod} in % for $\rho =$								
	%	1	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
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
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
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

Table 7: continued.

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
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
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
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
EC	**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 Member States (MS). The table lists the undershooting U (equations (6), (9), (13) and (17)) contained in the modified emission limitation or reduction targets δ_{mod} listed in Table 7.

MS	δ_{KP}	α	Undershooting U in % for $\rho =$								
	%	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
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
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
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

Table 8: continued.

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
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
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
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
EC	**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 listed in Table 8 multiplied with the factor $(-11/20)$ to reconcile the Und&VT concept with the emission reporting for the EU and to establish the base year–commitment year linear path undershooting targets for the year 2002.

MS	δ_{KP} %	α 1	**Undershooting U in % for $\rho =$**								
			0%	**2.5%**	**5%**	**7.5%**	**10%**	**15%**	**20%**	**30%**	**40%**
AT	**-7.8**	0.0	0.0	-1.3	-2.5	-3.6	-4.7	-6.8	-10.5	-16.7	-21.6
		0.1	0.0	-1.0	-2.0	-3.0	-3.9	-5.6	-9.1	-15.0	-19.7
		0.2	0.0	-0.8	-1.5	-2.2	-3.0	-4.3	-7.6	-13.1	-17.6
		0.3	0.0	-0.5	-1.0	-1.5	-2.0	-3.0	-5.9	-11.0	-15.3
		0.4	0.0	-0.3	-0.5	-0.8	-1.0	-1.5	-4.1	-8.7	-12.5
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	-2.2	-6.0	-9.3
BE	**-4.5**	0.0	0.0	-1.4	-2.6	-3.9	-5.9	-10.1	-13.8	-20.0	-24.9
		0.1	0.0	-1.1	-2.1	-3.1	-5.0	-8.9	-12.4	-18.3	-23.0
		0.2	0.0	-0.8	-1.6	-2.4	-4.0	-7.6	-10.9	-16.4	-20.9
		0.3	0.0	-0.5	-1.1	-1.6	-3.1	-6.3	-9.2	-14.3	-18.6
		0.4	0.0	-0.3	-0.5	-0.8	-2.0	-4.8	-7.4	-12.0	-15.8
		0.5	0.0	0.0	0.0	0.0	-1.0	-3.3	-5.5	-9.3	-12.6
DK	**-12.6**	0.0	0.0	-1.2	-2.3	-3.3	-4.3	-6.2	-7.9	-11.9	-16.8
		0.1	0.0	-0.9	-1.8	-2.7	-3.5	-5.1	-6.5	-10.2	-14.9
		0.2	0.0	-0.7	-1.4	-2.0	-2.7	-3.9	-5.1	-8.3	-12.8
		0.3	0.0	-0.5	-0.9	-1.4	-1.8	-2.7	-3.5	-6.2	-10.5
		0.4	0.0	-0.2	-0.5	-0.7	-0.9	-1.4	-1.8	-3.9	-7.7
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	-4.5
FI	**0.0**	0.0	0.0	-3.0	-5.9	-8.7	-11.5	-17.0	-22.5	-33.6	-45.7
		0.1	0.0	-2.7	-5.3	-8.0	-10.6	-15.9	-21.2	-32.4	-44.8
		0.2	0.0	-2.4	-4.8	-7.2	-9.7	-14.7	-19.8	-30.9	-43.9
		0.3	0.0	-2.1	-4.3	-6.5	-8.7	-13.4	-18.3	-29.4	-42.8
		0.4	0.0	-1.8	-3.7	-5.7	-7.7	-12.0	-16.7	-27.7	-41.5
		0.5	0.0	-1.5	-3.2	-4.9	-6.7	-10.6	-15.0	-25.7	-40.0
FR	**0.0**	0.0	0.0	-3.0	-5.9	-8.7	-11.5	-17.0	-22.5	-33.6	-45.7
		0.1	0.0	-2.7	-5.3	-8.0	-10.6	-15.9	-21.2	-32.4	-44.8
		0.2	0.0	-2.4	-4.8	-7.2	-9.7	-14.7	-19.8	-30.9	-43.9
		0.3	0.0	-2.1	-4.3	-6.5	-8.7	-13.4	-18.3	-29.4	-42.8
		0.4	0.0	-1.8	-3.7	-5.7	-7.7	-12.0	-16.7	-27.7	-41.5
		0.5	0.0	-1.5	-3.2	-4.9	-6.7	-10.6	-15.0	-25.7	-40.0
DE	**-12.6**	0.0	0.0	-1.2	-2.3	-3.3	-4.3	-6.2	-7.9	-11.9	-16.8
		0.1	0.0	-0.9	-1.8	-2.7	-3.5	-5.1	-6.5	-10.2	-14.9
		0.2	0.0	-0.7	-1.4	-2.0	-2.7	-3.9	-5.1	-8.3	-12.8
		0.3	0.0	-0.5	-0.9	-1.4	-1.8	-2.7	-3.5	-6.2	-10.5
		0.4	0.0	-0.2	-0.5	-0.7	-0.9	-1.4	-1.8	-3.9	-7.7
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	-4.5
GR	**15.0**	0.0	0.0	-4.8	-9.6	-14.3	-18.9	-28.2	-37.5	-48.6	-60.7
		0.1	0.0	-4.5	-9.0	-13.4	-17.9	-26.9	-36.2	-47.4	-59.8
		0.2	0.0	-4.1	-8.3	-12.5	-16.8	-25.6	-34.8	-45.9	-58.9
		0.3	0.0	-3.8	-7.7	-11.6	-15.7	-24.2	-33.3	-44.4	-57.8
		0.4	0.0	-3.4	-7.0	-10.7	-14.5	-22.7	-31.7	-42.7	-56.5
		0.5	0.0	-3.1	-6.3	-9.7	-13.3	-21.2	-30.0	-40.7	-55.0

Table 9: continued.

IE	**7.8**	0.0	0.0	-4.7	-9.2	-13.8	-18.3	-24.8	-30.3	-41.4	-53.5
		0.1	0.0	-4.3	-8.7	-13.0	-17.4	-23.7	-29.0	-40.2	-52.6
		0.2	0.0	-4.0	-8.1	-12.2	-16.4	-22.5	-27.6	-38.7	-51.7
		0.3	0.0	-3.7	-7.5	-11.4	-15.4	-21.2	-26.1	-37.2	-50.6
		0.4	0.0	-3.4	-6.9	-10.6	-14.4	-19.8	-24.5	-35.5	-49.3
		0.5	0.0	-3.1	-6.3	-9.7	-13.3	-18.4	-22.8	-33.5	-47.8
IT	**-3.9**	0.0	0.0	-1.4	-2.7	-4.2	-6.5	-10.7	-14.4	-20.6	-25.5
		0.1	0.0	-1.1	-2.2	-3.4	-5.6	-9.5	-13.0	-18.9	-23.6
		0.2	0.0	-0.8	-1.6	-2.7	-4.6	-8.2	-11.5	-17.0	-21.5
		0.3	0.0	-0.6	-1.1	-1.9	-3.7	-6.9	-9.8	-14.9	-19.2
		0.4	0.0	-0.3	-0.6	-1.1	-2.6	-5.4	-8.0	-12.6	-16.4
		0.5	0.0	0.0	0.0	-0.3	-1.6	-3.9	-6.1	-9.9	-13.2
LU	**-16.8**	0.0	0.0	-1.1	-2.1	-3.0	-3.9	-5.6	-7.2	-10.0	-12.6
		0.1	0.0	-0.8	-1.7	-2.4	-3.2	-4.6	-6.0	-8.4	-10.7
		0.2	0.0	-0.6	-1.3	-1.9	-2.4	-3.6	-4.6	-6.6	-8.6
		0.3	0.0	-0.4	-0.8	-1.3	-1.7	-2.4	-3.2	-4.6	-6.3
		0.4	0.0	-0.2	-0.4	-0.6	-0.8	-1.3	-1.7	-2.4	-3.5
		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3
NL	**-3.6**	0.0	0.0	-1.4	-2.7	-4.5	-6.8	-11.0	-14.7	-20.9	-25.8
		0.1	0.0	-1.1	-2.2	-3.7	-5.9	-9.8	-13.3	-19.2	-23.9
		0.2	0.0	-0.8	-1.6	-3.0	-4.9	-8.5	-11.8	-17.3	-21.8
		0.3	0.0	-0.6	-1.1	-2.2	-4.0	-7.2	-10.1	-15.2	-19.5
		0.4	0.0	-0.3	-0.6	-1.4	-2.9	-5.7	-8.3	-12.9	-16.7
		0.5	0.0	0.0	0.0	-0.6	-1.9	-4.2	-6.4	-10.2	-13.5
PT	**16.2**	0.0	0.0	-4.9	-9.6	-14.4	-19.0	-28.4	-37.7	-49.8	-61.9
		0.1	0.0	-4.5	-9.0	-13.5	-18.0	-27.1	-36.4	-48.6	-61.0
		0.2	0.0	-4.2	-8.4	-12.6	-16.9	-25.7	-35.0	-47.1	-60.1
		0.3	0.0	-3.8	-7.7	-11.7	-15.8	-24.3	-33.4	-45.6	-59.0
		0.4	0.0	-3.4	-7.0	-10.7	-14.6	-22.8	-31.8	-43.9	-57.7
		0.5	0.0	-3.1	-6.3	-9.7	-13.3	-21.2	-30.0	-41.9	-56.2
ES	**9.0**	0.0	0.0	-4.7	-9.3	-13.9	-18.4	-26.0	-31.5	-42.6	-54.7
		0.1	0.0	-4.4	-8.7	-13.1	-17.5	-24.9	-30.2	-41.4	-53.8
		0.2	0.0	-4.1	-8.1	-12.3	-16.5	-23.7	-28.8	-39.9	-52.9
		0.3	0.0	-3.7	-7.5	-11.5	-15.5	-22.4	-27.3	-38.4	-51.8
		0.4	0.0	-3.4	-6.9	-10.6	-14.4	-21.0	-25.7	-36.7	-50.5
		0.5	0.0	-3.1	-6.3	-9.7	-13.3	-19.6	-24.0	-34.7	-49.0
SE	**2.4**	0.0	0.0	-4.5	-8.3	-11.1	-13.9	-19.4	-24.9	-36.0	-48.1
		0.1	0.0	-4.2	-7.7	-10.4	-13.0	-18.3	-23.6	-34.8	-47.2
		0.2	0.0	-4.0	-7.2	-9.6	-12.1	-17.1	-22.2	-33.3	-46.3
		0.3	0.0	-3.7	-6.7	-8.9	-11.1	-15.8	-20.7	-31.8	-45.2
		0.4	0.0	-3.4	-6.1	-8.1	-10.1	-14.4	-19.1	-30.1	-43.9
		0.5	0.0	-3.1	-5.6	-7.3	-9.1	-13.0	-17.4	-28.1	-42.4
UK	**-7.5**	0.0	0.0	-1.3	-2.5	-3.7	-4.8	-7.1	-10.8	-17.0	-21.9
		0.1	0.0	-1.0	-2.0	-3.0	-3.9	-5.9	-9.4	-15.3	-20.0
		0.2	0.0	-0.8	-1.5	-2.3	-3.0	-4.6	-7.9	-13.4	-17.9
		0.3	0.0	-0.5	-1.0	-1.5	-2.0	-3.3	-6.2	-11.3	-15.6
		0.4	0.0	-0.3	-0.5	-0.8	-1.0	-1.8	-4.4	-9.0	-12.8
		0.5	0.0	0.0	0.0	0.0	0.0	-0.3	-2.5	-6.3	-9.6
EC	**-4.8**	**0.0**	**0.0**	**-1.3**	**-2.6**	**-3.9**	**-5.6**	**-9.8**	**-13.5**	**-19.7**	**-24.6**
		0.1	**0.0**	**-1.1**	**-2.1**	**-3.1**	**-4.7**	**-8.6**	**-12.1**	**-18.0**	**-22.7**
		0.2	**0.0**	**-0.8**	**-1.6**	**-2.4**	**-3.7**	**-7.3**	**-10.6**	**-16.1**	**-20.6**
		0.3	**0.0**	**-0.5**	**-1.1**	**-1.6**	**-2.8**	**-6.0**	**-8.9**	**-14.0**	**-18.3**
		0.4	**0.0**	**-0.3**	**-0.5**	**-0.8**	**-1.7**	**-4.5**	**-7.1**	**-11.7**	**-15.5**
		0.5	**0.0**	**0.0**	**0.0**	**0.0**	**-0.7**	**-3.0**	**-5.2**	**-9.0**	**-12.3**

4 Interpretation of Results and Conclusions

To interpret the results for 2002, we display:

(I) U by ρ with α as a parameter;

i.e., the Member States' undershooting U that matches the relative uncertainty ρ 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 α 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 ρ takes on the values 5, 10, 20 and 40%.

With respect to ρ, we follow Jonas and Nilsson (2001), who recommended in their earlier study 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. We proceed similarly with respect to α.

The DTI displayed in Figure 2 is always shown to contrast the Member States' linear path undershooting targets for the year 2002 with their actual emission situation in that year.

(I) U by ρ with α as a parameter. Figure 5 displays U by ρ for $\alpha = 0.5$. For this α value, U equals zero (Case 1: equations (6)) or $U_{Gap} > 0$ (Cases 2–4: equations (9), (13) and (17) in which U_{Gap} is > 0 because it has not yet been multiplied with the factor $(-12/20)$). U_{Gap} is the initial or obligatory undershooting that is required to achieve detectability before the Member States are permitted to make use of their excess emission reductions.

U_{Gap} is a function of δ_{crit} (Equations (10), (14) and (18)) and thus of ρ (Equation (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 four countries that exhibit a negative DTI: FR, DE, SE and the UK (Figure 2). Given $\alpha = 0.5$, DE is the best potential seller followed by the UK, SE and FR. DE can report with a relative uncertainty > 40% and still exhibit a detectable emission signal, while the UK must report with a relative uncertainty falling into the interval $[20,40[$ (more correctly: up to approximately 33%), SE with a relative uncertainty falling into the interval $[5,10[$ (more correctly: up to approximately 6%), and FR even with a relative uncertainty falling into the interval $[0,5[$ % (more correctly: up to approximately 3%), respectively.[7]

Figures 6–10 display U by ρ for $\alpha = 0.4,...,0.0$. These figures can be interpreted similarly to Figure 5, bearing in mind that U increases in absolute terms with decreasing α. For $\alpha = 0.0$, DE and the UK must report with a relative uncertainty falling into the interval $[10,20[$ (more correctly: up to approximately 15%), and both SE and FR even with a relative uncertainty falling into the interval $[0,5[$ % (more correctly: up to approximately 3% and 2%, respectively).[8]

(II) U by a with ρ as a parameter. Figure 11 displays U by α for $\rho = 5\%$. For this ρ value, a white bar or, equivalently, a $U_{Gap} < 0$ (i.e., > 0 if the factor $(-12/20)$ is disregarded) appears only for Member States committed to emission limitation (ES, FI, FR, GR, IE, PT and SE; see Table 1). A $U_{Gap} < 0$ satisfies our 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 ρ (Figures 12–14), an increasing number of Member States committed to emission reduction also exhibit a $U_{Gap} < 0$, for $\rho = 40\%$ eventually all of them (Figure 14). For $\rho = 10\%$, 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 ($\rho = 40\%$), where the length of the white bars is equivalent to the combined length of the green, yellow, orange and red bars in Figure 5. Figures 12–14 still resolve U_{Gap} better than the remainder of U.

We prefer interpretation I (U by ρ with α as a parameter; Figures 5–10) over interpretation II (U by α with ρ as a parameter; Figures 11–14), as the use of α instead of ρ 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 ρ. (SE, e.g., meets U_{Gap} for $\rho = 5\%$ but not any more for $\rho = 10\%$; Figures 11 and 12.)

The following four conclusions emerge from our exercise:

(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

---

[7] The exact values are derived by demanding that U_{Gap} (as given by equation (10) for the UK and equation (14) for FR and SE) equals a Member State's DTI (multiplied with $(-20/12)$) and resolving the resulting equation for the relative uncertainty ρ.

[8] The exact values are derived by demanding that a Member State's DTI (multiplied with $(-20/12)$) is reproduced by using equation (6) for DE, (9) for the UK, (13) for FR and (17) for SE, respectively.

preparatory signal detection techniques to the Annex I countries under the Kyoto Protocol. The frame of reference for preparatory signal detection is that Annex I countries comply with their committed emission targets in 2008–2012. By contrast, in this study we apply one of these techniques, the Und&VT concept, to the Member States of the European Union under the EU burden sharing in compliance with the Kyoto Protocol, but with reference to the base year–commitment year linear path undershooting targets in 2002. Thus, our exercise shows that preparatory signal detection can also be applied in connection with interim emission targets.

(2) To advance the reporting of the EU we take, in addition to the DTI, uncertainty and its consequences into consideration, i.e., we determine (i) the risk that a Member State's true emissions in the commitment year/period are above its true EU reference line; and (ii) the detectability of its target. We anticipate 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 2002 only four Member States exhibit a negative DTI and thus appear as potential sellers: DE, FR, SE and the UK (Figure 2). However, expecting that the EU Member States exhibit relative uncertainties in the range of 5–10% and above rather than below, excluding emissions/removals due to LUCF (Table 2), 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 are above their true EU reference lines. These conditions can only be met by two Member States, DE and the UK (ranked in terms of creditability) (Figure 9). SE and FR can only act as potential high-risk sellers, SE within the 5–10% relative uncertainty class and FR within the 0–5% relative uncertainty class (Figure 5).

(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 committed emission limitation or reduction targets δ_{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 to achieve detectability. That is, for $\rho = 5\%$ only the Member States committed 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 $\rho = 10\%$, BE, IT, the NL as well as the EU (EU-15) as a whole also require a $U_{Gap} < 0$ (Figure 12), indicating that somewhere within the 5–10% relative uncertainty range non-detectability will become a problem also for these Member States as well as the EU. 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 8.1% (BE), 7.0% (IT), 6.4% (NL) and 8.7% (EU-15), respectively, assuming that the emission limitation or reduction targets are met under the 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.

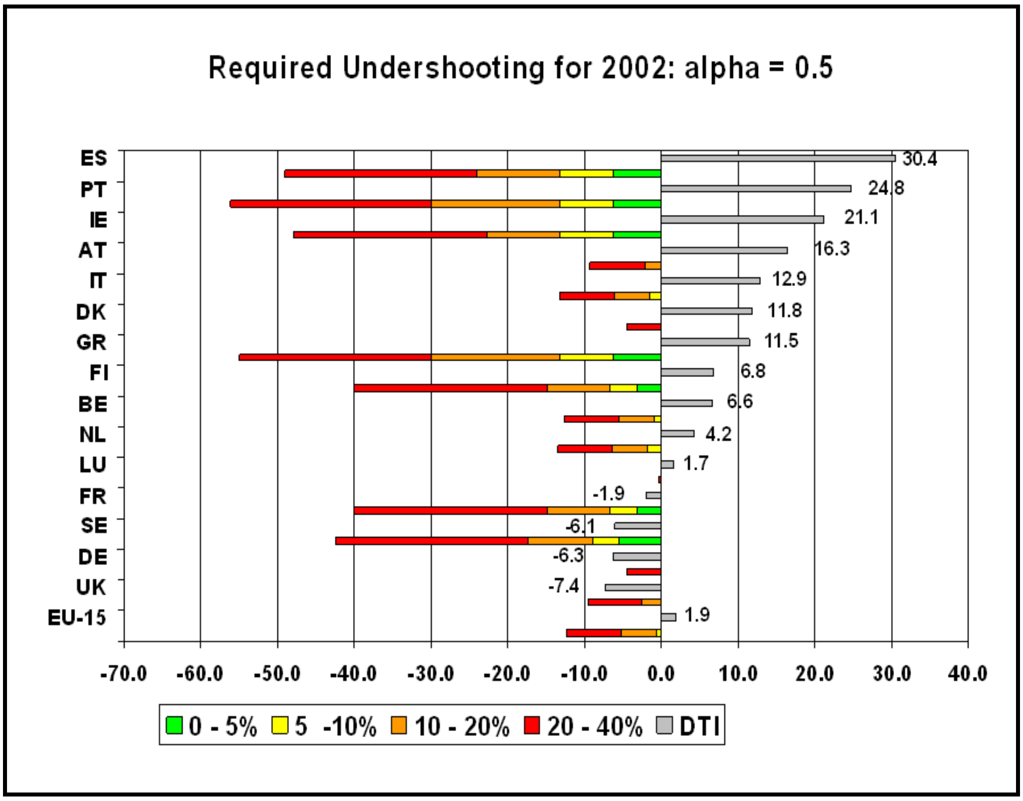


Figure 5: U by ρ (see intervals) for $\alpha = 0.5$ in addition to the DTI.

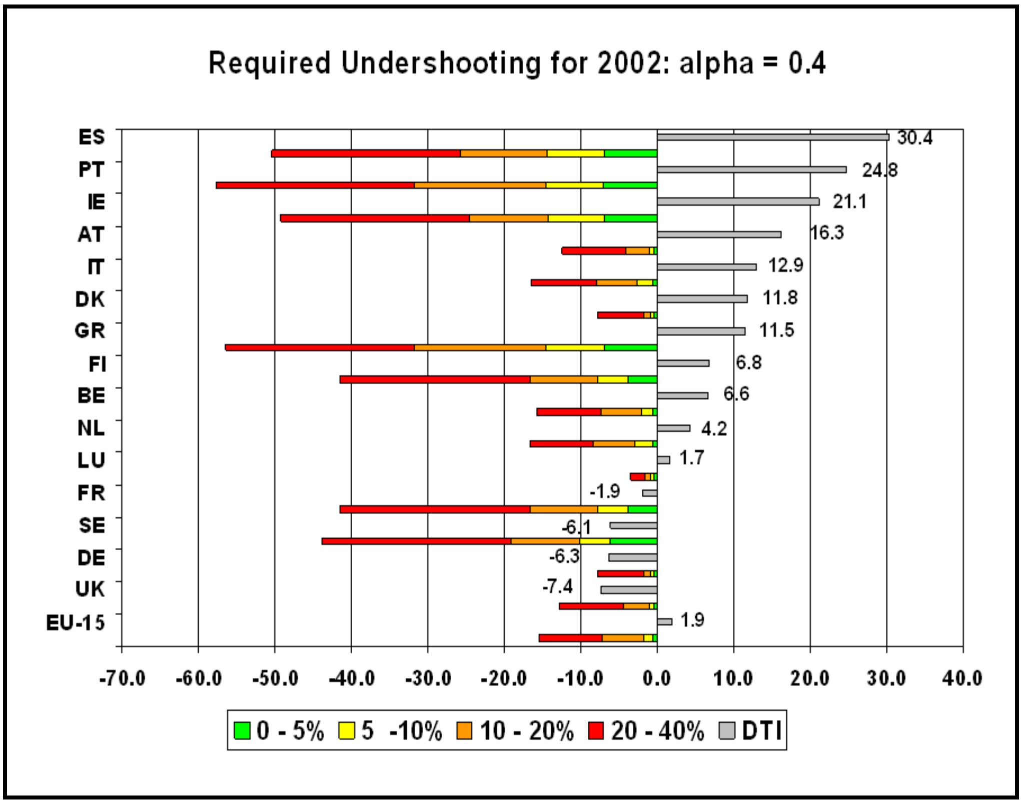


Figure 6: U by ρ (see intervals) for $\alpha = 0.4$ in addition to the DTI.

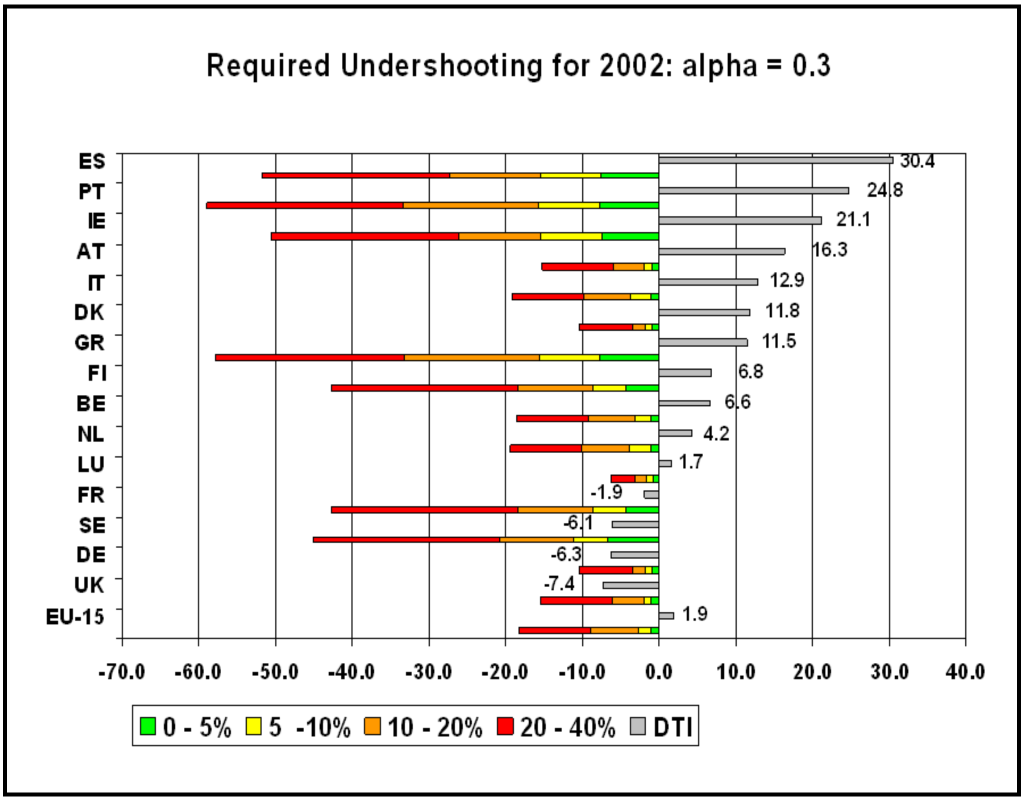


Figure 7: U by ρ (see intervals) for $\alpha = 0.3$ in addition to the DTI.

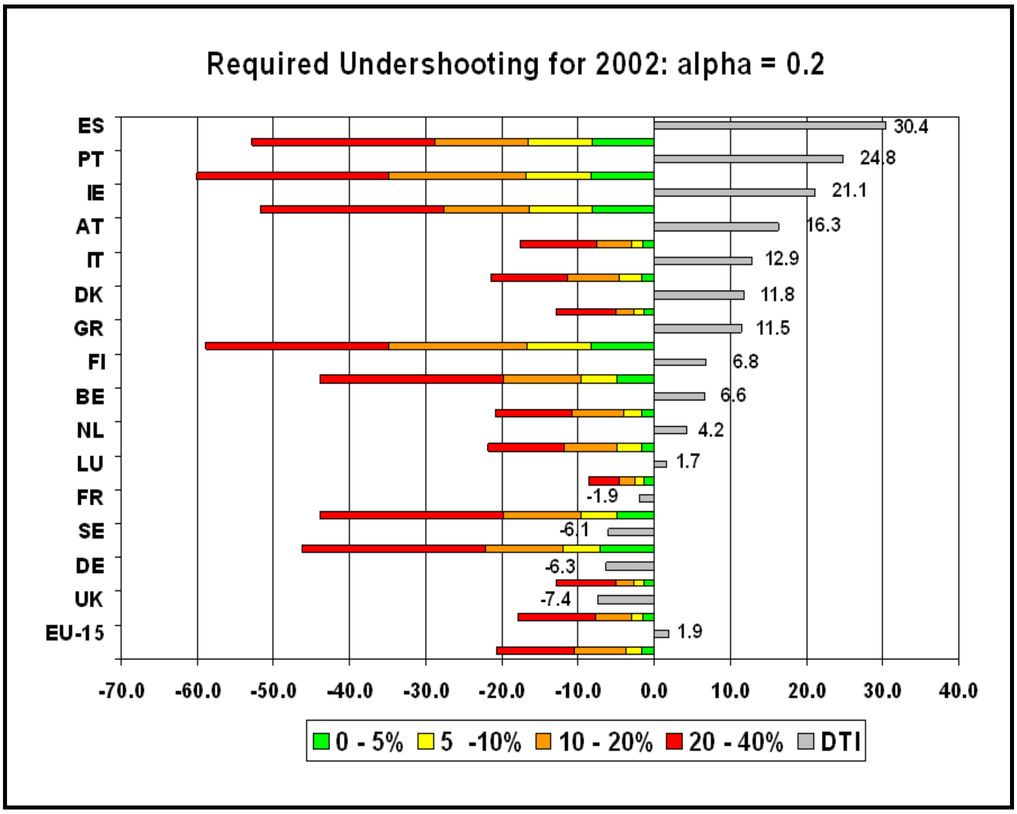


Figure 8: U by ρ (see intervals) for $\alpha = 0.2$ in addition to the DTI.

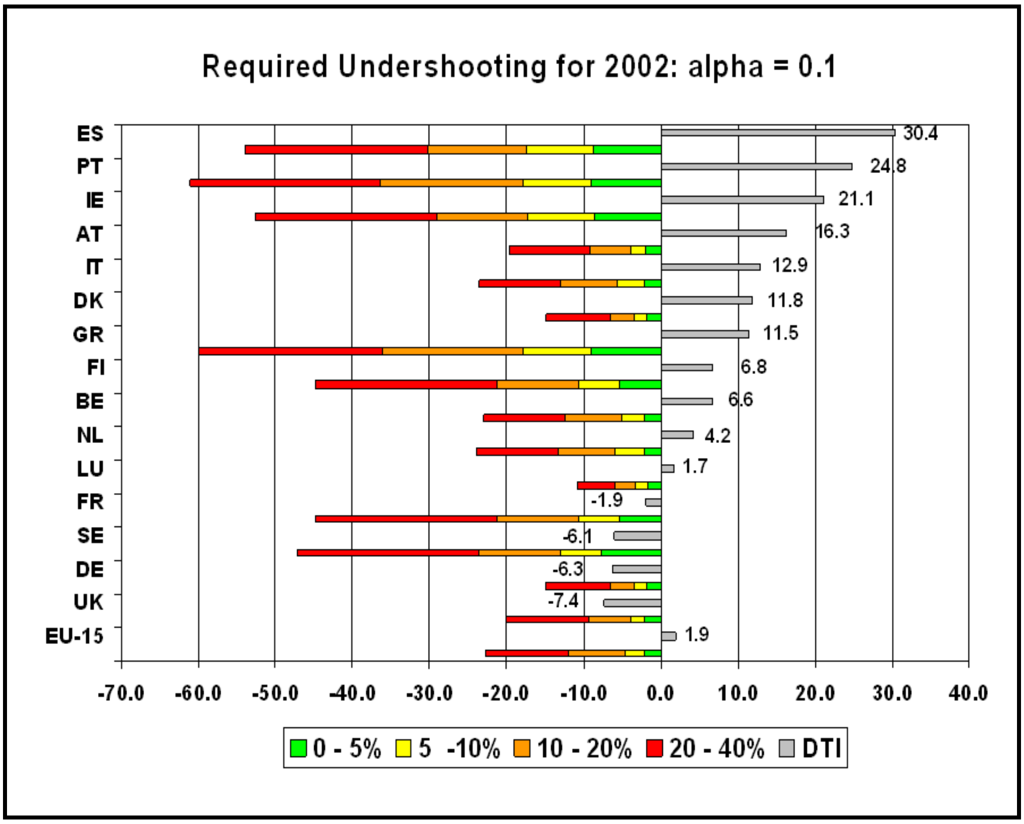


Figure 9: U by ρ (see intervals) for $\alpha = 0.1$ in addition to the DTI.

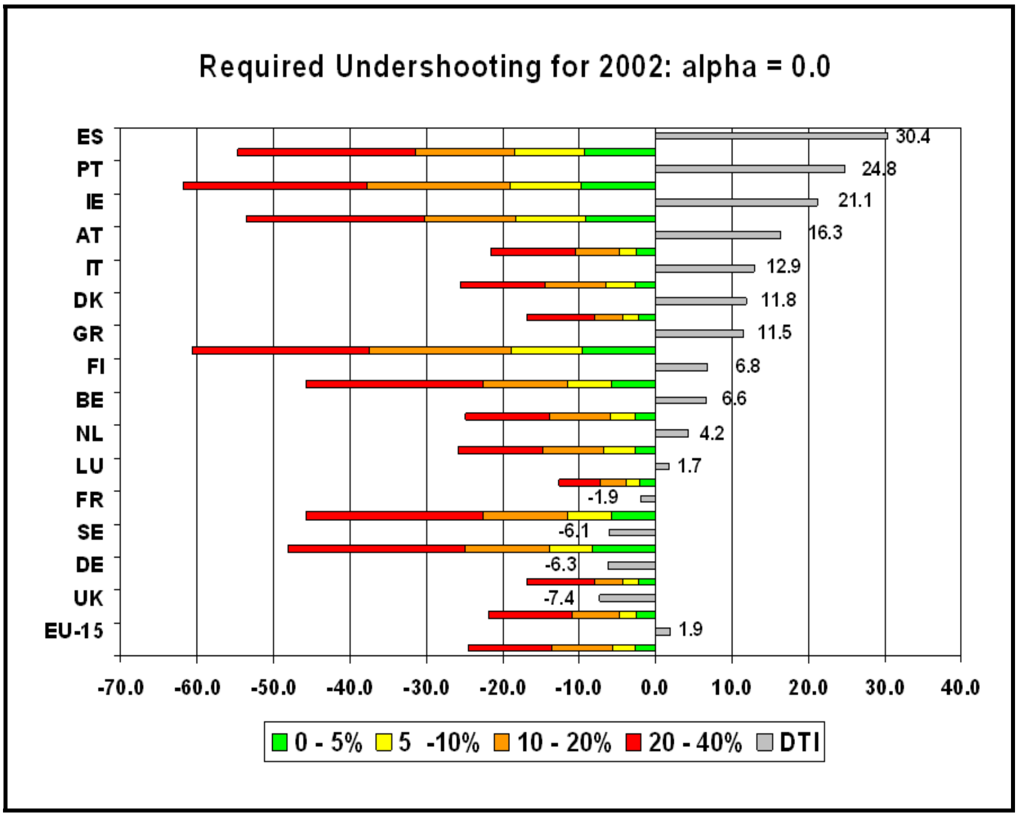


Figure 10: U by ρ (see intervals) for $\alpha = 0.0$ in addition to the DTI.

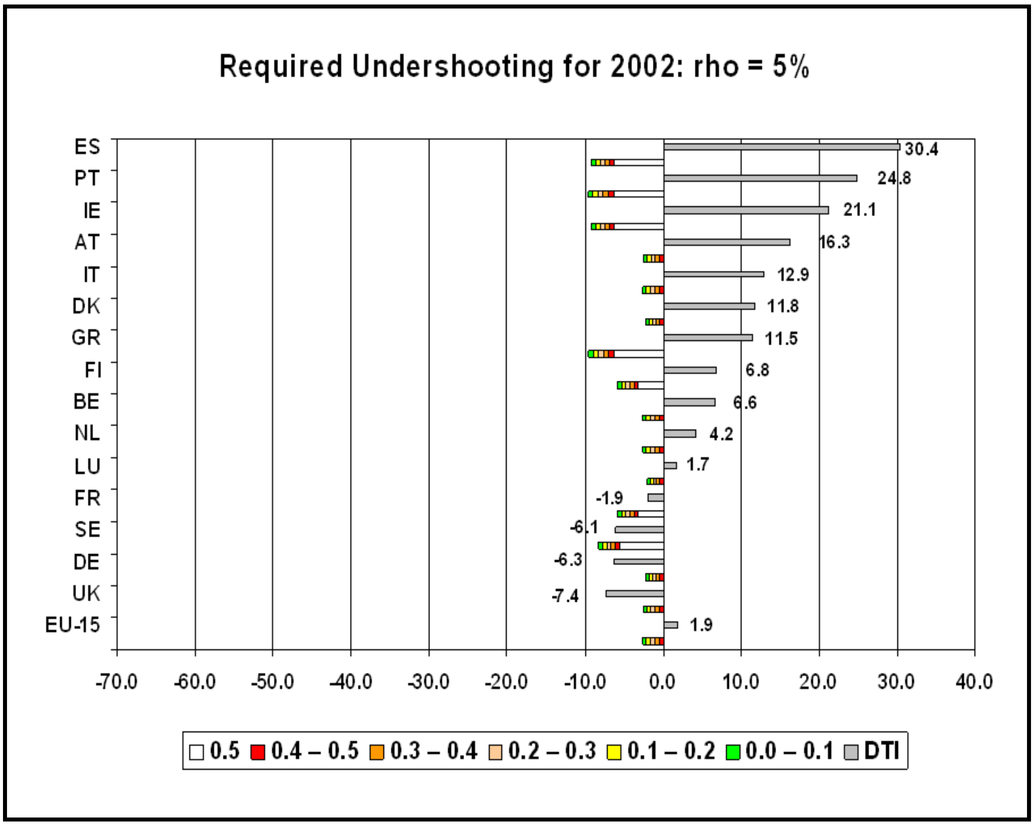


Figure 11: U by α (see value and intervals) for $\rho = 5\%$ in addition to the DTI.

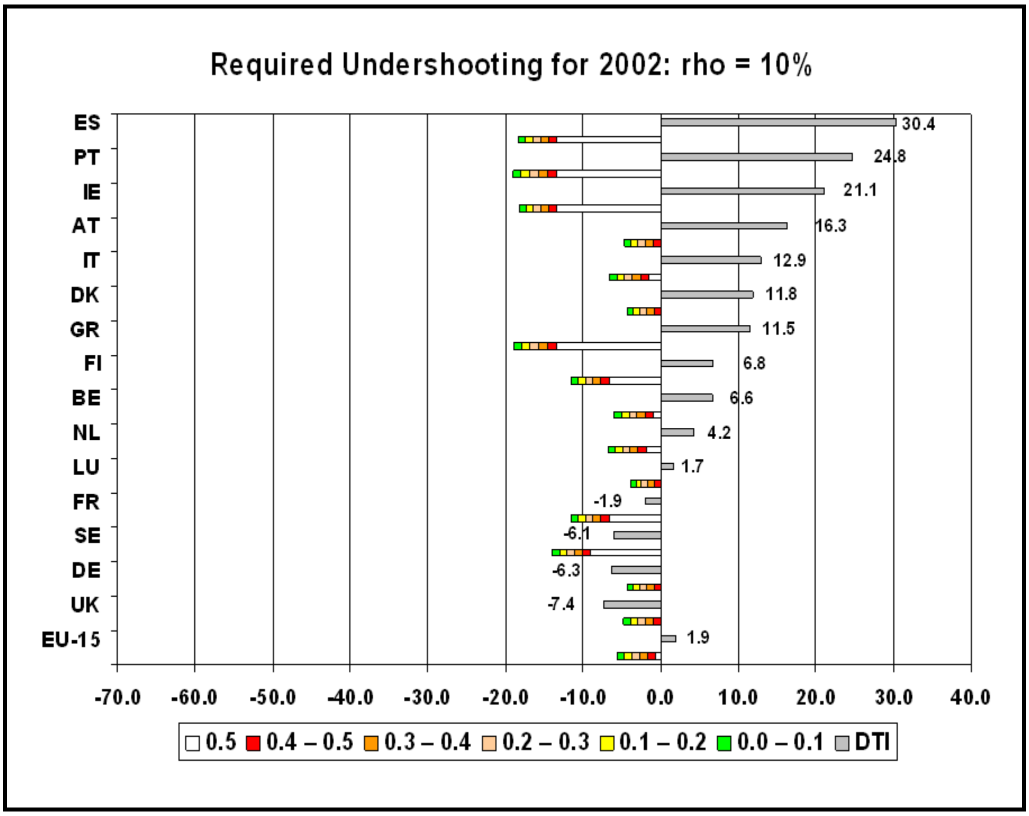


Figure 12: U by α (see value and intervals) for $\rho = 10\%$ in addition to the DTI.

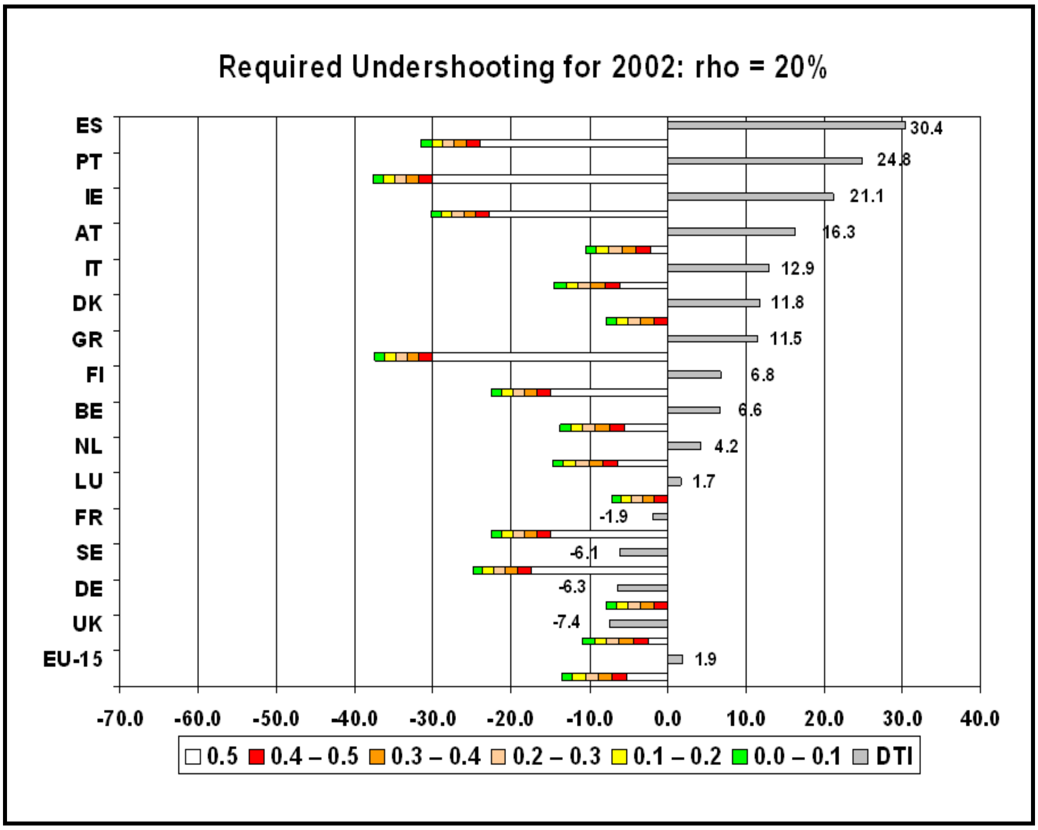


Figure 13: U by α (see value and intervals) for $\rho = 20\%$ in addition to the DTI.

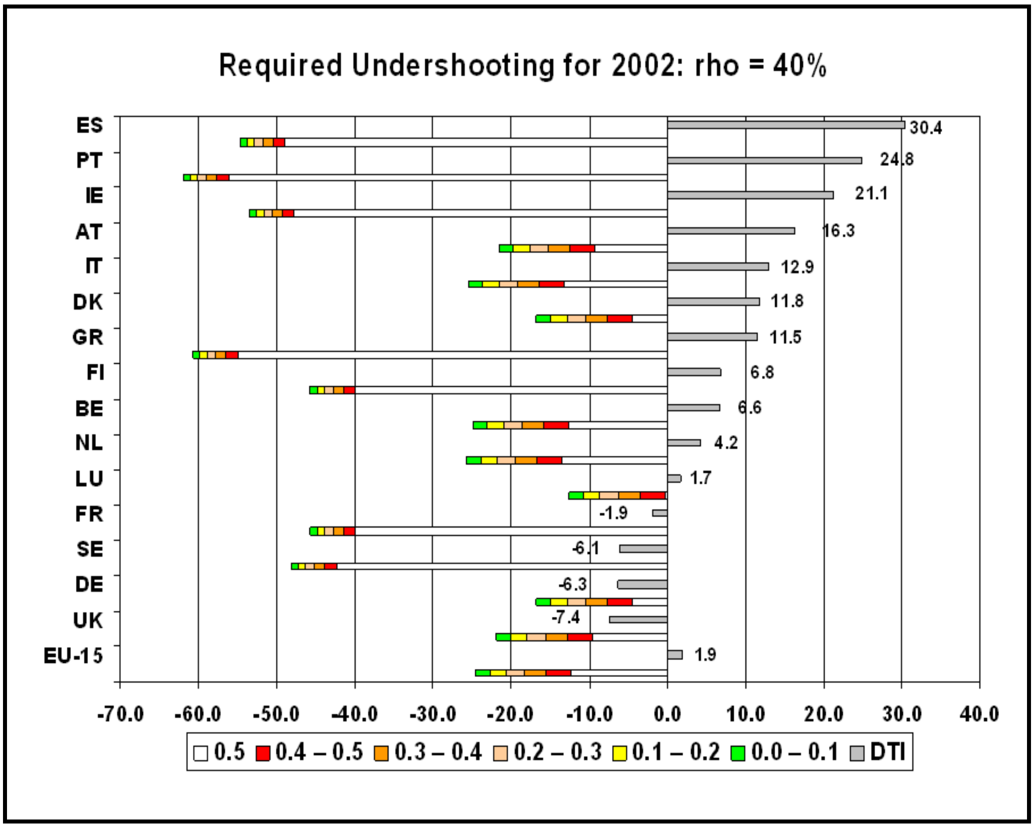


Figure 14: U by α (see value and intervals) for $\rho = 40\%$ in addition to the DTI.

References

EEA (2003). EU greenhouse gas emissions rise for second year running. News Release, 6 May, European Environment Agency (EEA), Copenhagen, Denmark. Available at: http://org.eea.eu.int/documents/newsreleases/ghg-2003-en.

EEA (2004). EU greenhouse gas emissions decline after two years of increases. News Release, 15 July, European Environment Agency (EEA), Copenhagen, Denmark. Available at: http://org.eea.eu.int/documents/newsreleases/tec2-2004-en.

Gugele, B., K. Huttunen, M. Ritter and M. Gager (2004). Annual European Community Greenhouse Gas Inventory 1990–2002 and Inventory Report 2004. Technical Report No. 2, European Environment Agency (EEA), Copenhagen, Denmark, pp. 177. Available at: http://reports.eea.eu.int/technical_report_2004_2/en.

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.htm.

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, 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. 91. Available at: http://www.iiasa.ac.at/Publications/Documents/IR-04-029.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/gpgaum.htm.

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
DE	Germany
DK	Denmark
EC	European Community
ES	Spain
FI	Finland
FR	France
GR	Greece
IE	Ireland
IT	Italy
LU	Luxembourg
NL	Netherlands
PT	Portugal
SE	Sweden
UK	United Kingdom