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Hamal, K. and Jonas, M.

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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

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Preparatory Signal Detection for the EU-27 Member States Under EU Burden Sharing—Advanced Monitoring Including Uncertainty (1990–2005)

Khrystyna Hamal (kh.hamal@gmail.com)
Matthias Jonas (jonas@iiasa.ac.at)

Approved by

Anatoly Shvidenko
Acting Leader, Forestry Program

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Corrigenda

Figure 2 and Table 9 contained numerical misprints (Fig. 2: the DTPI value for Austria was incorrect; Tab. 9: the δ_{KP} values had not been multiplied with (-15/20)) and are now updated.

Table A1 is also updated as a consequence of renumbering the equations in the Appendix (two equations were numbered (A12)).

21 March 2011

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 SF6) 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 27 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 2005.

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 target, or EU-compatible but detectable, target can decrease this risk. The Member States' potential linear path undershooting opportunities as of 2005 are contrasted with their actual

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

In 2005, fourteen EU-27 Member States exhibit a negative DTPI and thus appear as potential sellers: Bulgaria, Czech Republic, Estonia, France, Finland, Germany, Hungary, Latvia, Lithuania, Poland, Romania, 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 2005, these conditions can only be met by ten (nine new and one old) Member States (ranked in terms of credibility): Latvia, Lithuania, Estonia, Bulgaria, Romania, Hungary, Slovakia, Poland, Czech Republic, and the United Kingdom; while four old Member States, Germany, Sweden, Finland and France, can only act as potential sellers with a higher risk (Germany: $a \approx 0.25$; Sweden, Finland and France: $a = 0.5$). The other EU-27 Member States do not meet their linear path (base year–commitment year) undershooting targets as of 2005 (i.e., they overshoot their intermediate targets), or do not have Kyoto targets at all (Cyprus and Malta).

The relative uncertainty, with which countries report their emissions, matters. 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.

About the Authors

Khrystyna Hamal graduated (M.Sc.) from Lviv National Polytechnic University, Ukraine, in Applied Mathematics in 2006. She is now a Ph.D. student at the same university. Matthias Jonas is a Research Scholar in IIASA's Forestry Program.

Preparatory Signal Detection for the EU-27 Member States Under EU Burden Sharing—Advanced Monitoring Including Uncertainty (1990–2005)

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 27 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 2005 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-27 as a whole, of trends in emissions of GHGs up to 2005. 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-path indicator (DTPI; formerly: distance-to-target indicator) introduced in Figure 2, based on the country data listed in Table 1, is a measure for how much the Member States' actual (2005) 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 DTPI 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, 2007a: Table 16.1; EEA, 2007b: Tables ES.1 and 2.1).[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 2005 and their linear path targets for that year (Table 1). Figure 3 facilitates understanding the 2005 situation of the EU in quantitative terms.

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 emissions 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 2005, i.e., the linear target path 1990–2008/12 is evaluated with respect to this year.

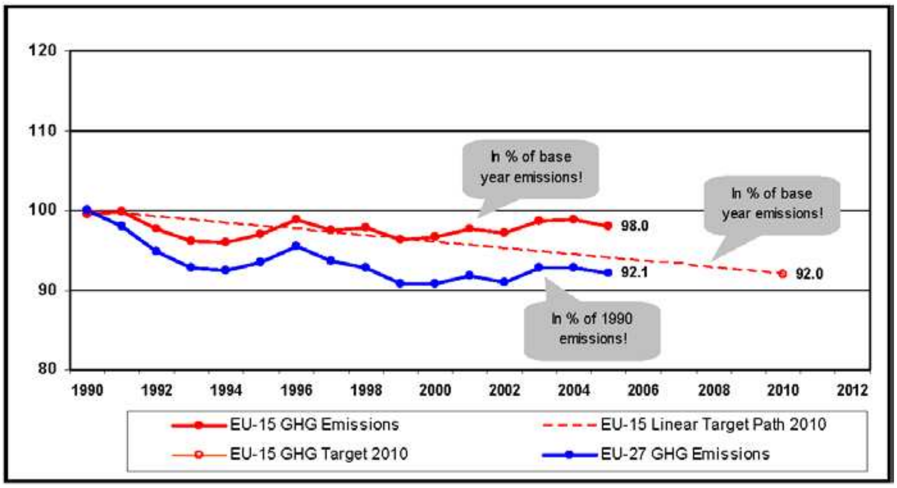

Figure 1: EU-27 GHG emissions for 1990–2005 (excluding LUCF and Kyoto mechanisms) with 1990 emissions as reference. The corresponding EU-15 GHG emissions and linear target path 1990–2008/12, with base-year emissions as reference, are shown for comparison. Source: EEA (2007b: Tables ES.1 and ES.2, and 2.1 and 2.2, respectively); reproduced with the help of original data from Gugele (2008).

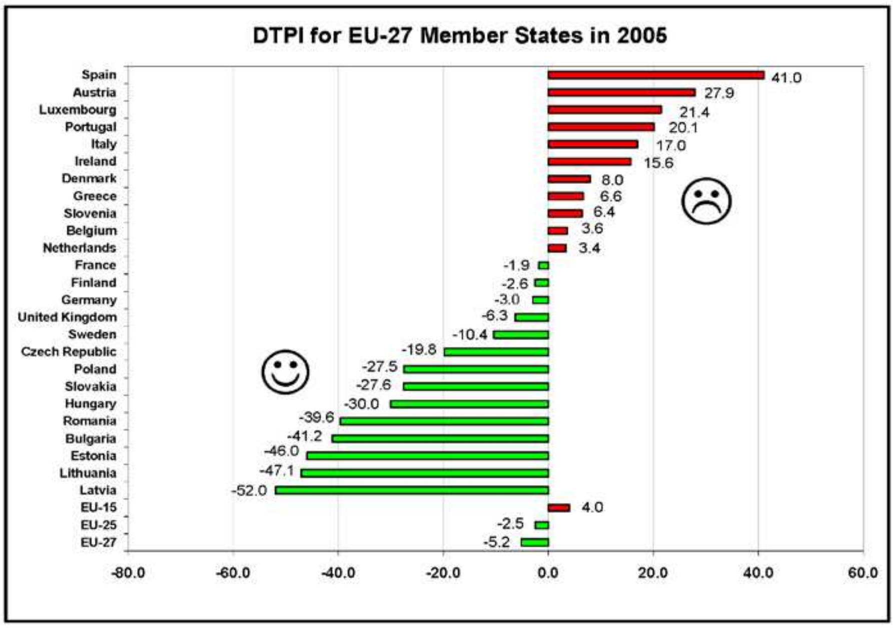

Figure 2: Distance-to-target-path indicator (DTPI) for EU-27 as a whole and its Member States in 2005 under the Kyoto Protocol and EU burden sharing (excluding LUCF and Kyoto mechanisms). The DTPIs for the EU-15 and EU-25 as a whole are shown for comparison.

Table 1: Distance-to-target-path indicator (DTPI) for EU-27 as a whole and its Member States in 2005 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 2005 GHG emissions (excluding LUCF and Kyoto mechanisms; in CO_2-equivalents); 4th and 5th columns: 2004–2005 and base year–2005 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 (2007a: Table 16.1), Gugele (2008).

Country	Base-year emissions (1)	2005 emissions	Change 2004–2005	Change 2005/ base year	EU burden-sharing or Kyoto target		DTPI (2005 emissions relative to target path)(3) without/with Kyoto mechanisms and carbon sinks
	Mt CO_2	Mt CO_2	%	%	%	Mt CO_2	Percentage points
Austria	79.0	93.3	2.3	18.1	– 13.0	68.7	+ 27.9 / + 18.7
Belgium	146.9	143.8	– 2.6	– 2.1	– 7.5	135.9	+ 3.6 / 0.0
Bulgaria	132.1	69.8	1.3	– 47.2	– 8.0	121.5	– 41.2 / n.a.
Cyprus	6.0 (2)	9.9	0.2	63.7	No target	No target	No target
Czech Republic	196.3	145.6	– 1.0	– 25.8	– 8.0	180.6	– 19.8 / n.a.
Denmark	69.3	63.9	– 6.3	– 7.8	– 21.0	54.8	+ 8.0 / + 1.0
Estonia	43.0	20.7	– 2.3	– 52.0	– 8.0	39.6	– 46.0 / n.a.
Finland	71.1	69.3	– 14.6	– 2.6	0.0	71.1	– 2.6 / – 5.7
France	563.9	553.4	– 0.5	– 1.9	0.0	563.9	– 1.9 / n.a.
Germany	1 232.5	1 001.5	– 2.3	– 18.7	– 21.0	973.7	– 3.0 / n.a.
Greece	111.1	139.2	1.2	25.4	25.0	138.8	+ 6.6 / n.a.
Hungary	123.0	80.5	1.2	– 34.5	– 6.0	115.7	– 30.0 / n.a.
Ireland	55.8	69.9	1.9	25.4	13.0	63.0	+ 15.6 / + 8.0
Italy	519.5	582.2	0.3	12.1	– 6.5	485.7	+ 17.0 / + 11.8
Latvia	25.9	10.9	1.5	– 58.0	– 8.0	23.8	– 52.0 / n.a.
Lithuania	48.1	22.6	7.2	– 53.1	– 8.0	44.3	– 47.1 / n.a.
Luxembourg	12.7	12.7	– 0.4	0.4	– 28.0	9.1	+ 21.4 / – 6.4
Malta	2.2(2)	3.4	6.1	54.8	No target	No target	No target
Netherlands	214.6	212.1	– 2.9	– 1.1	– 6.0	201.7	+ 3.4 / – 3.7
Poland	586.9	399.0	0.6	– 32.0	– 6.0	551.7	– 27.5 / n.a.
Portugal	60.9	85.5	1.0	40.4	27.0	77.4	+ 20.1 / + 7.2
Romania	282.5	153.7	– 4.0	– 45.6	– 8.0	259.9	– 39.6 / n.a.
Slovak Republic	73.4	48.7	– 1.6	– 33.6	– 8.0	67.5	– 27.6 / n.a.
Slovenia	20.2	20.3	2.1	0.4	– 8.0	18.6	+ 6.4 / – 2.1
Spain	289.4	440.6	3.6	52.3	15.0	332.8	+ 41.0 / + 31.3
Sweden	72.3	67.0	– 3.9	– 7.4	4.0	75.2	– 10.4 / – 12.6
United Kingdom	779.9	657.4	– 0.5	– 15.7	– 12.5	682.4	– 6.3 / – 6.7
EU-15	4 278.8	4 192.0	– 0.8	– 2.0	– 8.0	3 936.5	+ 4.0 / + 1.4
EU-27	5 818.4 (2)	5 177.0	– 0.7	– 11.0	No target	No target	No target
Croatia	34.6	29.2	0.0	– 15.5	– 5.0	32.9	– 11.8 / n.a.
Iceland	3.4	3.7	0.7	10.5	10.0	3.7	+ 3.0 / n.a.
Liechtenstein	0.2	0.3	0.1	17.4	– 8.0	0.2	+ 23.4 / n.a.
Norway	49.8	54.2	– 1.3	8.8	1.0	50.2	+ 8.1 / – 7.0
Switzerland	52.7	53.6	1.1	1.7	– 8.0	48.5	+ 7.7 / + 5.4

Note: (1) The base year (first column) refers to the base year of the Initial Reports due at the end of 2006 and do not consider changes due to UNFCCC reviews, as the base years were not finalised in time to be considered in this report. The base years of the EU-15 are consistent with the base years of the EC Initial Report.

(2) The EU-27, Cyprus and Malta have no target under the Kyoto Protocol, and therefore no legal base year. As a result, in this table, 1990 emissions were taken as reference emissions for the EU-27, Cyprus and Malta and Turley.

(3) The distance-to-target-path indicator (DTPI) measures the deviation in percentage points of actual emissions in 2005 from a (hypothetical) linear path between base-year emissions and the burden-sharing target for 2010. A positive value suggests an underachievement and a negative value an overachievement by 2005. The DTPI is used as an early indication of progress towards the Kyoto and burden-sharing targets.

The mention n.a. indicates that the country does not intend to use carbon sinks or Kyoto mechanisms to meet its target.

Source: EEA, based on EU Member States greenhouse gas inventories.

Figure 3: Figure 2 presented in absolute terms. Potential buyers in 2005: AT, BE, DK, ES, GR, IE, IT, LU, NL, PT, SI; potential sellers in 2005: BG, CZ, DE, EE, FI, FR, HU, LT, LV, PL, RO, 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 (2007b: Table 1.13) and is reproduced as Table 2. This compilation makes available quantified uncertainty estimates from 21 of the EU-27 Member States (extracted from their National Inventory Reports 2006 and 2007). From the remaining Member States national inventory reports were available but without uncertainty estimates, or national inventory reports were not provided. The listed uncertainties refer to a confidence of 95% confidence interval[5] and exclude, with the exception of a few Member States, CO_2 emissions/removals due to land-use change and forestry (LUCF). Germany, Poland, Portugal, Slovakia, 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-27 Member States excluding LUCF (with the exception of Germany, Poland, Portugal, Slovakia, and the United Kingdom) and Kyoto mechanisms.[6] Source: EEA (2007b: Table 1.13).

Member State	Austria		Belgium	Bulgaria	Cyprus	Czech Republic	Denmark	Estonia	Finland	
Citation	Austrian NIR Mar 2007, p.46-50		Belgian NIR 2006, p. 15-22	No NIR provided	No uncertainty estimates provided	Czech NIR 2007, p. 24-25	Danish NIR 2007 p. 51-54	NIR Apr 2006	Finnish NIR Mar 2007 p. 27-28	
Method used	Tier 1, Tier 2		Tier 1			Tier 1	Tier 1		Tier 1, Tier 2	
Documentation in NIR (according to Table 6.1/6.2 of GPG)	Annex 6 (planned for April version)		Yes			Yes: Table 1.3	Yes	No information provided	Yes: Annex 1	
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, 2005 - All sources (key sources and "others")	1990, 2005 - The sources included in the uncertainty estimate cover 99.9% of the total Danish greenhouse gas emission (CO2 eq., without CO2 from LUCF).		1990, 2005 – All sources [percentages below are calculated by EEA on basis of the NIR]	
Uncertainty (%)	Tier 1	Tier 2	Tier 1			Tier 1	Tier 1	Tier 1	Tier 1 (including LULUCF)	Tier 2 (excluding LULUCF)
CO_2	Base year: 0.9% 2004: 0.9%	1990: 2.3% 1997: 2.1%	1.9%				2005: 2.3%			1990: -4%/+2% 2005: -4%/+2%
CH_4	Base year: 13.1% 2004: 11.6%	1990: 48.3% 1997: 47.4%	24.0%				2005: 23%			1990: -25%/+25% 2005: -24%/+22%
N_2O	Base year: 24.6% 2004: 26.8%	1990: 89.6% 1997: 85.9%	27.0%				2005: 42%			1990: -47%/+113% 2005: -31%/+69%
F-gases	Base year: 33.5% 2004: 32.8%		100				2005: 49%			1990: -44%/+44% 2005: -11%/+11%
Total	Base year: 2.42% 2004: 1.81%	1990: 9.8% 1997: 8.9%	7.5%			6.7%	2005: 5.4%		2005: 58.8%	1990: -7%/+13% 2005: -4%/+7%
Uncertainty in trend (%)	Tier 1		Tier 1			Tier 1	Tier 1		Tier 1 (including LULUCF)	Tier 2 (excluding LULUCF)
CO_2							1.9 percentage points			
CH_4							10.2 percentage points			
N_2O							11.6 percentage points			
F-gases							64 percentage points			
Total	2.97%		2.7%			3.0%	2.2 percentage points		15.5%	-12/+8 percentage points

Table 2: continued

Member State	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta
Citation	French NIR 2007, p. 30-31	German NIR April 2007, p. 90-94	Greek Short-NIR 2007, p. 17-18.	Hungarian short NIR 2007, p. 16	Irish NIR 2007, p. 15-16, 21-22 (Tab. 1.8)	Italian NIR Aug 2006, p. 18, Annex 1	Latvian NIR Mar 2007, p. 16-17	Lithuanian NIR 2007, p.14	Luxembourg NIR 2006	No NIR provided
Method used	Tier 1	Tier 2	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1		
Documentation in NIR (according to Table 6.1/6.2 of GPG)	Yes: Annex 2	Yes: Annex [Anhang] 7 (according to Table 6.2 of GPG)	No	No	Yes: Table 1.8	Yes Annex 1 (Table A1.2)	Yes: Annex 2	Yes: Annex 2	No	
Years and sectors included	1990, 2005 – All sources	2005 - All sources	1990, 2005 - Almost all sources (not included sources represent less than 1% of total emissions)	1985-2004	1990, 2004 – All sources	1990, 2004 – All sources	1990-2004, All sources	1990-2005 (1995-2005 for F-gases), all source categories (except LULUCF and solvent sector)		
Uncertainty (%)	Tier 1	Tier 2	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1
CO_2		2005: +3.31%/-2.85%	4% (without LUCF)	+/- 2 to 4%	1.5%		3.4%	+/- 3.1%		
CH_4		2005: +.4.52%/-4.51%	33% (without LUCF)	+/- 15 to 25%	4.1%		16%	+/-10.2%		
N_2O		2005: +.109.13%/-45.82%	104% (without LUCF)	+/- 80 to 90%	32.7%		28%	+/-77.9%		
F-gases			113,7% (without LUCF)		0.02%			+/-0,0%		
Total	+-17.7%	2005: +11.68%/-5.77%	11% (without LUCF)	4.92%	6.2%	3,3% net 8,3% with LULUCF	5.1%	+/-9,55%		
Uncertainty in trend (%)	Tier 1		Tier 1	Tier 1	Tier 1	Tier 1	Tier 1			
CO_2					3.3%		1.3%			
CH_4					3.2%		8%			
N_2O					6.3%		13%			
F-gases					0.04%					
Total	3.0%		10.0%	2.45%	3.6%	2,6% net 7,9% with LULUCF	2.1%	+/-2,1%		

Table 2: continued.

Member State	Netherlands	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	United Kingdom	
Citation	Dutch NIR 2007, Mar 2007 p.29-33	Polish NIR Apr 2007, p. 5	Portuguese NIR 2007, p. 14-16	Romania NIR Mar 2007, p.28	Slovakian NIR July 2006, p.15	Slovenian NIR Mar 2007 p. 19	Spanish NIR Mar 2007, p. 1.26 -1.30	Swedish NIR 2007, p. 34-36	UK NIR April 2007, p. 68	
Method used	Tier 1	Tier 1	Tier 1			Tier 1	Tier 1	Tier 1	Tier 1, Tier 2	
Documentation in NIR (according to Table 6.1/6.2 of GPG)	Annex 7, Table A7.1 and A7.2	Partially in Annex 5	Yes: Annex B	No information provided	No	Yes: Annex 7	Yes: Table A7.1 and A7.2	Partially (Annex 2)	Yes: Tables in Annex 7 p. 417ff	
Years and sectors included	1990/95, 2004 – All sources	2005 - All sources	1990-2005 - All sources			1986, 2002, 2003 - All sources	Base year, 2003, 2004 - All sources	1990 and 2005 for all sectors and gases	1990, 2005 – All sources, AD, EF	
Uncertainty (%)	Tier 1	Tier 1	Tier 1 2005		Tier 1	Tier 1	Tier 1	Tier 1	Tier 1 2005	Tier 2 2005
CO_2	3%	7.3%	5%				-	2,4% (1990) 2,2% (2005)		2.1%
CH_4	25%	22.2%	27%				-	2,8% (1990) 2,1% (2005)		21.2% (net)
N_2O	50%	47.1%	103%				-	5,3 % (1990) 5,1% (2005)		233%
F-gases	50%	HFC 44.1% PFC 20% SF6 100%	65%					0,2% (1990) 0,3% (2005)		HFC 15% PFCs 5.8% SF6 24.5%
Total	5%		9.3%		9.7%	1986: 16% 2002: 13,1% 2003: 12%	Base year: +/-9.0% 2003: +/-6.9% 2004: +/- 7.0%	6,4% (1990) 6% (2005)	16.5%	14.3%
Uncertainty in trend (%)	Tier 1		Tier 1		Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 2 (range)
CO_2	+/- 2.5%									-8.9 to -3.7%
CH_4	+/- 10%									-65 to -34%
N_2O	+/- 15%									-89 to 215%
F-gases	+/- 7%									HFC 10 to 68%, PFCs -68 to -63%, SF6 -15 to 71%
Total	+/- 3%		13.2%		3.6%	2002: 4% 2003: 3%	2003: +/-3.3% 2004: +/- 4.2%		2.6 %	-28.7 to 0%

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 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 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 and 3.2 for details).

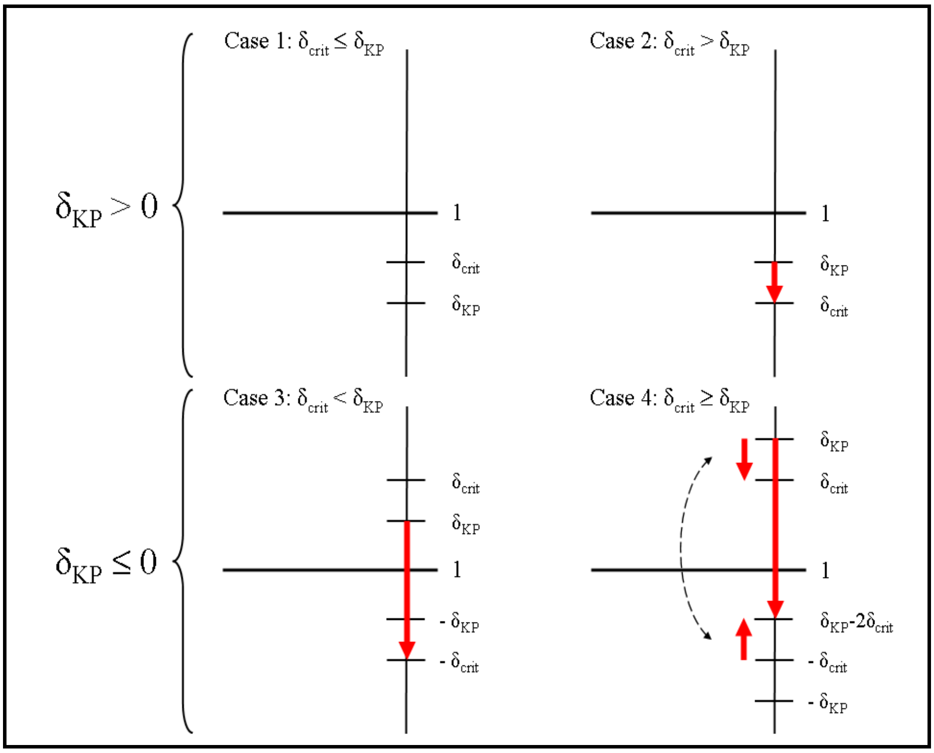

Figure 4: The four cases that are distinguished in applying the Und&VT concept (see also Table 3). Emission reduction: $\delta_{KP} > 0$; emission limitation: $\delta_{KP} \le 0$.

Case 1: $\delta_{KP} > 0 : \delta_{crit} \le \delta_{KP}$. Here, use is made of Eq. (43a), (B1), (D1), (B3) and (D2) of Jonas *et al*. (2004a: Appendix D) (see also Jonas *et al*., 2008: Appendix D):

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

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 equations (45a), (B1), (D3a,b), (D4) and (42b) of Jonas *et al*. (2004a: Appendix D) (see also Jonas *et al*., 2008: Appendix 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-$(1-\delta_{KP})x_{t,i}$ risk in Case 1) can be grasped and quantified although true emissions are unknown by definition (but not necessarily their ratios)

<u>*Case 3*</u>*:* $\delta_{KP} \le 0 : \delta_{crit} < \delta_{KP}$. Here, use is made of equations (50a), (B1), (D7a,b), (D8) and (52) of Jonas *et al*. (2004a: Appendix D) (see also Jonas *et al*., 2008: Appendix D):[9]

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

where

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

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

with

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

<u>Case 4</u>: $\delta_{KP} \le 0 : \delta_{crit} \ge \delta_{KP}$. Here, use is made of equations (55a), (B1), (D11a,b), (D12), (57) and (58) of Jonas *et al*. (2004a: Appendix D) (see also Jonas *et al*., 2008: Appendix D):[9]

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

where

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

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

with

$$U_{gap} = -2\delta_{crit} \qquad (18)$$

$$-\delta'_{crit} = \delta_{KP} - 2\delta_{crit}. \qquad (19)$$

The inversions $\rho = \rho(\delta_{KP}, U, \alpha)$ of Eq. (6), (9), (13) and (17) are given in the Appendix. They are used to determine the uncertainty for a given undershooting (typically for U equal to DTPI, here with reference to 2008/12) and in dependence of δ_{KP} and α.

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 rectified by introducing a minus sign when reporting the 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-27 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 2005.

The results are interpreted in Section 4, together with the conclusions that can be drawn from this interpretation.

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-27 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 $(-15/20)$. 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 $(-15/20)$ establishes the linear path (base year–commitment year) emission targets and undershooting opportunities for the year 2005 (see Table 9).

Table 6: The conditions (in the form of Cases 1–4) that underlie the emissions reporting of a particular EU-27 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
BG	**8.0**	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
RO	**8.0**	Case 1	Case 1	Case 1	Case 1	Case 2	Case 2	Case 2	Case 2	Case 2
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-27 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-$\left(1-(\delta_{KP}-2\delta_{crit})\right)x_{t,1}$’) 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
BG	**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
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	-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
RO	**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
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	-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-27 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	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
BG	**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
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
RO	**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
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 $(-15/20)$ to reconcile the Und&VT concept with the emissions reporting for the EU and to establish the linear path emissions targets and undershooting opportunities for 2005.

MS	δ_{KP_05}	α	Undershooting U in % for $\rho =$								
	%	**1**	**0%**	**2.5%**	**5%**	**7.5%**	**10%**	**15%**	**20%**	**30%**	**40%**
AT	**-9.8**	0.0	0,0	-1,6	-3,1	-4,6	-5,9	-8,5	-13,2	-20,9	-27,0
		0.1	0,0	-1,3	-2,5	-3,7	-4,8	-7,0	-11,4	-18,7	-24,7
		0.2	0,0	-1,0	-1,9	-2,8	-3,7	-5,4	-9,4	-16,4	-22,0
		0.3	0,0	-0,6	-1,3	-1,9	-2,5	-3,7	-7,4	-13,7	-19,1
		0.4	0,0	-0,3	-0,6	-1,0	-1,3	-1,9	-5,2	-10,8	-15,6
		0.5	0,0	0,0	0,0	0,0	0,0	0,0	-2,8	-7,6	-11,7
BE	**-5.6**	0.0	0,0	-1,7	-3,3	-4,8	-7,4	-12,7	-17,3	-25,0	-31,1
		0.1	0,0	-1,4	-2,7	-3,9	-6,2	-11,1	-15,5	-22,8	-28,8
		0.2	0,0	-1,0	-2,0	-3,0	-5,1	-9,5	-13,6	-20,5	-26,2
		0.3	0,0	-0,7	-1,4	-2,0	-3,8	-7,8	-11,5	-17,9	-23,2
		0.4	0,0	-0,3	-0,7	-1,0	-2,5	-6,1	-9,3	-14,9	-19,8
		0.5	0,0	0,0	0,0	0,0	-1,2	-4,2	-6,9	-11,7	-15,8
BG	**-6.0**	0.0	0,0	-1,7	-3,3	-4,8	-7,0	-12,3	-16,9	-24,6	-30,7
		0.1	0,0	-1,4	-2,7	-3,9	-5,9	-10,8	-15,1	-22,5	-28,4
		0.2	0,0	-1,0	-2,0	-3,0	-4,7	-9,2	-13,2	-20,1	-25,8
		0.3	0,0	-0,7	-1,4	-2,0	-3,4	-7,5	-11,1	-17,5	-22,8
		0.4	0,0	-0,3	-0,7	-1,0	-2,2	-5,7	-8,9	-14,6	-19,4
		0.5	0,0	0,0	0,0	0,0	-0,8	-3,8	-6,5	-11,3	-15,4
CZ	**-6.0**	0.0	0,0	-1,7	-3,3	-4,8	-7,0	-12,3	-16,9	-24,6	-30,7
		0.1	0,0	-1,4	-2,7	-3,9	-5,9	-10,8	-15,1	-22,5	-28,4
		0.2	0,0	-1,0	-2,0	-3,0	-4,7	-9,2	-13,2	-20,1	-25,8
		0.3	0,0	-0,7	-1,4	-2,0	-3,4	-7,5	-11,1	-17,5	-22,8
		0.4	0,0	-0,3	-0,7	-1,0	-2,2	-5,7	-8,9	-14,6	-19,4
		0.5	0,0	0,0	0,0	0,0	-0,8	-3,8	-6,5	-11,3	-15,4
DK	**-15.8**	0.0	0,0	-1,4	-2,8	-4,1	-5,4	-7,7	-9,9	-14,9	-21,0
		0.1	0,0	-1,2	-2,3	-3,4	-4,4	-6,3	-8,2	-12,7	-18,7
		0.2	0,0	-0,9	-1,7	-2,6	-3,4	-4,9	-6,3	-10,4	-16,0
		0.3	0,0	-0,6	-1,2	-1,7	-2,3	-3,4	-4,4	-7,7	-13,1
		0.4	0,0	-0,3	-0,6	-0,9	-1,2	-1,7	-2,3	-4,8	-9,6
		0.5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-1,6	-5,7
EE	**-6.0**	0.0	0,0	-1,7	-3,3	-4,8	-7,0	-12,3	-16,9	-24,6	-30,7
		0.1	0,0	-1,4	-2,7	-3,9	-5,9	-10,8	-15,1	-22,5	-28,4
		0.2	0,0	-1,0	-2,0	-3,0	-4,7	-9,2	-13,2	-20,1	-25,8
		0.3	0,0	-0,7	-1,4	-2,0	-3,4	-7,5	-11,1	-17,5	-22,8
		0.4	0,0	-0,3	-0,7	-1,0	-2,2	-5,7	-8,9	-14,6	-19,4
		0.5	0,0	0,0	0,0	0,0	-0,8	-3,8	-6,5	-11,3	-15,4
FI	**0.0**	0.0	0,0	-3,7	-7,3	-10,9	-14,4	-21,3	-28,1	-42,0	-57,1
		0.1	0,0	-3,4	-6,7	-10,0	-13,3	-19,9	-26,5	-40,4	-56,1
		0.2	0,0	-3,0	-6,0	-9,0	-12,1	-18,3	-24,8	-38,7	-54,8
		0.3	0,0	-2,6	-5,3	-8,1	-10,9	-16,7	-22,9	-36,7	-53,4
		0.4	0,0	-2,3	-4,7	-7,1	-9,6	-15,0	-20,9	-34,6	-51,9
		0.5	0,0	-1,9	-3,9	-6,1	-8,3	-13,2	-18,8	-32,1	-50,0
FR	**0.0**	0.0	0,0	-3,7	-7,3	-10,9	-14,4	-21,3	-28,1	-42,0	-57,1
		0.1	0,0	-3,4	-6,7	-10,0	-13,3	-19,9	-26,5	-40,4	-56,1
		0.2	0,0	-3,0	-6,0	-9,0	-12,1	-18,3	-24,8	-38,7	-54,8
		0.3	0,0	-2,6	-5,3	-8,1	-10,9	-16,7	-22,9	-36,7	-53,4
		0.4	0,0	-2,3	-4,7	-7,1	-9,6	-15,0	-20,9	-34,6	-51,9
		0.5	0,0	-1,9	-3,9	-6,1	-8,3	-13,2	-18,8	-32,1	-50,0

Table 9: continued.

DE	**-15.8**	0.0	0,0	-1,4	-2,8	-4,1	-5,4	-7,7	-9,9	-14,9	-21,0
		0.1	0,0	-1,2	-2,3	-3,4	-4,4	-6,3	-8,2	-12,7	-18,7
		0.2	0,0	-0,9	-1,7	-2,6	-3,4	-4,9	-6,3	-10,4	-16,0
		0.3	0,0	-0,6	-1,2	-1,7	-2,3	-3,4	-4,4	-7,7	-13,1
		0.4	0,0	-0,3	-0,6	-0,9	-1,2	-1,7	-2,3	-4,8	-9,6
		0.5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-1,6	-5,7
GR	**18.8**	0.0	0,0	-6,0	-12,0	-17,9	-23,7	-35,2	-46,9	-60,8	-75,9
		0.1	0,0	-5,6	-11,2	-16,8	-22,4	-33,7	-45,3	-59,2	-74,8
		0.2	0,0	-5,2	-10,4	-15,7	-21,0	-32,0	-43,5	-57,4	-73,6
		0.3	0,0	-4,7	-9,6	-14,5	-19,6	-30,3	-41,7	-55,5	-72,2
		0.4	0,0	-4,3	-8,7	-13,4	-18,2	-28,4	-39,7	-53,3	-70,6
		0.5	0,0	-3,8	-7,9	-12,2	-16,7	-26,5	-37,5	-50,9	-68,8
HU	**-4.5**	0.0	0,0	-1,7	-3,4	-5,6	-8,5	-13,8	-18,4	-26,1	-32,2
		0.1	0,0	-1,4	-2,7	-4,7	-7,4	-12,3	-16,6	-24,0	-29,9
		0.2	0,0	-1,0	-2,1	-3,7	-6,2	-10,7	-14,7	-21,6	-27,3
		0.3	0,0	-0,7	-1,4	-2,8	-4,9	-9,0	-12,6	-19,0	-24,3
		0.4	0,0	-0,4	-0,7	-1,8	-3,7	-7,2	-10,4	-16,1	-20,9
		0.5	0,0	0,0	0,0	-0,7	-2,3	-5,3	-8,0	-12,8	-16,9
IE	**9.8**	0.0	0,0	-5,8	-11,6	-17,2	-22,9	-31,0	-37,9	-51,8	-66,9
		0.1	0,0	-5,4	-10,9	-16,3	-21,7	-29,6	-36,3	-50,2	-65,8
		0.2	0,0	-5,0	-10,1	-15,3	-20,5	-28,1	-34,5	-48,4	-64,6
		0.3	0,0	-4,6	-9,4	-14,3	-19,3	-26,5	-32,7	-46,5	-63,2
		0.4	0,0	-4,2	-8,7	-13,2	-18,0	-24,8	-30,7	-44,3	-61,6
		0.5	0,0	-3,8	-7,9	-12,2	-16,7	-23,0	-28,5	-41,9	-59,8
IT	**-4.9**	0.0	0,0	-1,7	-3,3	-5,2	-8,1	-13,4	-18,0	-25,7	-31,9
		0.1	0,0	-1,4	-2,7	-4,3	-7,0	-11,9	-16,2	-23,6	-29,5
		0.2	0,0	-1,0	-2,0	-3,4	-5,8	-10,3	-14,3	-21,2	-26,9
		0.3	0,0	-0,7	-1,4	-2,4	-4,6	-8,6	-12,3	-18,6	-23,9
		0.4	0,0	-0,3	-0,7	-1,4	-3,3	-6,8	-10,0	-15,7	-20,5
		0.5	0,0	0,0	0,0	-0,4	-1,9	-4,9	-7,6	-12,4	-16,6
LV	**-6.0**	0.0	0,0	-1,7	-3,3	-4,8	-7,0	-12,3	-16,9	-24,6	-30,7
		0.1	0,0	-1,4	-2,7	-3,9	-5,9	-10,8	-15,1	-22,5	-28,4
		0.2	0,0	-1,0	-2,0	-3,0	-4,7	-9,2	-13,2	-20,1	-25,8
		0.3	0,0	-0,7	-1,4	-2,0	-3,4	-7,5	-11,1	-17,5	-22,8
		0.4	0,0	-0,3	-0,7	-1,0	-2,2	-5,7	-8,9	-14,6	-19,4
		0.5	0,0	0,0	0,0	0,0	-0,8	-3,8	-6,5	-11,3	-15,4
LT	**-6.0**	0.0	0,0	-1,7	-3,3	-4,8	-7,0	-12,3	-16,9	-24,6	-30,7
		0.1	0,0	-1,4	-2,7	-3,9	-5,9	-10,8	-15,1	-22,5	-28,4
		0.2	0,0	-1,0	-2,0	-3,0	-4,7	-9,2	-13,2	-20,1	-25,8
		0.3	0,0	-0,7	-1,4	-2,0	-3,4	-7,5	-11,1	-17,5	-22,8
		0.4	0,0	-0,3	-0,7	-1,0	-2,2	-5,7	-8,9	-14,6	-19,4
		0.5	0,0	0,0	0,0	0,0	-0,8	-3,8	-6,5	-11,3	-15,4
LU	**-21.0**	0.0	0,0	-1,3	-2,6	-3,8	-4,9	-7,0	-9,0	-12,5	-15,7
		0.1	0,0	-1,1	-2,1	-3,1	-4,0	-5,8	-7,4	-10,5	-13,4
		0.2	0,0	-0,8	-1,6	-2,3	-3,1	-4,5	-5,8	-8,2	-10,8
		0.3	0,0	-0,5	-1,1	-1,6	-2,1	-3,1	-4,0	-5,8	-7,8
		0.4	0,0	-0,3	-0,5	-0,8	-1,1	-1,6	-2,1	-3,1	-4,4
		0.5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-0,4
NL	**-4.5**	0.0	0,0	-1,7	-3,4	-5,6	-8,5	-13,8	-18,4	-26,1	-32,2
		0.1	0,0	-1,4	-2,7	-4,7	-7,4	-12,3	-16,6	-24,0	-29,9
		0.2	0,0	-1,0	-2,1	-3,7	-6,2	-10,7	-14,7	-21,6	-27,3
		0.3	0,0	-0,7	-1,4	-2,8	-4,9	-9,0	-12,6	-19,0	-24,3
		0.4	0,0	-0,4	-0,7	-1,8	-3,7	-7,2	-10,4	-16,1	-20,9
		0.5	0,0	0,0	0,0	-0,7	-2,3	-5,3	-8,0	-12,8	-16,9

Table 9: continued.

PL	**-4.5**	0.0	0,0	-1,7	-3,4	-5,6	-8,5	-13,8	-18,4	-26,1	-32,2
		0.1	0,0	-1,4	-2,7	-4,7	-7,4	-12,3	-16,6	-24,0	-29,9
		0.2	0,0	-1,0	-2,1	-3,7	-6,2	-10,7	-14,7	-21,6	-27,3
		0.3	0,0	-0,7	-1,4	-2,8	-4,9	-9,0	-12,6	-19,0	-24,3
		0.4	0,0	-0,4	-0,7	-1,8	-3,7	-7,2	-10,4	-16,1	-20,9
		0.5	0,0	0,0	0,0	-0,7	-2,3	-5,3	-8,0	-12,8	-16,9
PT	**20.3**	0.0	0,0	-6,1	-12,1	-18,0	-23,8	-35,4	-47,1	-62,3	-77,4
		0.1	0,0	-5,6	-11,3	-16,9	-22,5	-33,8	-45,5	-60,7	-76,3
		0.2	0,0	-5,2	-10,4	-15,7	-21,1	-32,1	-43,7	-58,9	-75,1
		0.3	0,0	-4,8	-9,6	-14,6	-19,7	-30,4	-41,8	-57,0	-73,7
		0.4	0,0	-4,3	-8,8	-13,4	-18,2	-28,5	-39,7	-54,8	-72,1
		0.5	0,0	-3,8	-7,9	-12,2	-16,7	-26,5	-37,5	-52,4	-70,3
RO	**-6.0**	0.0	0,0	-1,7	-3,3	-4,8	-7,0	-12,3	-16,9	-24,6	-30,7
		0.1	0,0	-1,4	-2,7	-3,9	-5,9	-10,8	-15,1	-22,5	-28,4
		0.2	0,0	-1,0	-2,0	-3,0	-4,7	-9,2	-13,2	-20,1	-25,8
		0.3	0,0	-0,7	-1,4	-2,0	-3,4	-7,5	-11,1	-17,5	-22,8
		0.4	0,0	-0,3	-0,7	-1,0	-2,2	-5,7	-8,9	-14,6	-19,4
		0.5	0,0	0,0	0,0	0,0	-0,8	-3,8	-6,5	-11,3	-15,4
SK	**-6.0**	0.0	0,0	-1,7	-3,3	-4,8	-7,0	-12,3	-16,9	-24,6	-30,7
		0.1	0,0	-1,4	-2,7	-3,9	-5,9	-10,8	-15,1	-22,5	-28,4
		0.2	0,0	-1,0	-2,0	-3,0	-4,7	-9,2	-13,2	-20,1	-25,8
		0.3	0,0	-0,7	-1,4	-2,0	-3,4	-7,5	-11,1	-17,5	-22,8
		0.4	0,0	-0,3	-0,7	-1,0	-2,2	-5,7	-8,9	-14,6	-19,4
		0.5	0,0	0,0	0,0	0,0	-0,8	-3,8	-6,5	-11,3	-15,4
SI	**-6.0**	0.0	0,0	-1,7	-3,3	-4,8	-7,0	-12,3	-16,9	-24,6	-30,7
		0.1	0,0	-1,4	-2,7	-3,9	-5,9	-10,8	-15,1	-22,5	-28,4
		0.2	0,0	-1,0	-2,0	-3,0	-4,7	-9,2	-13,2	-20,1	-25,8
		0.3	0,0	-0,7	-1,4	-2,0	-3,4	-7,5	-11,1	-17,5	-22,8
		0.4	0,0	-0,3	-0,7	-1,0	-2,2	-5,7	-8,9	-14,6	-19,4
		0.5	0,0	0,0	0,0	0,0	-0,8	-3,8	-6,5	-11,3	-15,4
ES	**11.3**	0.0	0,0	-5,9	-11,6	-17,3	-23,0	-32,5	-39,4	-53,3	-68,4
		0.1	0,0	-5,5	-10,9	-16,4	-21,8	-31,1	-37,8	-51,7	-67,3
		0.2	0,0	-5,1	-10,2	-15,4	-20,6	-29,6	-36,0	-49,9	-66,1
		0.3	0,0	-4,7	-9,4	-14,3	-19,3	-28,0	-34,2	-48,0	-64,7
		0.4	0,0	-4,3	-8,7	-13,3	-18,0	-26,3	-32,2	-45,8	-63,1
		0.5	0,0	-3,8	-7,9	-12,2	-16,7	-24,5	-30,0	-43,4	-61,3
SE	**3.0**	0.0	0,0	-5,7	-10,3	-13,9	-17,4	-24,3	-31,1	-45,0	-60,1
		0.1	0,0	-5,3	-9,7	-13,0	-16,3	-22,9	-29,5	-43,4	-59,1
		0.2	0,0	-4,9	-9,0	-12,0	-15,1	-21,3	-27,8	-41,7	-57,8
		0.3	0,0	-4,6	-8,3	-11,1	-13,9	-19,7	-25,9	-39,7	-56,4
		0.4	0,0	-4,2	-7,7	-10,1	-12,6	-18,0	-23,9	-37,6	-54,9
		0.5	0,0	-3,8	-6,9	-9,1	-11,3	-16,2	-21,8	-35,1	-53,0
UK	**-9.4**	0.0	0,0	-1,6	-3,1	-4,6	-6,0	-8,9	-13,5	-21,2	-27,4
		0.1	0,0	-1,3	-2,5	-3,7	-4,9	-7,4	-11,7	-19,1	-25,0
		0.2	0,0	-1,0	-1,9	-2,8	-3,7	-5,8	-9,8	-16,7	-22,4
		0.3	0,0	-0,6	-1,3	-1,9	-2,5	-4,1	-7,8	-14,1	-19,4
		0.4	0,0	-0,3	-0,6	-1,0	-1,3	-2,3	-5,5	-11,2	-16,0
		0.5	0,0	0,0	0,0	0,0	0,0	-0,4	-3,1	-7,9	-12,1
EU-15	**-6.0**	0.0	0,0	-1,7	-3,3	-4,8	-7,0	-12,3	-16,9	-24,6	-30,7
		0.1	0,0	-1,4	-2,7	-3,9	-5,9	-10,8	-15,1	-22,5	-28,4
		0.2	0,0	-1,0	-2,0	-3,0	-4,7	-9,2	-13,2	-20,1	-25,8
		0.3	0,0	-0,7	-1,4	-2,0	-3,4	-7,5	-11,1	-17,5	-22,8
		0.4	0,0	-0,3	-0,7	-1,0	-2,2	-5,7	-8,9	-14,6	-19,4
		0.5	0,0	0,0	0,0	0,0	-0,8	-3,8	-6,5	-11,3	-15,4

4 Interpretation of Results and Conclusions

To interpret the results for 2005, the following are displayed:

(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, 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 α is similar.

The DTPIs displayed in Figure 2 are always shown to contrast the Member States' linear path emission targets and undershooting opportunities for the year 2005 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: 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 ($-15/20$)). 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 14 countries that exhibit a negative DTPI: BG, CZ, DE, EE, FI, FR, HU, LV, LT, PL, RO, SE, SK and the UK (Figure 2). Given $\alpha = 0.5$, LV, LT, EE, BG, RO, HU, SK, PL and CZ are the best potential sellers followed by DE, the UK, SE, FI and FR (Figure 5). LV, LT, EE, BG, RO, HU, SK, PL and CZ can report with a relative uncertainty > 40% and still exhibit a detectable signal (see Table A1 for exact numbers); while DE and the UK must report within the 20–40% relative uncertainty class (more exactly: up to 33% and 26%, respectively), SE within the 5–10% relative uncertainty class (more exactly: up to 9%), and both FI and FR within the 0–5% relative uncertainty class (more exactly: up to 3.3% and 2.4%, respectively).

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 $\alpha = 0.0$ (Figure 10), LV, LT, EE, BG and RO can still report with a relative uncertainty > 40% (see Table A1 for exact numbers); while HU, SK, PL and CZ must report within the 20–40% relative uncertainty class (more exactly: up to 36%, 35%, 32% and 23%, respectively); the UK within the 10–20% relative uncertainty class (more exactly: up to 11%); both DE and SE within the 5–10% relative uncertainty class (more exactly: up to 5%); and both FI and FR within the 0–5% relative uncertainty class (more exactly: up to 1.7 and 1.3%, respectively).

(II) U by α 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 $(-15/20)$ 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 ρ (Figures 12–14), an increasing number of Member States agreed 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. In general, Figures 12–14 resolve U_{Gap} better than the remainder of U.

Here, interpretation I (U by ρ with α as a parameter; Figures 5–10) is preferred 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 DTPI meets U_{Gap} for a given ρ. (The UK, e.g., meets U_{Gap} for $\rho = 20\%$ but not any more for $\rho = 40\%$; 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 2005. 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 DTPI, 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 2005, fourteen EU-27 Member States exhibit a negative DTPI and thus appear as potential sellers: BG, CZ, DE, EE, FI, FR, HU, LT, LV, PL, RO, 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 fourteen old and seven new EU-27 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 (Figure 9: ranked in terms of credibility) are LV, LT, EE, BG and RO that can even report with a relative uncertainty > 40% and still exhibit a detectable signal; while HU, SK, PL and CZ, and the UK can still report within the 20–40% and 10–20% relative uncertainty class, respectively. In contrast, DE, SE, FI 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); SE only with $\alpha = 0.5$ in the 5–10% relative uncertainty class (Figure 5); and FI and FR also only with $\alpha = 0.5$ but in the 0–5% relative uncertainty class (Figure 5). The other EU-27 Member States exhibit positive DTPIs, i.e., they do not meet their linear path (base year–commitment year) emission targets as of 2005, 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 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 (i.e., increasingly negative) to achieve detectability. That is, for $\rho = 5\%$ 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 $\rho = 10\%$ 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 $U_{Gap} < \mathrm{DTPI}$), 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.

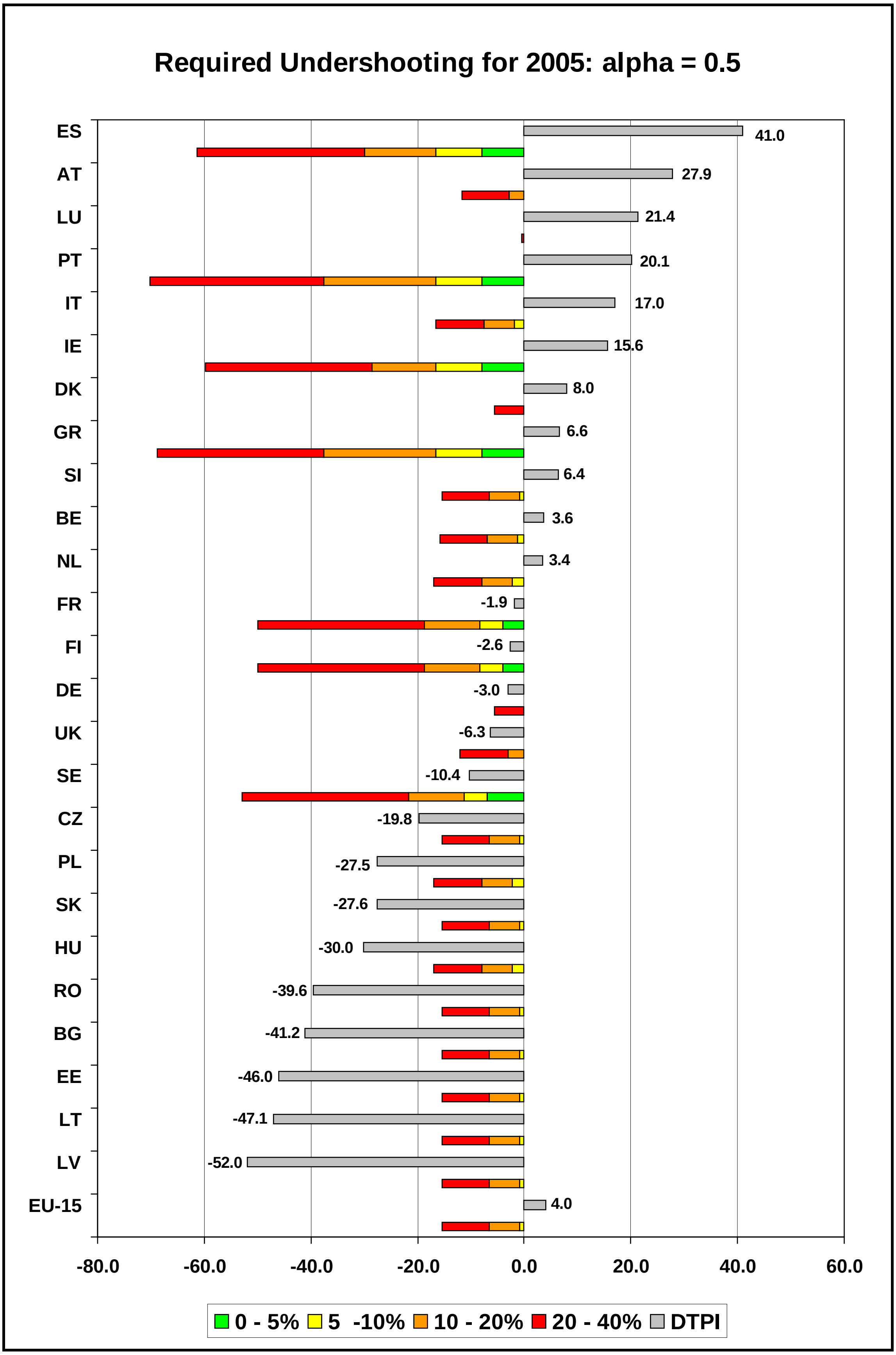

Figure 5: U by ρ (see intervals) for $\alpha = 0.5$ in addition to the DTPI.

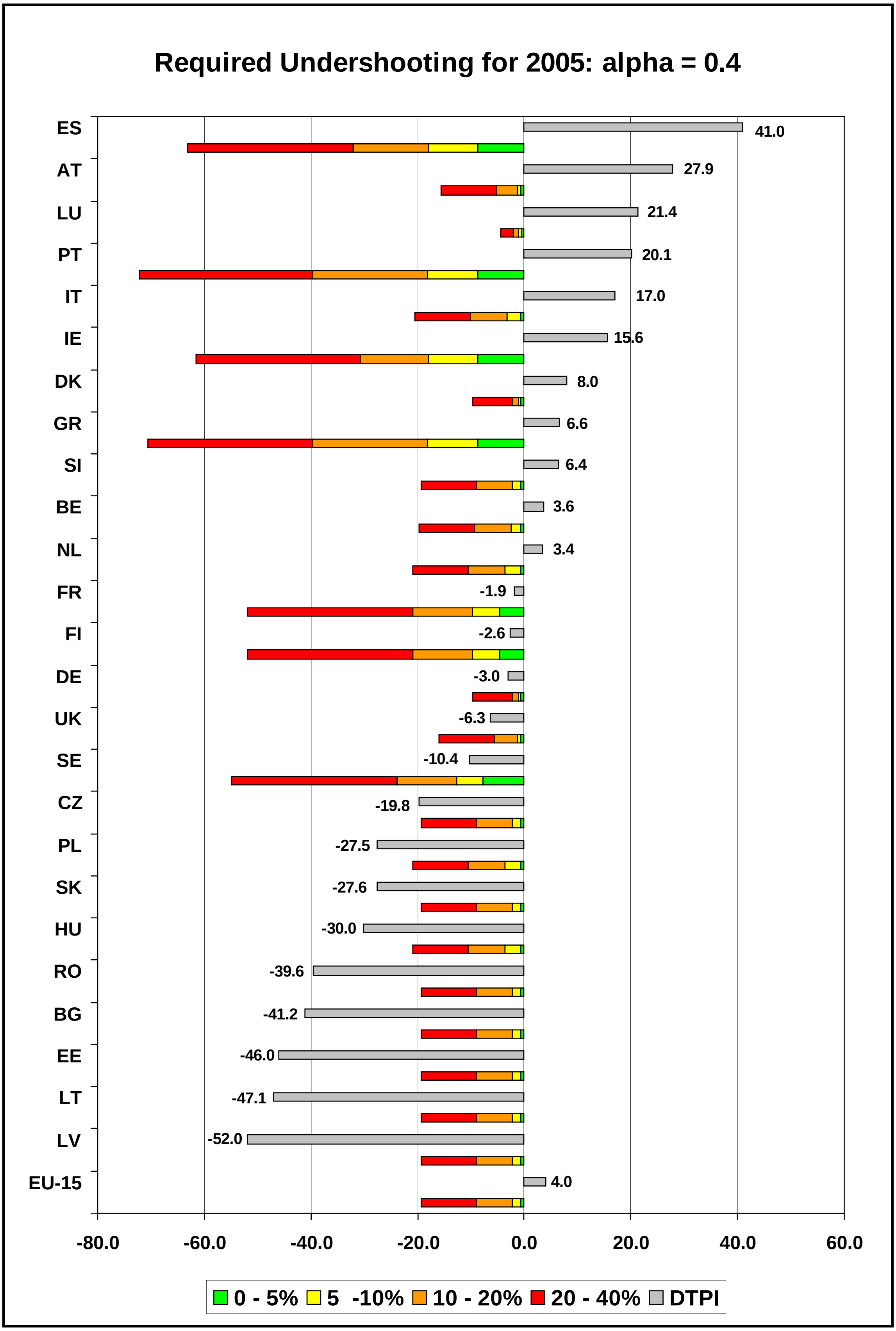

Figure 6: U by ρ (see intervals) for $\alpha = 0.4$ in addition to the DTPI.

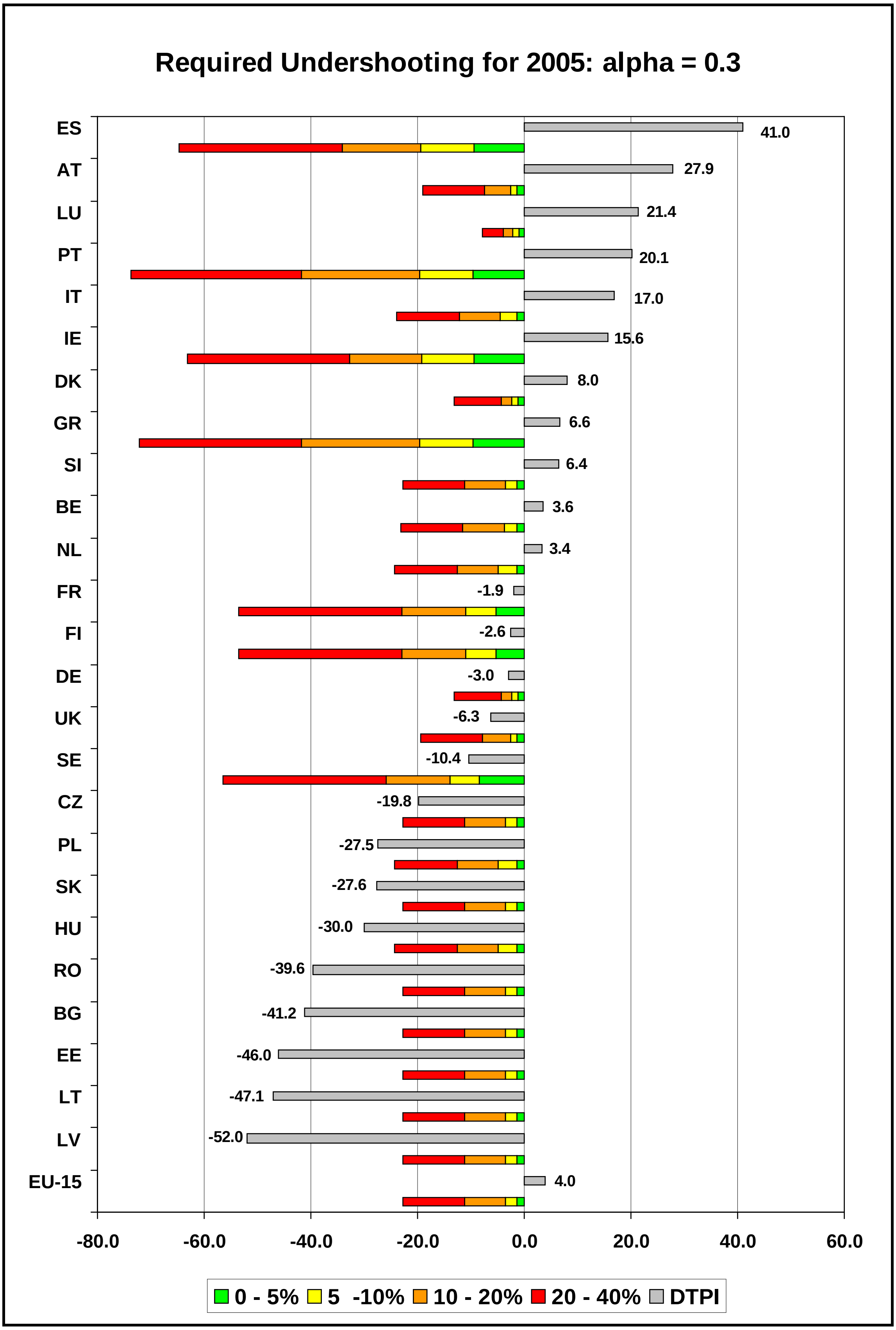

Figure 7: U by ρ (see intervals) for $\alpha = 0.3$ in addition to the DTPI.

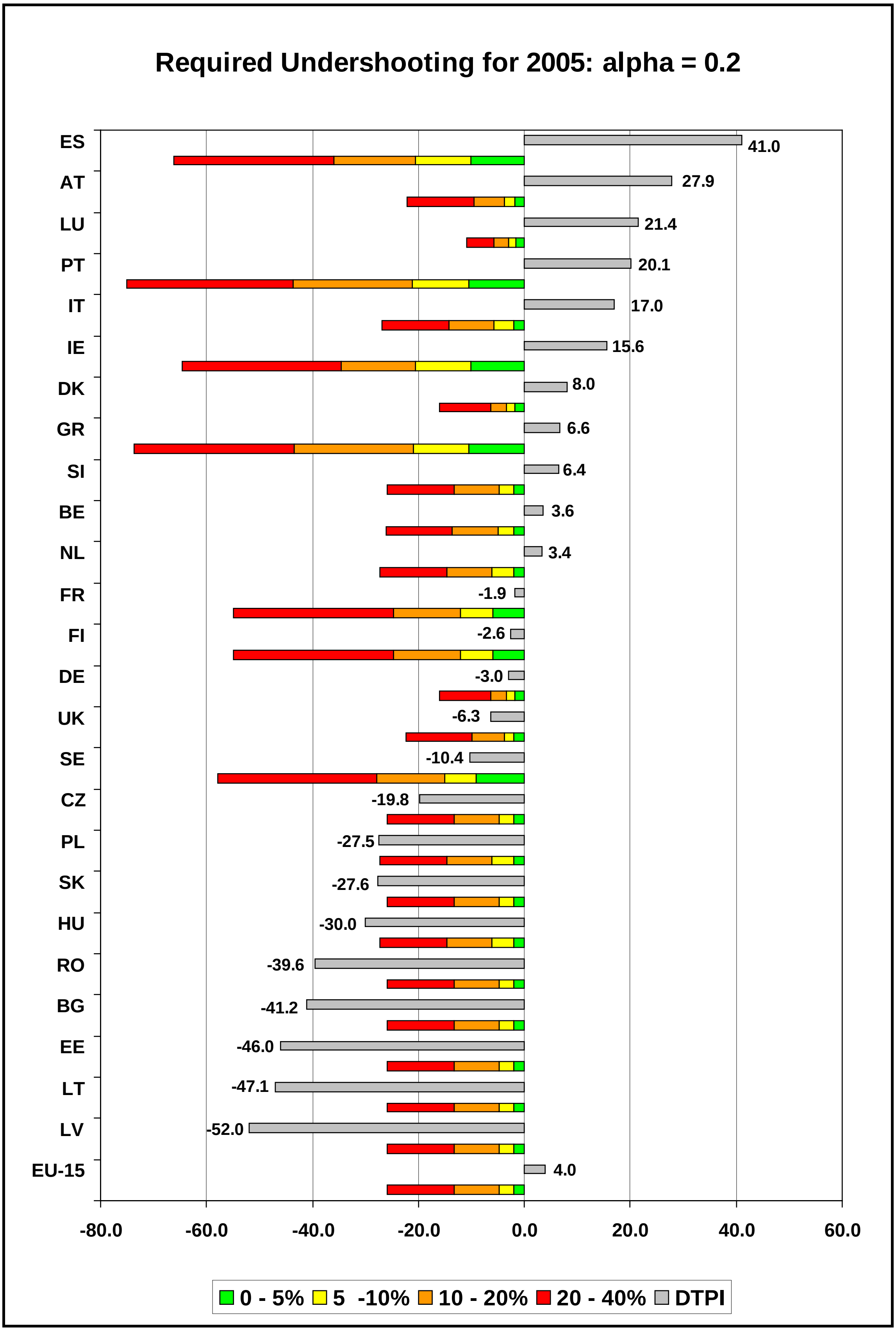

Figure 8: U by ρ (see intervals) for $\alpha = 0.2$ in addition to the DTPI.

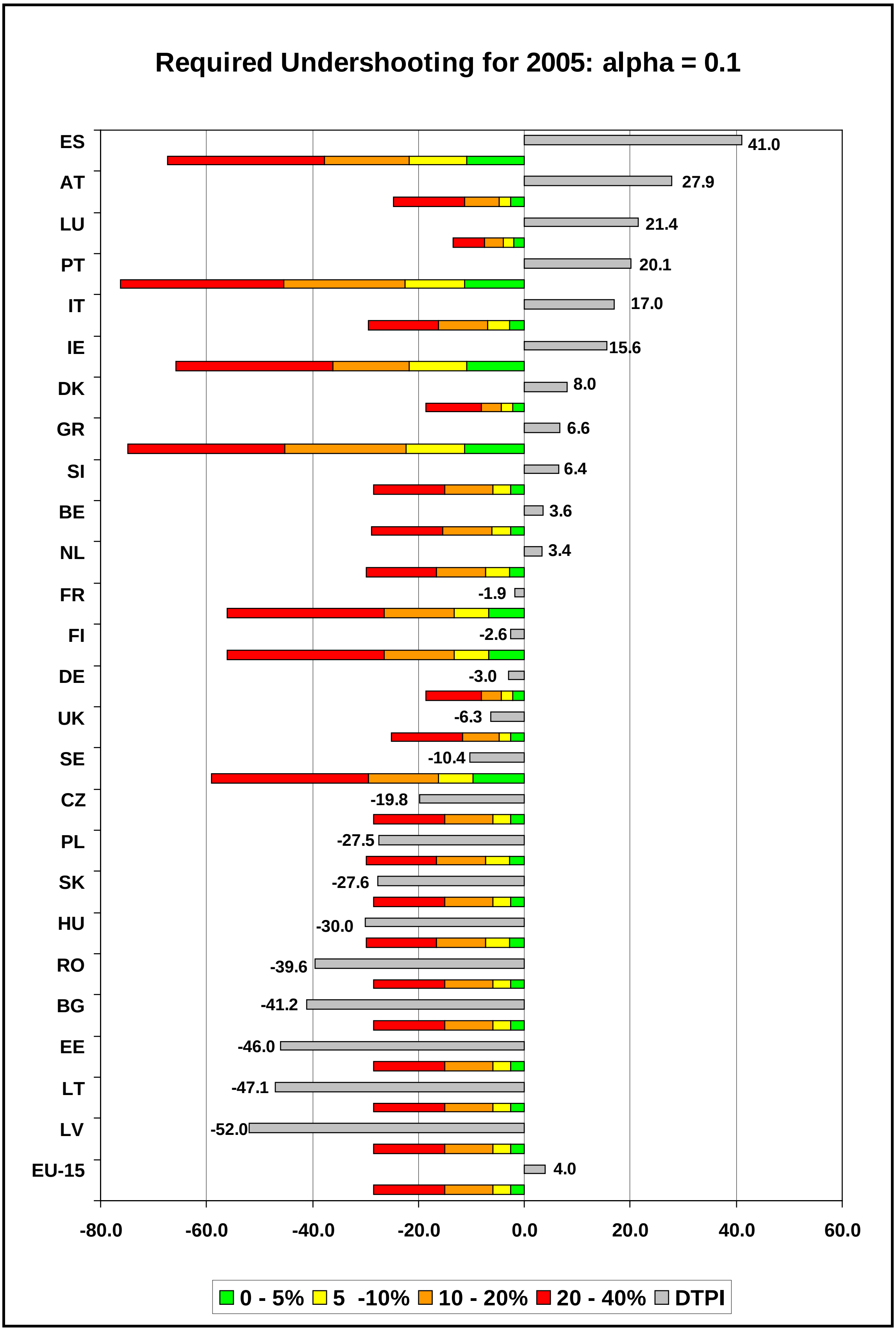

Figure 9: U by ρ (see intervals) for $\alpha = 0.1$ in addition to the DTPI.

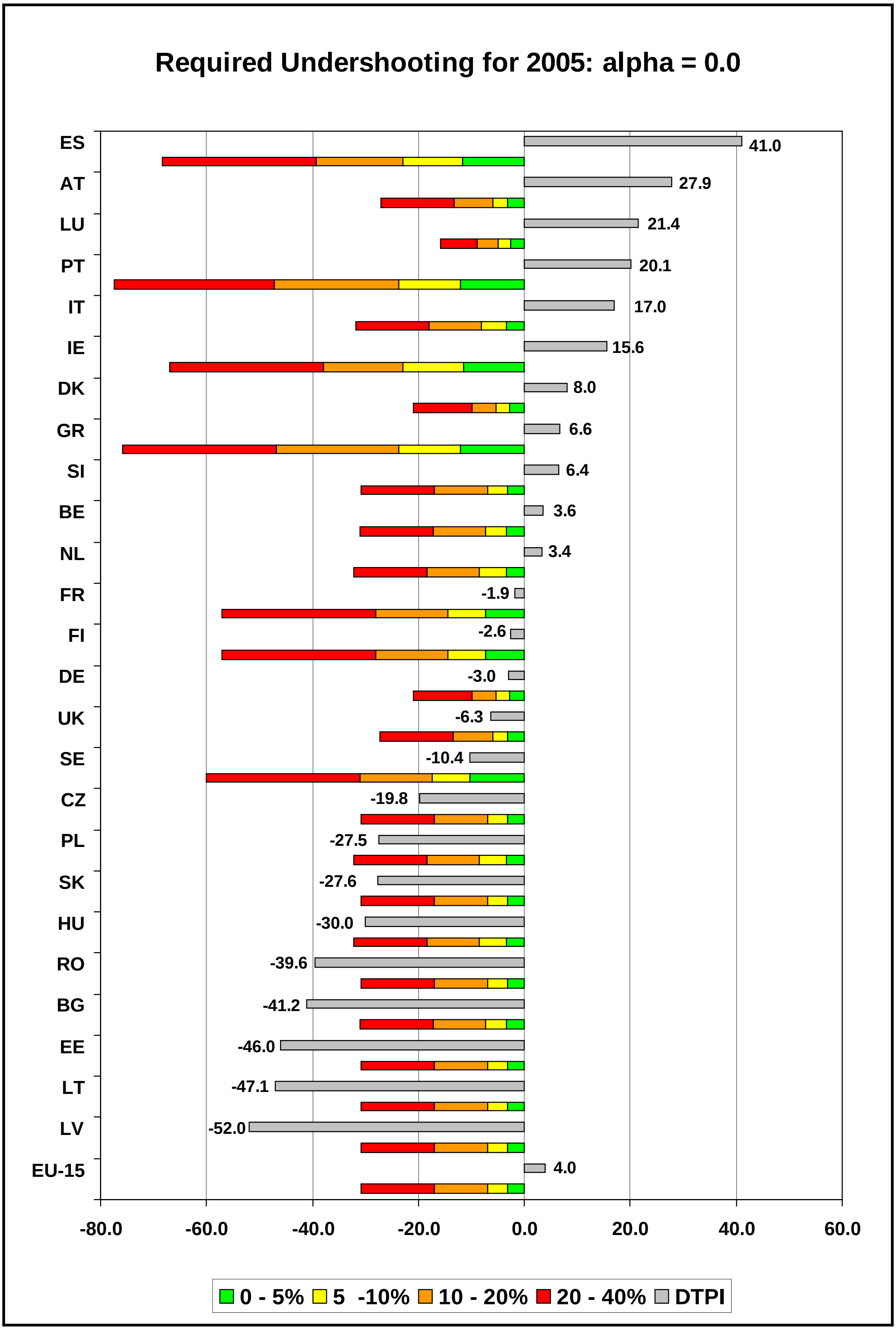

Figure 10: U by ρ (see intervals) for $\alpha = 0.0$ in addition to the DTPI.

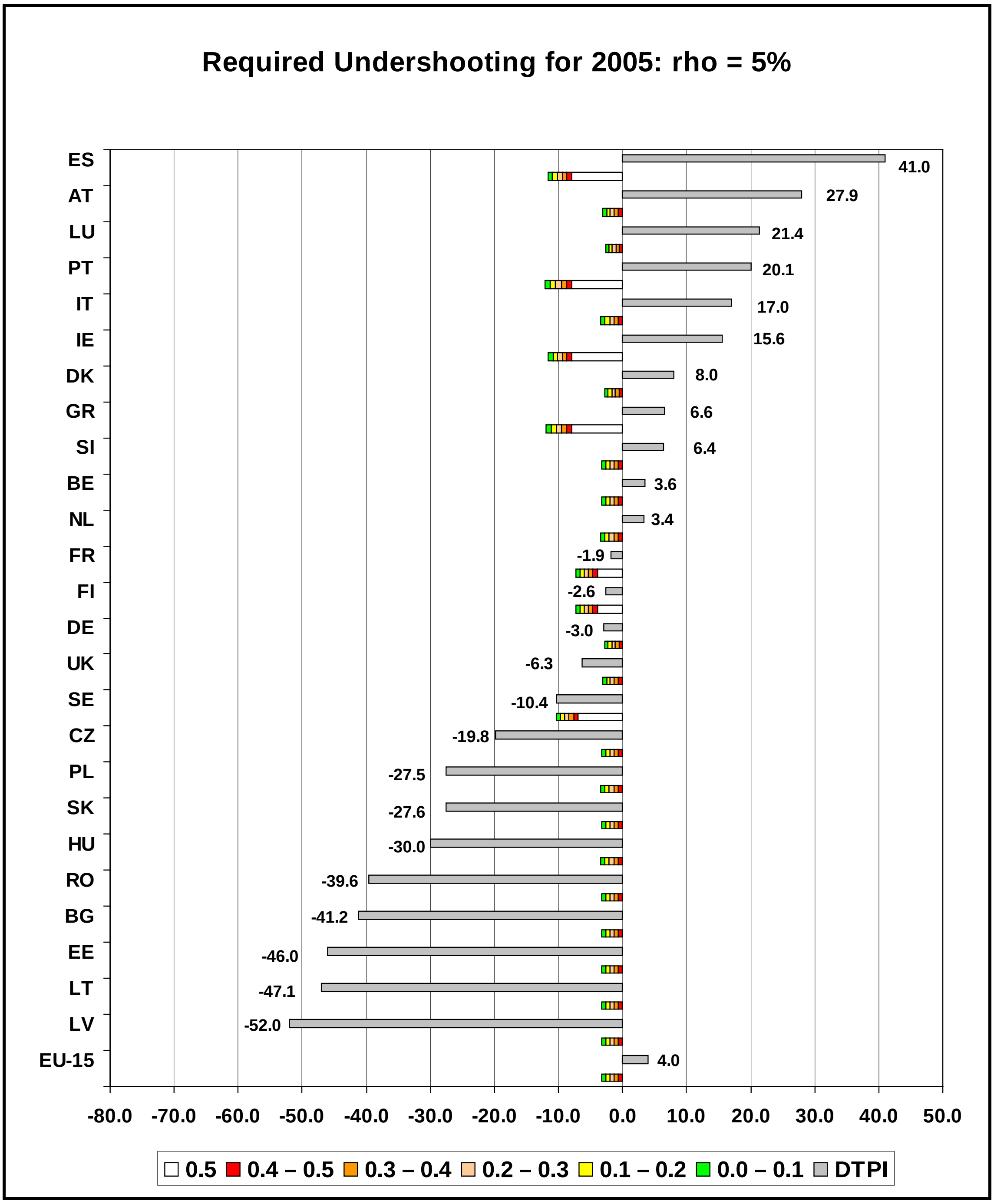

Figure 11: U by α (see value and intervals) for $\rho = 5\%$ in addition to the DTPI.

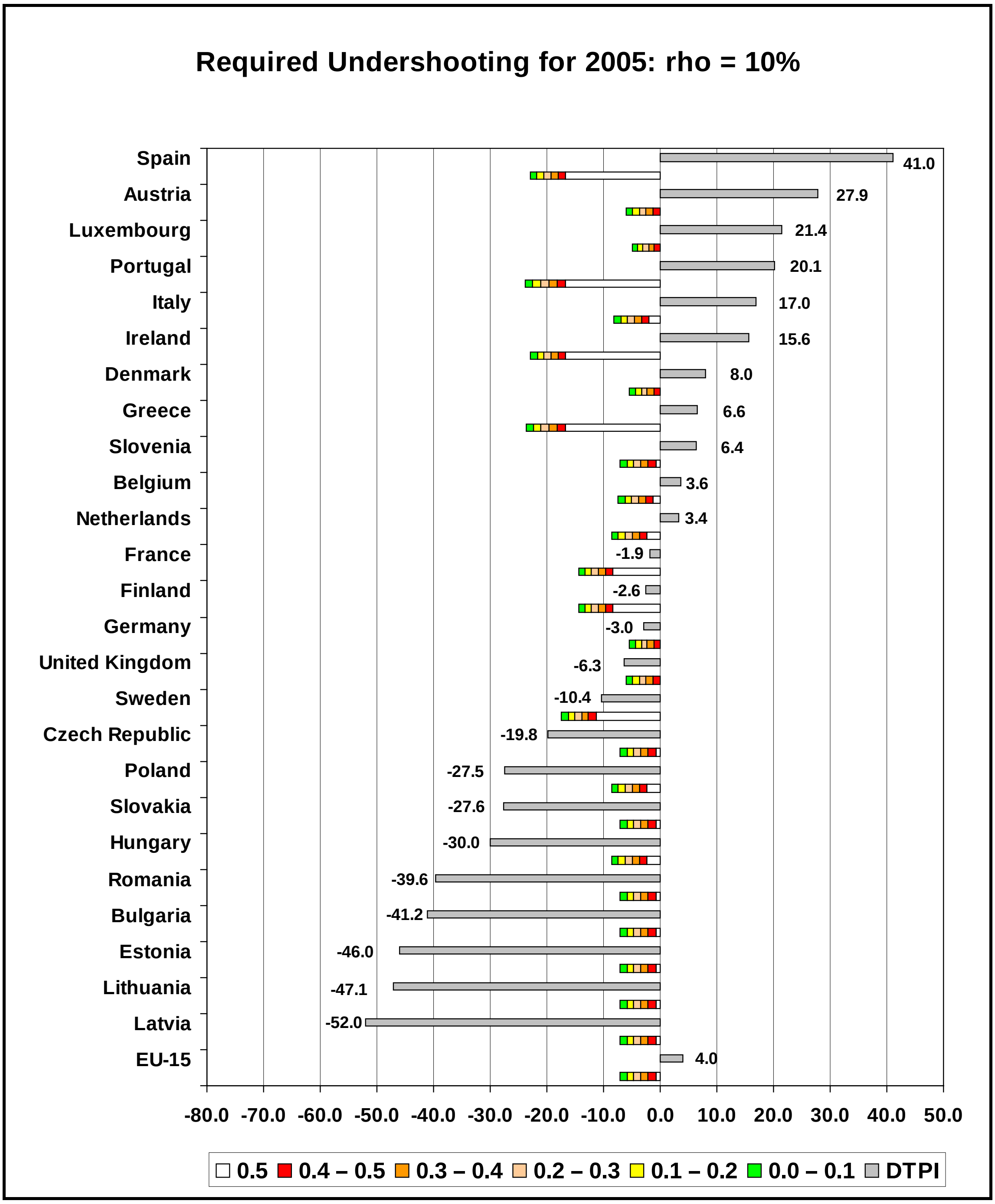

Figure 12: U by α (see value and intervals) for $\rho = 10\%$ in addition to the DTPI.

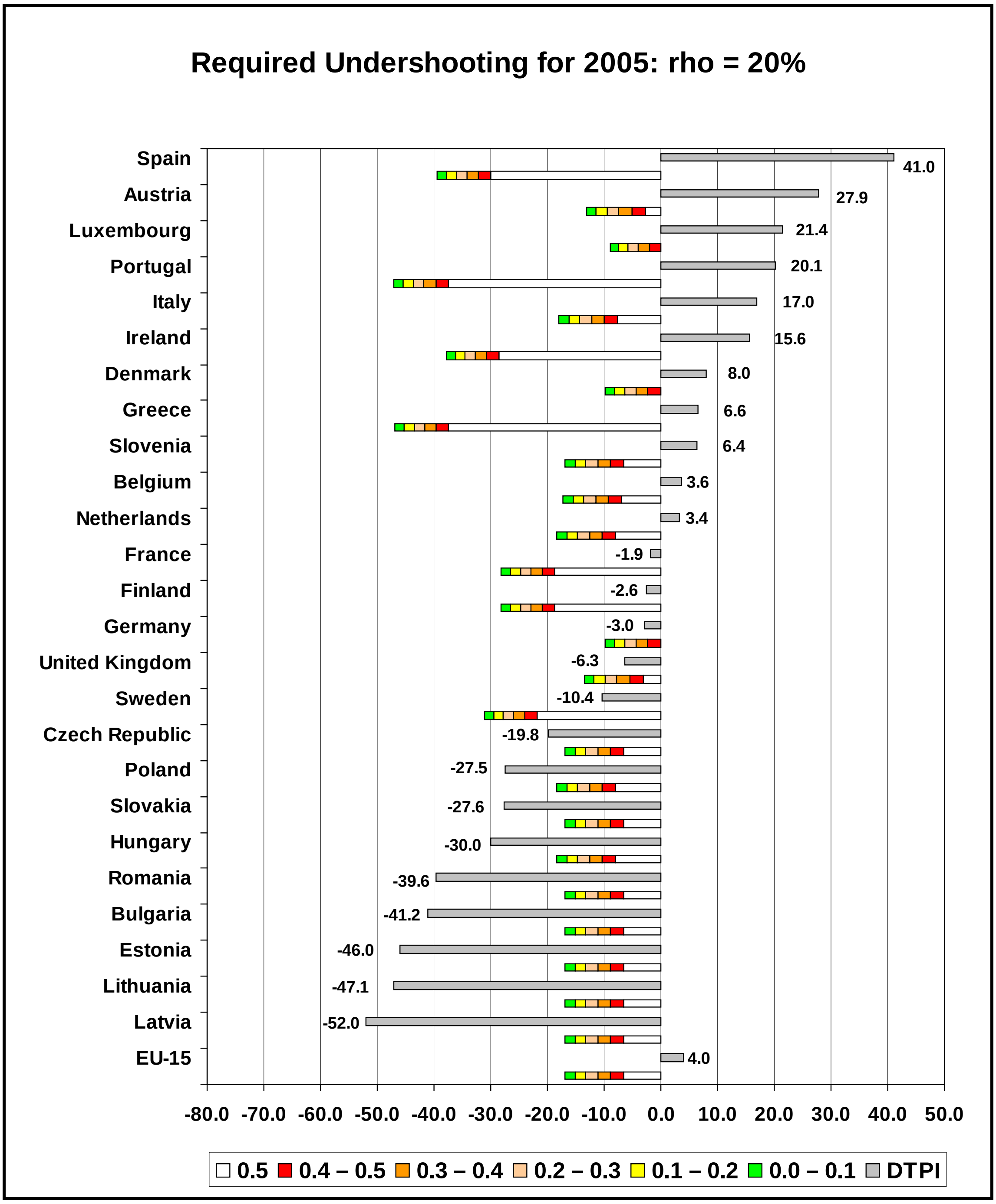

Figure 13: U by α (see value and intervals) for $\rho = 20\%$ in addition to the DTPI.

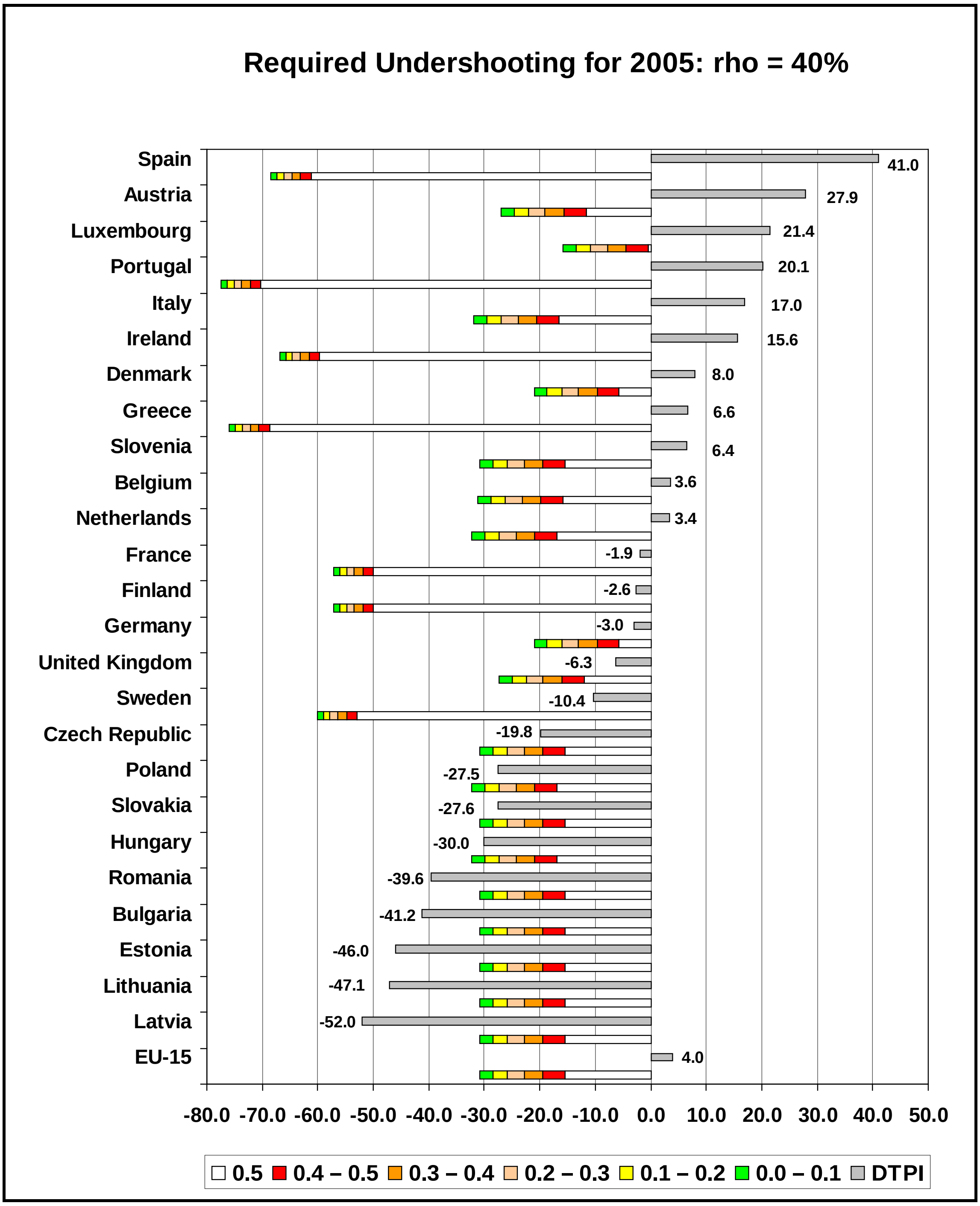

Figure 14: U by α (see value and intervals) for $\rho = 40\%$ in addition to the DTPI.

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Acronyms and Nomenclature

EU	European Union
DTPI	distance-to-target-path indicator
GHG	greenhouse gas
KP	Kyoto Protocol
KT	Kyoto (emissions) target
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	Bulgarian
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

Appendix

Below the inversions $\rho = \rho(\delta_{KP}, U, \alpha)$ of Eq. (6), (9), (13) and (17) are derived. They are used to determine the maximal uncertainties with which Member States with DTPI < 0 can report to meet a given risk α that their true emissions in the commitment year/period fall above their true emission targets.

<u>Case 1</u>: $\delta_{KP} > 0 : \delta_{crit} \le \delta_{KP}$. Eq. (6) for $\alpha = 0.5$ and $0 \le \alpha < 0.5$:

<u>α = 0.5:</u>

$U = 0$ for all ρ. (A1)

<u>0 ≤ α < 0.5:</u>

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

$$(1-\delta_{KP})\left(1-\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}\right) = 1-(\delta_{KP}+U) \tag{A2a}$$

$$(1-\delta_{KP})\frac{1}{1+(1-2\alpha)\rho} = 1-\delta_{mod}. \tag{A2b}$$

With $KT := 1-\delta_{KP}$ as the agreed Kyoto (emissions) target and $KT_{mod} := 1-\delta_{mod} = 1-(\delta_{KP}+U)$ the corresponding, or modified, Kyoto (emissions) target which encompasses undershooting:

$$(1-2\alpha)\rho = \frac{KT}{KT_{mod}} - 1 \tag{A3}$$

$$\rho = \frac{U}{(1-2\alpha)KT_{mod}}. \tag{A4}$$

<u>Case 2</u>: $\delta_{KP} > 0 : \delta_{crit} > \delta_{KP}$. Eq. (9) in combination with Eq. (10) for $\alpha = 0.5$ and $0 \le \alpha < 0.5$:

<u>α = 0.5:</u>

$$U = U_{Gap} = \frac{\rho}{1+\rho} - \delta_{KP} \qquad \text{(A5), (A6)}$$

in combination with Eq. (1a). Thus:

$$\frac{\rho}{1+\rho} = \delta_{mod} \tag{A7}$$

$$\rho = \frac{\delta_{mod}}{1-\delta_{mod}}. \tag{A8}$$

<u>*0 ≤ α < 0.5:*</u>

$$U = 1-(1-\delta_{crit})-\delta_{KP}+(1-\delta_{crit})\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho} \tag{A9}$$

$$(1-\delta_{crit})\left(1-\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}\right) = 1-(\delta_{KP}+U). \tag{A10}$$

In combination with Eq. (1a):

$$\left(1-\frac{\rho}{1+\rho}\right)\left(1-\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}\right) = KT_{mod} \tag{A11a}$$

$$\left(\frac{1}{1+\rho}\right)\left(\frac{1}{1+(1-2\alpha)\rho}\right) = KT_{mod} \tag{A11b}$$

$$(1+\rho)(1+(1-2\alpha)\rho) = \frac{1}{KT_{mod}} \tag{A11c}$$

$$1+(1-2\alpha)\rho+\rho+(1-2\alpha)\rho^2 = \frac{1}{KT_{mod}} \tag{A11d}$$

$$\rho^2+2\frac{1-\alpha}{1-2\alpha}\rho-\frac{1-KT_{mod}}{(1-2\alpha)KT_{mod}} = 0 \tag{A11e}$$

$$\rho_{1,2} = -\frac{1-\alpha}{1-2\alpha}\pm\sqrt{\left(\frac{1-\alpha}{1-2\alpha}\right)^2+\frac{1-KT_{mod}}{(1-2\alpha)KT_{mod}}}. \tag{A12a,b}$$

Eq. (A12a) provides the correct solution.

Case 3: $\delta_{KP} \leq 0 : \delta_{crit} < \delta_{KP}$. Eq. (13) in combination with Eq. (14) for $\alpha = 0.5$ and $0 \leq \alpha < 0.5$:

α = 0.5:

$$U = U_{Gap} = \frac{\rho}{1-\rho} - \delta_{KP} \tag{A5), (A13}$$

in combination with Eq. (1b). Thus:

$$\frac{\rho}{1-\rho} = \delta_{mod} \tag{A14}$$

$$\rho = \frac{\delta_{mod}}{1+\delta_{mod}}. \tag{A15}$$

0 ≤ α < 0.5:

$$U = 1 - (1+\delta_{crit}) - \delta_{KP} + (1+\delta_{crit})\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho} \tag{A16}$$

$$(1+\delta_{crit})\left(1 - \frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}\right) = 1 - [\delta_{KP} + U]. \tag{A17}$$

In combination with Eq. (1b):

$$\left(1 - \frac{\rho}{1-\rho}\right)\left(1 - \frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}\right) = KT_{mod} \tag{A18a}$$

$$\left(\frac{1-2\rho}{1-\rho}\right)\left(\frac{1}{1+(1-2\alpha)\rho}\right) = KT_{mod} \tag{A18b}$$

$$1 - 2\rho = KT_{mod} + (1-2\alpha)KT_{mod}\rho - KT_{mod}\rho - (1-2\alpha)KT_{mod}\rho^2 \tag{A19}$$

$$\rho^2 - 2\frac{1-\alpha KT_{mod}}{(1-2\alpha)KT_{mod}}\rho + \frac{1-KT_{mod}}{(1-2\alpha)KT_{mod}} = 0 \tag{A20}$$

$$\rho_{1,2} = \frac{1-\alpha KT_{mod}}{(1-2\alpha)KT_{mod}} \pm \sqrt{\left(\frac{1-\alpha KT_{mod}}{(1-2\alpha)KT_{mod}}\right)^2 - \frac{1-KT_{mod}}{(1-2\alpha)KT_{mod}}}. \tag{A21a,b}$$

Eq. (A21b) provides the correct solution.

Case 4: $\delta_{KP} \le 0 : \delta_{crit} \ge \delta_{KP}$. Eq. (17) in combination with Eq. (18) and (19) for $\alpha = 0.5$ and $0 \le \alpha < 0.5$:

α = 0.5:

$$U = U_{Gap} = \frac{2\rho}{1-\rho} \qquad \text{(A5), (A22)}$$

in combination with Eq. (1b). Thus:

$$\rho = \frac{U}{2+U}. \qquad \text{(A23)}$$

0 ≤ α < 0.5:

$$U = 1 - \delta_{KP} - \left(1 - \delta_{KP} + 2\delta_{crit}\right) + \left(1 - \delta_{KP} + 2\delta_{crit}\right)\frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho} \qquad \text{(A24)}$$

$$\left(1 - \delta_{KP} + 2\delta_{crit}\right)\left(1 - \frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}\right) = 1 - \left(\delta_{KP} + U\right). \qquad \text{(A25)}$$

In combination with Eq. (1b):

$$\left(KT - 2\frac{\rho}{1-\rho}\right)\left(1 - \frac{(1-2\alpha)\rho}{1+(1-2\alpha)\rho}\right) = KT_{mod}. \qquad \text{(A26a)}$$

$$\left(\frac{KT - (2+KT)\rho}{1-\rho}\right)\left(\frac{1}{1+(1-2\alpha)\rho}\right) = KT_{mod} \qquad \text{(A26b)}$$

$$KT - (2+KT)\rho = KT_{mod} + (1-2\alpha)KT_{mod}\rho - KT_{mod}\rho - (1-2\alpha)KT_{mod}\rho^2 \qquad \text{(A27)}$$

$$\rho^2 - 2\frac{1+\frac{KT}{2}-\alpha KT_{mod}}{(1-2\alpha)KT_{mod}}\rho + \frac{U}{(1-2\alpha)KT_{mod}} = 0 \qquad \text{(A28)}$$

$$\rho_{1,2} = \frac{1+\frac{KT}{2}-\alpha KT_{mod}}{(1-2\alpha)KT_{mod}} \pm \sqrt{\left(\frac{1+\frac{KT}{2}-\alpha KT_{mod}}{(1-2\alpha)KT_{mod}}\right)^2 - \frac{U}{(1-2\alpha)KT_{mod}}}. \qquad \text{(A29a,b)}$$

Eq. (A29b) provides the correct solution.

Table A1 provides the maximal uncertainties with which individual Member States with DTPI < 0 can report to meet a given risk $0 \le \alpha \le 0.5$ that their true emissions in the commitment year/period fall above their true emission targets.

Table A1: Maximal uncertainties with which Member States (MS) with DTPI < 0 can report to meet a given risk α that their true emissions in the commitment year/period fall above their true emission targets (see Figures 5–10). Note that the inverse equations $\rho = \rho(\delta_{KP}, U, \alpha)$ in the Appendix refer to 2008/12; i.e., the Member States' DTPIs for 2005 must be multiplied with (-20/15). Example: To meet $\alpha = 0.1$, the CZ can report with an uncertainty ρ of 26.1% owing to its DTPI of -19.8% (or 26.4% if multiplied with (-20/15); see Figure 9).

MS	δ_{KP} %	α 1	DTPI 1	ρ 1	Case	Eq.
BG	**8.0**	0.0	0.549	0.641	Case 2	(A12a)
		0.1	0.549	0.714	Case 2	(A12a)
		0.2	0.549	0.811	Case 2	(A12a)
		0.3	0.549	0.951	Case 2	(A12a)
		0.4	0.549	> 1.0	Case 2	(A12a)
		0.5	0.549	> 1.0	Case 2	(A8)
CZ	**8.0**	0.0	0.264	0.235	Case 2	(A12a)
		0.1	0.264	0.261	Case 2	(A12a)
		0.2	0.264	0.295	Case 2	(A12a)
		0.3	0.264	0.342	Case 2	(A12a)
		0.4	0.264	0.409	Case 2	(A12a)
		0.5	0.264	0.525	Case 2	(A8)
EE	**8.0**	0.0	0.613	0.805	Case 2	(A12a)
		0.1	0.613	0.897	Case 2	(A12a)
		0.2	0.613	> 1.0	Case 2	(A12a)
		0.3	0.613	> 1.0	Case 2	(A12a)
		0.4	0.613	> 1.0	Case 2	(A12a)
		0.5	0.613	> 1.0	Case 2	(A8)
FI	**0.0**	0.0	0.035	0.017	Case 3	(A21b)
		0.1	0.035	0.019	Case 3	(A21b)
		0.2	0.035	0.022	Case 3	(A21b)
		0.3	0.035	0.024	Case 3	(A21b)
		0.4	0.035	0.028	Case 3	(A21b)
		0.5	0.035	0.033	Case 3	(A15)
FR	**0.0**	0.0	0.025	0.013	Case 3	(A21b)
		0.1	0.025	0.014	Case 3	(A21b)
		0.2	0.025	0.016	Case 3	(A21b)
		0.3	0.025	0.018	Case 3	(A21b)
		0.4	0.025	0.020	Case 3	(A21b)
		0.5	0.025	0.024	Case 3	(A15)
DE	**21.0**	0.0	0.040	0.053	Case 1	(A4)
		0.1	0.040	0.067	Case 1	(A4)
		0.2	0.040	0.089	Case 1	(A4)
		0.3	0.040	0.133	Case 1	(A4)
		0.4	0.040	0.266	Case 2	(A12a)
		0.5	0.040	0.333	Case 2	(A8)
HU	**6.0**	0.0	0.400	0.361	Case 2	(A12a)
		0.1	0.400	0.402	Case 2	(A12a)
		0.2	0.400	0.456	Case 2	(A12a)
		0.3	0.400	0.530	Case 2	(A12a)
		0.4	0.400	0.642	Case 2	(A12a)
		0.5	0.400	0.853	Case 2	(A8)
LV	**8.0**	0.0	0.693	> 1.0	Case 2	(A12a)
		0.1	0.693	> 1.0	Case 2	(A12a)
		0.2	0.693	> 1.0	Case 2	(A12a)
		0.3	0.693	> 1.0	Case 2	(A12a)
		0.4	0.693	> 1.0	Case 2	(A12a)
		0.5	0.693	> 1.0	Case 2	(A8)

Table A1: continued.

LT	**8.0**	0.0	0.628	0.850	Case 2	(A12a)
		0.1	0.628	0.947	Case 2	(A12a)
		0.2	0.628	> 1.0	Case 2	(A12a)
		0.3	0.628	> 1.0	Case 2	(A12a)
		0.4	0.628	> 1.0	Case 2	(A12a)
		0.5	0.628	> 1.0	Case 2	(A8)
PL	**6.0**	0.0	0.367	0.321	Case 2	(A12a)
		0.1	0.367	0.357	Case 2	(A12a)
		0.2	0.367	0.404	Case 2	(A12a)
		0.3	0.367	0.469	Case 2	(A12a)
		0.4	0.367	0.567	Case 2	(A12a)
		0.5	0.367	0.745	Case 2	(A8)
RO	**8.0**	0.0	0.528	0.597	Case 2	(A12a)
		0.1	0.528	0.665	Case 2	(A12a)
		0.2	0.528	0.756	Case 2	(A12a)
		0.3	0.528	0.885	Case 2	(A12a)
		0.4	0.528	> 1.0	Case 2	(A12a)
		0.5	0.528	> 1.0	Case 2	(A8)
SK	**8.0**	0.0	0.368	0.346	Case 2	(A12a)
		0.1	0.368	0.385	Case 2	(A12a)
		0.2	0.368	0.436	Case 2	(A12a)
		0.3	0.368	0.507	Case 2	(A12a)
		0.4	0.368	0.614	Case 2	(A12a)
		0.5	0.368	0.812	Case 2	(A8)
SE	**-4.0**	0.0	0.138	0.050	Case 3	(A21b)
		0.1	0.138	0.055	Case 3	(A21b)
		0.2	0.138	0.061	Case 3	(A21b)
		0.3	0.138	0.069	Case 3	(A21b)
		0.4	0.138	0.078	Case 3	(A21b)
		0.5	0.138	0.089	Case 3	(A15)
UK	**12.5**	0.0	0.084	0.107	Case 1	(A4)
		0.1	0.084	0.134	Case 1	(A4)
		0.2	0.084	0.156	Case 2	(A12a)
		0.3	0.084	0.180	Case 2	(A12a)
		0.4	0.084	0.213	Case 2	(A12a)
		0.5	0.084	0.265	Case 2	(A8)

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 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 and 2004 (Bun and Jonas, 2006b; Hamal and Jonas, 2008).

[4] For example, Ireland is allowed a 13% increase from 1990 levels by 2008–2012, so its theoretical linear target for 2005 is a rise of no more than 9.8%. Its actual emissions in 2005 show an increase of 25.4% since 1990; hence, its DTPI is 25.4 - 9.8, or 15.6 percentage points. Germany's Kyoto target is a 21% reduction, so its theoretical linear target for 2005 is a decrease of 15.8%. Its actual emissions in 2005 were 18.7% lower than in 1990; hence, Germany's DTPI is (-18.7) - (-15.8), or -3.0 percentage points (rounded).

[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-27 Member State carried out full carbon accounting (FCA; Jonas and Nilsson, 2001: Table 14). It served as a basis for extracting a partial carbon account which encompasses CH4 and N2O 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 the Member States 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 DTPI reporting of the EU.

9 Note that in Cases 3 and 4, unlike in Jonas *et al.* (2008: Appendix D), the critical emission limitation or reduction δ_{crit} is not adjusted.