

## APPENDICES & METHODOLOGIES - USE OF KYOTO CREDITS BY EUROPEAN INDUSTRIAL INSTALLATIONS: FROM AN EFFICIENT MARKET TO A BURST BUBBLE

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This current document presents all appendices and methodologies used by the authors.

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## Appendix 1 – Estimated amount of credits that were not available for the EU ETS surrender process

The amount of credits available for the EU ETS surrendering process at a date  $D$  corresponds to the amount of credits issued at that date, from which we deducted the amounts already surrendered by installations subject to the EU ETS, as well as the credits held by governments and by non-European and Swiss companies. The underlying assumption is that a government or a non-European company that holds credits will use them for its own compliance purposes and will not resell them on the EU ETS. Switzerland is home to a large number of intermediaries that resell credits to companies governed by the EU ETS, so the credits held by Swiss companies were considered as “available for surrender”.

The difficulty in making estimates arises from the frequency with which data are made available: the amount of credits issued is available every month; however the other data are only available every year, in the UNFCCC SEF files for credits held by States and companies, and in the CITL for credits surrendered by companies governed by the EU ETS.

We initially estimated the total amount of credits available for the EU ETS surrender process on 1 May every year, which is the cut-off date for the EU ETS surrender process (**Equation 1**).

### Equation 1

$$Q_{a(t)} = Q_{i(t)} - Q_{si} - Q_{se(t)}$$

Where  $Q_a$  is the amount of credits available for the EU ETS surrender process at time  $t$  (May 1<sup>st</sup>),  $Q_i$  is the amount of credits issued at time  $t$ , i.e. the amount of credits delivered at that date,  $Q_{si}$  is the amount of credits surrendered by installations subject to the EU ETS, and  $Q_{se}$  is the amount of credits held by (EU and non-EU) States, or by private entities outside the EU and Switzerland.

The amount of credits held by (EU and non-EU) States and by private entities outside the EU and Switzerland as at May 1<sup>st</sup> was estimated via linear interpolation between the amounts held as at December 31<sup>st</sup> in the previous and following years, which was the only data available in the SEF files.

In total, we estimate that, following the May 2013 surrender, almost 560 million tonnes of CERs and ERUs were not captured by regulated global demand outside the EU ETS, but remained on accounts held by project developers, investors or financial intermediaries.

By continuing our analysis, we showed that there was an acceleration in the surrender of HFC and N<sub>2</sub>O credits during the last years of Phase II due to the regulatory environment.

For this, we assumed that the CER and ERU purchasing behaviour of governments and non-European companies was similar to the behaviour of EU ETS operators. In other words, they hold a proportion of credits for each project type on their account every year that is identical to the proportion surrendered by EU ETS installations. We limited this assumption for HFC and N<sub>2</sub>O credits in 2013 following the commitments to no longer use them made by several States by applying a 30% discount. This means that we specified the type of credits available for the EU ETS surrender process at a time  $t$  according to **Equation 2**.

### Equation 2

$$Q_{a(i,t)} = Q_{i(i,t)} - Q_{si(i,t)} - Q_{se(i,t)} \cdot \text{prop\_rem}(i)$$

Where  $Q_a$  is the amount of credits available for the EU ETS surrender process at time  $t$  (May 1<sup>st</sup>) for type  $i$  projects,  $Q_i$  is the amount of credits issued at time  $t$  for type  $i$  projects, i.e. the amount of credits delivered at that date,  $Q_{si}$  is the amount of credits surrendered by installations subject to the EU ETS for type  $i$  projects,  $Q_{se}$  is the amount of credits held by (EU and non-EU) States, or by private entities outside the EU and Switzerland, and  $\text{prop\_rem}(i)$  is the proportion of type  $i$  credits among those surrendered as part of the EU ETS process since 2008. The types of project are grouped into eight categories: HFC, N<sub>2</sub>O, hydropower, upstream energy efficiency (*own generation, supply side, industry*), wind power, fugitive emissions, and other projects.

**Appendix 2 – Estimated timeframe for the transfer of a credit**

To estimate the timeframe for the transfer of credits, we initially estimated the amount of credits that were not surrendered on May 1<sup>st</sup> every year, which is the cut-off date for the EU ETS surrender process (**Equation 1**).

The transfer time was then estimated based on the assumption that credits were surrendered in the order in which they were delivered (**Equation 3**). We note that the invalidity of this assumption does not affect the calculation of the average transfer timeframe, as its extension due to old non-surrendered credits is offset by a reduction relating to the surrender of recent credits.

*Equation 3*

$$\Delta t = t - t'$$

Where  $\Delta t$  is the transmission timeframe at time  $t$ , and  $t'$  is the date defined in Equation 4

*Equation 4*

$$Q_{i(t)} = Q_{i(t)} - Q_{a(t)}$$

where  $Q_a$  is the amount of credits available for the EU ETS surrender process at time  $t$ , and  $Q_i$  is the amount of credits issued at time  $t$ .

**Appendix 3 – Trend in the credits (CERs and ERUs) surrendered for each type of project by EU ETS installations (MtCO<sub>2</sub>eq)**

EU ETS credit surrendered (May 1 <sup>st</sup> )	2009	2010	2011	2012	2013	Total
HFCs	52	46	57	127	153	433
N <sub>2</sub> O	19	20	54	56	64	212
Hydropower	1	2	5	11	18	37
EE (own generation supply side, industry)	6	4	7	17	51	84
Fossil fuel switch	0	1	2	6	8	17
Wind power	1	2	2	4	5	15
Fugitive gases	1	0	4	10	157	172
Other	4	6	6	24	48	88
<b>Total</b>	<b>84</b>	<b>81</b>	<b>137</b>	<b>254</b>	<b>504</b>	<b>1 059</b>

Source: CDC Climat research and CITL

**Appendix 4– Change in the aggregate credit supply by type of project (MtCO<sub>2</sub>eq)**

Credit supply (1 May)	2009	2010	2011	2012	2013
HFCs	156	214	293	431	543
N <sub>2</sub> O	59	91	150	226	300
Hydropower	10	19	41	85	164
EE (own generation supply side, industry)	12	18	31	85	161
Fossil fuel switch	2	6	14	36	65
Wind power	12	20	36	67	125
Fugitive gases	5	5	14	29	382
Other	26	40	62	105	243
<b>Total</b>	<b>282</b>	<b>413</b>	<b>641</b>	<b>1,063</b>	<b>1,982</b>

Source: CDC Climat Research, CDM/JI pipeline

## Appendix 5 – Aggregate use of Kyoto credits for each registry compared with the authorised limit

Country	Authorised import limit	2008-2012 allocation	Authorised surrender	CERs & ERUs surrendered 2008-2012	Surrendered credits/allotments (%)	2008-2012 position
DE	22.0%	2,040.9	449.0	303.8	14.9%	-233.3
ES	20.6%	764.5	157.5	107.4	14.0%	70.2
IT	15.0%	1,012.6	151.9	96.0	9.5%	43.0
PL	10.0%	1,029.1	102.9	95.7	9.3%	33.8
GB	8.0%	1,152.5	92.2	79.3	6.9%	-49.9
FR	13.5%	692.8	93.5	76.7	11.1%	123.4
CZ	10.0%	431.1	43.1	38.7	9.0%	57.0
RO	10.0%	368.7	36.9	32.2	8.7%	108.6
NL	10.0%	433.4	43.3	29.2	6.7%	23.6
GR	9.0%	323.6	29.1	28.0	8.7%	9.0
BG	12.6%	198.8	25.0	23.4	11.8%	19.6
BE	8.4%	285.4	24.0	19.4	6.8%	42.3
FI	10.0%	189.5	19.0	16.5	8.7%	11.9
PT	10.0%	161.8	16.2	14.9	9.2%	27.7
AT	10.0%	162.6	16.3	14.2	8.7%	12.1
DK	17.0%	120.8	20.5	12.6	10.5%	2.6
SE	10.0%	113.8	11.4	10.7	9.4%	11.2
SK	7.0%	162.6	11.4	10.0	6.2%	50.8
HU	10.0%	123.9	12.4	10.0	8.0%	6.4
NO	13.0%	41.4	5.4	9.3	22.5%	-56.2
IE	10.0%	111.3	11.1	7.9	7.1%	14.3
LT	20.0%	39.2	7.8	6.8	17.4%	9.5
SI	15.8%	41.2	6.5	6.2	15.1%	0.4
EE	10.0%	65.5	6.6	2.7	4.1%	-1.4
CY	10.0%	27.6	2.8	2.7	9.6%	2.5
LV	10.0%	22.0	2.2	1.7	7.6%	7.6
MT	10.0%	10.9	1.1	1.1	10.1%	0.9
LU	10.0%	14.7	1.5	1.0	7.1%	2.5
IS	0.0%	0.4	0.0	0.1	12.7%	0.1
LI	8.0%	0.1	0.0	0.0	0.0%	0.1
<b>Total</b>	<b>13.6%</b>	<b>10,142.8</b>	<b>1,400.5</b>	<b>1,058.3</b>	<b>10.4%</b>	<b>350.0</b>

## Appendix 6 – Use of Kyoto credits by sector compared with the authorised limit

Sectors	Import limit	2008-2012 allocation	Authorised surrender	CERs & ERUs surrendered 2008-2012	Surrendered credits/allotments (%)	2008-2012 position
Combustion	13.6%	6,443.9	877.8	680.8	10.6%	-620.0
Steel works	14.4%	926.9	140.4	118.3	12.8%	358.8
Cement works	14.5%	1,070.0	152.3	111.0	10.4%	279.6
Refineries	14.2%	777.2	110.5	65.4	8.4%	60.0
Paper manufacturers	14.7%	196.8	28.7	19.3	9.8%	50.8
Other sectors	10.5%	121.8	15.2	13.8	11.3%	11.4
Glass manufacturing	15.1%	128.6	18.5	13.4	10.4%	25.4
Aviation	12.2%	161.0	21.4	11.0	6.8%	77.2
Coking plants	12.1%	112.9	10.9	10.1	9.0%	20.0
Metal ores	10.8%	110.1	11.1	7.9	7.2%	42.7
Ceramic products	14.7%	93.4	13.6	7.4	7.9%	44.8
New sectors	13.7%	0.2	0.0	0.1	34.3%	-0.7
<b>Total</b>	<b>13.6%</b>	<b>10,142.8</b>	<b>1,400.5</b>	<b>1,058.3</b>	<b>10.4%</b>	<b>350.0</b>

Source: CDC Climat Research, based on CITL, PNAQ and Sandbag data

Appendix 7 – Use of Kyoto HFC & N<sub>2</sub>O credits eligible in Phase II aggregated by sector

Sector	Project type	2008	2009	2010	2011	2012	Total
Combustion	Grey (HFC & N <sub>2</sub> O)	47.0	48.2	84.7	101.0	149.0	430.0
	Eligible in Phase III	9.2	11.4	18.6	38.9	183.1	261.2
	<b>Total</b>	<b>56.2</b>	<b>59.6</b>	<b>103.3</b>	<b>139.9</b>	<b>332.1</b>	<b>691.1</b>
Steel works	Grey (HFC & N <sub>2</sub> O)	8.1	5.0	8.1	34.1	16.1	71.4
	Eligible in Phase III	0.8	0.7	1.4	17.2	26.8	46.9
	<b>Total</b>	<b>8.9</b>	<b>5.7</b>	<b>9.6</b>	<b>51.3</b>	<b>42.9</b>	<b>118.3</b>
Cement works	Grey (HFC & N <sub>2</sub> O)	7.0	6.1	7.1	27.8	20.2	68.3
	Eligible in Phase III	1.4	0.9	2.8	6.3	31.4	42.8
	<b>Total</b>	<b>8.4</b>	<b>7.0</b>	<b>9.9</b>	<b>34.1</b>	<b>51.7</b>	<b>111.2</b>
Refineries	Grey (HFC & N <sub>2</sub> O)	3.5	3.4	5.8	8.7	11.2	32.7
	Eligible in Phase III	1.0	1.1	1.7	5.3	22.7	31.8
	<b>Total</b>	<b>4.5</b>	<b>4.4</b>	<b>7.6</b>	<b>13.9</b>	<b>34.0</b>	<b>64.5</b>
Paper manufacturers	Grey (HFC & N <sub>2</sub> O)	1.8	1.6	2.3	4.7	3.9	14.4
	Eligible in Phase III	0.6	0.3	0.5	0.9	2.7	5.0
	<b>Total</b>	<b>2.3</b>	<b>1.9</b>	<b>2.9</b>	<b>5.6</b>	<b>6.6</b>	<b>19.4</b>
Glass manufacturing	Grey (HFC & N <sub>2</sub> O)	0.8	0.3	1.4	3.1	3.6	9.2
	Eligible in Phase III	0.2	0.1	0.2	0.4	3.4	4.2
	<b>Total</b>	<b>1.0</b>	<b>0.3</b>	<b>1.6</b>	<b>3.5</b>	<b>7.0</b>	<b>13.4</b>
Aviation	Grey (HFC & N <sub>2</sub> O)	0.0	0.0	0.0	0.0	4.3	4.3
	Eligible in Phase III	0.0	0.0	0.0	0.0	6.7	6.7
	<b>Total</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>11.0</b>	<b>11.0</b>
Coking plants	Grey (HFC & N <sub>2</sub> O)	1.4	0.3	0.3	0.9	3.5	6.3
	Eligible in Phase III	0.0	0.1	0.2	1.1	2.3	3.8
	<b>Total</b>	<b>1.4</b>	<b>0.4</b>	<b>0.5</b>	<b>2.1</b>	<b>5.7</b>	<b>10.1</b>
Metal ores	Grey (HFC & N <sub>2</sub> O)	0.2	0.2	0.1	0.3	2.9	3.6
	Eligible in Phase III	0.0	0.0	0.0	0.2	4.1	4.3
	<b>Total</b>	<b>0.2</b>	<b>0.2</b>	<b>0.1</b>	<b>0.4</b>	<b>7.0</b>	<b>7.9</b>
Ceramic products	Grey (HFC & N <sub>2</sub> O)	0.5	0.8	0.9	1.1	1.2	4.4
	Eligible in Phase III	0.1	0.2	0.7	0.6	1.6	3.2
	<b>Total</b>	<b>0.6</b>	<b>1.0</b>	<b>1.6</b>	<b>1.6</b>	<b>2.8</b>	<b>7.6</b>
Other	Grey (HFC & N <sub>2</sub> O)	0.0	0.1	0.1	0.5	0.4	1.1
	Eligible in Phase III	0.0	0.0	0.1	0.5	2.6	3.2
	<b>Total</b>	<b>0.0</b>	<b>0.1</b>	<b>0.1</b>	<b>1.1</b>	<b>3.0</b>	<b>4.3</b>
Total	Grey (HFC & N <sub>2</sub> O)	70.3	65.8	110.9	182.2	216.4	645.7
	Eligible in Phase III	13.3	14.8	26.2	71.4	287.3	413.0
	<b>Total</b>	<b>83.6</b>	<b>80.6</b>	<b>137.2</b>	<b>253.6</b>	<b>503.7</b>	<b>1,058.7</b>

Source: CDC Climat Research, based on CITL data

## Appendix 8 – Rules for using offset credits in other ETS throughout the world

World ETS	Rules for using credits
<b>Korean ETS</b>	<p><b>Phase III:</b> 10% of the emissions may be offset by international credits, although the facility subject to the ETS must surrender at least as many domestic offset credits as international credits</p> <p><b>Types:</b> National credits: forestry and reforestation credits in South Korea</p> <p><b>International credits:</b></p> <p><b>Phases I and II:</b> ban on using international credits except for CERs generated by South Korean projects</p> <p><b>Phase III:</b> international credits are authorised (10% of emissions)</p> <p>National ACCU (Australian Carbon Credit Units) agricultural and forestry credits generated by the Carbon Farming Initiative (CFI) are eligible as from Phase I, and on an unlimited basis in Phases II and III, while international credits are subject to quantitative usage restrictions</p> <p><b>Phase I:</b> usable for up to 5% of compliance</p> <p><b>Phases II and III:</b> unlimited use</p>
<b>AU-ETS</b>	<p><b>International assets:</b></p> <p><b>Phase I:</b> ban on using them</p> <p><b>Phases II and III:</b> Kyoto credits (CERs, ERUs and RMUs) may be used for up to 12.5% of compliance. Credits from the EU ETS may be used for up to 50% of compliance. The total amount of international credits must not exceed 50% of emissions. Restriction on certain types of offset projects like forestry projects and those linked to major hydro-electric installations.</p>
<b>NZ ETS</b>	<p><b>National credits:</b> forestry credits within the framework of the ETS or via permanent programs (Permanent Forest Sink Initiative, and Project to Reduce Emissions). Option to convert UQAs into forestry ERUs.</p> <p><b>Kyoto assets (UQAs, CERs, ERUs, and UAs):</b></p> <p>Until May 31<sup>st</sup>, 2015, access to Kyoto assets, except for tCERs and ICERs resulting from forestry projects, ERUs and CERs from nuclear projects, unrecognised foreign UQAs and UAs, CERs from industrial gases (HFC-23 and N<sub>2</sub>O generated by the production of adipic acid) and CERs from major hydro-electric power plants.</p> <p>After June 1<sup>st</sup>, 2015, only domestic offsets will be allowed.</p>
<b>China</b>	<p>Project involving seven pilot ETS:</p> <p><b>Beijing ETS:</b> credits limited to 5% of compliance. 50% of these credits must be generated by local projects (in the City of Beijing).</p> <p>The Chongqing and Guangdong markets are planning to accept forestry credits to offset between 5 and 15% of the emissions subject to constraints.</p>
<b>RGGI</b>	<p>The use of offset credits generated in the local area – in one of the States concerned – is allowed, including for reforestation projects within a limit that depends on the allowance price level (from 3.3% of compliance to 10% if the allowance price reaches 2005 USD\$10). No international credits are allowed.</p>
<b>California</b>	<p>Credits located on US, Mexican or Canadian soil are authorised up to a limit of 8% of the allocation. Notwithstanding this geographical restriction, credits from sector-based REDD-type projects (sector-based credits) may be used within a limit of 25% of the amount of credits authorised in Phase 1, and 50% thereafter.</p>

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ources: Club Tendances Carbone report issued in April 2013, CDC Climat Research

## Appendix 9 – Statistical tests

### Surrender depending on installations' positions

Linear regression (in red on the figure):

$$\log \frac{(Q_{surr})}{(Alloc)} = -0.003 \times \frac{Pos}{Alloc} \quad r^2 = 0.004$$

where  $Q_{surr}$  is the amount of credits surrendered by the installation in tCO<sub>2</sub>eq,  $Alloc$  is the installation's allocation in tCO<sub>2</sub>eq, and  $Pos$  is the installation's net position ( $Alloc - \text{verified emissions}$ ) in tCO<sub>2</sub>eq.

Logistic regression:

$$P(surr) = \frac{e^{-Pos/Alloc}}{1 + e^{-Pos/Alloc}} \quad \text{P-value} = 0.36$$

where  $P(surr)$  is the probability that an installation has surrendered at least one credit,  $Alloc$  is the installation's allocation in tCO<sub>2</sub>eq, and  $Pos$  is the installation's net position ( $Alloc - \text{verified emissions}$ ) in tCO<sub>2</sub>eq.

### Surrender depending on the size of the installation

Logistic regression:

$$P(surr) = \frac{e^{-size}}{1 + e^{-size}} \quad \text{P-value} = 2 \times 10^{-16}$$

where  $P(surr)$  is the probability that an installation has surrendered at least one credit, and  $size$  is the size of the installation, as classified in five categories depending on its allocation (see Figure 11).

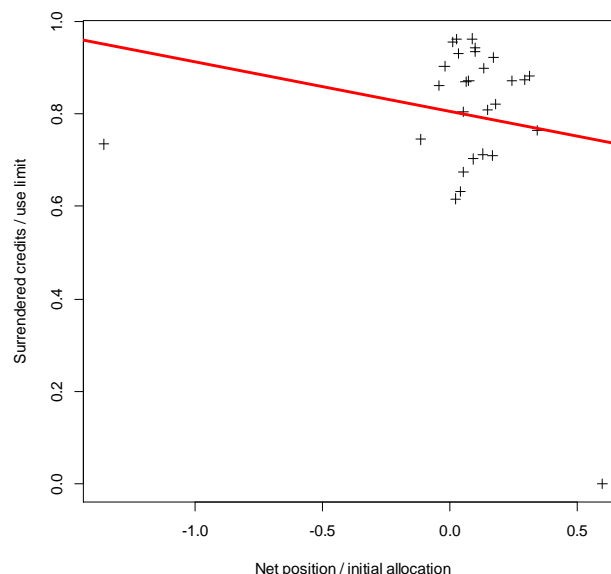
### Surrender depending on the authorised import limit

#### For countries

Linear regression (in red on the figure):

$$\frac{Q_{surr}}{Use\_lim} = -0.107 \times \frac{Pos}{Alloc} + 0.806 + \varepsilon \quad r^2 = 0.005$$

where  $Q_{surr}$  is the amount of credits surrendered by the country's installations in tCO<sub>2</sub>eq,  $Use\_lim$  is the authorised import limit in tCO<sub>2</sub>eq,  $Alloc$  is the aggregate allocation for the country's installations in tCO<sub>2</sub>eq and  $Pos$  is the country's net position ( $Alloc - \text{verified emissions}$ ) in tCO<sub>2</sub>eq.

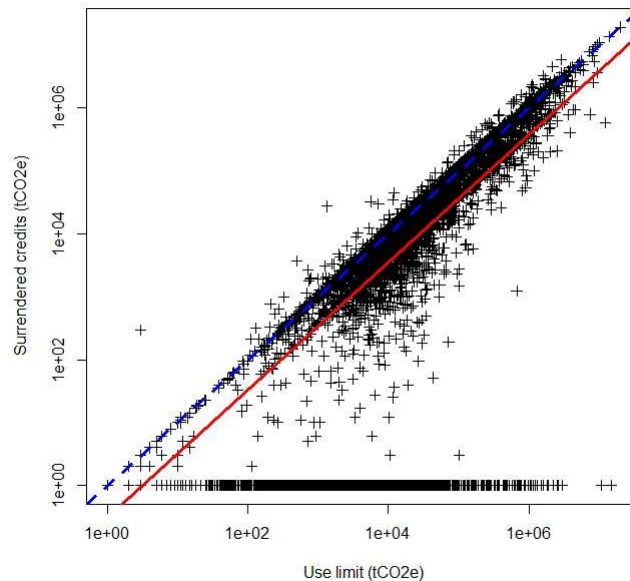


### For Installations

Linear regression (in red on the figure):

$$\frac{Q_{surr}}{Use\_lim} = -0.101 \times \frac{Pos}{Alloc} - 0.56 + \varepsilon \quad r^2 = 0.88$$

where  $Q_{surr}$  is the amount of credits surrendered by the installation in tCO<sub>2</sub>e,  $Use\_lim$  is the authorised import limit in tCO<sub>2</sub>e,  $Alloc$  is the installation's allocation in tCO<sub>2</sub>e and  $Pos$  is the installation's net position ( $Alloc$ - verified emissions) in tCO<sub>2</sub>e.



### Appendix 1 – Estimating savings from the use of credits with demand elasticity

The results of the ZEPHYR-Flex model indicate that with project-based mechanisms (Table 2), the total cost of compliance for Phase 2 reached €23.6 billion according to the following formula:

**Total compliance cost** (€23.6 billion) = reduction cost (€7.9 billion) + purchases value (€27.9 billion) – sales value (€12.2 billion)

In a scenario where there is banking/borrowing but without the use of international credits, the model results in a total compliance cost of €41 billion (Trotignon, 2013). In this scenario, credits are simulated as auctioned allowances.

According to ZEPHYR-Flex results, the differences between these two scenarios amounts to €17.4 billion, representing the additional cost that would have been supported by EU ETS operator without the use of international credits. By a simple rule of three, we adjust the results of the simulation which was performed before the 2012 data became available for the actual amount of credits surrendered in 2012, that is 504 million credits instead of the 344 million used in the original simulation.

**Actual savings** (€20.8 billion) = simulated savings (€17.4 billion) / credits surrendered in the simulation (891 million) \* credits actually surrendered (1,054 million)



**Table 2 – Compliance costs simulated by Zephyr-Flex with and without the offset provision**

	2005	2006	2007	2008	2009	2010	2011	2012	Phase 1	Phase 2	2005-2012
<b>ZEPHYR-Flex (trading only)</b>											
Carbon price	4	8	6	12	0	0	0	0	6	2	4
Verified emissions	2,176	2,175	2,175	2,083	1,936	1,973	1,926	1,899	6,526	9,817	16,343
Emission reductions	8	30	20	86	0	0	0	0	58	86	144
Traded volumes	227	228	227	246	197	213	183	173	682	1,012	1,694
Cumulated banking	0	0	0	0	0	0	0	0			
<b>Total cost</b>	<b>23</b>	<b>210</b>	<b>123</b>	<b>1,592</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>356</b>	<b>1,592</b>	<b>1,948</b>
<b>ZEPHYR-Flex (banking, borrowing w/o offsets)</b>											
Carbon price	22	13	0	31	16	21	27	27	12	24	20
Verified emissions	1,888	2,108	2,196	1,646	1,801	1,729	1,550	1,526	6,192	8,252	14,444
Emission reductions	296	97	0	523	135	244	377	372	393	1,652	2,045
Traded volumes	143	226	225	163	266	348	451	590	594	1,819	2,413
Cumulated banking	307	375	0	436	729	1,084	1,604	2,164			
<b>Total cost</b>	<b>4,921</b>	<b>990</b>	<b>0</b>	<b>13,472</b>	<b>2,984</b>	<b>5,586</b>	<b>9,416</b>	<b>9,608</b>	<b>5,911</b>	<b>41,068</b>	<b>46,979</b>
<b>ZEPHYR-Flex (banking, borrowing and offsets)</b>											
Carbon price	22	13	0	22	13	14	13	8	12	14	13
Verified emissions	1,888	2,108	2,196	1,876	1,851	1,870	1,841	1,870	6,192	9,308	15,500
Emission reductions	296	97	0	293	86	103	85	28	393	595	988
Traded volumes	143	226	225	204	299	419	583	762	594	2,268	2,861
Cumulated banking	307	375	0	297	610	965	1,457	1,994			
<b>Total cost</b>	<b>4,921</b>	<b>990</b>	<b>0</b>	<b>7,991</b>	<b>2,901</b>	<b>4,106</b>	<b>5,140</b>	<b>3,495</b>	<b>5,911</b>	<b>23,633</b>	<b>29,544</b>

Source: Trotignon, R. 2013

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