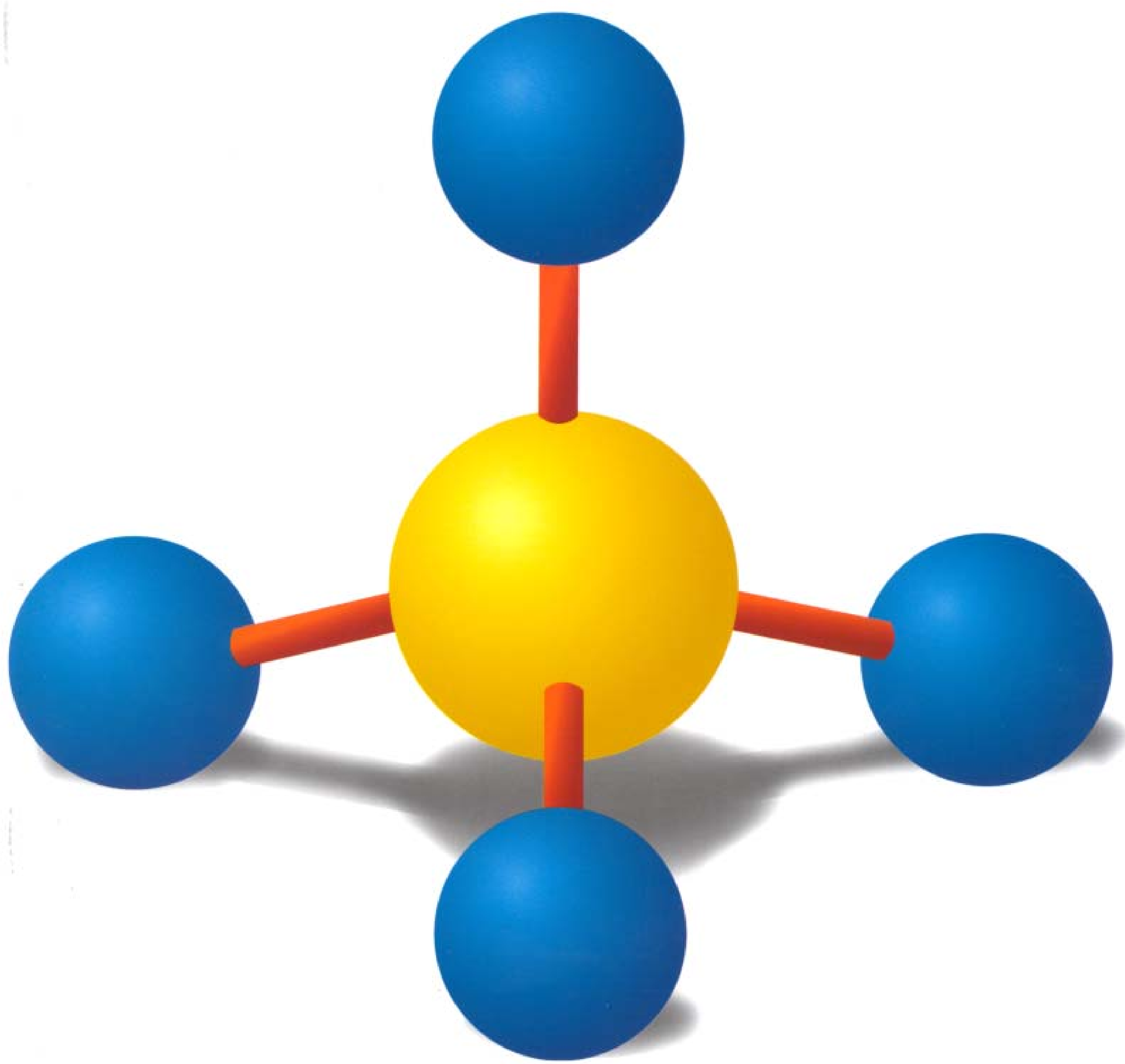
International Aluminium Institute

THE INTERNATIONAL ALUMINIUM INSTITUTE'S REPORT ON THE ALUMINIUM INDUSTRY'S GLOBAL PERFLUOROCARBON GAS EMISSIONS REDUCTION PROGRAMME – RESULTS OF THE 2003 ANODE EFFECT SURVEY



28 January 2005

Published by:
INTERNATIONAL ALUMINIUM INSTITUTE
New Zealand House
Haymarket
London
SW1Y 4TE
United Kingdom

Tel: + 44 (0) 20 7930 0528
Fax: + 44 (0) 20 7321 0183
Email: iai@world-aluminium.org
Website: www.world-aluminium.org

A company limited by guarantee. Registered in London no. 1052007
Registered Office New Zealand House, Haymarket, London SW1Y 4TE, United Kingdom

TABLE OF CONTENTS

Date of Report: 28 January 2005

1.0 Introduction

The results of the analysis of the 2003 IAI anode effect survey data are presented here. The 2003 survey is the sixth in a series of surveys covering anode effect data from global aluminium producers over the period from 1990 through 2003. The first survey covered the period from 1990 through 1993. The second survey covered the period 1994 through 1997. The third survey covered the period from 1998 through 2000 and also requested data for the base year 1990 and 1995 to improve the rate of data collection from these earlier years. After 2000, survey data has been requested annually. The survey results have been shown to be a useful tool in communicating the excellent results that the primary aluminium industry has made over the period from 1990 in reducing greenhouse gas emissions and has provided survey participants with valuable benchmarking information with which to judge current anode effect performance.

2.0 Survey Results

Table 1 shows a breakdown of production by reduction technology type for 2003. Participation in the 2003 survey accounted for 62 percent of overall global primary production, slightly lower than for the 2002 year survey. The small decrease in 2003 participation results from the growing global share of Chinese production. Chinese and Russian producers do not yet participate in the survey leaving the largest gaps in coverage, most noticeable in the two Søderberg technology categories.

Table 1 - 2003 Anode Effect Survey Participation by Technology Type

	PFPB	CWPB	SWPB	VSS	HSS	All
Participating in Survey (tonnes)	13,246,368	1,067,133	788,467	1,831,023	492,624	17,425,615
Non-Participants (tonnes)	5,256,000	850,407	409,212	2,551,429	1,517,000	10,584,048
Participation (Percent of total)	71.6%	55.7%	65.8%	41.8%	24.5%	62.2%

PFPB – Point Feed Prebake; CWPB – Bar Broken Center Work Prebake; SWPB – Side Work Prebake; VSS – Vertical Stud Søderberg; HSS – Horizontal Stud Søderberg

Figure 1 shows that global annual primary aluminium production rose over the period from 1990 when total primary production was 19.5 million tonnes to 28.0 million tonnes in 2003[1]. Figure 1 also illustrates that the increases in production over that time period are mainly due to increases in the lowest PFC emitting PFPB technology. Over the same period of time there have been some decreases in the amount of bar broken CWPB and SWPB production. Finally, the level of VSS and HSS Søderberg production has remained about constant from 1990 to 2003.

[1] Chinese and Russian production by technology are included in Figure 1 from experts' estimates.

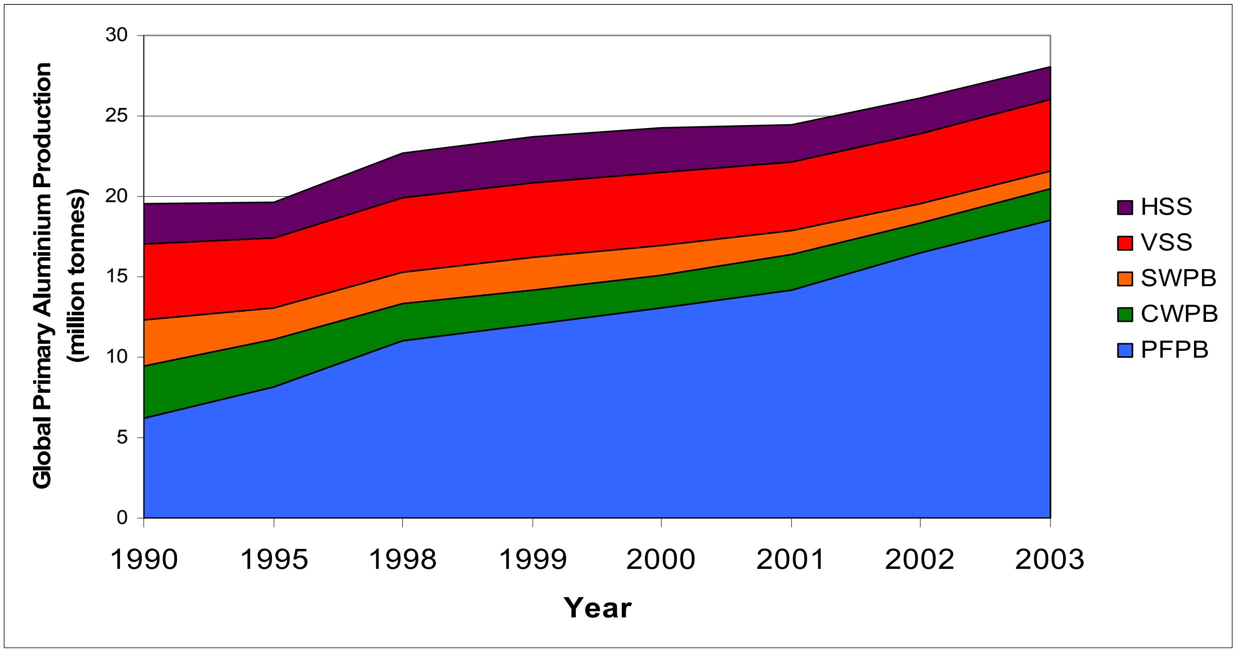


Figure 1 – Global Primary Aluminium Production by Technology Type from 1990 through 2003

The participation rate in the 2003 survey is highest for the facilities operating with Point Feed Prebake technology while less than half of those operating with Søderberg technology participated in the survey. Figure 2 shows the breakdown of the 110 reporting facilities by technology type. PFPB technology is the best represented group accounting for 66 of the reporting facilities. There is some double counting of facilities that report two different technologies within the same plant boundary. Reporting by individual reduction line is encouraged to provide as full a data set as possible; however, the data in figure 2 have been corrected to adjust for the facilities reporting data from multiple reduction lines of the same technology type.

The survey requested participants to report annual primary production, average anode effect frequency, average anode effect duration and, if applicable[2], average overvoltage. This anode effect performance data allows for the calculation of emission rates per tonne aluminium produced for tetrafluoromethane, CF_4, and hexafluoroethane, C_2F_6, by the Intergovernmental Panel on Climate Change (IPCC) Tier 2 method.[3] Total PFC emissions were then calculated by multiplying emissions per tonne primary aluminium times the production level in tonnes. In a continuing effort to improve the accuracy of the survey results, participants were also requested to report if a facility-specific PFC measurement had been conducted and if an IPCC Tier 3b coefficient were available for calculating PFC emissions for the facility. Of the 110 reporting facilities, twelve respondents reported facility-specific Tier 3b coefficients and these data were used in calculating PFC emissions per tonne aluminium produced for those facilities. The

[2] Overvoltage was specifically requested if operators employed AP-18 or AP-30 Point Feed Prebake Cells and if Sidework cells were used that utilized Pechiney control technology recording overvoltage.

[3] *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* Section 3.39, http://www.ipcc-nggip.iges.or.jp/public/gp/english/3_Industry.pdf.

remainder of the PFC emissions data was calculated using IPCC Tier 2 methodology with industry average coefficients[4].

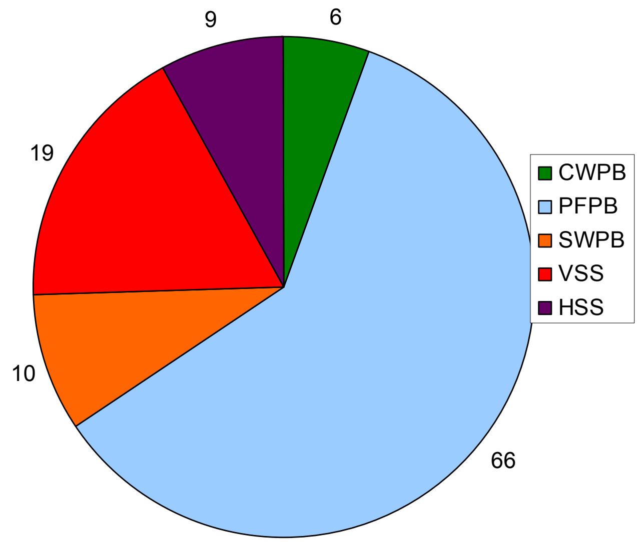


Figure 2 – Breakdown of Survey Reporting Facilities by Technology Type

Overall progress in reducing PFC emissions per tonne aluminium produced is shown in Figure 3. The production weighted, average combined emissions of CF_4 and C_2F_6 are expressed as tonne CO_2 equivalent per tonne of aluminium by multiplying each PFC component's emissions per tonne aluminium by the Global Warming Potential values reported in the IPCC Second Assessment Report; 6500 for CF_4 and 9200 for C_2F_6. The total tonne equivalent CO_2 emissions for all reporting facilities were determined by summing the CO_2 equivalent emissions for all facilities. The survey participants' average tonne equivalent CO_2 emissions per tonne aluminium produced was then calculated for those reporting anode effect data by dividing the sum total of CO_2 equivalent emissions for all reporting facilities by the sum of the total production for those facilities. Figure 3 shows that IAI survey participants have reduced PFC emissions per tonne aluminium produced from 4.03 tonne equivalents CO_2 per tonne aluminium in 1990 to 1.09 in 2003, a reduction of 73%.

[4] Greenhouse Gas Emissions Monitoring and Reporting by the Aluminium Industry, http://www.world-aluminium.org/environment/climate/ghg_protocol.pdf, p22, May 2003.

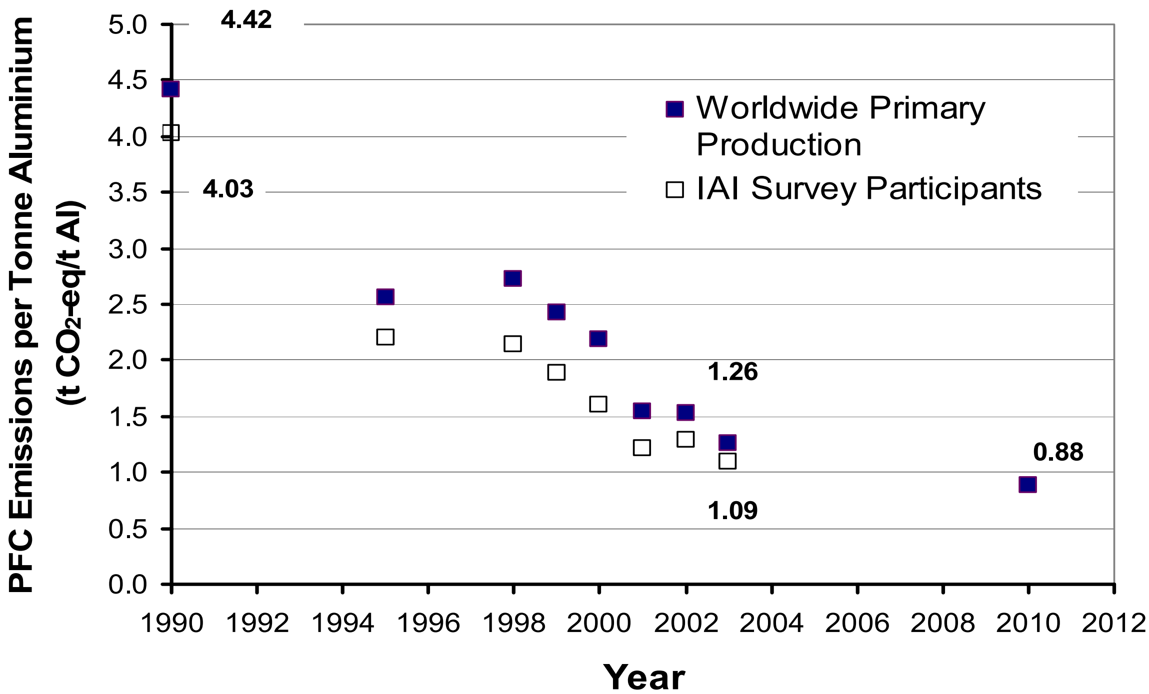


Figure 3 – Trend in Reduction in PFC Emissions per Tonne Primary Aluminium Produced from 1990 to 2003

Global PFC emissions, expressed as CO_2 equivalents, were estimated by multiplying the median PFC emission value per tonne aluminium, as tonne CO_2 equivalent per tonne aluminium, for each of the five reduction technology types by the number of tonnes of primary production for each technology type that did not respond to the survey data request. The additional tonnes CO_2 equivalents for the non participating production were then added to the tonnes CO_2 equivalents from survey participants. The total CO_2 equivalents from both survey participants and non participants were then divided by the total global primary production to obtain an estimate of global PFC emissions per tonne aluminium. Figure 3 shows that global emissions have been reduced from 4.42 tonne equivalents CO_2 per tonne aluminium in 1990 to 1.26 in 2003, a reduction of 71%. The slightly higher global PFC emission values per tonne aluminium produced relative to survey participants reflect the fact that the higher emitting Søderberg facilities are under-represented in the survey results.

Calculated total global PFC emissions per year released to the atmosphere, including emissions from survey participants and non-participants, over the period from 1990 through 2003 is shown in Figure 4. The total emissions are a function of both the annual emissions per tonne aluminium of the two PFCs and the total primary aluminium production levels for each year. It is notable that the total emissions have been reduced from 86.1 million tonnes CO_2 equivalents in 1990 to 35.2 million tonnes CO_2 equivalents in 2003, a reduction of 59 percent, even though the total primary production has increased over that same period from 19.5 to 28.0 million tonnes, an increase of 43.6 percent. The PFC emissions calculated for 2003 are the lowest yet recorded for the period beginning in 1990 and reverses the small rise noted for 2002 in both PFC emissions per tonne aluminium and total emissions.

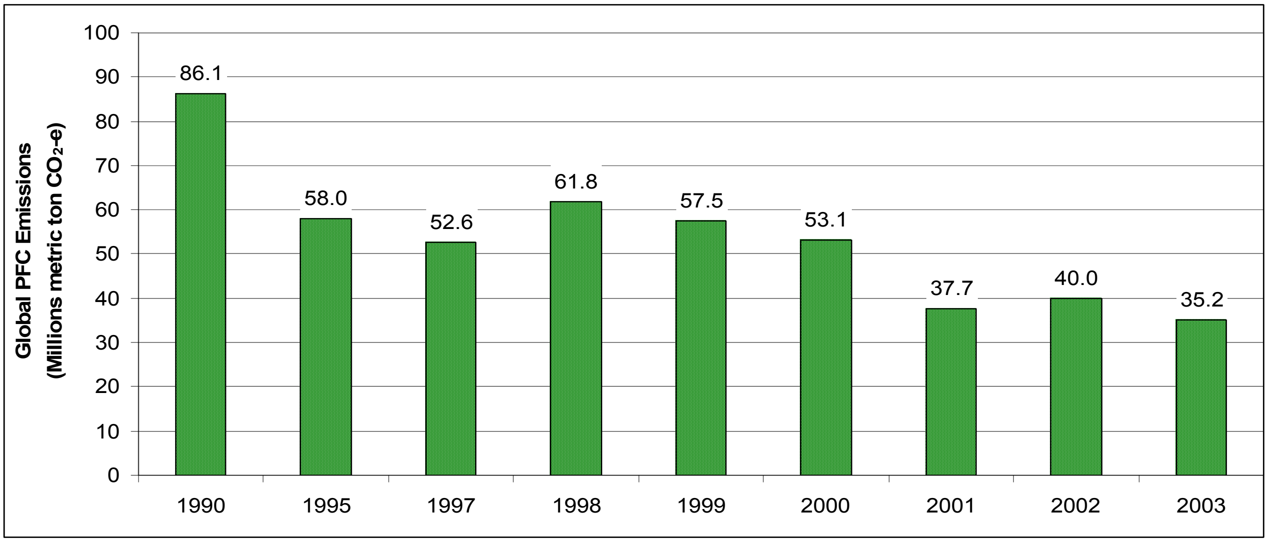


Figure 4 – Total PFC Emissions from Primary Aluminium Production by Year

Figure 5 shows the trend in median emissions of CF_4 per tonne aluminium produced over the period from 1990 through 2003 for each of the major 5 reduction technology types.

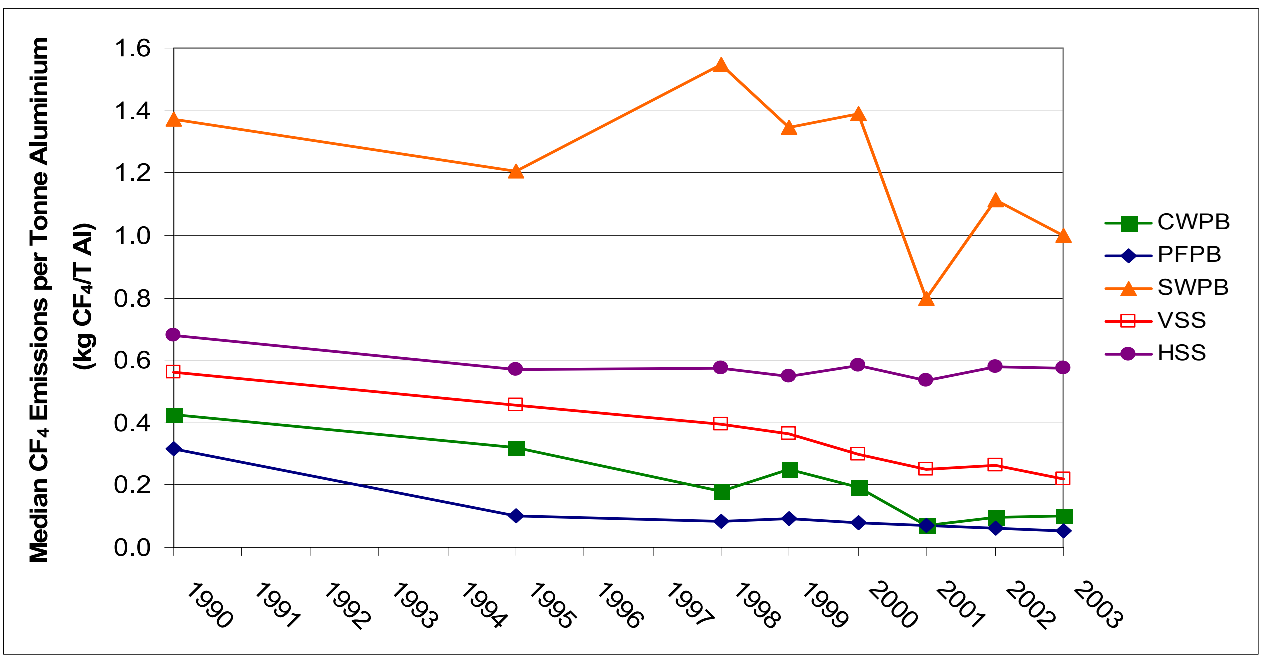


Figure 5 – Median CF_4 Emissions per Tonne Aluminium Produced by Reduction Technology Type from 1990 through 2003

Record performance was recorded for both PFPB and VSS technology groups in 2003 with the lowest median performance recorded since 1990. The SWPB and HSS technologies showed some reductions in emissions per tonne aluminium over 2002 and the CWPB category was slightly higher than 2002 performance.

3.0 Uncertainty in Emissions Projections

This section considers the uncertainty in calculations of PFC emissions from IAI survey participants and the uncertainty in projecting PFC emissions globally. Understanding sources of, and magnitude of, uncertainty is important because the global Industry has made specific commitments to reduce PFC emissions by 80% from the 1990 baseline by 2010. A high level of uncertainty has the potential of discounting the credibility of claims of emissions reduction. Potential significant sources of uncertainty include:

a. the uncertainty in the average industry Tier 2 calculation factors,
b. use of Tier 2 factors for calculating PFC emissions for survey participants where suitable facility-specific measurements are not available, and,
c. estimates of emissions for producers that do not participate in the survey.

Uncertainty arises from the use of average industry factors for two reasons. First, there is uncertainty in the determination of the mean slope values due to the scarcity of measurements. Secondly, there is uncertainty in assuming statistical equivalence between survey participants and facilities where measurements have been made. The potential impact of using industry average parameters on uncertainty was estimated by performing a Monte Carlo simulation using the 2003 IAI anode effect survey data and substituting the current proposed IPCC revised slope values for the current values. Uncertainty in the new slope values was modelled from the statistical distribution of the slope values that were included in the calculated mean values. The results of the simulation are shown in Figure 6.

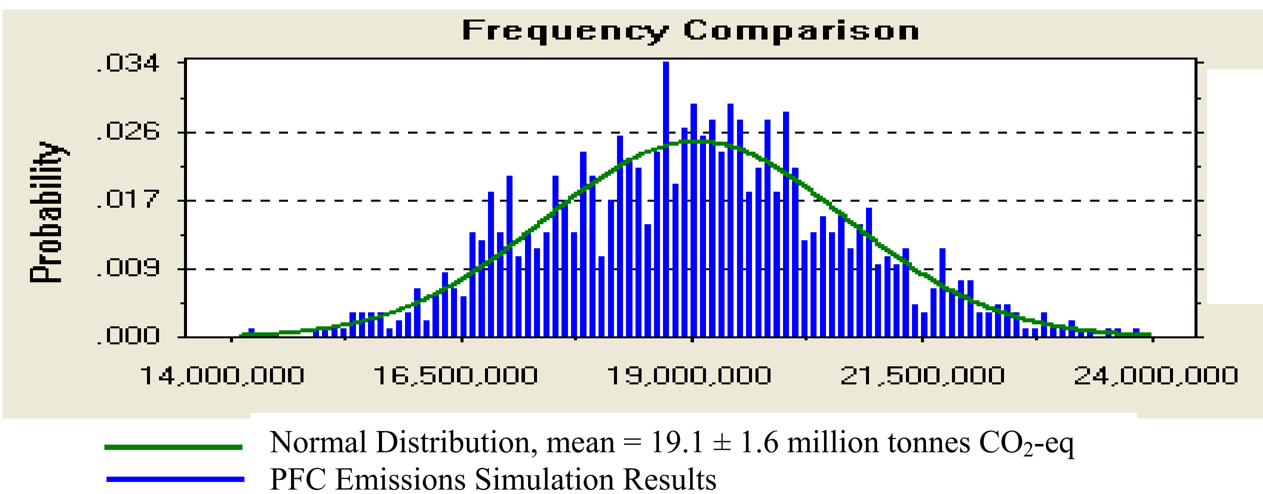


Figure 6 – Simulation of PFC Emissions Based on Proposed IPCC Factors

The analysis predicts that, with 95% confidence, 2003 PFC emissions lie between 15.9 and 22.3 tonnes CO_2-eq. The mean value of 19.1 is quite close to the 19.0 million tonnes CO_2-eq determined from the calculations using the current IPCC Tier 2 coefficients. PFC emissions per tonne aluminium produced take a similar form as for total emissions with a mean of 1.10 tonnes CO_2-eq per tonne aluminium and a 95% confidence range from 0.92 to 1.26. This analysis shows that, for the mix of cell technologies in 2003, adoption of the new Tier 2 coefficients does not greatly impact IAI PFC emissions calculations.

The Industry has stated its emissions reductions objective as a global goal of 80% reduction. The uncertainty in projecting survey results globally requires an estimate of anode effect performance for producers that do not participate in the anode effect survey. The convention that has been used in past calculations is to apply the median performance of survey participants for each cell technology group to the non participating production by technology. It can be argued that this approach might be overly optimistic and that survey non-participants are likely to operate at lower performance levels than the median of survey participants. A Monte Carlo simulation was run where performance of non-participants was treated in a more conservative manner. The simulation used randomly distributed values for PFC emissions per tonne aluminium, by technology group, ranging from the median survey performance to the poorest performance level reported in the survey. Total PFC emissions for survey participants and non-participants were calculated treating survey participants as in the first simulation shown in Figure 6. The result of the new simulation is shown in Figure 7.

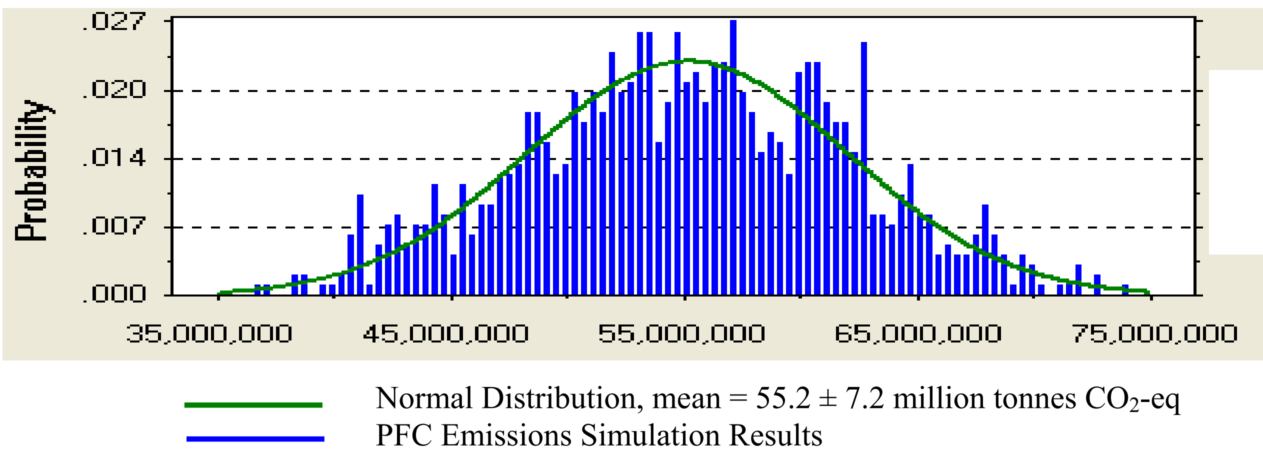


Figure 7 – Simulation of Global PFC Emissions Using Conservative Approach for Non-Participants

The analysis predicts a mean value of 55.2 million tonnes CO_2-eq and a 95% confidence range in global 2003 emissions from 40.8 to 69.6 million tonnes CO_2-eq. The result in Figure 7 should be compared with the estimate of 35.2 million tonnes CO_2-eq total PFC emissions currently in the IAI calculation that ascribes median performance to survey non-participants and shows that the assumption regarding non-participant performance is the largest source of uncertainty in global PFC emissions calculations. This uncertainty can be reduced by getting higher rates of participation in the annual anode effect survey.

4.0 Benchmark Data

The IAI anode effect survey has provided valuable benchmark information allowing global producers to judge their performance relative to others operating with similar technology. The benchmark data is presented in this section in the form of cumulative probability graphs for a rapid visual overview of the data. The detailed supporting data are tabulated in Appendix I of this report so that individual operators can identify their facilities from the data they submitted in response to the survey. The cumulative probability graphs show the benchmark parameter (PFC emissions per tonne aluminium, anode effect frequency, anode effect duration and overvoltage) on the horizontal axis and the vertical axis shows the cumulative percentage of reporting facilities that perform at or below the level chosen. For facilities reporting data from multiple potlines a data point is shown for each potline.

Figure 8 shows the 2003 benchmark data for PFC emissions per tonne aluminium produced by technology type.

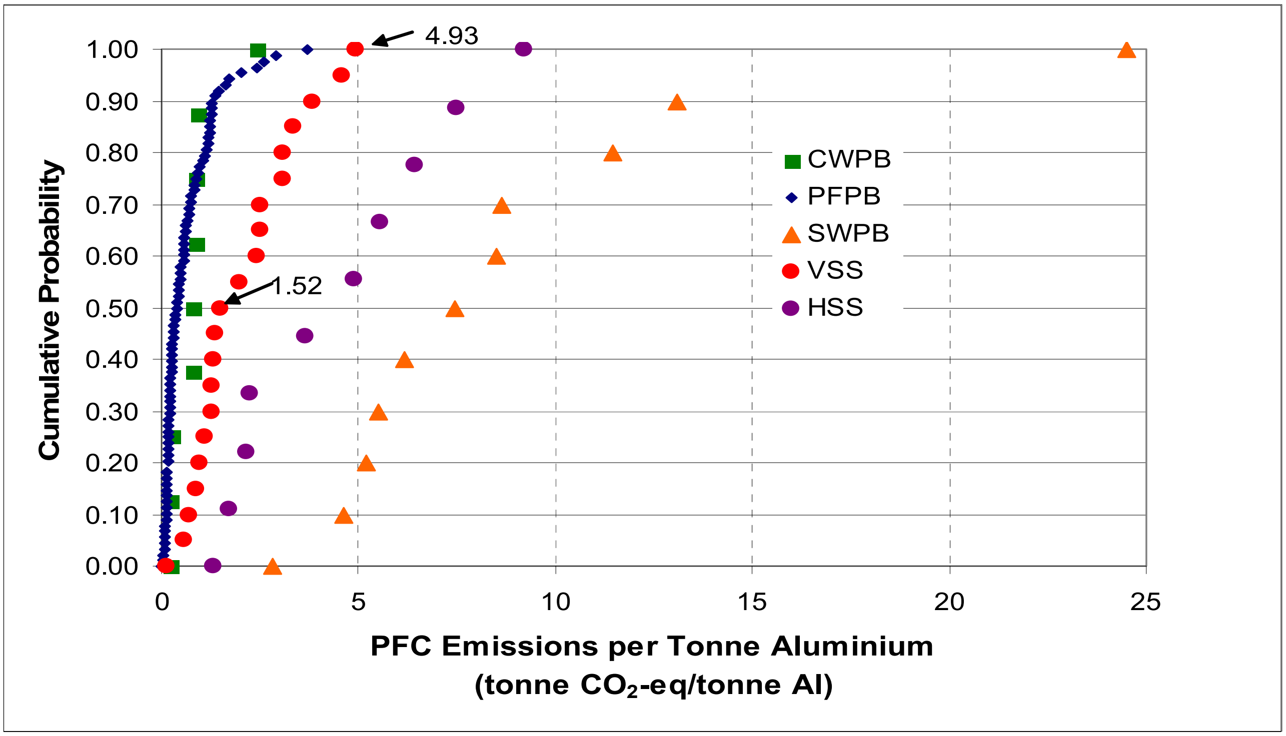


Figure 8 – Cumulative Probability Graph for PFC Emissions per Tonne Aluminium Produced for Survey Participants by Technology Type

To illustrate how the graph is interpreted, take for example in Figure 8 the 0.50 point on the vertical axis where the VSS data point is 1.52 tonne CO_2-eq/tonne Al. The interpretation is that 50% of all operators reporting VSS anode effect data operate at or below PFC emissions per tonne aluminium produced of 1.52 tonne CO_2-eq/tonne Al. At 1.00 on the vertical axis the VSS point is 4.93. The interpretation is that all VSS facilities reported anode effect data that reflected PFC emissions performance at or below 4.93 tonne CO_2-eq/tonne Al, or the maximum value calculated for VSS operators in 2003 was 4.93 tonne CO_2-eq/tonne Al. Figure 8 shows that the lowest PFC emissions per tonne aluminium produced are obtained from PFPB and CWPB operators. The Søderberg facilities show a distribution of values for PFC emissions per tonne aluminium higher than the PFPB and CWPB facilities; and the highest PFC emissions per tonne aluminium produced result from the SWPB cells.

Figure 9 shows the distribution of anode effect frequency data for reporting facilities in 2003. As can be expected from the greater degree of control capability, the PFPB anode effect frequency distribution is the lowest of the five technology groups. The remaining four technology groups show considerable overlap. The VSS facility with the lowest anode effect frequency, 0.13 anode effects per cell day, operates with point feeders and demonstrates the impact that installation of point feeders can have on anode effect frequency for Søderberg cells.

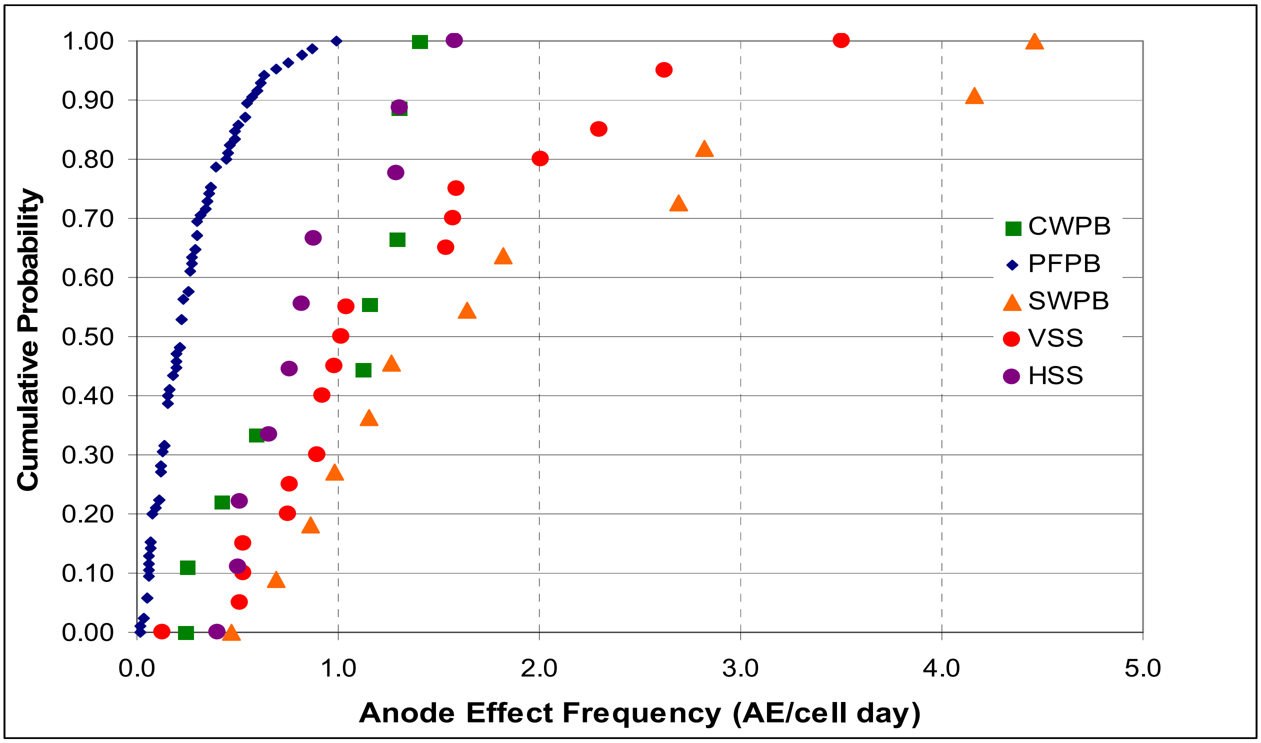


Figure 9 - Cumulative Probability Graph for Anode Effect Frequency for Survey Participants by Technology Type

Figure 10 shows comparative performance for anode effect duration performance for all reporting facilities.

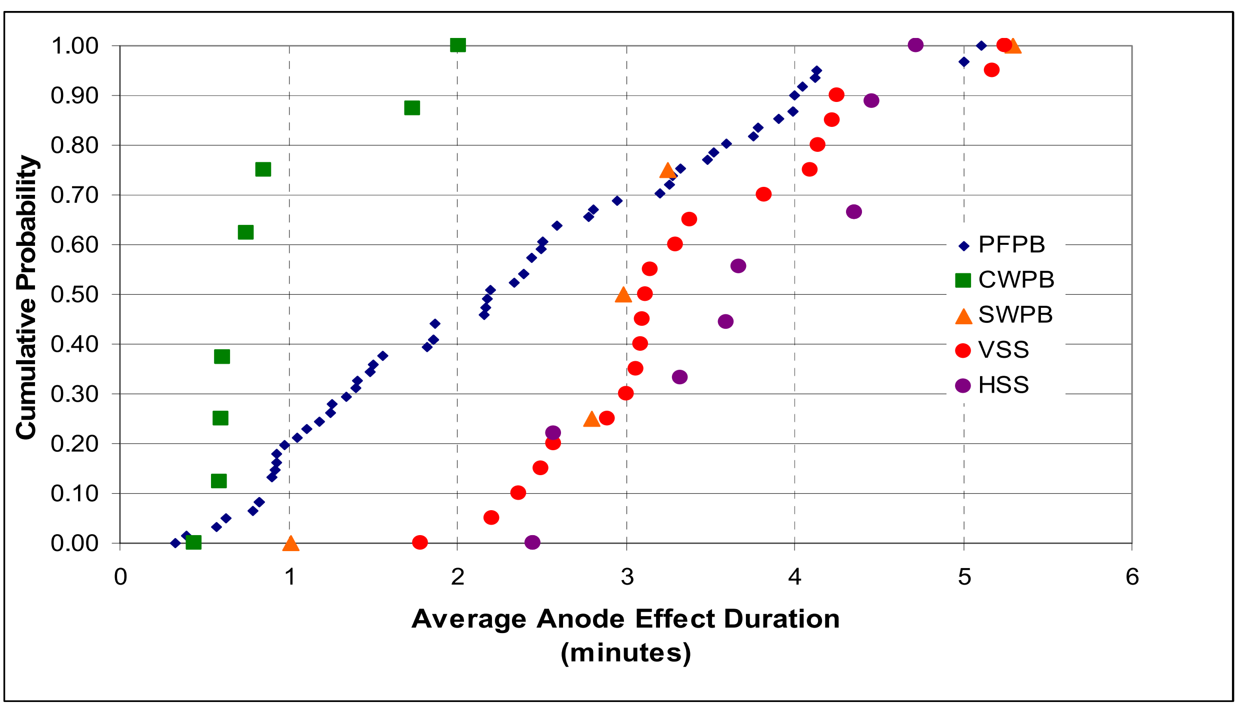


Figure 10 - Cumulative Probability Graph for Anode Effect Duration for Survey Participants by Technology Type

The shortest average anode effect durations are recorded for the bar broken CWPB cells. The distribution of duration for PFPB cells is next; and the range of average anode effect durations is similar for SWPB, VSS and HSS cells.

Figure 11 shows the cumulative probability graph for anode effect overvoltage for PFPB cells operating with AP-18 or AP-30 technology and SWPB cells operating with Aluminium Pechiney technology. The more modern PFPB cells show lower average overvoltage values than do the SWPB cells and with a much more narrow range.

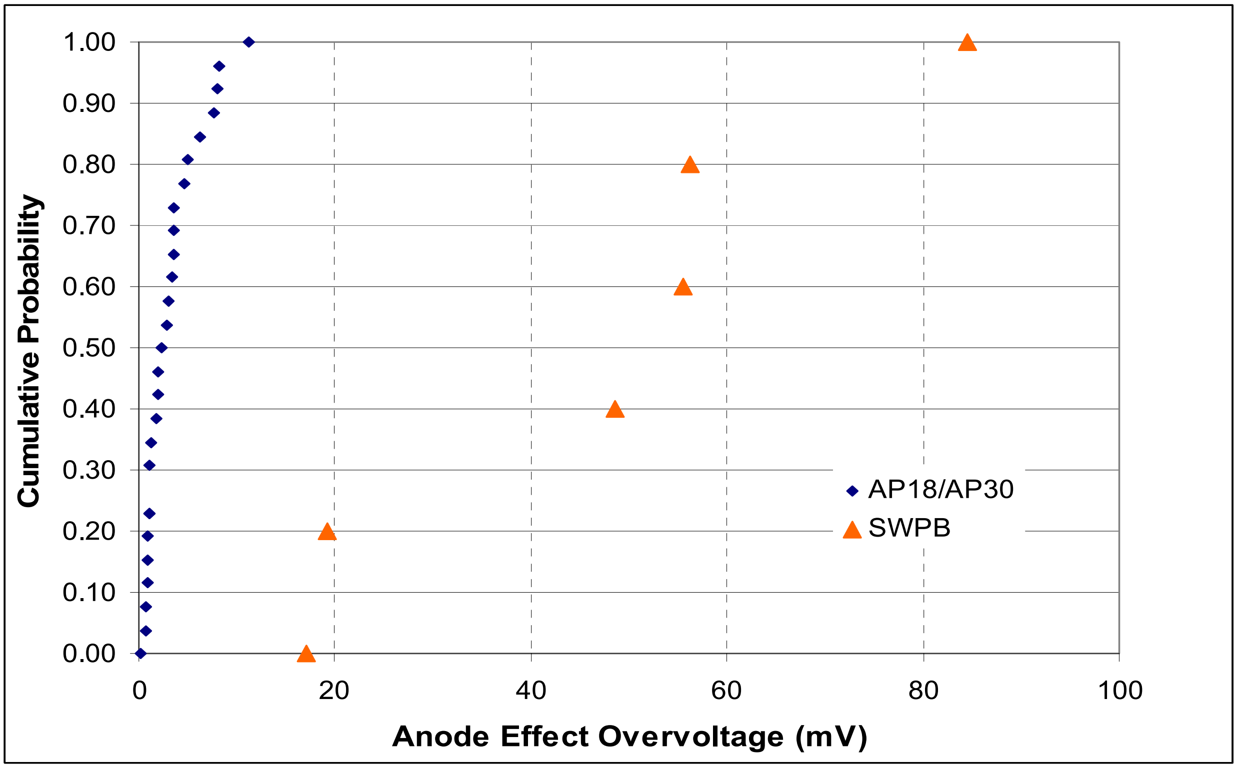


Figure 11 - Cumulative Probability Graph for Anode Effect Overvoltage for Survey Participants Operating with AP-18, AP-30 and Pechiney SWPB Technologies

5.0 Summary and Conclusions

The 2003 IAI anode effect performance survey results restored the trend of global PFC emissions reductions after a small rise in PFC emissions per tonne aluminium produced for survey participants in 2002. Combined PFC emissions for IAI survey participants were 1.09 t CO_2 equivalents/t Al. Projections of global PFC emissions per tonne aluminium produced based on applying the participants' median anode effect performance levels to non-participating production show an improvement to 1.26 t CO_2 equivalents/t Al. Calculation of total global emissions of PFCs to the atmosphere in 2003 from primary aluminium production showed the lowest emissions of PFCs to the atmosphere over the period of the study from 1990, 35.2 million tonnes CO_2 equivalents.

Consideration of uncertainty in calculations of PFC emissions shows that adopting revised IPCC Tier 2 coefficients should not greatly impact emissions calculations; however, further analysis is required to assess the impact of the revised Tier 2 coefficients covering anode effect data back to 1990 when the mix of technology was different. Additional PFC measurements are needed to reduce the uncertainty in the Tier 2 coefficients for technologies other than PFPB and CWPB. The largest source of uncertainty in calculating global PFC emissions is estimating PFC emissions performance from producers who do not participate in the survey. Additional survey participation will reduce this uncertainty.

There is still a considerable range of anode effect performance seen in the benchmark data for facilities operating with similar reduction technologies. This would indicate that there is still an excellent opportunity for making progress in reducing anode effects and the resulting PFC emissions through driving toward best work practices.

Survey participation, as measured by the percentage of global production reporting data, decreased in 2003 to 62% overall, due mainly to increases in production in China. Chinese producers do not currently participate in the IAI anode effect performance survey. The participation of Chinese and Russian producers is needed to reduce the uncertainty in projections of global emissions from primary aluminium production.

The return to reduced PFC emissions should not take industry's attention from the continued aggressive pursuit of anode effect reductions necessary to achieve the IAI Board's goal of an 80% reduction in PFC emissions by 2010 from the 1990 baseline.

Appendix I – 2003 Benchmark Data

A. PFPB Rankings

Data Point	Rank	t CO2-e/t Al	cum Prob	Data Point	Rank	AEF	cum Prob	Data Point	Rank	AED	cum Prob	Data Point	Rank	AEO	cum Prob
136	1	0.018	0.00	135	1	0.014	0.00	53	1	0.33	0.00	135	1	0.22	0.00
135	2	0.034	0.01	88	2	0.020	0.01	84	2	0.40	0.02	86	2	0.65	0.04
27	3	0.051	0.02	1	3	0.030	0.02	136	3	0.57	0.03	13	3	0.70	0.08
53	4	0.071	0.03	35	4	0.030	0.02	28	4	0.63	0.05	56	4	0.83	0.12
35	5	0.081	0.05	136	5	0.030	0.02	27	5	0.79	0.07	44	5	0.85	0.15
84	6	0.10	0.06	14	6	0.050	0.06	65	6	0.83	0.08	12	6	0.90	0.19
86	7	0.10	0.07	57	7	0.050	0.06	92	7	0.83	0.08	14	7	1.00	0.23
13	8	0.11	0.08	123	8	0.050	0.06	127	8	0.83	0.08	57	8	1.00	0.23
56	9	0.13	0.09	100	9	0.057	0.09	52	9	0.90	0.13	69	9	1.10	0.31
44	10	0.13	0.10	101	10	0.058	0.11	79	10	0.92	0.15	68	10	1.20	0.35
1	11	0.13	0.11	27	11	0.060	0.12	93	11	0.93	0.16	137	11	1.83	0.38
123	12	0.13	0.13	4	12	0.062	0.13	112	12	0.93	0.18	67	12	1.90	0.42
127	13	0.13	0.14	22	13	0.068	0.14	64	13	0.98	0.20	88	13	1.91	0.46
12	14	0.14	0.15	24	14	0.070	0.15	18	14	1.05	0.21	76	14	2.40	0.50
32	15	0.14	0.16	38	15	0.070	0.15	70	15	1.11	0.23	21	15	2.80	0.54
52	16	0.15	0.17	69	16	0.070	0.15	32	16	1.18	0.25	124	16	3.00	0.58
14	17	0.15	0.18	121	17	0.070	0.15	73	17	1.25	0.26	19	17	3.30	0.62
57	18	0.15	0.18	68	18	0.080	0.20	51	18	1.26	0.28	20	18	3.50	0.65
76	19	0.16	0.20	63	19	0.090	0.21	75	19	1.34	0.30	110	19	3.60	0.69
69	20	0.17	0.22	32	20	0.11	0.22	125	20	1.40	0.31	87	20	3.61	0.73
110	21	0.18	0.23	61	21	0.11	0.22	120	21	1.41	0.33	98	21	4.60	0.77
125	22	0.18	0.24	67	22	0.11	0.22	48	22	1.48	0.34	7	22	4.90	0.81
63	23	0.18	0.25	127	23	0.11	0.22	23	23	1.50	0.36	109	23	6.20	0.85
68	24	0.18	0.26	89	24	0.12	0.27	62	24	1.56	0.38	9	24	7.70	0.88
4	25	0.19	0.27	56	25	0.12	0.28	116	25	1.82	0.39	126	25	8.00	0.92
73	26	0.19	0.28	125	26	0.12	0.28	113	26	1.86	0.41	8	26	8.20	0.96
101	27	0.20	0.30	86	27	0.13	0.31	114	27	1.86	0.41	78	27	11.22	1.00
100	28	0.20	0.31	12	28	0.14	0.32	63	28	1.87	0.44				
28	29	0.22	0.32	13	29	0.14	0.32	91	29	2.16	0.46				
18	30	0.22	0.33	37	30	0.14	0.32	115	30	2.17	0.48				
124	31	0.23	0.34	73	31	0.14	0.32	99	31	2.18	0.49				
75	32	0.23	0.35	77	32	0.14	0.32	132	32	2.20	0.51				
92	33	0.23	0.36	118	33	0.14	0.32	130	33	2.34	0.52				
38	34	0.25	0.38	52	34	0.15	0.39	47	34	2.39	0.54				
79	35	0.26	0.39	87	35	0.15	0.40	129	35	2.39	0.54				
121	36	0.27	0.40	7	36	0.16	0.41	134	36	2.44	0.57				
65	37	0.27	0.41	75	37	0.16	0.41	35	37	2.50	0.59				
24	38	0.27	0.42	30	38	0.18	0.44	37	38	2.51	0.61				
137	39	0.28	0.43	18	39	0.20	0.45	131	39	2.51	0.61				
67	40	0.29	0.44	90	40	0.20	0.46	82	40	2.60	0.64				
88	41	0.29	0.45	53	41	0.20	0.47	128	41	2.78	0.66				
109	42	0.30	0.47	9	42	0.21	0.48	4	42	2.81	0.67				
51	43	0.37	0.48	76	43	0.21	0.48	30	43	2.95	0.69				
22	44	0.37	0.49	82	44	0.21	0.48	101	44	3.20	0.70				
37	45	0.38	0.50	99	45	0.21	0.48	100	45	3.26	0.72				
64	46	0.41	0.51	74	46	0.22	0.53	77	46	3.28	0.74				
120	47	0.44	0.52	109	47	0.22	0.53	38	47	3.32	0.75				
62	48	0.45	0.53	124	48	0.22	0.53	123	48	3.48	0.77				
61	49	0.46	0.55	84	49	0.24	0.56	121	49	3.52	0.79				
99	50	0.49	0.56	8	50	0.26	0.58	24	50	3.60	0.80				
77	51	0.49	0.57	92	51	0.26	0.58	31	51	3.76	0.82				
89	52	0.50	0.58	110	52	0.26	0.58	10	52	3.78	0.84				
87	53	0.55	0.59	79	53	0.27	0.61	61	53	3.91	0.85				
30	54	0.57	0.60	62	54	0.27	0.62	89	54	3.99	0.87				
21	55	0.57	0.61	51	55	0.27	0.64	90	55	3.99	0.87				
82	56	0.59	0.63	10	56	0.29	0.65	118	56	4.00	0.90				
48	57	0.59	0.64	120	57	0.29	0.65	1	57	4.05	0.92				
118	58	0.60	0.65	21	58	0.30	0.67	111	58	4.12	0.93				
112	59	0.62	0.66	65	59	0.30	0.67	74	59	4.13	0.95				
19	60	0.67	0.67	126	60	0.30	0.69	71	60	5.00	0.97				

A. PFPB Rankings (continued)

Data Point	Rank	t CO_2-e/t Al	cum Prob	Data Point	Rank	AEF	cum Prob	Data Point	Rank	AED	cum Prob	Data Point	Rank	AEO	cum Prob
98	61	0.71	0.68	28	61	0.32	0.71	72	61	5.00	0.97				
20	62	0.71	0.69	91	62	0.34	0.72	22	62	5.11	1.00				
7	63	0.75	0.70	78	63	0.35	0.73								
70	64	0.76	0.72	19	64	0.36	0.74								
93	65	0.82	0.73	20	65	0.37	0.75								
90	66	0.84	0.74	48	66	0.37	0.75								
23	67	0.88	0.75	111	67	0.37	0.75								
91	68	0.91	0.76	64	68	0.39	0.79								
74	69	0.98	0.77	132	69	0.45	0.80								
132	70	1.05	0.78	131	70	0.45	0.81								
113	71	1.08	0.80	128	71	0.46	0.82								
114	72	1.14	0.81	130	72	0.48	0.84								
10	73	1.18	0.82	47	73	0.49	0.85								
9	74	1.18	0.83	129	74	0.50	0.86								
130	75	1.22	0.84	71	75	0.54	0.87								
131	76	1.22	0.85	113	76	0.54	0.87								
126	77	1.23	0.86	23	77	0.54	0.89								
47	78	1.26	0.88	114	78	0.57	0.91								
8	79	1.26	0.89	31	79	0.60	0.92								
129	80	1.29	0.90	112	80	0.62	0.93								
128	81	1.37	0.91	70	81	0.63	0.94								
116	82	1.47	0.92	72	82	0.69	0.95								
111	83	1.64	0.93	116	83	0.75	0.96								
78	84	1.72	0.94	93	84	0.82	0.98								
115	85	2.03	0.95	115	85	0.87	0.99								
31	86	2.41	0.97	134	86	0.99	1.00								
134	87	2.60	0.98												
71	88	2.90	0.99												
72	89	3.71	1.00												

B. CWPB Rankings

Data Point	Rank	t CO_2-e/t Al	cum Prob	Data Point	Rank	AEF	cum Prob	Data Point	Rank	AED	cum Prob
16	1	0.215	0.00	16	1	0.25	0.11	36	1	0.44	0.00
17	2	0.233	0.13	17	2	0.24	0.00	41	2	0.59	0.13
36	3	0.279	0.25	36	3	0.59	0.33	40	3	0.6	0.25
43	4	0.786	0.38	43	4	1.15	0.56	42	4	0.61	0.38
2	5	0.810	0.50	2	5	0.42	0.22	43	5	0.61	0.38
41	6	0.886	0.63	41	6	1.3	0.89	16	6	0.75	0.63
40	7	0.894	0.75	40	7	1.29	0.67	17	7	0.85	0.75
42	8	0.909	0.88	42	8	1.29	0.67	2	8	1.74	0.88
29	9	2.421	1.00	29	9	1.12	0.44	29	9	2.01	1.00
				38	10	1.4	1.00				

C. SWPB Rankings

Data Point	Rank	t CO2-e/t Al	cum Prob
55	1	2.83	0.00
106	2	4.63	0.10
107	3	5.20	0.20
54	4	5.53	0.30
119	5	6.17	0.40
50	6	7.43	0.50
39	7	8.50	0.60
108	8	8.62	0.70
80	9	11.48	0.80
133	10	13.12	0.90
95	11	24.50	1.00

Data Point	Rank	AEF	cum Prob
55	1	0.47	0.00
106	2	0.69	0.09
54	3	0.86	0.18
107	4	0.98	0.27
133	5	1.15	0.36
83	6	1.265	0.45
80	7	1.64	0.55
108	8	1.82	0.64
39	9	2.69	0.73
119	10	2.823	0.82
50	11	4.16	0.91
95	12	4.46	1.00

Data Point	Rank	AED	cum Prob
119	1	1.015	0.00
55	2	2.8	0.25
54	3	2.99	0.50
80	4	3.253	0.75
133	5	5.3	1.00

Data Point	Rank	AEO	cum Prob
106	1	17.1	0.00
107	2	19.2	0.20
50	3	48.5	0.40
39	4	55.5	0.60
108	5	56.27	0.80
95	6	84.5	1.00

D. VSS Rankings

Data Point	Rank	t CO2-e/t Al	cum Prob
45	1	0.15	0.00
83	2	0.57	0.05
94	3	0.71	0.10
3	4	0.87	0.15
103	5	0.95	0.20
34	6	1.09	0.25
102	7	1.29	0.30
59	8	1.29	0.35
60	9	1.33	0.40
117	10	1.36	0.45
55	11	1.52	0.50
58	12	2.00	0.55
49	13	2.43	0.60
45	14	2.50	0.65
105	15	2.51	0.70
26	16	3.07	0.75
25	17	3.09	0.80
104	18	3.35	0.85
122	19	3.83	0.90
15	20	4.57	0.95
33	21	4.93	1.00

Data Point	Rank	AEF	cum Prob
45	1	0.13	0.00
83	2	0.517	0.05
94	3	0.526	0.10
102	4	0.53	0.15
34	5	0.75	0.20
117	6	0.76	0.25
59	7	0.9	0.30
60	8	0.9	0.30
103	9	0.92	0.40
55	10	0.98	0.45
105	11	1.02	0.50
3	12	1.04	0.55
58	13	1.04	0.55
26	14	1.54	0.65
45	15	1.576	0.70
25	16	1.59	0.75
49	17	2.01	0.80
15	18	2.3	0.85
104	19	2.3	0.85
122	20	2.621	0.95
33	21	3.5	1.00

Data Point	Rank	AED	cum Prob
3	1	1.78	0.00
103	2	2.21	0.05
83	3	2.362	0.10
45	4	2.5	0.15
49	5	2.57	0.20
94	6	2.888	0.25
33	7	3	0.30
59	8	3.06	0.35
34	9	3.09	0.40
104	10	3.1	0.45
122	11	3.115	0.50
60	12	3.15	0.55
55	13	3.3	0.60
45	14	3.38	0.65
117	15	3.82	0.70
58	16	4.09	0.75
25	17	4.14	0.80
15	18	4.23	0.85
26	19	4.25	0.90
102	20	5.17	0.95
105	21	5.25	1.00

E. HSS Rankings

Data Point	Rank	t CO2-e/t Al	cum Prob
84	1	1.31	0.00
66	2	1.72	0.11
11	3	2.16	0.22
97	4	2.26	0.33
85	5	3.65	0.44
81	6	4.89	0.56
46	7	5.55	0.67
96	8	6.42	0.78
6	9	7.51	0.89
5	10	9.20	1.00

Data Point	Rank	AEF	cum Prob
84	1	0.4	0.00
66	2	0.5	0.11
97	3	0.51	0.22
11	4	0.66	0.33
85	5	0.76	0.44
81	6	0.82	0.56
46	7	0.88	0.67
6	8	1.29	0.78
96	9	1.31	0.89
5	10	1.58	1.00

Data Point	Rank	AED	cum Prob
11	1	2.45	0.00
84	2	2.45	0.00
66	3	2.57	0.22
97	4	3.32	0.33
85	5	3.60	0.44
96	6	3.67	0.56
5	7	4.36	0.67
6	8	4.36	0.67
81	9	4.46	0.89
46	10	4.72	1.00