Australian Government

International Aluminium Institute

Aluminium Measuring & Benchmarking 2009

A report prepared for the Australian Government as part of the Asia Pacific Partnership on Clean Development & Climate Aluminium Task Force

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The International Aluminium Institute has prepared this report as part of a three year project to collect and publish benchmarking data, for which it received funding from the Australian Government as part of the Asia-Pacific Partnership on Clean Development and Climate.

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In 2009 Asia Pacific Partnership country producers represent almost 60% of global aluminium production (compared to less than 45% in 1990), a function of exponential growth in the size of the Chinese industry. In terms of its technological makeup, the growth of China and phasing out of some older facilities in other APP regions, means that the majority of APP facilities are centre work/point fed prebake (the most modern of the aluminium producing technologies, usually at the better end of the performance curves).

The International Aluminium Institute's annual benchmarking data collection and reporting system is one of the most well developed of any industry and has one of the best production coverages (representing between 45% and 80% of production per indicator). For Asia Pacific Partnership members this translates as almost, if not complete, 100% coverage of facilities in Australia, Canada, Japan & Korea and the United States of America, reasonable coverage (30-80%) of the Indian industry and limited (< 5%) of the Chinese industry.

Per tonne of production, the benchmarking data in this report shows APP average (production weighted mean and/or median) performance equivalent to that of the rest of the world. However, the lack of reporting by the modern Chinese industry means that these averages are likely to be underestimating the performance of the complete APP cohort. That is to say that the inclusion of Chinese data might well improve the global energy consumption and greenhouse gas emissions averages and, to an even greater extent, the APP average performance. Such data would also add significantly to the certainty in global greenhouse gas estimations and the credibility of the IAI and APP datasets.

Through such initiatives as the Asia Pacific Partnership on Clean Development & Climate, the IAI is striving both to increase Chinese industry participation in its surveys and to improve its understanding of the environmental profile of the Chinese industry.

Against all of the sustainability metrics included in this report, considerable ranges in performance continue to be reported in the benchmark data (at both global and APP scales). This indicates that the opportunity remains to make further progress in performance from a greater achievement of industry best practice.

Through the Institute's programme of voluntary objective setting, annual performance measurement and benchmarking and the sharing of best practices, the global aluminium industry is continuously striving to improve the sustainability of its operations and products.

Primary Aluminium Production Trends

The year 2009 saw the first fall in global aluminium production for well over a decade, a function of the global financial crisis causing decreased demand from the building & construction and transport sectors, the two largest markets for primary aluminium products. Curtailments in production have been experienced across the industry, with facility closures occurring among older technologies which were already facing diminishing access to competitively priced power or pressure from other external factors.

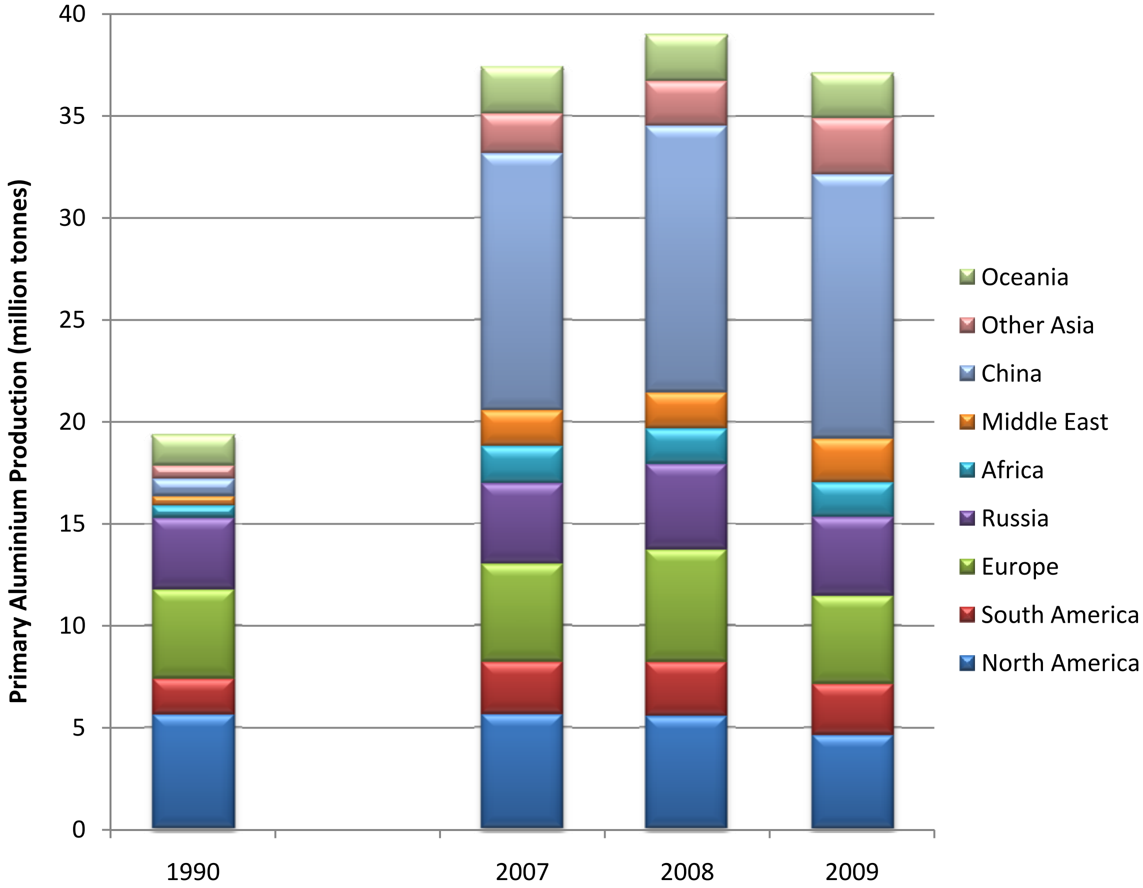


Figure 1 – Geographical location of primary aluminium production, 1990 & 2007-2009 (SOURCE: IAI)

With newer, more cost competitive smelters located in emerging areas of production, such as the Arabian Gulf and Iceland, and with Chinese smelters supplying a domestic (building) market that has not felt the shock of the global financial crisis as keenly as other regions, the effect of curtailments in production are not uniform across the globe. In fact, the pattern of recent years, of the industry shifting away from traditional centres of production, through development of new, efficient, low emitting capacity in new regions, was continued and accelerated in 2009.

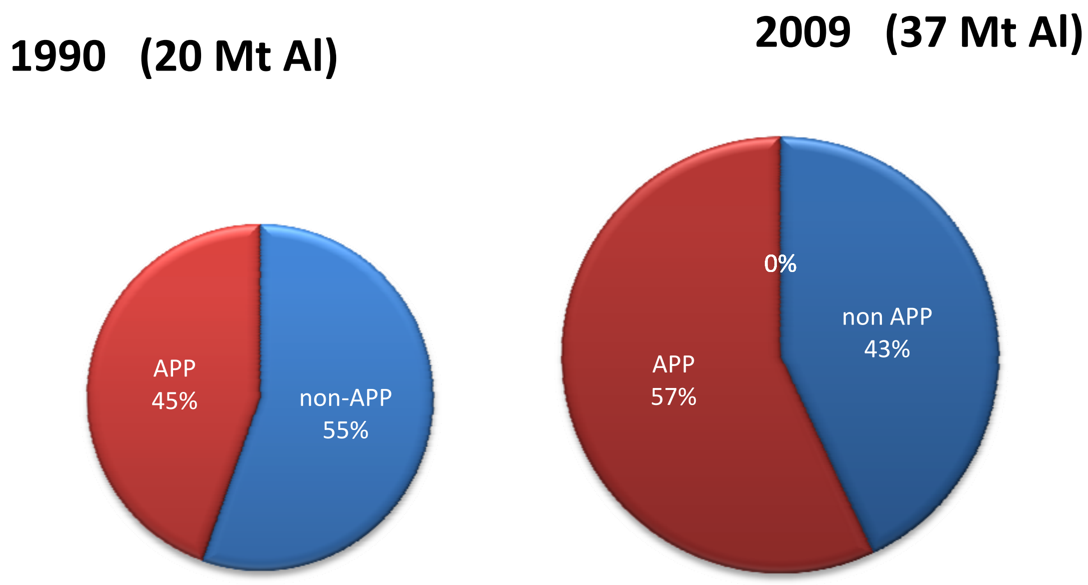


Figure 2 – APP/non-APP member state location of primary aluminium production, 1990 & 2009

New smelting capacity generally utilises best available technology, pushing performance benchmarks (including greenhouse gas emissions) steadily higher, while increasing the sector's ability to meet demand for metal. Thus the new centres of production generally have more modern facilities with the potential for higher efficiencies and lower emissions.

Surveys conducted by the Institute separate aluminium smelting technologies into four or five categories, reflecting types of anode utilised and alumina feed configuration, both influential factors in the PFC emissions outcome; these are outlined below. PFPB is a subset of CWPB and in some instances the CWPB category alone is used, or even a split by prebake and Søderberg technologies, in order to protect individual facilities' data.

TECHNOLOGY CATEGORY	ACRONYM	ANODE TYPE/ CONFIGURATION	ALUMINA FEED CONFIGURATION
Centre Worked Prebake	CWPB	Pre-baked/ Vertical	Bar broken centre feed
Point Fed Prebake	PFPB	Pre-baked/ Vertical	Point centre feed
Side Worked Prebake	SWPB	Pre-baked/ Vertical	Manual side feed
Vertical Stud Søderberg	VSS	Baked in-situ/ Vertical	– Manual side feed – Point feed
Horizontal Stud Søderberg	HSS	Baked in-situ/ Horizontal	– Manual side feed – Bar broken feed – Point feed

Table 1 – Aluminium smelting technologies

The separation of industry production into these cohorts allows for:

- Calculation of PFC emissions inventories using the more accurate IPCC Tier 2 methodology;
- More realistic estimates of performance of non-reporters, based on the performance of reporting facilities within cohorts (technology averages), as opposed to "industry averages";
- More useful benchmarking information, allowing facilities, corporations and external stakeholders to judge realistic potentials for improvements in performance by technology;
- Quantification of improvements in performance through investment in retro-fitting, new capacity and soft technology (e.g. control algorithms, operator training, etc);
- The development of technology-specific solutions for improving anode effect performance at the corporate level or through programmes such as that of the APP.

The doubling of primary aluminium production since 1990 is largely due to investments in new capacity, employing the best available, most energy efficient and lowest PFC emitting PFPB technology (up 400% from 1990), along with production creep in existing capacity and the phasing out of older VSS, HSS and SWPB technologies (down 20%, 75% and 80% respectively).

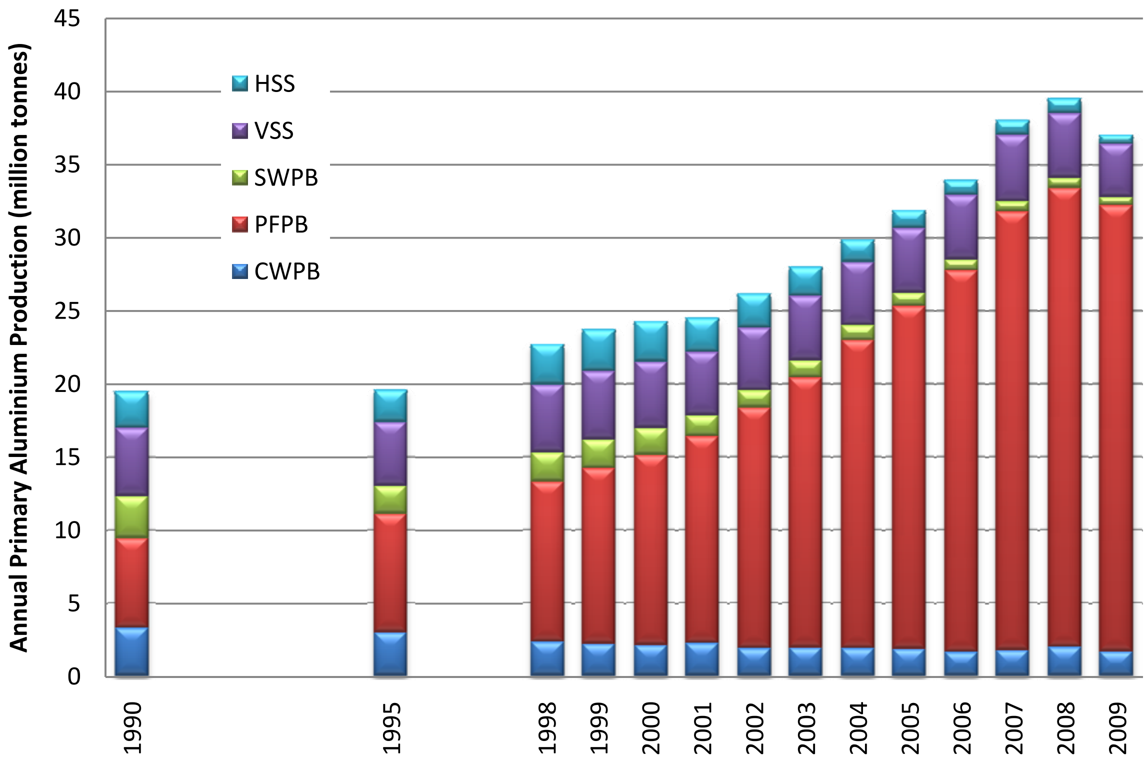


Figure 3 - Changes in aluminium smelting technology mix, 1990-2009

The change in the technology profile of the global aluminium industry over the past two decades is the single most important driver behind the industry's improvement in its anode effect and thus its perfluorocarbon emissions performance. The relative PFC emissions performance of the technologies is such that, while PFPB makes up over three quarters of production capacity worldwide, emissions from its facilities represent less than half of the global industry's PFC emissions inventory. Thus the relative increase in production share by PFPB from 32% in 1990 to 83% in 2009 has seen specific emissions (per unit production) fall by almost 90% in the same period and absolute emissions (total PFC emissions to the atmosphere from aluminium smelters worldwide) driven down by over 75%.

In fact, the reduction in absolute PFC emissions has offset the impact of rising production on other direct GHG emissions sources from bauxite mining, alumina refining and aluminium smelting processes, such as CO2 from carbon anode consumption and fuel combustion emissions from furnaces and boilers.

Absolute direct greenhouse gas emissions from all primary aluminium and upstream production processes (bauxite mining, alumina refining, aluminium smelting & casting) remain at 1990 levels, even though production has doubled over the same period.

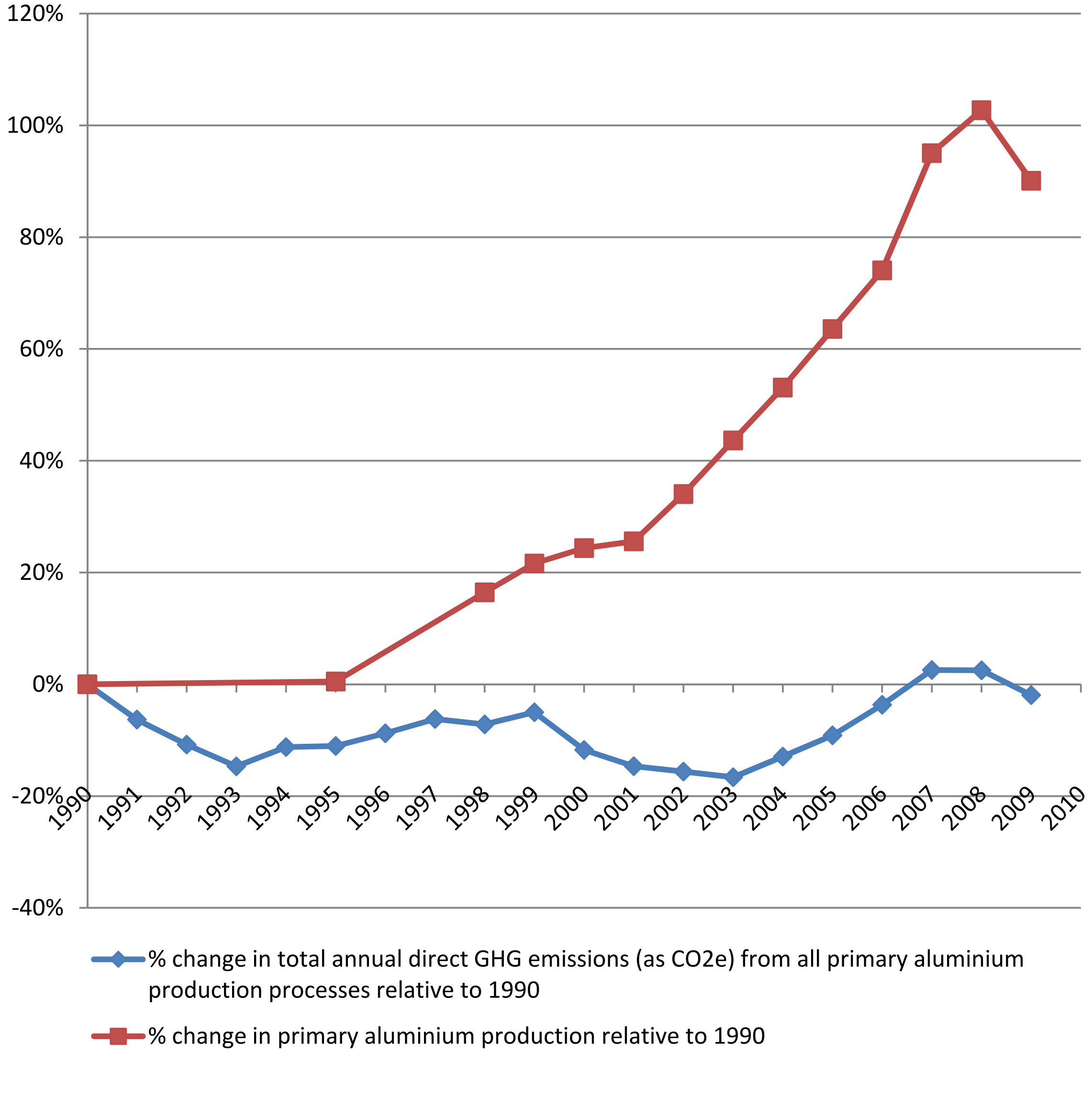


Figure 4 – Percentage change in primary aluminium production and total direct greenhouse gas emissions (including PFCs) from aluminium and upstream production processes, 1990-2009, relative to 1990

Perfluorocarbon Emissions (Anode Effect Survey)

NOTE:

The data in this section should be interpreted in conjunction with the IAI's *2009 Anode Effect Survey Report* – the report of the global industry's PFC emissions performance, available from http://www.world-aluminium.org/Downloads/Publications/Download.

Perfluorocarbons, or PFCs, are a group of potent greenhouse gases with long atmospheric lifetimes (in the thousands of years), of which the greatest volume is emitted from industrial processes. PFCs are occasionally produced in the primary aluminium electrochemical smelting process during events known as "anode effects".

An anode effect is a process upset condition where an insufficient amount of alumina (Al_2O_3), the raw material for primary aluminium production, is dissolved in the electrolyte bath, contained in the electrolytic cells (or pots) within a smelter reduction line (potline), causing voltage to be elevated above the normal operating range and resulting in the emission of gases containing the PFCs tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6).

The International Aluminium Institute has been tracking PFC emissions for some years and the industry has worked hard to improve its emissions performance, such that per tonne PFC emissions are almost 90% less than they were in 1990, with total PFC emissions to the atmosphere reduced by over 75% over the same period, despite a 90% increase in primary aluminium production, from 19.5 to 37 million tonnes..

Survey Participation

Participants in the 2009 Anode Effect Survey account for 60% of global primary metal production and 60% of PFC emissions, but there continues to be low participation from Chinese producers. China is the single largest primary aluminium producing country (and the largest consumer) and also one of the fastest growing, employing modern PFPB technology in all of its 90+ smelters. Outside of China, participation has for a number of years remained around the 90% mark, but as China continues to make up a larger share of global production, the total survey participation rate falls annually.

While 2009 reporting by China is at 1.5% by production, recent surveys have seen a significant increase in reporting by Chinese smelters (from <1% in 2006 to 8% in 2008) and an improved understanding of the technological and emissions profile of the Chinese industry. However, the critical issue for the global industry is even greater participation from Chinese facilities in the IAI's annual surveys, in order to build confidence in its reported PFC results.

Outside of China, participation has increased to over 90%; the inclusion of all Russian smelter data from 2007 onwards means that today only 20 non-China smelters, representing around 2 million tonnes of production (equivalent to 6% of worldwide production), remain outside of the IAI survey process. The almost complete coverage of the IAI survey data outside China (with respect to both metal production and emissions), combined with the fact that the IAI uses actual measurements and secondary information to make an informed estimate of Chinese industry performance, positions the aluminium industry inventory (accounting for the total global industry) very favourably compared to the greenhouse gas inventories of other commodities.

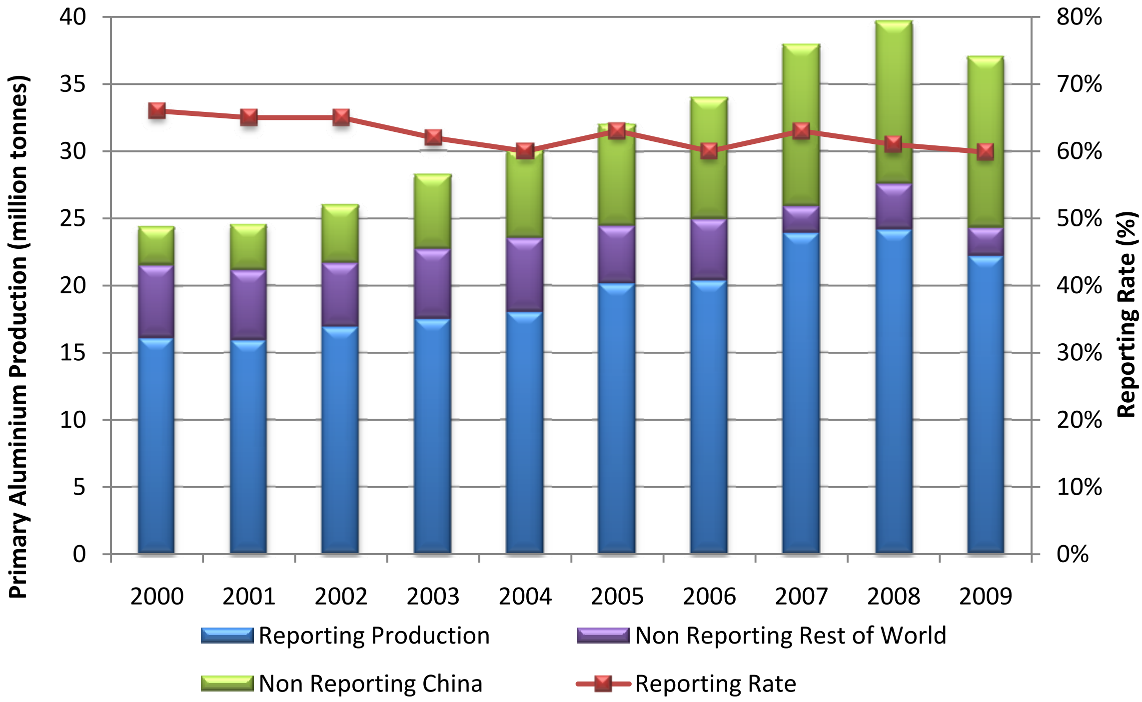


Figure 5 – Primary aluminium production reporting in Anode Effect Survey and global reporting rate, 2000-2009

It is significant that the 2009 Survey results include data representing production from 100% of SWPB, 99% of VSS and 90% of HSS technology categories. On average, these technologies produce more emissions per tonne of aluminium production than the CWPB and PFPB categories.

TECHNOLOGY	2009 PRIMARY ALUMINIUM PRODUCTION ('000 TONNES)	2009 PRODUCTION REPRESENTED IN SURVEY ('000 TONNES)	2009 PARTICIPATION RATE BY PRODUCTION	
CWPB	1,637	998	61 %	
PFPB (Rest of World)	17,644	16,293	92 %	54 %
PFPB (China)	12,964	195	1.5 %	
SWPB	550	550	100 %	
VSS	3,653	3,603	99 %	
HSS	605	545	90 %	
All Technologies (excluding China)	24,090	21,990	91 %	
All Technologies (Including China)	37,054	22,184	**60 %**	

Table 2 - 2009 Anode Effect Survey participation by technology with respect to global aluminium production

Note: any inconsistencies due to rounding

TECHNOLOGY	2009 APP PRIMARY ALUMINIUM PRODUCTION ('000 TONNES)	2009 APP PARTICIPATION RATE BY PRODUCTION	2008 APP PRIMARY ALUMINIUM PRODUCTION ('000 TONNES)	2008 APP PARTICIPATION RATE BY PRODUCTION
CWPB	425	46 %	600	71 %
PFPB	19,700	33 %	20,000	36 %
SWPB	350	100 %	400	100 %
VSS	375	87 %	600	77 %
HSS	165	100 %	300	93 %
All Technologies	**21,000**	**36 %**	22,000	41 %

Table 3 – Anode Effect Survey 2009 & 2008 APP participation rate by technology

Note: any inconsistencies due to rounding

COUNTRY	2009 PRIMARY ALUMINIUM PRODUCTION ('000 TONNES)	2009 APP PARTICIPATION RATE BY PRODUCTION	2008 APP PRIMARY ALUMINIUM PRODUCTION ('000 TONNES)	2008 APP PARTICIPATION RATE BY PRODUCTION
Australia	2,000	100 %	2,000	100 %
Canada	3,000	100 %	3,000	100 %
China	13,000	1.5 %	13,000	8 %
India	1,500	66 %	1,250	29 %
Japan & Korea	< 10	100 %	< 10	100 %
United States	1,500	84 %	3,000	84 %
APP Total	**21,000**	**36 %**	22,000	41 %

Table 4 – Anode Effect Survey 2009 & 2008 APP participation rate by country

Note: any inconsistencies due to rounding

The biggest gap in the dataset is the 99% of missing Chinese industry data. Recent years have seen a significant increase in reporting by Chinese smelters (from <1% in 2006 to 8% in 2008) and a much better understanding of the technological and emissions profile of the Chinese industry, but the critical issue for the industry in maintaining the credibility of its PFC emissions reporting, accurately calculating its emissions inventory and building confidence in results is even greater participation from Chinese facilities in the IAI's annual surveys.

Calculation of Global PFC Emissions

Using the data reported in the Survey, the IAI develops and reports annually an estimate of global PFC emissions from the whole industry, both Survey respondents and non-reporters. This global indicator is the metric upon which the industry judges its performance against the industry's voluntary objective for reduction in specific emissions of PFCs (see below). Thus the IAI member companies (which represent around 80% of global production) are taking a leadership position, and driving improvement through an objective that covers 100% of the industry:

The International Aluminium Institute PFC Emissions Reduction Voluntary Objective (2006-2020)

- *The primary aluminium industry seeks to achieve the long term elimination of perfluorocarbon (PFC) emissions.*
- *Following an 86% reduction in PFC emissions per tonne of primary aluminium produced between 1990 and 2006, the global aluminium industry will further reduce emissions of PFCs per tonne of aluminium by at least 50% by 2020 as compared to 2006.*
- *Coverage of the annual survey of PFC emissions from IAI member and non-member aluminium producers has almost doubled from a global aluminium production of 12 Mt in 1990 to 22 Mt (60% of the industry's production) in 2009. The IAI is striving to increase the global aluminium production coverage of its annual Surveys to over 80%.*
- *Based on IAI annual survey results, by 2020 IAI member companies commit to operate with PFC emissions per tonne of production no higher than the 2006 global median level for their technology type.*
- *Progress will be monitored and reported annually and reviewed periodically by a recognised and independent third party. There will be interim reviews to ensure progress towards achievement of the 2020 objective.*

In 2009, the global industry PFC emissions performance was 0.59 t CO2e/t Al, equivalent to absolute emissions of 22 million tonnes of CO_2e. These data are shown below as part of a time series against a 2006 baseline.

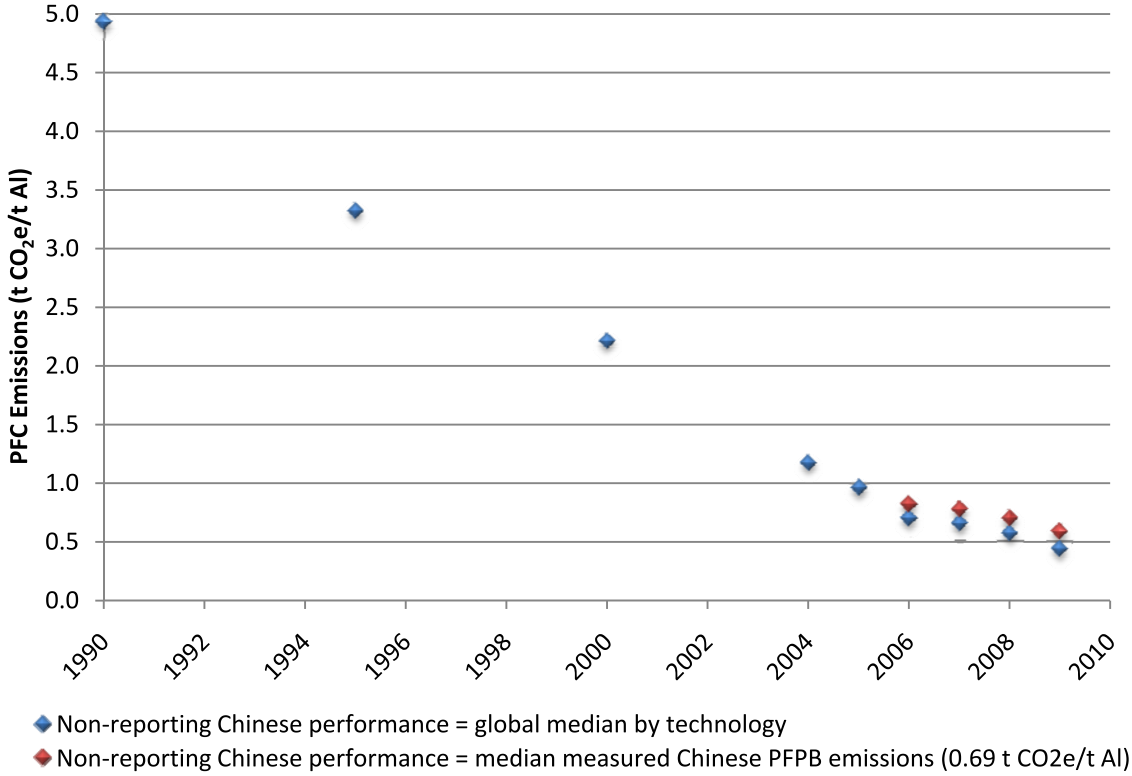


Figure 6 - Specific PFC emissions (t CO_2e/t Al) reduction, 1990-2009

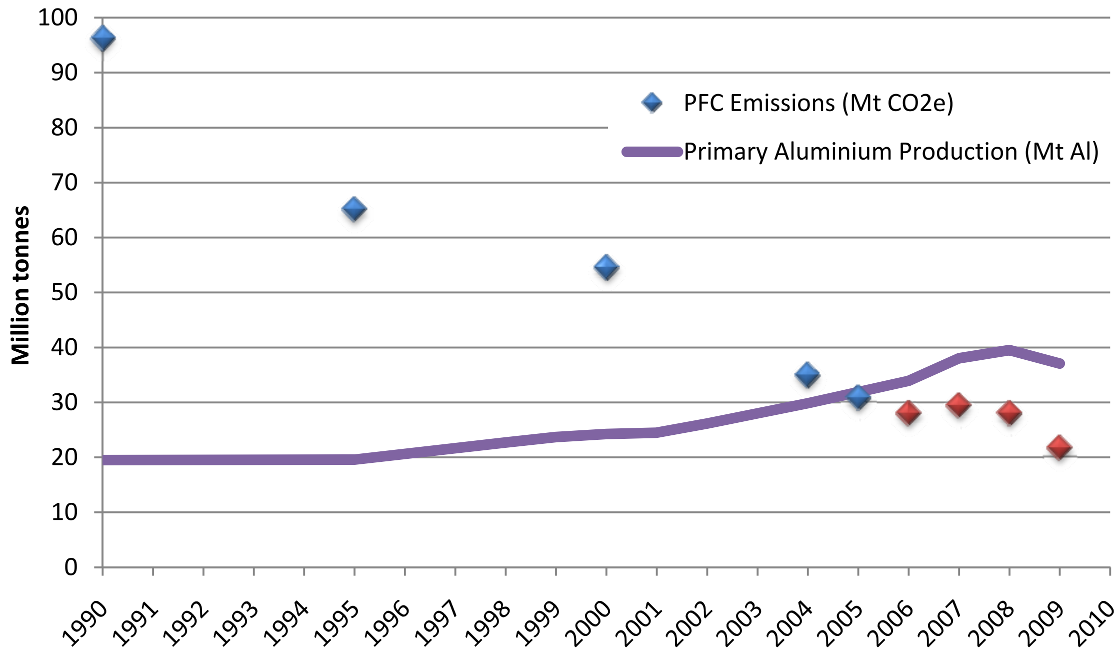


Figure 7 - Absolute PFC emissions (t CO_2e/annum) reduction, 1990-2009

Calculation of APP PFC Emissions

Using the same methodology as employed for the global dataset (applying median technology performance to non reporters - for reference see the 2009 Anode Effect Survey Report), APP member emissions are calculated to be:

$$0.65 \text{ t } CO_2\text{e/t Al}$$ (Compared to 0.69 t CO_2e/t Al in 2008).

This is equivalent to an absolute emission figure of 14 million tonnes of CO_2e (or 62% of global PFC emissions), compared to 15 million tonnes (54% of global) in 2008, of which only 4 million tonnes are represented in the data (due to poor Chinese reporting). The non-represented data (representing almost 10 million tonnes CO_2e is estimated, based on survey returns and (for China) on the outcome of the APP Project: Management of PFC Emissions, which indicated Chinese median emission performance to be 0.69 t CO_2e/t Al.

2009 Benchmark Data

The IAI Anode Effect Survey provides valuable benchmark information to respondents, allowing producers to judge their performance relative to others operating with similar technology. The anode effect benchmark data for PFC emissions per tonne of production are presented in this section in the form of cumulative probability and cumulative production graphs by technology. Performance of APP member country facilities are indicated on cumulative production graph. For further benchmark data (on other anode effect parameters and by technology)[1] please see the 2009 Anode Effect Report.

[1] APP plants' performance are not indicated on technology specific graphs in order to avoid the possibility of identification of plant identity from production levels in cohorts with few APP facilities (i.e. SWPB and Søderberg).

Global PFC Performance by Cumulative Probability

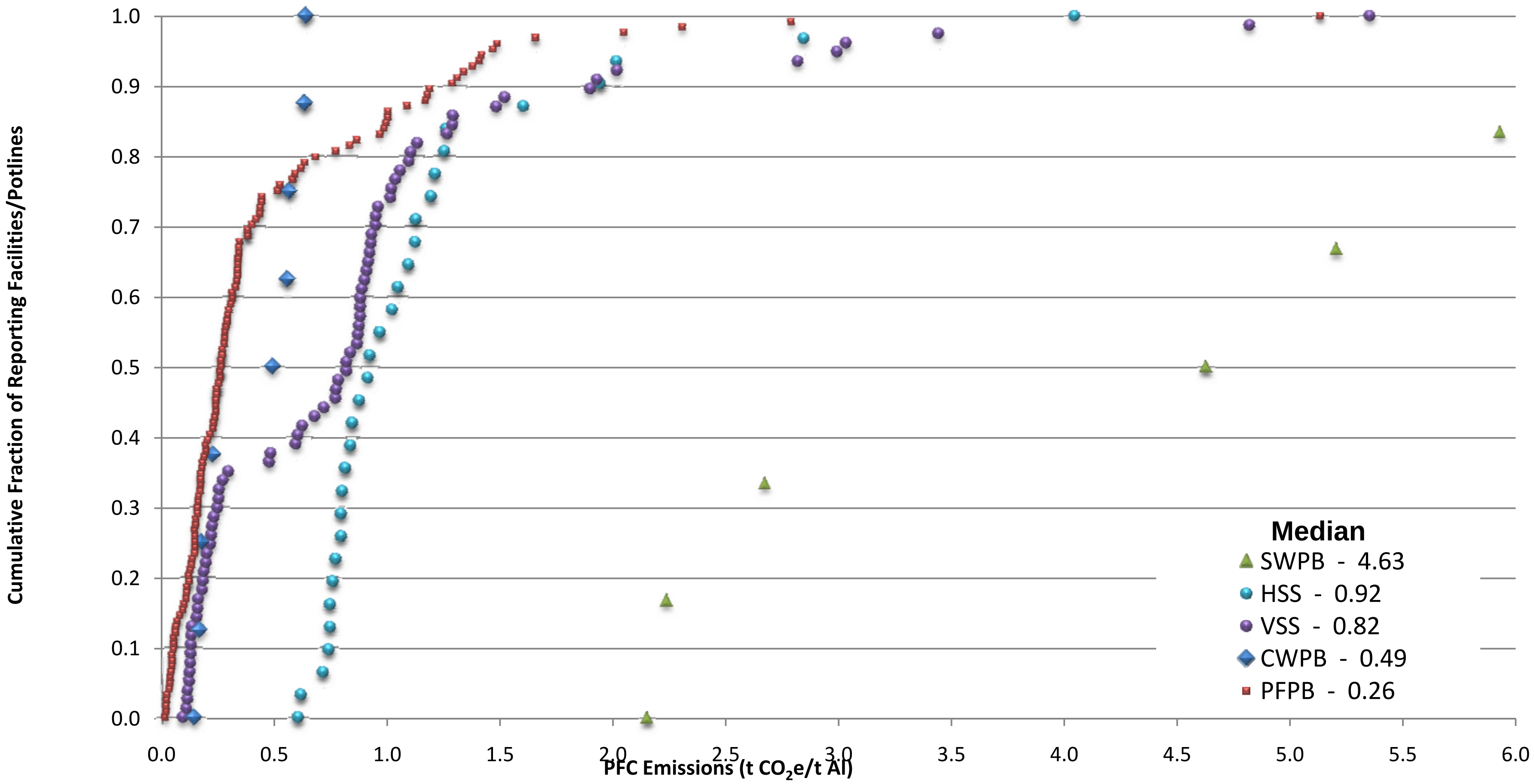


Figure 8 - Specific PFC emissions performance of reporters, benchmarked as cumulative fraction within technologies

Note: SWPB 100th percentile outlier at 23.5 t CO2e/t Al

APP PFC Emissions Benchmarking (All Technologies) by Cumulative Production

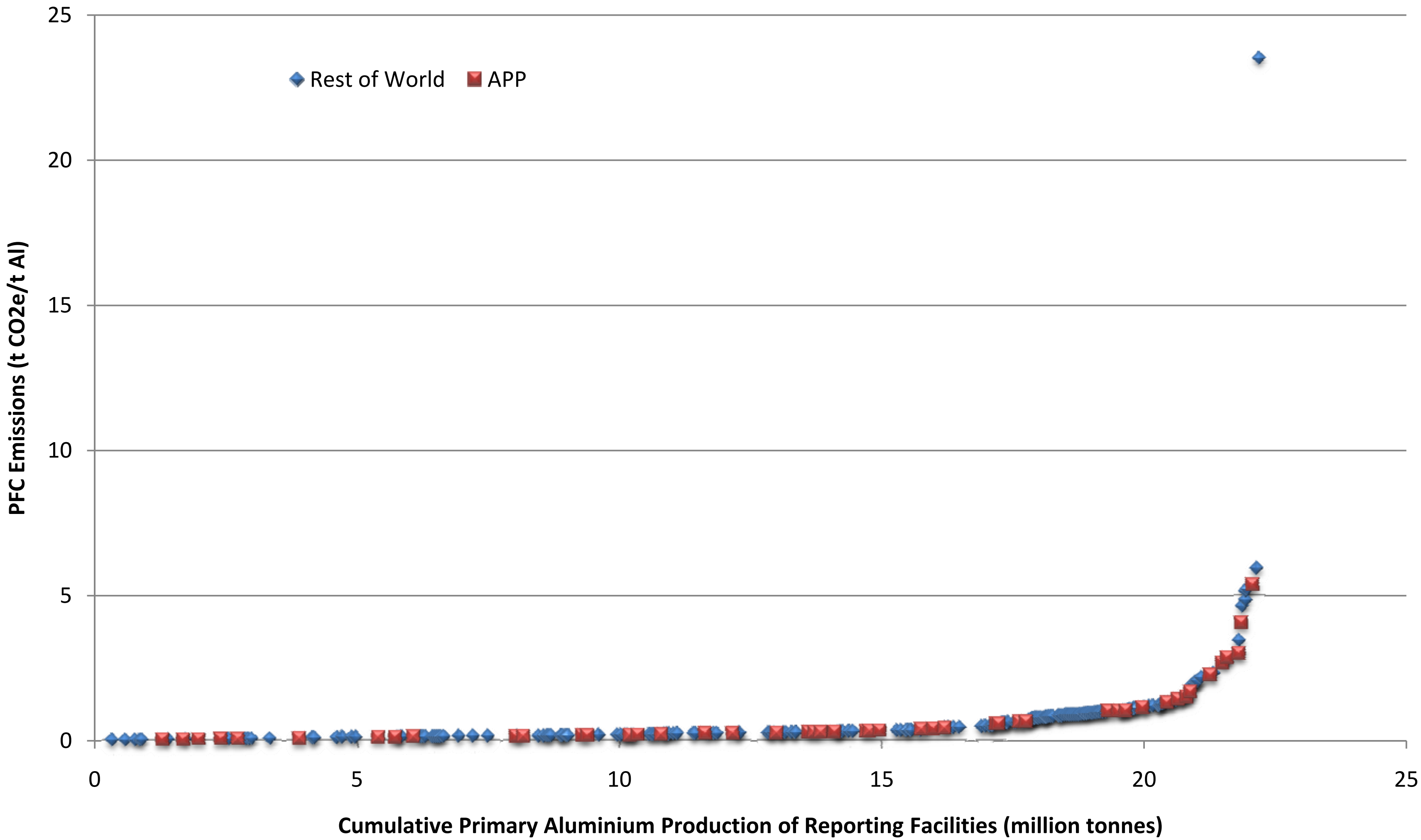


Figure 9 - Specific PFC emissions performance of reporters, benchmarked as cumulative production within technologies

Sustainable Development Indicators (SDI) Survey

NOTE:

The data in this section should be interpreted in conjunction with the IAI's *2009 Sustainability Update* – the report of the global industry's PFC emissions performance, available from http://www.world-aluminium.org/.

Survey Participation

Participants in the 2009 Sustainable Development Indictors (SDI) Survey account for around 45% of global primary metal production, with incomplete reporting from IAI member companies (which collectively represent between 70% and 80% of global production).

COUNTRY	2009 PRIMARY ALUMINIUM PRODUCTION ('000 TONNES)	IAI MEMBERSHIP AS A PROPORTION OF COUNTRY PRODUCTION	2009 SDI SURVEY GLOBAL PARTICIPATION RATE BY PRODUCTION
Australia	2,000	100 %	100 %
Canada	3,000	100 %	80 %
China	13,000	20-30 %	0 %
India	1,500	37 %	37 %
Japan & Korea	< 10	100 %	0 %
United States	1,500	80 %	67 %
APP Total	21,000	c. 50%	**29 %**
GLOBAL	37,000	70 – 80 %	**45 %**

Note: any inconsistencies due to rounding

Table 5 – SDI Survey 2009 APP participation rate by country

Fluoride Emissions

The International Aluminium Institute Fluoride Emissions Reduction Voluntary Objective (1990-2010)

- *A minimum 33% reduction in fluoride emissions by IAI member companies per tonne of aluminium produced by 2010 versus 1990.*

For many decades, fluoride emissions (as gases and particulates) were considered to be the most important pollutants from aluminium smelters. Fluorides accumulate in vegetation and can damage coniferous trees. They also accumulate in the teeth and bones of ruminants eating fluoride-contaminated forage.

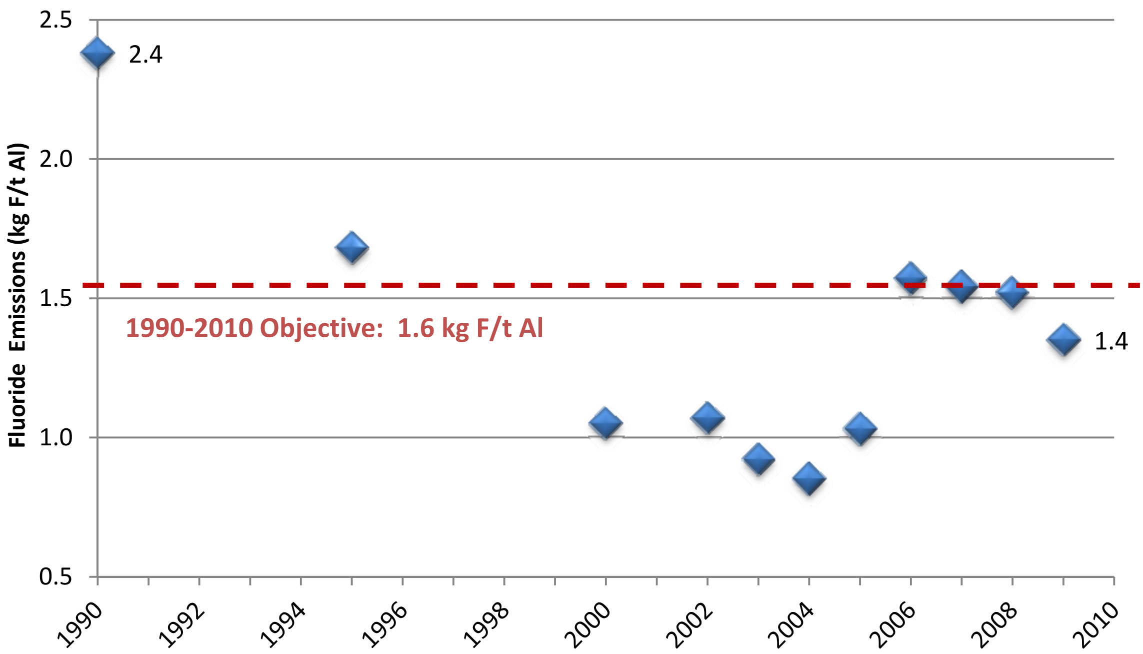


Figure 10 - Specific fluoride (gaseous & particulate) emissions reduction, 1990-2009

The changing cohort of reporting companies (particularly the inclusion of Russian – predominantly Søderberg – facilities since 2006) has led to a fluctuation in reported performance since 2000, although the IAI membership is on course to achieve its goal of a 33% reduction in total fluorides per unit production by 2010 and is currently achieving this objective, with survey respondents reporting an average 1.4 kg F/t Al in 2009.

APP reporting facilities' production weighted mean is half of the global mean, though note the low participation rate in the key producing areas of China and India:

0.8 kg F/t Al

More useful is a comparison of median values within technology classes, illustrating that APP performance is equivalent to that in the rest of the world.

Region/Technology	2009 MEDIAN PERFORMANCE (kg F/t Al)	2008 MEDIAN PERFORMANCE (kg F/t Al)
APP Prebake	0.5	0.6
ROW Prebake	0.6	0.7
APP Søderberg	2.0	2.2
ROW Søderberg	2.4	2.4

Table 6 – 2008-2009 Median Fluoride Emissions by Technology & APP/Non-APP Regions

2009 Total Fluoride Emissions (Prebake & Søderberg) by Cumulative Production

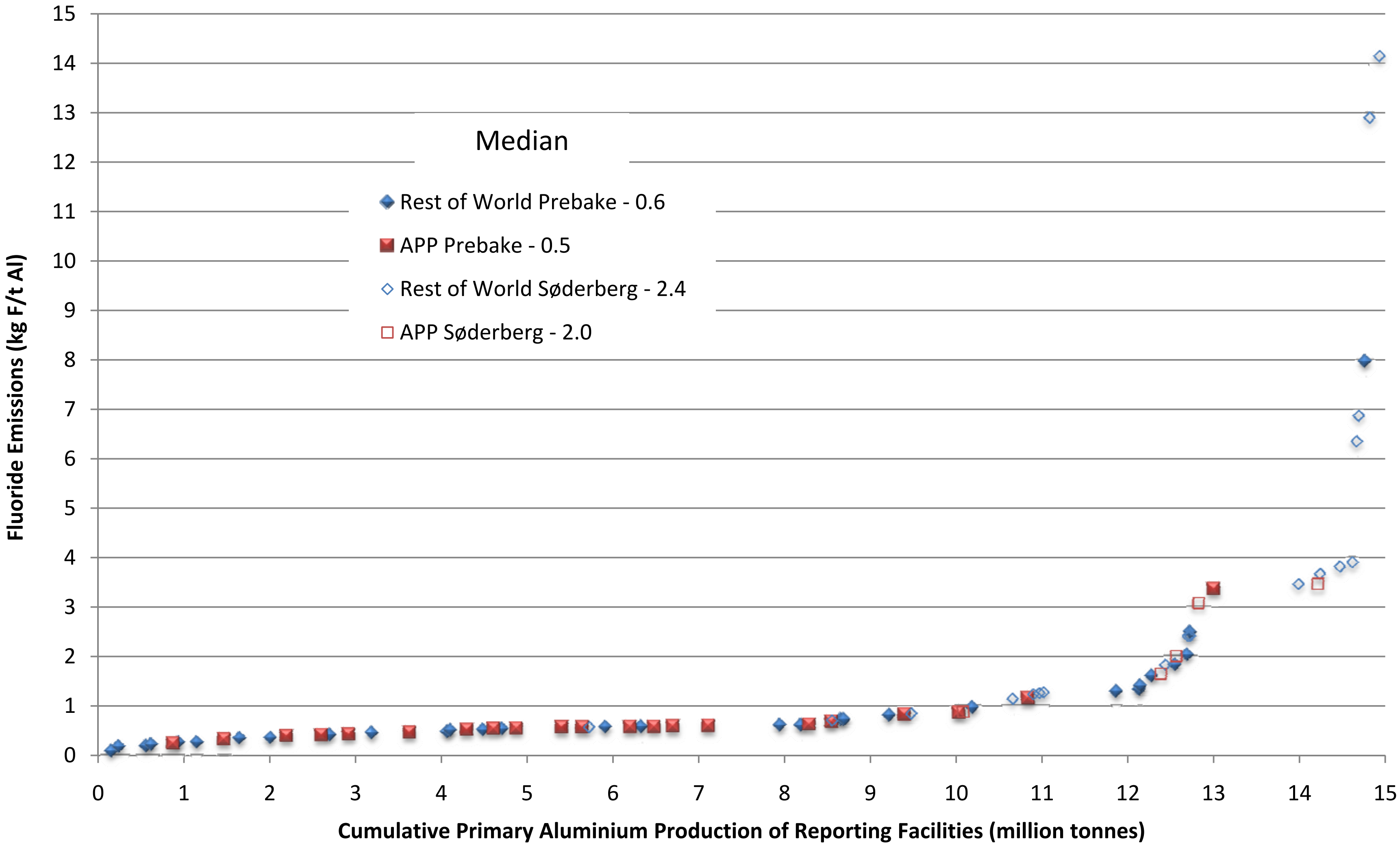


Figure 11 - Specific fluoride emissions performance of reporters, benchmarked as cumulative production within technologies

Spent Pot Linings Disposal

The International Aluminium Institute SPL Voluntary Objective

- *The Aluminium Industry recognises that spent pot-lining has properties that makes it a valuable material for use in other processes and will therefore strive to convert all spent pot lining into feed stocks for other industries, which include cement, steel, mineral wool and construction aggregate companies or to re-use and or process all SPL in its own facilities.*
- *Pending final deposition, the industry will endeavour to store all spent pot-lining in secure, waterproof, ventilated buildings/containers that will maintain the spent pot-lining in a dry state with no potential for the build up of noxious gases.*

Spent pot lining (SPL) is an unavoidable by-product of the aluminium smelting process. In 2009, 36% of SPL output was recycled externally out of a total reported output of 365,000 tonnes, compared to 34% of 370,000 tonnes of SPL in 2008.

Of a total of 158,000 tonnes of SPL produced, APP reporters recycled:

50% (Compared to 35% of 46,000 tonnes reported in 2008).

Around 40% of the SPL output from reporters was deposited in form of treated deposition or stored pending final deposition or recycling (compared to 50% in 2008). Of APP reported SPL, the percentage stored or deposited as a treated residue was:

31% (Compared to 30% in 2008).

The industry has systematically worked to minimize the amount of SPL produced, by extending the lifetime of the lining in the smelter pots. Since the 1970s, SPL has been recognised as a valuable resource for other industries, including as a feedstock in the cement, mineral wool and steel production processes. However, the main barrier to supply of SPL as a feedstock has been economics. Individual smelters do not produce enough SPL to provide a continuous supply of feedstock for a cement plant to justify their conversion to receiving this material. Through collaboration with potential customers, and between companies to increase regional supply, the recycling of this material has become more viable and widespread.

Aluminium Smelter Electrical Energy Survey

NOTE:
The data in this section should be interpreted in conjunction with the IAI's global energy statistics, available from http://www.world-aluminium.org/Statistics/Current+statistics.

Survey Participation

Smelter reporters in the 2009 Energy Survey account for around 60% of global primary metal production. Outside of China, participation has for a number of years remained around 80-90%:

TECHNOLOGY	2009 GLOBAL PRIMARY Al PRODUCTION ('000 TONNES)	2009 PARTICIPATION RATE BY PRODUCTION		2008 GLOBAL PRIMARY Al PRODUCTION ('000 TONNES)	2008 PARTICIPATION RATE BY PRODUCTION	
PFPB (Rest of World)	19,250	86 %	57 %	20,300	79 %	51 %
PFPB (China)	13,000	14 %		13,000	2 %	
SWPB	550	100 %		700	84 %	
VSS	3,600	84%		4,500	93 %	
HSS	600	90%		1,000	92 %	
All Technologies (excluding China)	24,000	86 %		26,500	90 %	
All Technologies (Including China)	**37,000**	**60 %**		39,500	62 %	

Table 7 – Smelter Electrical Energy Survey 2009 & 2008 participation rate by technology

TECHNOLOGY	2009 APP PRIMARY Al PRODUCTION ('000 TONNES)	2009 APP PARTICIPATION RATE BY PRODUCTION	2008 APP PRIMARY Al PRODUCTION ('000 TONNES)	2008 APP PARTICIPATION RATE BY PRODUCTION
PFPB/CWPB	20,100	39 %	20,600	38 %
SWPB	350	100 %	400	100 %
VSS	375	88 %	600	67 %
HSS	165	100 %	300	93 %
All Technologies	**21,000**	**42 %**	22,000	41 %

Table 8 – Smelter Electrical Energy Survey 2009 & 2008 APP participation rate by technology

COUNTRY	2009 PRIMARY Al PRODUCTION ('000 TONNES)	2009 APP PARTICIPATION RATE BY PRODUCTION	2008 PRIMARY AL PRODUCTION ('000 TONNES)	2008 APP PARTICIPATION RATE BY PRODUCTION
Australia	2,000	100 %	2,000	100 %
Canada	3,000	100 %	3,000	100 %
China	13,000	12 %	13,000	2 %
India	1,500	66 %	1,250	29 %
Japan & Korea	< 10	100 %	< 10	100 %
United States	1,500	98 %	3,000	87 %
APP Total	**21,000**	**42 %**	22,000	41 %

Table 9 – Smelter Electrical Energy Survey 2009 & 2008 APP participation rate by country

Note: any inconsistencies in above tables due to rounding

Aluminium Smelting Industry Energy Usage

The International Aluminium Institute Smelting Energy Use Voluntary Objective (1990-2010)

- *A 10% reduction in smelter electrical energy usage by IAI member and reporting companies per tonne of aluminium produced by 2010 versus 1990.*

The last two decades have seen an improvement in smelter electricity consumption (of around 5% per tonne of production); although in recent years the high demand for metal has led many facilities to run over-capacity (sacrificing efficiency for yield) and a plateau in the reported kWh/t Al data.

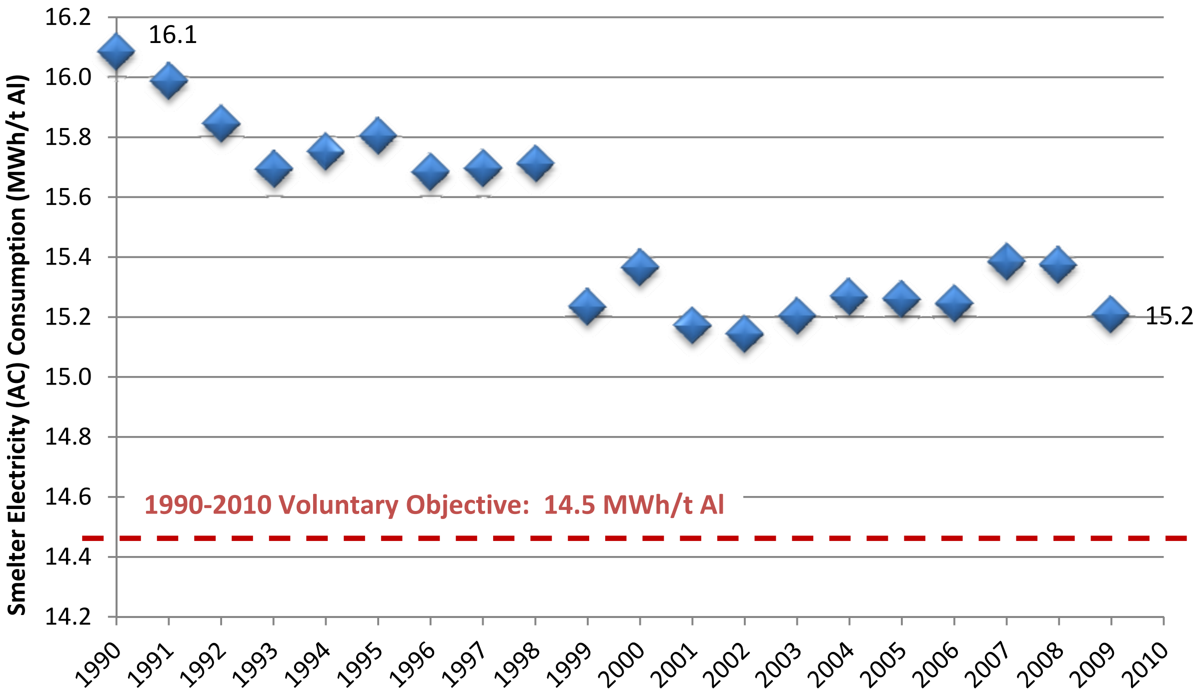


Figure 12 – Smelter electrical (AC) energy efficiency, 1990-2009

Compared to the reported production weighted mean of 15.2 MWh/t Al, reporting APP facilities had a production weighted mean of:

14.9 MWh/t Al (Compared to 15.2 MWh/t Al in 2008).

However, a changing reporting cohort (and a shift in the technological profile of the reporting cohort relative to the global reality), means that care needs to be taken when interpreting improvements over time, or of using the reported data to assume the actual global kWh/t Al performance:

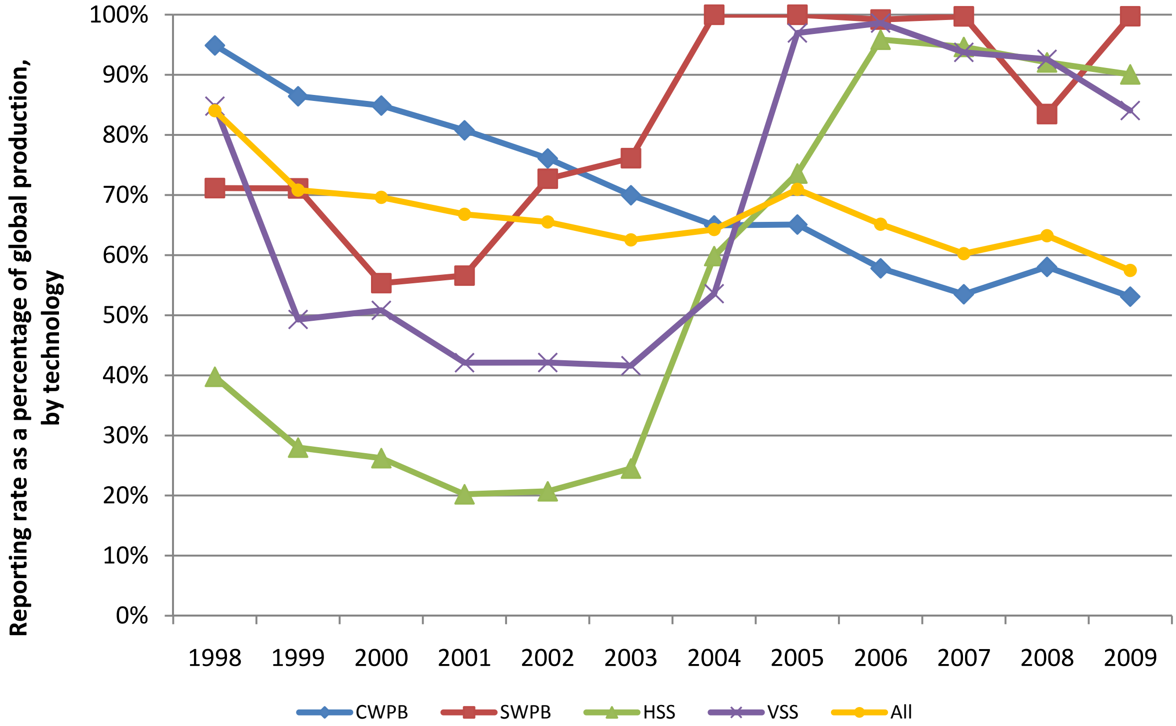


Figure 13 – Reporting rates for Energy Survey by technology, 1998-2009

As can be seen from the graph above, the fall in global reporting rate is linked to the fall in CWPB reporting rate, which in turn is a function of the rapid and exponential growth in Chinese (non-reporting) production.

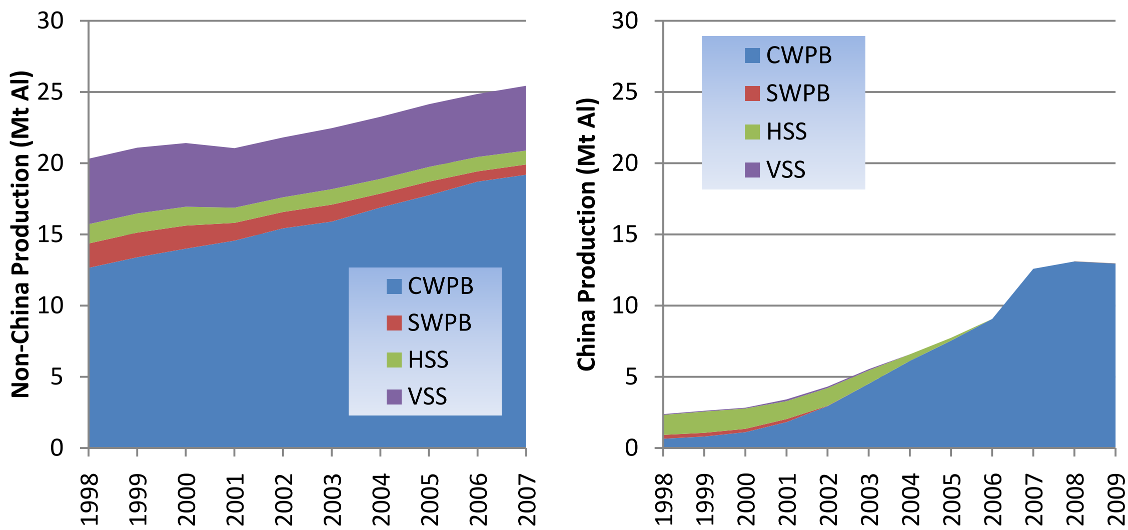


Figure 14 –Growth in primary aluminium production in China and rest of world by technology, 1998-2009

We know something of China's performance because we have received some China industry-wide average (AC and DC) data from CNIA.

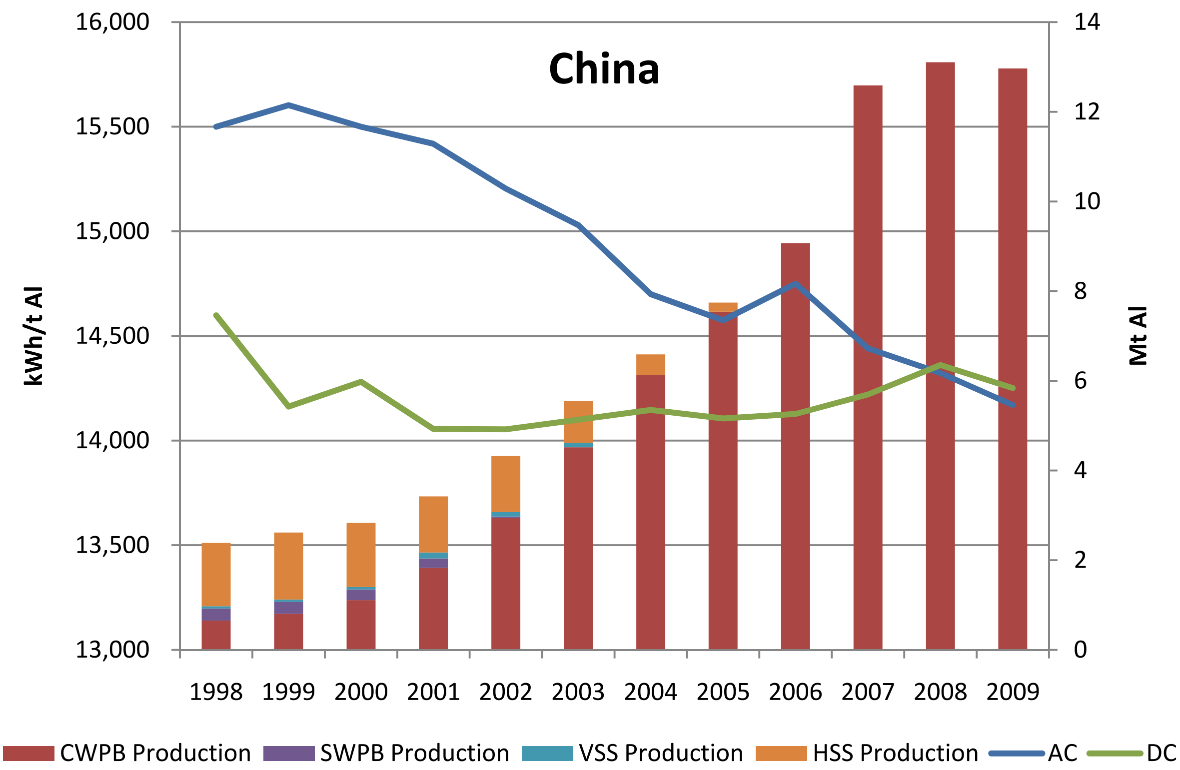


Figure 15 – China's production technology mix & average electrical energy efficiency, 1998-2009 (Source: CNIA)

Knowing the technology mix in China over time and the technology mix in the global industry, as well as the technology mix of the reporting cohort, we can work out the non-Chinese, non-reporting technology mix over time. By applying median performance in the reporting cohort by technology to the non-reporting (as we do for PFCs) we can estimate the non-reporting performance. Having such (mean) performance for China, reporting rest of world and non-reporting rest of world and knowing the production in each, we can derive a global production weighted average AC number.

DC is more problematic because we have only collected this data since 2008. The methodology used was the same as for AC for years 2008 and 2009, where DC data is available.

For 1998-2007, China-specific data was used for China, while for rest of world, the ratio of DC:AC for year 2008 for each technology, was applied to the derived (reporting and non-reporting non China) average AC for each technology annually, and so the DC tracks the AC within technologies. However, due to a) differences in the DC:AC ratio for each technology b) changes in technology mix over time and c) the inclusion of China reported values in the annual global weighted average, the global DC is not directly proportional to AC, but rather converges between 1998 and 2009.

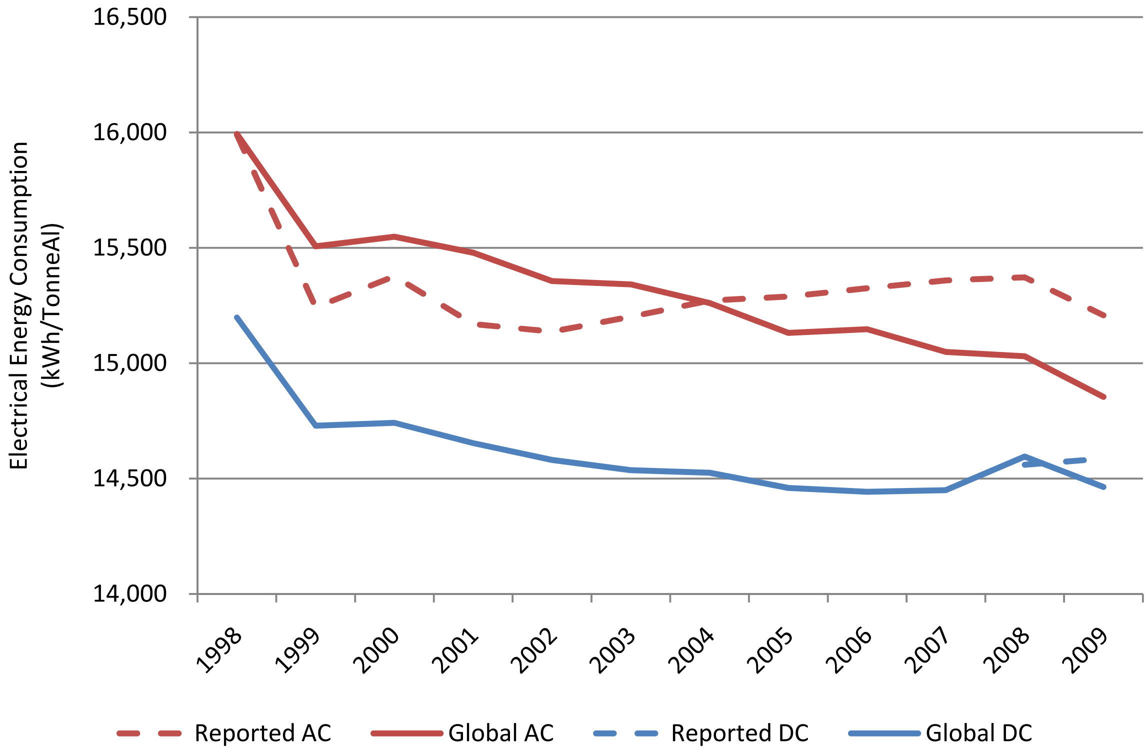


Figure 16 – IAI reported & calculated global average electrical energy efficiency, 1998-2009

APP calculated performance is lower than the “Global” values outlined above (c. **14,500 kWh(AC)/t**), due to the high proportion of APP production in China (60%) which is relatively energy efficient compared to rest of world (and other APP country facilities), a function of having a high level of new, best available technology, operations.

As of 2008, IAI collects Direct Current (DC) as well as Alternating Current (AC) data. DC data is a better indicator of efficiency of the smelting process, AC numbers containing electrical energy used in auxiliary processes such as fume treatments systems, heating and lighting etc. Both AC and DC data are benchmarked below, but only include IAI reported facility data, not the country-wide averages calculated for China.

Smelter Electrical (Total AC) Energy Efficiency Performance by Cumulative Production

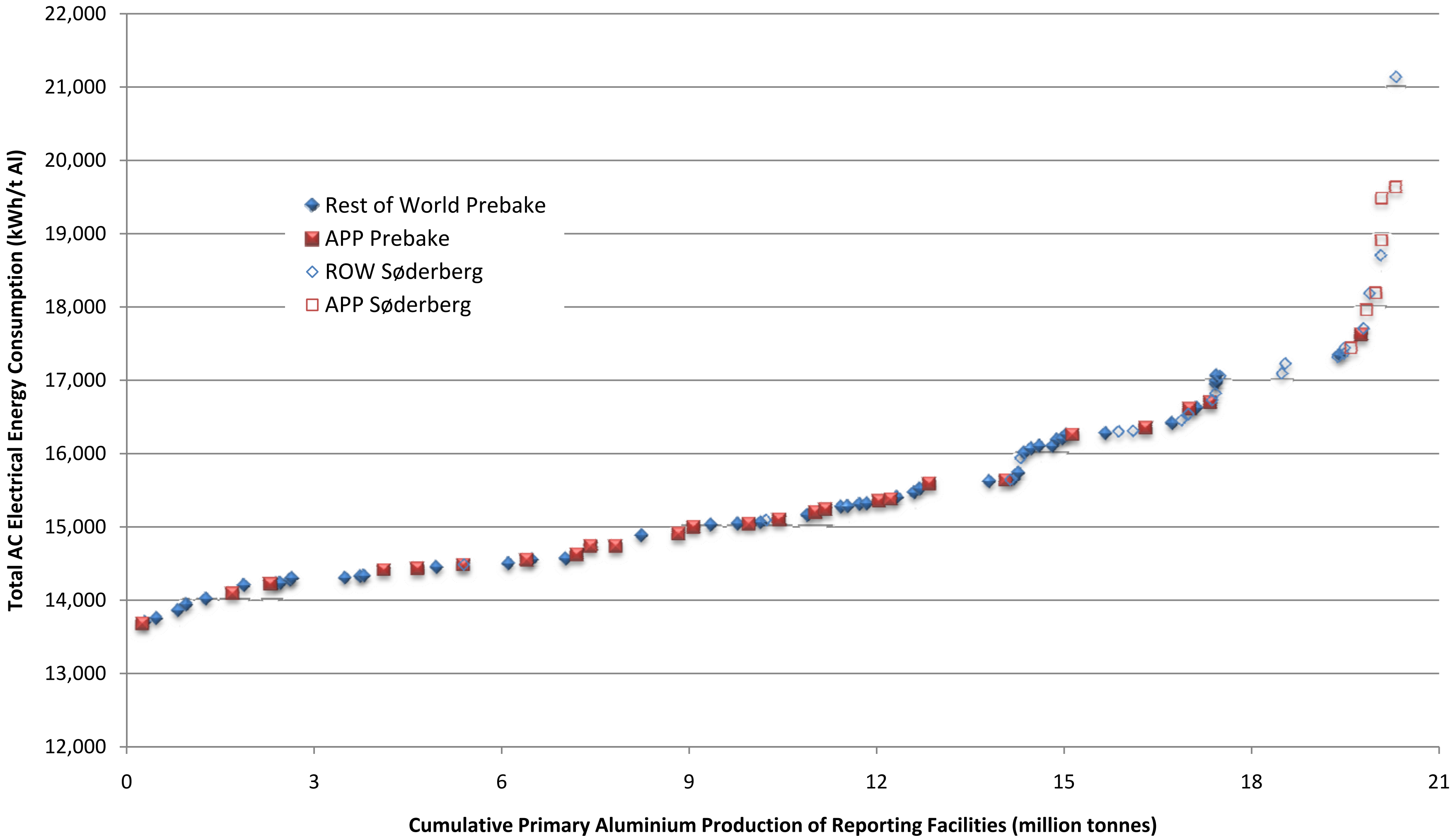


Figure 17 – Total AC Electrical energy efficiency performance of reporters, benchmarked as cumulative production within technologies

Smelter Electrical (DC) Energy Efficiency Performance by Cumulative Production

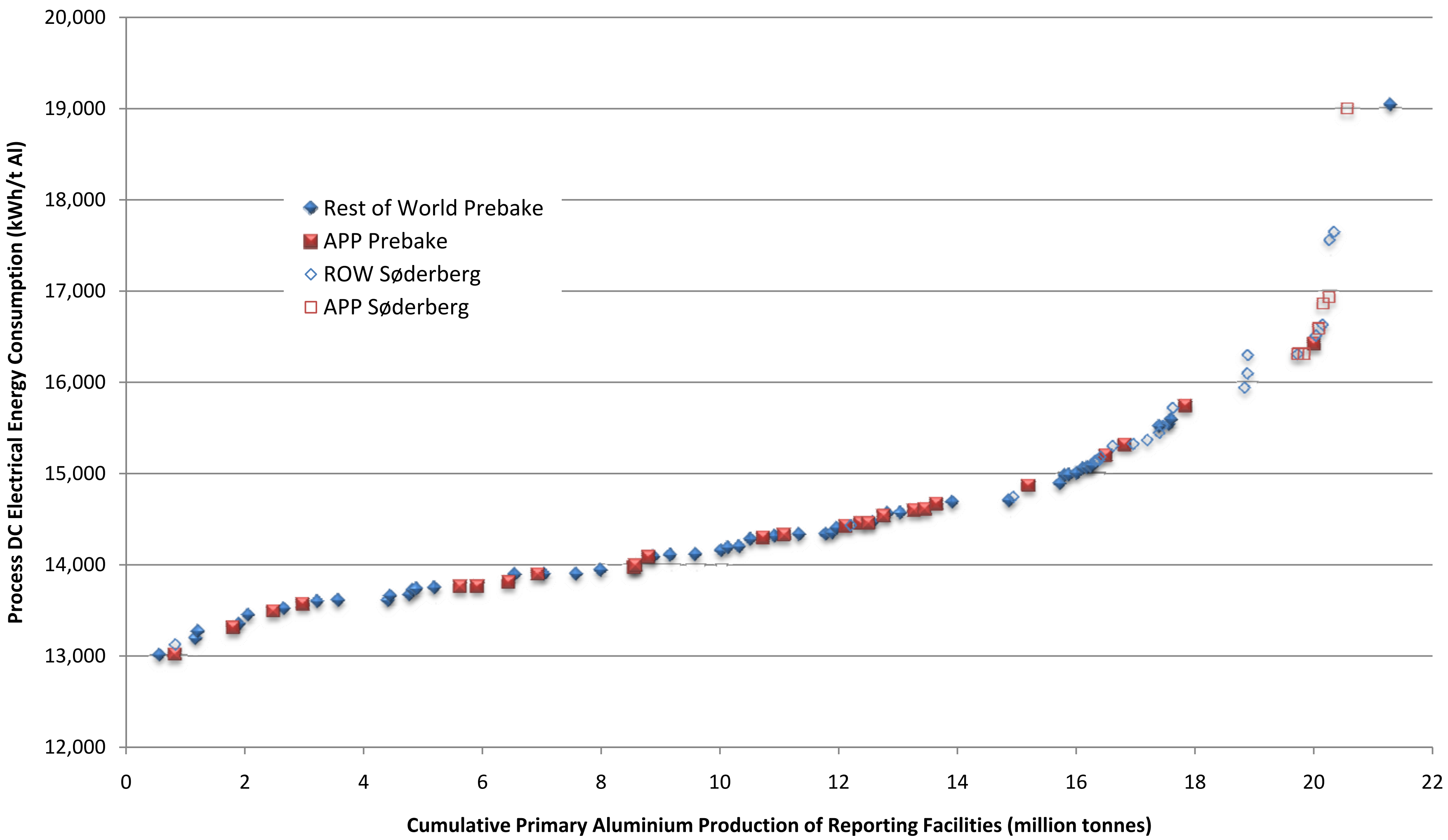


Figure 18 – Process DC Electrical energy efficiency performance of reporters, benchmarked as cumulative production within technologies

Alumina Refinery Energy Survey

NOTE:

The data in this section should be interpreted in conjunction with the IAI's global energy statistics, available from http://www.world-aluminium.org/Statistics/Current+statistics.

Survey Participation

Alumina reporters in the 2009 Energy Survey account for around 60% of global metallurgical alumina production:

	2009 GLOBAL METALLURGICAL (SMELTER GRADE) ALUMINA PRODUCTION ('000 TONNES)	2009 PARTICIPATION RATE BY PRODUCTION	2008 GLOBAL METALLURGICAL (SMELTER GRADE) ALUMINA PRODUCTION ('000 TONNES)	2008 PARTICIPATION RATE BY PRODUCTION
GLOBAL	c. 75,000	**c. 60 %**	c. 80,000	**c. 60 %**
GLOBAL (exc China)	c. 50,000	**c. 85 %**	c. 58,000	**> 75 %**

Note: any inconsistencies due to rounding

Table 10 – Refinery Energy Survey 2009 & 2008 participation rate

COUNTRY	2009 METALLURGICAL (SMELTER GRADE) ALUMINA PRODUCTION ('000 TONNES)	2009 APP PARTICIPATION RATE BY PRODUCTION	2008 METALLURGICAL (SMELTER GRADE) ALUMINA PRODUCTION ('000 TONNES)	2008 APP PARTICIPATION RATE BY PRODUCTION
Australia	20,000	80 %	19,000	90 %
Canada & US	3,500	80 %	5,250	75 %
China	23,000	0 %	22,000	0 %
India	3,000	85%	3,000	63 %
Japan & Korea	< 10	100 %	13	100 %
APP Total	**50,000**	**45 %**	50,000	45 %

Note: any inconsistencies due to rounding

Table 11 – Refinery Energy Survey 2009 & 2008 APP participation rate by country

Reporting facilities submit data on fuel and electricity usage, which is converted to GJ values using specific or general conversion factors (see Appendix A for details).

Alumina Refining Industry Energy Usage

The International Aluminium Institute Refining Energy Use Voluntary Objective (2006-2020)

- *A 10% reduction in energy use per tonne of alumina produced for the industry as a whole by 2020 versus 2006 levels.*

On average, 14.7 GJ energy were used in Low Temperature, High Temperature and Bayer Sinter alumina refining processes to produce one tonne of alumina in 2009 an improvement of 5% on 2006. Data are based on IAI reporting companies (outlined in tables above) supplemented with alternative statistics (e.g. CRU).

IAI surveyed plants (around 60% of global production) reported a 5% improvement from 2006-2009:

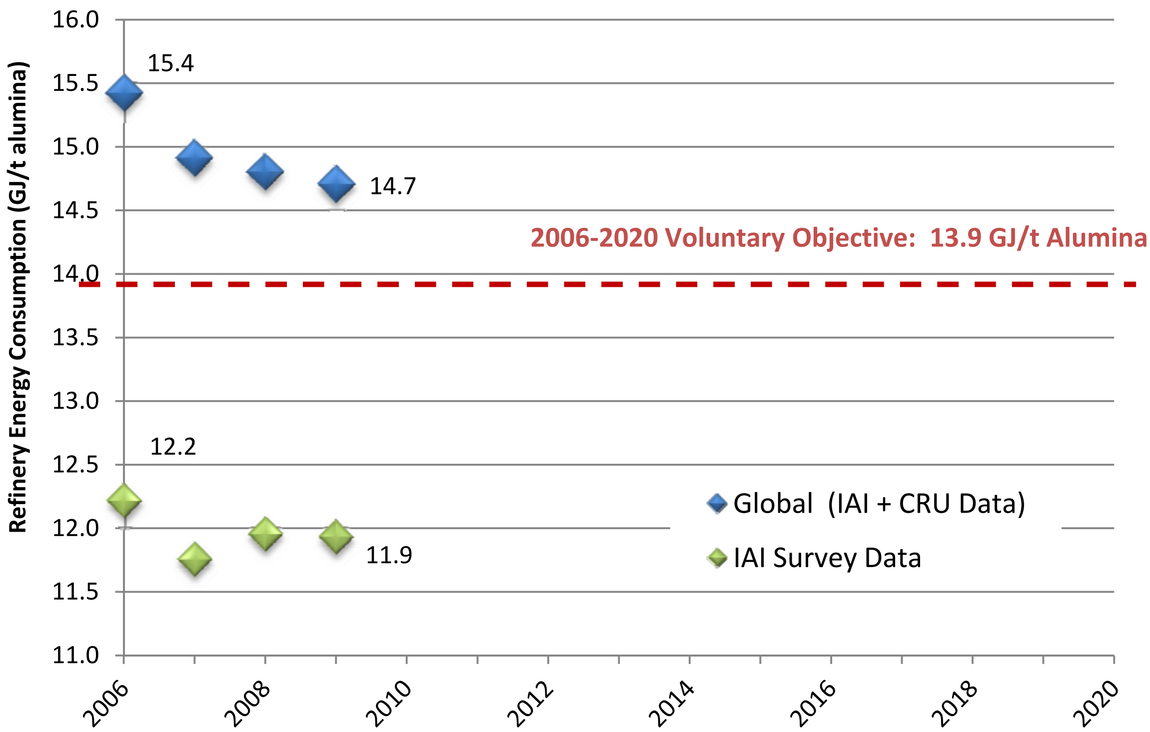


Figure 19 – Refinery energy efficiency, 2006-2009

Equivalent to the complete IAI reporting dataset (of 11.9 GJ/t Alumina), APP reporting facilities had a 2009 production weighted mean energy performance of:

11.0 GJ/t Alumina (Compared to 11.6 GJ/t Al in 2008).

Refinery Energy Efficiency Performance by Cumulative Production

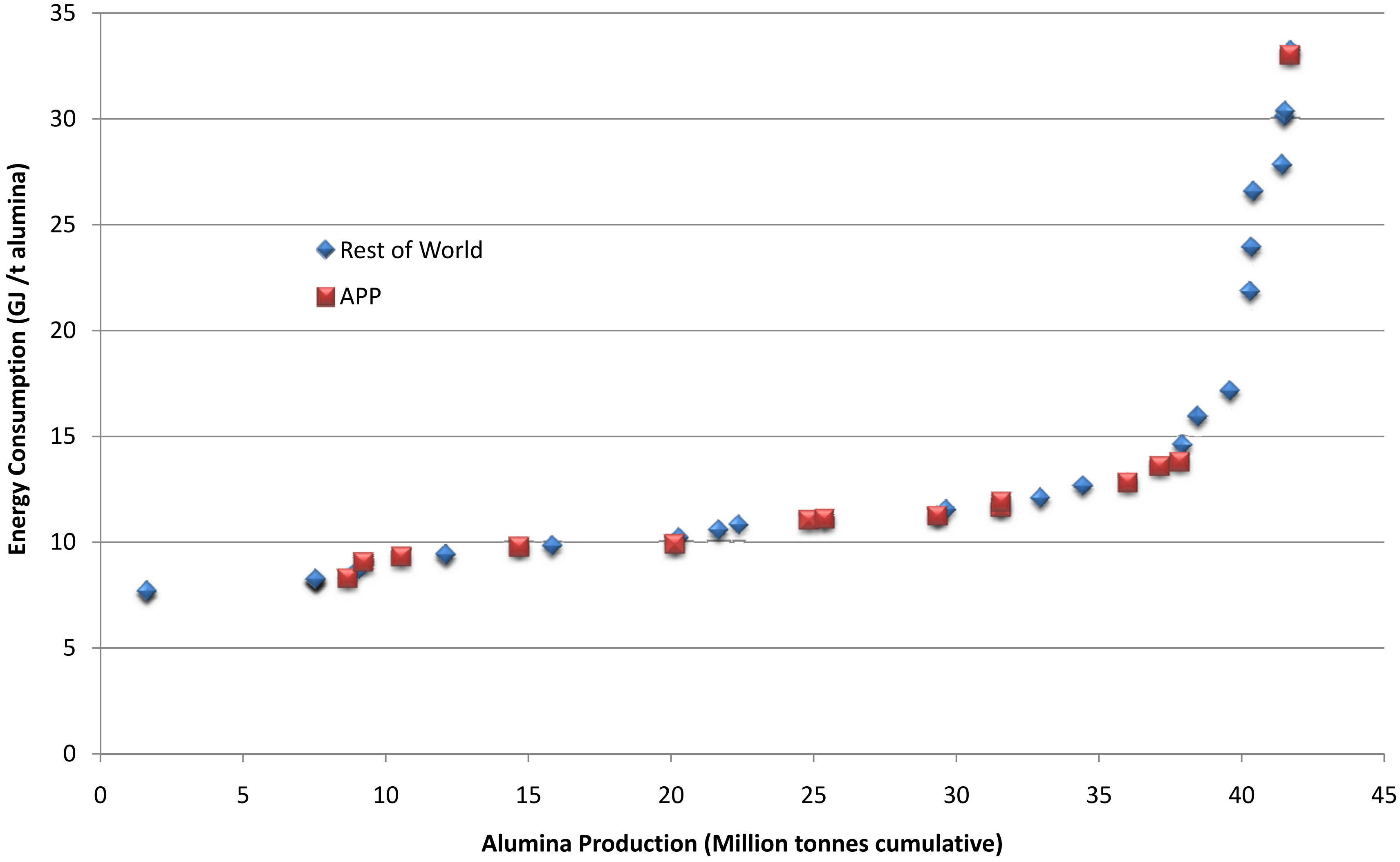


Figure 20 – Refinery energy efficiency performance of reporters, benchmarked as cumulative production

Regional Market Metrics

Data on recycling rates and on shipments of aluminium semi fabricated products is collected from regional and national aluminium associations as input data to the IAI's mass flow modelling work (see http://www.world-aluminium.org/cache/fl0000181.pdf for further details). As of August 2010, 2009 data is not yet available from all APP member states and therefore this report provides detail results from 2008.

Recycling Rates

The International Aluminium Institute Recycling Modelling Voluntary Objective

- *The IAI has developed a mass flow model to identify future recycling flows. The industry will report regularly on its global recycling performance.*

The aluminium industry is a pioneer in tracking the global flows of its products through the full value chain from mining, through use, to recycling and reuse. To do so it has developed a comprehensive mass flow model based on "Material Flow Analysis" methodology. The industry illustrates the model's output in a flow chart, which is made available to the public on an annual basis. The IAI has published annual mass flow charts since 2003.

The industry is continuously improving the model, with more accurate statistics and with the help of research centres and universities. Due to uncertainties in the data on product life times and recycling rates for some products in certain regions, the IAI is conducting additional research on the 3.5 million tonnes of scrap which has been identified as possibly available for recycling or stored in use.

Just under 44 million tonnes of aluminium, from primary and recycled sources, ended up in finished products in 2008 (approximately the same figure as in 2007). In the same year, approximately one-third of the metal in products available on the market was sourced from recycled and two-thirds from primary metal). Projected growth rates in the demand for aluminium products, combined with the long lifetimes of most products, suggest that this ratio of recycled to primary sourced metal is unlikely to change significantly into the future. Around 10 million tonnes of scrap from used products (old scrap) were recovered globally in 2008.

Three quarters of all the aluminium ever produced (since the 1880s) is still in productive use. In 2008 this stock had grown to almost 640 million tonnes. Of the aluminium currently stored in productive use, equally one third is in buildings (windows, roofing, cladding etc), transport (automotive, public transport etc.) and engineering & cable (overland cable, machinery) applications.

APP Member and Global Estimated Collection (Recycling) Rates of Old (Post Consumer) Scrap

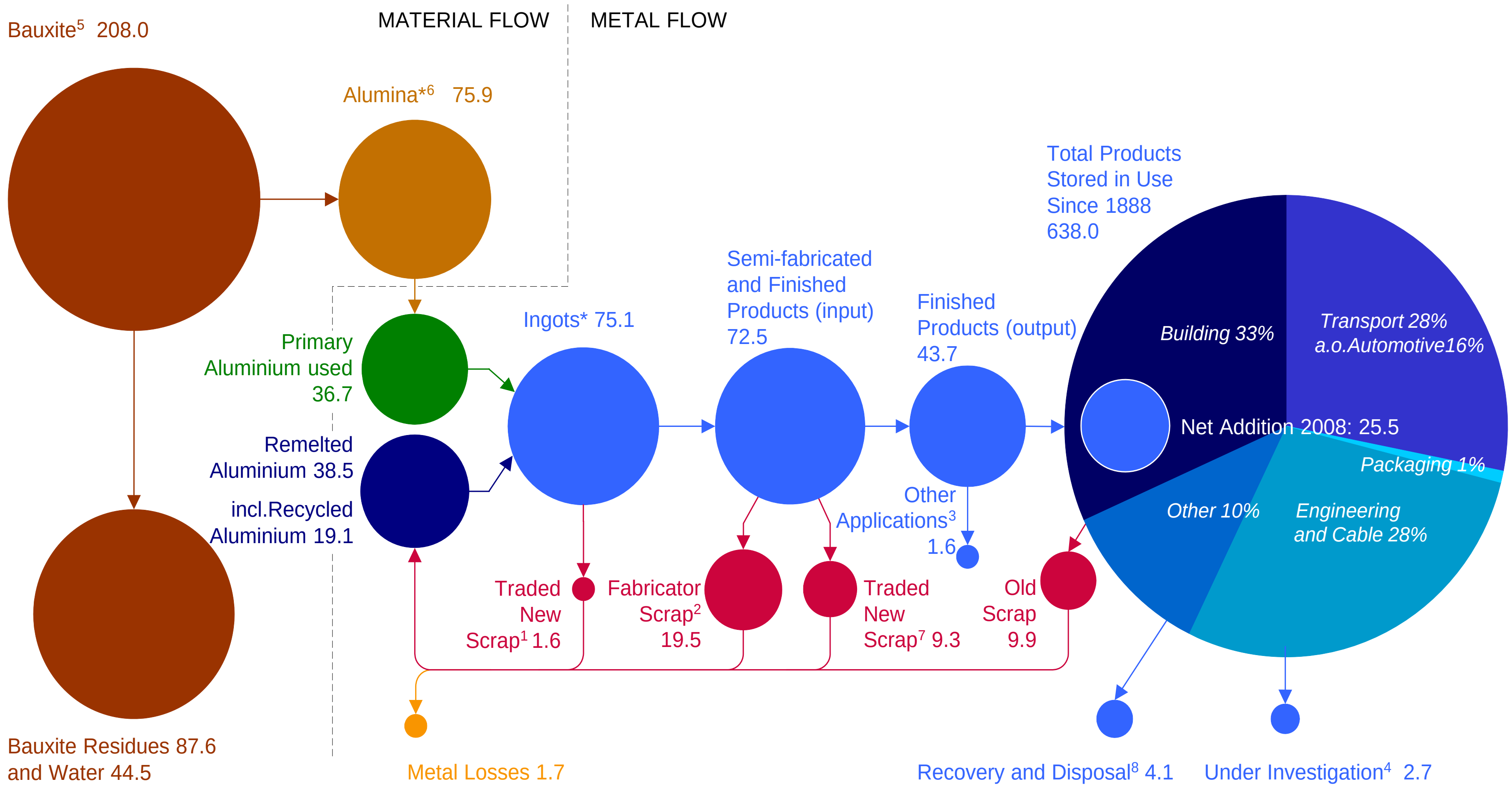
		Australia	China	India	Japan & Korea*	US & Canada	World (2008)	World (2007)
Building & Construction		80%	80%	80%	80%	80%	89%	85%
Transportation	Automotive & Light Truck	80%	80%	80%	91%	85%	88%	86%
	Aerospace	80%	90%	80%	88%	75%	81%	82%
	Truck, Bus, Trailer, Rail; Marine, etc	40%	90%	80%	88%	70%	84%	83%
Packaging	Cans	70% **	80%	80%	87%	54% ***	69%	63%
	Other (Foil)	5%	20%	20%	52%	5%	19%	18%
Machinery & Equipment		15%	30%	30%	30%	40%	62%	45%
Electrical	Cable	80%	60%	60%	80%	80%	67%	67%
	Other	30%	30%	30%	30%	10%	74%	38%
Consumer Durables		30%	30%	30%	26%	15%	54%	27%
Other (excluding Destructive Uses)		30%	20%	20%	20%	15%	31%	21%

* Japan & Korea (2007): B&C - 80%; Auto - 90%; Aero - 80%; Mass Transport - 90%; Cans - 91%; Other Packaging - 20%; M&E - 30%; Cable - 80%; Other Electrical - 30%; Consumer Durables - 30%; Other - 20%; ** Australia Cans (2007) - 63%; *** N America Cans (2007) - 52% in 2007

Table 12 –APP scrap recycling rate by market and country, 2008

Global Aluminium Mass Flow (2008)

Figure 21 – Global Aluminium Mass Flow, 2008



Values in millions of metric tonnes. Values might not add up due to rounding. *Change in stocks not shown

1 Aluminium in skimmings; 2 Scrap generated by foundries, rolling mills and extruders. Most is internal scrap and not taken into account in statistics; 3 Such as deoxidation aluminium (metal property is lost) 4 Area of current research to identify final aluminium destination (reuse, recycling, recovery or disposal); 5 Calculated based on IAI LCI report - update 2005. Includes, depending on the ore, between 30% and 50% alumina; 6 Calculated. Includes on a global average 52% aluminium; 7 Scrap generated during the production of finished products from semis; 8 Either incinerated with/without energy recovery, material recovery or disposal.

Aluminium Shipments to Transport

The International Aluminium Institute Transport Shipments Monitoring Voluntary Objective

- *The industry will monitor annually aluminium semis shipments for use in transport in order to track aluminium's contribution through light-weighting to reducing greenhouse gas (GHG) emissions from road, rail, air and sea transport.*

Aluminium semi-fabricated products shipped to the transport sector dropped for the first time in at least two decades in 2008, as a result of the global financial crisis. Global greenhouse gas savings from the use of aluminium for light weighting vehicles have the potential to double between 2005 and 2020 to 500 million tonnes of CO_2e per year.

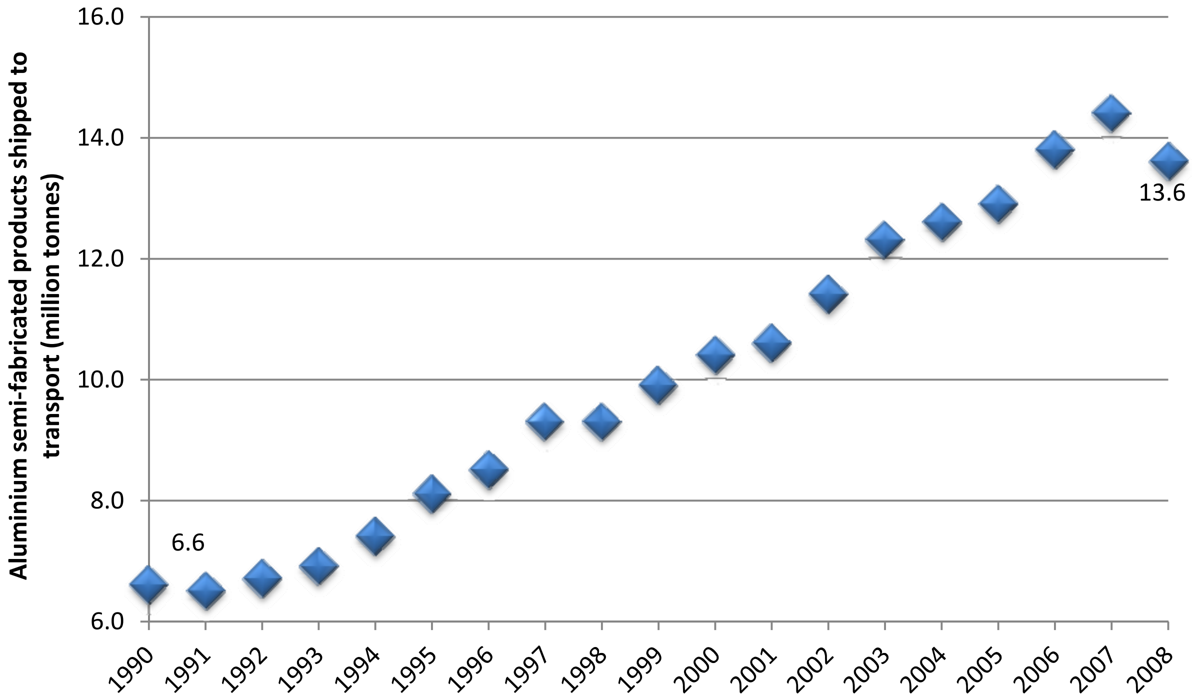


Figure 22 – Shipments of aluminium semi-fabricated products to transport, 1990-2008

APP Member and Global Product Shipments, 2008 ('00,000 tonnes Al)

		Australia	China	India	Japan & Korea	US & Canada	World	World % growth from 2007
Building & Construction		2	45	2	6	12	125	3 %
Transportation	Automotive & Light Truck	< 1	16	1	15	17	92	- 1 %
	Aerospace	0	< 1	0	< 1	2	4	18 %
	Truck, Bus, Trailer, Rail; Marine, etc	0	10	1	2	11	40	- 14 %
Packaging	Cans	1	3	0	4	18	44	2 %
	Other (Foil)	0	9	1	2	4	37	4 %
Machinery & Equipment		< 1	8	1	2	7	32	- 25 % *
Electrical	Cable	< 1	8	5	< 1	3	31	- 27 % *
	Other	0	25	0	2	4	52	92 % *
Consumer Durables		< 1	15	1	3	6	41	1 %
Other (excluding Destructive Uses)		1	2	< 1	3	2	14	- 40 % *
Destructive Uses		0	8	0	2	1	20	- 3 %
	TOTAL	5	149	13	40	87	531	- 2 %

Note: any inconsistencies due to rounding

* Changes in M&E, electrical and "other" due in large part to recategorization of products within (in particular China) reported data

Table 13 –APP semi fabricated product shipments by market and country, 2008

Bauxite Residue Management

In 2008 the IAI Bauxite and Alumina Committee developed the following metrics for measuring bauxite residue management in alumina refineries globally.

1. **Active Residue Management:** The volume of stored bauxite residue produced in a calendar year per 1000 tonnes of alumina produced in that same year (m^3/kt alumina).

   Indicator is influenced by improvements to consolidation/density of the deposit, extraction efficiency, bauxite quality and use of residue

2. **Historical Residue Management:** The land area (footprint) utilised to store the bauxite residue since refinery operation commenced per 1000 tonnes of alumina produced over the same period (km^2/kt alumina).

   Land area does not include ponds constructed for the sole purpose of storing water and will not contain residue at the time of refinery closure.

   Indicator is influenced primarily by moves to store more residue within a given footprint.

3. **Residue Storage Area (RSA) Rehabilitation:** The surface area and percentage of total RSA's that has been converted to productive and sustainable land use (km^2 & %)

   This Indicator includes areas that have been closed, re-vegetated and managed in a sustainable manner as per existing best practice.

As of August 2010, limited (year 2008 and 2009) data has been collected against these objectives and not enough to undertake either global or APP benchmarking.

Appendix A – IAI Survey Return Forms

Anode Effect Survey (PFC001)

International Aluminium Institute Confidential Return **IAI**

PFC EMISSIONS FROM PRIMARY ALUMINIUM SMELTING **IAI FORM PFC001**

Annual Report for: Due Date:

Please read the Reporting Guidelines on page 2 very carefully before completing this form.

1. Smelter
Name or Location of Smelter

2. Anode Effect Data

Potline Number	Technology Category	Cell Technology	Feed Type	Primary Aluminium Production (Tonnes)	Number of Cells Operating per Day (Average)	Number of Anode Effects per Cell Day (Average)	Average Anode Effect Duration (Minutes)	Averaged Anode Effect Over-voltage per Cell Day*	
								Over-voltage (mV)	Algebraic or Positive

*** See Guideline 9**

3. Anode Effect Control Procedures
(Write "All", "None" or list which potlines have the computer-based procedures)

a. Which potlines, if any, have computer-based procedures in place to predict the beginning of an anode effect?
b. Which potlines, if any, have automated procedures in place to terminate anode effects once they have begun? (For example: lowering and raising of anodes, tilting of anodes, automated alumina feed or blowing compressed air under anodes)

4. PFC Emission Measurements
(Only complete this Section if actual PFC Emissions have been directly measured and the resulting Tier 3 CF_4 coefficient and C_2F_6/CF_4 weight fraction used to calculate PFC Emissions per tonne of aluminium – see Guideline 10)

Year of Measurement	Potline Number	Calculated Tier 3 Data			
		Slope Method		Over-voltage Method	
		CF_4 Emissions Coefficient	C_2F_6/CF_4 weight fraction	CF_4 Emissions Coefficient	C_2F_6/CF_4 weight fraction

5. Verified by: (Please complete – **see Guideline 11**)
a. Name: c. Third Party:
b. Appointment: d. Date of verification:

Reported by: (Please complete)
Name: Tel No:
Appointment: Fax No:
Company: E-Mail:

Please return completed form by email or fax to:
Chris Bayliss Tel No: + 44 20 7930 0528
International Aluminium Institute Fax No: + 44 20 7321 0183
London SW1Y 4TE, United Kingdom E-Mail: bayliss@world-aluminium.org

PFC EMISSIONS FROM PRIMARY ALUMINIUM SMELTING **IAI FORM PFC001**

Reporting Guidelines

1. Data are reported by technology category and, preferably, by potline. Data for different technology categories should not be mixed.

2. If anode effect data are not available then data for technology category, cell technology, feed type, primary aluminium production and average number of cells operating per day are still reported. Anode effect frequency data should be reported, if available, even though anode effect duration or overvoltage data are not available.

3. Technology category is reported as:
   a. PFPB - where cell technology is Centre Worked Prebake with a Point Feed System.
   b. CWPB - where cell technology is Centre Worked Prebake with a Bar Break Feed System.
   c. SWPB - where cell technology is Side Worked Prebake.
   d. HSS - where cell technology is Horizontal Stud Søderberg.
   e. VSS - where cell technology is Vertical Stud Søderberg.

4. Cell technology is the particular cell technology used (RA-300, SY300, AP18, Reynolds P19 etc.)

5. Potline number is the reference number or letter used to identify the potline. If data from two or more potlines are combined, then all relevant reference numbers or letters relating to the combined data are shown.

6. Feed type is reported as:
   a. PF - where a Point Feed System is applied to Prebake or Søderberg technologies.
   b. BF - where a Bar Break Feed System is used.
   c. SF - where a manual Side Feed System is used.

7. Primary aluminium production is molten (liquid) aluminium as tapped from the pots. It is reported in tonnes (metric tons) and is that production relevant to the anode effect and cell technology type data being reported.

8. Anode effect measurements are reported to two decimal places if possible. If the reported average anode effect duration is estimated, then this is indicated by adding the letter "E" against the reported figure. When data from two or more potlines are combined, the reported average anode effect frequency, average anode effect duration and averaged anode effect over-voltage are production-weighted averages.

9. Averaged anode effect over-voltage in millivolts is <u>only</u> reported for Alcan Pechiney cell technology types AP18, AP30, growth versions of these two cell technologies (e.g. AP33, AP35) and applicable Alcan Pechiney technology SWPB (Side Worked Prebake) potlines. Over-voltage can also be reported as integrated anode effect over-voltage in units of mv.day per cell day. Over-voltage is reported as either positive or algebraic according to the following definitions:
   a. Positive Anode Effect Over-voltage is the sum of the product of time and voltage <u>above</u> the pot target operating voltage (corresponding to the target resistance), divided by the time over which the data are collected (hour, shift, day, month etc.).
   b. Algebraic Anode Effect Over-voltage is the sum of the product of time and voltage <u>above and below</u> the pot target operating voltage (corresponding to the target resistance), divided by the time over which the data are collected (hour, shift, day, month etc.).

10. Section 3 is completed only if PFC emissions have been directly measured and the resulting CF_4 emissions coefficient and C_2F6/CF_4 weight fraction are applicable for production for the year being reported (in accordance with the USEPA/IAI *Protocol for Measurement of Tetrafluoromethane (CF4) and Hexafluoroethane (C2F6) Emissions from Primary Aluminum Production* - **http://www.epa.gov/aluminum-pfc/documents/measureprotocol.pdf**. The directly measured emissions, and hence also the calculated emission coefficients, are to take account of both duct and fugitive emissions. Emission rates and emission coefficients are reported to two decimal places.

11. If Anode Effect and PFC Emissions Measurement data (where appropriate) has been verified by a Third Party (e.g. auditor, regulatory authority) then please fill in details of the verifying body (fields a-d). If third party verification of the data has not occurred then please request internal verification of the data submitted by a senior manager and fill in their details in fields (a, b & d).

PFC001.09/26.11.08

SDI Survey

Sustainable Development Indicators Survey 2008

* 2008 data
* White fields require input
* Grey fields are autocalculated data
* Yellow fields are autocalculated normalised data (which can be amended to include manually entered data instead of white fields)

Please enter your company name:

Corporate

Activity	Total Number of Facilities	Number of facilities with a formal and documented EHS Management System in place?	Number of facilities with ISO 14001 certification?	Number of facilities with OHSAS 18000 certification?	Percentage of facilities with a formal and documented EHS Management System in place?
Bauxite Mining					0.0%
Alumina Refining					0.0%
Primary Aluminium Smelting					0.0%

Activity	Total Number of Facilities	Number of facilities with Hazard Identification, Risk Assessment, Risk Control (HIRARC) and Employee Health Assessment Programmes? (see note for target conditions) Reporting Guidelines - HIRARC	Number of facilities with at least 2 ongoing health-related community initiatives? (see note for target conditions) Reporting Guidelines - Commu	Percentage of facilities with HIRARC and Employee Health Assessment Programmes?	Percentage of facilities with HIRARC and Employee Health Assessment Programmes?
Bauxite Mining				0.0%	0.0%
Alumina Refining				0.0%	0.0%
Primary Aluminium Smelting				0.0%	0.0%

Refining

Refinery Name	Metallurgical Alumina Production (dry tonnes)	Fresh Water Input (m³)

Smelting

Smelter Name	Technology type	Primary Aluminium Production (tonnes)	Fresh Water Input (m³)	Particulate Fluoride Emissions (tonnes)	Gaseous Fluoride Emissions (tonnes)	Particulate Fluoride Emissions (kg/tonne Al)	Gaseous Fluoride Emissions (kg/tonne Al)
						0	0
						0	0

Smelter Name	Technology type	Primary Aluminium Production (tonnes)	Spent Pot Lining (SPL) from normal operations recycled externally (tonnes)	Spent Pot Lining (SPL) from normal operations deposited with treatment (tonnes)	Spent Pot Lining (SPL) from normal operations deposited without treatment (tonnes)	Spent Pot Lining (SPL) from normal operations stored (tonnes)	Spent Pot Lining (SPL) generated from normal operations (tonnes)
							0
							0

Smelter Name	Technology type	Primary Aluminium Production (tonnes)	Spent Pot Lining (SPL) from potline closures recycled externally (tonnes)	Spent Pot Lining (SPL) from potline closures deposited with treatment (tonnes)	Spent Pot Lining (SPL) from potline closures s deposited without treatment (tonnes)	Spent Pot Lining (SPL) from potline closures stored (tonnes)	Spent Pot Lining (SPL) generated from potline closures (tonnes)
							0
							0

International Aluminium Institute Confidential Return **IAI**

ELECTRICAL ENERGY USED IN PRIMARY ALUMINIUM SMELTING **FORM ES001**

Annual Report for: Due Date:

Please read the Reporting Guidelines on page 3 very carefully before completing this form.

1. Smelter

   Location of Smelter ……………………

2. Cell Technology

   Cell Technology Category ……………………

3. Primary Aluminium Production

   Production Relating to this Smelter and Cell Technology [ ] Tonnes

4. Electrical Energy Used for Smelting ($a \approx b + c$)

   a. Total AC Relating to this Smelter and Cell Technology [ ] MWh

   Exclude electrical energy used in anode production and casting. Include electrical energy lost in AC/DC rectification, and the electrical energy used by associated auxiliaries (e.g. pollution control equipment, compressed air generation, heating and lighting See Reporting Guidelines 2 and 3.

   b. Technological Electrical Energy (AC) [ ] MWh

   Include electrical energy for smelting processes and electrical energy lost in AC/DC rectification. Exclude electrical energy used in anode production and casting and the electrical energy used by associated auxiliaries (e.g. pollution control equipment, compressed air generation, heating and lighting).

   c. Electrical Energy for Auxilliary Processes (AC) [ ] MWh

   Exclude electrical energy used in anode production and casting, technological electrical energy for smelting processes and electrical energy lost in AC/DC rectification. Include electrical energy used by smelting associated auxiliaries (e.g. pollution control equipment, compressed air generation, point feeders, heating and lighting).

   d. Electrolysis Electrical Energy (DC) [ ] MWh

   Include DC electrical energy for electrolysis only.

---

5. Electrical Energy Used for Smelting

   Table 1 – Relating to this Smelter and Cell Technology (From 4a above)

Energy Source	Electrical Energy Used for Primary Aluminium Smelting (GWh)			
	Self generated	Purchased		Total
	(a)	From National or Regional Grid (b)	From Other Sources (c)	(d) = (a) + (b) + (c)
Hydro				
Coal				
Oil				
Natural Gas				
Nuclear				
Total				

6. Self-Generated Electrical Energy

(Only complete this Section if appropriate)

a. Table 2 – Total Electrical Energy Self-Generated (See Reporting Guideline 4)

Energy Source	Electrical Energy Self-Generated (GWh)			
	Used in Operating the Smelter		Used for Other Purposes	Total
	As Reported in Table 1 for Smelting (a) From Table 1	Other Smelter Operations (e)	(f)	(g) = (a) + (e) + (f)
Hydro				
Coal				
Oil				
Natural Gas				

Note that "Other Smelter Operations" include anode production and casting

b. Table 3 – Quantities of Fuel Used (See Reporting Guidelines 5 and 6)

Energy Source (Fuel)	Total Electrical Energy Self-Generated (GWh) (g) From Table 2	Quantity of Fuel Consumed In Generating Electrical Energy (h)	Calorific Value Of Fuel (j)	Fuel Energy Consumed In Generating Electrical Energy (k) = (h) x (j) x 10^{-9}
Coal		kg	kJ/kg	TJ
Oil		kg	kJ/kg	TJ
Natural Gas		m^3	kJ/m^3	TJ

Reported by:

Name: Tel No:

Appointment Fax No:

Company: E-Mail:

Date:

Please return completed form by email or fax to:

Marlen Bertram
International Aluminium Institute
London SW1Y 4TE, United Kingdom

Tel No: + 44 20 7930 0528
Fax No: + 44 20 7321 0183
E-Mail: **bertram@world-aluminium.org**

ELECTRICAL ENERGY USED IN PRIMARY ALUMINIUM SMELTING **FORM ES001**

Reporting Guidelines

1. Primary aluminium production reported in Section 3 is molten (liquid) aluminium as tapped from the pots. It is reported in tonnes (metric tons) and is that production appropriate to the specified smelter and cell technology.

2. Electrical energy reported for smelting is energy used for electrolysis and all associated smelter auxiliaries up to the point where the molten aluminium is tapped from the pots. It includes electrical energy lost in rectification from AC to DC and energy used for pollution control, compressed air generation, heating and lighting. It excludes electrical energy used for anode production (reported on sister Form ES001A) and electrical energy used in the casting plant (reported on sister Form ES001D). If separate forms are completed for Söderberg and prebake technologies employed at the smelter, then the electrical energy included for non-electrolysis functions such as heating and lighting is, if not precisely known, to be an appropriate proportion of the relevant total.

3. The electrical energy reported in Table 1 is that used to produce the quantity of primary aluminium stated in Section 3.

4. The self-generated electrical energy reported in Table 2 is the total electrical energy self-generated at the smelter or associated power plant. It includes the self-generated electrical energy reported in Table 1; that used for other smelter operations (e.g. in carbon, casting and administrative areas and, if the smelter employs both Söderberg and prebake technologies, that reported in Table 1 of the second, associated Form ES001); and that used for other purposes (i.e. purposes unconnected with the actual operation of the smelter, such as the supply of power to the local community or for desalination).

5. The quantities of fuel reported in Table 3 are those used to produce the self-generated electrical energy reported in Table 2. The quantities of fuel entered in Table 3 are reported in the units indicated. If conversion from other units is necessary, then the Form is annotated to show the original units and the conversion factors used. Any conversion of units is carried out as precisely as possible but conversion factors given in the IAI Energy Returns Data Sheet are used as default values.

6. In Table 3, the reported calorific value of the fuel is ideally the actual average gross calorific value of the fuel. If the actual average gross calorific value of a fuel is not known, then the appropriate default value given in the IAI Energy Returns Data Sheet is used. If fuel is supplied by energy content: the 'Fuel Energy Consumed' column is completed first; a precise or default calorific value is entered in the 'Calorific Value of Fuel' column; hence the equivalent quantity of fuel is calculated and entered in the 'Quantity of Fuel Consumed' column; and finally a circle is drawn around the quantity of fuel consumed figure to indicate that it has been calculated from its energy content.

26.11.08
ES001.4

Refinery Energy Survey (ES011)

International Aluminium Institute Confidential Return **IAI**

ENERGY USED IN METALLURGICAL ALUMINA PRODUCTION **FORM ES011**

Annual Report for: Due Date:

Please read the Reporting Guidelines on page 4 very carefully before completing this form.

1. Refinery
   Location of Refinery ______________________

2. Metallurgical Alumina Production
   Quantity of Metallurgical Alumina Produced [   ] Tonnes
   (As nominal aluminium oxide (Al_2O_3))

PART 1 – PRODUCTION OF HYDRATE

3. Energy Used for Hydrate Production (Do NOT include energy used to produce Chemical Alumina)
   a. Table 1 – Energy from Fuel used for Direct Heating and to produce Self-Generated Electricity

Energy Source (Fuel)	Quantity of fuel Consumed (a)	Calorific Value of Fuel (b)	Fuel Energy Consumed (c) = (a) x (b) x 10^{-9}
Coal	kg	kJ/kg	TJ
Heavy oil	kg	kJ/kg	TJ
Diesel oil	kg	kJ/kg	TJ
Gas	m^3	kJ/m^3	TJ
Other (e.g. purchased steam)		kJ/unit	TJ

Please specify "Other" fuel type and units of quantity. If "Other" fuel type is purchased steam, then please state the fuel (for example, coal) used to produce the steam. ______________________

b. Table 2 – Energy from Purchased Electricity

Energy Source (Fuel)	Electrical Energy Consumed (d)	Conversion Factor (e)	Fuel Energy Consumed in Generating Electrical Energy Consumed (f) = (d) x (e) x 10^{-9}
Hydro	kWh	3600 kJ/kWh	TJ
Coal	kWh	kJ/kWh	TJ
Oil	kWh	kJ/kWh	TJ
Natural Gas	kWh	kJ/kWh	TJ
Nuclear	kWh	3600 kJ/kWh	TJ

PART 2 – CALCINATION

4. Energy Used for Calcination (Do NOT include drying energy used to produce Chemical Alumina)

a. Table 3 – Energy from Fuel used for Direct Heating and to produce Self-Generated Electricity

Energy Source (Fuel)	Quantity of fuel Consumed (a)	Calorific Value of Fuel (b)	Fuel Energy Consumed (c) = (a) x (b) x 10^{-9}
Coal	kg	kJ/kg	TJ
Heavy oil	kg	kJ/kg	TJ
Diesel oil	kg	kJ/kg	TJ
Gas	m^3	kJ/m^3	TJ
Other		kJ/unit	TJ

Please specify "Other" fuel type and units of quantity ______________________

b. Table 4 – Energy from Purchased Electricity

Energy Source (Fuel)	Electrical Energy Consumed (d)	Conversion Factor (e)	Fuel Energy Consumed in Generating Electrical Energy Consumed (f) = (d) x (e) x 10^{-9}
Hydro	kWh	3600 kJ/kWh	TJ
Coal	kWh	kJ/kWh	TJ
Oil	kWh	kJ/kWh	TJ
Natural Gas	kWh	kJ/kWh	TJ
Nuclear	kWh	3600 kJ/kWh	TJ

PART 3 – SURPLUS ENERGY EXPORTED FROM SITE

5. Surplus Energy Exported from Site
(Only complete this Section if appropriate)

Table 5 – As Electricity or Steam

Energy Source (Fuel)	Quantity of fuel Consumed (a)	Calorific Value of Fuel (b)	Fuel Energy Consumed (c) = (a) x (b) x 10^{-9}
Coal	kg	kJ/kg	TJ
Heavy oil	kg	kJ/kg	TJ
Diesel oil	kg	kJ/kg	TJ
Gas	m^3	kJ/m^3	TJ
Other		kJ/unit	TJ

Please specify "Other" fuel type and units of quantity ______________________

Reported by:
Name:
Appointment: Tel No:
Company: Fax No:
Address: E-Mail:
Date:

Please return completed form to:
Deputy Secretary General
International Aluminium Institute
New Zealand House
Haymarket
London SW1Y 4TE
United Kingdom

Tel No: + 44 20 7930 0528
Fax No: + 44 20 7321 0183
E-Mail: bertram@world-aluminium.org

ENERGY USED IN METALLURGICAL ALUMINA PRODUCTION **FORM ES011**

Reporting Guidelines

1. Metallurgical alumina production is the quantity of metallurgical (smelter) grade alumina produced during the reporting year. It is reported in tonnes (metric tons) as nominal aluminium oxide (Al_2O_3). The Reporting Guidelines to Form 600 (Alumina Production) provide a definition of nominal aluminium oxide if required.

2. The material quantities and the fuel and electrical energy quantities reported in Part 1 are the quantities used to produce the hydrate that is subsequently calcined to produce the reported quantity of metallurgical alumina. The fuel and electrical energy quantities reported in Part 2 are the quantities used for calcination.

3. Energy reported for hydrate production in Tables 1 and 2 is all energy used within the plant perimeter associated with the relevant hydrate production. It includes energy used in the Bayer process and in all auxiliary operations on-site that are directly connected with the relevant hydrate production. Energy reported for calcination in Tables 3 and 4 is all energy used within the plant perimeter associated with the calcination of hydrate to produce metallurgical alumina. Reported energy excludes energy used for external activities such as mining, shipping, harbour operations, use of motor vehicles and railway operations.

4. The quantities of fuel reported in Tables 1 and 3 are those quantities of fuel used for on-site direct heating combined, if applicable, with the quantities of fuel used to self-generate or cogenerate electrical energy for on-site use. If surplus electricity or steam is exported from the site, the fuel relating to these exported quantities is not included in Table 1, but is reported in Table 5.

5. Electricity that is purchased is reported in Tables 2 and 4. If a precise conversion factor (kJ of fuel energy consumed per kWh of electrical energy generated) is not known, then the default value given in the IAI Energy Returns Data Sheet is used.

6. The fuel relating to the production of surplus electricity or steam exported from the site is reported separately in Table 5.

7. The quantities of fuel entered in Tables 1, 3 and 5 are reported in the units indicated. If conversion from other units is necessary, then the Form is annotated to show the original units and the conversion factors used. Any conversion of units is carried out as precisely as possible but conversion factors given in the IAI Energy Returns Data Sheet are used as default values.

8. In Tables 1, 3 and 5, the reported calorific value of the fuel is ideally the actual average gross calorific value of the fuel. If the actual average gross calorific value of a fuel is not known, then the appropriate default value given in the IAI Energy Returns Data Sheet is used. If fuel is supplied by energy content: the 'Fuel Energy Consumed' column is completed first; a precise or default calorific value is entered in the 'Calorific Value of Fuel' column; hence the equivalent quantity of fuel is calculated and entered in the 'Quantity of Fuel Consumed' column; and finally a circle is drawn around the quantity of fuel consumed figure to indicate that it has been calculated from its energy content.

22.02.08

ES011.5

Energy Data Sheet (ES001 & ES011)

International Aluminium Institute Confidential Return **IAI**

IAI ENERGY RETURNS DATA SHEET

1. Fuel Calorific Values
   (Default values to be used when precise values are not known)

Energy Source	Default Calorific Value (kJ/kg or kJ/m^3 for Gas)							
	Area 1 Africa	Area 2 North America	Area 3 Latin America	Area 4 East Asia	Area 5 South Asia	Area 6A West Europe	Area 6B East/Central Europe	Area 7 Oceania
Coal	25 728	23 497	23 312	21 422	23 238	24 237	18 386	21 515
Heavy Oil	42 176	41 868	42 860	42 077	42 695	41 868	42 287	41 868
Diesel Oil	42 176	41 868	42 860	42 077	42 695	41 868	42 287	41 868
Gas	40 000	38 200	38 000	39 300	39 300	37 800	37 700	38 200

2. Electrical Energy Generation Conversion Factors
   (Default values to be used when precise values are not known)

Electrical Energy Source	Default Electrical Energy Generation Conversion Factor (kJ/kWh)							
	Area 1 Africa	Area 2 North America	Area 3 Latin America	Area 4 East Asia	Area 5 South Asia	Area 6A West Europe	Area 6B East/Central Europe	Area 7 Oceania
Coal	12 758	10 680	12 939	8 321	12 107	13 498	18 784	15 286
Oil	9 033	8 156	11 776	8 335	12 103	9 018	27 180	11 140
Natural Gas	8 962	6 533	16 837	8 756	10 899	10 529	28 360	10 806

3. Unit Conversion Factors
   (Specific Gravity values for oil are default values to be used when precise values are not known)

Category	Conversion Factors		
Weight	1 kg	=	2.20462 lb
	1 lb	=	0.4536 kg
Volume	1 m^3	=	35.3147 ft^3
	1 ft^3	=	0.0283168 m^3
	1 US Gallon	=	3.7854 litres
	1 UK Gallon	=	4.546 litres
Energy	1 J	=	0.2388 cal
	1 cal	=	4.187 J
	1 kJ	=	0.948 Btu
	1 Btu	=	1055 J
	1 Therm	=	100 000 Btu
	1 kWh	=	3600 kJ
Oil (Volume)	1 Barrel	=	42 US gallons
		=	34.97 UK gallons
		=	159 litres
Oil (Specific Gravity)	1 litre Fuel Oil (Heavy)	=	0.96 kg
	1 litre Fuel Oil (Light)	=	0.87 kg
	1 litre Diesel Oil	=	0.87 kg
	1 litre Gas Oil	=	0.87 kg

03.02.04