

Results of the 2017 Anode Effect Survey

Report on the Aluminium Industry's Global
Perfluorocarbon Gases Emissions

30 July 2018



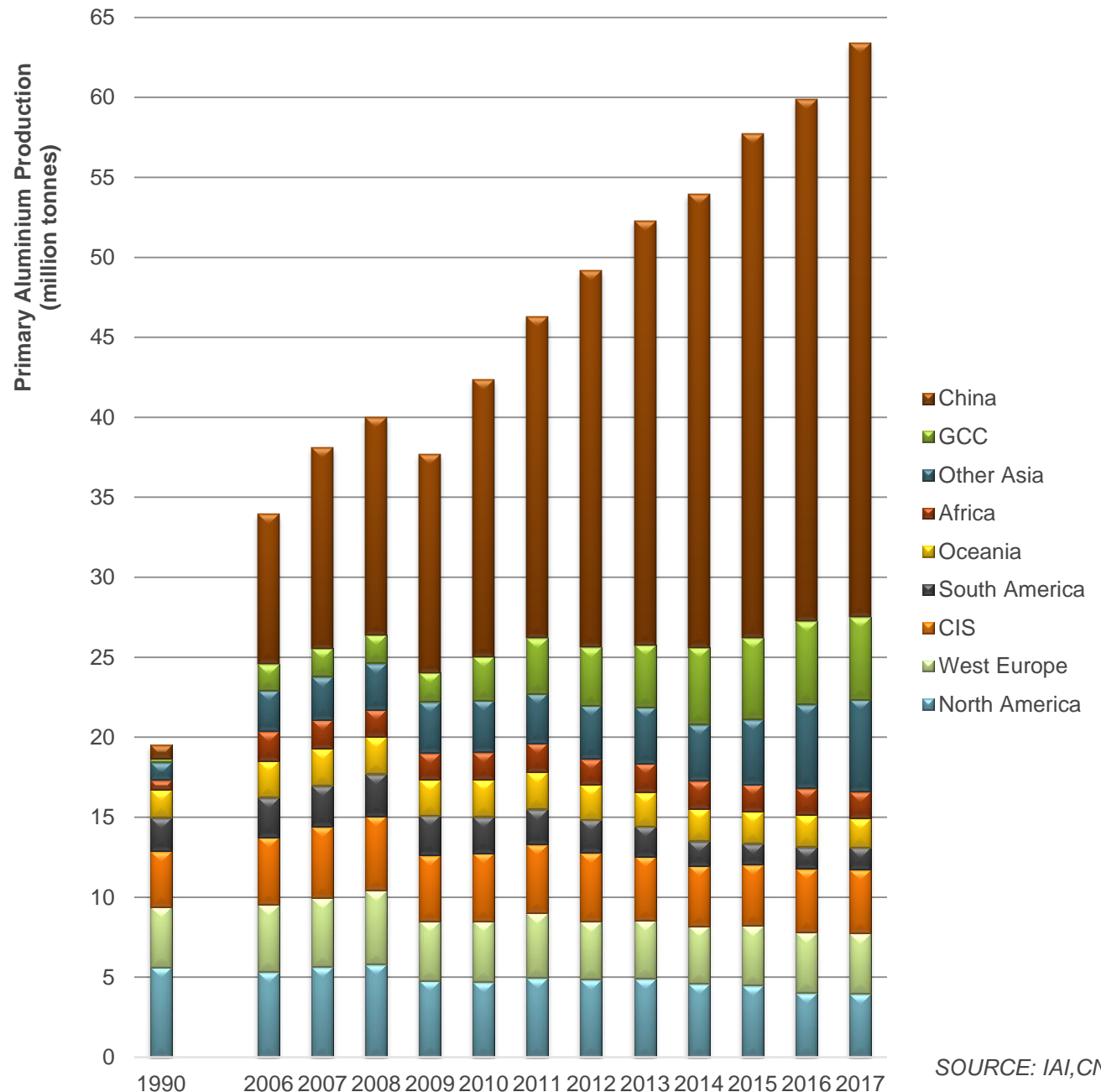
Contents

- *Industry Summary*
- *2017 Anode Effect Survey*
- *Global Emissions Estimations*
- *Conclusion*

INDUSTRY SUMMARY

Industry Trend

- Growth in primary aluminium production continues to be driven by countries in Asia, particularly China;
- 2017 global primary aluminium production is over 63 million tonnes, and China has contributed about 57%;
- Among all technologies, PFPB kept increasing and the rest were decreasing.



2017 ANODE EFFECT SURVEY

Survey Methodology

- The IAI Anode Effect Survey requests all aluminium smelting facilities to report data by potline (where possible), via IAI member companies, direct correspondence with non-member producers and regional industry associations. The reporting form and guidelines (*PFC001*) can be found from the IAI website (http://www.world-aluminium.org/media/filer_public/2018/07/31/pfc001_version2018.xls).
- Data calculation follows 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3, Chapter 4, Section 4.4 --- Primary Aluminium Production, (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf)
- Carbon dioxide equivalent (CO_2e) emissions for survey participants are calculated by multiplying the total tonnes of each PFC component gas by the Global Warming Potential (GWP) values reported in the IPCC 4th Assessment Report (i.e. 7,390 for CF_4 and 12,200 for C_2F_6).

2017 Anode Effect Survey participation by technology

| TECHNOLOGY | 2017 primary aluminium production (1,000 tonnes) | 2017 production represented in survey (1,000 tonnes) | 2017 participation rate by production | |
|---------------------------------------|--|--|--|-----|
| CWPB | 821 | 432 | 53% | |
| PFPB (Rest of World) | 22,935 | 15,992 | 70 % | 27% |
| PFPB (China) | 35,905 | 0 | 0 % | |
| SWPB | 393 | 393 | 100 % | |
| VSS | 3,277 | 3,277 | 100 % | |
| HSS | 73 | 73 | 100 % | |
| All Technologies (excluding China) | 27,499 | 20,167 | 73 % | |
| All Technologies (Including China) | 63,404 | 20,167 | 32 % | |

Note: any inconsistencies due to rounding

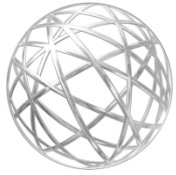
Perfluorocarbon emission results from facility data reporting to the 2017 Anode Effect Survey

| Technology | IPCC Tier | No. of reporting entities | Reported production (kt Al) | Total CF ₄ emissions (Gg CF ₄) | Total C ₂ F ₆ emissions (Gg C ₂ F ₆) | Median CF ₄ intensity (kg CF ₄ /t Al) | Median C ₂ F ₆ intensity (kg C ₂ F ₆ /t Al) | Mean C ₂ F ₆ : CF ₄ weight ratio | IPCC 4 th GWP | | |
|------------|-----------|---------------------------|-----------------------------|---|---|---|---|---|--|---|---|
| | | | | | | | | | Total PFC emissions (kt CO ₂ e) | Median PFC intensity (t CO ₂ e/t Al) | Mean PFC intensity (t CO ₂ e/t Al) |
| CWPB | 2 | 2 | 432 | 0.009 | 0.001 | 0.018 | 0.002 | 0.12 | 76 | 0.16 | 0.17 |
| | 3 | 0 | | | | | | | | | |
| PFPB | 2 Slope | 46 | 5,654 | 0.121 | 0.014 | 0.313 | 0.104 | 0.10 | 2,502 | 0.15 | 0.16 |
| | 3 Slope | 37 | 7,487 | 0.109 | 0.009 | | | | | | |
| | 2 OV | 11 | 1,666 | 0.037 | 0.004 | | | | | | |
| | 3 OV | 5 | 1,185 | 0.024 | 0.002 | | | | | | |
| SWPB | 2 | 1 | 39 | 0.016 | 0.004 | 0.315 | 0.090 | 0.32 | 1,150 | 3.96 | 2.93 |
| | 3 | 2 | 353 | 0.086 | 0.028 | | | | | | |
| VSS | 2 | 18 | 726 | 0.096 | 0.005 | 0.131 | 0.007 | 0.06 | 2,824 | 1.05 | 0.86 |
| | 3 | 51 | 2,251 | 0.254 | 0.015 | | | | | | |
| HSS | 2 | 4 | 73 | 0.010 | 0.001 | 0.133 | 0.011 | 0.09 | 81 | 1.12 | 1.11 |
| | 3 | 0 | 0 | 0 | 0 | | | | | | |
| ALL | - | 177 | 20,167 | 0.761 | 0.083 | - | - | 0.11 | 6,633 | - | 0.33 |

Note: any inconsistencies due to rounding

Note: any inconsistencies due to rounding

GLOBAL EMISSIONS ESTIMATIONS



Estimation of Emissions from Non-reporting Facilities

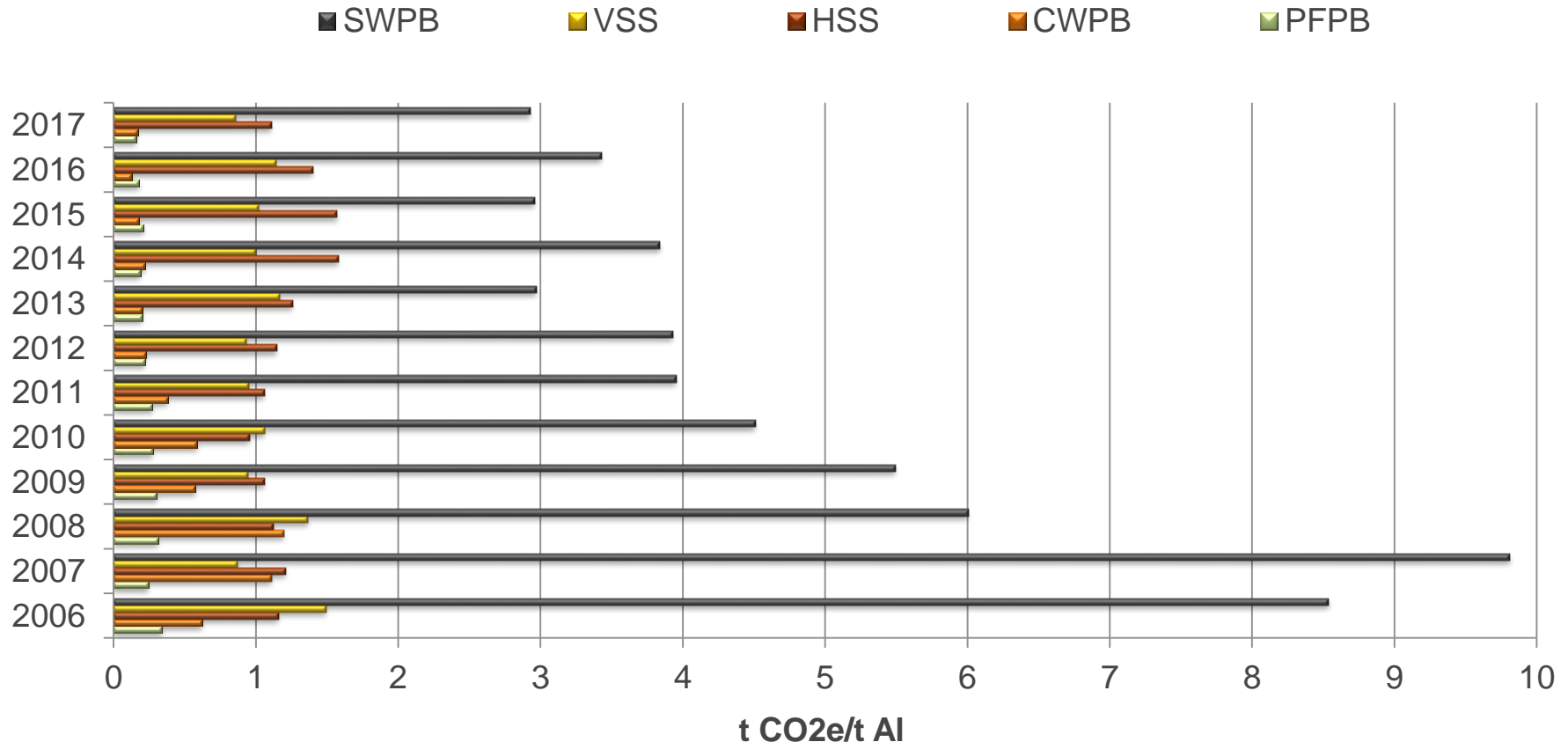
China

- Latest measurement (2008-2013) of PFC emissions at 27 PFPB facilities in China is adopted
- Median emission factor = 0.80 t CO₂e /t Al
- CF₄ median = 0.100 kg/t Al;
- C₂F₆:CF₄ weight fraction = 0.046

Rest of World

- Median PFC emissions performance per technology from the survey result is applied to non-reporting production by technology

Median PFC emission rates (as CO₂e) of reporting entities, per technology, 2006-2017



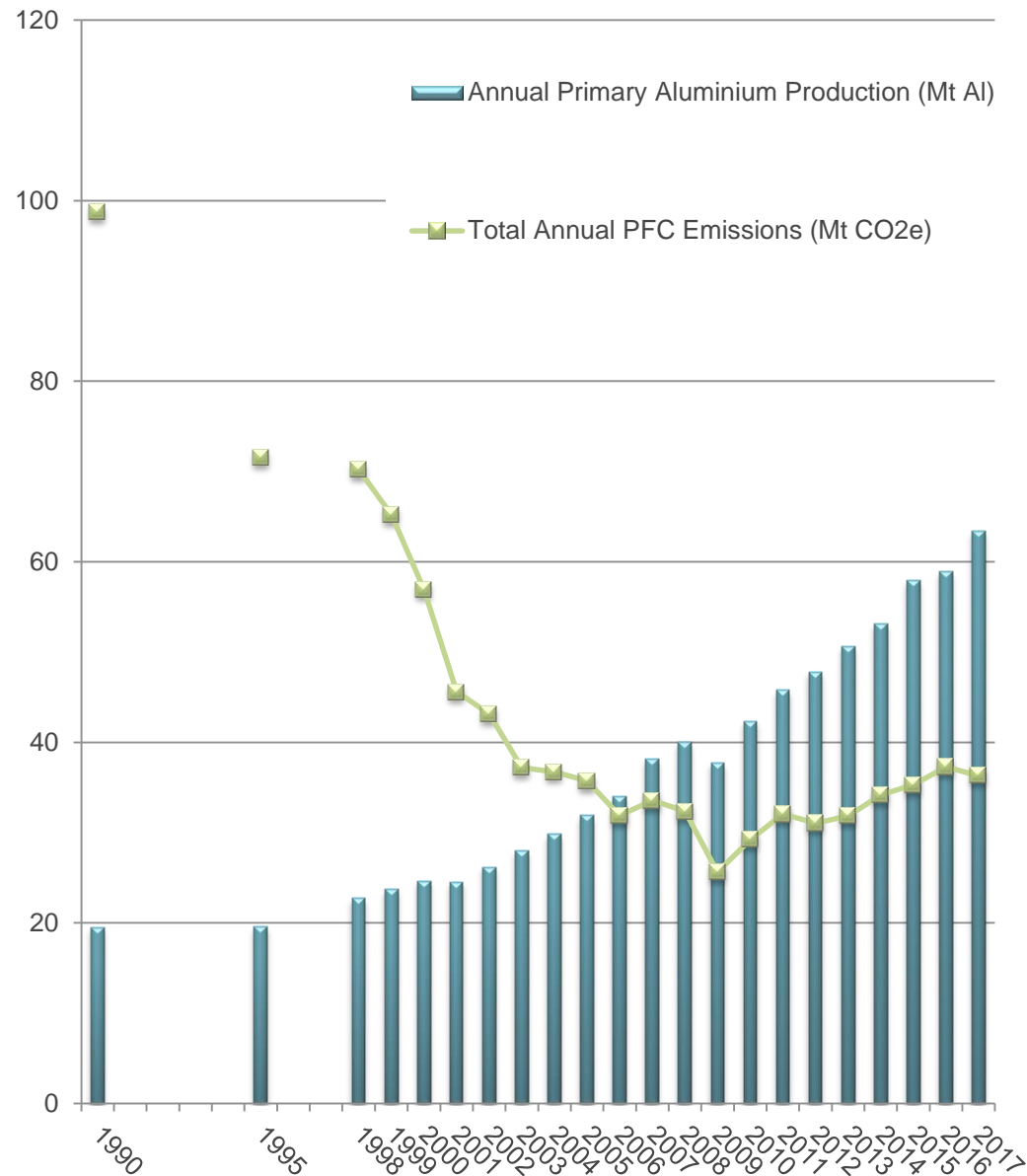
Total global 2017 PFC emissions

| | Total PFC emissions (1,000 t CO ₂ e) | Total aluminium production (1,000 tonnes) | PFC emission factor (t CO ₂ e/t Al) |
|-------------------------------|--|--|---|
| | | | IPCC 4 th GWP |
| Reported | 6,633 | 20,167 | 0.33 |
| Calculated from non-reporters | 29,683 | 43,237 | 0.69 |
| TOTAL GLOBAL | 36,316 | 63,404 | 0.57 |

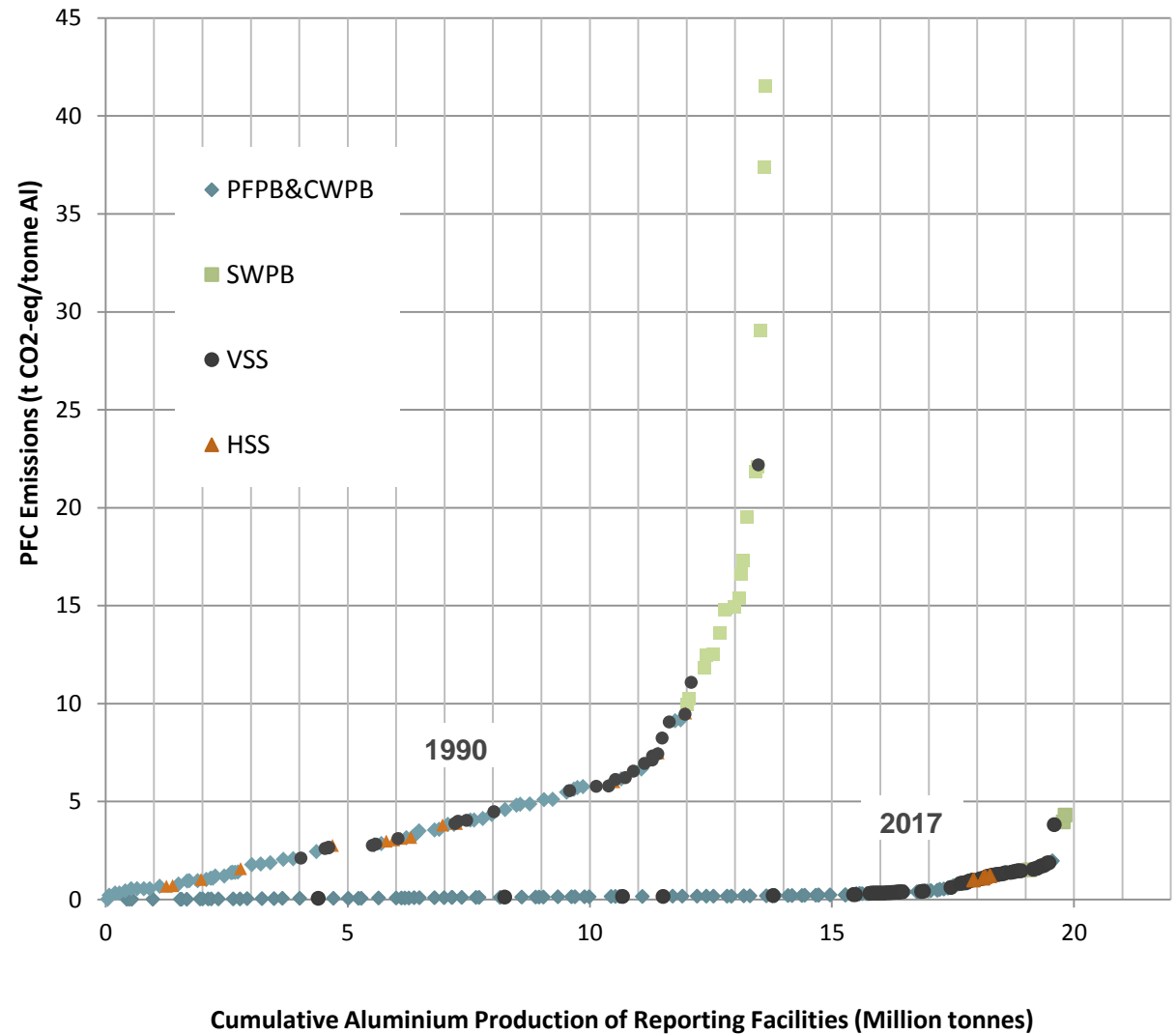
CONCLUSION

With PFC emissions per tonne cut by almost 90% since 1990 and primary aluminium production having grown by over 200% over the same period, absolute emissions of PFCs by the aluminium industry have been reduced from approximately 100 million tonnes of CO₂e in 1990 to 36 million tonnes in 2017, a fall of 63%.

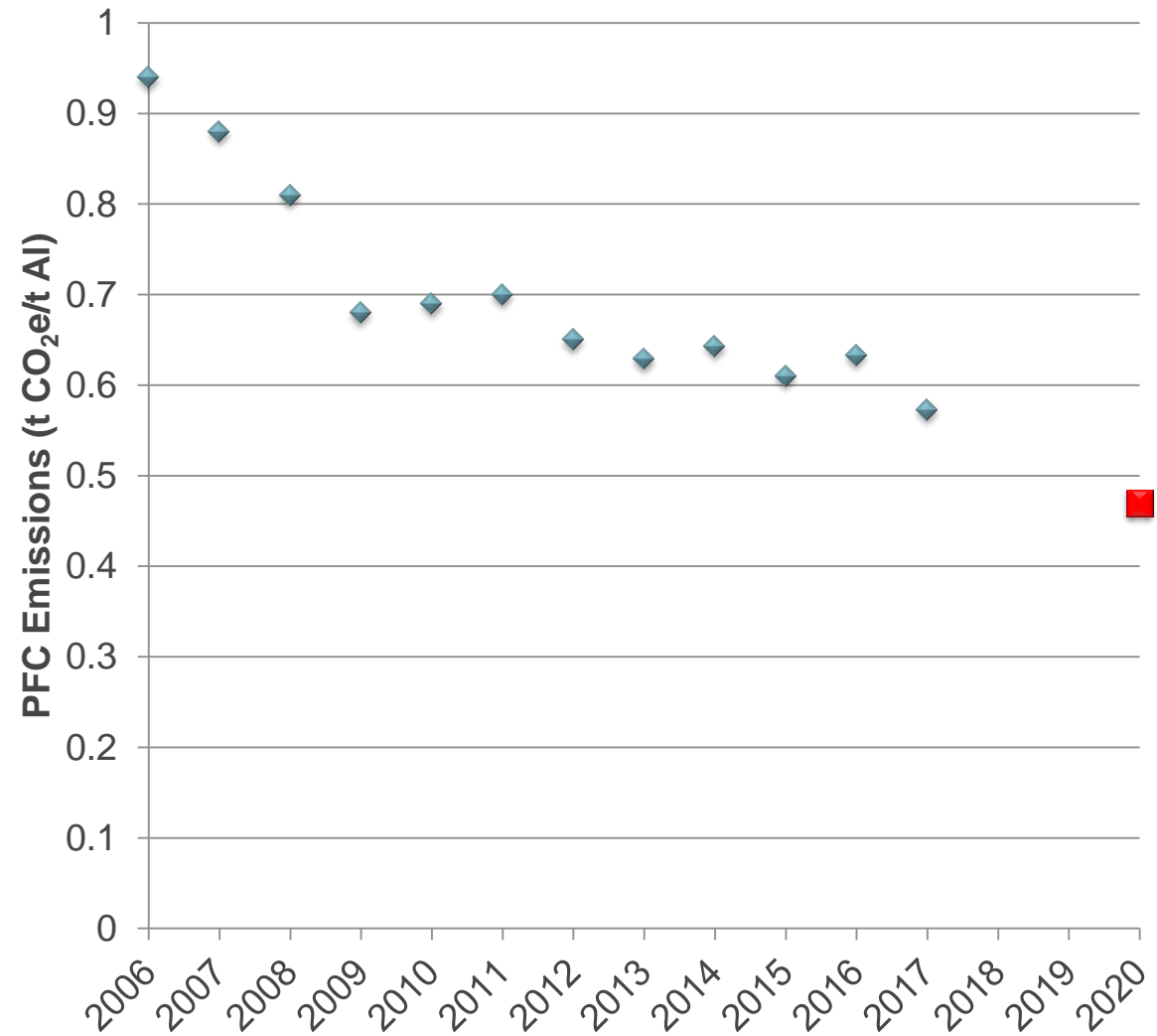
An increase in total emission estimates since 2009, however, reflects the growth in Chinese PFPB production. This has a high uncertainty given the low number of emission measurements (27 facilities) on which a Chinese average is based.



Taking the 1990 reporting cohort and plotting it against 2017 data shows improvement both from existing facilities over this time but also, importantly, the positive contribution of new (predominantly PFPB) capacity added since 1990.



- Global PFC emissions (as CO₂e) per tonne of production have been reduced by nearly 40% since 2006, by 89% since 1990
- The global PFC emission intensity remains stable since 2009 due to China, where emission intensity is based on an assumed average, majority of PFC emission is from this area, in correspondence to its significant aluminium production.



INTERNATIONAL ALUMINIUM INSTITUTE

3rd floor, 2 Duke Street

London SW1Y 6BN

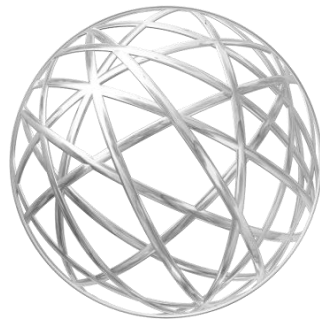
United Kingdom

Tel: + 44 (0) 20 7930 0528

Email: wu@world-aluminium.org

© International Aluminium Institute

A company limited by guarantee.
Registered in London no. 1052007



WORLD
ALUMINIUM