ADDDENDUM TO THE LIFE CYCLE INVENTORY DATA AND ENVIRONMENTAL METRICS FOR THE PRIMARY ALUMINIUM INDUSTRY

2015 DATA

FINAL

August 2018

Contents

1. Introduction

In 2017, The International Aluminium Institute (IAI), published the Life Cycle Inventory and Environmental Metrics Report for the Primary Aluminium Industry – 2015 Data (IAI 2017a).

This (2018) addendum to that report provides an update on follow-up work undertaken by the Institute, based on the 2015 life cycle inventory (LCI) dataset. A comprehensive overview of the initial data collection, collation and environmental impact analysis (based on modelled results using thinkstep's GaBi life cycle assessment software) is available in the full 2017 report, which should be read in conjunction with this addendum.

This addendum focuses on the integration of LCI data into third-party life cycle databases, GaBi and ecoInvent, and, importantly, improvements to the aluminium industry specific, upstream electricity datasets that are now available in the GaBi software, for use by LCA practitioners.

The IAI has collected data for use in LCAs from the global primary aluminium industry since the late 1990s, publishing LCI datasets from 1998, 2000, 2005, 2010 and 2015. The IAI aims to publish LCI data from primary aluminium production processes, from mining of bauxite ore to ingot manufacture, including: raw material inputs, energy use, emissions to air and water and solid waste generation. With the increasing importance of life cycle assessment as a tool for decision making, the need for up-to-date, robust inventory data is clear.

In 2017, the IAI published regionalised LCI datasets for the first time, to ensure that users have access to more specific data for analyses related to regional markets or for the modelling of specific inter-regional material flows (IAI 2017a). These LCI datasets provide production weighted mean data of the reporting sites and can also be used as benchmarks for individual companies to determine significant environmental aspects within their own processes. These regionalised datasets were reviewed by a panel of independent LCA experts (IAI 2017a) and published on the IAI website for public use in June 2017. As part of the impact assessment phase of the LCA, the new regional datasets, as well as regionalised power mixes and, where available, regionalised background data (e.g. Europe, Canada) were utilised and *example* impact scenarios of primary aluminium production from mine to casthouse were published.

2. Life Cycle Inventory Data

2.1. Integration of LCI Data

Regionalised primary aluminium LCI datasets were integrated into the GaBi and ecoInvent life cycle databases, two of the most widely used databases by LCA practitioners.

Between June 2017 and July 2018, IAI published LCI data for all major producing regions of the world, made available by region and unit process in three key locations:

1. IAI Website

Datasets are available to download as a *Microsoft Excel* file (Appendix A) attached to the 2015 Life Cycle and Environmental Metrics Report (2017): http://www.world-aluminium.org/publications/tagged/life%20cycle/

2. ecoInvent

Along with GaBi, ecoInvent is one of the most widely used databases by LCA practitioners. Datasets are available to registered users: https://www.ecoinvent.org/.

Existing ecoInvent 3.4 contains 2010 LCI datasets provided by IAI, with 2012 energy updates. ecoInvent 3.5, which has adopted the 2015 datasets from IAI, will be released in Q3 2018.

3. GaBi Database

Along with ecoInvent, GaBi is one of the most widely used databases by LCA practitioners. Datasets are available *on-demand* from thinkstep (fabian.bosch@thinkstep.com) for all GaBi Professional Database licence holders. Datasets will be available directly from GaBi Professional Database after the next annual update from thinkstep (Q1 2019).

The availability of some regional datasets differs due to the different data publishing requirements specified by the database (e.g. no regional cross-over). The data integrated into each database, however has all been derived from the IAI Website Publication (2017a).

Full Life Cycle (cradle-to-cradle) regional datasets for North America and Europe, along with accompanying analysis, is available from The Aluminum Association (http://www.aluminum.org/) and European Aluminium (https://www.european-aluminium.eu/).

Region Name	1. IAI Website	2. ecoInvent	3. GaBi	
	Unit Process	*Unit Process*	*Unit Process*	*Cradle to Gate*
Global	✓		✓	✓
Africa	✓	✓		
Asia ex China	✓	✓		
Canada	✓		✓	✓
China	✓	✓	✓	✓
Europe (EU28 & EFTA)	✓	✓	✓	
Gulf Cooperation Council	✓	✓	✓	✓
North America	✓	✓	✓	
Oceania	✓	✓	✓	
Russia and Other Europe	✓	✓	✓	✓
South America	✓	✓	✓	✓
Rest of the World		✓		

Table 1: IAI LCI regional dataset availability

2.2. Using the LCI Data

The LCI data in its most disaggregated form (i.e.by region and by unit process) allows LCA practitioners, with detailed knowledge about the aluminium supply chain, to model as accurately as possible the flow of material between regions from mine to casthouse.

For data extracted from the IAI website and the ecoInvent database, users should carefully consider the most representative electricity mix and dataset for modelling. Electricity is often the most significant influence on the impact results as the aluminium electrolysis process is an energy intensive process. Incorrect electricity dataset assumptions can greatly impact the representativeness of results. The aluminium industry electricity supply mix typically differs from the national or regional grid mix due to captive or directly delivered power supplies and as such, industry specific mixes should be applied (see Section 3.1). The aluminium industry mix in China for example is 90% coal and 10% hydropower compared to a grid mix of 70% coal and 30% hydropower.

In both GaBi and ecoInvent databases, the electrolysis process is available as a partly-aggregated dataset which includes a pre-defined electricity mix, applied to the relevant GaBi/ecoInvent electricity generation datasets and based on IAI published electricity consumption data (http://www.world-aluminium.org/statistics/primary-aluminium-smelting-power-consumption/).

Such pre-aggregation reduces issues for the practitioner regarding selection of the correct electricity mix or regional electricity generation dataset. In GaBi, data is also available in cradle-to-gate format for select regions (see Table 1). These datasets are fully aggregated, supply chain datasets from mine to casthouse with pre-defined background and ancillary processes included. These datasets are useful for practitioners who do not have specific information about the aluminium supply chain but require regionalised data for their studies.

3. Life Cycle Impact Modelling

The goal of the Life Cycle Impact Assessment (LCIA) phase, reported in (IAI, 2017a) was to evaluate potential environmental and human impacts of resource uses and releases as a result of the primary aluminium production process, as identified during the LCI phase. The system boundary was thus expanded to include environmental impacts of background or ancillary processes (e.g. electricity generation, lime production) from cradle to gate. IAI does not directly collect LCI data for such processes (other than their inputs to the IAI's LCI system boundary) and thus third-party, background datasets were used in the impact modelling phase. Five example regional scenarios and the global impact results were modelled using thinkstep's GaBi software.

	Bauxite Mining	Alumina Production	Anode production, Electrolysis and Casting
Scenario 1	China (CNA)	China (CNA)	China (CNA)
Scenario 2	Oceania (OCA)	Oceania (OCA)	China (CNA)
Scenario 3	South America (SAM)	Europe (EUR)	Europe (EUR)
Scenario 4	Oceania (OCA)	Oceania (OCA)	Gulf Cooperation Council
Scenario 5	South America (SAM)	North America (NAM)	Canada (CAN)

Table 1: Example regional scenarios considered for impact modelling

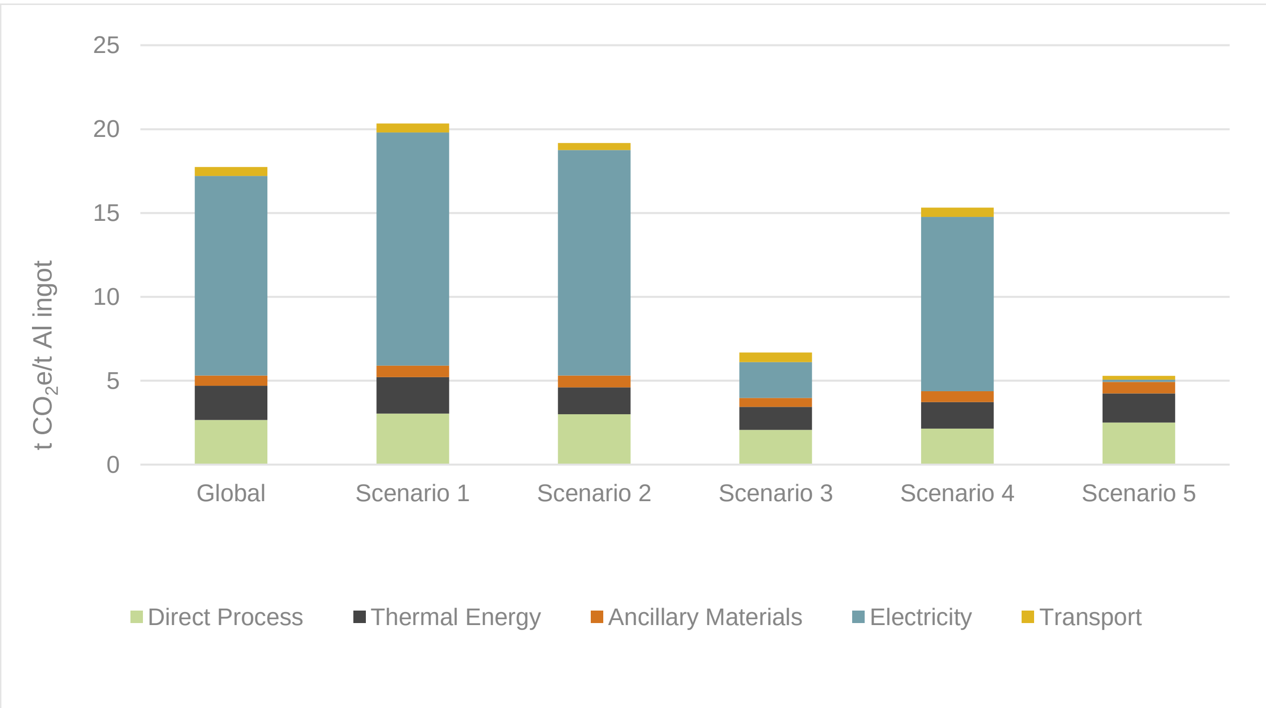

Figure 1: GWP results for example regional scenarios (IAI 2017a)

3.1. Background data: updating electricity datasets

Electricity is a significant input to the aluminium production process, and a significant contributor to its potential environmental impacts. Special attention is thus required when defining the electricity supply mix in the impact modelling phase. Usually the aluminium industry electricity supply mix differs from the national or regional grid mix due to captive or directly delivered power supplies. The significant influence of electricity on primary aluminium environmental impact results has been noted in previous studies (IAI 2014, 2017a). Although aluminium industry specific power mix data (http://www.world-aluminium.org/statistics/primary-aluminium-smelting-power-consumption) was used for the (IAI, 2017a) modelling (and is publicly available for use by practitioners), the lack of industry-specific, regional/country level electricity generation LCI datasets meant that for some regions, the impacts were significantly overestimated.

Limited availability of representative electricity generation datasets had a significant impact on results for aluminium producing regions dependent on thermal power generation for the electrolysis process (e.g. GCC, China). Impacts associated with electricity contributed approximately 70% to the overall global warming potential result (IAI 2017a). These newer regions of aluminium production typically have large scale, integrated operations adopting the best available and highly efficient technology which is often captured in the LCI data but not always adequately captured in regional background datasets such as electricity generation.

3.1.1. Gulf Cooperation Council: electricity from natural gas

The results for Scenario 4, which modelled primary aluminium production in the GCC, were significantly overestimated in IAI, 2017a, as a suitable regional proxy dataset for *electricity generation from natural gas* was not available in the GaBi Professional Database. The data available did not reflect the electricity consumed by the aluminium industry. The power stations in the GCC region that supply electricity for aluminium production are mostly using best available technology (and are often operated by the smelters themselves as captive plants). This challenge in the modelling phase highlighted the potential for inaccuracies in LCA results for studies on aluminium-containing products or processes, including metal sourced from the Gulf producers.

Consequently, the IAI commissioned an update to the *electricity generation from natural gas* dataset specifically for aluminium production in the Gulf region. The new dataset built upon existing electricity models within the GaBi database but crucially, incorporated the latest key data (e.g. efficiency) published by commercial gas turbine equipment suppliers to the power stations that supply the Gulf smelters. Estimates from gas turbine producers indicated emissions factors significantly lower (approximately 0.3-0.4kg CO_2e/kWh) than existing assumptions in the GaBi database (approximately 0.4-0.7kg CO_2e/kWh).

Using the new *electricity from natural gas dataset (aluminium industry)*, the impact results were recalculated (Figure 2) and cross checked directly with aluminium producers in the region. The modelled results are considered to be more representative of the impacts associated with aluminium production in the Gulf. The new dataset now has an estimate for emissions from electricity from natural gas of 0.4kg CO_2e/kWh. This revision resulted in a decrease in the result for global warming potential (from 15t CO_2e/t Al ingot to 11 CO_2e/t Al ingot) and depletion of fossil energy resources (from 183,000MJ/t Al ingot to 154,000MJ/t Al ingot). There were no material changes in the result for acidification potential, eutrophication potential, ozone layer depletion or photochemical ozone creation potential.

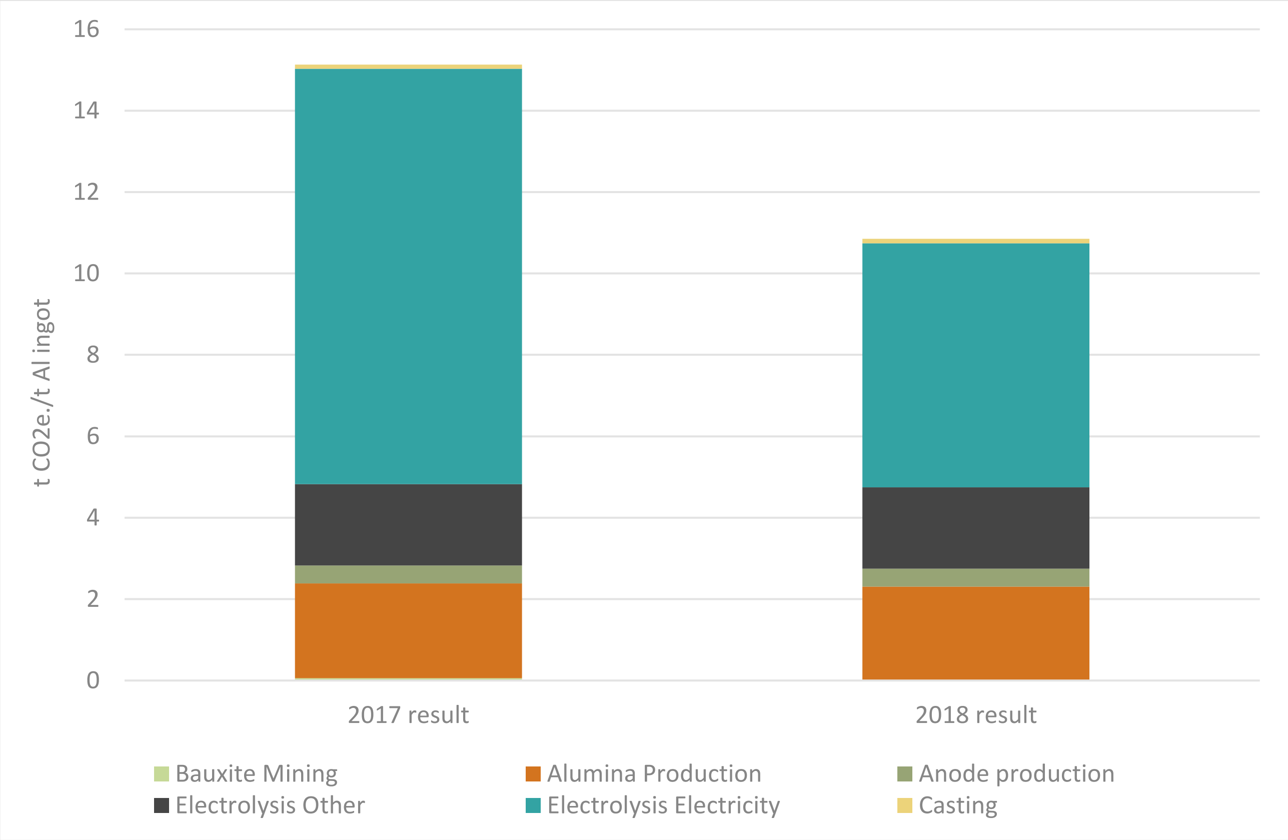

Figure 2: Scenario 4 (OCA-OCA-GCC) GWP result by unit process recalculated using new electricity dataset

3.1.2. China: electricity from hard coal

The significant shifts in the location of primary aluminium production over the past decade, have been accompanied by significant changes in the global power mix. Hotspot analysis has shown that increased aluminium production in China, of which 90% uses coal-fired electricity, has contributed to the increase in potential impact across the suite of indicator results. The significant and increasing influence that background datasets have had on LCIA results for primary aluminium necessitated further investigation of existing background data and models available to practitioners in life cycle software and data providers.

In 2016, IAI commissioned a project to understand the quality of background data available in existing life cycle databases, with a particular focus on Chinese electricity generation. As part of the project, a provincial level electricity supply model (IKE 2017, IAI 2017a) was produced to provide the flexibility needed to accurately reflect the existing and future spread of aluminium production across different provinces in China. The results of this study, which included key LCI data points for electricity generation by province, were shared with thinkstep to assist in updating the existing Chinese background electricity generation datasets for an aluminium context.

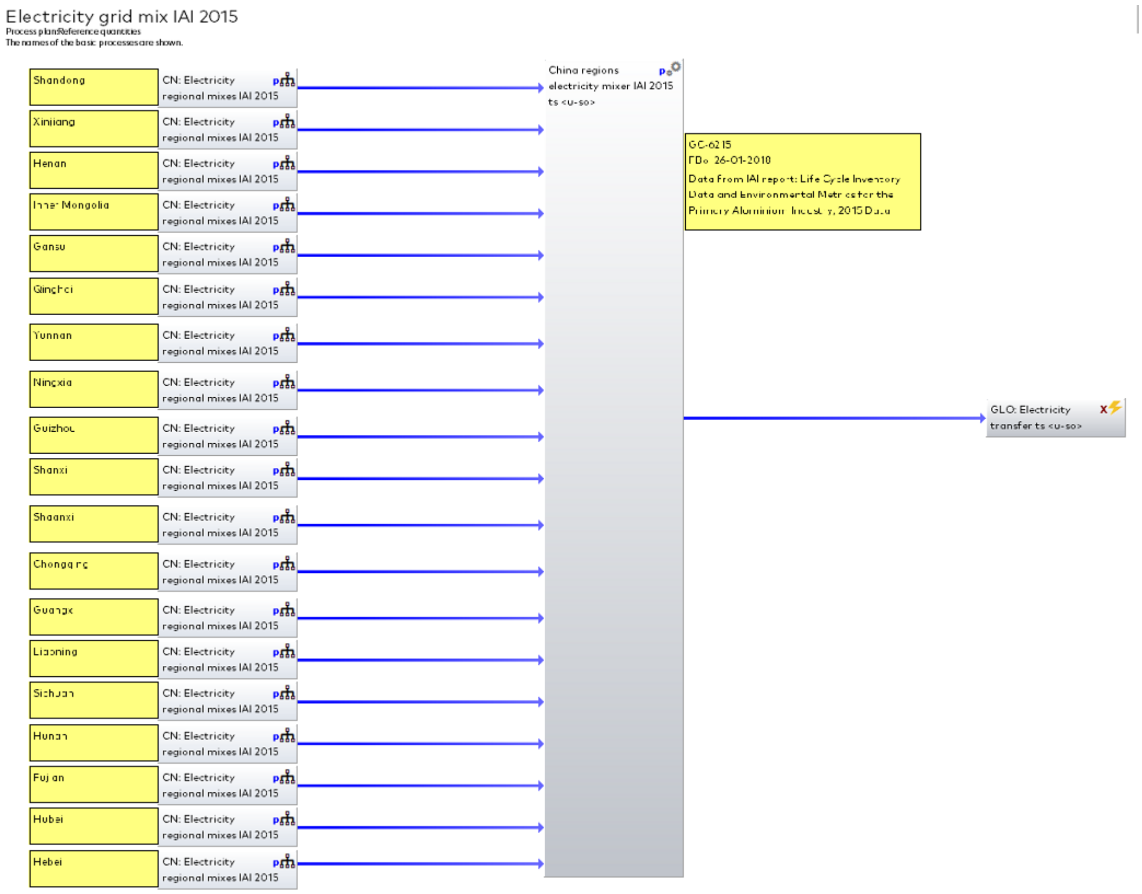

Figure 3: Plan view of new provincial level model for electricity generation for aluminium production in China in GaBi

Using the new China *electricity generation from hard coal* dataset, the GWP impact results were recalculated (Figure 4). The new results, although very close to the previous 2017 modelled result, are considered to be more representative of the impacts associated with aluminium production as aluminium production-weighted provincial averages were used rather than national averages. This ensures that the electricity dataset is representative of the electricity consumed by the industry rather than of electricity generation across the whole country. The development of the provincial level model also provides a high degree of flexibility and will allow for future changes in the aluminium industry at the provincial level to be better reflected in the dataset.

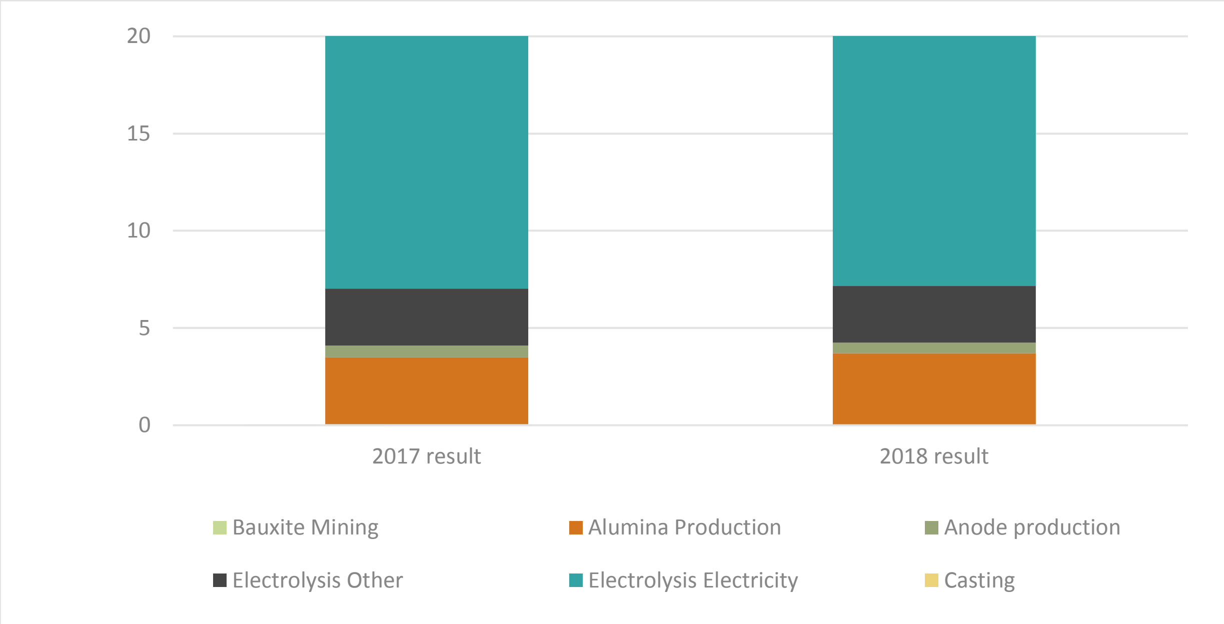

Figure 4: Scenario 1 (China) GWP result by unit process recalculated using new electricity dataset

3.2. Updating the global impact results

In 2017, the Gulf region accounted for approximately 8% of primary aluminium production, a slight decrease from 9% in 2015. China continued to be the largest producing region globally with over 56% of global production, up from 55% in 2015. These two key production hubs have a significant influence on the global or sector-wide impact indicator results (Table 2) and as such, the global results have been recalculated, with the 2017 regional production weightings, to take into consideration some of the key changes outlined above.

At the global level, the relative contribution of the process categories compared to the previous results show some differences. The contribution of electricity to the GWP impact indicator result has been reduced from 67% to 64%. Electricity consumed in global primary aluminium production contributed between 50% and 90% of the environmental impact across all impact categories considered in the 2017 report (IAI 2017a). The updated result indicates electricity continues to be the largest contributor across all impact categories however there is a slight reduction in the contribution of electricity to the impact indicator results as a result of the downward revisions to the Gulf and China electricity generation datasets.

There are also notable differences in the contribution of other process types for some impact indicator results. Ancillary materials contribution to the ozone depletion potential (ODP) impact indicator result for example, has increased due to an update to the background data for caustic soda. Thermal energy has also increased across a number of indicator impact results, due to revisions for thermal energy as part of the annual GaBi update.

	Global 2017 Result	Global (update) 2018 Result
Acidification Potential (AP) **[kg SO_2-Equiv.]**	100	92
Depletion of fossil energy resources (DFE) **[MJ]**	166,000	162,000
Eutrophication Potential (EP) **[kg Phosphate-Equiv.]**	7	6
Global Warming Potential (GWP 100 years) **[tonne CO_2-Equiv.]**	18	17
Ozone Layer Depletion Potential (ODP) **[kg R11-Equiv.]**	1. 1E-8	1.6E-9
Photochemical Ozone Creation Potential (POCP) **[kg Ethene-Equiv.]**	7	6

Table 2: Impact category and additional indicator results (per tonne of primary aluminium ingot)

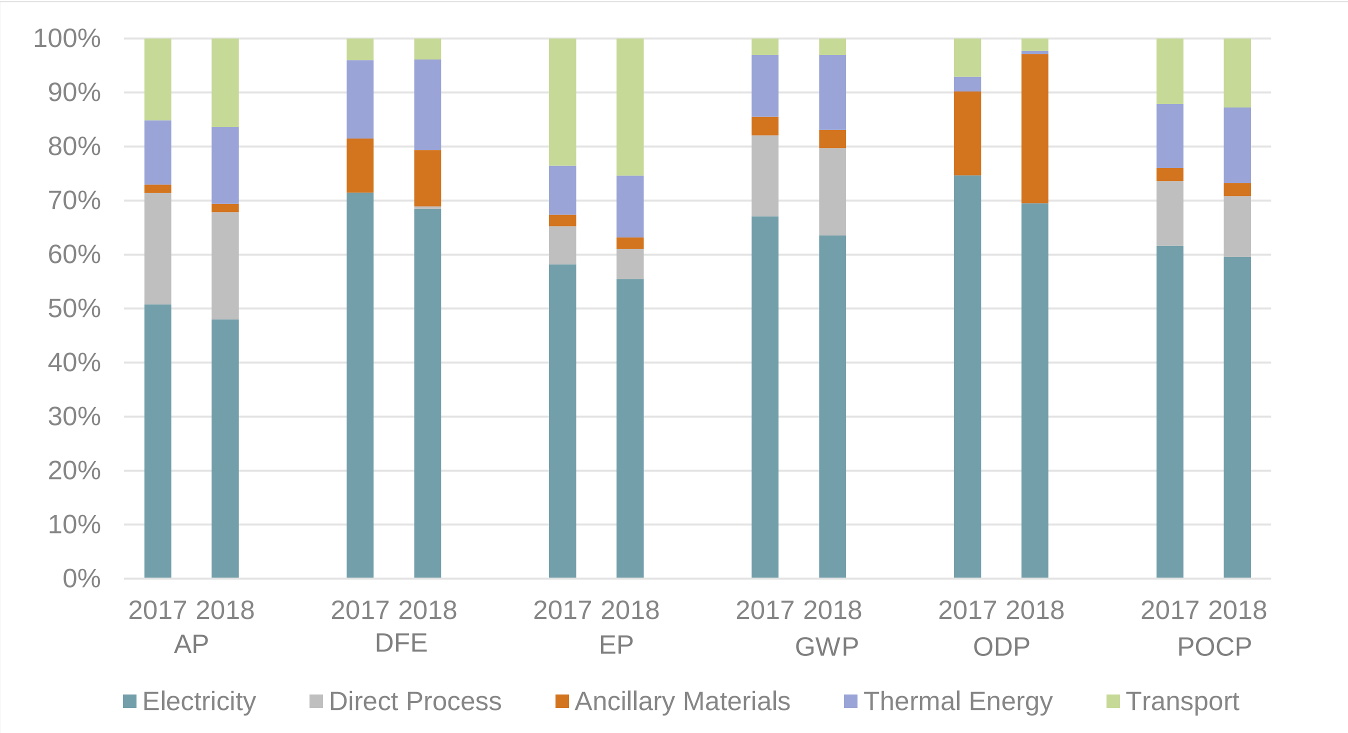

Figure 4: Relative contribution to impact indicator results by key process type (IAI 2017a) compared to the updated results

Further breakdown for the results for GWP is shown in Figure 5. The impact related to electricity for the electrolysis process has decreased from 11t CO_2e/t Al ingot in the 2017 result to 10t CO_2e/t Al ingot. This is due to the slightly lower results calculated using the new background electricity datasets for China aluminium production and Gulf Cooperation Council aluminium production.

GaBi datasets are updated annually, and datasets which are commonly used across many LCAs e.g. electricity generation and thermal energy are often revised to reflect the availability of new data or information on technology. Some updates within the GaBi Professional database since the 2017 report, and related to background datasets for thermal power generation and ancillary materials, have also been included in this update. These are not aluminium specific datasets as the new electricity datasets for China and the Gulf region are but reflect changes more generally to processes in the given proxy countries or regions. The latest background datasets have been used to calculate the updated results to ensure the most up to date results as possible.

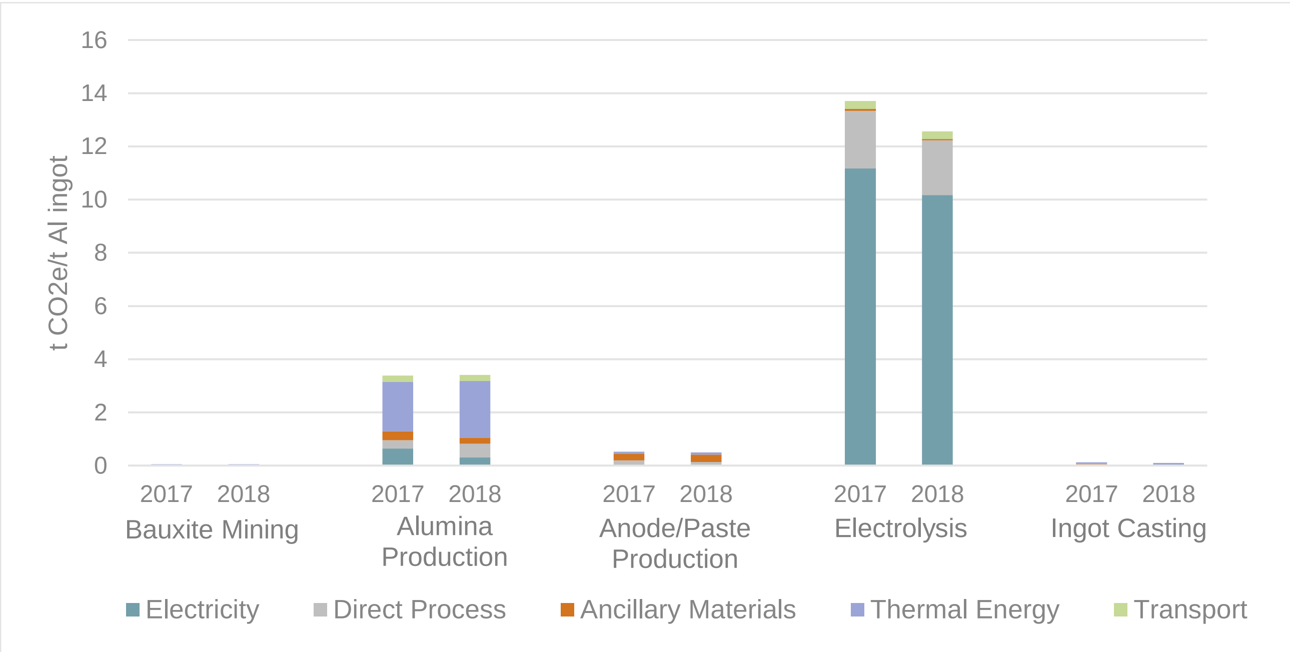

Figure 5: Global GWP by unit process and process type and by process (IAI 2017a) compared to the updated results

4. Conclusions and Next Steps

The integration of primary aluminium inventory datasets by region and unit process into third-party datasets ensures that LCA practitioners are able to access and utilise the most accurate and up-to-date LCI data available on primary aluminium production. The increased granularity of the published datasets allows for greater flexibility when modelling aluminium production as part of aluminium product LCAs and can allow users to be increasingly confident that the results generated are representative of material produced in specific regions from mine to casthouse. It also supports the movement towards integrating life cycle assessment with mass flow analysis and the increasing need to understand specific supply chain impacts. In future work, it is hoped that this can continue to be developed and used by practitioners as a tool in decision making, allowing for impact modelling both across space and through time

The updated LCIA results validate previous findings (IAI, 2017a) and again, highlight the impact of electricity generation datasets on the potential environmental impacts of primary aluminium production at the global level and regional level. The development and integration of industry specific electricity generation datasets for two significant aluminium producing regions (China and GCC) should improve the accuracy of LCA results that include modelling of primary aluminium from these regions (and globally, given the significant contribution of the two regions to overall global production).

There is potential for further work evaluating other background datasets that may have a material impact on the impact indicator results e.g. thermal energy. This may also apply at the regional level e.g. for scenarios which are dependent on hydropower electricity generation a review of the most material background datasets to the indicator results could be conducted to ensure that they are representative for the aluminium industry context.

The IAI has an ongoing commitment to understand better the potential environmental impacts associated with the full lifecycle of aluminium production and products and will continue to make available any relevant data to support wider life cycle practices. The IAI updates LCI data at five-year intervals and as such, the next update is planned to be published in 2022, representing data for the year 2020.

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