



## B2DS-aligned GHG Emissions by Unit Process

### 1. Introduction

The International Energy Agency (IEA) published the Beyond 2°C Scenario ([B2DS](#)) in 2017.

The B2DS comprises the most comprehensive dataset released by IEA so far. Under the B2DS, the IEA forecasts that by 2050 there should be a total reduction in anthropogenic CO<sub>2</sub> emissions from 34.3 Gt CO<sub>2</sub> (2014) to 4.8 Gt CO<sub>2</sub> (2050), reaching a net-zero CO<sub>2</sub> emissions by 2060. The IAI has decided to work with the B2DS framework due to:

1. Availability of regional electricity data;
2. Publication of direct CO<sub>2</sub> emissions for the aluminium sector;
3. Sustainability Development Scenario ([SDS](#)) targeting net-zero CO<sub>2</sub> emissions by 2070;
4. Net Zero 2050 Scenario ([NZE](#)) was published after the IAI commenced work on a B2D-aligned scenario.

The IAI will continue to improve its scenarios based on material flow modelling and updated climate science. The IEA's B2DS budget for the aluminium sector includes a subset of the industry's own total direct emissions – this excludes emissions from mining or Perfluorocarbons (PFCs). The IEA has also published regional pathways for electricity consumption under B2DS.

For the specific aluminium sector B2DS-aligned analysis, the IAI has brought together the IEA's scenario for the aluminium sector's direct CO<sub>2</sub> emissions and power consumption and developed B2DS-aligned pathways for the emissions not included in the IEA's dataset.

**Table 1** shows the aluminium sector's 2018 global greenhouse gas (GHG) emissions split by direct CO<sub>2</sub> emissions as covered by the IEA (279 million tonnes (Mt) CO<sub>2</sub>), CO<sub>2</sub>e emissions associated with electricity used for electrolysis (670Mt CO<sub>2</sub>e) and other CO<sub>2</sub>e emissions (145Mt CO<sub>2</sub>e).

Units in (Mt) CO <sub>2</sub> e		Mining	Refining	Anode	Electrolysis	Casting	Recycling	Semis	Internal Scrap	Total
Electricity	Indirect	0.6	16.9		670.2		3.1	9.5	2.5	703
PFC	Direct				35.4					35
Process	Direct			6.4	92.6					99
Ancillary	Indirect		14.8	19.3	6.4					41
Thermal energy	direct/indirect	2.6	124.3	6.4		6.4	15.6	19.0	8.4	183
Transport	Indirect		15.4		18.7					34
Total	cradle to gate	3	171	32	823	6	19	29	11	1095

*Table 1: 2018 GHG emissions split by IEA covered (blue), electricity (orange) and other (green).*

**Table 2** shows 2050 global B2DS-aligned GHG emissions in the aluminium sector split by direct CO<sub>2</sub> emissions as covered by IEA (171Mt CO<sub>2</sub>), CO<sub>2</sub>e emissions associated with the electricity used for electrolysis (8Mt CO<sub>2</sub>e) and other emissions (77Mt CO<sub>2</sub>e).

Units in Mt CO <sub>2</sub> e		Mining	Refining	Anode	Electrolysis	Casting	Recycling	Semis	Internal Scrap	Total
Electricity	Indirect	0.3	8.8		7.8		1.6	4.9	1.3	25
PFC	Direct				18.8					19
Process	Direct			3.5	50.1					54
Ancillary	Indirect		7.8	10.2	3.4					21
Thermal energy	direct/indirect	1.7	65.0	3.4		3.4	19.6	20.6	5.5	119
Transport	Indirect		8.2		9.9					18
Total	cradle to gate	2	90	17	91	3	21	26	7	250

*Table 2: 2050 B2DS GHG emissions split by IEA covered (blue), electricity (orange) and other (green).*

To calculate the 2050 emission budget for the aluminium sector, the following data was used:

- 1) **Electricity:** IEA B2DS primary production data, IAI electricity consumption per tonne of primary aluminium, IEA B2DS regional emission intensity data (CO<sub>2</sub>e/kWh), IEA transmission losses, and estimate for upstream emissions;
- 2) **IEA covered:** IEA direct B2DS CO<sub>2</sub> emissions;
- 3) **Other:** Estimate based on IEA B2DS data.

To calculate the intensity data (CO<sub>2</sub>e per tonne), the IAI material flow model data was used as the denominator. The overall global results show that under a B2DS scenario, the aluminium sector needs to reduce its emissions by about 80%. This reduction in emissions is predicted to happen alongside a rise in demand for the metal. The IAI predicts that the demand for aluminium products will grow by 80% (see **Figure 1**). Simultaneously reducing emissions while meeting increasing demand will require huge investment in technology, and a commitment from all along the value chain.

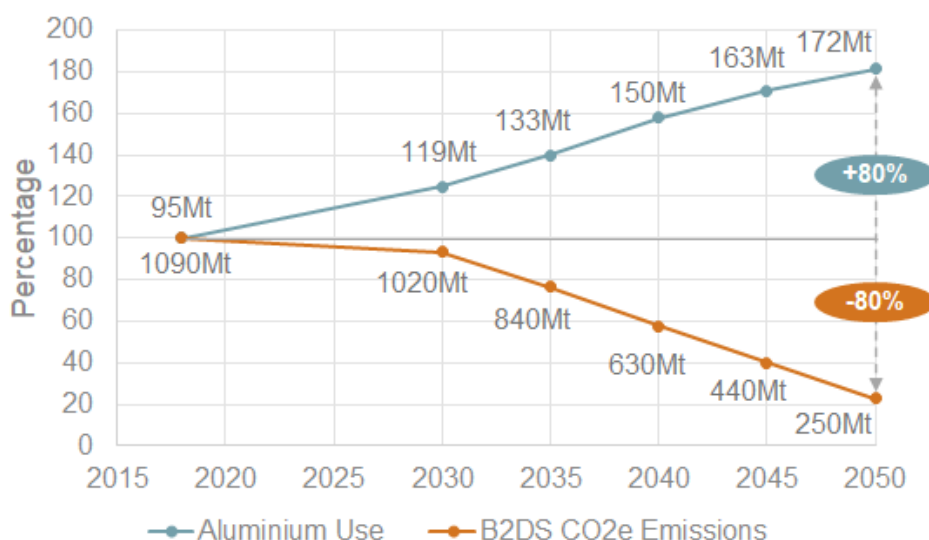


Figure 1: Forecast for aluminium use and GHG emissions in line with the B2DS.

### 1.1 Direct CO<sub>2</sub> emissions covered by IEA for the aluminium sector

In 2014, IEA reported 261Mt of direct CO<sub>2</sub> emissions for the aluminium sector. The aluminium sector definition used by IEA excluded mining, electricity use, non-CO<sub>2</sub> GHG emissions, ancillary processes and transport. The number calculated by IAI was 259Mt for the same period and 279Mt for 2018.

**Table 3** shows the 2018 dataset for direct CO<sub>2</sub> emissions as defined by the IEA and calculated by the IAI.

Units in Mt CO <sub>2</sub> e		Mining	Refining	Anode	Electrolysis	Casting	Recycling	Semis	Internal Scrap	Total
Electricity	Indirect									
PFC	Direct									
Process	Direct			6.4	92.6					99
Ancillary	Indirect									
Thermal energy	direct/indirect		124.3	6.4		6.4	15.6	19.0	8.4	180
Transport	Indirect									
Total	cradle to gate		124	13	93	6	16	19	8	279

Table 3: 2018 direct CO<sub>2</sub> emissions in Mt for the aluminium sector as defined by the IEA.

**Figure 2** shows the B2DS data for 2030, 2035, 2040, 2045 and 2050 as published by the IEA. Total 2018-2050 reductions are -39%. These emissions are then distributed among the different processes and results for 2050 are shown in **Table 4** as follows:

- 2050 Direct CO<sub>2</sub> (Internal Scrap) = 2018 Direct CO<sub>2</sub> (Internal Scrap) x 61%
- 2050 Direct CO<sub>2</sub> (Recycling) = 2050 IEA B2DS Recycling Production x Weighted Average [2018 Recycling Intensity + 2018 Internal Scrap Intensity] x 73% - 2050 Direct CO<sub>2</sub> (Internal Scrap)
- 2050 Direct CO<sub>2</sub> (Semis) = (2050 IEA Primary Production + IAI Old Scrap Recycling) x (2018 Semis Intensity x 73%)
- 2050 Direct CO<sub>2</sub> (Primary) = 2050 Direct CO<sub>2</sub> (Sector) – 2050 Direct CO<sub>2</sub> (Internal Scrap) – 2050 Direct CO<sub>2</sub> (Recycling) – 2050 Direct CO<sub>2</sub> (Semis)
- Split within primary production using the same ratio as in 2018.

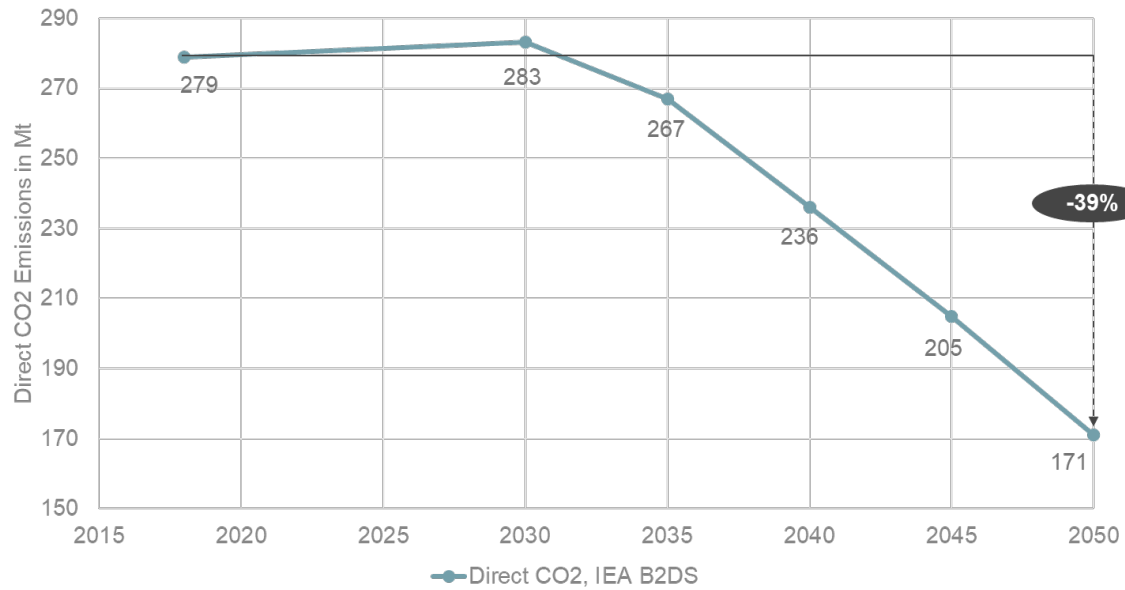


Figure 2: Direct CO<sub>2</sub> emissions published by IEA under B2DS.

Units in Mt CO <sub>2</sub> e		Mining	Refining	Anode	Electrolysis	Casting	Recycling	Semis	Internal Scrap	Total
Electricity	Indirect									
PFC	Direct									
Process	Direct			3.5	50.1					54
Ancillary	Indirect									
Thermal energy	direct/indirect		65.0	3.4		3.4	19.6	20.6	5.5	117
Transport	Indirect									
Total	cradle to gate		65	7	50	3	20	21	5	171

Table 4: 2050 direct CO<sub>2</sub> emissions in Mt for the aluminium sector as defined by IEA.

## 1.2 Electricity for electrolysis

**Table 5** shows GHG emissions associated with the use of electricity for electrolysis in 2018 by region. For B2DS, it is assumed that the existing capacity which is currently using fossil fuel for electricity production will connect to the specific regional B2DS IEA grid by 4% per annum, starting in 2025 (data publicly available for Europe, China, USA, Brazil, South Africa

and India; and shared under a confidentiality agreement for Australia and Middle East). By 2050, all fossil fuel smelters are connected to a B2DS grid mix. Hydropower electricity is not connected to the B2DS grid and the current emission intensity (CO<sub>2</sub> per kWh) is halved from 2040. In 2035 it is assumed that all plants will run at 12'700kWh/tonne aluminium. By 2050, all existing production will be connected to a B2DS equivalent grid or will be using hydropower. All new capacity will be connected to the equivalent of a global B2DS grid once production starts and run at 12'700kWh/tonne aluminium.

**Table 6** shows the regional and global results for electricity use in a B2DS-aligned scenario.

	Production Million tonnes	Energy Efficiency kWh/tonne	HYDRO	COAL	OIL	NATURAL GAS	NUCLEAR	CO <sub>2</sub> tonnes/tonne	CO <sub>2</sub> Mt
Africa	1.7	14,512	51%	49%	0%	0%	0%	9.2	15
Asia (ex China)	4.4	14,914	11%	89%	0%	0%	0%	15.4	68
GCC	55.3	15,094	0%	0%	0%	100%	0%	6.1	33
China	36.4	13,555	10%	89%	0%	0%	1%	13.0	474
North America	3,8	14,791	83%	13%	0%	3%	0%	2.6	10
South America	1.2	15,919	77%	0%	0%	23%	0%	4.1	5
Europe & Russia	7.8	15,442	81%	7%	0%	3%	9%	2.1	16
Oceania	1.9	14,517	30%	69%	0%	1%	0%	9.8	19
Non- Reporters	1.7	15,919	0%	100%	0%	0%	0%	17.6	31
<b>Global</b>	<b>64</b>	<b>14,238</b>	<b>25%</b>	<b>64%</b>	<b>0%</b>	<b>9%</b>	<b>2%</b>	<b>10.4</b>	<b>670</b>

*Table 5: 2018 primary production, energy efficiency, electricity source and CO<sub>2</sub> emissions for electricity use by region.*

	2018	2030	2035	2040	2045	2050
Africa	15	13	8	5	3	0
Asia (ex China)	68	56	37	26	13	2
GCC	33	32	24	19	10	1
China	474	394	285	183	86	1
North America	10	8	6	4	2	0
South America	5	4	3	2	1	1
Europe & Russia	16	14	10	7	4	2
Oceania	19	15	10	6	3	0
Non-Reporters	31	25	17	11	6	0
2018 Capacity	670	563	400	264	129	8
Additional Capacity		31	42	23	7	0
<b>World</b>	<b>670</b>	<b>594</b>	<b>442</b>	<b>287</b>	<b>135</b>	<b>8</b>

*Table 6: Total CO<sub>2</sub> emissions in Mt for primary aluminium electricity use in a B2DS-aligned scenario.*

### 1.3 Other emissions not covered under 1.1 and 1.2

The IEA's definition for the aluminium sector excludes bauxite mining (thermal), electricity use (mining, refining, recycling, semis production, internal scrap remelting), PFC emissions, ancillary processes and transport ("Other Emissions"), which amounted to 145Mt in 2018 (see **Table 7**). Due to the importance of electricity in the electrolysis process, 61% of total sector emissions were modelled separately (see chapter 1.2). Other Emissions were reduced by the same percentage as CO<sub>2</sub> emissions allocated to primary aluminium in section 1.1 and were split up using same ratio as for 2018. Results for 2050 B2DS-aligned scenario are shown in **Table 8**.

Units in Mt CO <sub>2</sub> e		Mining	Refining	Anode	Electrolysis	Casting	Recycling	Semis	Internal Scrap	Total
Electricity	Indirect	0.6	16.9				3.1	9.5	2.5	33
PFC	Direct				35.4					35
Process	Direct									
Ancillary	Indirect		14.8	19.3	6.4					41
Thermal energy	direct/indirect	2.6								3
Transport	Indirect		15.4		18.7					34
Total	cradle to gate	3	47	19	60		3	10	3	145

*Table 7: 2018 CO<sub>2</sub>e emissions (Mt) for electricity-related emissions (except electrolysis), PFC, ancillary materials, mining and transport.*

Units in Mt CO <sub>2</sub> e		Mining	Refining	Anode	Electrolysis	Casting	Recycling	Semis	Internal Scrap	Total
Electricity	Indirect	0.3	8.8				1.6	4.9	1.3	17
PFC	Direct				18.8					19
Process	Direct									
Ancillary	Indirect		7.8	10.2	3.4					21
Thermal energy	direct/indirect	1.7								2
Transport	Indirect		8.2		9.9					18
Total	cradle to gate	2	25	10	32		2	5	1	77

*Table 8: 2050 CO<sub>2</sub>e emissions (Mt) for electricity-related emissions (except electrolysis), PFC, ancillary materials, mining and transport, B2DS-aligned.*

## 2.0 GHG emission intensity (cradle to gate emissions)

For GHG intensity, the average production data from the baseline Material Flow Model scenario, is available on [Alucycle](#), under [2020 IAI REFERENCE SCENARIO](#) – a scenario with same demand figures as the baseline scenario but increases the collection of end-life-products to approximately 100% by 2050.

**Figure 3** illustrates the production of primary aluminium (liquid aluminium tapped from electrolytic cells or pots), recycled aluminium (recycled aluminium = post-consumer scrap + pre-consumer scrap from manufacturing processes – melting losses + alloying elements) and semis production.



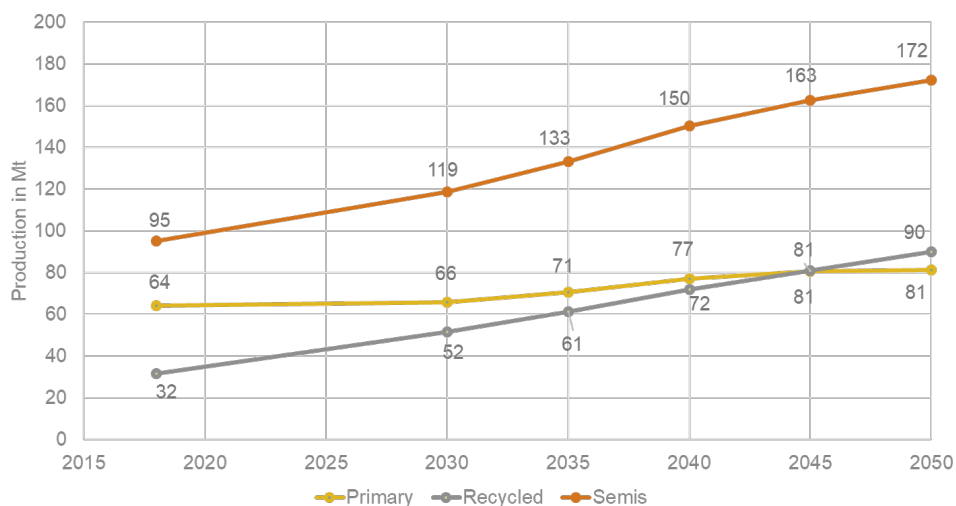


Figure 3: Production data used to calculate the GHG emissions intensity for B2DS-aligned scenario.

## 2.1 Primary aluminium (cradle to gate emissions)

Figure 4 shows GHG emissions per tonne of primary aluminium projected to 2050 for B2DS indicating a reduction of 85% by 2050 on a per tonne level.

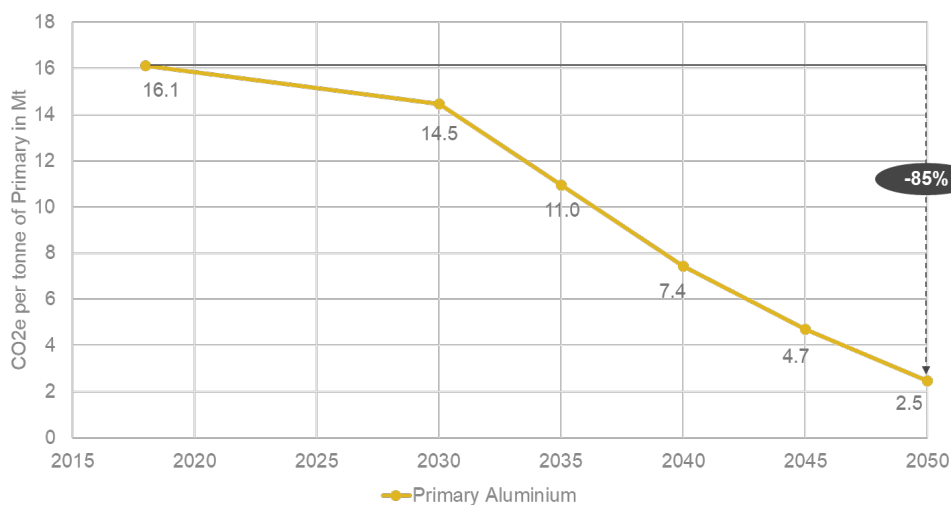


Figure 4: CO<sub>2</sub>e process emissions per tonne of primary aluminium (equivalent to the carbon footprint of primary aluminium).

## 2.2 Recycled aluminium (emissions for collection, pre-melt processing, remelting)

Figure 5 shows GHG emissions for collection of end-life-products, pre-melt processing of scrap and remelting of one tonne of recycled aluminium forecasted to 2050 and aligned to B2DS.

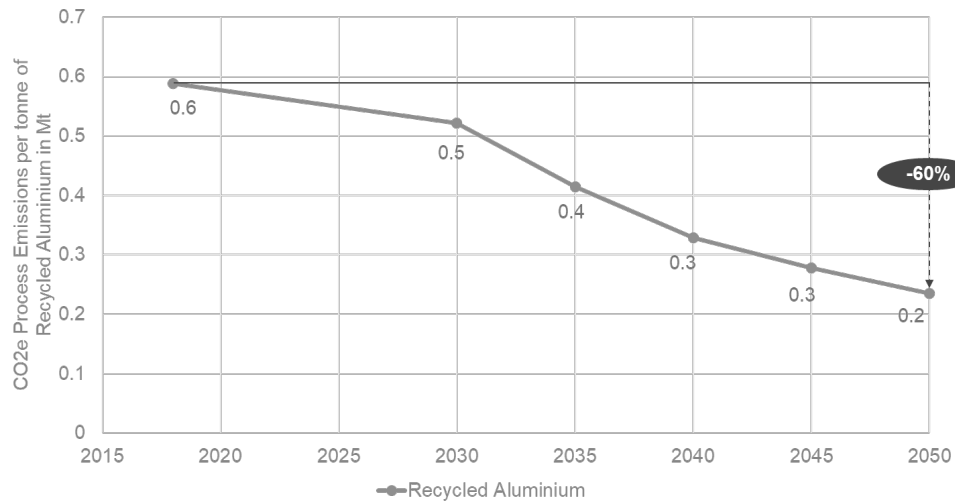


Figure 5: CO<sub>2</sub>e process emissions per tonne of recycled aluminium (this number should not be used for the carbon footprint of recycled aluminium without prior consultation).