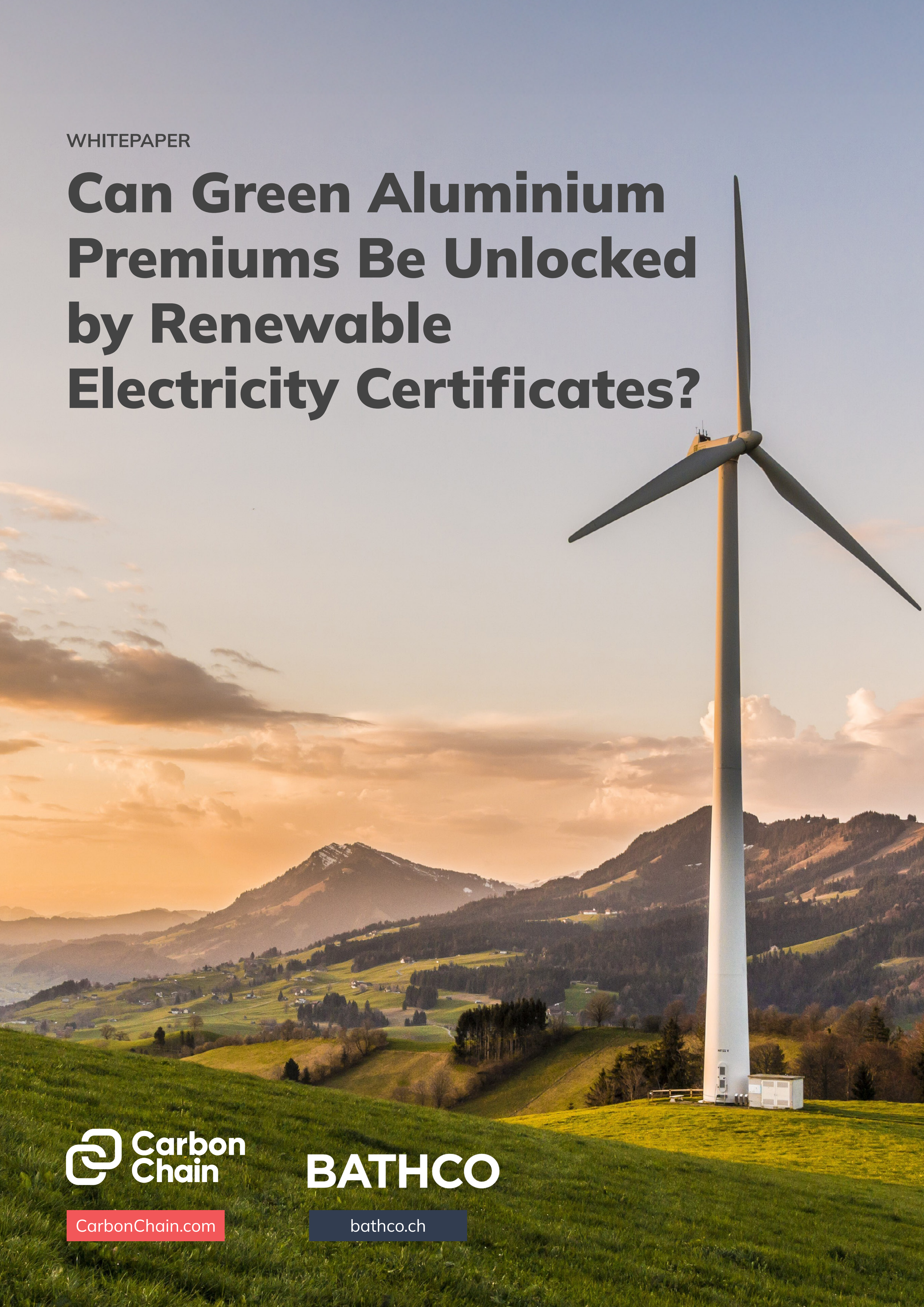

WHITEPAPER

Can Green Aluminium Premiums Be Unlocked by Renewable Electricity Certificates?

Carbon Chain

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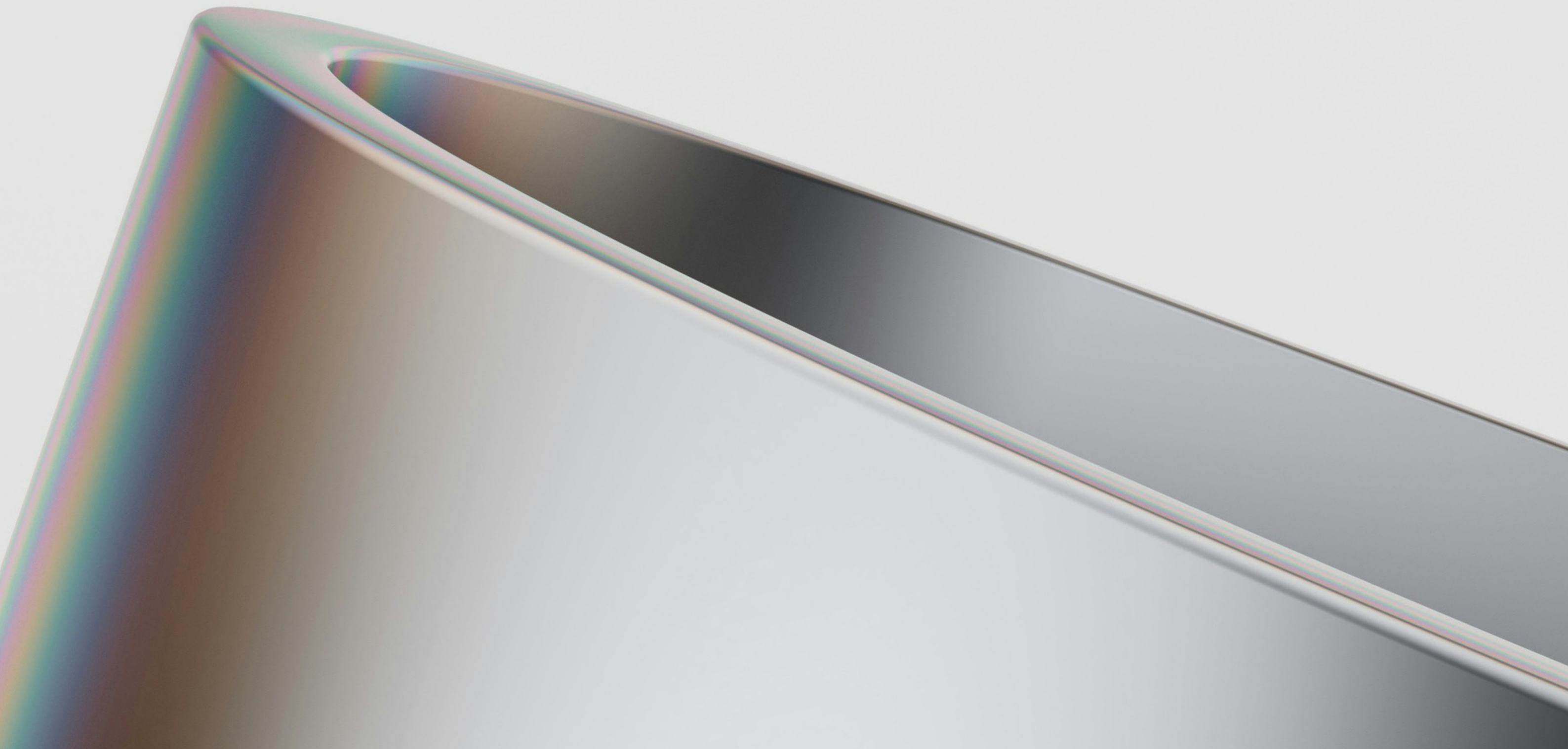
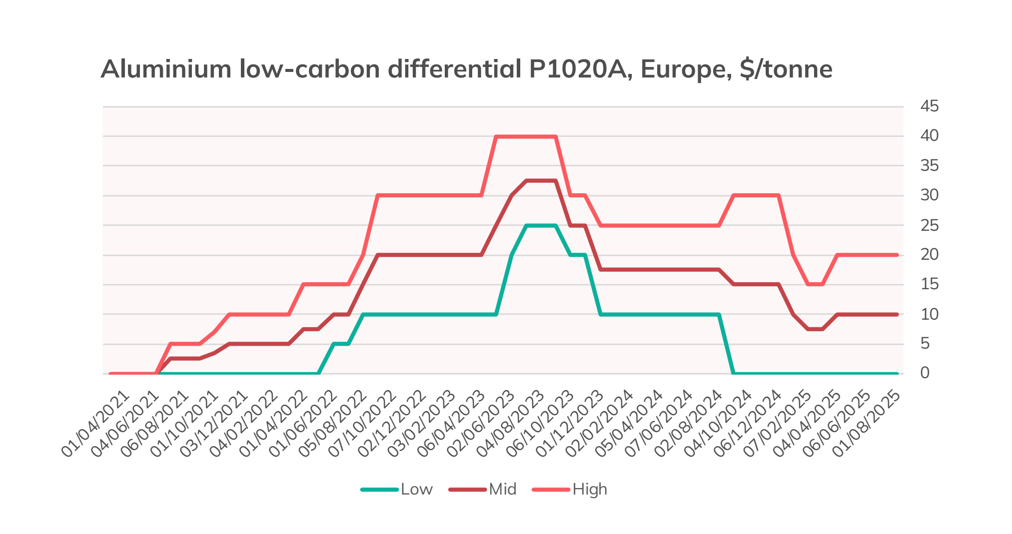
Contents



Introduction

The aluminium industry needs to move quickly, and together, to decarbonise on Paris aligned trajectories. Existing top-down initiatives, accounting and certifying smelter carbon intensities, are driving decarbonisation, but not fast enough. At the same time, consumer demand for low carbon aluminium is increasing[1] and even low-carbon premiums have been falling recently, due to an increased supply of low carbon material and weaker demand. At the same time analysts see a pickup in demand ahead of the 2026 CBAM implementation.[2]

Figure 1: Fastmarkets Aluminium low-carbon differential P1020A, Europe, $/tonne.[3]



And yet, the integrity and comparability of the calculations and chain of custody controls that underpin them, lags behind other comparable industries such as steel, where green market premiums are comparably high to the material value[4] and does not account for electrolytic aluminium's unique position to help decarbonise electricity markets through unlocking stranded renewables with rigorous Scope 2 accounting.

In this paper, we explore the complexities of setting up an industry wide low carbon standard, the importance of aligning on indirect emissions accounting for aluminium to build confidence with consumers that low-carbon means low carbon and is positively contributing to the energy transition.

As industry bodies, consumers and producers enter this critical second half of the decade, we call for renewed focus and collaboration on indirect emissions in accounting for low-carbon and zero-carbon aluminium to provide the missing piece in the supply chain infrastructure to drive real reductions through consumer demand.

Meet your experts

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Renewables in Aluminium Decarbonisation Pathways

The International Aluminium Institute (IAI) has developed a science-based sectoral decarbonisation pathway outlining the steps necessary to decarbonise by 2050 in line with the International Energy 1.5-degree warming scenario.[4] The Aluminium Stewardship initiative (ASI) has translated this scenario into installation pathways consistent with the required sectoral trajectory.[5] Three key levers are identified to meet the required carbon budget in 2050: electricity decarbonisation, direct emissions reduction and recycling & resource efficiency.[6]

The production of Aluminium through the Hall-Héroult process consumes approximately 1920 kg Alumina, 560 kg of carbon anode material and 13 MWh of electricity.[7] Before 2021, an increase in aluminium production always caused an increase in CO_2 emissions. In 2021 the total aluminium output increased for the first time without a corresponding increase in emissions due to an increasing in recycling operations.[8] However, the "business as usual" scenario presented is still far from where it needs to be to realise aspired 2050 targets (see Figure 3) increasing over the next two decades.[9] There is also a slight fall in emissions in primary aluminium production per ton of aluminium produced, but total emissions are still growing due to steady production increases.[9] As this trend is not expected to continue without actionable change, we can assume the quick wins for the industry in the biggest levers, grid decarbonisation and recycling, have already been creamed and installations are lacking either the incentive or the means to start or continue. Of the three decarbonisation levers presented we focus the discussion on grid decarbonisation as it represents a large potential gain to the industry (33% reduction relative to the "business as usual" (BAU) scenario,)[10] but one that smelters feel they have least agency in actions they can take, causing an effective supply constraint on low-carbon aluminium.

> *Commitments from producers to mid-century targets … will need to be bolstered and enabled by policies that secure long-term aluminium sector access to competitively priced renewable electricity*
>
> **— International Aluminium Institute[10]**

Figure 2: Aluminium production vs GHG emission in million tonnes.[9]

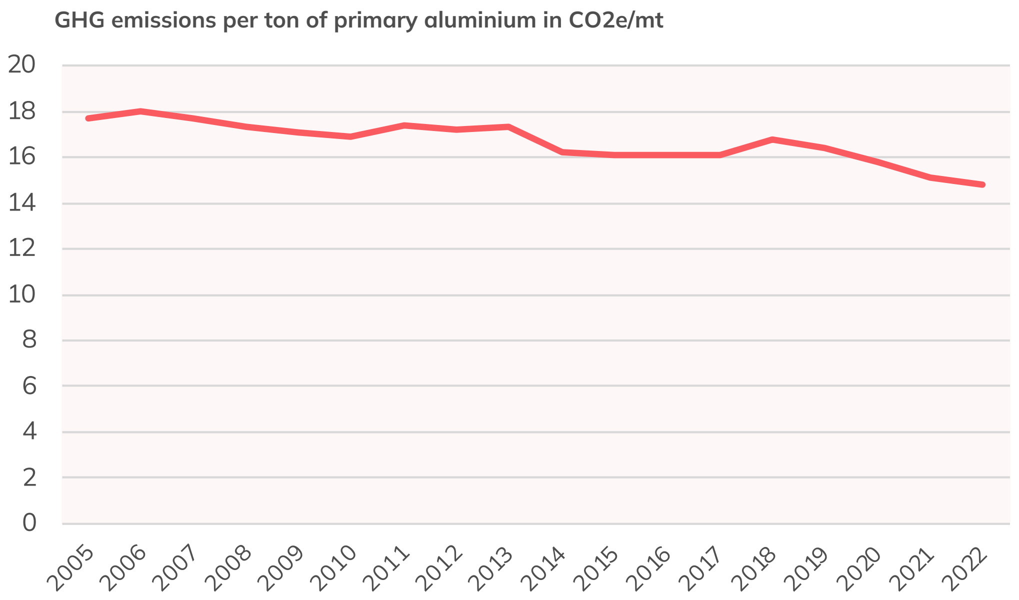
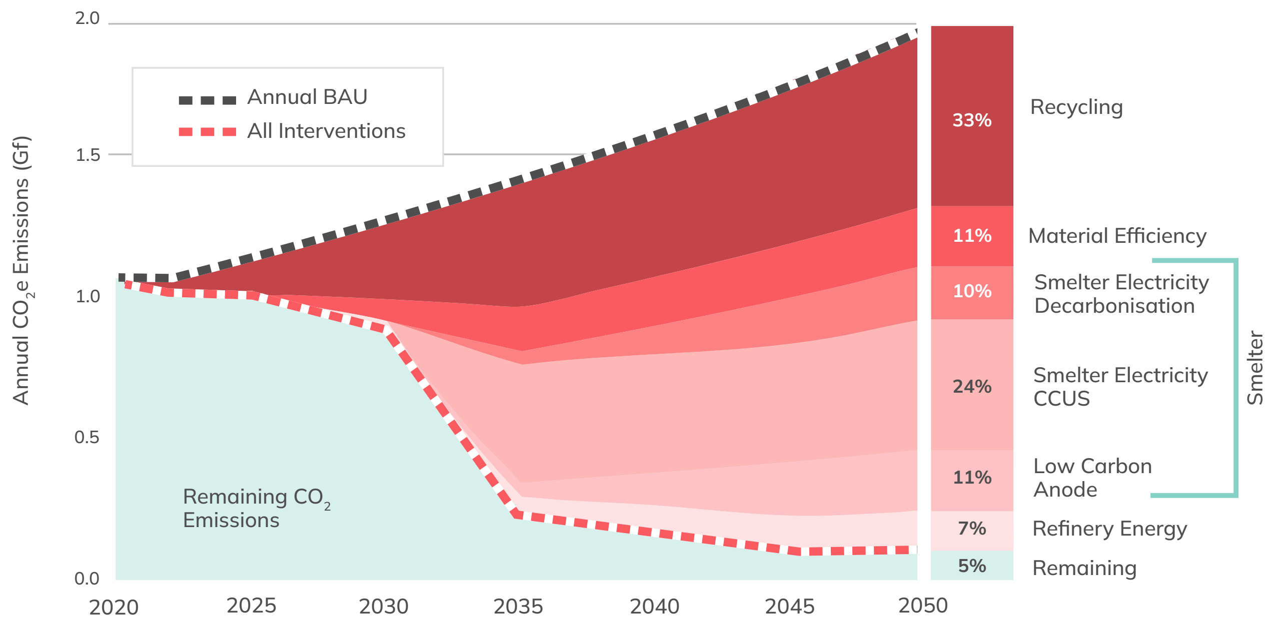


Figure 3 Industry Decarbonisation Pathways against a business as usual (BAU) Scenario produced by Eunomia in partnership with the International Aluminium Institute (IAI)[10]



Decarbonisation Lever 1:

Direct Emissions Reduction and Increased Operational Efficiency

Direct emissions reductions through technology improvements are varied, and will contribute to individual aluminium product intensities, and we welcome investment into novel and established direct emission decarbonisation strategy in addition to the systematic lever presented in this paper. Some examples are summarised in Table 1.

Table 1 Direct decarbonisation and increased efficiency potential for the aluminium supply chain

Bauxite refining	Approximately 4500 kg of Bauxite are digested to produce the Alumina for one ton of aluminium.[11] Most of the energy consumed there is used to generate steam and to calcine the recovered aluminium hydroxide. The main energy source are fossil fuels, and the associated emissions are seen as "hard to abate" as electricity as a heat source is too expensive.[12] However, the Bayer process with its average 2.4 tCO_2e/t Al only accounts for around 16% of the total greenhouse gas emissions[7] and the best available technology sits at 1 tCO_2e/t Al.[13]
Optimisation of the Hall-Héroult process	Technological improvements in the Hall-Héroult process have led to a significant reduction in energy consumption and increased in productivity over the last decades. Ranging from better thermal control, operating with lower cell voltage and strictly controlled electrolyte composition[14,15] to sophisticated magnetic compensation.[16] With new prospects such as supra conductors to reduce internal resistance[17] and AI supported pot control.[18]
Inert anode	Various producers do or did research on inert anodes to get rid of the carbon anodes and its associated emission of approximately 1.5 tons[5] of CO_2 per ton of Aluminium. The hope in this technology is also to reduce electricity consumption and costs and improve HSE. The challenge is to find a material, that has a low reactivity, resist the highly corrosive environment of the electrolyte in the cell and does not contaminate the produced metal. However, until today there is no industrial ready solution and only RUSAL produced notable.[19]
Chloride Process	An alternative process promoted by Hydro as HalZero is based on the carbochlorination of alumina followed by an electrolysis of the aluminium chloride and a recycling step for the chlorine and carbon dioxide gases.[20,20] The process promises a significant lower electricity consumption on the one hand and a manyfold production on the other hand compared with the Hall-Héroult process. However, the challenge is scaling/clogging and the formation of toxic chlorinated hydrocarbons[21]
Carbon Capture and Storage	As in other CO_2 intense industries, there are also concepts to capture the CO_2 from the off gas of aluminium smelters. Unfortunately, the off gas of cells consists of approximately 1-1.5 vol%[21] CO_2 and therefore needs to enter chemical absorption process to be extracted. There are a couple of projects working on pilot plans, but so far there is no commercially available technology available.[22]

Decarbonisation Lever 2:

Recycling and Material Efficiencies

In the most recent Eunomia pathway, recycling and material efficiency has the potential to decarbonise 45% of the sectors projected BAU emissions. However, the projected 2050 absolute emissions that can be reduced by recycling and material efficiency are more than off-set by the increase in demand for aluminium.[10] Progress driving secondary aluminium through demand lead schemes has been positive, in part driven by chain of custody schemes (e.g ASI Chain of Custody Standard)[23] and eco-labelling connecting the limited supply of secondary aluminium to conscientious customers. In this paper we explore the possibility of unlocking the same demand drivers for primary aluminium.

> *Supply of lower carbon 'primary aluminium' is not constrained, and increase in demand caused by successful deployment of a 'lower carbon primary aluminium' label could lead to increased supply to meet this demand, and hence a reduction in global emissions.*
>
> — **The Carbon Trust (The Carbon Trust, 2020)**

Decarbonisation Lever 3:

Change of Electricity Source

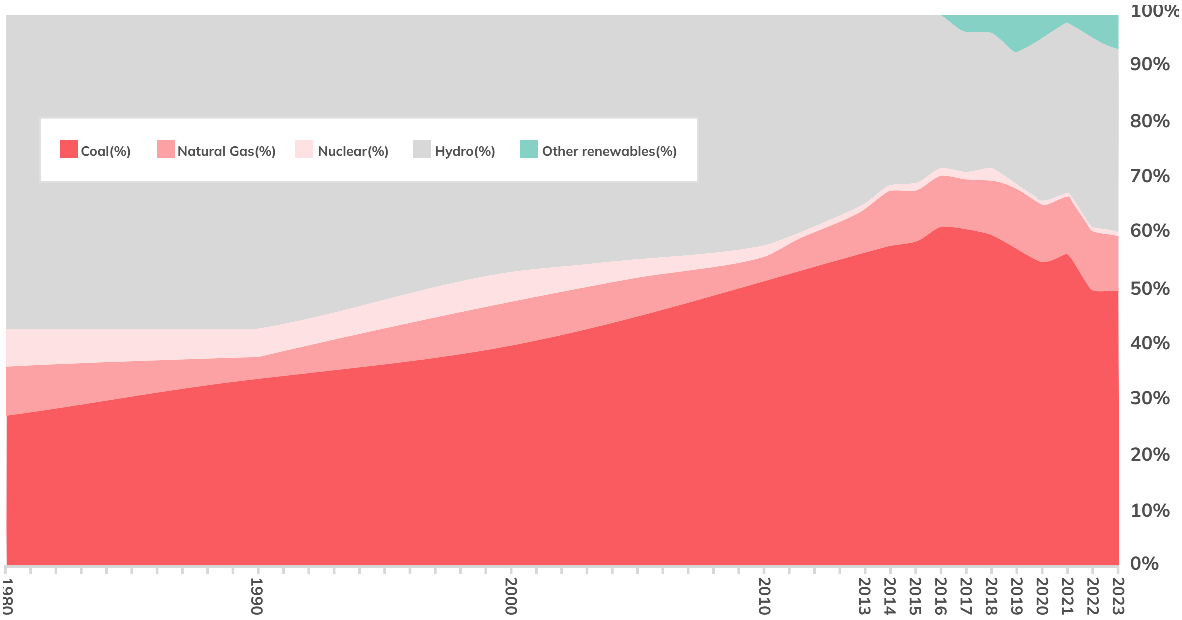
Compared to the emissions that can originate from the electricity production for aluminium electrolysis the emissions of all other production steps are minor (see Table 2). Therefore, the electricity source is the biggest single factor for the total GHG emissions for the aluminium production. Figure 4 below shows the relative intensity of electricity production for aluminium production from the energy mix through time.

> *Increasing the proportion of aluminium production from low-emission electricity should be a top priority and represent the largest source of potential emissions reductions in the short term.*
>
> — **International Energy Agency**

Table 2: Primary aluminium GHG emissions intensity per process step. Adapted from[7]

Process step	Global average [tCO_2e/tAl]	% of total
Mining	0.07	0.47
Refining	2.40	16.25
Anode Production	1.00	6.77
Electrolysis	11.20	75.83
Casting	0.10	0.68
Total	**14.77**	**100.00**

Figure 4 Electricity sources for aluminium production. Figure adapted from[14]



To shift production away from fossil electricity, there must be an economic or regulatory incentive to transition to green electricity. The "green aluminium premium," has potential to serve as such an incentive — and is currently benefiting producers that already have low emissions due to access to hydro or nuclear power. Where smelters have no control over their grid mix or are stranded by existing self-generation infrastructure, we question the scalability of the incentive to realise industry wide decarbonisation.

Regionally, the US based Aluminium Association (AA) make the case for decarbonisation through grid greening by comparing their relative intensity to Canadian producers that are currently linked to 100% hydropower. Although this is a credible pathway to decarbonisations, it is one that smelters have no influence over, implying the biggest impact will be driven by policy. No case is made for demand premium driven decarbonisation.[24] Similarly, European Aluminium (EA) recognise electricity decarbonisation as critical to the pathway but call for European policymakers to drive the change.[25]

> *In the short to medium term, [low-carbon electricity] can significantly reduce the emission profile of the overall European aluminium industry. However, at the current pace, the electricity grid will not decarbonise fast enough to meet the industry's demand requirements*
>
> — **European Aluminium[26]**

There is a natural inflection point when the current capacity for green aluminium production is outstripped by the demand for it, and it no longer drives additional decarbonisation. Demand is increasing, driven by (a) consumer requirements and (b) legislative controls, such as the EU's fleet emission regulations.

Decarbonisation trajectories heavily rely on carbon capture and storage to decarbonise both self-generating smelters and fossil grids in general, up to 25% of smelter power according to the Eunomia decarbonisation pathway. This is identified as a risk to the sector pathway by the study as the CCUS capacity planned globally falls short of meeting this demand without a shift in financial incentives. To realise this reduction we should be looking at other mechanisms to green the power mix.[10]

To ensure continued decarbonisation at this stage, the economic incentive will also need to extend to electricity producers, motivating them to invest in additional green electricity generation at a premium. It should be noted that the aluminium sector will face competition for green electricity from other energy-intensive industries, such as steelmaking and chemicals.

Depending on the extent of CCUS deployment in smelters, an additional 300 to 800 terawatt- hours (TWh) of low carbon electricity generation is required by 2050 to meet projected demand.

— **Eunomia report prepared for the International Aluminium Association**[10]

Due to the way power grids and the relationships between producers and consumers are structured in most regions, direct supply of green electricity is often not feasible. Therefore, a sophisticated system for allocating green electricity certificates to ensure the result is grid decarbonisation and not simply re-allocation of existing green power to aluminium, leaking carbon outside the sectoral decarbonisation boundary.

The Corporate–Product Accounting Gap

The translation of corporate emissions inventories to product carbon footprints or vice versa is a non-trivial problem. Corporate emissions have a temporal boundary where product emissions have a life cycle boundary, corporate emissions have different triggers for relevance, materiality and re-baselining. Indirect emissions in the context of corporate reporting are well defined. The leading framework for carbon accounting, the GHG Protocol defines a specific set of guidelines for Scope 2 (indirect energy)[26] accounting which is broadly applicable and widely followed.

Market-based and location-based methods can be deployed but must be reported in parallel allowing for green electricity procurement through a range of instruments broadly known as Energy Attribute Certification (EAC) schemes (examples include Renewable Energy Certificates (RECs), Guarantees of Origin (GO), Power purchase agreements (PPAs)). Certificates are designed to be retired by an organisation, this claiming the environmental attributes of the power generation, with full transparency to the end-user of the emissions inventory. In the GHG Protocol Product Standard[27] however, there is significant scope for interpretation of how energy indirect emissions should be calculated across the supply chain, neither ruling out a market-based system, nor preventing mixed methodologies at different stages of the supply chain. The GHG Protocol is now considering recommending location-based accounting in all circumstances[28] due to concerns with the efficacy of the market-based method. Langer et al.[29] model electricity markets without their REC scheme in place and conclude that the decarbonisation impact of such schemes is negligible, though proponents claim this does not invalidate the underlying emissions allocation model.[30]

Even if the corporate carbon accounting guidance remains unchanged going forward, the possible methodology divergences permitted by the GHG Protocol Product Standard make it inappropriate to use for product comparison on its own. Controls to ensure methodological decision points, including how energy indirect emissions are accounted for, are standardised across calculations. Hence, any claims made for green aluminium must be supported by such industry led methodologies to support and Type I, Type II or Type III environmental product claims. With the range of claims, methodologies and driving forces behind them, that aren't always applicable to the aluminium industry, we believe a comprehensive indirect emissions reporting guide for the industry is missing and has the potential to drive a key decarbonisation lever through credible and comparable low carbon claims.

Table 3 Environmental claims used in the aluminium sector

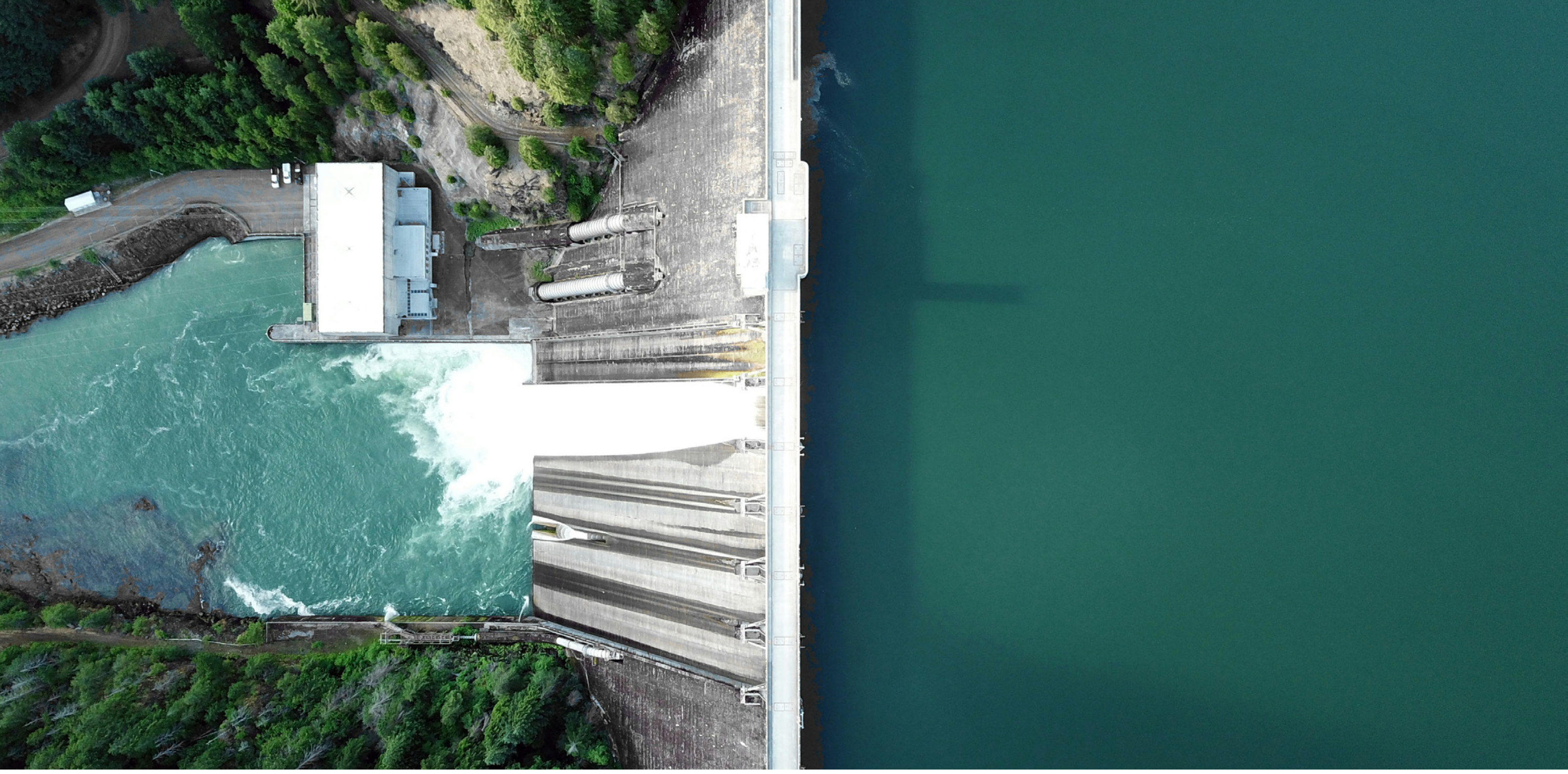
Claim Type	Use	Key Features:
ISO Type I (14024)[31]	Industry body Certifications	Third-party eco-labels. An independent organization verifies that a product or service meets specific environmental criteria.
ISO Type II (14021)[32]	Company Self-Declaration	Environmental claims made by the manufacturer or seller of a product or service.
ISO Type III (14025)[33]	Environmental Product Declaration (EPD)	These are comprehensive environmental declarations based on a life cycle assessment (LCA). Must be verified by a third party and are often used for comparing the environmental performance of different products. Must use the defined product category rules (PCRs) for a given product.
Product Carbon Footprint (PCF) Intensity	Carbon emissions inventory calculated according to recognised accounting frameworks.	Can be verified or unverified by 3rd party depending on use. Methodology divergence limits comparability.
Cost of Carbon Calculations	Calculated cost of carbon due to carbon taxes duties or cap and trade schemes.	Carbon emissions directly in scope for carbon taxes that must be born producers or passed through to customers.

Indirect Energy Emissions Accounting

The 'market-based' indirect emissions calculation approach is designed to aid with the allocation of electricity emissions given the fungible nature of electrical power. It posits that where producers or consumers of green energy can be commonly accounted for and the environmental attributes conveyed as well as the power, the inefficiencies of building direct exclusive connections simply to attribute low emission power to consumers should not be needed.
The total renewable power generated, and the total renewable power claimed by consumers, is balanced in such systems.

The first systems to track and allocate renewables on the grid were developed in the US and EU before wide adoption across grids globally. The initial aim of such schemes was to incentivise new renewable power development by allowing producers to sell to direct consumers who were prepared to pay a premium for low carbon power using an energy balance calculation. The scope has since expanded allocation of attributable indirect emissions in product inventories, including aluminium products, effectively passing on the environmental attribute to consumers of manufactured goods.

Aluminium smelters typically provide a continuous stable load to electricity grids with a high degree of predictability in demand fluctuation.[34] Renewable power is also temporally constrained e.g. solar during the day; wind when the wind is blowing. Renewable sources may also be geographically constrained, limited to certain localities and available transmission infrastructure, so an exclusive connection between renewable sources and installations or renewable self-generation of power is rarely viable. These temporal and geographical constraints impact how transfer of environmental attributes must



be considered by the registry that convey and retire Energy Attribute Certificates (EACs). End-users of product carbon footprints are seldom aware that the quoted intensity of the product can vary depending on the practices of the registry.

Methodological choices exist between Energy Attribute Certificate (EAC) frameworks that can hinder direct comparisons of embedded emissions. The original intent was to drive decarbonisation by unlocking lower carbon inventories for corporate carbon accounting and attributing emissions in a way that would fairly represent this. RE100, a global corporate renewables accounting initiative argues that if this accounting mechanism does not drive the intended decarbonisation, then it is akin to offsetting scheme, rather than attributable CO_2 accounting (RE100, 2016). The concept that indirect energy emission accounting[35] should drive decarbonisation to be valid is more commonly referred to as the additionality criterion.

The American Center for Life Cycle Assessment (ALCLA) make the case that grid additionality is not the concern of product accounting, since the goal and scope of the product carbon footprint is to inform the consumer of the product attributional emissions only[31] and a mathematical, power balance based accounting mechanism is representative of value chain, where electricity environmental attributes are part of a products value. They therefore recommend accepting a broad range of instruments in indirect product emission accounting. This has conceptually been adopted by some product category rules (PCRs) for Environmental Product Declarations (EPDs), though others lag behind (Table 5). European Guarantees of Origin (GOs) are accepted by European EPD programme operators but no framework is provided for the upstream supply chain or mixed geographies of production.[36,37]

Opponents to the market-based method argue that even if the drive is exclusively fair and proportionate attribution of emissions, electrons cannot be individually tracked or individually accounted for.[38] Modelling decisions need to consider the impact the attribution of environmental attributes of green electricity. More generally, a product carbon footprint is measured in CO_2e (carbon dioxide equivalent) which is a measure of Global Warming Potential (GWP) over a defined period (typically

100 years). The relative climate impact of electricity allocation is therefore relevant to any accounting framework and making claims to a low carbon product based on certificates that is potentially increasing demand in a fossil fuel intensive grid, thus increasing emissions over time is not only possible, but a likely, misleading scenario.

One such example of a modelling choice critical for the use of RECs in the aluminium industry is the temporal boundary of the environmental attributes that EAC registries balance. Aluminium smelters require a stable continuous base power supply, and renewable sources are typically temporally constrained. Until grids start implementing renewable power storage projects, it is unlikely that smelters are powered entirely through renewables hour to hour, where environmental claims can be made to all the electricity consumed through most common schemes. Opponents claim this is not a fair way to represent the attributable Scope 2 emissions, as the resultant inventory cannot be represented physically. Hourly generation of environmental attributes and consumption has been developed by some certification schemes (e.g. EnergyTag)[39] to combat this effect. However, it can be argued that predictable ancillary loads in the grid can unlock stranded renewable projects that can service the variable power demand of the wider system, that would not have been supported by variable lower demand[40,41,42] (Deutsche Energie-Agentur (DENA), 2021). Novel technologies such as “EnPot” may play a role in further enhancing aluminium smelter capacity to load shed in support of decarbonised grid stability and viability.[43] This brings the question of proving the integrity of purchased environmental attributes and defining additionality in the case of aluminium uniquely challenging.

Where EAC instruments are broadly accepted, methodologies do require efforts to eliminate double counting of environmental attributes as an acceptance criterion. Double counting can creep into the market-based method in the definition of the residual grid emission factor. This is the term used to define the indirect electricity emissions for which environmental properties will not be claimed. It is used by the reporting organisation to calculate emissions for the electricity that does not have an accompanying environmental claim. Where there is a difference in issued vs. retired certificates over the reporting period, electricity or environmental attributes being imported or exported from the locality, or ambiguities in the definition of renewable power, inconsistencies in the calculation can lead to double counting of the environmental attributes in the emissions a producer are claiming to be from non-renewable sources.[44,45]

A range of guard rails can be put in place, but this introduces the issue of comparability of indirect emissions across jurisdictions and accounting frameworks. Some favour the use of "bundled" RECs only, where the environmental attribute is always tied to the electricity produced. Others go further to suggest that environmental attributes should only be sold if there is a direct contract between the operator of a fixed generation facility and the consumer, a so-called Power Purchase Agreement (PPA). Un-bundled RECs, where the environmental attribute is decoupled from the electricity at point of production, are criticized as studies have shown that rather than creating a premium, unlocking renewable production, profits from the environmental attributes are absorbed in the trading and marketing of the product. The I-REC system has shown unbundled RECs are helpful in less established markets where a national production tracking system is absent and/or a limited proportion of the production is tracked,[46,47] allowing aluminium producers in those markets to compete for green premiums, and renewable project to be established where they would otherwise be stranded.

An even more controversial application of EACs in product accounting is the mass balance allocation of renewable energy emissions. This is the practice of creating varying carbon intensity products from the same installation through differentially allocating renewable energy purchased through an EAC scheme. The Rocky Mountain Institute (RMI) specifically prohibit this practice in their aluminium accounting guidelines.[48] Allowing mass balance of indirect emissions can introduce carbon leakage in the system, i.e. allow installations to allocate all their emissions to products sold in markets where there is no demand for low carbon aluminium can devalue the carbon reduction associated with a green premium. The integrity of such practice could be improved through next generation granular hourly tracked EACs which linked to specific product batches.

Table 4 Range of Energy Attribute Certificate Types (After ALCLA[31])

<table>
<tr><th colspan="3">Indirect Emissions Accounting Instrument</th><th>What is purchased?</th><th>Meets Additionality Criteria?</th></tr>
<tr><td rowspan="3">RETAIL SUPPLY OPTIONS:

Standardised products that are typically short-term comments on the part of supplier and consumer.</td><td colspan="2">Unbundled Renewable Energy Certificates (REC):
Environmental attribute is produced at point of generation, decoupled from the power but tracked by a credible registry (state or private).
Consumers can trade, purchase and retire certificates to claim the environmental attribute in their emissions inventory.
Low carbon premium may not reach renewable power producer but be consumed by EAC infrastructure.
Limited evidence for new project generation as easy and low-cost creamed off and fossil projects displaced to base grid load or periods of no renewable availability.</td><td>Environmental attribute</td><td>Strongly depends on the registries.</td></tr>
<tr><td colspan="2">Granular RECs:
Hourly tracking to improve additionality of unbundled RECs. “Hard to decarbonise” hours are tracked independently rather than accounting for a renewable supply budget over a year reporting period.</td><td>Environmental attribute</td><td>Improved additionality performance relative to traditional unbundled RECs[40]</td></tr>
<tr><td>Bundled Renewable Energy Certificates (REC)</td><td>Supplier Green Power Products: An optional product offering that allows customers in competitive retail electricity markets to procure bundled electricity and from an electricity supplier.
RECs may still not be linked to specific power generation facilities.</td><td>Environmental attribute and power</td><td>Strong dependence on the corresponding REC scheme and registry integrity and how RECs are transferred from producer to utility provider.</td></tr>
<tr><td rowspan="4">PROJECT SPECIFIC SUPPLY:

Customised and negotiated products that involve a long-term commitment to a specific power generation facility.</td><td rowspan="2">Direct contract between a producerand a consumer.</td><td>Physical power purchase agreements (PPA): A contract for the purchase of power and associated EACs from a specificrenewable energy generator. Physical PPAs are
usually 10 to 20-year agreements,[49] define the commercialterms for the sale of renewable electricity and the environmental attributes.</td><td>Environmental attribute and power</td><td rowspan="4">Strong evidence for additionality as low carbon premiums support specific projects[50]</td></tr>
<tr><td>Financial power purchase agreements (F-PPA):
Also known as a virtual power purchase agreement (V-PPA) or acontract for differences.
A financial arrangement between the producer and consumer to pay the difference between the wholesale price and an agreed strike price in exchange for the environmental attributes of the power generation.</td><td>Environmental Attribute</td></tr>
<tr><td colspan="2">Self-supply:
Consumer owns the renewable electricity generator and is responsible for its operation. The renewable electricity generator may be directly connected at or near the point of use, off-site with the electricity being grid-delivered to the user, or off-site with the power sold to others but the EACs are retained by the consumer.</td><td>Environmental attribute and power</td></tr>
<tr><td colspan="2">Project green tariffs:
These are optional programs in regulated electricity markets offered by utilities and supported by a regulated tracking registry that allows eligible customers to buy bundled renewable electricity from a specific project through a dedicated utility tariff rate.</td><td>Environmental attribute and power</td></tr>
</table>

Climate Claims in Aluminium

Frameworks for carbon intensity claims in the aluminium sector are underdeveloped. As Hasanbeigi et al. describe in their review of standards, policies and guidelines "What is Green Aluminum?"[51] focus has always been placed on producer intensity calculation with the intent of facilitating a smelter's own decarbonisation pathway, but not facilitating the chain of custody of the embedded emissions of their aluminium to their customers.

Only 1/12 of the initiatives interrogated in the study was specifically aimed at demand as the market focus area. This has meant that the chain of custody of climate environmental credentials in aluminium lags other comparable industries such as steel. The only demand focussed guideline, the World Economic Forum's First Movers Coalition,[52] sets procurement intensity target but does not provide details as to what methodology should be applied to calculate it. As we move into the next critical phase of the energy transition the industry may have to reconsider what the drivers will be for change, and if a credible low carbon aluminium framework will unlock real decarbonisation from the other end of the supply chain. If so, there is a need for a demand-side framework that caters to the global nature of aluminium supply chains and standard indirect energy emissions accounting to compare an electrolytically derived product effectively.

Midstream and downstream producers and consumers have limited place in the current leading industry decarbonisation pathways (Mission Possible Partnership[53] or The ASI Pathways)[54] that look at industry wide emissions budgets but cannot facilitate downstream pathways on the basis that the size of the prize is too small. However, it is becoming clear that consumers looking to reduce their scope 3 inventories to align with voluntary and mandatory reporting requirements at a corporate level, or meet product intensity thresholds for their customers or importers to carbon taxed market, is also driving decarbonisation through changing procurement strategies and demand may be a more impactful lever for change than has previously been acknowledged.

The most rigorous environmental claims to support supply chain decarbonisation could be based on EPDs; extensive expert Life Cycle Assessment (LCA) studies followed by 3rd party verification. The scope of such studies may be an exclusionary burden for smaller producers and even EPDs have Scope 2 methodological divergence between the verifying programme operators (Table 5). There is also an issue

with the temporal bounds of such detailed schemes. With the decarbonisation horizon to be critical for smelters in the next 5 years, a system that captures variability at a frequency shorter than this is needed, whereas EPDs can take anywhere up to a year to complete, and are valid for 5 years going forward.[55] At the other end of the complexity spectrum, simple threshold values have been proposed elsewhere, or in the case of CBAMs cost of embedded carbon applied at the border, indirect emissions excluded entirely – making all electrification equally valuable, while reducing the calculation overhead burden to companies. For aluminium, this can put green electrified smelters at a competitive disadvantage.

> *There is currently no definitive low carbon aluminium standard that specifies both the carbon footprint threshold and the measurement methodology.*
>
> **— International Aluminium Association Low Carbon Aluminium Fact Sheet[56]**

The response to this has been several disaggregated methodologies, brands and labels to convey to consumers relative emissions intensity typically based on a threshold intensity of around 4tCO_2e/t,[56] rather than an absolute intensity appropriate for a consumer's own carbon accounting needs, or able to differentiate in the 0-4tCO_2e/t.[57] A common best practice for Aluminium carbon accounting, and indirect energy emission accounting could unlock a valuable green aluminium market. Where other industries can rely on generic standards to produce meaningful product carbon footprints, the aluminium industry's reliance on indirect energy emissions introduces complexities in comparability that need to be addressed.

Table 5 Product Carbon Accounting Frameworks in Aluminium

Accounting Methodology	Description	EAC Supported	EAC Additionality Requirement	EAC Mass Balance	Common Uses
RMI (Rocky Mountain Institute) Emissions Reporting Guide[58]	Guideline specifically aiming to facilitate product comparisons. It is based on the GHG Protocol methods for carbon accounting. It is a flexible and detail focussed approach that provides transparency to the end user but makes direct comparison challenging to an average user of a PCF due to broad acceptance of approaches.	Broad support according to GHG Scope 2 Guidance hierarchy, including unbundled RECs. Dual-reporting required.	Yes	Not permitted.	Platts Low Carbon Aluminium Premium[59] Type II Unverified Claims Verified and unverified PCFs FMC Claims[60]
IAI (International Aluminium Institute) Aluminium Carbon[5]	Carbon accounting methodology based on the ISO standards for product accounting. Has specific purchased electricity accounting rules which allows for quick comparison of products but does not address the issue of additionality or mass balance of environmental attributes.	PPAs, Self Supply or Bundled Project Tariffs V-PPAs excluded due to lack of direct connection.	Instruments limited to those that have strong case for additionality.	Not specifically prohibited.	Harbor Aluminum Green Premium[62,63] Platts Low Carbon Aluminum Premium[60] Type II Unverified Claims Verified and unverified PCFs Alcoa Ecolum[64] FMC Claims[61]
ASI (Aluminium Stewardship Initiative) Performance and Chain of Custody standards[65,66]	Focusses on broader sustainability issues than climate, allowing for claims of responsibly sourced aluminium only, with pre-approval of the specific claim from the ASI required. A product claim requires meeting the ASI Performance Standard and the Chain of Custody Standard[67] Broadly, this requires meeting both a threshold smelter intensity and aligning to an appropriate decarbonisation pathway for the smelter baseline. This sectoral decarbonisation, binary, approach does not support downstream carbon accounting and demand driven smaller cumulative incremental gains form aluminium fabricators and end consumers procurement decisions. The ASI has announced that the standard will be updated for 2027 with a renewed focus on claims in scope to be reviewed[66]	Not specifically prohibited.	Not specifically required.	Not specifically prohibited.	Type I Declaration
EPD Product Category Rules (PCRs) Programme Operators: European Aluminium (EA)[67] ULSE Inc. (UL)[68] EPD-Norge[69,70]	Type III environmental declarations for the creation of EPDs, currently the most rigorous controlled and regulated environmental impact calculation. EPDs are 3rd party verified by definition and moderated by programme operators' product category rules. 5-year validity period of the of the EPD puts the onus on reporting companies to ensure the energy mix claimed in the calculation remains constant for the validity period as major changes will trigger invalidation procedures.	Programme operators take a range of approaches: EA and EPD-Norge accept GO for EU aluminium but does not cover other jurisdictions specifically. UL version 4 explicitly forbids the use of EACs but is under revision "to develop a consensus-based method to include contractual instruments (e.g. RECs, PPAs) in LCA and EPD results".	Not yet required.	Not specifically prohibited.	Type III EPDs Hydro REDUXA 4.0 Low-carbon aluminium[71] Alcoa Ecolum[72]
EU CBAM (Cross Border Adjustment Mechanism)[73]	Combats carbon leakage due to the increased costs to EU producers subject to carbon taxes in the EU. In its current form the EU requires embedded indirect emissions to be calculated and reported on for all aluminium products, but they do not contribute to the import burden placed on the goods.	PPAs Supplier EF GOs or RECs prohibited, The I-REC organisation has developed a template contract to effectively re-bundle their certificates with supplier contracts so that this instrument can also be used for CBAM.[74]	Instruments limited to those that have strong case for additionality.	Not specifically prohibited.	Import duty applied at point of entry to the EU for aluminium products above a certain carbon intensity threshold.

An Electricity Focussed Accounting Claims Framework for Aluminium?

The aluminium industry is unique in its relationship to power grids as a major stable industrial consumer and potential to be a shedding load.[42] We see the potential for aluminium to support the decarbonisation of grids but so far, we have not seen this occur on a fast enough timeline. There is increasing demand for low carbon aluminium from semi-fabricators and consumers looking to meet their own climate obligations to regulators and consumers through their procurement power, that cannot be due to a disconnect in product intensity reporting in aluminium supply chains. As an industry we must align on:

1. The use of accounting instruments in indirect emissions accounting is inconsistent and must be addressed in a common framework to ensure comparability of products.
2. An agreed temporal boundary that captures variability in procurement and grid mix changes through time is necessary on the aspired decarbonisation trajectories for installations.
3. The quality of renewable energy certificates varies, yet traditional claims of non-additionality are not always applicable to aluminium production.
4. Consensus on allocation of embedded indirect emissions across products from the same facility.
5. How national policy and permitting constraints on new renewable infrastructure interacts with green certificate markets and how the aluminium industry can influence this.

Each of these elements can cause a given aluminium product carbon intensity to rank differently against its peers and so a common approach and consensus is called for to build consumer confidence in green claims and associated premiums.

Following dedicated discussions at our launch event this September we propose a working group be set up with relevant stakeholders to build consensus and work towards a common but simple intensity calculation, that consumers have confidence in.

BATHCO
Empowering Green Aluminium

The Bathco Group advances a more circular Aluminium economy.

We trade Green Aluminium, upcycle by-products, and secure critical raw materials to keep value in the loop.

We develop and implement state-of-the-art technology to improve smelting efficiency and reduce CO_2 intensity.

Aluminium sits at the heart of the energy transition: it is energy- and carbon-intensive to produce, yet essential for electrification and resilient infrastructure.

Our commitment is clear: to expand the supply and transparency of genuinely **Green Aluminium** by accelerating upcycling, advancing best practices, and driving innovation across raw material supply.

Our aim is a measurable, greener future for Aluminium.

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Many well-known industry leaders are leveraging CarbonChain to comply with sustainability regulations and expectations and capitalize on green premiums across various products and industries.

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