NET-ZERO BY 2050: SCIENCE-BASED DECARBONISATION PATHWAYS FOR THE EUROPEAN ALUMINIUM INDUSTRY

Executive Summary

European Aluminium
ANYTHING BUT BASIC

Foreword

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European Aluminium's commitment to decarbonisation by 2050 was first established several years ago, but commitments only matter when they're backed up by concrete plans to act. With the publication of ***'Net-zero by 2050: Science-Based Decarbonisation Pathways for the European Aluminium Industry,'*** our community has taken the next step, moving beyond promises about our destination to focus on the journey itself.

Since aluminium is both a significant source of greenhouse gas emissions today and a strategic material for the clean energy sector of tomorrow, the stakes are high, and our responsibility is clear. Taking alignment with the IPCC's 1.5°C scenario as its north star, this study provides a comprehensive overview of the technological solutions that will be needed across the entire European aluminium value chain and offers recommendations for a policy framework that will allow these various solutions to deliver on their potential.

While we are excited about this milestone, the real satisfaction will come from watching our member companies, together with a broad range of partners and stakeholders, take this initial vision and transform it into reality on the ground in the years to come. We are under no illusions as to the scale of the challenge, but we are focused, motivated and united by a powerful sense of opportunity and responsibility.

This is our pathway. Let's take it together!

Paul Voss
Director General
European Aluminium

Background

The European aluminium industry plays a vital role in supplying the clean technologies necessary to meet the EU's ambitious 2050 climate objectives. Yet, the industry faces the critical imperative of accelerating its decarbonisation efforts. Our study, titled ***'Net-zero by 2050: Science-Based Decarbonisation Pathways for the European Aluminium Industry,'*** charts a path to reduce emissions while sustaining growth.

Today, the industry emits around 24 million tonnes of CO_2 equivalent each year, primarily from primary aluminium production. The sector is classified as 'hard to abate,' facing challenges due to the high costs and/or limited availability of decarbonisation technologies. However, substantial investments in research, innovation, and the development of new technologies offer viable solutions that can significantly expedite the decarbonisation journey.

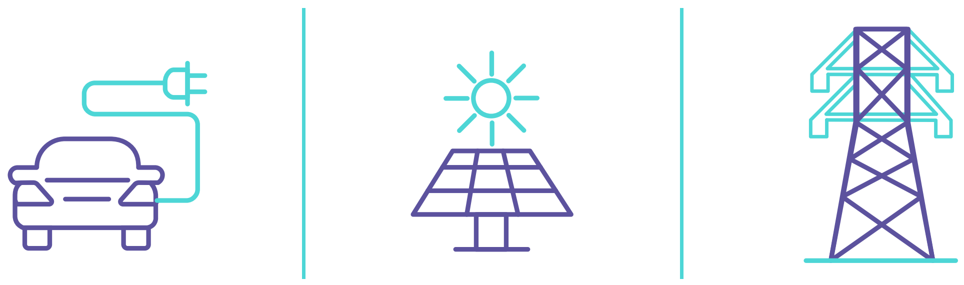
This is particularly crucial given the rising demand for sustainably produced aluminium in Europe. **Projections indicate a potential 30% increase in aluminium demand by 2040, driven largely by the adoption of clean technologies like solar photovoltaics and electric vehicles.** Advancing decarbonisation isn't just an environmental necessity for the aluminium industry; it's also a strategic imperative to ensure its long-term competitiveness and sustainability.

Projections indicate a **potential 30% increase in aluminium demand by 2040**, driven largely by the adoption of clean technologies like solar photovoltaics and electric vehicles.

European aluminium demand for the energy transition by 2040

Europe's energy transition alone will require **an increase of 30% compared to today's consumption (2022).**

Main Drivers:



Objectives

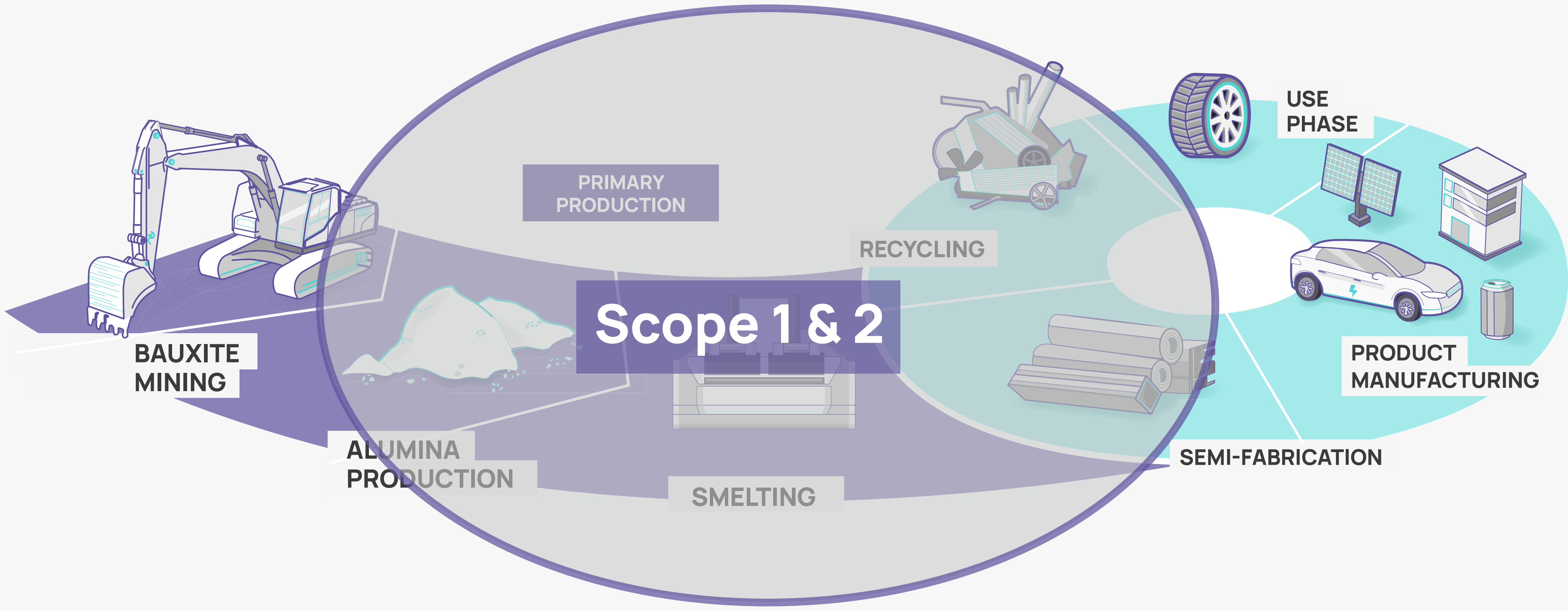
The overarching objective of this study, conducted in collaboration with Ramboll, is to align the European aluminium industry with the Intergovernmental Panel on Climate Change's (IPCC) 1.5°C by 2050 scenario while offering a comprehensive overview of the different steps needed to reach this ambitious goal.

The study specifically aims to:

- Demonstrate the industry's dedication to operational decarbonisation;
- Balance the benefits of aluminium usage with insights into production and manufacturing;
- Provide a sectoral framework for member companies to establish their decarbonisation pathways;
- Offer policy recommendations to create an enabling environment for achieving a 1.5°C-aligned trajectory.

Methodology

This study thoroughly analyses the European aluminium value chain, covering alumina refining, primary smelting, semi-fabrication, and recycling. It assesses emissions (Scope 1 and Scope 2) to identify decarbonisation technologies for European operations.

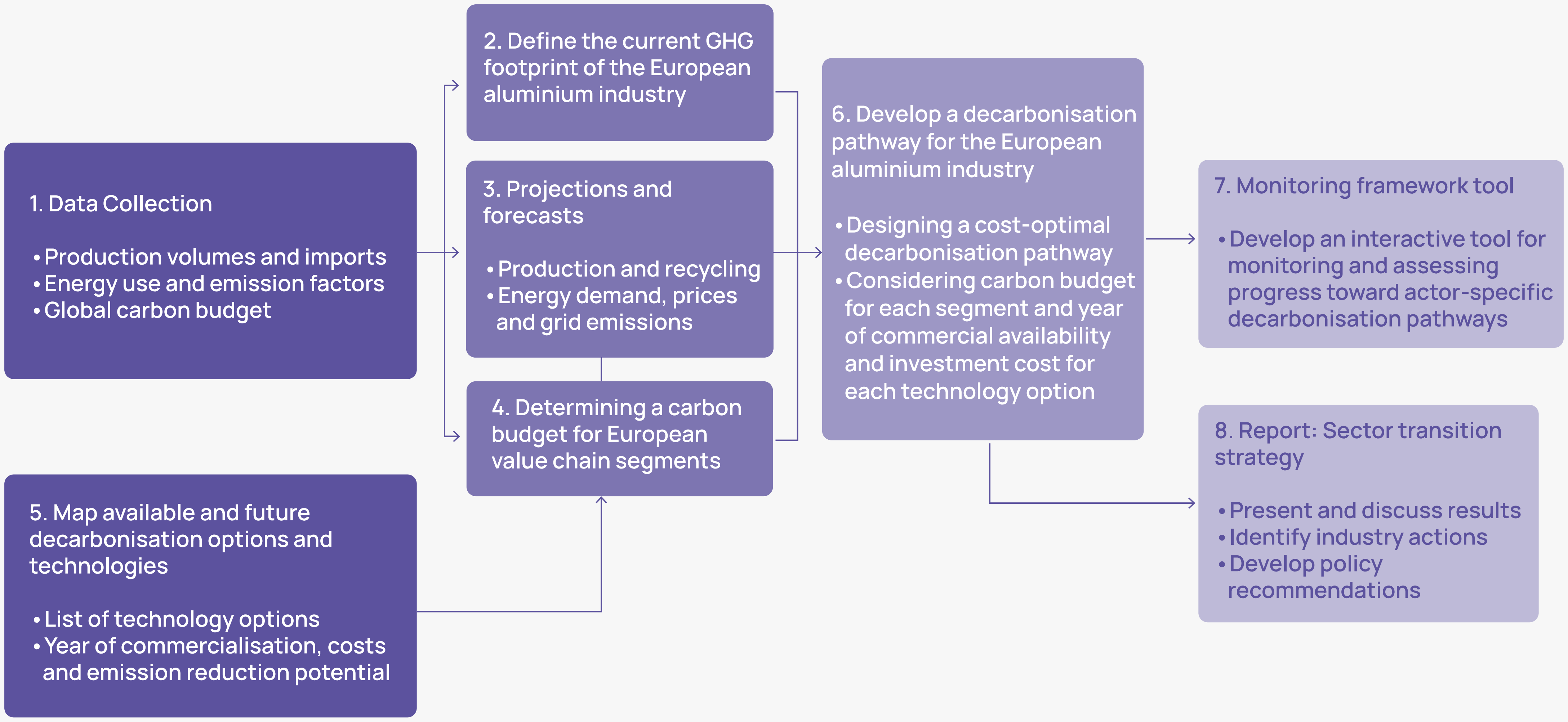


After defining the study's scope, it assesses key parameters like material flows, greenhouse gas (GHG) emissions, energy demand, and decarbonisation options for the entire sector and specific segments. The study's scenarios for aluminium demand and GHG budget rely on the International Aluminium Institute's (IAI) 1.5°C pathway, which is based on the International Energy Agency's Net Zero Emissions 2050 scenario, encompassing the global aluminium industry.

To evaluate decarbonisation options, the study combines a rigorous literature review and expert consultations to define parameters for each technology. All data feeds into a mathematical model developed by Ramboll, aiming to meet 2050 carbon budgets at the lowest possible cost.

The model results depend on assumptions and data inputs, subject to potential changes due to evolving policies. The assumptions and data used represent the best available information. These results apply to the European sector overall, although local factors such as resource availability, national incentives, and geography may lead to slightly different decarbonisation implementations, all in alignment with the goal of reducing carbon emissions.

The methodological approach step by step:

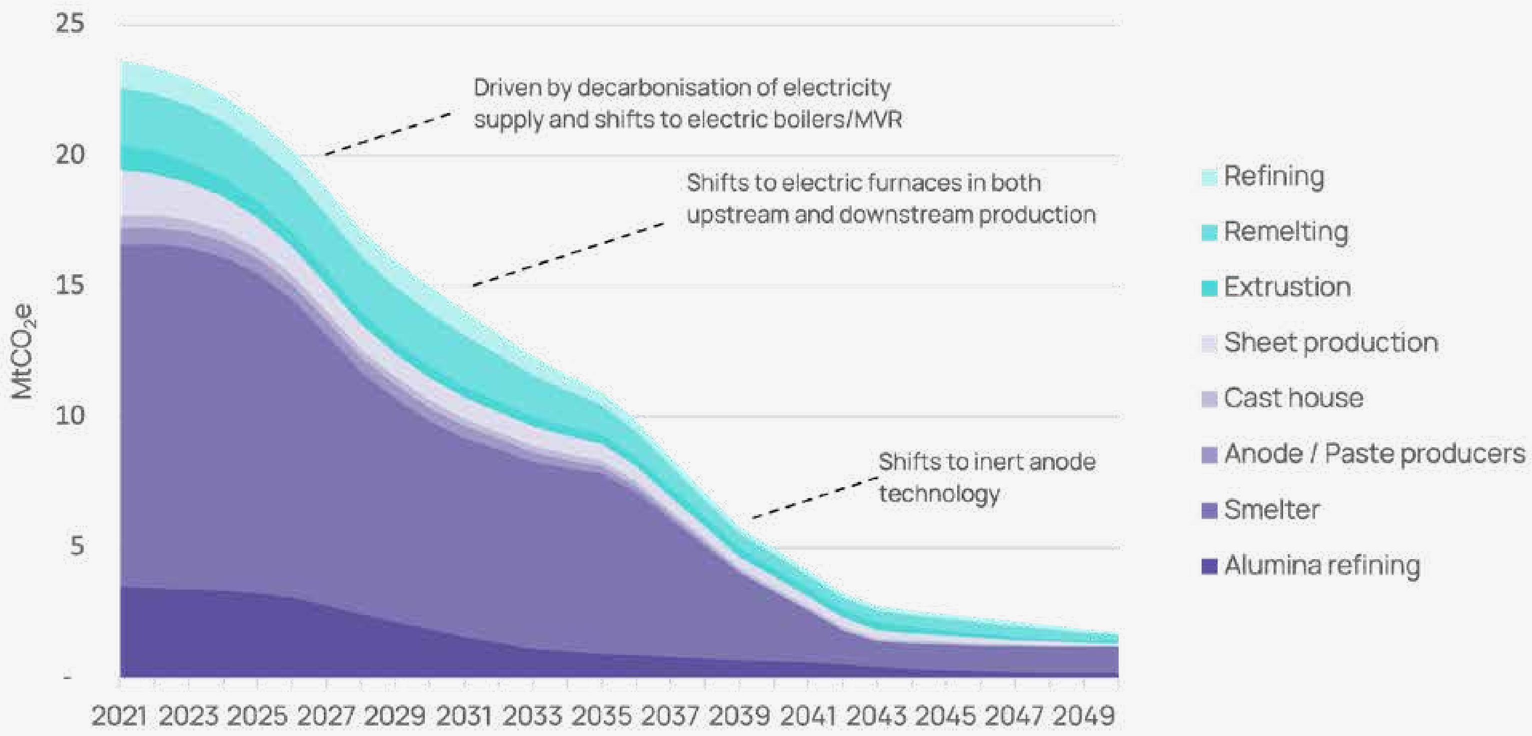


Source: Ramboll.

Key Findings

The analysis presented in this study demonstrates that decarbonising the European aluminium industry is possible but will require ambitious actions. By 2030 and 2040, the emissions profile of European aluminium production should be cut by at least 37% and 78%, respectively, as explained in the figure below.

Decarbonisation pathway for European aluminium production



Source: Ramboll analysis.

The study's conclusions reveal that 93% of the total greenhouse gas emissions of the sector must be eliminated by 2050. This ambitious target aims to reduce the sector's current total emissions of 24 $MtCO_2e$ to approximately 1.8 $MtCO_2e$ in 2050.

-93% of the sector's total greenhouse gas emissions must be eliminated by 2050

The main levers identified for this substantial emissions reduction can be summarised as follows:

- **Swift decarbonisation of the electricity supply**, benefiting both currently electrified segments (i.e, primary smelting) and those that will transition to electrified processes;
- **Introduction of inert anodes in primary smelters** to eradicate direct emissions from the most carbon-intensive segment of the value chain;
- **Adoption of low-carbon furnaces and alternative heat systems** to tackle emissions arising from fuel combustion in heating and melting processes throughout the value chain;
- **Increased use of scrap recycling**, leveraging the lower carbon intensity of the recycling process compared to primary production.

The electrification of certain segments of the value chain, coupled with the electro-intensity of primary aluminium smelting, is projected to result in a 82% surge in the sector's annual power requirements. This would elevate the current yearly electricity consumption level of approximately 60 terawatt-hours (TWh) to around 110 TWh, an increase equivalent to the annual electricity demand of a country like Greece.

The journey towards decarbonisation also comes with significant financial implications, with an estimated total cost of around €33 billion for deploying decarbonisation technologies throughout all value chain segments. It is crucial to note that this figure accounts for deployment costs (mostly brownfield costs) but excludes research and development costs necessary for developing and refining innovative technologies. Furthermore, costs associated with building infrastructure and supporting services for these new technologies are not considered.

Finally, it's essential to note that the estimate does not include costs related to expanding capacity, which are particularly relevant given the substantial growth required in the recycling and semi-fabrication segments. These expansion costs are also substantial, in the order of magnitude of billions of euros. As a result, the actual total investment needed for the sector to meet future demand with a decarbonised supply significantly exceeds the €33 billion estimate. This underscores the necessity for various forms of support and incentives to successfully navigate the transition phase.

+82%

Low-carbon electricity required annually in 2050 compared to 2022

+33 Billion €

Required for deploying decarbonisation technologies throughout all value chain segments.

Policy Recommendations

Achieving a fully decarbonised European aluminium industry necessitates proactive policy interventions. The study has identified four main priorities:

1. **Accelerate the decarbonisation of power generation at a competitive price**
2. **Prioritise and increase investments in R&D for low-carbon technologies**
3. **Increase scrap recovery and recycling**
4. **Incentivise and support European low-carbon and circular production capacity**

The associated policy recommendations for each of these areas are presented below.

1. Accelerate the decarbonisation of power generation at a competitive price

As electricity costs represent up to 40% of the operating costs of primary smelters, and indirect greenhouse gas emissions are responsible for ~60% of the greenhouse gas footprint of the primary metal, access to cost-competitive low-carbon electricity is clearly the most promising opportunity. In the short to medium term, this 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. Power Purchase Agreements (PPAs) and/or a shift to self-generation of decarbonised power will be essential to deliver on the pathways.

Today, aluminium producers, like other heavy industries, cannot match the price for PPAs paid by companies in sectors with relatively low energy consumption and without a baseload consumption profile, such as consumer goods and services. Therefore, earmarked support to increase the share of aluminium production from low-carbon electricity should be a top priority for policymakers.

So far, the progress in deploying and connecting clean energy sources to the grid has varied significantly among EU Member States, despite the EU's ambitious targets, limiting the access of aluminium plants to renewable grid power. To accelerate the transition to a fully decarbonised power sector, simplifying the permitting process for renewable energy development or setting up Member State/European Investment Bank financial guarantees for long-term PPAs will be essential.

In addition, pooling solutions[1] will help deal with significant shaping/firming costs, caused by the intermittent nature of renewable generation, especially in countries where baseload decarbonised electricity is unavailable.

[1] Where an aggregator "pools" together the renewable electricity produced, undertaking all shaping risks and supplying the consumer with baseload power.

The transition to intermittent renewable sources should also include policies promoting the implementation of energy storage solutions and supporting developments in stand-by operations of flexible power plants to ensure that smelters have access to reliable green power.

Lastly, European consumers who sign PPAs for renewables will still face carbon costs due to the marginal pricing in the European electricity markets. This is not the case for their competitors in other world regions, hence the indirect costs compensation mechanisms should be kept and harmonised to ensure the global competitiveness of the European electro-intensive industries.

2. Prioritise and increase investments in R&D for low-carbon technologies

Boosting investments in Research & Development (R&D) to support the implementation of low-carbon technologies will be crucial to meeting the 2050 targets. The groundwork for these technologies must be established as soon as possible to ensure readiness for the upcoming investment cycle.

For primary aluminium, the most carbon-intensive segment of the value chain, the introduction of inert anodes is expected to eliminate direct emissions, though extensive R&D efforts will be needed in this direction. Carbon Capture and Storage (CCS) has been assessed as a bridging reduction measure until the inert anode technology is fully developed, but the study shows that financial support is essential to make it cost-effective at sectoral level. For the remaining segments of the value chain, electrification or the replacement of gas with alternative fuels will be key in addressing the emissions derived from the heating and melting processes.

The use of green hydrogen as a substitute for natural gas in furnaces is currently being explored. However, the high costs associated with the production of green hydrogen, which can significantly differ across Member States, still limit the economic viability of this fuel. Concerns also remain regarding the future available supply of green hydrogen in Europe, which might not be enough to satisfy the green energy demand from industry to align with the pathways.

For these reasons, it is essential to conduct additional research and pilot testing to determine the most effective technological approach for mitigating process emissions from natural gas in various sectors. This is crucial to ensure the implementation of appropriate solutions. Furthermore, efforts should be made to investigate measures that promote the expansion of competitive infrastructure for hydrogen production, storage, and transport throughout Europe. This will contribute to cost reduction and ensure a secure supply of hydrogen.

While this study has estimated substantial investment costs for the industry to align with the 1.5°C pathways, it has not factored in R&D costs for the development and testing of new technologies or the energy systems developments which are necessary to facilitate these technological shifts. Consequently, the total cost of decarbonising aluminium production will likely be substantially higher and warrants additional support through both public and private funding.

Effective policy and financial support on scaling and accelerating the clean technologies that can be successfully used in the sector will be essential. R&D grants can provide financial support for R&D initiatives focused on developing low-carbon technologies and processes for aluminium production. Additionally, green bonds for infrastructure or contracts for difference (CfDs) schemes could finance projects related to sustainable aluminium production with breakthrough technologies, including building or retrofitting low-carbon smelters.

3. Increase scrap recovery and recycling

Aluminium recycling consumes only 5% of the energy required for primary aluminium production. Therefore, enhancing the use of recycled aluminium becomes a pivotal strategy in not only reducing emissions within the aluminium sector but also fostering circularity, and it should receive support and incentives.

The projections of our study estimate that European recycling production will increase by about 70% by 2050. To ensure a consistent supply of high-quality scrap for these operations, comprehensive efforts are necessary, beginning with the enhancement of recycling systems and sorting methods. Additional measures that can contribute to this objective include:

- Extended producer responsibility schemes;
- Methods to divert aluminium from landfills;
- Designing products that can be easily separated, collected, and recycled;
- Incentives to aluminium alloy users to choose alloys that can be produced utilising higher scrap content.

Compared to other regions, recycling rates in Europe are already substantial, with over 90% aluminium recycled in the automotive and building sectors and approximately 75% for aluminium cans. Increasing these rates remains a key lever for decarbonisation. Still, it is important to note that even with 100% recycling rates, secondary metal production alone cannot meet the demand for aluminium. Therefore, in addition to increasing the secondary capacity, efforts will be needed to safeguard European primary aluminium production in the coming decades.

4. Incentivise and support European low-carbon and circular production capacity

Aluminium has been identified by the EU Institutions as a strategic raw material for the European transition due to its crucial role in meeting the Green Deal objectives. Ensuring access to this metal in the coming decades will therefore be of paramount importance for building European strategic autonomy in the aluminium supply.

Increasing production of both secondary and primary aluminium in Europe to meet the growing future demand makes sense, not only from a supply perspective but also from a climate perspective. European primary production, which is the most carbon-intensive segment of the value chain, currently has an average carbon footprint that is about one-third of the global average and approximately 60% of the average of the metal imported into Europe.

GHG intensity comparison	[tCO_2e/t Al]
Average European production	5.10
Average of imports to Europe	8.32
Global average	15.06

As further evidence of the climate benefits of relying on European production and limiting imports, the model demonstrates that European aluminium operations emit 24 $MtCO_2e$ annually, whereas the yearly imports of aluminium into Europe are associated with about 27 $MtCO_2e$.

Policymakers must incentivise and support production capacity growth across the entire European supply chain, while at the same time protecting the competitiveness of the existing European facilities, which operate as price-takers in the global market. This entails maximising European recycling potential on one hand, while restarting and expanding existing production capacity in the primary segment on the other.

Robust carbon leakage protection measures are pivotal in supporting the sector in its challenging decarbonisation journey. A thorough assessment should be conducted before fully replacing the existing measures[2] with untested new instruments like the EU Carbon Border Adjustment Mechanism (CBAM). Considering the huge financial investments required for the transition and the growth opportunities stemming from increased demand, initiatives should be put in place to bolster investor confidence. Increasing European capacity in production and transformation is the best option for a sustainable European future.

Last, but not least, the challenge of CO_2 emissions associated with imported products persists. Considering that a rapid alignment in emissions levels between European and imported products is unlikely in the short and medium term, and acknowledging the likely need for imports to meet demand, it becomes crucial to introduce strong incentives for decarbonisation through well-informed sourcing practices and requirements.

[2] The free allocation of allowances and the compensation of the indirect costs of EU ETS

Conclusions

Our study underscores the critical need and clear opportunity for the European aluminium industry to transition to net-zero emissions by 2050. The path involves ambitious yet achievable actions across various segments of the industry, supported by proactive policy interventions and significant investments in low-carbon technologies and infrastructure. By embracing these science-based decarbonisation pathways, the industry can not only significantly reduce its environmental footprint but also strengthen its competitiveness and sustainability in the long term. Now, the pressing task at hand is to translate these insights into concrete actions, with collaborative efforts from industry players, policymakers, and other stakeholders, to realise a greener, more resilient future for the European aluminium sector.

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Given aluminium’s energy-intensive nature and its status as a strategic material for the energy transition, a clear and ambitious decarbonisation pathway is a must! We warmly welcome the work done by European Aluminium to help underpin this endeavour. We are ready to work closely with the industry to turn vision into reality.

Kerstin Jorna, Director-General for Internal Market, Industry, Entrepreneurship and SMEs (DG Grow) at the European Commission.

European Aluminium

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