Why Europe struggles to decarbonise aluminium, even in a world without US tariffs

Aluminium's push towards sustainability reveals a complex blend of challenges and opportunities. Even without the added weight of US tariffs, European producers face mounting hurdles – and the continent's climate ambitions could be at risk of being brought swiftly back down to earth

In this bundle

Article | 29 July 2025 **Energy** | **Manufacturing, Construction and Retail** | **Sustainability**

Tariffs, costs and carbon – the triple challenge of greening aluminium

Aluminium's shift towards sustainability presents a complex mix of challenges and opportunities. This article explores the business case for decarbonising aluminium production, with leading producers currently prioritising clean electricity and recycling initiatives

A dual strategy will be key for reaching sustainability goals: increasing the share of recycled aluminium through better recycling technologies and infrastructure, while also making primary aluminium production as environmentally friendly as possible

Reducing carbon emissions from aluminium production: a focus on the business case

Aluminium is integral to modern life. Its lightweight, durable, and versatile properties make it indispensable across numerous industries, from transportation to construction. The metal's role in the transition to a low-carbon economy is equally significant. Aluminium is crucial in the manufacture of solar panels, wind turbines, battery enclosures, and hydrogen fuel cells – all essential technologies for a sustainable future. Moreover, the industry has garnered renewed interest as gallium, a byproduct of refining bauxite into alumina, is now recognised as a critical mineral for semiconductors, 5G networks, artificial intelligence, satellite systems, and defence technologies.

In 2024, global primary aluminium production totalled 73 million metric tons, with China commanding the lion's share at 60%, while the US and Europe contributed less than 10% combined.

Despite aluminium's pivotal role in the energy transition, its production is marred by significant carbon emissions, emitting nearly 1.1 gigaton of CO_2. That equals about 3% of the world's direct industrial CO_2 emissions and 0.5% of total global greenhouse gas emissions. That might not seem like much, but aluminium stands out when compared to other modern materials. Producing a ton of aluminium in Europe or the US releases about 4,800 kilograms of CO_2 into the atmosphere, which is far more than a ton of cement (800 kilograms), plastic (1,300 kilograms), or steel (1,900 kilograms). The contrast is even starker in China, where coal-intensive production methods push emissions to around 15,000 kilograms of CO_2 per ton, making aluminium one of the most carbon-intensive materials in the global industrial landscape.

Aluminium is one of the most carbon-intensive industrial materials in the world

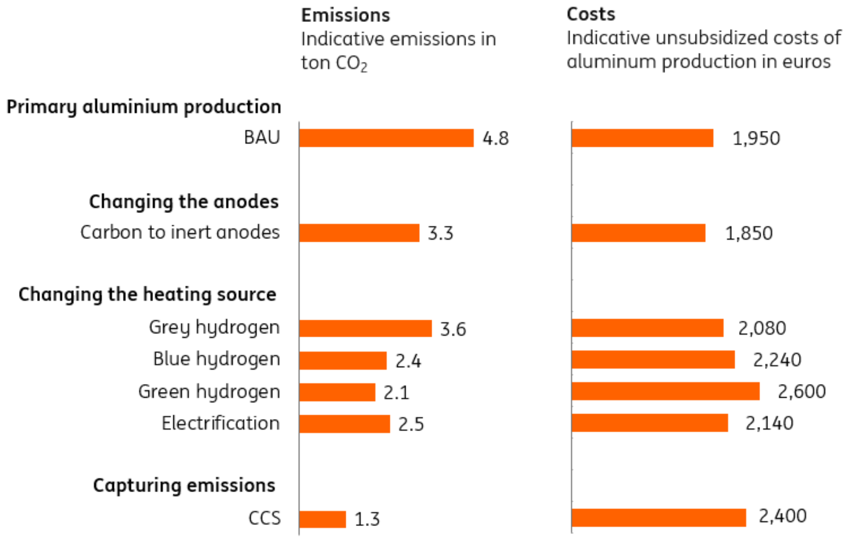
Fortunately, several technologies and strategies offer promising pathways for reducing emissions in aluminium production. They are described in the tech-explainer at the bottom of this article, and we have discussed sector pathways here. This article focuses on the business case for various greening options, making it particularly relevant to corporate decision-makers who drive investment through viable business cases.

We analyse the business case of different ways to green aluminium production:

1. **Switching the anodes** used in the production process. Anodes are often made from carbon, which reacts with CO_2 in the process. Inert anodes are not made from carbon, and in turn, this source of emissions is eliminated.
2. **Change the heating source** from fossil fuels like coal or gas to electricity or hydrogen.
3. **Capturing and storing** the emissions from aluminium production (CCS).
4. **Switching from virgin production to recycled aluminium** with hardly any loss in product quality.

Switching to inert anodes, other heating sources or CCS can significantly reduce aluminium's emissions, though most options come with a distinct cost

Indicative emissions and costs of primary aluminium production in Europe*



Source: ING research

*Production costs for the North Western part of Europe, based on current technology costs and energy prices and without carbon pricing (so assuming 100% free allowances under EU-ETS). Key economic assumptions can be found in the appendix at the bottom of the article.

Changing the anodes

Traditionally, the smelting process relies on carbon anodes, which contribute significantly to CO_2 emissions during the chemical process. Switching to **inert anodes** can potentially reduce emissions by approximately 1.5 tons of CO_2 per ton of aluminium produced – about a third of emissions for EU and US manufacturers, and around 10% for Chinese producers, who emit nearly three times more due to their reliance on coal.

Firstly, inert anodes have a longer lifespan and require less frequent replacement, reducing maintenance and operational costs. Secondly, they consume less electricity during the smelting process, leading to significant energy savings. Additionally, these anodes do not produce CO_2 emissions during the reaction, eliminating the need for costly carbon offsets or mandatory carbon credits. Furthermore, they do not emit fluorocarbons, which are potent greenhouse gases with a global warming potential 6,000 to 11,000 times greater than CO_2.

Despite these potential benefits, inert anodes are not yet widely used. Companies like Alcoa, Rio Tinto and Rusal are developing it, but the technology is still in the pilot or early commercial stage. The biggest hurdle is finding a material that is truly inert in the extreme conditions of the aluminium electrolysis. While the upfront costs of adopting inert anodes are not the primary obstacle, some hesitation remains in the industry. Traditional carbon anodes have demonstrated reliability and process optimisation for more than a century, making aluminium smelters cautious about transitioning to newer, less proven technologies.

Changing the heating source

Aluminium production requires very high temperatures that are currently generated with fossil fuels, so changing the heating source can lead to significant reductions.

Aluminium smelting is already fully electrified worldwide – a key reason for its high electricity demand – yet alternative technologies such as industrial heat pumps, plasma heating, and induction heating are emerging as promising methods for generating the intense heat required for production. While these **electrification** technologies remain challenging to implement in the core refining process, they are increasingly used for preheating, drying, alloying, and casting.

For example, Hydro signed a €1.63 million contract with Pyrogenesis to procure plasma technology for its cast house in Sunndal, Norway. This technology will enable Hydro to use electricity instead of natural gas or other fuels to produce the high-temperature heat required in cast-houses. The company aims to start operating this facility in 2026. When powered by renewable energy, they can further reduce emissions. Our analysis suggests that electrifying the heating process with renewables could cut emissions by half, though this transition comes with a 10% increase in costs, as these technologies are still in their early stages and remain relatively expensive.

Hydrogen could, in theory, be used as a heating source. While several laboratory-scale tests have been conducted worldwide, hydrogen's unique properties – burning hotter and faster than natural gas – pose challenges for furnace and burner design, as well as for safety and control systems. In 2023, Norwegian company Hydro achieved a milestone by producing its first batch of aluminium using hydrogen, although this process was applied to recycled rather than primary aluminium. And Novelis conducted a successful trial in the UK with support from Progressive Energy and UK government funding.

Should the technical hurdles be overcome at an industrial scale, using green hydrogen could cut emissions by up to 60%, offering a substantial environmental benefit. Yet, the current supply of blue and green hydrogen falls far short of what would be required for large-scale aluminium production. Even if it were available, relying on green hydrogen would increase aluminium production costs by roughly one third – a significant challenge in a market where producers must contend with fierce international competition. Additionally, the limited availability of low-carbon hydrogen means it may be more effective to prioritise its use as a feedstock in greener steel or plastic manufacturing, rather than dedicating it solely to aluminium heating.

Capturing and storing emissions (CCS)

Capturing and storing emissions from the production process and power generation by coal or gas plants yields the biggest climate impact in the case of virgin aluminium production. Emissions can be reduced by up to 75%, but it comes with a 25% cost increase in the absence of carbon pricing. While carbon capture and storage (CCS) technology is being developed for aluminium production, it remains in the early stages of implementation. For instance, Norwegian company Hydro is working on CCS solutions that could be retrofitted into existing aluminium smelters, aiming to launch an industrial-scale pilot by 2030.

However, capturing CO_2 from smelter off-gases presents significant challenges, as the concentration of CO_2 is relatively low – about 1%. This low concentration makes the process more complex compared to other industries, such as refineries, plastics, cement, hydrogen, or fertiliser production, where CO_2 concentrations are typically much higher and therefore easier to capture. As a result, CCS is likely to advance more rapidly in those sectors than in aluminium production.

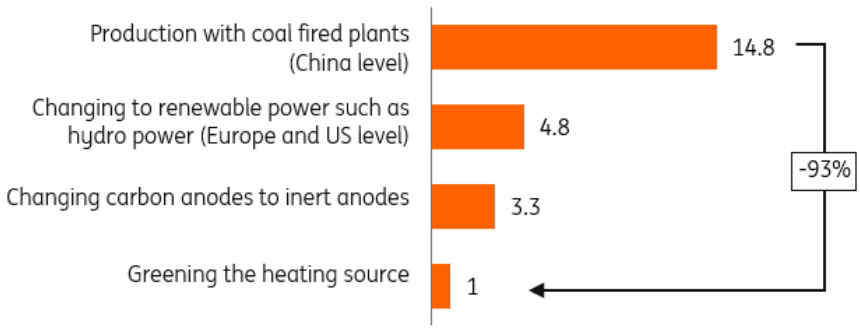
Ways to green primary production of aluminium

How can the sector set itself on a path to net zero with these novel technologies?

Switching to renewable power sources is the most significant step in reducing the carbon footprint of aluminium production. At present, China, which is responsible for 60% of global aluminium output, primarily depends on coal-fired power plants, resulting in remarkably high emissions of approximately 15 tons of CO_2 for every ton of aluminium produced. By contrast, Europe and the US predominantly use hydropower, which reduces emissions to about five tons of CO_2 per ton. Since the start of 2024, aluminium producers have committed to 4.9GW of renewable power purchase agreements, according to Bloomberg New Energy Finance. However, even with 100% renewable energy, emissions from primary aluminium production remain significantly higher than those from materials such as cement, plastic, or steel.

Switching to renewable power is the biggest lever for cutting aluminium's carbon footprint

Indicative emissions for primary production in ton CO_2 per ton aluminium



Source: ING research

To further reduce emissions, the industry must adopt **inert anodes** to prevent CO_2 emissions that inevitably arise when carbon anodes are used. Together with the use of renewable power, this could lower emissions to about 3.3 tons of CO_2 per ton. Greening the fossil-based heating sources could further reduce emissions to about one ton of CO_2 per ton. Carbon capture and storage (CCS) could be applied if producers continue to use fossil fuels like coal or gas, either through post-combustion CCS or pre-combustion using blue hydrogen. **Electrification** of heating sources could reduce the sector's dependence on fossil fuels, either through heat pumps or electric boilers powered by renewable energy or through green hydrogen produced by electrolysers powered by renewable energy.

These measures collectively yield an impressive 93% reduction in emissions for primary aluminium production, providing the prospect of primary production in a net-zero economy. The remaining emissions (about one ton of CO_2 per ton of aluminium) could be offset in other markets or avoided by substituting the demand for aluminium.

> *A suite of technologies could reduce emissions from primary aluminium production by over 90%, but emissions cannot be eliminated*

While these innovative technologies are still in their infancy, meaningful progress will depend on three factors.

First, extensive pilot programs and significant scaling efforts need to be undertaken before the sector can truly achieve net zero. At present, such efforts are limited. Bloomberg New Energy Finance tracks developments within the industry, and notably, there have been no new projects aimed at decarbonising primary aluminium production since November 2024. The industry's main priority remains the transition from coal-fired power to cleaner electricity sources, including hydropower, wind, solar, and nuclear energy. This gradual transition is already shaping the emissions profile of the sector; despite global aluminium production increasing by 6% annually, total emissions have levelled off. Nevertheless, significant reductions in absolute emissions are still required if the industry is to make a meaningful contribution to combating global warming.

Second, aluminium buyers must be willing to pay a green premium to motivate producers to invest in environmentally friendly aluminium and help bridge the price gap. Unfortunately, enthusiasm among buyers – automobile manufacturers, for instance – for paying higher prices remains limited. This hesitancy complicates the London Metal Exchange's efforts to introduce a green premium for sustainably produced metals. While industry advocates have called for price differentiation between clean and conventional supplies, these calls have yet to translate into higher premiums, rendering price signals largely ineffective.

Finally, this situation increases the responsibility of governments to close the price gap if they are truly committed to advancing the decarbonisation of primary aluminium production.

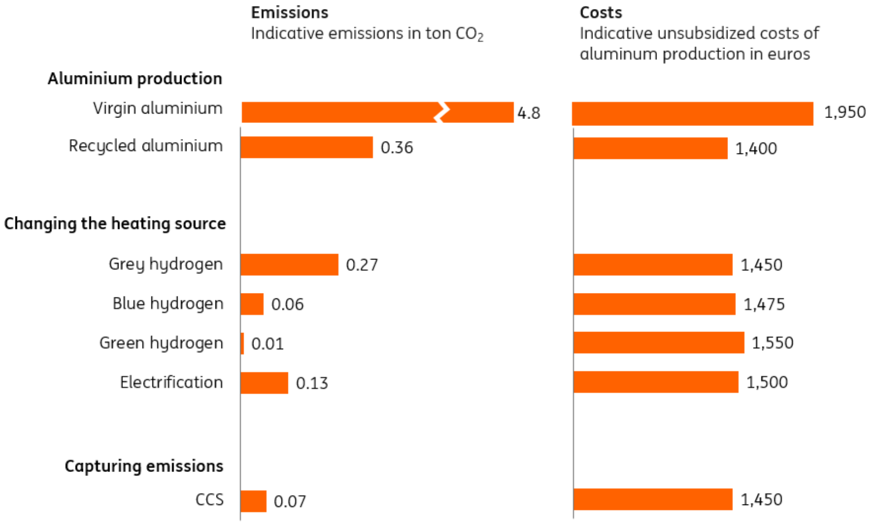
The strong case for aluminium recycling

There's no way of getting around recycling when thinking about the sector's current and future state, as it significantly reduces both costs and emissions compared to primary aluminium production. By reprocessing scrap aluminium, the industry can save up to 95% of the energy required to produce aluminium from raw materials. This energy efficiency leads to a dramatic decrease in CO_2 emissions, with recycled aluminium currently generating only about 0.4 tons of CO_2 per ton, compared to the 4.8 tons produced by virgin aluminium in Europe. And with elevated energy prices in Europe, it does so at a 25% to 30% cost reduction, lowering the price of aluminium to about €1,400 per ton.

Furthermore, recycling aluminium can be repeated almost indefinitely without significant degradation in quality, making it an excellent sustainable alternative. In that regard, recycled aluminium tops recycled plastic or steel, which often yield quality degradation due to impurities, limiting their application in fields such as food packaging or precision machinery.

Recycling brings lower costs and emissions

Indicative emissions and costs of recycled aluminium production*



Source: ING research

*Detailed assumptions are provided in the appendix below. The figure for virgin aluminium production applies to the EU and the US, while in China, it is three times higher.

The emissions from aluminium recycling can be lowered further by applying similar principles as in primary aluminium (changing the heating source and capturing emissions, note that recycling does not involve anodes). However, from an absolute emissions reduction perspective, these technologies can be best applied to primary production. And shifting from primary production to recycling makes a far bigger impact than further greening the recycling process. The cost advantage of recycled aluminium compared to virgin aluminium and the robust quality recycling yields will be strong drivers in this direction.

It's more impactful to enhance recycling rates than to further green the recycling process

Despite these advantages, the global recycling input rate (RIR) for aluminium remains at just 32. In other words, only 320 kilograms of every ton produced comes from recycled sources. North America leads with a rate of 57, indicating that recycled aluminium now exceeds primary production there. However, there is considerable room for improvement worldwide, as currently only about half of all aluminium scrap is actually recycled.

Innovation is now largely driven by the waste collection industry, where companies are increasingly investing in advanced technologies such as laser-induced spectroscopy and digitalisation to enhance the precision of recycling sorting. By purifying the feedstock for aluminium recycling in this way, recyclers are able to achieve higher product quality and more competitive pricing.

Although global demand for aluminium continues to rise, it's important to note that about 75% of the nearly 1.5 billion tonnes of aluminium ever produced remains in active use – and isn't likely to become scrap in the near future. As a result, the industry will need to rely on a combination of recycled and primary aluminium for years to come. To meet sustainability goals, the sector must pursue a dual strategy: increasing the share of recycled aluminium through better recycling technologies and infrastructure, while also making primary aluminium production as environmentally friendly as possible. This article explores the business cases for both approaches, offering insights that may help to guide future decisions by corporate leaders and policymakers.

Special thanks to

The authors thank Brett Belien, master's student in Chemical Engineering at Delft University of Technology, for excellent research assistance.

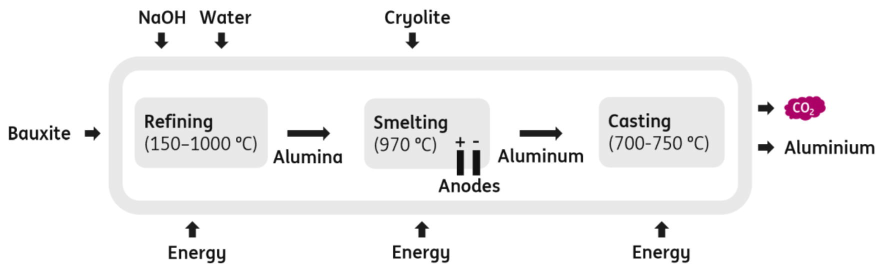
Appendix: Aluminium's tech explainer from an economist

The production of virgin (primary) aluminium consists of three major steps.

1. **Refining**. The first step begins with the mining of bauxite ore, which contains alumina (aluminium oxide) as its key component. Through the Bayer process, alumina is refined from bauxite using caustic soda (NaOH) at temperatures ranging from 150°C to 1000°C. The heat used for this process is typically generated by burning fossil fuels like coal or natural gas.
2. **Smelting**. The purified alumina is then smelted into aluminium metal via the Hall-Héroult process, which involves dissolving alumina in molten cryolite and applying a strong electric current (around 400 kA) at approximately 950°C. This process consumes about 14 MWh of electricity per ton of aluminium, roughly equivalent to the annual electricity use of five Dutch households. A typical smelter, with an output of up to 500,000 tons per year, can use as much electricity as entire cities like San Francisco or Amsterdam. CO_2 emissions arise both from the carbon anodes used in the reaction and, more significantly, from fossil-fuel-based electricity generation.
3. **Casting**. The resulting molten aluminium is cast at around 700°C into ingots, again using heat typically sourced from fossil fuels.

Process of producing primary aluminium

Visualisation of current process (business as usual)



Source: ING Research

Process of greening primary aluminium production

Visualisation of different greening steps to the process

	Refining energy source	Smelting energy source	Anode type	Casting energy source	CO2 Output
Business as usual	Coal/gas	Electricity (hydro/coal/gas)	Carbon anodes	Coal/gas	
Changing the anodes					
Inert anodes			Inert anodes		
Changing the heating source					
Grey Hydrogen Blue Hydrogen Green Hydrogen Electrification	Grey Hydrogen Blue Hydrogen Green Hydrogen Electricity (hydro/coal/gas/oil)			Grey Hydrogen Blue Hydrogen Green Hydrogen	
Capturing emissions					
CCS					80% of CO2 stored underground

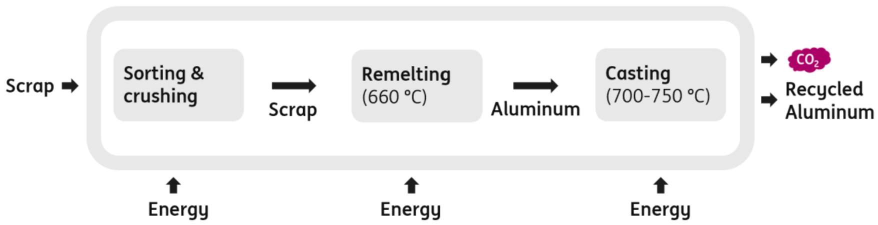
Source: ING research

*Differences compared to BAU. Blank cells represent same situation as in business as usual

In contrast, recycled (secondary) aluminium production bypasses the energy-intensive refining and smelting steps. Scrap aluminium, sourced from used products or manufacturing waste, is simply cleaned, sorted, and remelted at around 600–700°C. This process requires only about 5% of the energy needed for primary aluminium production and results in significantly lower CO_2 emissions. However, the quality and type of scrap can influence the energy use and emissions profile. Despite its lower environmental footprint, recycled aluminium still relies on fossil fuels for heat unless alternative energy sources are used.

Process of producing secondary/recycled aluminium

Visualisation of current process (business as usual)



Source: ING Research

Appendix: our economic assumptions

For aluminium production, capital expenditure (capex) assumptions vary by region. In Europe and the US, capex ranges from €5,000 to €7,000 per ton of annual aluminium capacity, while in China it ranges from €2,000 to €4,000. The lower end reflects a business-as-usual (BAU) scenario. Increases in capex are attributed to the installation of inert anodes, modifications to enable hydrogen use in the Bayer process, and the retrofitting of refining and casting facilities to replace fossil fuels with electricity. Plants are assumed to operate at a 90% capacity factor. The plant lifetime is assumed to be 35 years, with a discount rate of 8% and inflation at 3%.

Our figures are calibrated for Europe using a power price of €45/MWh (low power price region such as the Nordics), a gas price of €38/MWh, and a coal price of €95/ton. Key input prices include €70/ton for bauxite, €450/ton for carbon anodes, and €1125/ton for aluminium scrap.

Specific capex adjustments include an increase of €360*year/ton for inert anode fittings, plus an additional 10% for general retrofitting. Hydrogen-readiness adds 25% to capex, while electrification of the refining process (excluding smelting, which is already electric) applies a 250% capex multiplier on the refinery. Hydrogen is assumed to be produced on-site (so no transport costs) at prices of €1.40/kg for grey hydrogen, €2.20/kg for blue hydrogen, and €4.10/kg for green hydrogen.

For carbon capture and storage (CCS), the assumed cost (including capex) is €55/ton CO_2 for emissions from coal power plants, €100/ton CO_2 from gas power plants, and €225/ton CO_2 for process emissions from the Hall-Héroult reaction between alumina and carbon anodes. The effective CCS capture rate was set at 82% and the EU ETS carbon price at €75/ton. When carbon prices are applied, we have assumed full carbon pricing (no free allowances, so every ton of carbon is priced).

We have used an exchange rate of 1 dollar to 0.90 euro to convert dollar values to euro.

In practice, all these input variables show considerable variation, which yields a wide range of outcomes for every technology. We have chosen to present point estimates as they often capture the main insights better than wide ranges. Treat these numbers as indicative outcomes around which real-time projects will vary.

Author

Gerben Hieminga
Senior Sector Economist, Energy
gerben.hieminga@ing.com

Edse Dantuma
Senior Sector Economist, Industry and Healthcare
edse.dantuma@ing.com

Ewa Manthey
Commodities Strategist
ewa.manthey@ing.com

Coco Zhang
ESG Research
coco.zhang@ing.com

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Aluminium's green transformation: can Europe compete with China and the US?

European aluminium producers face a threefold challenge: cheap Chinese imports, escalating US tariffs, and Big Tech's ability to pay high power prices. These pressures could accelerate a movement away from energy-intensive primary production in favour of sustainable aluminium recycling solutions

The energy crisis has left Europe at a persistent cost disadvantage in the global aluminium marketplace

Three challenges for European aluminium producers

Transforming the aluminium industry to become greener presents both significant costs and the need for substantial investment, particularly in primary aluminium production. This creates a formidable challenge for European manufacturers, who already operate on thin margins or even face losses. Although energy prices have eased since their peak during the Covid-19 crisis, they remain well above pre-crisis levels and are unlikely to match those of competing regions in the near future. This is especially problematic for aluminium producers, as smelting requires enormous amounts of electricity.

For aluminium, everything comes down to electricity. Aluminium *basically is electricity in solid form*

In addition to persistently high wholesale electricity prices, the industry faces challenges such as grid congestion and increasing grid tariffs, further eroding Europe's competitive edge. While our previous article examined the financial viability of various green solutions, this one focuses on the three main challenges confronting European aluminium producers.

1 Competing with China and the US remains a formidable challenge for Europe, even in regions where power prices are relatively low

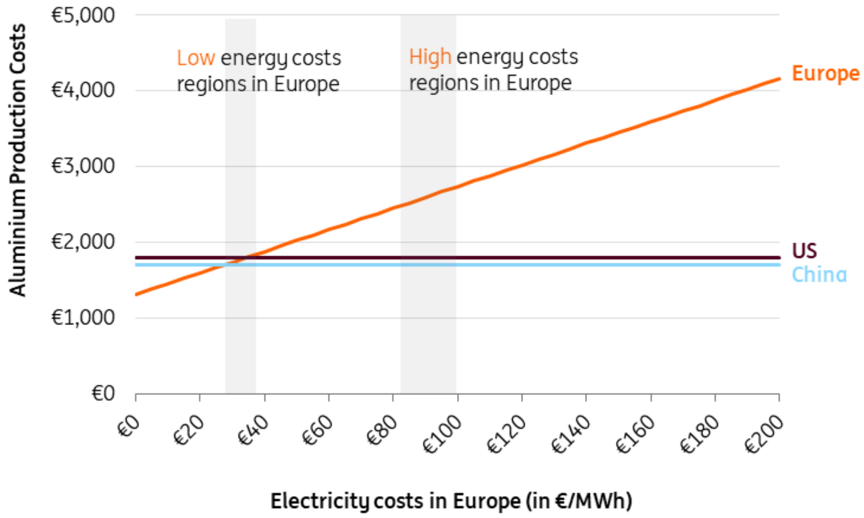
Aluminium produced in China (using cheap coal) and the US (using cheap shale gas) enjoys a significant cost advantage, with production costs around €1,800 per tonne, calculated without factoring in carbon pricing. To be on equal footing, European producers would need electricity prices to drop to between €30 and €40 per megawatt-hour. These levels are only achievable in southern countries like Spain and Portugal, which benefit from plentiful solar and wind resources, as well as the Nordic nations, which have abundant hydropower.

The energy crisis has left Europe at a persistent cost disadvantage in the global aluminium marketplace

Previously, such favourable electricity rates were common across northwestern Europe – including Germany, the Benelux region, and the UK. However, the aftermath of the energy crisis has seen power prices soar to between €75 and €100 per megawatt-hour, largely owing to a greater reliance on liquefied natural gas within the energy mix. Considering the many stages involved in LNG production – including extraction, liquefaction, transportation, and regasification – power prices in Europe are expected to remain higher than those in other regions, even as additional LNG capacity gradually comes online in the coming years.

Europe’s higher power prices make it hard to compete with low-cost aluminium from the US and China

Indicative costs of primary aluminium production without carbon pricing in euros per tonne of aluminium



Source: ING research

Production costs based on local technology costs and energy prices, without carbon pricing and tariffs. Key economic assumptions can be found in the appendix of our previous article (see link in this article).

2 Carbon pricing could level the playing field with China, but not for a while

Given the current state of aluminium production in Europe, carbon pricing could be crucial in making European aluminium competitive with Chinese production. Europe's higher power prices present a challenge, but implementing carbon pricing on both domestically produced and imported aluminium could level the playing field. Applying a cost to every tonne of CO_2 produced, regardless of its origin, might make European aluminium more favourable despite its higher energy costs.

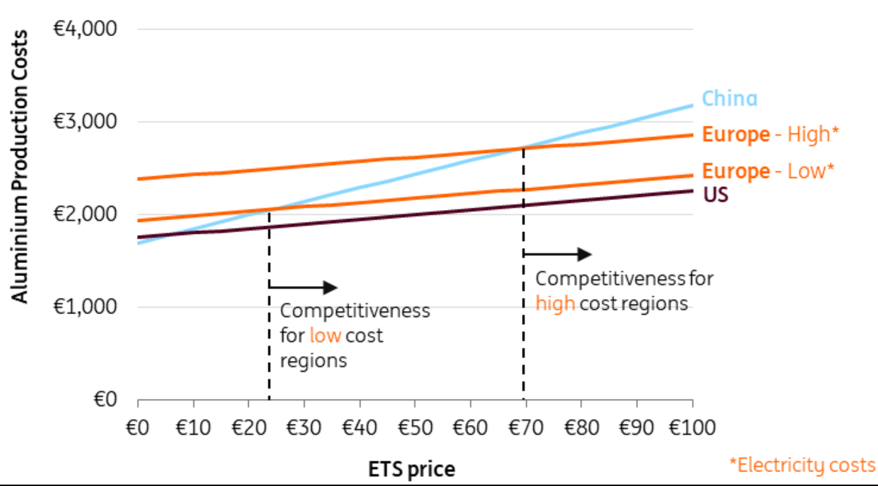
This is particularly evident when comparing the carbon footprint of aluminium production in China and Europe. Every tonne of aluminium produced in China emits three times as much CO_2 as in Europe, due to China's reliance on coal-fired power plants (approximately 15 tonnes of CO_2 per tonne of aluminium in China versus just under 5 tonnes in Europe). In Europe’s regions with low power prices, a carbon price of €25-30 per tonne of CO_2 would level the playing field, while the high power price regions would require a carbon price of €65-70 per tonne.

Currently, EU ETS carbon prices fall within this range for domestic production, but producers still receive significant free allowances. The complete phase-out of all free allowances and the pricing of every tonne of imported CO_2 through the carbon border adjustment mechanism (CBAM) is not expected before 2034. As a result, although the gap is gradually closing, significant differences in competitiveness are likely to remain for at least the next decade.

Despite the compelling case for taxing imported emissions, it will still take years before European producers, who generate emissions two-thirds lower than their Chinese counterparts, are shielded from Chinese imports

Taxing carbon emissions from 'dirty' Chinese imports levels the playing field at €25/tonne CO2 for low electricity cost regions and €70/tonne CO2 for high electricity cost regions

Indicative costs of virgin aluminium production for different carbon prices



Source: ING research

Production costs based on local technology costs and energy prices and without tariffs. Key economic assumptions can be found in the appendix or our other article (follow link in this article).

Unlike with China, carbon pricing alone cannot bridge the competitive gap between European and US aluminium producers. This is because both regions share similar carbon emissions profiles for their electricity supplies, with hydropower playing a significant role in aluminium production. As a result, the introduction of carbon pricing simply raises costs on both sides proportionally, without shifting the balance of competitiveness.

Trade policy, particularly US tariffs introduced under the Trump administration, has had a more decisive impact on market dynamics between Europe and the US. In 2018, a 10% tariff was imposed on aluminium and steel imports, increasing to 25% in March 2025 and to 50% by June. These high tariff barriers have made it virtually impossible for European – and even Chinese – producers to compete with US manufacturers in the American market. Consequently, Europe now faces the risk of an influx of inexpensive Chinese aluminium, intensifying competitive challenges for domestic producers.

European aluminium producers are losing to Big Tech

One of the greatest challenges facing aluminium producers today is negotiating favourable electricity rates, since energy costs make up roughly a third of aluminium's production price. Recently, these producers have found themselves vying with technology giants for access to affordable, low-carbon power. The surge in demand from AI-driven data centres, operated by companies such as Google, Microsoft, Meta and Amazon, has intensified electricity competition, particularly the renewable sources also sought by aluminium smelters.

Unlike aluminium manufacturers, which often operate on thin margins or even at a loss, tech firms have a far higher capacity to pay premium prices for power. As a result, European aluminium producers now face a threefold challenge: competing with cheap Chinese imports, contending with US tariffs, and struggling at home against the formidable purchasing power of Big Tech.

As demand for energy from AI-driven data centres grows, Big Tech is likely to secure its electricity needs in advance. This, in turn, gives utilities greater leverage in negotiations and is likely to drive up power prices for both Big Tech and aluminium producers. Additionally, as renewable energy sources become a larger part of Europe's power grid, the frequency of zero or even negative electricity prices is increasing. This results in more congestion and curtailment of wind and solar generation, which heightens risks for developers and pushes Power Purchase Agreement (PPA) prices higher – directly impacting both aluminium producers and tech giants seeking affordable, long-term contracts.

Developers' risk is compounded by governments trying to future-proof subsidies for renewables in response to higher occurrences of negative power prices. For example, Germany has proposed reducing solar compensation when electricity prices dip below zero and is considering the adoption of two-sided feed-in tariffs, where developers must pay the government if power prices exceed certain thresholds. These evolving policies add further uncertainty for developers who need to raise the price premium of their product. And with increasing risks, the supply of fixed-price PPAs is likely to fall, or be unaffordable, leaving aluminium producers exposed to market risk.

Recycling provides a solution

Recycled aluminium production in Europe offers a promising path forward: it is about 30% less expensive than primary aluminium, with costs averaging around €1,400 per tonne compared to €1,950 per tonne for newly produced aluminium. This makes recycling competitive – even against primary output from China. However, for recycling to truly solve the industry's challenges, two key conditions must be met.

First, Europe needs to safeguard its market from an influx of cheap recycled aluminium imports from China. This "infant industry" approach is justified when fostering local, circular value chains.

Second, recycling rates for aluminium must be raised not just in Europe, but globally. Europe alone cannot fulfil its aluminium demand using only domestically sourced scrap. If primary aluminium production becomes unprofitable and ceases domestically, Europe may need to import a large amount of aluminium scrap. However, if other regions do not also boost their recycling efforts, increased demand will likely be met through higher levels of primary production to compensate for greater exports of scrap.

In that case, Europe's recycling gain will be offset by primary production elsewhere, largely in

China, where carbon emissions for aluminium are three times higher than in Europe. This would ultimately exacerbate the climate challenge, rather than alleviate it.

In summary, while Europe's aluminium sector faces mounting obstacles, these pressures are likely to accelerate the shift toward recycling. However, realising real climate benefits will depend not only on European efforts, but also on the policies adopted by other regions.

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Author

Gerben Hieminga
Senior Sector Economist, Energy
gerben.hieminga@ing.com

Edse Dantuma
Senior Sector Economist, Industry and Healthcare
edse.dantuma@ing.com

Ewa Manthey
Commodities Strategist
ewa.manthey@ing.com

Coco Zhang
ESG Research
coco.zhang@ing.com

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