7 Aluminium industry net-zero tracker

To reach net zero, the industry will need to increase use of clean power, improve the share of recycled aluminium and progress low-emission smelting and refining technologies.

Key emissions data[325, 326, 327, 328, 329, 330]

3%
Contribution to global GHG emissions

1.2 gtCO_2e
Scope 1 and 2 emissions

4%
Emissions growth (2019-2021)

11.2 tCO_2
Emissions intensity (per tonne of aluminium, 2021)

67%
Fossil fuels in the smelting power mix (2021)

1.7 times
Expected demand increase by 2050

<1%
Current low-emission primary production

47%
Reduced emission primary production

Readiness key takeaways

Technology

Aluminium should use clean power and scrap to reduce its emissions. Low-emission refining and smelting methods are proposed to be accessible by 2030. Production costs for low-emission aluminium can be up to 40% higher than traditional methods.[331]

Infrastructure

30% of clean power infrastructure exists while current hydrogen and CO_2 transport infrastructure is below 1% of what is required by 2050.[332] Investments of up to $560 billion[333] are needed to accelerate infrastructure development.

Demand

Low-emission aluminium held less than 1% of the market in 2022. A B2B green premium of around 40%[334] may be necessary, with about 1-2% affecting consumers.[335] However, this remains untested.

Policy

Global aluminium trade requires both domestic and international regulations for decarbonization. Key producing countries, such as China, require more tangible policies especially focused on improving access to clean power infrastructure.

Capital

Over $200 billion in CapEx[338] is required by 2050 to retrofit existing assets with inert anode technology and low-emission smelting technology. However, the business case remains weak, given 8% industry profit margin and 9% WACC.[339]

Stated energy transition goals

- Current industry net-zero scenarios propose a 30% reduction in emissions intensity by 2030 and 97% emissions by 2050.[336]
- 71%[337] of large publicly-traded aluminium companies consider climate change in their decision-making processes.

Emission focus areas for tracker

Aluminium emissions can be divided into two main categories:

1. **Energy-related emissions** primarily due to fossil-based electricity consumption during smelting and thermal energy consumption during refining.
2. **Process emissions** from smelting requiring the presence of carbon-based anodes.

Sector priorities

Exisiting assets

Reduce near-term emissions intensity by:

- Switching to clean power sources for smelting operations where feasible
- Retrofitting existing fossil-fuel-based captive power assets with CCUS, where access to clean power grids is not economical
- Improving end-user scrap collection rate from 70% currently to maximize secondary production.[340]

Next generation assets

Accelerate technology and infrastructure development to drive absolute emissions reduction by:

- Investing in clean power grid capacity supported by energy storage systems to support transition
- Accelerating market readiness for low-emission smelting technologies like inert anodes
- Develop and deploy low-emission refining technologies like electric boilers, mechanical vapour recompression, etc.

Ecosystem

De-risk capital investment to scale infrastructure capacity by:

- Implementing policies that level the playing field for low-emission technologies, enable access to clean power infrastructure and encourage scrap use
- Reducing production cost premiums through an increased number of low-emission projects
- Enabling shared infrastructure and supply chain stability through strategic partnerships.

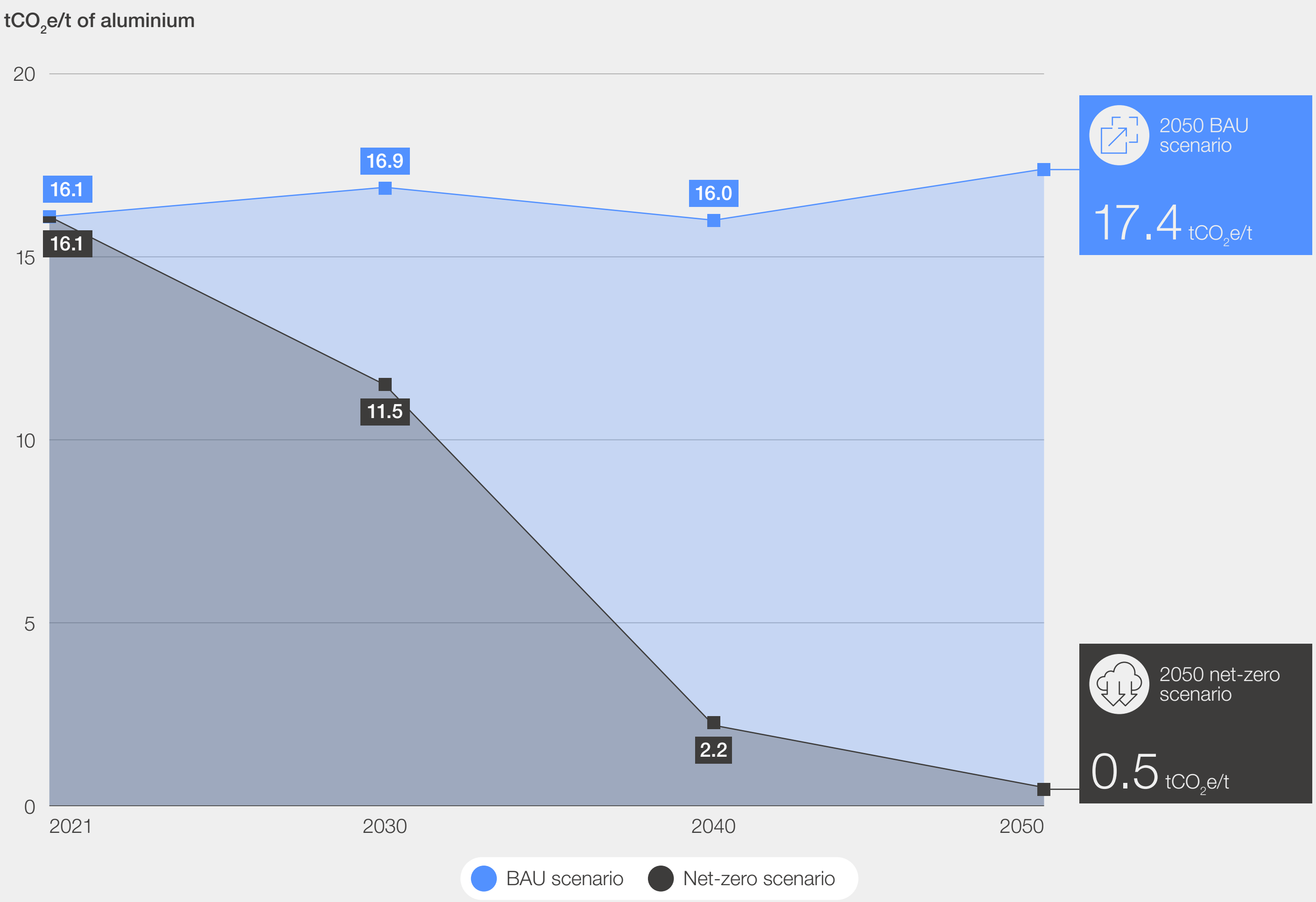
Performance

Nearly 70% of the emissions from the aluminium production process arise due to electricity consumption during smelting.[341] This electricity requirement accounts for around 4% of global power consumption, with up to 70% sourced from fossil fuels (predominantly coal) and the remaining 30% from renewables, primarily hydropower.[342] Among the industrial sectors, it features one of the highest levels of renewable energy use for energy requirements. Process emissions during the smelting process contribute 13% to the emissions, while the use of fossil fuels for providing thermal energy across the value chain results in a further 13% of emissions.[343]

Both absolute emissions and emission intensity have remained stable over the past three years due to the smelting power mix remaining almost constant.

The energy intensity of primary aluminium is around 70 GJ/tonne, making it more energy-intensive than steel and cement on a per-tonne basis. Secondary aluminium production consumes just 5% of the energy required for primary production.[344]

FIGURE 51 **Emissions intensity trajectory, net-zero vs BAU scenario[345]**



Note: Based on primary production only

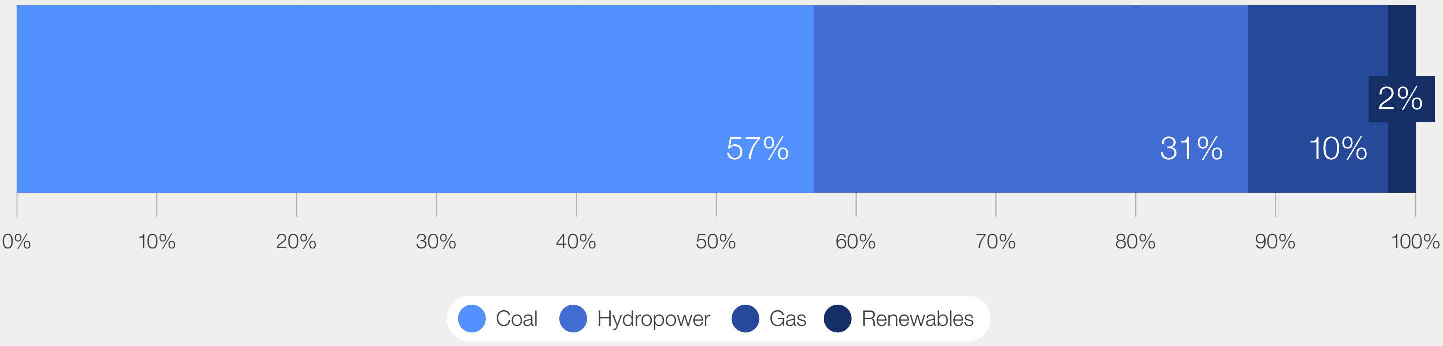
Source: IEA and IAI

Path forward

Aluminium needs to reduce its absolute emissions by 80% to reach net zero by 2050.[346] Achieving this reduction will involve switching to completely clean power sources for smelting – either renewables (solar, wind, hydro, nuclear, etc.) or through captive power plants retrofitted with CCUS.

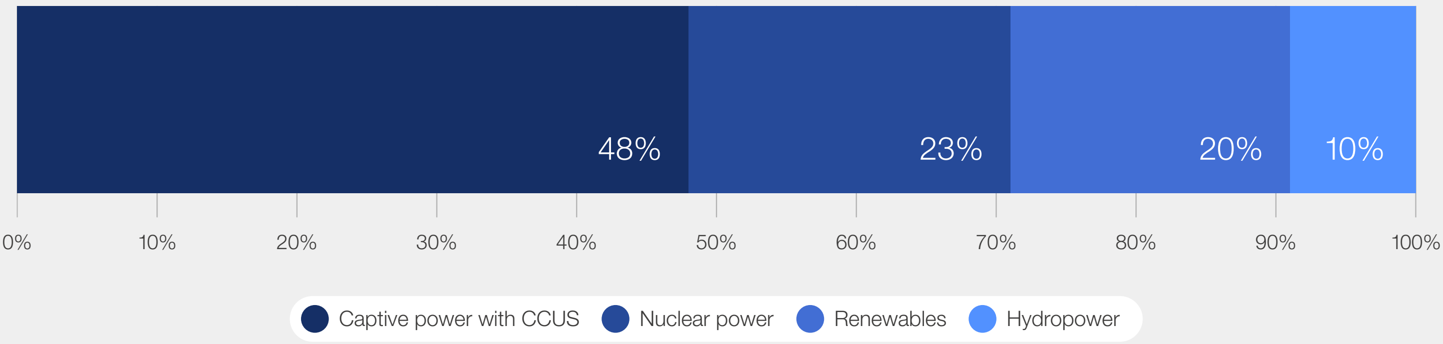
Furthermore, accelerating the adoption of secondary aluminium is key. By 2050, secondary aluminium production is projected to constitute 50% of the production as per industry net-zero projections.[347]

FIGURE 52 | **2021 primary smelting power mix**



Source: International Aluminium Initiative

FIGURE 53 | **2050 primary smelting power mix – net-zero scenario**



Source: MPP

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3 Technology

Three leading decarbonization pathways have emerged. Two of these pathways are currently available: shifting to clean power and transitioning to secondary aluminium. The third pathway explores low-emission refining and smelting processes, which are still mostly in early stages and are expected to be commercially available by 2030 or after. Deploying these technology pathways can lead to production cost increase of around 40%.[348]

Clean power for smelting

Clean power solutions for aluminium include; decarbonizing electricity input through renewable grids/purchase power agreements (PPAs) and using CCUS with captive power plants where access to renewables is not feasible. Using nuclear-powered small modular reactors is also an alternative, but the technology is still emerging. Between 30-35% of the current primary production is already through hydro-based electricity production.[349] While renewables are cost-competitive in many areas, fossil fuels with CCUS come with a cost premium of up to 30% in some regions.[350] Smelters need continuous access to electricity. Thus, assets switching to renewables with a lower capacity factor will need supporting technologies like battery storage, which can further add to costs. Innovative technologies like EnPot that, which enables smelters to vary energy consumption based on available power will also be key.[351]

Secondary production

Maximizing secondary aluminium production has great potential for emissions reduction owing to its low-carbon footprint. Transitioning to secondary aluminium could result in up to a 25% reduction in annual emissions by 2050,[352] by avoiding the loss of 15 million tonnes of metal at end-of-life. However, this has a strong dependency on increasing post-consumer scrap collection from current levels of 70% to near 100%.[353] Also, technologies that improve scrap quality, like scrap sorting and purification technologies, will be vital. Secondary production is reliant on fossil fuels (especially gas) for heat. There is an opportunity to make this production process net zero by switching to cleaner energy sources like clean power, hydrogen, biofuels, etc.

Low-emission refining and smelting technologies

Low-emission refining technologies are expected to increase production costs by 6-11%.

Low-emission refining technologies like use of electric boilers, and mechanical vapour compression (MVR) will be critical to remove thermal energy emissions from the refining process. Electric boilers are already available and have been successfully tested across other industries. MVR technology is expected to be available after 2027. These technologies address the digestion process, which contributes 70% of refining energy consumption.[354] The remaining 30% of energy is consumed by the calcination process, where technologies like hydrogen calciners or electrified calciners can reduce emissions. These technologies are still emerging, with TRL levels of 4-5. Low-emission refining technologies are expected to increase the production costs by 6-11%.[355]

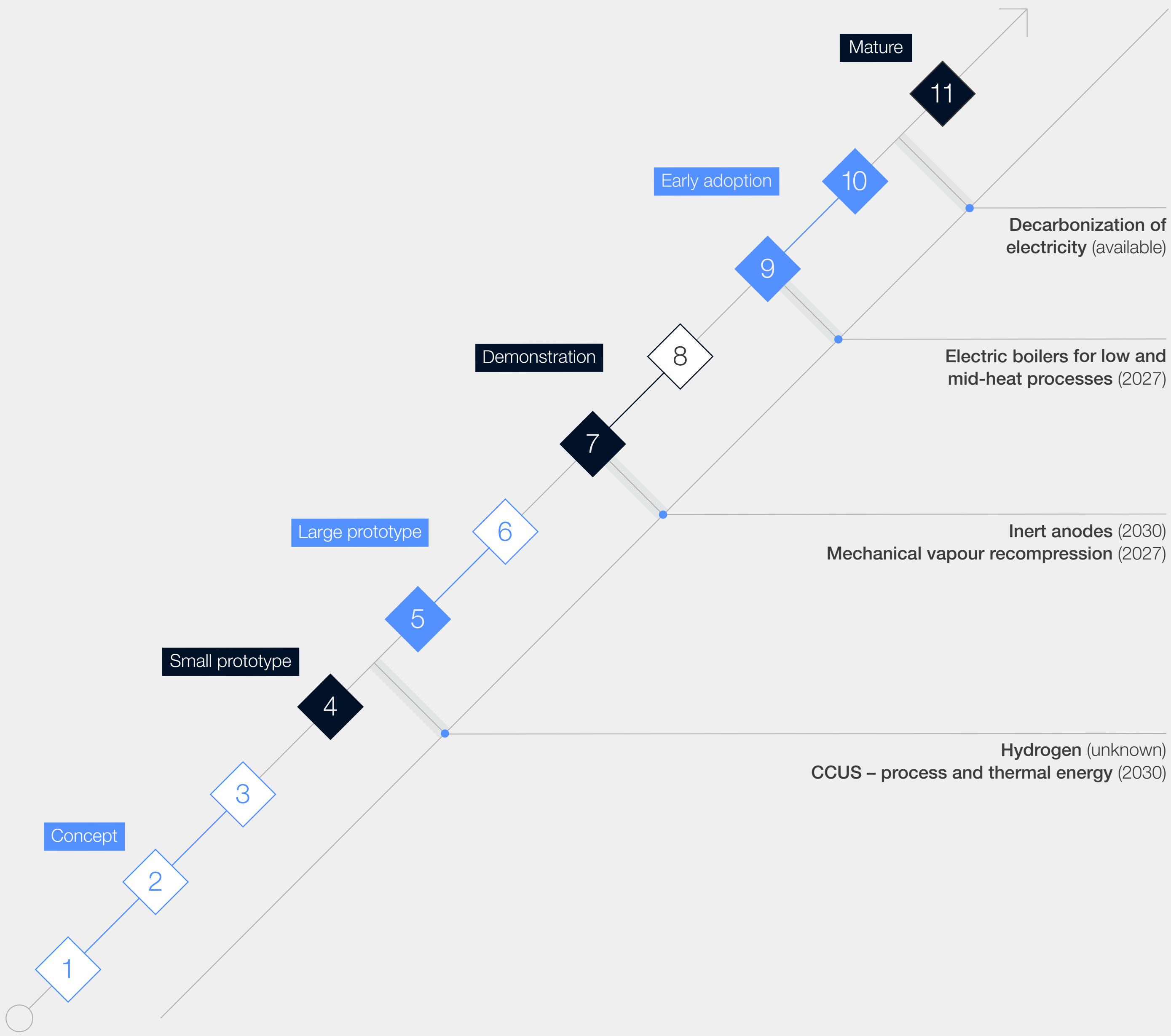
Low-emission smelting technologies include inert anodes and CCUS. Inert anodes are critical to remove the process emissions during smelting and are expected to be commercially available after 2030 with a production cost increase of 9%. ELYSIS, a joint venture between Alcoa and Rio Tinto, is working on commercializing a patented inert anode technology with support from the Canadian government.[356]

CCUS in smelting applications is still in early stages, and with low CO_2 concentrations in smelting flue gas, it is expected come with increased costs of carbon capture.

Technology pathways

FIGURE 54

Estimated TRL and year of availability for key technology pathways



Source: IEA

3

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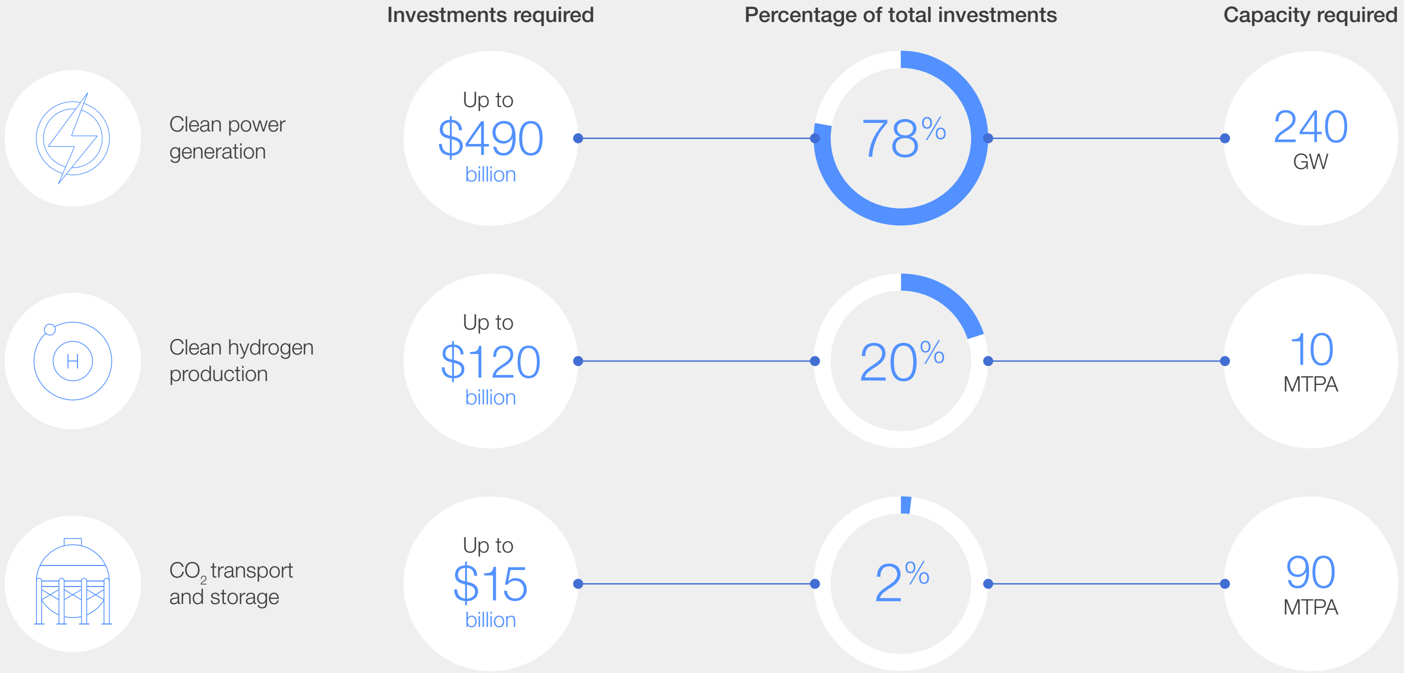
Infrastructure

Aluminium decarbonization relies primarily on clean power generation for electricity in smelting, supported by clean hydrogen infrastructure for refining. CO_2 transport and storage infrastructure will be required if CCUS technology is scaled, to address smelting process emissions. A total of 30%[357] of the clean power infrastructure required already exists, while hydrogen and CO_2 transport infrastructure are below 1% of what is required. The total infrastructure investment required to support the global aluminium industry is estimated at up to $630 billion through 2050.[358]

To decarbonize primary aluminium smelting, approximately 240 GW of clean electricity generation capacity is needed, requiring an investment of $490 billion. A significant challenge is proximity to clean power plants, with 30% of global smelting facilities currently at risk of having no access to clean power.[359] These plants will either need to relocate or adopt CCUS technologies. For instance, numerous Chinese aluminium plants are moving to provinces with better access to low-carbon power,[360] with up to 50% of their smelters at risk of no access to clean power.

The required hydrogen capacity for refining is estimated to be at 9.3 MTPA by 2050, necessitating an investment of $40-120 billion.[361] CO_2 transport and storage infrastructure to support CCUS deployment in smelting will need a further investment of up to $15 billion.[362]

FIGURE 55 **Investments required for enabling infrastructure**



Source: Accenture analysis based on multiple data sources, including IAI, IEA and BloombergNEF

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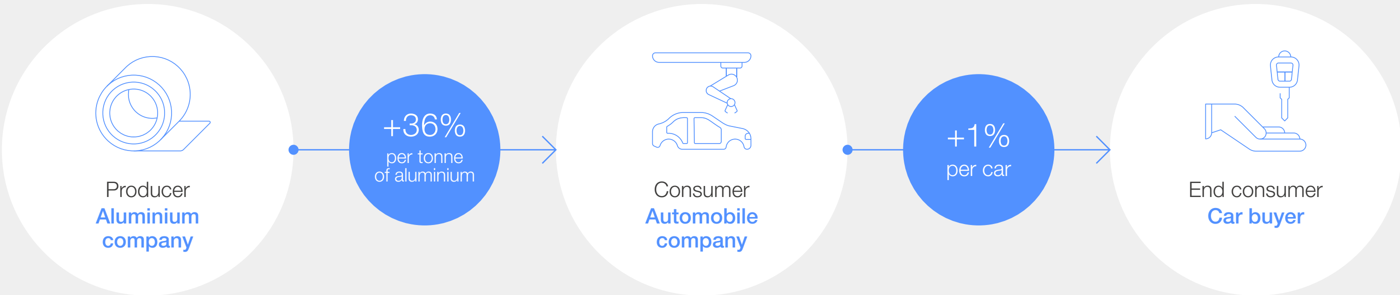
4 Demand

The market's capacity to accommodate a 40% per tonne green premium[363] remains unverified beyond prototype projects. At present, less than 1% of aluminium adheres to industry net-zero thresholds for low-emission aluminium, as implied by current net zero by 2050 scenarios. Still, the demand for green aluminium is growing stronger, evident by its inclusion in the scope of the FMC and several other offtake agreements. Also, consumer goods companies like Apple are increasingly targeting to source low-emission aluminium for their electronic products.[364]

A 40% increase in aluminium production costs translates to a 1-2%[365] increase for end consumer industries such as automobiles or consumer goods.

FIGURE 56 **Estimated B2B and B2C green premium**



Source: Accenture analysis based on multiple data sources, including CRU, INSEE and European Aluminium

Business model shifts have been observed including investing and prioritizing secondary smelting over primary.

To position the industry to fulfil low-emission demand, business model modifications may be necessary. This includes widening the scope of industrial customers beyond traditional applications. Aluminium is a critical metal from a technologies perspective, as the foundation of a net-zero future: electric vehicles (EVs), wind turbines, photovoltaics, and energy storage. Therefore, regions such as China,[366] which are expected to witness a growth in demand for such technologies, will demand more low-emission aluminium as compared to other regions.

A business model shift that has been observed in the industry, which includes investing and prioritizing secondary smelting assets over primary.[367] Companies are also introducing "low-carbon" products as part of their portfolio. For instance, Alcoa is expanding its EcoSource™ low-carbon alumina brand to include non-metallurgical grade alumina.[368] In 2021, Rusal launched ALLOW, 98% of which is claimed to be produced using renewable energy supplied by hydropower plants in Siberia.[369]

To incorporate transparency for end users, Rio Tinto has launched START, aimed at empowering end users to make informed choices about the products they buy.[370] In a similar move, The London Metal Exchange (LME) announced the launch of LME passports. This digital register stores electronic certificates of analysis and sustainability credentials for LME-listed metals.[371] Price assessments of "low-carbon" aluminium by commodity research firms such as Standard & Poor's (S&P) also provide transparency and enable consumer demand.[372] The industry, however, needs to adhere towards globally recognized, standardized definitions of low-emission aluminium, to comply with net-zero thresholds and boost demand signals.

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2 Policy

Global aluminium production is highly concentrated, with China contributing 60%[373] of the total output. However, it is also extensively traded, which means that both domestic and global regulations significantly influence aluminium production. The policy landscape for creating a low-emission aluminium industry is still developing. Key producing regions require more robust and tangible policies, especially with regard to improving access to clean power infrastructure.

Public policies should be directed towards supporting the following aspects in the aluminium sector: facilitating clean power adoption and access to clean power infrastructure, promoting R&D alongside market-based approaches to accelerate early-stage low-emission smelting and refining technologies, and encouraging higher recycling rates through infrastructure buildout that improves sorting and purification of aluminium scrap.

Currently, policy measures to support decarbonization across the four readiness enablers are still in the early stages. While a few initiatives have been explored in Canada, the EU and China, the need for more concrete policy actions, especially in key producing regions, remains paramount.

Existing policy landscape

TABLE 10 **Policy summary**

Enabler	Policy type	Policy instruments	Key examples	Impact
Technology	Incentive-based	Direct R&D funds/grants	– Canada's investment in ELYSIS' inert anode technology	$60 million in direct funding positions ELYSIS to support further R&D and achieve commercial scale.[374] R&D funding support to accelerate innovative technologies need to be supported by policies that enable technology access and transfer to developing countries.
	Market-based	Carbon price	– EU-ETS[375]	Incentivizes aluminium producers to reduce emissions.
		Border adjustment tariff	– CBAM[376]	Emission-intensive aluminium exporters to the EU face increased costs of compliance. Currently, 50% of aluminium consumed is imported from non-EU countries. Needs to be complemented by transparent and fair carbon accounting standards.
	Mandate-based	Direct regulations	– Inclusion of aluminium in the EU's Critical Raw Material Act[377]	Improves the circularity and sustainability of critical raw materials like aluminium. Still in the proposal stage.
Infrastructure	Mandate-based	Government targets	– China's renewable energy use targets for aluminium	Doubles the share of renewables in the aluminium energy mix by 2045.[378]
Demand	Market-based	Product standard	– Aluminium Stewardship Initiative's Performance Standard 3, recognized by Green Building Council of Australia	Provides transparency and standardization to the environmental performance of aluminium products.[379]
Capital	Incentive-based	Subsidies	– China: provincial level subsidy	Public support to smelters to move to incentivize energy-efficiency technologies.[380]

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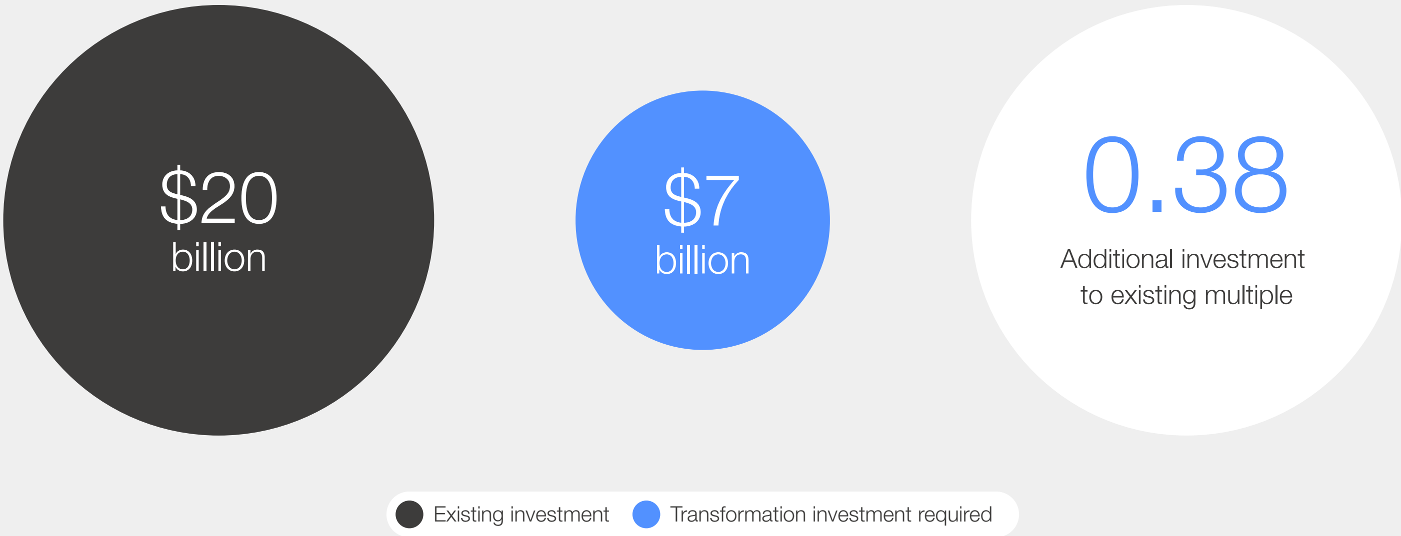
1 Capital

The aluminium industry will require significant capital investment in low-emission smelting and refining technologies beyond power decarbonization. The capital requirements can be estimated with some degree of certainty for the predominant low-emission smelting technology, inert anodes. Retrofitting existing assets with inert anodes could require cumulative investments of $200 billion by 2050.[381] This implies annual investments of $7 billion, in addition to the regular annual CapEx of $20 billion – an additional 38% investment.[382] Additional capital will be needed to improve refining, recycling and sorting processes.

To direct the capital towards transforming the industry, policy interventions like carbon pricing, subsidies/incentives and R&D funding for technology development will need to be adopted to guarantee returns. Large institutional investors and multilateral banks (World Bank, Asian Development Bank, etc.) can play a crucial role by providing access to low-cost capital linked to stringent emission reduction targets.

The business case for investment remains weak with additional costs of 38%[383] and uncertainties around returns from low-emission aluminium. Current industry profit margins of 13%[384] and WACC of 9%[385] suggest that the industry is not positioned to absorb these additional costs and generate sufficient returns to fund through its own generated cash flows.

FIGURE 57 **Additional investment required to existing investment ratio**

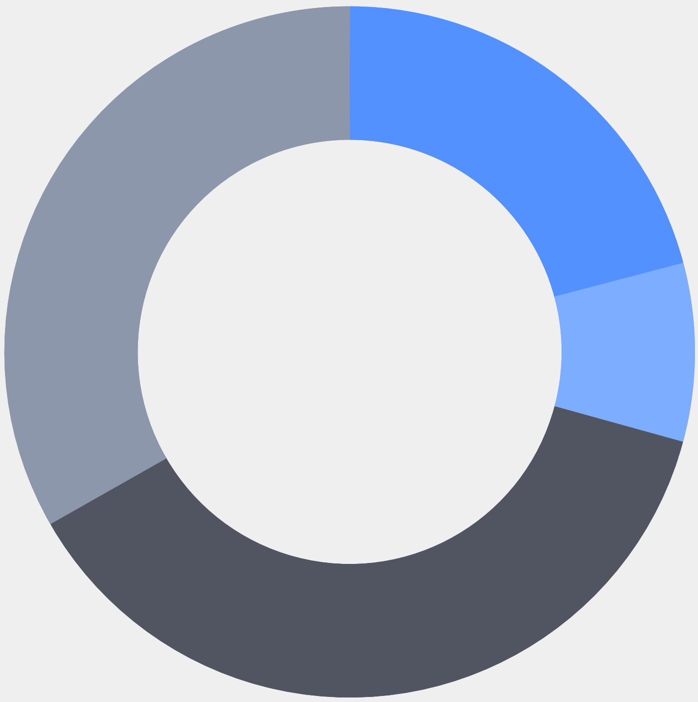


Source: Accenture analysis based on MPP data

There is a need for workable and increased support for funding for clean technology value chains across enterprises. A key development includes Canada's innovation funding for inert anode technology through ELYSIS. Another notable development includes collaboration between top lenders to the aluminium industry – Citi, ING and Societe Generale – and the Rocky Mountain Institute to develop a climate-aligned financing framework, currently in progress.[386]

Approximately 70% of large, publicly-traded aluminium companies consider climate change as a key consideration for their strategic assessment and integrate it into their operational decision-making.[387] Meanwhile, 8% of companies are building basic emissions management systems and process capabilities. Finally, 21% of companies acknowledge climate change as a business issue.

FIGURE 58 **Distribution of companies in the aluminium sector according to the management of their GHG emissions and of risks and opportunities related to the low-carbon transition.**



0 **Level 0:** Unaware 0.0%

1 **Level 1:** Aware 20.8%

2 **Level 2:** Building capacity 8.3%

3 **Level 3:** Integrating into operational decision-making 37.5%

4 **Level 4:** Strategic assessment 33.3%

Source: LSE-TPI Centre

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