

MAKING NET-ZERO ALUMINIUM POSSIBLE

An industry-backed, 1.5°C-aligned transition strategy

EXECUTIVE SUMMARY / APRIL 2023



**MISSION
POSSIBLE
PARTNERSHIP**

Sponsored by



In collaboration with
the International
Aluminium Institute





THE MISSION POSSIBLE PARTNERSHIP

At current emissions levels, staying within the global carbon budget for 1.5°C might slip out of reach in this decade. Yet efforts to slow climate change by reducing greenhouse gas (GHG) emissions run into a central challenge: some of the biggest emitters of greenhouse gases into the atmosphere – transportation sectors like aviation, shipping and trucking, and heavy industries like steel, aluminium, cement/concrete, and chemicals manufacturing – are the hardest to abate. Transitioning these industries to climate-neutral energy sources requires complex, costly, and sometimes immature technologies, as well as direct collaboration across the whole value chain, including companies, suppliers, customers, banks, institutional investors, and governments.

Catalysing these changes is the goal of the Mission Possible Partnership (MPP), an alliance of climate leaders focused on supercharging efforts to decarbonise these industries. Our objective is to propel a committed community of CEOs from carbon-intensive industries, together with their financiers, customers, and suppliers, to agree and, more importantly, to act on the essential decisions required for decarbonising heavy industry and transport. Led by the Energy Transitions Commission, the Rocky Mountain Institute, the We Mean Business Coalition, and the World Economic Forum, MPP will orchestrate high-ambition disruption through net-zero industry platforms for seven of the world’s most hard-to-abate sectors: aviation, shipping, trucking, steel, aluminium, cement/concrete, and chemicals.

The foundation of MPP’s approach: 7 Sector Transition Strategies

Transitioning heavy industry and transport to net-zero GHG emissions by 2050 – while complying with a target of limiting global warming to 1.5°C from preindustrial levels – will require significant changes in how those sectors operate. MPP facilitates this process by developing **Sector Transition Strategies** for all seven hard-to-abate sectors.

A Sector Transition Strategy
is a suite of user-friendly tools
(including a report, an online explorer, and an open-source model)
aiming to inform decision makers
from the public and private sectors
about the nature, timing, cost, and
scale of actions necessary to deliver
net zero within the sector by 2050
and to comply with a 1.5°C target.



In line with industry-specific replacement cycles of existing assets (like steel plants or aircraft) and the projected increase in demand, the market penetration of viable decarbonisation measures each sector can draw on is modelled.

The objectives of the MPP Sector Transition Strategies are:

- 1. To demonstrate industry-backed, 1.5°C-compliant pathways to net zero,** focusing on in-sector decarbonisation and galvanising industry buy-in across the value chain.
- 2. To be action-oriented with clear 2030 milestones:** By quantifying critical milestones for each sector in terms of its required final energy demand, upstream feedstock resources, and capital investments, MPP wants to lay the foundation for tangible, quantitative recommendations of ways to reach these milestones through collaboration among industry, policymakers, investors, and customers.
- 3. To be transparent and open:** MPP's long-term goal is to fully lay open the internal machinery of the Sector Transition Strategies, that is, to make its Python models open source and all data inputs open access. In addition, MPP is developing online explorers that bring the Sector Transition Strategy reports to life: individual users will be able to explore the results of the reports and to customize model input assumptions, study the impact of individual levers, and dive deeper into regional insights.
- 4. To break free from siloed thinking:** The transition of a sector to net zero cannot be planned in isolation since it involves interactions with the broader energy system, for instance, via competing demands for resources from multiple sectors. All MPP Sector Transition Strategies are based on similar assumptions about the availability and costs of technologies and resources like electricity, hydrogen, or sustainable biomass. By providing a harmonized, cross-sectoral perspective, we intend to inform decision makers with a fair, comparable assessment of transition strategies for all seven sectors.

On the basis of its Sector Transition Strategies, MPP intends to develop practical resources and toolkits to help operationalize industry commitments in line with a 1.5°C target. Among others, the quantitative results of the Sector Transition Strategies will inform the creation of standards, investment principles, policy recommendations, industry collaboration blueprints, and the monitoring of commitments. These will be developed to expedite innovation, investments, and policies to support the transition.

Goals of the MPP Aluminium Transition Strategy

In this report, we explore the potential to reduce emissions associated with the production of aluminium. This analysis has been conducted using the Aluminium Sector Transition Strategy Model and is informed by the valuable work conducted by the International Aluminium Institute for the “1.5 Degrees Scenario: A Model to Drive Emissions Reduction” and extensive engagement with the wider aluminium community and aluminium sector experts as part of the Aluminium for Climate initiative (initiated by the World Economic Forum in 2019). The approach here is shaped by four main objectives:

- Provide a first detailed open-sourced asset-based analysis of the approach that the aluminium sector can use to reach 1.5°C.
- Provide a detailed reference point for the changes that will be needed over the next 30 years to underpin corporate target setting, science-based targets, and financial-sector alignment methodologies.
- Inform priority actions, trade-offs, and decisions in the 2020s by stakeholders that will shape the aluminium markets, including industry leaders, governments, buyers of carbon-intensive materials, and financial institutions.
- Underpin a coherent set of commitments to action from stakeholders across the value chain, which together will unlock investment in zero-carbon solutions.

To promote transparency and collaboration, the model materials and analytics are open-access tools, such that the inputs and assumptions are available for enquiry, and future iterations may build on this effort. This open-access approach lends itself to periodic refinement as data and insights evolve. Critically, it also ensures that the industry can align behind a strategy it considers technically and economically feasible, subject to appropriate value-chain collaboration, finance, and policy support. The Archetype Explorer tool that accompanies this report enables users to adjust various parameters in the model to reflect the circumstances faced in a particular geography, supporting real-world decision-making.



Industry support for MPP’s Aluminium Transition Strategy

This report constitutes a collective view of participating organisations in the Aluminium Sector Transition Strategy. Participants have generally validated the model inputs and architecture and endorse the general thrust of the arguments made in this report but should not be taken as agreeing with every finding or recommendation. These companies agree on the importance of limiting global warming to 1.5°C and the importance of reaching net-zero GHG emissions in heavy industry and transport by mid-century, and they share a broad vision of how a 1.5°C-aligned transition scenario could be achieved. The companies recognize that actions to support this broad vision should be pursued expeditiously.

The fact that this agreement is possible among the industry leaders listed below should give decision makers around the world confidence that it is possible to simultaneously meet

rising aluminium demand, reduce emissions from the sector to net zero by 2050, and comply with a 1.5°C target. It should also provide confidence that the critical actions required in the 2020s to set the sector on the right path are clear and should be pursued without delay, and that the industry is ready to collaborate with its value chain.

Unless otherwise stated, the report is based on publicly available, open-access input assumptions, and endorsers have not provided commercially sensitive information for technologies under development. Although assumptions have been developed through a consensus view of participants, there are significant risks and uncertainties, particularly related to cost, performance, and rate of implementation for technologies. Actual results may differ materially from those indicated by these forward-looking assumptions.



AUTHORS & ACKNOWLEDGEMENTS

This report was prepared by the Mission Possible Partnership aluminium team in collaboration with the International Aluminium Institute (IAI).

The coordination of the report, analysis, and stakeholder engagement was led by:

Marten Ford (Energy Transitions Commission, ETC)

Min Guan (ETC)

Jason Martins (ETC)

and supported by:

Pernelle Nunez (IAI)

Marlen Bertram (IAI)

Jörgen Sandström (World Economic Forum, WEF)

The model and analytics effort was led by **Min Guan** (ETC) and delivered by:

Jason Martins (ETC)

Luis Natera (ETC)

Hugo Stevens (ETC)

Abindra Soemali (ETC)

Aparajit Pandey (ETC)

Steering and guidance were provided by MPP leadership who oversee the development of all the MPP Sector Transition Strategies:

Faustine Delasalle (Executive Director, MPP)

Eveline Speelman (ETC)

Alasdair Graham (ETC)

We thank Andrea Bath, Henry Gilks, Andrew Isabirye, Laëtitia de Villepin, Maaïke Witteveen, Ben Dixon, Adair Turner (all from ETC), Linlin Wu (IAI), Renée Van Heusden (WEF), Wen Zhang (WEF), aluminium sector experts as part of the Aluminium for Climate initiative (initiated by the World Economic Forum in 2019) and other collaborators for providing valuable contributions to this project. The report was edited and designed by M. Harris & Company.





Mission Possible Partnership (MPP)

Led by the ETC, RMI, the We Mean Business Coalition, and the World Economic Forum, the Mission Possible Partnership is an alliance of climate leaders focused on supercharging the decarbonisation of seven global industries representing 30% of emissions: aviation, shipping, trucking, steel, aluminium, cement/concrete, and chemicals. Without immediate action, these sectors alone are projected to exceed the world's remaining 1.5°C carbon budget by 2030 in a Business-as-Usual scenario. MPP brings together the world's most influential leaders across finance, policy, industry, and business. MPP is focused on activating the entire ecosystem of stakeholders across the entire value chain required to move global industries to net-zero. www.missionpossiblepartnership.org



Energy Transitions Commission

Energy Transitions Commission (ETC)

ETC is a global coalition of leaders from across the energy landscape committed to achieving net-zero emissions by mid-century, in line with the Paris climate objective of limiting global warming to well below 2°C and ideally to 1.5°C. Our commissioners come from a range of organizations – energy producers, energy-intensive industries, technology providers, finance players, and environmental NGOs – which operate across developed and developing countries and play different roles in the energy transition. This diversity of viewpoints informs our work: our analyses are developed with a systems perspective through extensive exchanges with experts and practitioners. www.energy-transitions.org



World Economic Forum

The World Economic Forum is the international organization for public-private cooperation. The Forum engages the foremost political, business, cultural, and other leaders of society to shape global, regional, and industry agendas. Learn more at www.weforum.org.



RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing. rmi.org

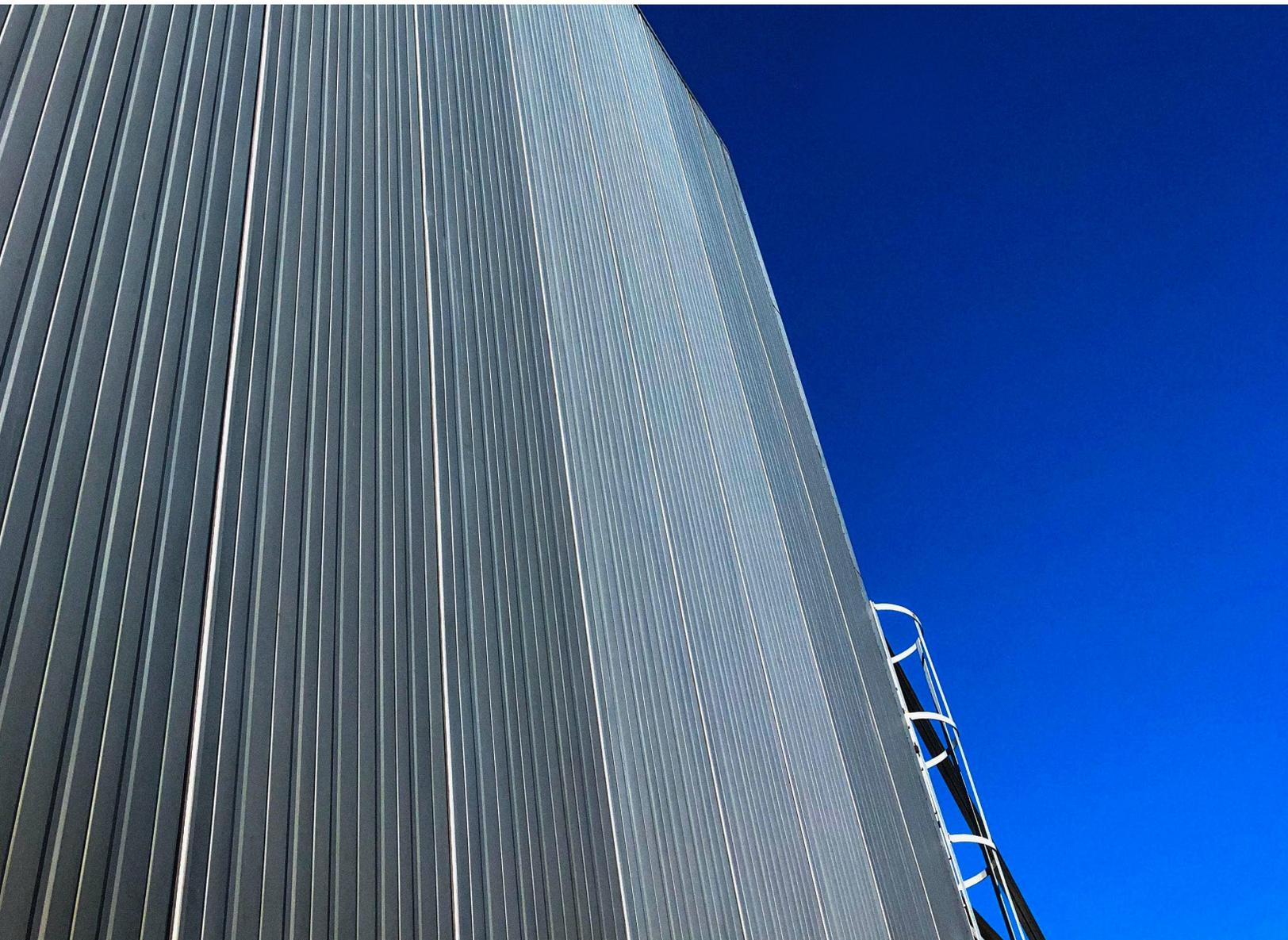


International Aluminium Institute (IAI)

The International Aluminium Institute is the only body representing the global primary aluminium industry and was established in 1972. Current IAI membership includes global bauxite, alumina, and aluminium companies in all the major producing regions. Through the IAI, the aluminium industry aims to promote a wider understanding of its activities and to demonstrate both its responsibility in producing the metal and the potential benefits to be realised through its use in sustainable applications and recycling. international-aluminium.org



TEN CRITICAL INSIGHTS ON THE PATH TO A NET-ZERO ALUMINIUM SECTOR



1. Bringing the aluminium sector on a path to net zero by 2050 is technically and economically possible. Achieving it will require a mix of levers within the primary aluminium sector, in the wider aluminium value chain, and in partnership with the power sector.

The aluminium sector is currently responsible for approximately 2% of global emissions, about 1 gigatonne of carbon dioxide equivalent (1 Gt CO₂e). Without efforts to curtail them, annual emissions could grow by as much as 90% by 2050 as a result of population growth and economic development (Exhibit A).

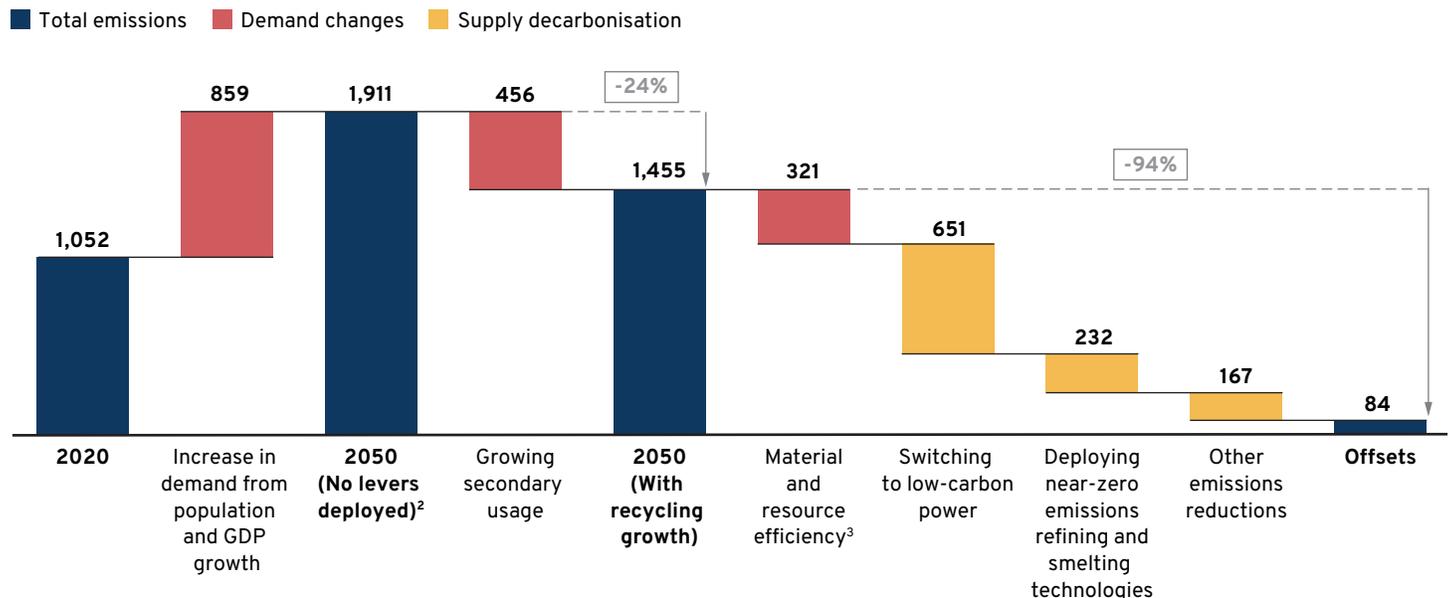
As Exhibit A shows, the aluminium sector can deliver a net-zero sector through four major levers, which are common across all scenarios developed to look at the sector's low-carbon transition:

- **Transitioning to low-carbon power (651 million tonnes [Mt] of CO₂e savings in 2050).** Aluminium is a heavily electricity-intensive industry, with almost 1,000 terawatt-hours (TWh) of electricity demand. Switching to low-carbon electricity is the biggest step the industry can take to deliver a sector compatible with net zero.
- **Maximising secondary aluminium production (456 Mt CO₂e in 2050).** Recycling aluminium (secondary production) has a significantly lower carbon footprint than new (primary) aluminium production (0.5 t CO₂e/t aluminium [Al] versus up to 16 t CO₂e/t Al).
- **Maximising resource efficiency (321 Mt CO₂e in 2050).** The industry should ensure that product design uses aluminium efficiently. Examples include extending the life of buildings in

EXHIBIT A

A low-carbon aluminium sector is possible by 2050

Emissions for the aluminium sector,¹ Mt CO₂e/y



¹ Includes all direct and indirect emissions along the value chain for primary and secondary aluminium production (i.e., mining, alumina refining, aluminium smelting, anode production, casting, fabrication, recycling, and transport).

² Based on the IAI's Reference scenario, except for primary/secondary production ratio, which is assumed constant between 2020 and 2050; 2020 carbon intensity of aluminium assumed constant.

³ Based on demand projections from the IAI's 1.5°C scenario.

Source: IAI Material Flow Model (2021); Aluminium Sector Transition Strategy Model (2022)



China, extending automotive lifetimes, and using mobility-as-a-service in order to reduce the number of vehicles needed to meet people's mobility needs.

- **Deploying new technology to deliver near-zero-emissions refineries and smelting facilities (232 Mt CO₂e in 2050).** New technology is required to decarbonise thermal energy in refineries, such as heat recovery and fuel switching, and low-carbon anodes in smelters. These technologies need to be commercialised and be widely available by 2030.

Particular uncertainties, such as material substitution (both from and to the aluminium sector), could also play a role in delivering these reductions in emissions.

To deliver these steps, the whole value chain will have to address key problems such as access to low-cost and low-carbon power, lack of availability of aluminium to recycle, and lack of a business case for low-carbon aluminium production.



2. Rapid action is required in order for the sector to adhere to a 1.5°C pathway. Power decarbonisation by 2035 is necessary but not sufficient, with almost half of cumulative emissions savings requiring additional levers.

A Business-as-Usual (BAU) scenario would be responsible for cumulative GHG emissions between 2020 and 2050 of 37 Gt CO₂e – an overshoot of more than 100% against a 1.5°C carbon budget for the aluminium sector of 15 Gt CO₂e.

In contrast to this BAU scenario, two net-zero scenarios combine different power decarbonisation pathways to reach net zero by 2050. The main difference between the 1.5°C scenario and the No CCS scenario is that the former focuses on using carbon capture and storage (CCS) for existing fossil fuel power assets, while No CCS focuses on new connections to low-carbon power grids.

In the 1.5°C scenario, low-carbon power will deliver over half of these emissions reductions (12 Gt CO₂e), decarbonising the

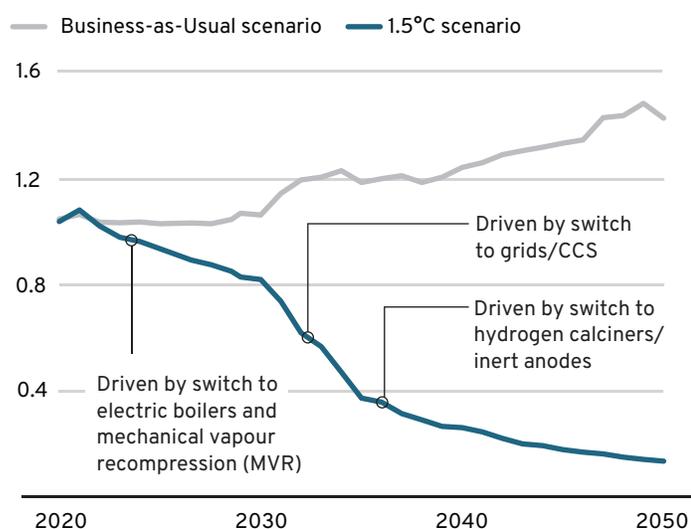
sector's power needs by 2035 through decarbonising power grids and deploying CCS, and, in the longer term, using small modular nuclear reactors (Exhibit B).

Power decarbonisation is necessary but not sufficient to adhere to a 1.5°C pathway. Solutions such as low-carbon heat in refineries must be deployed beginning in the late 2020s, low-carbon anodes in smelters need to start commercially deploying at scale by 2030, and material efficiency is critical. These technologies are generally at a lower readiness level than are power decarbonisation technologies and require not only further research and development, but also access across the industry.

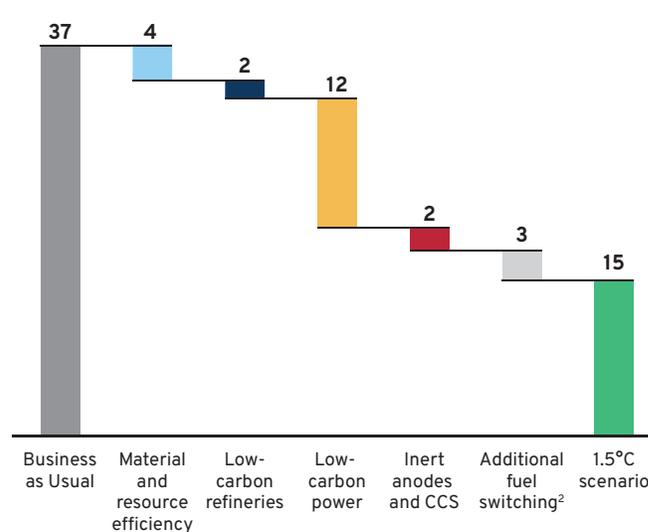


Delivering 1.5°C requires rapid action across the aluminium value chain

Emissions¹ pathways, Gt CO₂e/y



Cumulative emissions, Gt CO₂e, 2020 to 2050



¹ Includes all Scope 1, Scope 2, and Scope 3 emissions associated with primary and secondary aluminium production.

² Includes additional value chain emissions reduction via low-carbon fuel switching and other decarbonising levers for mining, casting, fabrication, recycling, and transport.

Source: Aluminium Sector Transition Strategy Model (2022)

3. Power decarbonisation is the biggest decarbonisation lever, with 1,000 TWh of low-carbon electricity required by 2035, up from 250–300 TWh today.

Aluminium is a particularly electro-intensive industry, accounting for ~4% of global electricity demand in 2020. Approximately 250–300 TWhⁱ is low carbon already through captive hydroelectric generation and connections to grids which are low carbon through a mix of hydro and nuclear. Decarbonising this power will require up to 1,000 TWh of low-carbon power by 2050. The falling costs of variable low-carbon power represent an opportunity; however, significant challenges remain, as aluminium smelters require constant power inputs. Greater development of other complementary power technologies such as batteries and hydrogen will be needed over the coming decades.

Aluminium's share of global power demand will shrink from 4% to ~1%–2% by 2050 as a result of the growing electrification of other sectors. This shift will, in the long term,

weaken the aluminium sector's bargaining power for access to low-cost electricity.

To achieve a 1.5°C pathway, producers that currently use captive power production will face a choice, either producing low-carbon captive power through CCS, connecting to a low-carbon grid, or developing power purchase agreements (PPAs) with low-carbon power providers. Not every location will be able to use the grid or PPAs, because local grids do not decarbonise fast enough to keep the sector as a whole on track for 1.5°C. There are numerous combinations of power supply that can deliver power needs broadly in line with a 1.5°C trajectory (Exhibit C). The difference between the 1.5°C scenario and the No CCS scenario is that in the latter, no carbon capture is used for decarbonising smelters' power supplies.

ⁱ IAI 2020 data on primary production (hydro, other renewables, and nuclear).

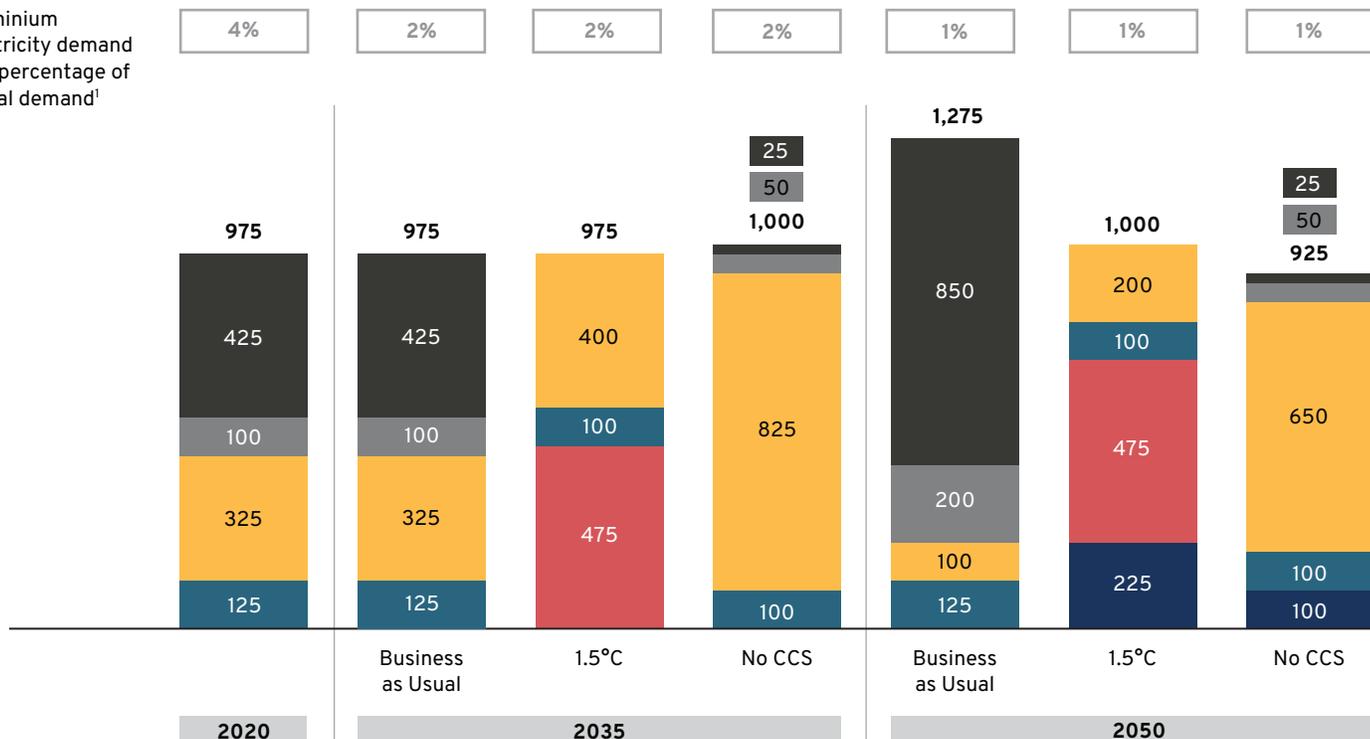


Delivering a 1.5°C pathway requires a significant amount of power from CCS or from low-carbon grids

Smelter power demand mix across scenarios, TWh per year

■ Coal ■ Natural Gas ■ Grid ■ Hydro ■ CCS ■ SMR²

Aluminium electricity demand as a percentage of global demand¹



¹ Global electricity demand in 2020, 2035, and 2050 is sourced from ETC, *Making Clean Electrification Possible*, 2021, www.energy-transitions.org/wp-content/uploads/2021/04/ETC-Global-Power-Report-.pdf.

² SMR = small modular reactor, up to 3,000 MW in capacity.

Source: Aluminium Sector Transition Strategy Model (2022)



4. Location matters for how smelters and refineries decarbonise. There is significant variation in availability of local low-carbon power and in how quickly the local grids can decarbonise.

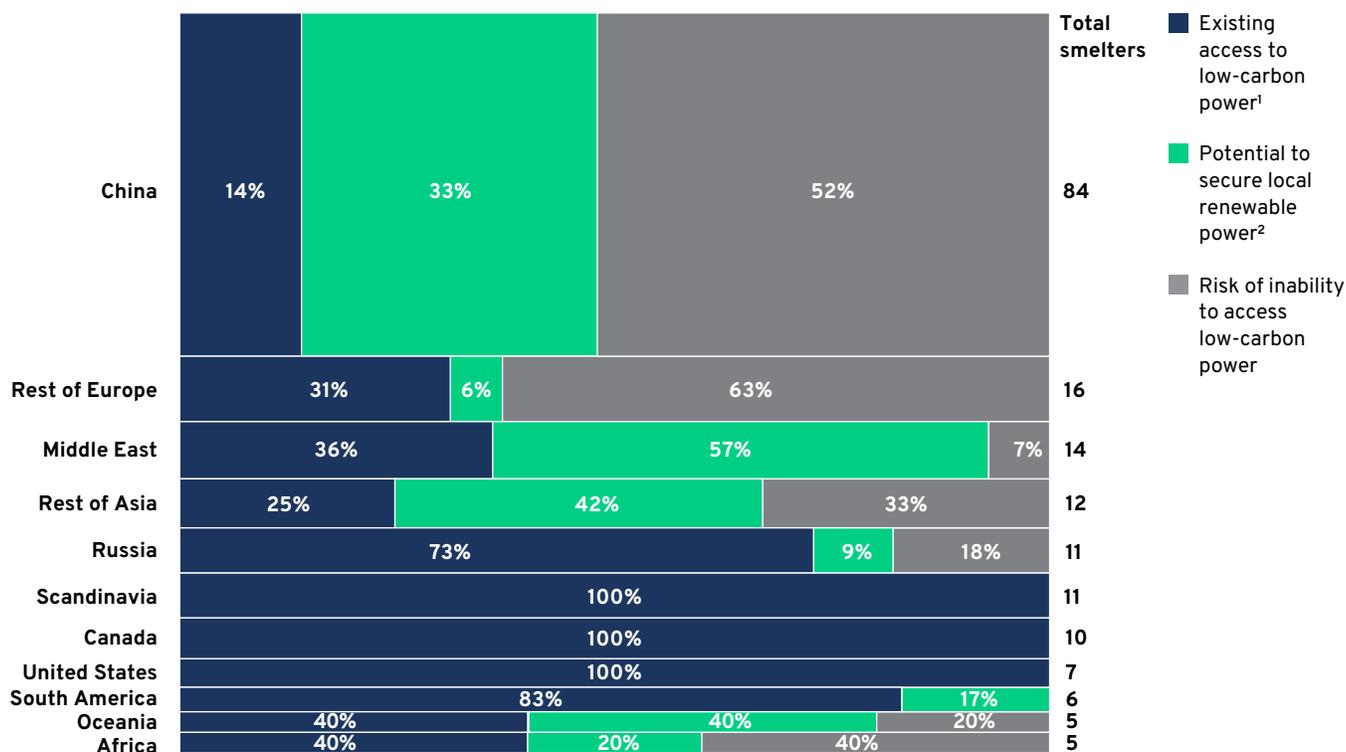
It is expected that about 65% of aluminium smelters (representing 60% of global production capacity) will be able to source PPAs or low-carbon grid power to reduce their average emissions intensity while still benefitting from the dependability of a grid connection. A significant exception for this is in China, where about 52% of smelters are unlikely to access local PPAs, as they are not located in areas with sufficiently high wind or solar generation capacity factors above 20% (Exhibit D).

In the absence of an affordable low-carbon energy source, it is expected that these smelters may be shut down and relocated, with potential implications for the shape of global aluminium production and trade. Alternatively, they could retrofit their direct power generation facilities to include CCS, employ novel low-carbon power solutions (for example, using portfolios of renewables), or use long-distance transmission connections to regions with greater low-carbon power availability. All of these alternative options carry significant extra complexity and challenges.

Access to low-carbon power varies significantly by location, and some regions have particular challenges

EXHIBIT D

Access to low-carbon power supply by smelter in 2020, % of regional smelters



¹ Includes captive hydropower, renewables, PPAs, and grids with carbon intensity currently less than 100 g CO₂/kWh.

² Defined by geolocal data for smelters with local capacity factors for solar PV or wind power greater than 20% or 30%, respectively.

Source: Aluminium Sector Transition Strategy Model (2022)



5. Secondary aluminium plays a critical role in the expanding aluminium market, increasing from 33% of total demand (33 Mt/y) in 2020 to 54% (81 Mt/y) in 2050.

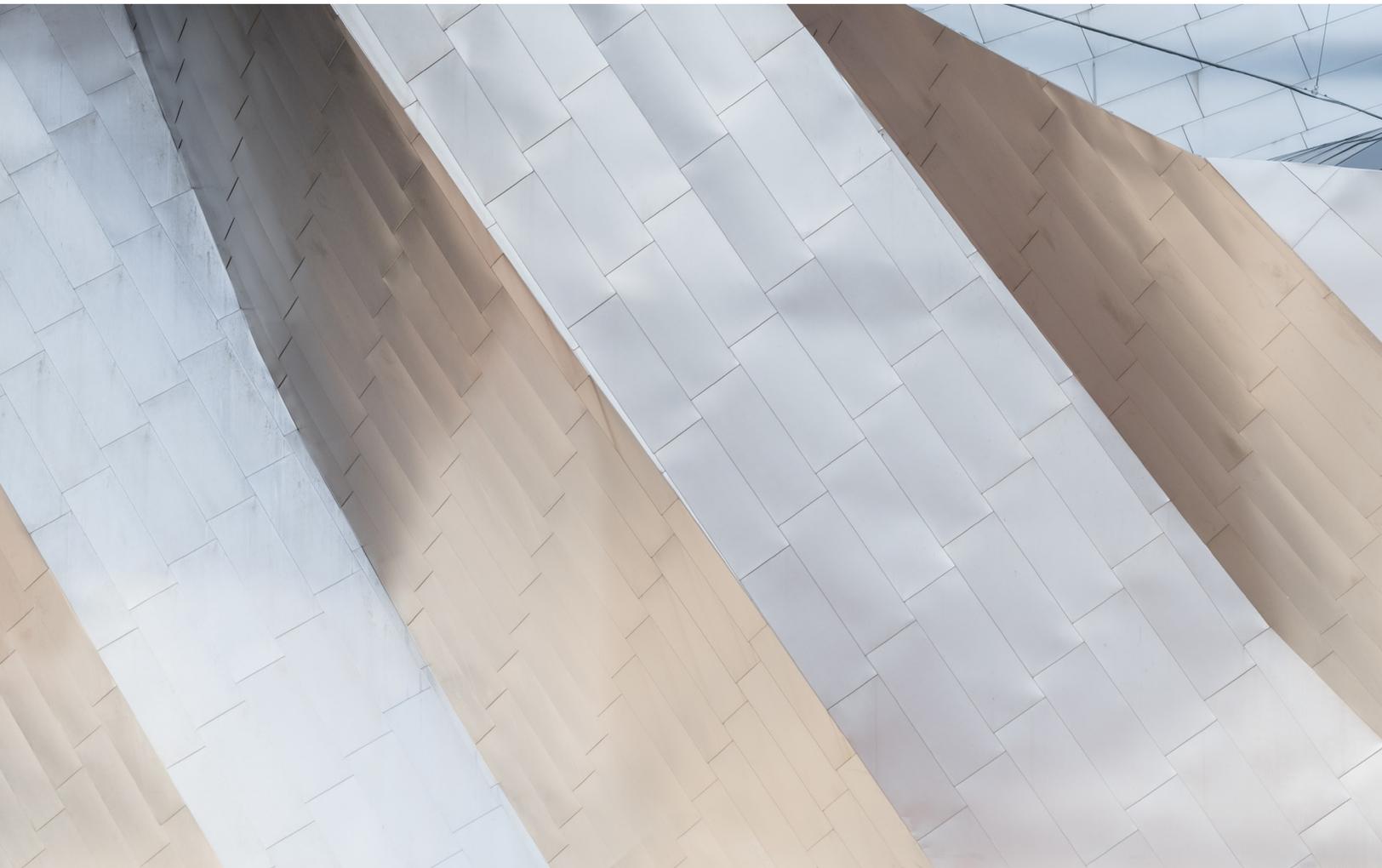
Current post-consumer scrap collection rates vary widely across geographies and sectors; for example, the aluminium can collection rate is above 95% in Brazil but only approximately 50% in North America. Globally, average scrap collection rates for all end-use sectors will need to move from about 70% today to more than 90% by 2050 to maximise circularity in the sector. Achieving this shift will require greater emphasis on eco-design, whereby the design of products and buildings incorporates end-of-life planning as a critical element for increasing reuse and recycling rates.

In addition, alloy separation, sorting, and purification methods will all need to be developed to maximise the volumes of available post-consumer scrap. A particular challenge is presented by composite materials in which aluminium accounts for a low percentage of the overall product, making the metal difficult and expensive to recover and often leading to downcycling into lower value products. Avoiding downcycling

will require close cooperation between the aluminium end-use sectors and policymakers in order to develop strategies for recycling alloy-contaminated products.

Taken together, the aforementioned measures allow the secondary sector to grow its supply of aluminium from 33 Mt in 2020 to 81 Mt by 2050 (Exhibit E). If this can be achieved, secondary aluminium production can address the expected demand growth over the coming 30 years, reducing the role for new carbon-intensive primary production.

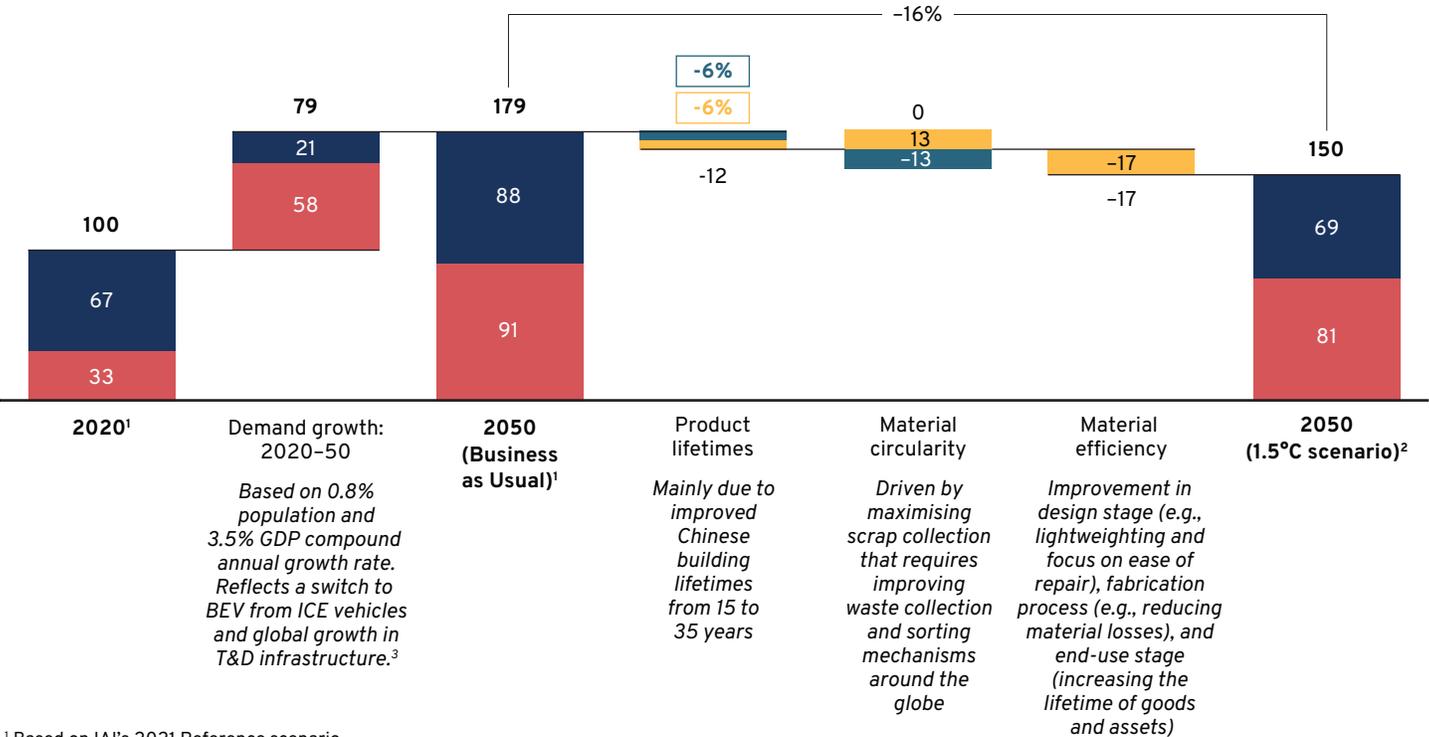
The good news is that some levers in achieving this growth are already proven. For example, Germany has achieved high can collection rates (over 98%) through regulating and normalising scrap collection via a deposit return scheme. The challenge is how this success can be replicated in more complex situations, such as extracting scrap aluminium from buildings, where it is likely to be mixed with other material.



Majority of aluminium demand by 2050 is expected to be met by secondary aluminium in a 1.5°C scenario

Demand for aluminium, Mt per year

■ Primary ■ Secondary ■ Shift in primary ■ Shift in secondary



¹ Based on IAI's 2021 Reference scenario.

² Based on IAI's 1.5°C scenario.

³ BEV = battery electric vehicle, ICE = internal combustion engine, T&D = transmission and distribution.

Source: IAI Material Flow Model (2021)

6. Without any action, aluminium demand is expected to rise 80% by 2050. Material efficiency can play a critical role in ensuring that aluminium is used effectively, potentially reducing demand by 29 Mt and limiting growth to 50%.

Approximately 50% of global aluminium demand today comes from the transport and construction sectors (26% and 24%, respectively). Additional significant demand comes from electrical and machinery equipment (11% each), foil stock and packaging (8% each), and consumer durables (6%).

Without deliberate action being taken, the underlying demand for aluminium is expected to increase by 80% between 2020 and 2050 (Exhibit E). Increased material and product efficiency from, for example, longer building lifetimes in China could reduce this to a 50% increase.

Measures across all end-use sectors will be required in order to limit demand growth. Such measures include reducing losses in product manufacturing processes; designing end-use products with greater durability, longevity, and lightweighting; shifting consumption patterns from single-use to multiuse packaging; and developing business models focused on repair and refurbishment at product end-of-life stages.



7. Cumulative investment of approximately US\$1 trillion across the primary production value chain will be needed to deliver a net-zero sector, or a 1.5°C pathway. The majority of this investment will be needed in power supply and smelters.

The 1.5°C pathway will require four key categories of investment over the coming 30 years (Exhibit F):

- Investments in low-carbon power both within and outside the aluminium industry (including renewable PPAs, grid decarbonisation, CCS retrofits to existing thermal captive power): requiring approximately \$500 billion by 2050
- Investments by aluminium producers in smelters, primarily in low-carbon anode retrofits: approximately \$200 billion by 2050 (different anode technologies will have different investment-operational cost trade-offs; given the stage of technology development, this is highly uncertain)

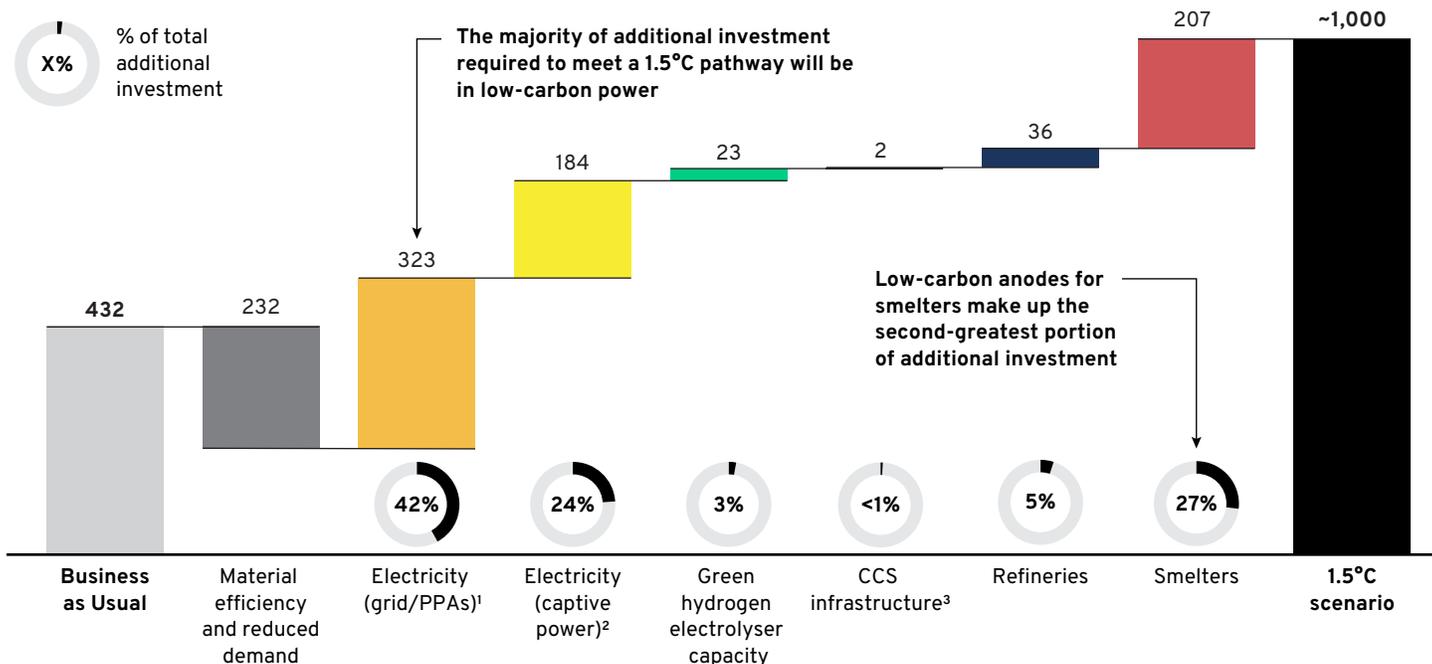
- Investments by aluminium producers in refineries covering the transition to low-carbon fuels at refineries: estimated to be \$36 billion by 2050
- Investments in CO₂ transport and storage infrastructure as well as hydrogen production: estimated to be \$26 billion by 2050

Delivering these significant investments in diverse and new types of projects will require significant partnership across the value chain, particularly in coordinating power investments with the aluminium sector needs.

EXHIBIT F

Total additional investment to deliver 1.5°C is mainly outside the primary aluminium industry in electricity generation

Cumulative investments required in the primary aluminium sector, billion \$, 2020–50



¹ Uses an assumption that refineries will use 100% electricity from PPAs.
² Includes investments in captive power such as fossil CCS or nuclear SMR.
³ Uses an estimate of \$5/t CO₂ capital expenditure for CO₂ transport and storage infrastructure.

Source: Aluminium Sector Transition Strategy Model (2022)



8. Low-carbon aluminium will cost up to \$400/t more to produce than conventional aluminium on average by 2035. However, cost increases will vary significantly from producer to producer.

Delivering low-carbon aluminium will result in particularly high costs for retrofitting existing refineries and smelters. These additional costs in the initial roll-out will be driven by the higher capital expenditures associated with most technology changes, as well as higher running costs. Over a longer period of time as capital is amortised, this cost differential will be driven down.

These increases in costs will vary significantly depending on the current circumstances of individual refineries and smelters. They are also highly dependent on long-term energy prices. As illustrated in Exhibit G, global averages highlight two key trends:

- **Refineries** could see increases of **\$150/t AI** (30% above current levels) for converting to low-carbon means of production.

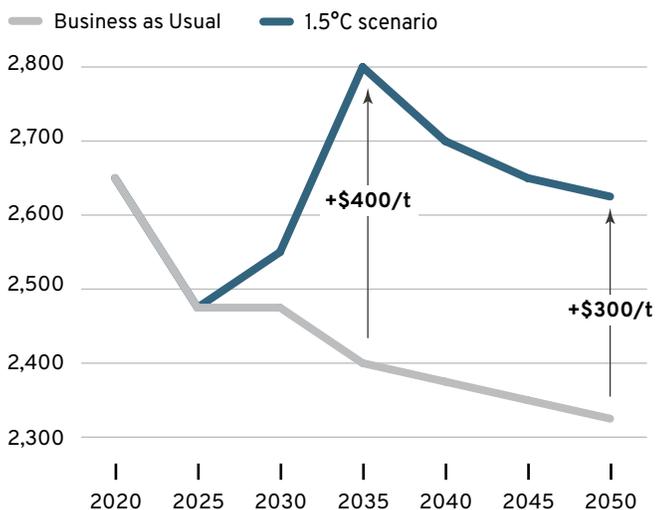
- **Smelters** could see significant variation, with cost increases of **\$75/t-\$600/t AI** depending on their current power arrangements.

Clear action is required to address this cost gap: (1) action to bring down costs of technologies through early stage R&D and continued power decarbonisation rollout; (2) policy action and action from buyers to facilitate a market for low-carbon aluminium (through a combination of carbon pricing, green premium, and removing support for high-carbon production); and (3) the mobilisation of green and sustainable financing across the entire value chain.

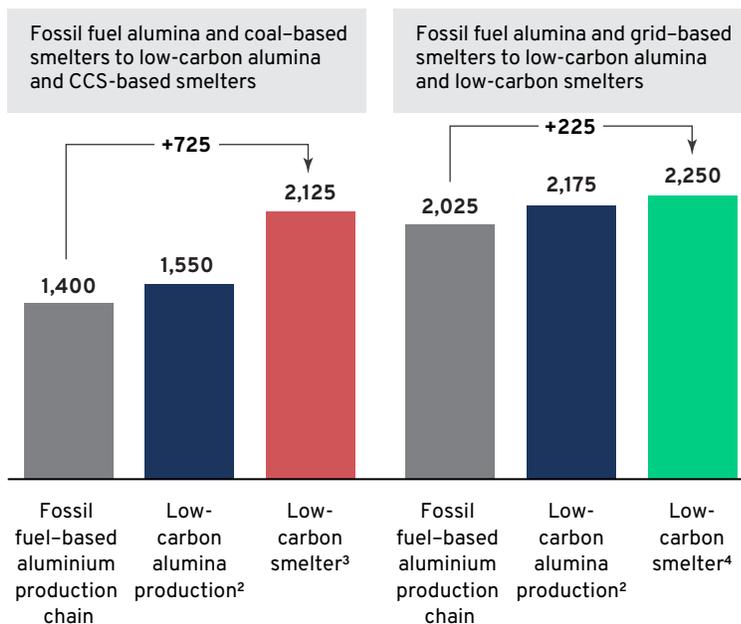
EXHIBIT G

Individual asset transitions will vary by situation, but the overall transition could increase the average cost of aluminium production by \$400/t by 2035

Aggregate levelised cost of aluminium, \$ per tonne



2035 marginal cost of aluminium by technology,¹ \$ per tonne



¹ These case studies are examples of the costs of retrofit (so do not include existing capital expenditures associated with the existing asset, unlike aggregate levelised cost); they represent only some transition paths for the industry, and the entire transition will not be complete by 2035.

² Switch from coal- and gas-based refineries to MVR- and hydrogen-based refineries.

³ Switch from a captive coal and carbon anode smelter to coal-CCS and inert anode smelter.

⁴ Switch from a typical grid-connected and carbon anode smelter to grid and inert anode smelter.

Source: Aluminium Sector Transition Strategy Model (2022)



9. The aluminium sector can reduce emissions by 2050 by up to 95%. Therefore, further breakthrough technologies or a limited number of offsets will be needed to deliver a net-zero sector.

Low-carbon power, low carbon anodes, and fuel switching in refineries can reduce emissions from the production of aluminium by 95%. Residual emissions in 2050, totalling approximately 84 Mt CO₂e/y, are largely derived from the role CCS might play in power provision (assuming a CO₂ capture rate of 90%) and from remaining carbon anodes and fossil-fuelled calciners.

Those residual emissions will need to be mitigated by carbon dioxide removal (CDR) solutions, including, for example, natural climate solutions (NCS); hybrid solutions such as bioenergy with carbon capture and storage (BECCS); and engineered solutions such as direct air carbon capture and storage (DACCS). Offsetting the residual emissions would cost an additional \$10.5 billion in 2050 alone at an average abatement cost of \$125/t CO₂.

CDR solutions are required in addition to, and not instead of, deep and rapid in-sector decarbonisation.



10. Delivering net zero will require different forms of coordination across the value chain and with policymakers and regulators across the energy system.

Delivering a low-carbon aluminium sector will require a step change in engagement and coordination along every link of the value chain. Four areas of focus are particularly key:

Technology dissemination: Dissemination is critical as key new technologies such as low-carbon anodes and new calcination methods will be required by all sites. Strategies involving low- or zero-cost licencing and building supply chains will be helpful in this process.

Secondary aluminium: The users of aluminium, the waste sector, and the wider value chain will have to work together and with policymakers to maximise scrap recycling rates in order to enable the significant expansion of the secondary sector.

In addition, the secondary sector will have to decarbonise its recycling processes.

Electricity markets: Close collaboration between the aluminium sector and the electricity market is vital. It will be needed to make sure long-term investment plans are aligned, so that aluminium smelters can access low-carbon electricity at the right price and so that the benefits a long-term secure buyer can offer can be included.

CCS: Finally, where CCS is required, collaboration with other potential local users of CO₂ transport and storage networks and local project developers and policymakers will be necessary to generate the economies of scale to make it affordable. A stable underlying regulatory framework will be required as well.



CONCLUSION

Transforming the aluminium sector to a 1.5°C-aligned sector is possible. It will require a substantial investment and change in how the whole value chain coordinates, particularly with the power sector and recycling sector, to deliver technical change, and with users of aluminium, finance institutions, and policymakers to deliver the market to enable low-carbon aluminium to flourish.

Early action during this decade through planning and delivering power decarbonisation is a vital first step. This action must be complemented with action to build the secondary aluminium market, commercialise new technologies, and build a business case that can bridge the cost gap between fossil fuel and low-carbon aluminium production.

A joint effort by actors along the entire value chain can make this mission possible.





**MISSION
POSSIBLE
PARTNERSHIP**

The Mission Possible Partnership is an alliance of climate leaders focused on supercharging efforts to decarbonise some of the world's highest-emitting industries in the next 10 years.

© COPYRIGHT 2023 MISSION POSSIBLE PARTNERSHIP