Assessment of techno-economic feasibility of Carbon Capture and Storage (CCS) on aluminium potlines

Public Summary Report

Report summarising key findings from study prepared for International Aluminium Institute (IAI)

JUNE 2025

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Glossary

Abbreviation	Definition	Abbreviation	Definition	Abbreviation	Definition
CAPEX	Capital expenditure	GCC	Gulf Cooperation Council countries (e.g. Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates)	NPV10	Net Present Value calculated using a 10% discount rate
CBAM	Carbon Border Adjustment Mechanism	GTC	Gas Treatment Centre	OPEX	Operating expenditure
CC	Carbon capture	HEX	Heat Exchanger	PFC	Perfluorocarbon (PFC)
CCS	Carbon capture and storage	HF	Hydrogen fluoride	PIA	Pot Integrated Abart
CCUS	Carbon capture, utilisation, and storage	IRR	Internal rate of return	RES	Renewable energy source
CO_2	Carbon dioxide	kA	Kiloampere	SO_2	Sulphur dioxide
DCF	Discounted cashflow	MENA	Middle East and North Africa	T&S	Transport and storage for carbon dioxide
ETS	Emissions Trading System	mtpa	Million metric tonnes per annum	Tonne	Metric tonne
FEED	Front-End Engineering Design	N/a	Not applicable	tpy	Tonne per year
FID	Final Investment Decision	NOx	Nitrogen oxides	TRL	Technology Readiness Level
		NPV	Net present value	WHR	Waste Heat Recovery

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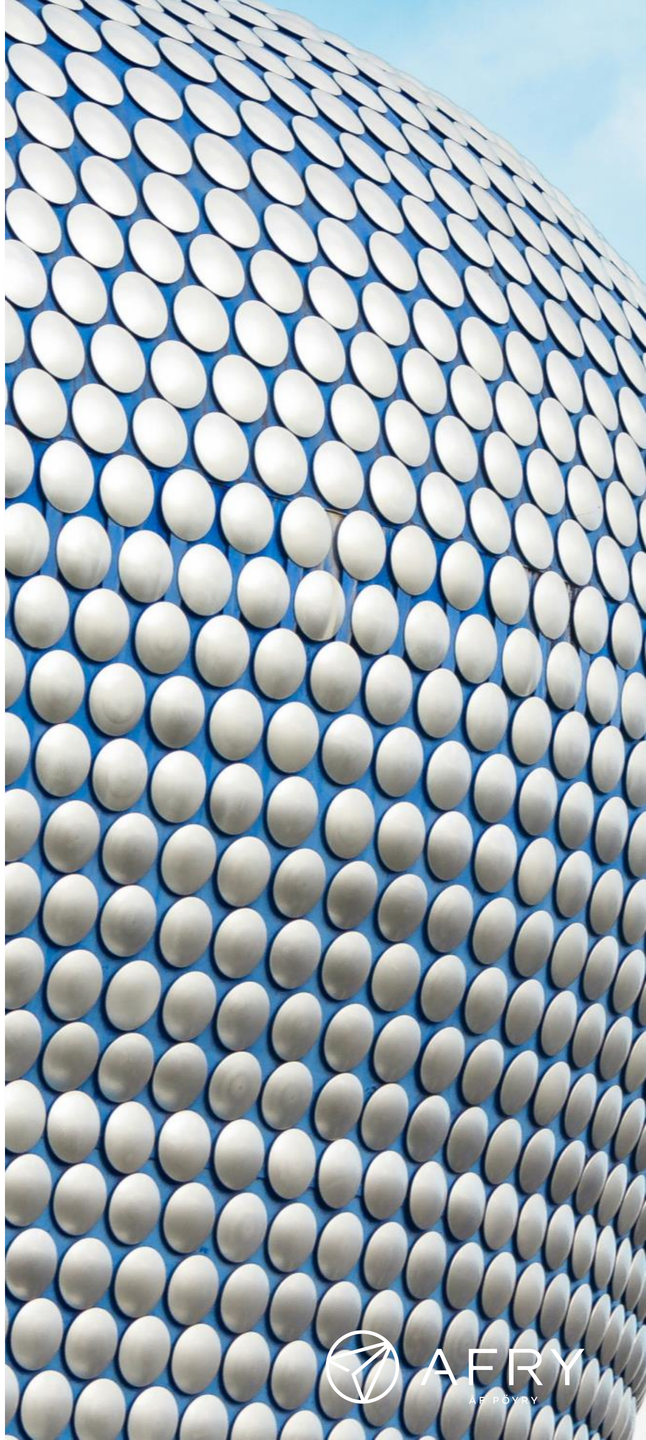

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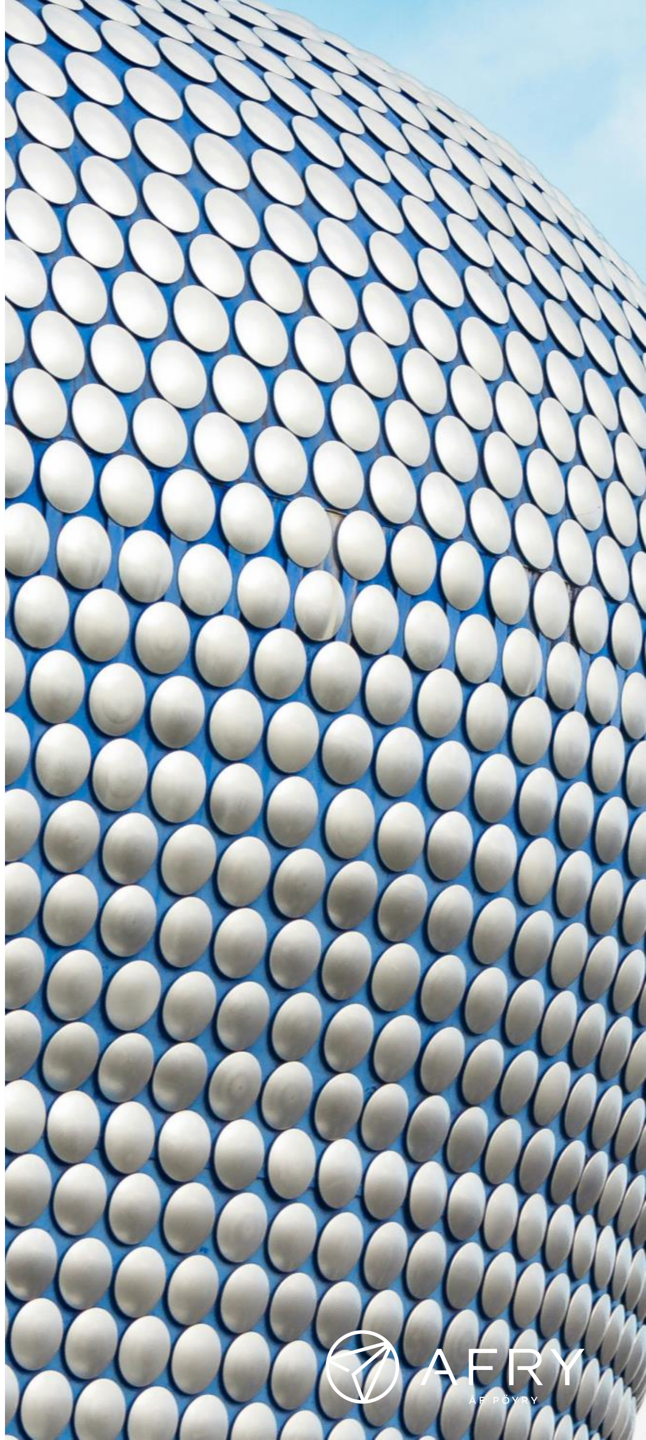

Economic viability of carbon capture on potlines depends on achievable CO_2 concentration and carbon pricing, as well as wider integration challenges

1 Carbon Capture and Storage (CCS) retrofits can enable smelter decarbonisation

CCS retrofits to existing smelters are a **technically feasible** means to decarbonise direct emissions from smelters, although further research and testing of both CO_2 capture optimisation for smelting and potential smelter modification are required before widespread commercialisation can occur.

2 Extension of carbon pricing is likely the key driver for the CCS business case

CCS on potlines reduces CO_2 emissions but requires significant CAPEX and OPEX, making carbon pricing a key economic driver for adoption. Assuming technology progress continues to address challenges, a breakeven CO_2 price of between **\$180 and \$205/tCO_2** is required for a representative Middle East smelter CCS retrofit. **This range is subject to significant uncertainty** and regional and site specific differences will increase costs in other locations.

3 Higher CO_2 concentration in flue gas boosts capture efficiency but has technical challenges

Elevating flue-gas CO_2 concentrations from 1% to 3% could **reduce capture costs by 22-32%,** potentially enhancing economic feasibility. This must be balanced against additional smelter costs for elevating CO_2 concentrations which will vary by site, and will need further investigation as new technology solutions are developed.

4 Opportunities for CCS on specific potlines will be site dependent

Smelter-specific characteristics will enhance the case for a particular smelter to fit CCS. A favourable policy environment, including political and financial support for carbon capture and carbon price exposure, is likely to be a primary driver. Other site characteristics including available site space and access to CO_2 infrastructure will also be important.

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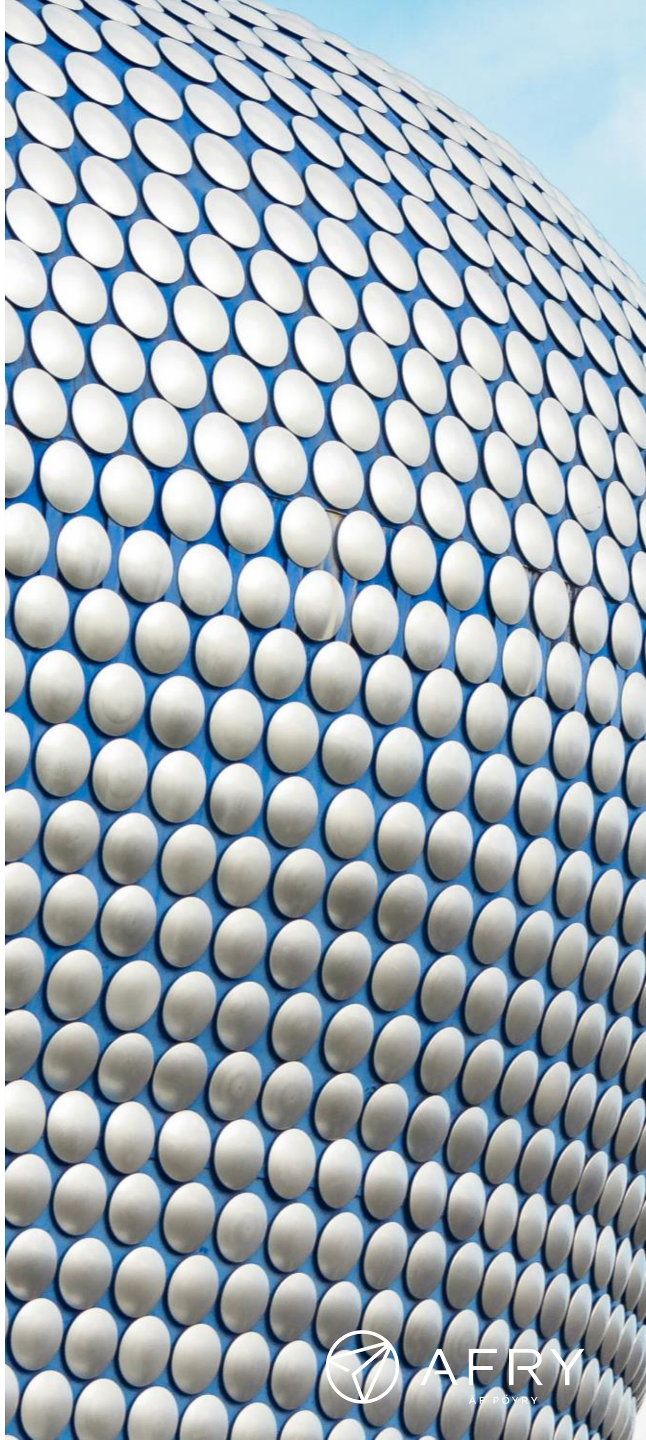
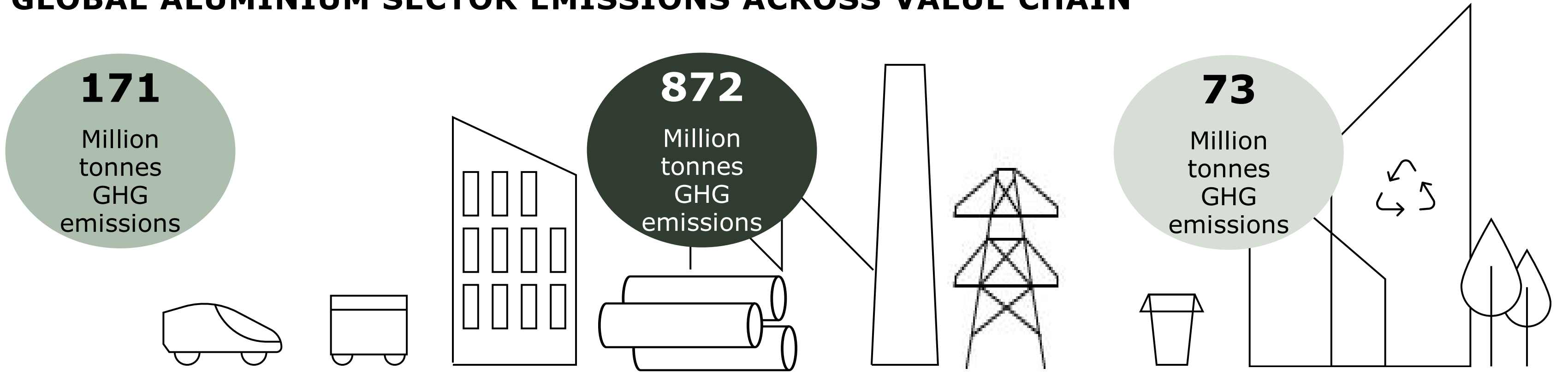


Reducing carbon emissions from primary aluminium smelters is key to aligning with a 1.5-degree scenario

GLOBAL ALUMINIUM SECTOR EMISSIONS ACROSS VALUE CHAIN



Upstream	**Primary aluminium smelting**	**Downstream & recycling**
Bauxite mining, alumina refining	Electrolysis, casting, anode furnace	Semi-fabricated products, secondary aluminium

Global emissions from aluminium sector 2023

1,116 Million tonnes GHG emissions

Target global emissions from aluminium sector by 2050 to achieve 1.5 degree scenario

53 Million tonnes GHG emissions

Reducing carbon emissions from primary aluminium smelters is crucial for aligning with a 1.5°C climate scenario.

The global aluminium industry contributes approximately 1.1 billion tonnes of CO_2 equivalent annually, accounting for about 2% of worldwide anthropogenic emissions.

Primary aluminium production accounts for 78% of global aluminium value chain emissions.

The emissions intensity of primary aluminium production has been declining since 2019, indicating improved efficiency and cleaner production methods.

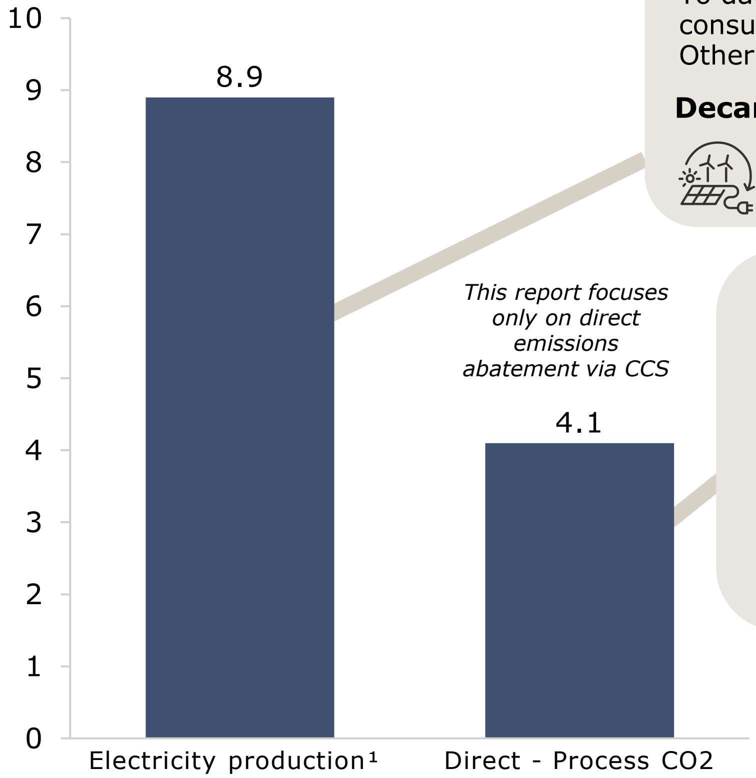
Achieving alignment with a 1.5°C scenario necessitates a further 95% cut in aluminium value chain emissions.

Source: Emissions estimates from IAI and World Economic Forum

Carbon Capture and Storage (CCS) is a significant potential lever to reduce direct and indirect emissions from primary aluminium production

GHG INTENSITY PER TONNE OF PRIMARY ALUMINIUM (2023)

Tonnes CO_2e/tonne primary aluminium (cradle to gate world average)



ELECTRICITY PRODUCTION

To date the greatest focus for aluminium decarbonisation has been on reducing indirect emissions from electricity consumption. Here Carbon Capture and Storage (CCS) has potential to reduce emissions on power generation. Other levers include the use of other forms of renewable energy and improvements in potline energy efficiency.

Decarbonisation levers

- Zero carbon electricity
- Energy efficiency
- CCS

DIRECT EMISSIONS AT SMELTER

To achieve the last mile of decarbonisation, reduction of direct emissions is required. A key source of direct emissions is from carbon anode consumption in the electrolysis cells of a smelter potline, as well as other process emissions. CCS is a means by which to reduce process emissions from smelter potlines, in addition to other methods such as fuel switching or electrification. Inert anodes and aluminium chloride-based electrolysis with carbon looping also represent alternative methods of decarbonisation.

Decarbonisation levers

- Inert anodes
- Fuel switching / electrification
- Aluminium chloride-based electrolysis with carbon looping
- CCS

Source: IAI, Direct – Process CO2 includes PFC emissions at smelter of ~0.8tCO2e/tonne, process CO2 of ~1.6tCO2e/tonne and thermal energy emissions 1.7tCO2e/tonne. Includes upstream emissions such as from refining and mining.

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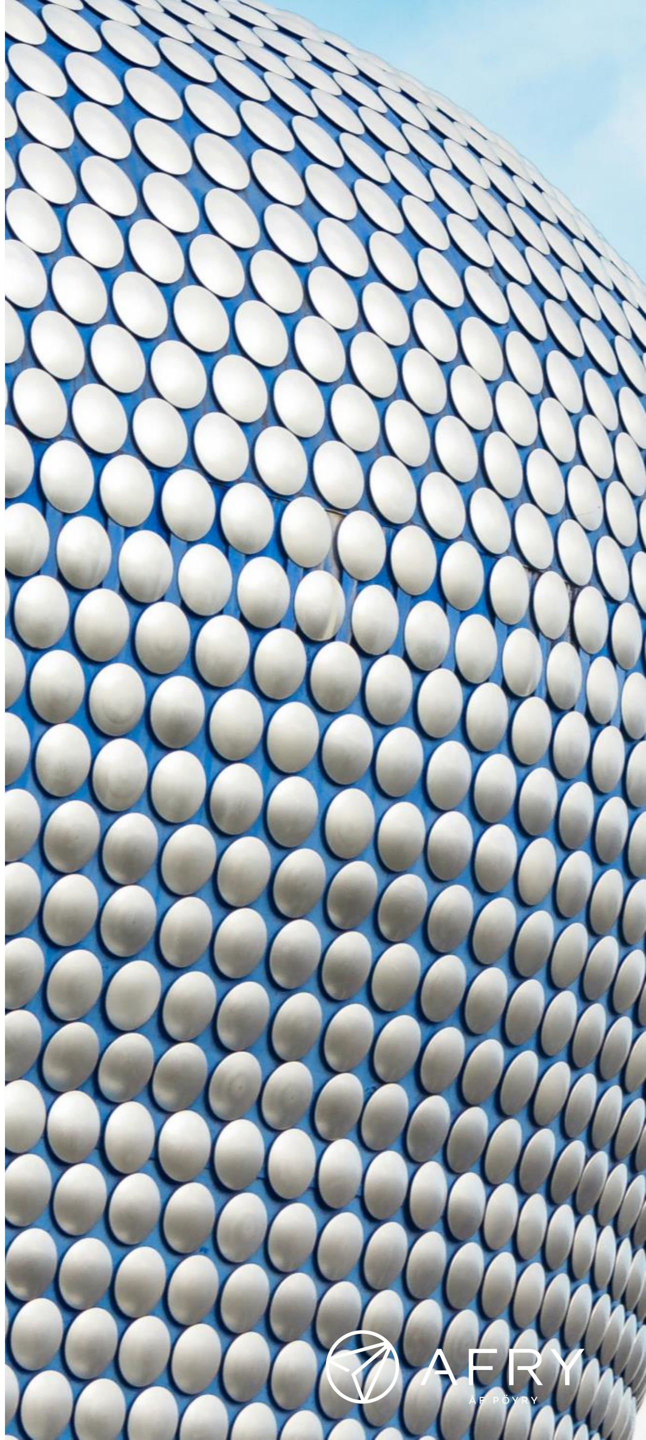
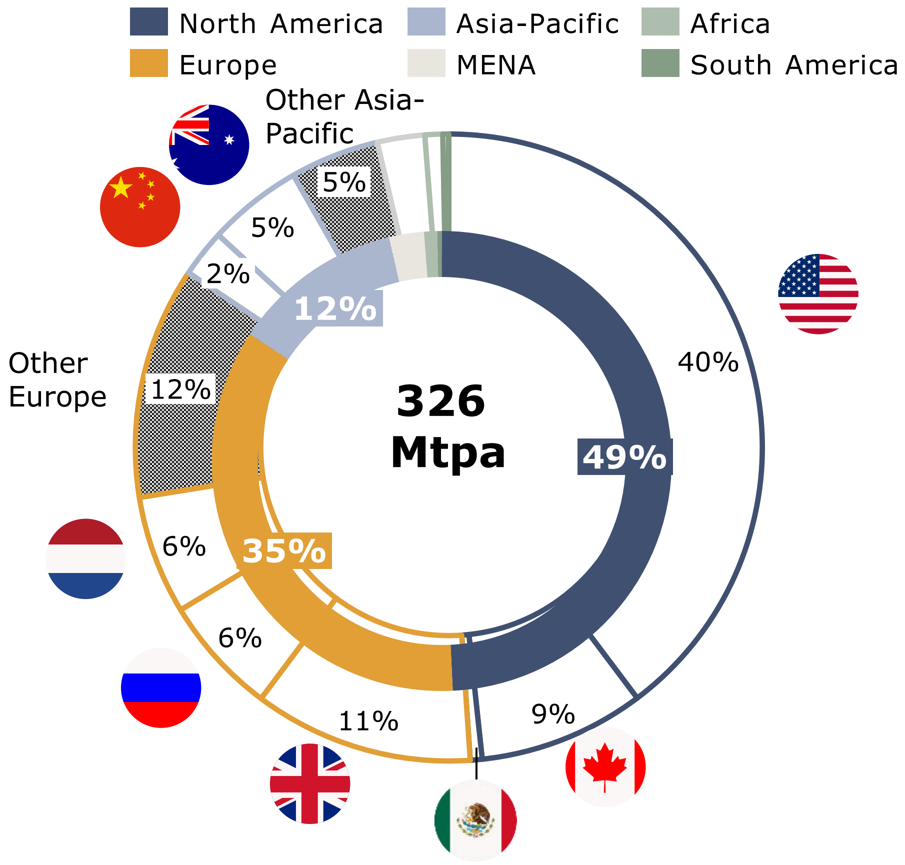
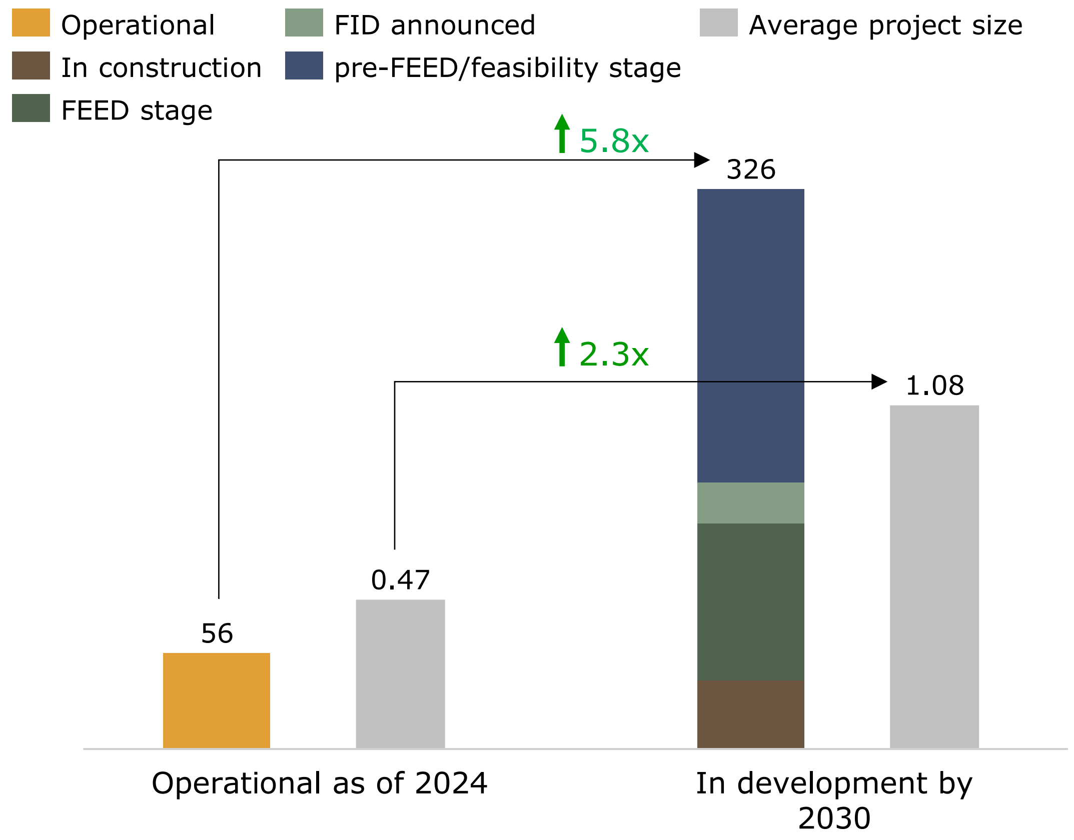


North America and Europe anticipated to be primary regions driving carbon capture advancements worldwide, with interest growing in MENA & Asia

ANNOUNCED REGIONAL CAPTURE CAPACITY BY 2030 (MILLION TPA CO_2)



ANNOUNCED CAPACITY OF GLOBAL CO_2 CAPTURE FACILITIES (MILLION TPA CO_2)



Notes: The displayed data are estimates from publicly available open-source databases MENA = Middle East and North Africa

CCS is already being piloted at primary smelters, mostly in Europe and GCC

Smelter	Owner	Partners	Country	Status	Value chain stage	Technology	Timing	Potential Emission Abatement
Hydro Aluminium	Hydro	VERDOX		Plans for Pilot plant	Potline	Electro-Swing Adsorption	Aim: 2030	N/A
Various sites in Europe	Hydro, RioTinto	Hydro, RioTinto		Research, pilots	Potline	Not decided yet	2025-2030	N/A
Aluminium Dunkerque	Aluminium Dunkerque	fives, trimet, EDF, RioTinto		Pilot plant	Potline	Solvent	Industrial deployment by 2028	N/A
Australia's CSIRO	CSIRO			Research	Potline	Solvent	No timelines announced	N/A
Emirates Global Aluminium (EGA)	EGA	GE		Pilot plant	Power Generation	Not decided yet	No timelines announced	N/A
Alba	alba	MITSUBISHI HEAVY INDUSTRIES		Pilot plant	Power Generation	Not decided yet	No timelines announced	~0.5-1 mtpa

Notes: EGA also looking into CCUS on broader smelting process

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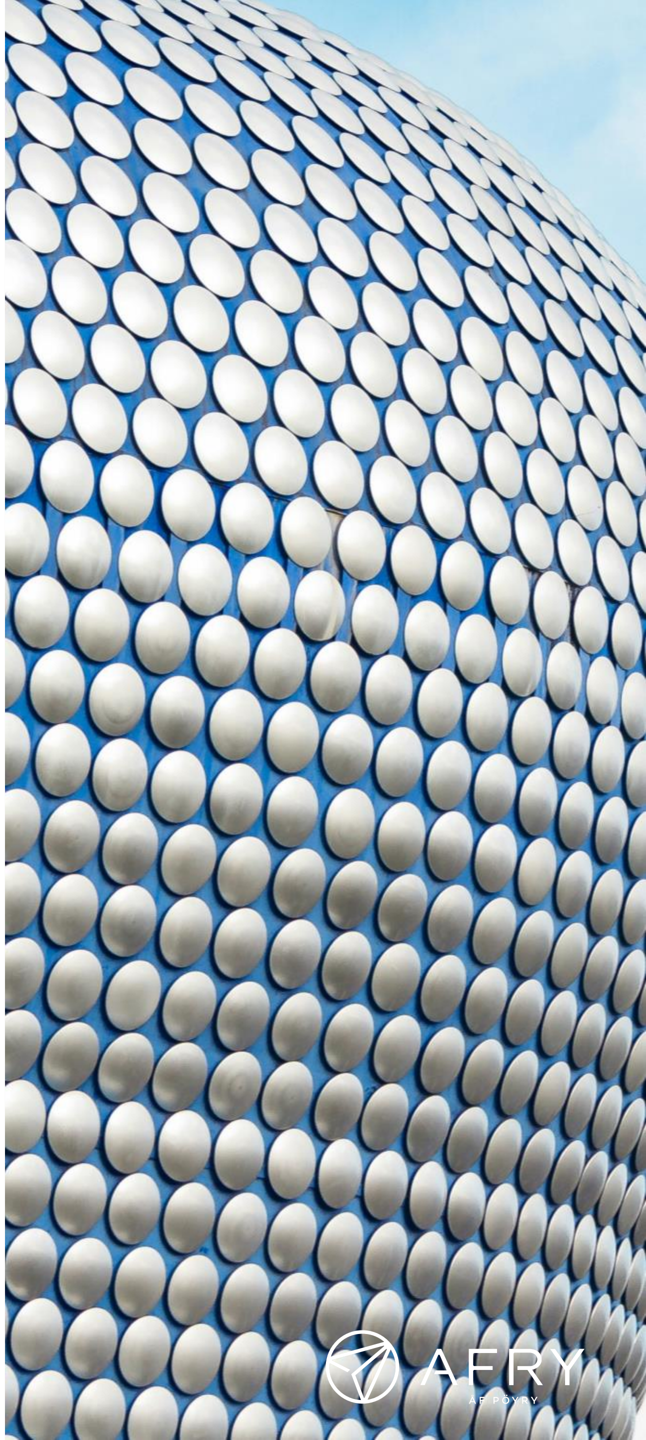
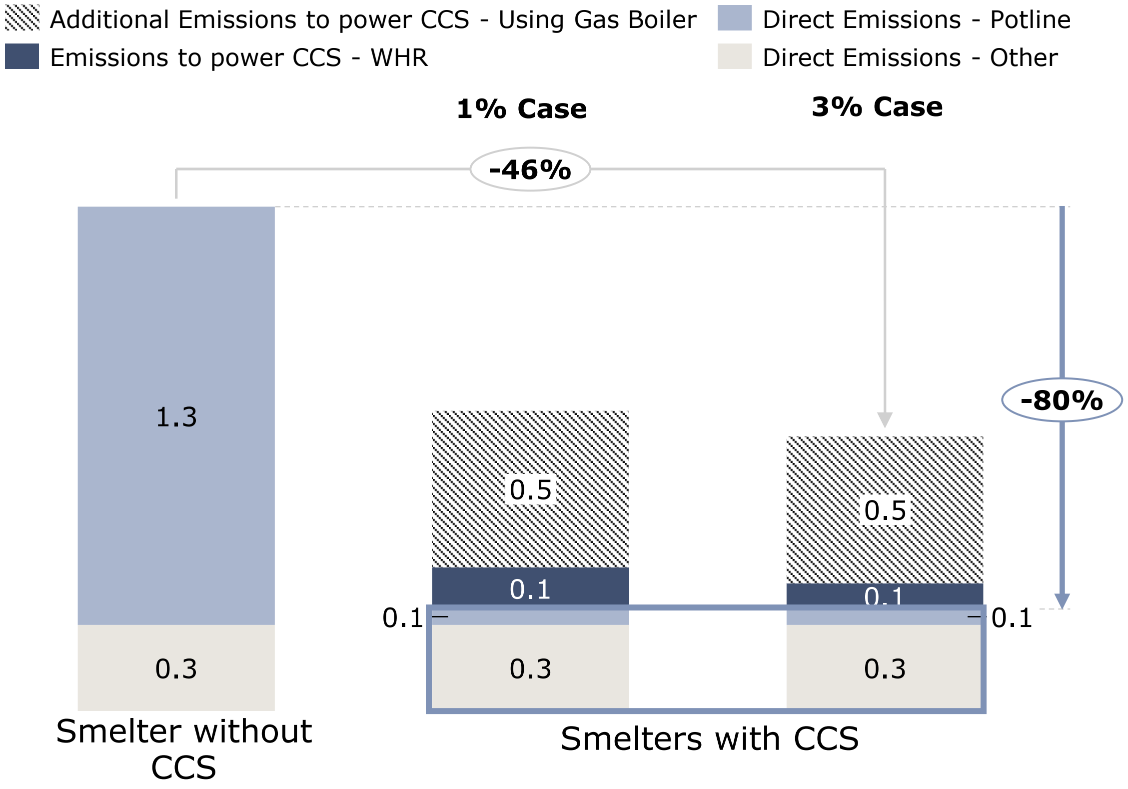


CCS can enable a large reduction in smelter direct emissions, but it may need to be applied elsewhere in the value chain to result in "green" aluminium

DIRECT EMISSIONS FROM THE SMELTER WITH / WITHOUT CCUS

Tonnes CO2 / tonne primary aluminium (direct emissions only)



Source: AFRY calculations for process emissions from smelting for a generic representative primary aluminium smelter in GCC. Includes PFC emissions and excludes upstream emissions (e.g. from mining/refining).

The use of CCS on potlines results in the following **reductions in direct emissions**[1]:

- **41-46%** – Use of boiler powered by fossil-based electricity
- **70-80%** – Use of waste heat recovery (WHR) depending on source of process energy
- **80%** – Use of electric boiler with fossil-free electricity[1]
- **>100%** – Application of CCS to other parts of smelter and broader site, including anode furnace and alumina refining. Potential to bring a sizeable reduction in electricity-related emissions which accounts for 81% of the GCC representative smelter's total emissions

[1] % reflect reduction in direct emissions from representative GCC smelter. In excess of 100% represents emissions reductions beyond direct emissions, such as indirect emissions. Reductions beyond direct emissions alone will be needed to meet "green" aluminium levels of =< 4t CO2e/t of aluminium, which are based on lowest current achievable level at commercial scale technology.

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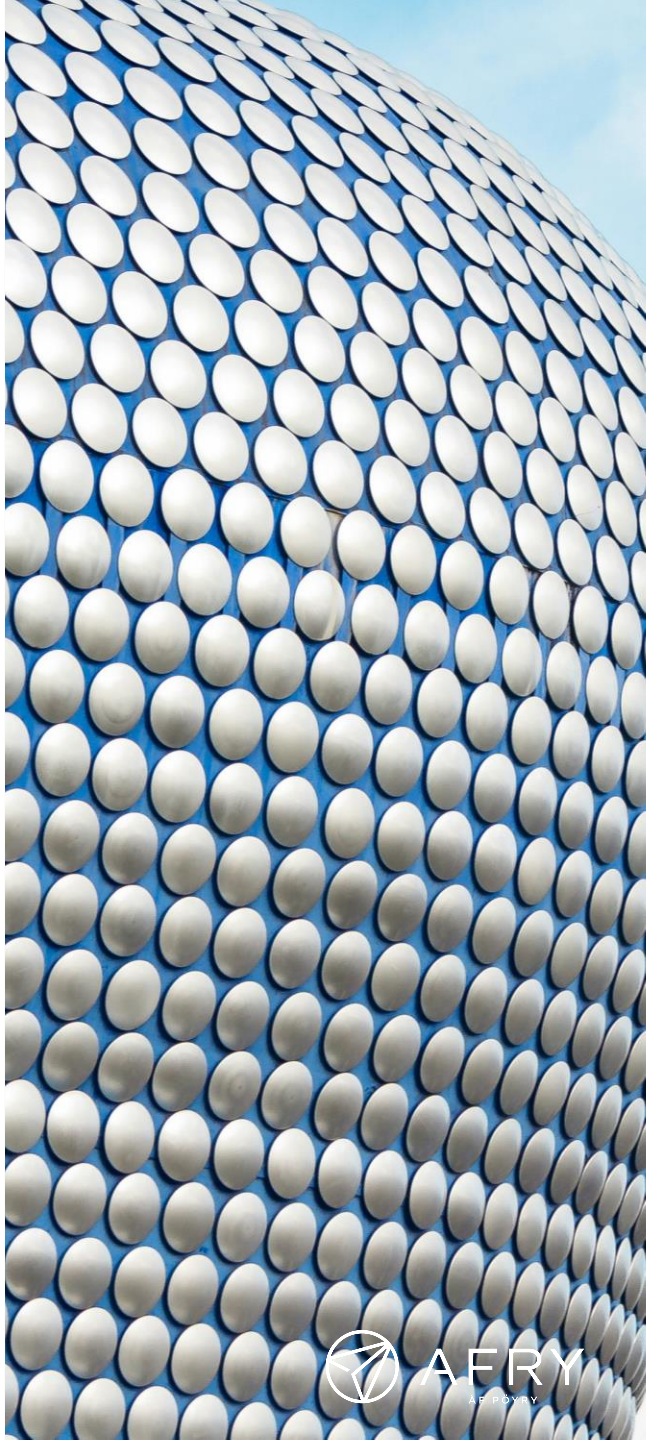

POTENTIAL ISSUES IN APPLYING CCS TO ALUMINIUM SMELTERS

Whilst CCS on potlines is technically feasible, it is not without its challenges and further advancements and financial support are needed

CHALLENGES FOR CCS IN ALUMINIUM POTLINES

Challenge	Details	Mitigants/actions required
CO_2 concentration	• CO_2 concentration levels from potlines are low at <1 volume percent (vol%). Typically carbon capture (CC) used on processes with CO_2 purity >3-4% • Lower CO_2 content in the gas stream leads to higher costs as it is more difficult to extract a unit of CO_2	• Upgrading CO_2 via reduced gas flows and additional sources of CO_2, - options to do this vary by smelter and come with own challenges • Collaboration with technology suppliers and aluminium smelters to overcome the challenges of applying CCS to potlines, beyond just CC systems themselves
High volumes and high temperature pot gas	• Pot gas is high in temperature at 100-160°C, and cooling is required • Extremely high potline gas ("pot gas") volume rate means that the size of the CC column would be significantly larger than most of the available units by vendors	• Opportunity to utilise high temperature heat, for example through Waste Heat Recovery (WHR) and heat integration • Monitor and engage with emerging technologies and equipment capabilities and suppliers
CCS energy consumption	• Electricity costs are often the single largest operating expense of amine-based CC processes	• Potential of WHR • Secure renewable energy to maximise CO2 abatement
Impurities	• Impurities can impact the effectiveness of some carbon capture technologies, including hydrogen fluoride (HF), sulphur dioxide (SO_2) and nitrogen oxides (NO_x). • PFCs are not absorbed in the wet scrubbing process	• Further testing of solvents for use in CC systems on smelters required
Retrofits	• Existing smelters will need to accommodate the additional equipment required for CCS on site, requiring space and process integration	• Solutions will need to be tailored to different smelters
Access to CO_2 transport and storage	• Smelters will need access to CO_2 transport and storage infrastructure – such as suitable geological formations for permanent storage, or a local liquid CO_2 offtaker for utilisation • CO_2 transport and storage (T&S) networks are growing globally, but their extent and stage of development varies greatly by location, and they need to scale up considerably to meet future demand	• Collaboration with CCS hubs, regulators, and policymakers is essential for economic viability • Discuss options with third party T&S operators

Access available subsidies

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HIGHER CO_2 CONCENTRATION IN FLUE GAS BOOSTS CAPTURE COST EFFICIENCY

There is no simple means to upgrade CO_2, and technology is still too early stage to understand its full integration costs

POTENTIAL CHANGES

REDUCED AIRFLOWS TO INCREASE CO_2 %

- Reducing gas flows by 50% increases CO_2 concentration to 1.62 vol%; a 75% reduction raises it to 3.35 vol% but both will create additional complexity and cost to implment.[1]
- Potential use of heat exchanger technology (HEX) – for example REEL's Pot Integrated Abart (PIA) technology

ADDITIONAL CO_2 SOURCES

- Use of additional CO_2 from other point sources, e.g. anode furnace, refining, or gas-fired power generation, to raise CO_2 concentration

EQUIPMENT MODIFICATIONS

- Potential savings on GTCs and SO_2 scrubbers are offset by the increased complexity of CO_2 absorbers, requiring inter-stage cooling for higher CO_2 concentrations.
- Cell upgrades to manage heat changes are expensive and involve significant redesigns.

IMPACT

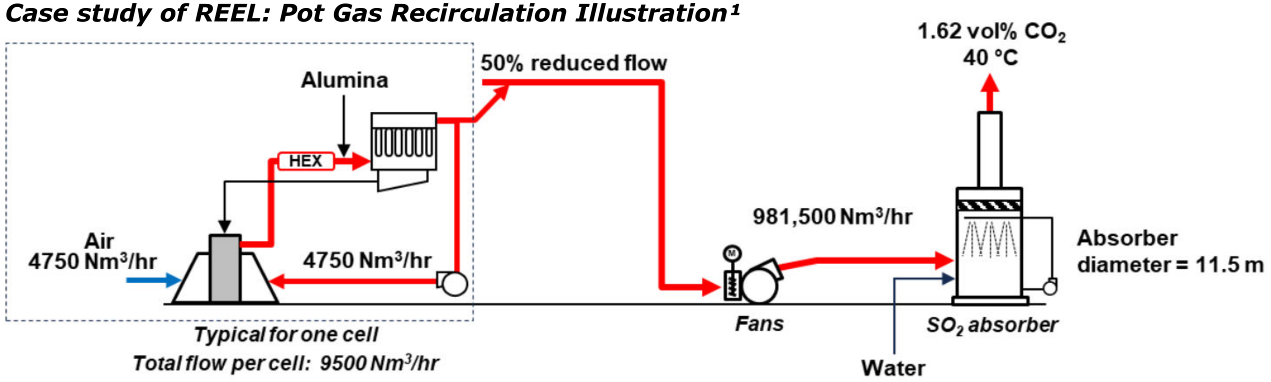
IMPACT ON GAS CLEANING SYSTEMS

- Smaller gas volumes may push existing gas treatment centre (GTC) compartments beyond their operating limits.
- Alumina flow remains constant, adding strain to the GTC's performance.

OPERATIONAL & SAFETY CHALLENGES

- Higher gas temperatures cause roof emissions and unsafe superstructure conditions.
- Heat balance shifts in cells may require costly lining redesigns.

Case study of REEL: Pot Gas Recirculation Illustration[1]



*Source: Broek, Stephan, and Versteeg, Geert, "Towards Carbon Neutral Primary Aluminium Smelting via Carbon Dioxide (CO2) Capture" from TRAVAUX 52, Proceedings of the 41st International ICSOBA Conference, Dubai, 5 - 9 November 2023. Notes: AFRY presents REEL as an example of one possible means of upgrading CO2 gas for capture to a higher CO2%, it does not represent an endorsement by AFRY of this technology or approach

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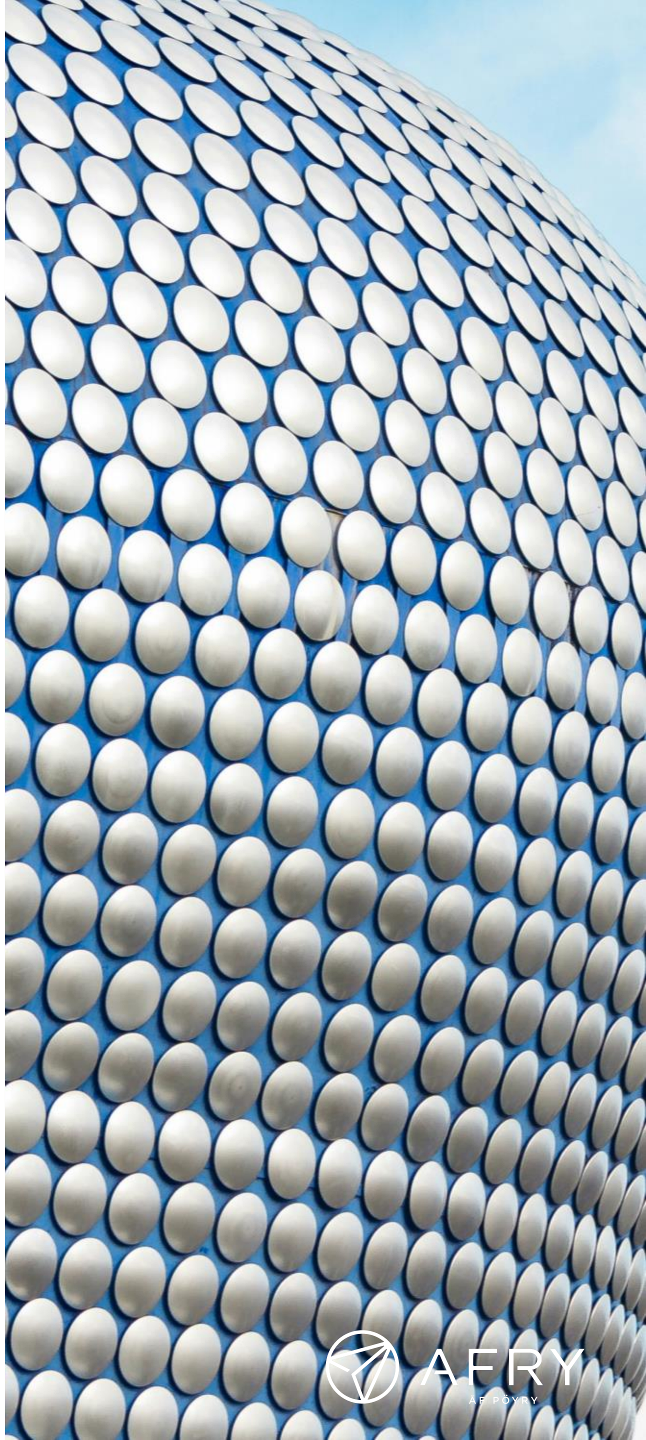
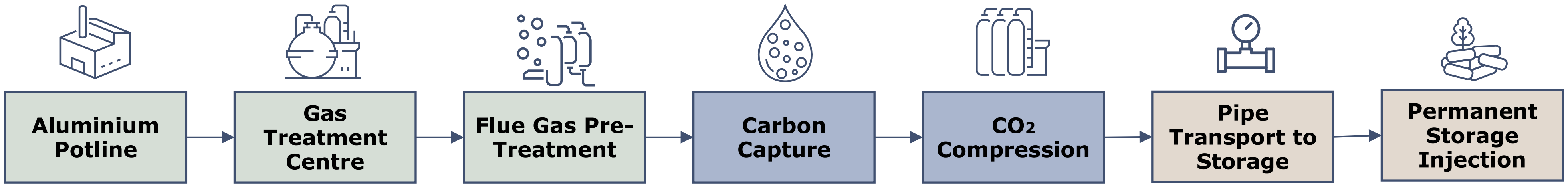


To assess the techno-economic feasibility of CCS on a potline, the IRR and NPV of a representative existing GCC smelter with/without CCS was calculated

KEY COST ASSUMPTIONS IN TECHNO-ECONOMIC MODELLING



Aluminium production costs	Capture costs	CO2 transport & storage costs
Estimated operating costs of representative 400,000 tpy primary aluminium smelter in GCC Retrofit to existing smelter[1] Gas-fired power generation 2023 basis	Capture costs estimated by AFRY engineers for 2 scenarios – 1% and 3% vol. CO_2 based on retrofit A 90% capture rate is the industry standard for amine-based carbon capture, balancing feasibility and cost[2] Flue gas upgrading costs variable by smelter Estimate out of scope	Representative costs assumptions for CO_2 Transport & Storage ("T&S") Assumed CO_2 T&S contracted out to a third party Storage on a permanent basis

[1] Assumes no space or energy sourcing constraints. [2] Assumes separately 91% availability of CC unit accounting for regular maintenance and unexpected downtime.

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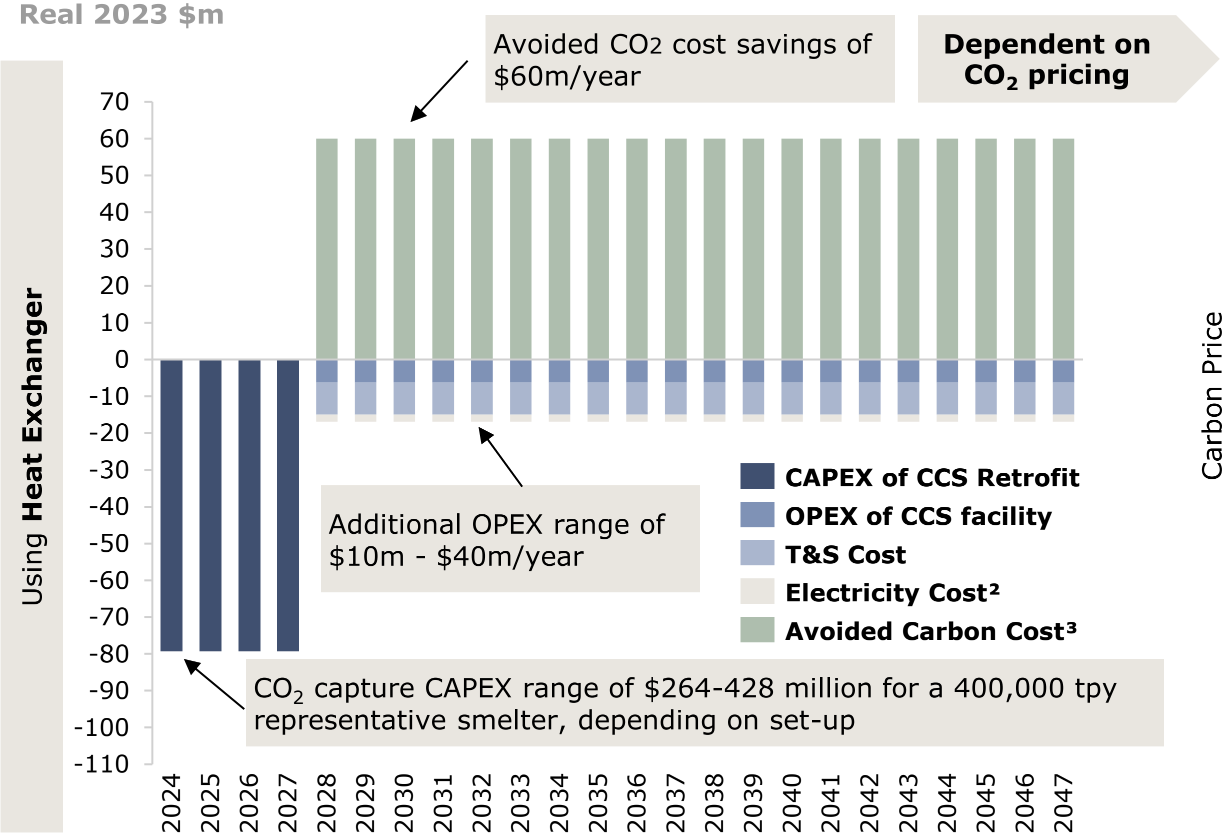
EXTENSION OF CARBON PRICING IS KEY DRIVER FOR CCS BUSINESS CASE

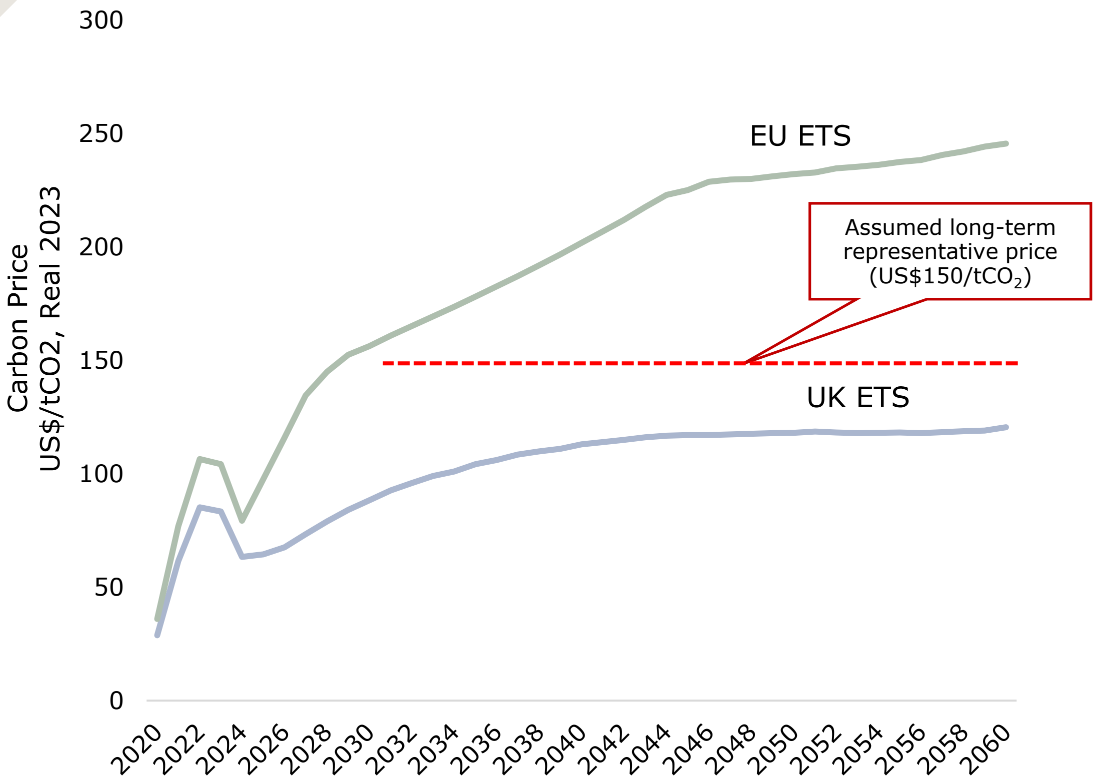
The avoided carbon cost is the main benefit of retrofitting a smelter with CCS, with significant CAPEX and OPEX over the life of the asset

EXAMPLE OF CASHFLOW ANALYSIS FOR CCS RETROFIT[1]

Real 2023 $m



EUROPEAN CARBON PRICE PROJECTIONS ($/TCO$_2$, REAL 2023)

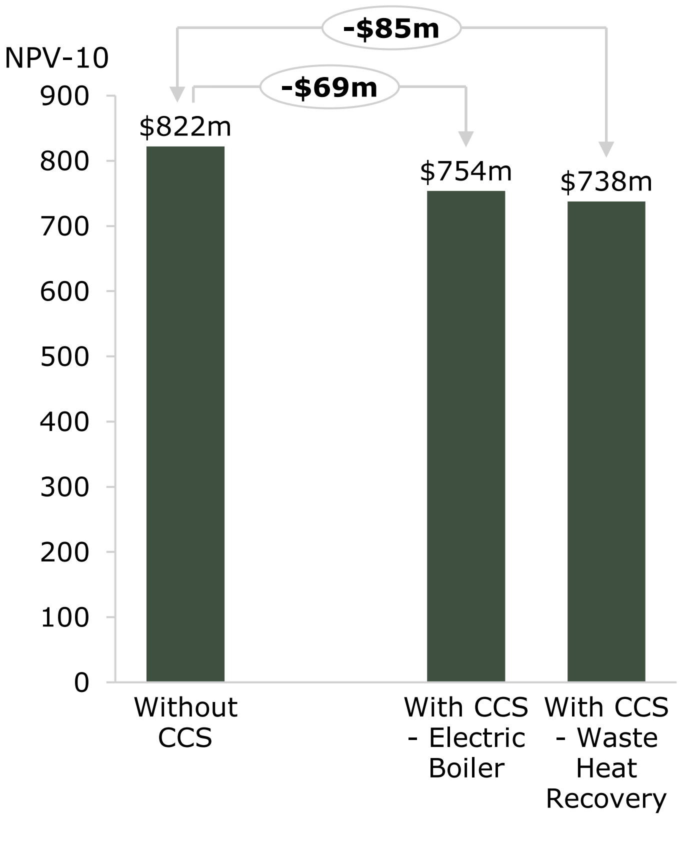


Note: 1) We are showing the cashflow of the difference between the cases without and with CCS for 3% CO_2 excluding costs associated with upgrading CO_2. 2) Does not include extra CAPEX for dedicated renewable energy sources (RES) or additional RES power procurement costs which may arise 3) Avoided Carbon Cost is a positive term as it shows the avoided carbon cost related to the emissions capture with the CCS.

HIGHER CO_2 CONCENTRATION IN FLUE GAS BOOSTS CAPTURE COST EFFICIENCY

Assuming carbon price of $150/t, 1% cases show a negative NPV10 with an IRR of ~5% showing that CO2 price is insufficient incentive without support

NET PRESENT VALUE DIFFERENCE: 1% CO_2 CONCENTRATION[1 2]



Internal Rate of Return – Electric Boiler: **5.3%**

Internal Rate of Return – Waste Heat Recovery[3]: **5.0%**

In the full member report, we also analyse cases where the flue gas CO_2 concentration is increased from 1%-3%. Although our analysis did not extend to a full cost assessment for increasing the flue gas CO2 %, the set up showed potential cost savings in the capture unit of **22-32%** compared to the 1% case.

COMMENTARY

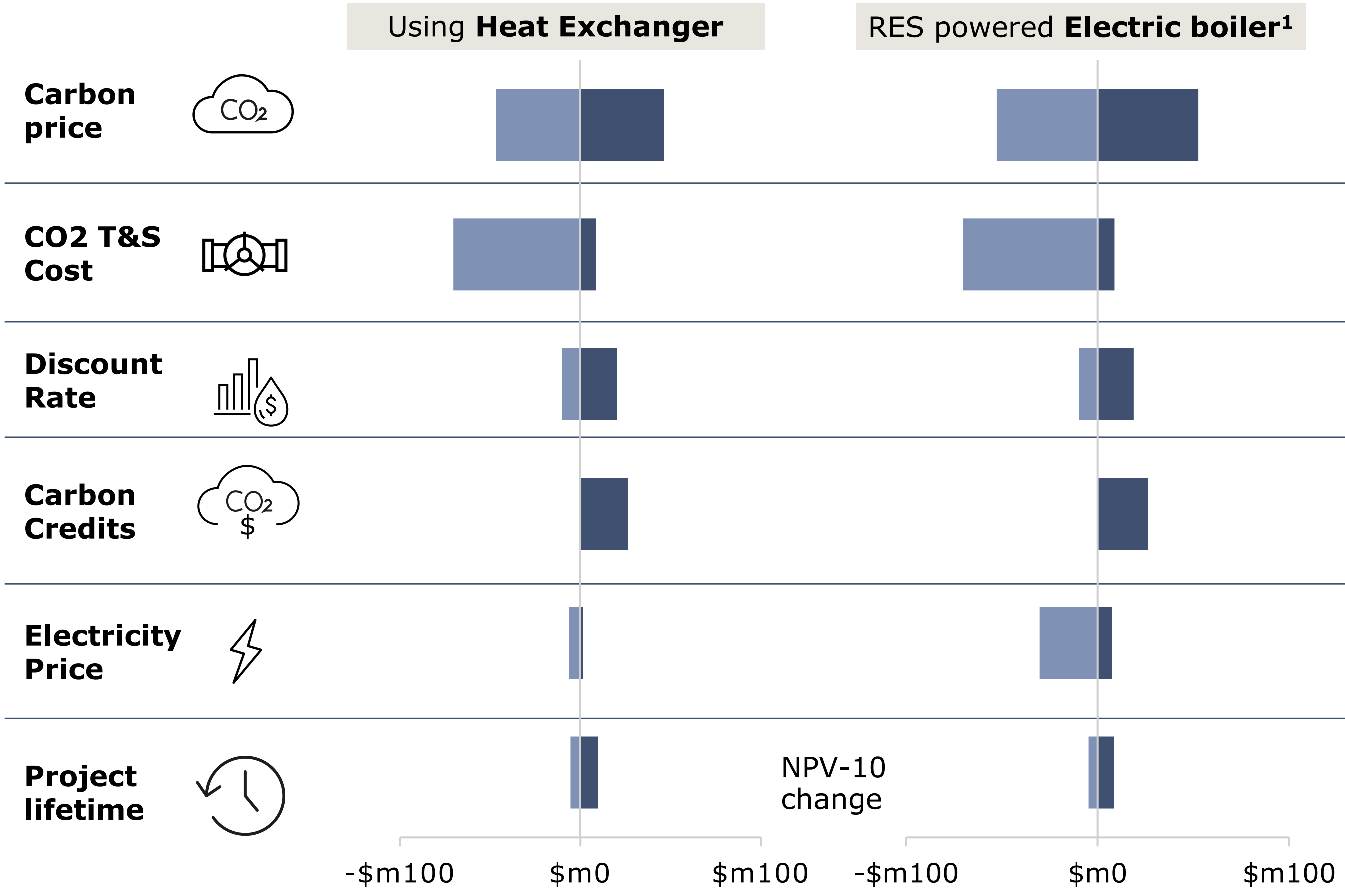
- Assuming a CO2 price of $150/t$CO_2$ the IRR of the CCS investment is <10% i.e. the NPV10 of the project is negative.
- The **breakeven CO_2 price** in the set-ups with 1% CO_2 concentration of flue gas is always higher than $150/t
  - $181/t for the lowest cost case considered – electric boiler with electricity for boiler and capture supplied by renewables; and
  - $205/t for the highest cost case considered - waste heat recovery (WHR) system, with electricity for capture supplied by gas.
  - Other cases with 1% CO_2 concentration typically fell between these two set-ups, but noting that using an electric boiler powered with gas had a significant detrimental effect on the project by dramatically lowering the CO2 benefit (see slide 14)
- The cases considered and assumptions made are subject to significant uncertainty at this stage. The following slide analysis some of the key uncertainties and their impact on the project NPV.

Notes: 1) We have not taken into account in this analysis the CAPEX of the smelter itself as this would be a retrofit. 2) All monetary units are in real 2023 terms; 3) Project examined multiple approaches to generating heat for CO2 capture process including new boiler and technologies to recover waste heat from the potline process.

OTHER KEY DRIVERS OF CCS BUSINESS CASE

The biggest drivers reviewed which could affect the NPV of the smelter are the carbon price and the CO_2 T&S cost

SENSITIVITY ANALYSIS ON NET PRESENT VALUE: 1% CO_2 CASE



	Impact	Sensitivity description
Carbon price	Red	• Represents greatest uncertainty in a retrofit project • A ±20% fluctuation in carbon price (±$30/t$CO_2$) leads to a ~$50 million increase or decrease in project's NPV
CO2 T&S Cost	Red	• Cost of T&S will vary significantly by location (showing range of $15 to $50 vs $20 in base) • Note T&S cost expected to decrease significantly as more infrastructure built
Discount Rate	Amber	• Significant CAPEX requirements of all cases make the discount rate a key sensitivity (8% and 12% vs 10% in base)
Carbon Credits	Amber	• Carbon credits, where additional value of CO2 is delivered from sales on voluntary credit market at US$15/t – could be seen as a proxy for 'additional green value above CO2 tax avoided'
Electricity Price	Amber	• Range of electricity prices between $35 and $60/MWh vs $40 in base – variation in costs across smelter locations • Impact greater on electric boiler scenario where electricity consumption greater as waste heat is not utilised
Project lifetime	Green	• Project lifetime, assumed at 18 & 25 years (against 20 years in base), influences financial outlook, but not a large NPV driver unless much shorter timeframes assumed

Notes: 1) Does not include extra CAPEX for dedicated RES or additional RES power procurement costs over and above the assumed market power price which may arise

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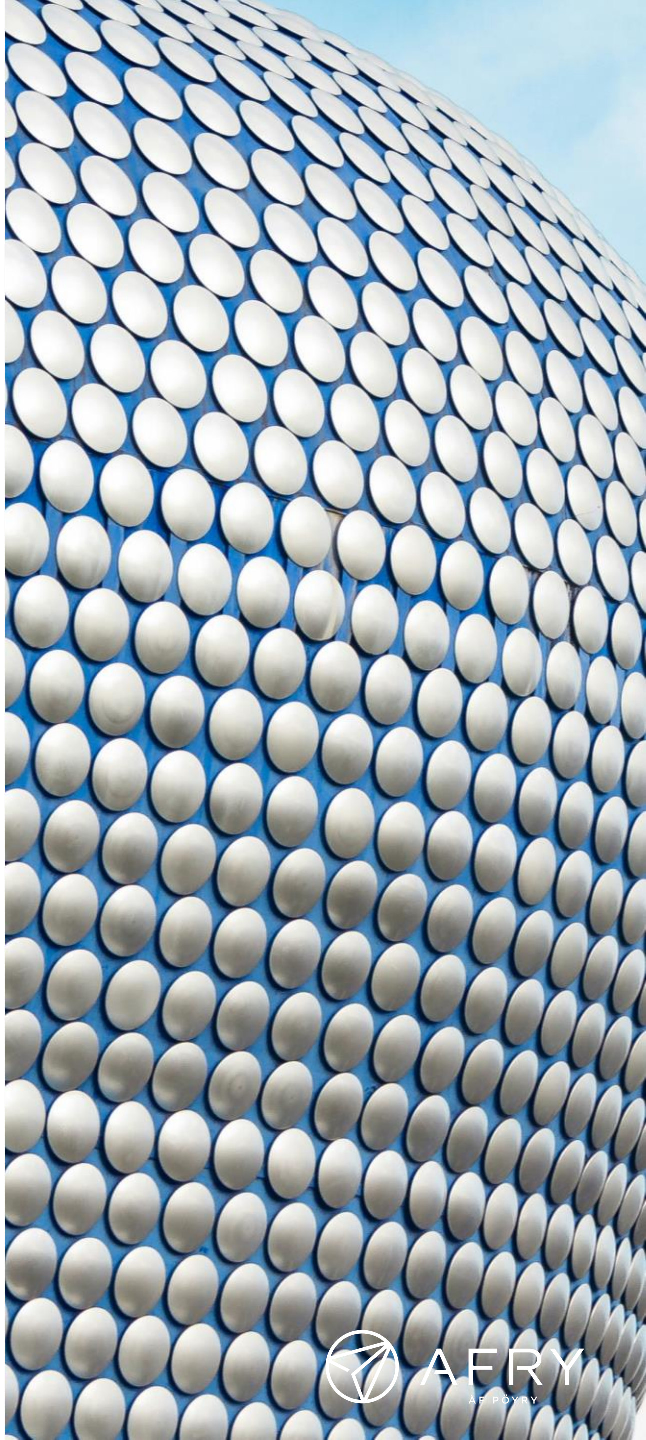

OPPORTUNITIES FOR CCS ON SPECIFIC POTLINES WILL BE SITE DEPENDENT

Smelter-specific characteristics including policy setting, site characteristics and access to CO_2 infrastructure will drive the individual opportunity

SMELTER CCS USE CASE: SITE OPPORTUNITY DRIVERS

- Smelters co-located with additional CO_2 sources, such as anode furnaces or power plants, can raise CO_2 concentrations and benefit from economies of scale
- Smelters with available space for equipment required for CCS retrofits, as modifications in existing plants can be complex and those with fewer space limitations may have more technology/process options
- Newer smelters able to have a longer operational period for CCS installations and their cost recovery
- Smelters with larger pots that may be better suited to heat exchanger technology (HEX) technology to upgrade flue gas CO_2 concentrations

- Smelters located in close proximity to CO2 transport and storage infrastructure to reduce CO2 T&S costs
- Smelters with access to additional supplies of low cost zero carbon electricity, such as hydro or renewables, in order to power the carbon capture operations and maximise the emissions reductions
- Smelters in countries with carbon pricing schemes covering aluminium production where they can avoid carbon costs through emissions abatement, especially those in regions with higher carbon pricing (e.g. the EU)
- Smelters in countries with specific political and financial support for fitting CCS

- Smelters selling to countries with carbon pricing on primary aluminium imports, such as under the EU’s Carbon Border Adjustment Mechanism (CBAM), can avoid carbon costs
- Smelters selling to customers that value the last mile of decarbonisation of primary aluminium, and that are pursuing other decarbonisation initiatives to meet the required “green aluminium” levels

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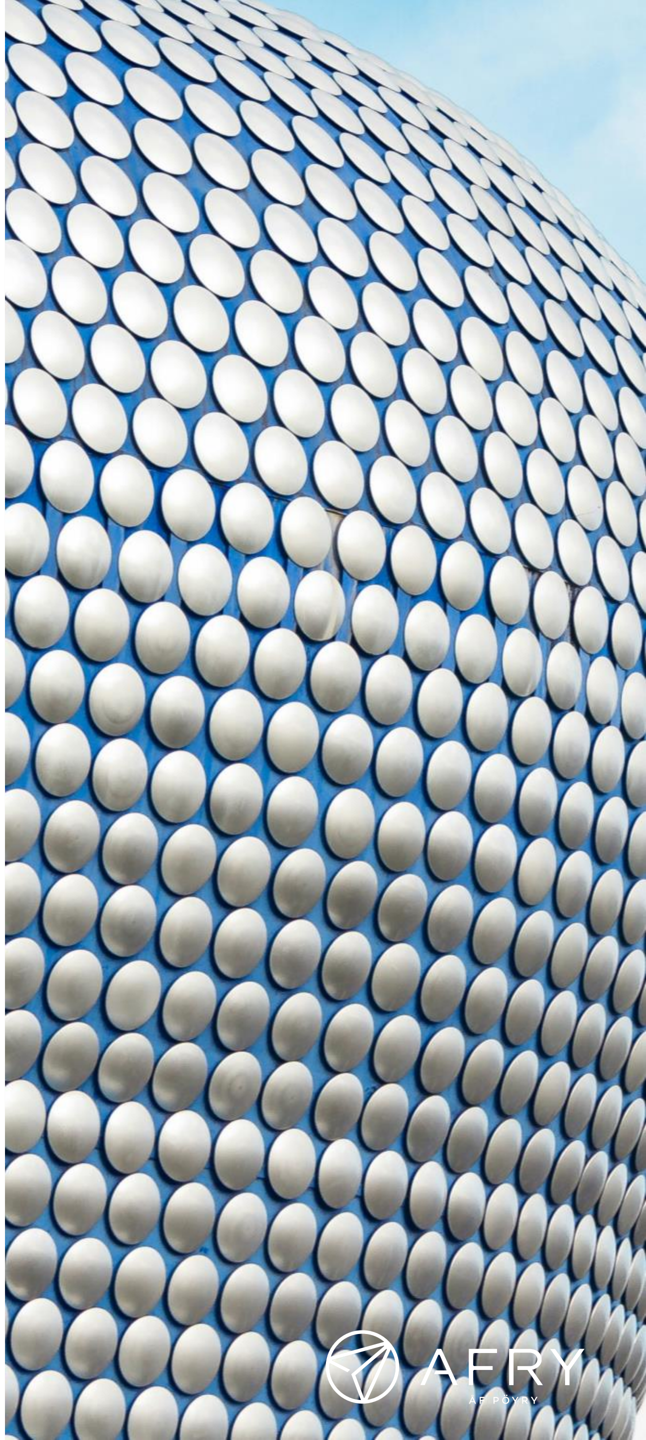

CCS is a last-mile decarbonisation tool, requiring policy support, technology advancements, and incentives to enhance feasibility and competitiveness

The Path Forward

Collaboration between carbon capture and other technology suppliers and aluminium smelters to overcome the challenges of applying CCS to potlines, including optimising CO_2 upgrading and waste recovery, not just capture technology

Improve understanding of costs of upgrading CO_2 concentration of flue gas, and increase funding for and advance technical solutions for upgrading.

Collaboration with CCS hubs, regulators, and policymakers is essential for economic viability

Monitoring and advancing emerging technologies – both for carbon capture and waste heat recovery – can enhance cost competitiveness

Incentives and subsidies (e.g., tax credits, funding schemes) could improve CCS feasibility. Smelters should **position CCS adoption as a competitive advantage** in the low carbon aluminium market

CCS for aluminium potlines is technically feasible but challenges remain to achieve technical and economic viability and widespread adoption

Technical Viability

- CCS technology is rapidly advancing with growing global adoption across many industries.
- In the primary aluminium industry to date, the focus has been initially on indirect emissions, as the main source of emissions. However, in order to achieve the "last mile" of decarbonisation, primary aluminium smelters need to reduce direct emissions from potlines.
- There is increasing interest from aluminium smelters to fit CCS, with a range of potentially applicable technologies for potlines, although many are only at pilot stage.
- CCS retrofits to existing smelters are a technically feasible means to decarbonise direct emissions from smelters, subject to space and other constraints.
- Challenges remain for the application of CCS technology to smelters, meaning that further technical research and testing and modifications to smelters are still required before widespread commercialisation of CCS in smelters occurs.

Challenges

- CCS units significantly increase energy consumption and operational expenses.
- Dilute CO_2 emissions from smelting processes mean that strategies to increase the flue gas CO_2 portion can reduce capture costs. However, reduced gas flows pose operational/safety challenges, particularly if cell re-design required.
- Utilising waste heat could potentially reduce the energy costs of carbon capture, vis-a-vis reliance on more conventional electric boilers.
- Flue gas containing impurities require pre-treatment, adding complexity and costs to CCS.
- Amine-CCS technology whilst in use today needs adapting to aluminium, for example, further testing to optimise solvent selection is required.
- Carbon capture and any additional equipment (such as heat exchangers for heat recovery) have a large equipment footprint that some smelters may struggle to accommodate.
- Limited infrastructure for CO_2 transport and storage necessitates collaboration with emerging CO_2 hubs to overcome logistical barriers.

Economic Viability

- CCS on potlines reduces CO_2 emissions but requires significant CAPEX and OPEX, making carbon pricing the key economic driver for adoption. A minimum breakeven CO_2 price of **\$180 and \$205/tCO_2** is required for a positive NPV, if other subsidy or revenues remain limited.
- Elevating flue-gas CO_2 concentrations can **reduce capture costs by 22-32%**, potentially enhancing economic feasibility. This must be balanced against additional smelter costs for elevating CO_2 concentrations which will vary by site and will need further investigation as new technology solutions are developed.
- Smelters operating in regions with established carbon pricing or facing significant new CO_2 costs stand to gain most from implementing CCS.
- Extra revenue may come through premiums for low carbon aluminium, although CCS on potlines alone may not be sufficient to get to low carbon aluminium benchmarks (e.g. <4tCO_2e/t Al).
- Adding CCUS to other co-located parts of the value chain could improve economic viability – e.g. refining, anode furnace, and captive power.

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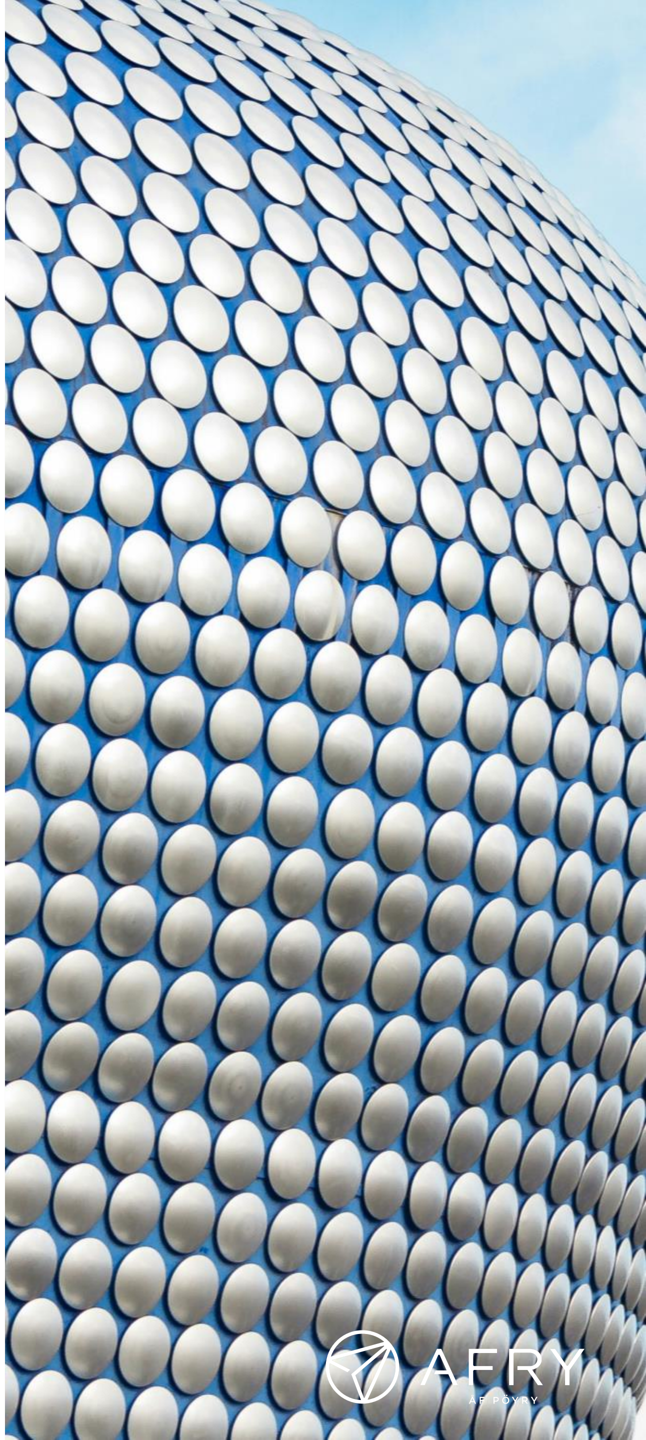
Contents



International Aluminium Institute (IAI) commissioned AFRY to undertake phased techno-economic analysis of CCS on aluminium smelter potlines

Phase 1
CO_2 Capture Technology Assessment

A. Overview of CCS value chain, global projects, and capture technologies
B. Assess capture technologies including pros/cons, TRL, commercialization timeline, cost drivers and impact of contaminants
C. High-level review of status of CCS in primary aluminium industry

Phase 2
CO_2 Capture Concept Study

A. Concept study of amine-based carbon capture (CC) for retrofitting aluminium smelter potlines
B. Evaluate design, CAPEX/OPEX estimates, energy use, and emissions reduction for smelter with 3% CO_2 concentration [1% concentration assessment added during project through member feedback]
C. AFRY outlined assumptions and assessed technical viability and cost-effectiveness

Phase 3
Techno-Economic Assessment

A. Techno-economic analysis with quantitative modelling for two CO_2 concentration options in aluminium potlines
B. Assess CAPEX/OPEX, CO_2 capture rates, and transport/storage cost scenarios and sensitivities
C. Outputs include CO_2 intensity reductions, cost savings, NPV, IRR, and levelised CCS costs

[Full study with Phases 1-3 available to IAI members only]

Phase 4
Public Report

A. Summarise technology assessment, concept study, and cost-benefit analysis findings in member report
B. Provide insights for IAI members and opportunity for feedback
C. Public report with main findings

AFRY assessed CCS retrofitting viability by comparing it to a baseline smelter scenario using a DCF model with set assumptions and costs

We defined the parameters for input into the techno-economic model, a simplified discounted cashflow (DCF) model[1], calculating costs with and without CCS for the representative GCC smelter, comparing the scenarios and assessing the results of these calculations.

Techno-Economic Model
(including DCF Model)

Defined Parameters

Set commissioning date, plant lifetime, and discount rate

Determined CAPEX/OPEX for smelter and CCS retrofit

Included assumptions for carbon pricing, aluminium price, and CO_2 capture rate

Calculated Baseline Costs (No CCS)

Estimated smelter operating costs (electricity, alumina, anodes, labour, maintenance, etc)

Applied carbon price to uncaptured emissions

Calculated Scenario Costs (With CCS)

Added CCS facility CAPEX and OPEX

Subtracted carbon costs avoided for captured emissions

Incorporated additional CC electricity, transport, and storage expenses

Compared Scenario Results

Computed NPV and IRR for baseline vs. CCS scenarios

Evaluated financial viability (Delta NPV, IRR) at different potline CO_2 percentages (1% and 3%)

Assessed Results

Identified conditions under which CCS is economically favourable

Highlighted key sensitivities (carbon price, aluminium price, capture rate)

[1] Pre-tax basis

AFRY AT A GLANCE

AFRY is a global engineering and advisory company offering expertise across CCUS and metals and mining

AFRY AT A GLANCE

EMPLOYEES GLOBALLY

~ 19,000

NET SALES

€ 2.1 bn

NUMBER OF COUNTRIES WITH OFFICES

> 50

NUMBER OF COUNTRIES WITH PROJECTS

> 100

AFRY CORE EXPERTISE


Engineering


Design


Digitalisation


Management Consulting

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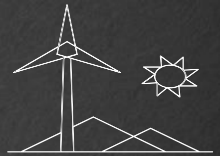
RELEVANT AFRY EXPERTISE


Energy


Mining and Metals

Carbon removals

Power-to-X – CCUS/H2

AFRY

CONTACT INFORMATION

Assessment of techno-economic feasibility of CCS on aluminium potlines for IAI

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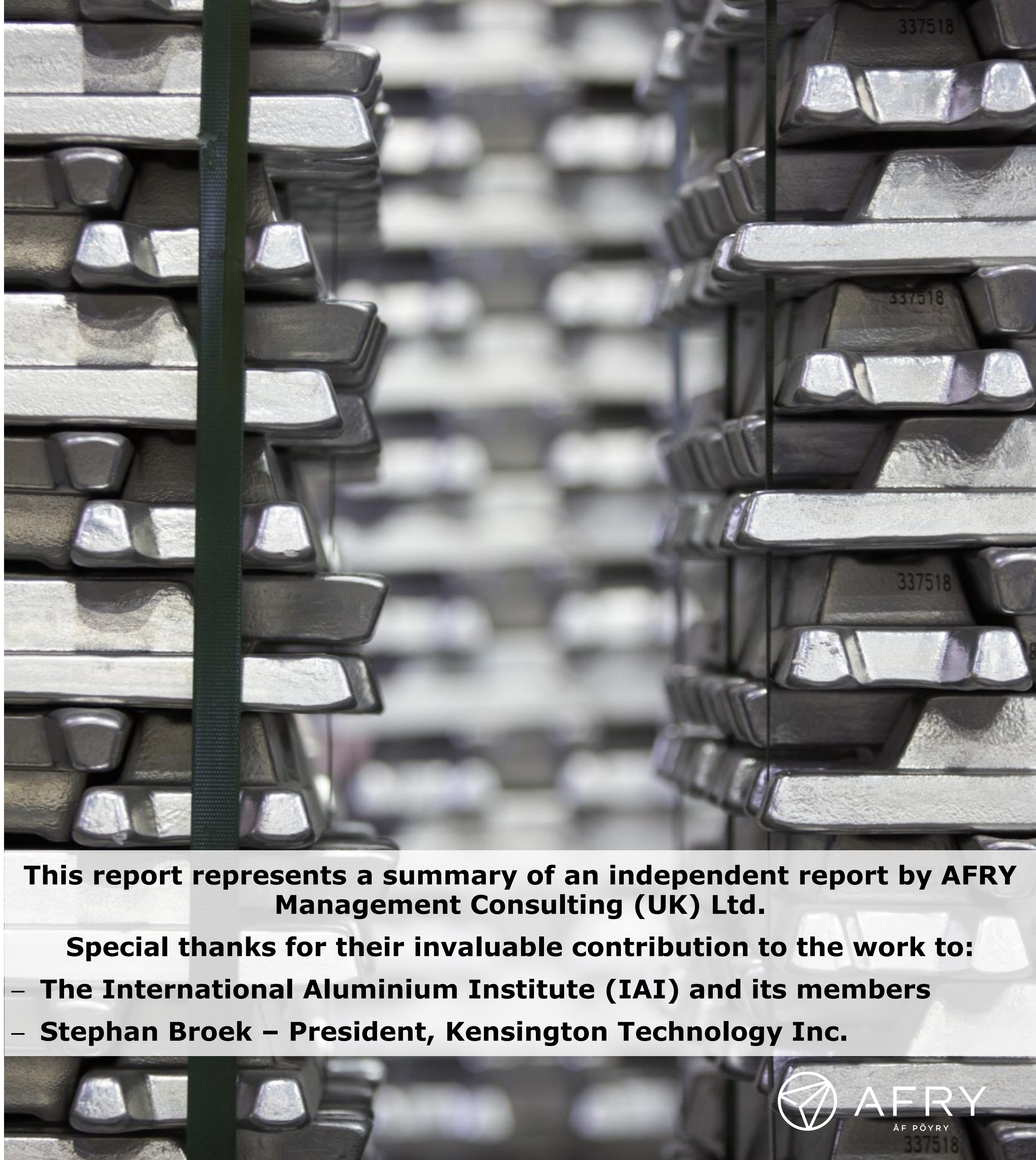

This report represents a summary of an independent report by AFRY Management Consulting (UK) Ltd.

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- **The International Aluminium Institute (IAI) and its members**
- **Stephan Broek – President, Kensington Technology Inc.**