UNLOCKING THE FIRST WAVE OF BREAKTHROUGH STEEL INVESTMENTS

in the United Kingdom

Prepared by

Energy Transitions Commission

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PREFACE

In *Making Net-Zero Steel Possible*, published September 2022, the **Mission Possible Partnership** (MPP) found that approximately 70 'near-zero-emissions' primary (iron ore-based) steel mills need to be operational by 2030 for the global steel industry to be on a 1.5°C-aligned pathway to net zero. As of 2022, the pipeline of projects falls well short of this target, and even among projects that have been announced, few have secured final investment decisions (FIDs) to proceed. Growing the project pipeline and accelerating commercial-scale proposals to FIDs is the critical task to decarbonise steel globally.

As a core partner of the MPP, the **Energy Transitions Commission** (ETC) has sought to build upon *Making Net-Zero Steel Possible* by answering the question of what it will take to achieve FIDs on near-zero-emissions primary steel projects in the next five years. Breakthrough Energy supported the ETC to answer this question by conducting a series of regionally focused forums to determine what is needed to make these projects investable under a given set of local conditions.

This insight report outlines the findings of the forum focused on the United Kingdom, covering the need for near-zero-emissions 'breakthrough' steelmaking in the UK, the financial gap this type of steelmaking faces under prevailing conditions, and potential pathways to making it investable in the immediate future. Crucially, this report suggests a route to breakthrough steel, using hydrogen-based steelmaking technology, is viable in the UK if a few key conditions are created. Effective carbon pricing on both domestic production and steel imports, lower costs associated with sourcing and processing scrap steel, and guarantees to de-risk new technology are essential for establishing its investment case. Alternatively, in place of carbon pricing on steel imports, direct government funding (particularly to support upfront project capital expenditures) and a market for differentiated low-emissions steel (initially sold at a commensurate premium) would need to be in place to make breakthrough steelmaking investable in the UK. Given the variety of stakeholders required to make these conditions a reality and advance potential projects, strategic collaboration across the UK steel value chain will be critical.

Energy Transitions Commission

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AUTHORS & ACKNOWLEDGEMENTS

This report was prepared by the Energy Transitions Commission (ETC) as part of the Mission Possible Partnership (MPP) and with the support of Breakthrough Energy. This report represents an adjusted version that reflects changes to the underlying modelling to allow direct comparison between the UK and other countries in the breakthrough steel investment regional forum series, namely Spain, France, and the USA. The key changes to the methodology are: (1) a shift to unlevered NPV; (2) adjustment to the LCOS calculation to reflect the present value of each cost line item; (3) the exclusion of debt as a component of amortization; and (4) using accounting depreciation in the EBIT calculation. For more detail on how this affects the financial analysis please refer to the accompanying Technical Appendix.

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PART I

TWO YEARS THAT WILL DEFINE THE UK STEEL INDUSTRY

Steel constitutes a fundamental component of most elements of everyday life. From buildings to cars, from chemicals to food, steel underpins a range of industries and processes. Steel constitutes an important part of the UK's foundation industries, so called because they supply materials to multiple strategic manufacturing and construction supply chains. The UK steel industry, including the ~77,500 high-value jobs it sustains[i] (with wages higher than national and regional averages),[ii] represents an important component of the national economy.

This important industry faces a number of interconnected challenges in the UK, the first of which is decarbonisation. The iron and steel sector is the largest industrial emitter of greenhouse gases in the UK, making up ~15% of total industrial emissions in 2020.[iii] Any credible pathway to net zero for the UK must address the decarbonisation of steel.

At the same time, the importance of steel to the UK economy is only growing. Apparent annual demand for semi-finished and finished steel products in the UK is expected to grow from 8.9

i *Key Statistics Guide*, Make UK, April 2022, p. 2. Referring to direct (~34,500) + indirect (~43,000) employment.

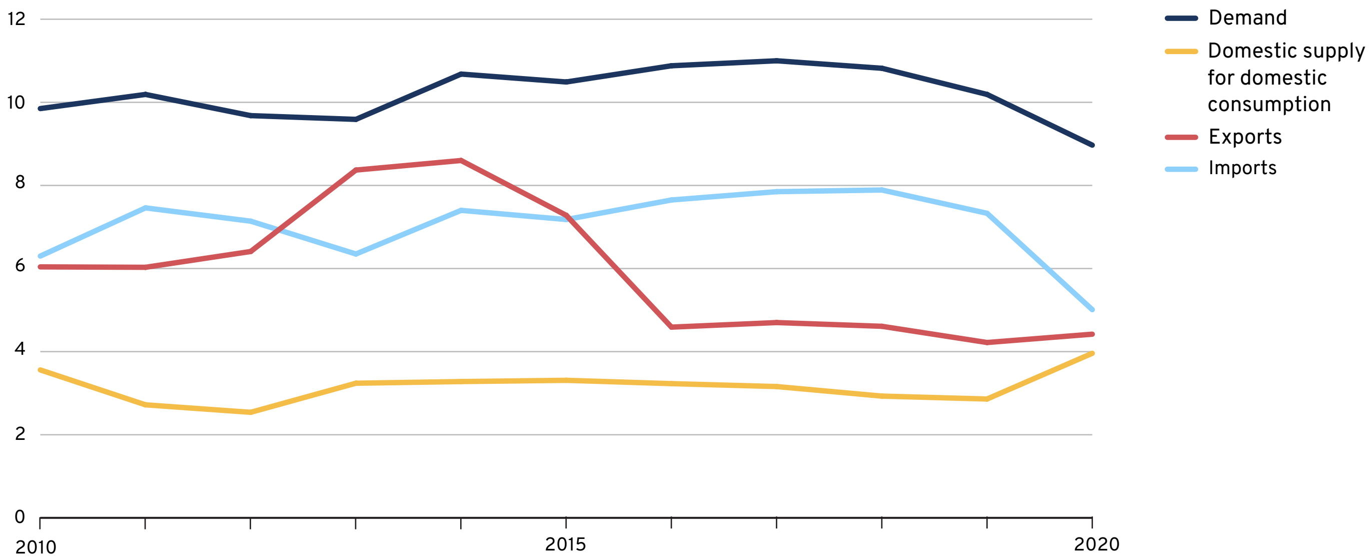
ii *Net Zero Steel: A Vision for the Future of UK Steel Production*, Make UK, July 2022, p. 45.

iii Based on iron and steel data reported by the UK to the United Nations Framework Convention on Climate Change (~11.5 metric tonnes of CO_2 equivalent [$MtCO_2e$]) and baseline 'industry' emissions from *Net Zero Strategy: Build Back Greener*, Department for Business, Energy and Industrial Strategy (BEIS), October 2021 (78 $MtCO_2e$ for 2019 and 74 $MtCO_2e$ for 2020).

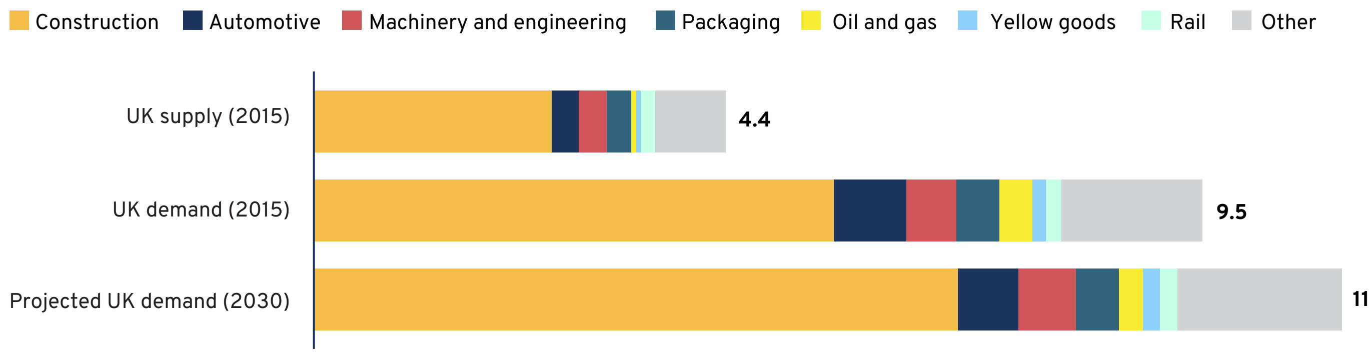
EXHIBIT 1

Most recent UK steel demand is met through imports, with demand forecast to grow by 2030

UK steel flows over time, *million tonnes*



Steel demand by sector, *million tonnes*



Note: Steel refers to semi-finished and finished steel products. Demand refers to apparent use of finished steel products. Domestic supply refers to steel produced within the UK for domestic consumption.

Source: Make UK 2021; *Steel Public Procurement 2022*, BEIS, June 2022; worldsteel, *Steel Statistical Yearbook 2020*, 2020; worldsteel, *Steel Data Viewer*, 2022; *Future Capacities and Capabilities of the UK Steel Industry*, BEIS, 2017

million tonnes (Mt) in 2020 to almost 11 Mt by 2030 (Exhibit 1).[iv] Crucially, growing demand for steel in the UK will be driven by the energy transition itself. Steel will be integral to building the cleaner and more self-sufficient national energy system envisaged by the UK government in its *Energy Security Strategy* last year, being an essential material for everything from power infrastructure to electric vehicles. UK steelmakers have recently highlighted the millions of tonnes of steel that will be required by all of the wind, solar, nuclear, hydrogen, and carbon capture projects planned up to 2030.[v] Relatedly, the value represented by this demand is also expected to grow, with buyers showing greater demand for value-adding advanced high-strength steels and ultra-high-strength steels.

These demand forecasts assume that steel end-use markets in the UK continue to use current levels of local content. Changes to local content requirements in UK infrastructure and manufacturing could further increase demand for steel produced in the UK. However, current production volumes and slate of steel grades made in the UK mean it relies on imports

iv *Future Capacities and Capabilities of the UK Steel Industry*, BEIS Research Paper Number 26, Department for Business, Energy & Industrial Strategy, 2017. Apparent demand only captures part of total 'true' steel demand, which also comprises indirect demand of steel in imported finished products.

v *The UK will need 10 million tons of steel by 2030 for energy security*, GMK Center, 2023.

to meet over half (55%) of its apparent demand, a reliance that appears set to continue in the future. Government ministers and industry have recently warned against allowing this dependence to grow, citing recent energy security crises in the UK and elsewhere as examples of the risks of over-reliance on foreign supplies for critical resources.

Whilst domestic production does not mirror domestic demand, UK steel has found valuable markets abroad. Approximately 50% of domestic production (across a variety of grades) is exported, and 70% of those exports go to the European Union (EU). However, the significance of European export markets presents a challenge of its own.

The European Commission is in the process of establishing a carbon border adjustment mechanism (CBAM) to equalise the carbon cost levied on imported and domestic products. Steel is planned to be one of the first sectors to be incorporated into the mechanism, currently expected to begin affecting the prices of imported goods by 2026, given that it is considered a strategic sector at risk of carbon leakage.[vi]

With the majority (~75%) of steel made in the UK today being produced via highly emissions-intense blast furnace-basic oxygen furnace (BF-BOF) facilities, UK steel exports using current technologies could be significantly impacted by a unilateral CBAM if the price of carbon in the UK begins to fall below that of the EU. As the decarbonisation of steel progresses in Europe, as evidenced by its growing pipeline of low-emissions projects, UK integrated producers could find themselves less and less competitive in their largest export market if they reinvest into existing technologies, particularly if the CBAM imposes a need to mirror EU carbon pricing.

The present circumstances of the UK's steel assets impose a tight time frame to address these interconnected challenges. Most of the UK's blast furnaces are expected to require major investments in refractory relining (renovation) before 2035 at the latest, with certain assets potentially requiring an investment decision as early as 2025. The coming two years offer a narrow but clear window of opportunity.

Navigating the challenges faced by the steel industry in the UK broadly leaves the country with three strategic options:

1. **Carbon 'lock-in'** — reinvesting in existing integrated production assets, preserving (emissions-intensive) steelmaking capacity at the risk of missing decarbonisation targets and diminishing competitiveness in European export markets

2. **Import 'lock-in'** — forgoing investment in existing integrated steelmaking capacity and cutting emissions, but incurring steel job losses, forgoing valuable export markets and increasing dependence on steel imports to meet domestic demand

3. **Revitalisation** — replacing existing steelmaking with low-emissions iron- and steelmaking capacity in the UK, thereby preserving domestic industry and employment, enabling low-carbon exports for European markets, all while meeting decarbonisation objectives

Looming reinvestment decisions for the UK's integrated iron- and steelmaking capacity mean that failing to take an active decision will be a decision itself, for either carbon lock-in or import lock-in by default. There have already been clear signals of the immediate consequences that would follow these outcomes, particularly import-lock in. Government ministers have highlighted that the closure of blast furnaces operated by British Steel, owned by China's Jingye Group, would be estimated to cost £1 billion in decommissioning and other liabilities as well as lead to thousands of job losses. Revitalising the UK steel industry with breakthrough technology offers the best route to address the challenges the industry faces and avoid disruption to the country's steelmaking capacity and capabilities, but time is of the essence to pursue this option.

vi **EU Carbon Border Adjustment Mechanism – Implications for Climate and Competitiveness**, European Parliamentary Research Service, 2022.

PART 2

THE ECONOMICS OF BREAKTHROUGH STEEL INVESTMENTS

Steelmaking is highly capital-intensive, requiring significant investment into assets with long life spans. The cost of developing a conventional blast furnace–basic oxygen furnace (BF-BOF) facility with the best available technology for a production capacity of 1 million tonnes per annum (Mtpa) stands at almost £1 billion.[vii] Although investors in steel assets normally expect them to pay back their upfront investment in 10 years or fewer, such an asset could be expected to operate for decades, with a major reinvestment every 20 years on average to reline its blast furnaces.[viii]

Given the nature of these investments, steel mills have historically been located in areas that offered the best possible conditions, such as proximity to buyers, access to raw materials (particularly coal), transport infrastructure, and a skilled workforce. In a world undergoing a profound energy transition, the significance of some of these factors may shift and incorporate new factors, such as access to low-emissions electricity and proximity to CO_2 storage sites.[ix]

vii All monetary values are denoted in real 2020 GBP. The underlying modeling and analysis of this report were conducted in real 2020 USD (due to the international nature of steel investment and lending portfolios, where finances are assessed in USD terms) with final figures converted into GBP at a rate of 0.779.

viii *Making Net-Zero Steel Possible*, Mission Possible Partnership, 2022, pp. 29, 59. The precise investment cycle length of a blast furnace depends on its 'campaign' (operational) life and operational characteristics.

ix *World Energy Outlook 2022*, International Energy Agency, 2022, p. 211.

Like other forms of capital-intensive investments, the scale and complexity of steelmaking investments mean that proposed projects are subject to comprehensive techno-economic assessments, with crucial steps such as feasibility studies and front-end engineering design (FEED) studies. A final investment decision (FID) represents a critical point in the investment process, signalling a firm financial commitment upon which contractors can proceed with procurement, construction, design, and engineering works. FID status, therefore, represents a vital stage gate in realising a steel project in the real world.

2.1 Progressing Breakthrough Steel Investments

With the support of Breakthrough Energy, the ETC launched a series of forums, bringing together stakeholders spanning the full UK steel value chain, to resolve what it will take to reach FIDs on a first wave of commercial-scale breakthrough steel projects in the UK within the coming years.

To underpin the discussions, the ETC developed an open-source tool to model the finances of potential projects.[x] The architecture and input assumptions of the tool were stress tested and validated with industry experts and other forum participants, allowing the tool to reflect the realistic economics of making such an investment in the UK.

Analysis and discussion for the forums revolved around a set of breakthrough steel project 'archetypes' that assumes 2 Mtpa as a reference plant capacity to enable direct comparison between the options (Exhibit 2, next page). These archetypes were developed to provide a foundation for open discussion on the investment prerequisites, whilst avoiding debate on particular assets. All the archetypes were centred on green hydrogen–based direct reduced iron–electric arc furnace (H_2-DRI-EAF) steelmaking as a reference for breakthrough steelmaking technology. This technology route was selected because of (a) its technology readiness level[xi] and (b) its international project pipeline, which is the strongest of all 'near-zero-

x This tool has been made publicly available and allows users to modify inputs to explore the impact of changing assumptions on the financials of breakthrough steel projects.

xi Technology readiness level (TRL) refers to a method of assessing where a given technology stands in its journey to widespread adoption, commonly reflected by a score between 1 (initial idea) and 9 (commercially available). In the International Energy Agency's ***ETP Clean Energy Technology Guide***, last updated September 2022, H_2-DRI was given a TRL score of 6 (full prototype at scale) and the technology has seen further development since then.

EXHIBIT 2

Select breakthrough steel project archetypes for the UK

	Brownfield conversion	Greenfield H_2	Separate iron and steelmaking
Pre-existing technology	• BF-BOF	• N/A – Greenfield	• N/A – Greenfield
Target site technology	• DRI & EAF	• DRI & EAF	• EAF
DRI feedstock	• 100% green H_2	• 100% green H_2	• N/A – Use of non-captive low-emissions hot briquetted iron (HBI)
Potential emissions reductions	90%–95%	94%–97%	95%–97%
Known developments	• SSAB, Sweden • Salzgitter, Germany • ArcelorMittal, Spain • ArcelorMittal, Canada • Tata Steel, Netherlands • HBIS, China	• H2 Green Steel, Sweden	• GravitHy, France

Note: Potential emissions reduction compared with a BF-BOF using the best technology available today, assuming ferrous input with 30% scrap intake and electricity supply from the grid. Although the GravitHy case represents the ironmaking part of the separation of iron and steelmaking, this report considers the steelmaking part only.

Source: ETC analysis

emissions' primary steelmaking technologies with over 60 Mtpa of planned capacity globally as of mid-2022.[xii] H_2-DRI-EAF technology is, consequently, considered a credible contender for commercial-scale investment in the near term, particularly compared with alternatives such as carbon capture with sufficiently high (+90%) effective capture rates or nascent electrolysis-based production processes.

The three archetypes selected for the UK were designed based on their relevance to the country's steelmaking context and validated by forum participants and other expert stakeholders.[xiii]

1. **Brownfield conversion:** Retrofitting an existing BF-BOF site and switching it to DRI-EAF technology, using green hydrogen from the start of operations; relevant given the UK's existing BF-BOF sites and the country's decarbonisation ambitions

2. **Greenfield H_2:** Building a new DRI-EAF mill using green hydrogen from the start of operations; developing new steelmaking capacity in the most favourable locations is an archetype being pursued in other countries and worth exploring for the UK

3. **Separate iron and steelmaking:** Building a new EAF mill and importing green DRI, in the form of hot briquetted iron (HBI), from outside the UK; an option to address the possibility that conditions for domestic hydrogen ironmaking may not be economically favourable in the UK

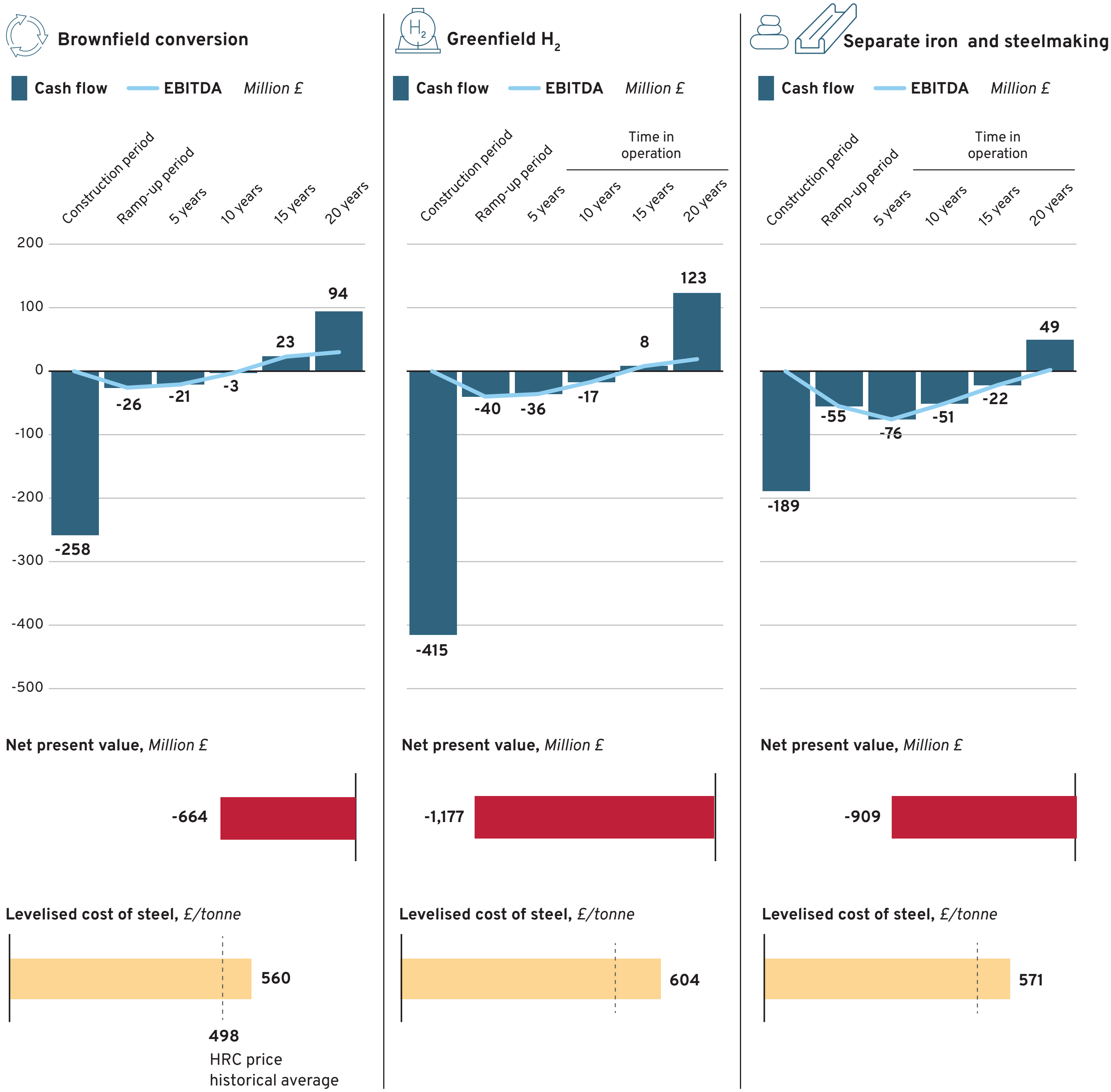
xii ETC analysis based on company announcements, press releases, and discussions with industry.

xiii The DRI technology archetypes analysed in this report are not exhaustive. Variants include the use of submerged arc furnace (SAF) technology and electric melters in combination with a BOF. Several projects and feasibility studies using such technologies were announced over the course of the forum. It is possible to explore such variants in the accompanying financial model, provided the techno-economic input assumptions can be sourced

EXHIBIT 3

Breakthrough steel business case in the UK under baseline conditions

Plant size:	Plant lifetime:	Utilisation rate:	Scrap intake:	Debt-to-equity:	Equity IRR:	Average interest rate:	FID date:
2 Mtpa of HRC	20 years	90%	40%	1.5	8%	6%	2024



Note: Financial modelling assumes three years for construction and one year to ramp up production, 15 years for debt repayment with a one-year grace period, 30% tax on earnings, and the Internal Revenue Service General Depreciation System (IRS GDS) with 200% declining balance and straight line (DB + SL) depreciation as the method to calculate depreciation for tax purposes. IRR refers to investment rate of return. Hot-rolled coil (HRC) price projections are based on 20-year historical global HRC price behaviour as reported by UN Comtrade. NPV figures do not take into account any residual or non-amortised value of existing assets for the brownfield archetype.

Source: ETC analysis

2.2 Investment under Prevailing Policy and Market Conditions

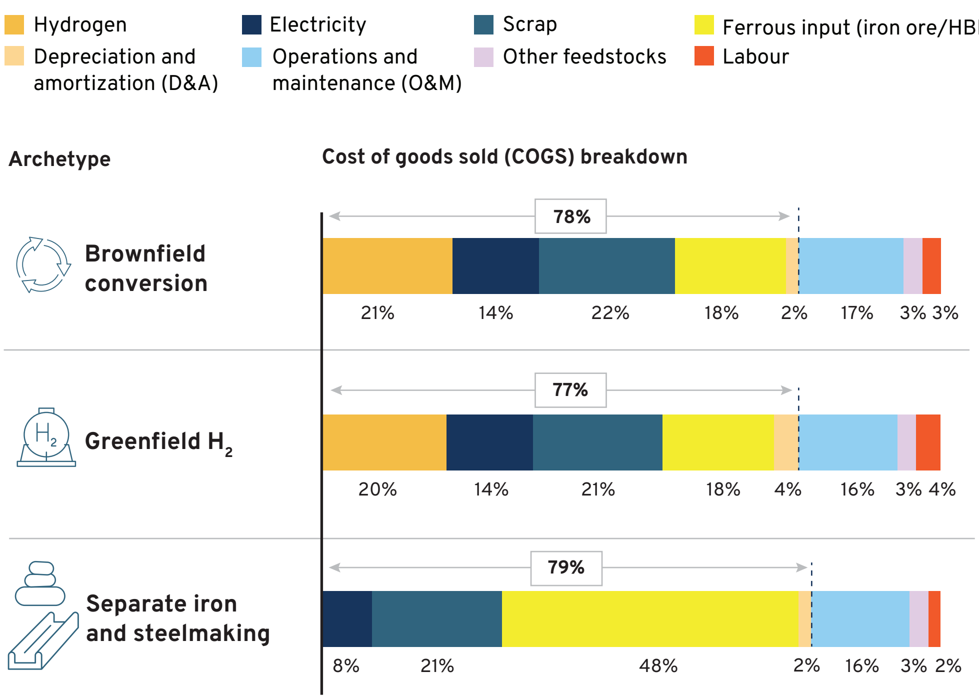
Before committing to an FID, investors consider a wide range of factors in evaluating a prospective investment. One metric that is commonly used to comprehensively assess the attractiveness of an investment is net present value (NPV). Based on an assessment of the NPV of the three archetypes in the UK today, the investment case for breakthrough steel under prevailing market conditions is not attractive (Exhibit 3, previous page).[xiv] Although the UK has carbon pricing regulation in the form of the UK Emissions Trading Scheme (UK ETS), this has not been included in the baseline scenario. This is because the UK ETS does not affect all steel sold in the country, as some steel is imported from countries that do not apply carbon pricing, meaning the impact of carbon pricing on archetype financial performance cannot be guaranteed (see Exhibit 5). The impact of carbon pricing, when applied effectively, is detailed in subsequent sections of this report.

High levels of up-front capital expenditures (£774 million for Archetype 1, £1,243 million for Archetype 2, and £567 million for Archetype 3) create a heavy financial burden for all three archetypes, particularly in the early years of the investment. Add to this high levels of operational expenditures, driven primarily by energy and feedstocks, and the result is a levelised cost of steel (LCOS) that is higher than projected market prices (between 12%-21% higher, depending on the archetype).[xv] If these archetypes cannot produce steel at a cost that is competitive under prevailing policy and market conditions, a positive investment case for breakthrough steel will remain out of reach unless action is taken to either (a) lower the supply-side cost of production or (b) create conditions under which low-emissions steel can achieve higher margins when sold.

EXHIBIT 4

Key cost drivers for breakthrough steel

Plant size:	Plant lifetime:	Utilisation rate:	Scrap intake:	Debt-to-equity:	Equity IRR:	Average interest rate:	FID date:
2 Mtpa of HRC	20 years	90%	40%	1.5	8%	6%	2024



	Price CAGR, *2024-2050*	2024 reference price
Scrap	1%	£281/t
Electricity	-2%	£77/MWh
Hydrogen	-3%	£5/kg H_2
HRC	0%	£498/t
HBI	1%	£287/t
Carbon cost	0%	£0/tCO_2

Note: See Exhibit 3 note for underlying assumptions.

Source: ETC analysis

xiv Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time.

xv LCOS is a form of discounted cash flow analysis that expresses the present value of non-revenue cash flows per unit of production. In this report all LCOS values are reported on a pre-tax basis. NPV values, on the other hand, include tax. For more information on financial methodologies, please see the Technical Appendix to this report.

2.3 Cost Drivers of Breakthrough Steelmaking

Today's steel markets are highly globalised and competitive, meaning the business case for steelmaking is driven to a large extent by the cost of production. Breaking down the cost of goods sold (COGS) for the three archetypes offers insight into the key cost drivers of breakthrough steel (Exhibit 4, previous page).

Under baseline conditions, the biggest cost drivers are:

- **(Green) hydrogen (20%-21%):** The main feedstock utilised by Archetypes 1 and 2 to process iron ore into DRI, which can then be transformed into steel. Hydrogen has no direct bearing on the costs of Archetype 3 because it is already built into the cost of producing the HBI that the archetype imports.

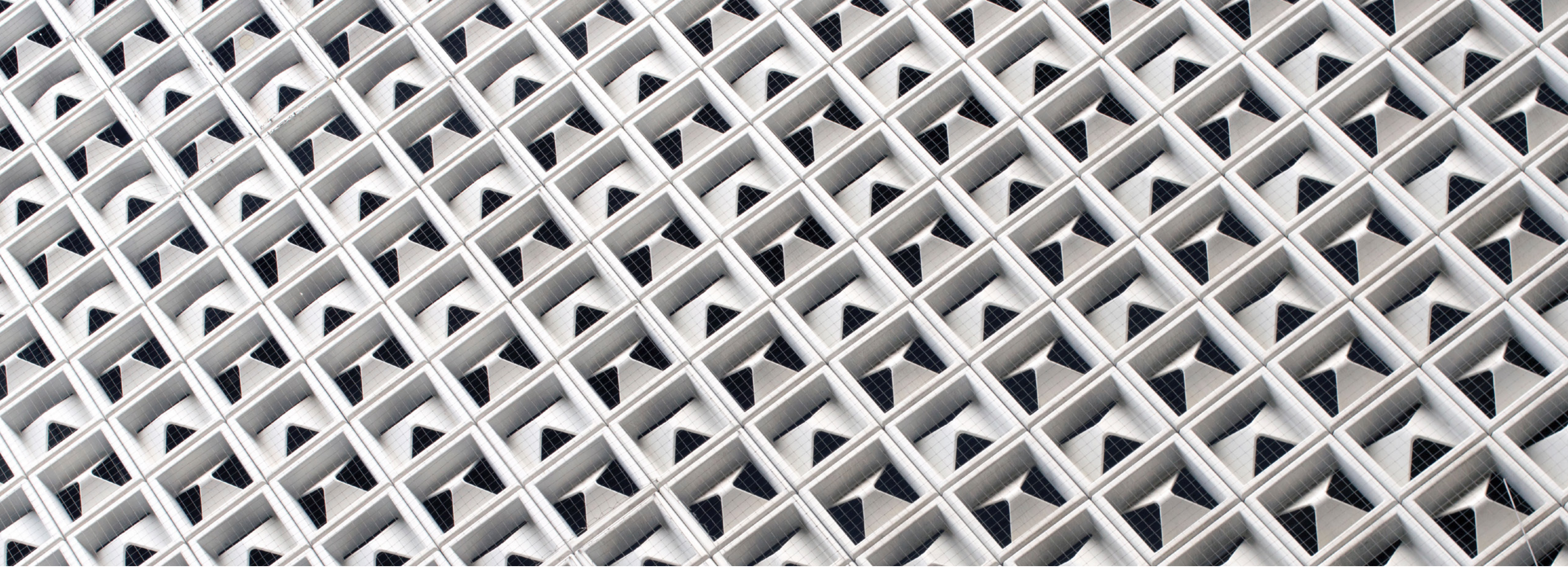
- **Electricity (8%–14%):** The main power source for plant equipment, notably the EAFs that melt steel via electrical heating and constitute the essential piece of steelmaking equipment in all three archetypes.

- **Iron ore/HBI (18%–48%):** Key ferrous base materials for integrated steelmaking. Archetype 3 faces a proportionally higher cost in this category because it must use HBI instead of iron ore, which includes the cost of the ironmaking feedstocks that Archetypes 1 and 2 face directly.

- **Scrap steel (21%-22%):** An alternative ferrous base material that can be recycled to produce new steel without sourcing and reducing iron ore, and incurring the associated costs. This value is reflected in the higher cost of scrap versus iron ore.

- **Depreciation and amortisation (D&A) (2%–4%):** A reflection of the cost of the up-front capital expenditure in plant equipment. Although capital expenditure is significant in all three archetypes, it is highest in Archetype 2 because it involves building an entire integrated steelmaking facility from scratch (comprising a DRI furnace, an EAF, pelletiser, and downstream equipment to process crude steel into HRC), while Archetypes 1 and 3 requires comparatively fewer new pieces of equipment.

Taken together, these categories amount to ~80% of the cost of producing breakthrough steel in the UK, with the rest comprising some remaining operational expenditures (chiefly labour and other feedstocks). Tackling the most costly categories is crucial to improving the business case of corresponding projects.



2.4 Critical Levers

As it stands today, the investment case for breakthrough steel in the UK requires interventions to make it positive. Discussions among value chain stakeholders highlighted a variety of levers that could be applied to improve the underlying business case.

After analysing the sensitivity of the three archetypes to a variety of levers (Exhibit 6, next page), six have the greatest relative impact on the business case by reducing key cost drivers or offsetting them by increasing revenues (Exhibit 5).

EXHIBIT 5

Levers impacting financial performance of breakthrough steel investments

Lever	Description
Effective carbon pricing	Raises the production cost of conventional, emissions-intensive steelmaking, thereby raising the overall market price of steel. This improves the margins of a breakthrough mill by allowing it to sell its output at market price while avoiding the carbon costs of emissions-intensive competition. Carbon prices are projected to rise over time in a visible and predicable way. This lever assumes free allocations of carbon allowances for steelmakers that are phased out over time, in line with current plans for the UK ETS. Crucially, this lever assumes the markets in which a breakthrough project operates are all subject to the same projected carbon price. To ensure this is the case, at least in the breakthrough project's domestic/regional market, the lever assumes a carbon border adjustment mechanism (CBAM) or equivalent measure that guarantees imported iron and steel face the same carbon price as domestic producers. These assumptions are crucial because otherwise the effect of carbon pricing on steel market prices cannot be ensured.
Green hydrogen subsidies	Applies a direct subsidy to reduce the production cost of green hydrogen, passed on as lower green hydrogen market prices, which lower the production cost of DRI.
Capital expenditure subsidies	Applies direct subsidy to cover part of the upfront cost of new steelmaking equipment. The subsidy also effectively reduces the amount of debt financing required by a breakthrough steel project, thereby lowering the cost of capital by cutting the amount paid back as interest.
Premium offtake	Guarantees a given price for some or all of the product manufactured and sold by a breakthrough mill. Additionally, raises the sale price for the chosen share of production by applying a premium above market prices (including the effect of carbon pricing). Offtake at a premium price reflects the added value ascribed by buyers to breakthrough steel as a near-zero-emissions material, allowing the breakthrough mill to achieve higher margins on that offtake.
Higher scrap intake	Optimises the ferrous input, increasing scrap consumption if it is cheaper than producing/importing DRI and reducing scrap intake if the opposite is true.
Electricity supply	Switches power supply away from the grid to an alternative (such as a power purchase agreement [PPA] or captive power generation), assuming it would be less exposed to costs normally associated with grid-supplied electricity (such as high network charges), lowering overall electricity costs.

Sensitivity of breakthrough steel archetypes to different levers

EXHIBIT 6

Plant size:	Plant lifetime:	Utilisation rate:	Scrap intake:	Debt-to-equity:	Equity IRR:	Average interest rate:	FID date:
2 Mtpa of HRC	20 years	90%	40%	1.5	8%	6%	2024

Levers' effect on net present value, *Million £*

Discrete levers   Incremental levers

Lever type		Brownfield conversion	Greenfield H_2	Separate iron and steelmaking
Policy	UK ETS carbon allowance (UKA) price rising to £95/t CO_2 by 2050	934	1,033	1,025
	UKA price rise with linear increase to £195 /t CO_2 by 2050	979	1,080	1,072
	UKA price rise with fast increase to £235/t CO_2 by 2050	1,407	1,539	1,514
	£0.8/kg of hydrogen subsidy for 5 years	143	143	0
	£0.8/kg of hydrogen subsidy for 10 years	259	259	0
	10% subsidy on DRI capex	40	40	0
	10% subsidy in EAF capex	20	20	40
Financing	3% reduction on interest rate	47	30	-57
Demand	£80/t premium on all offtake	1,001	1,095	1,074
Operational	20% increase in scrap intake	266	266	511
	PPA electricity supply	123	123	34
	Captive electricity supply	397	402	90

Note: Assumptions remain the same as in Exhibit 3 unless otherwise stated. Small improvements in equity IRR and interest rate (represented by the financing levers) can result in a negative effect on project NPV given that a reduction in the value of capital can also lower its benefit as a tax 'shield, thereby decreasing overall NPV. Financing levers such as these should not be assumed to have a linear impact on archetype financial performance.

Source: ETC analysis

A WAY FORWARD

Although there is presently no investment case for breakthrough steel in the UK, relatively minor adjustments to the prevailing conditions could change this.

In this section, we set out two perspectives that are differentiated by the extent to which the government and steel buyers in the UK are willing to directly bear the costs of supporting breakthrough steel.

3.1 Two Perspectives to Progress to FIDs

To understand the combined effect of levers needed for an investable case for breakthrough steel in the UK, two scenarios set out plausible blueprints for revitalising and decarbonising the country's steel industry (Exhibit 7, next page). The scenarios were designed to create a viable investment case for at least two of the three archetypes considered, defined as a positive NPV and a payback period of 10 years or fewer.

- **Scenario 1 – Enabling environment:** A combination of industry and policy action is used to strengthen the investment case for breakthrough steel. Policy action takes the form of regulatory intervention, namely extending carbon pricing to imported steel and facilitating greater usage of the domestic scrap supply, and helps close the financial gap for the **brownfield conversion** and **separate iron and steelmaking archetypes**.

- **Scenario 2 – Steel-specific support:** Industry and policy action are similarly used to strengthen the investment case for breakthrough steel. However instead of regulatory action on carbon pricing, government offers more targeted support for breakthrough projects in the form of direct subsidies for capital expenditures. This support, combined with steel buyers paying a premium for the first volumes of breakthrough steel, offers an alternative route to closing the financial gap for the **brownfield conversion** and **separate iron and steelmaking archetypes**.

EXHIBIT 7

Financial metrics of breakthrough steel archetypes under different scenarios

Metric	SCENARIO 1		SCENARIO 2	
	Brownfield conversion	Separate iron and steelmaking	Brownfield conversion	Separate iron and steelmaking
Production capacity Million tonnes per year	2	2	2	2
Capital expenditure outlay Million £	774	567	774	567
Payback period Years	9	10	6	9
Net present value Million £	477	514	426	330
Levelised cost of steel £ per tonne of steel (hot-rolled coil)	547	541	531	537
Gross profit £ per tonne of steel (hot-rolled coil)	79	75	51	45
Average premium (over the market price) for premium offtake £ per tonne of steel (hot-rolled coil)	0	0	50	50
Direct government subsidy Million £	0	0	133	0

To achieve positive business cases for the archetypes in question, a combination of levers were applied (Exhibit 8, next page). The choice and size of the levers aimed to strike a balance between three criteria: (1) efficiency (pulling as few levers as possible), (2) effect (selecting levers that had the greatest impact), and (3) feasibility (selecting levers and applying them as far as was deemed plausible by forum experts and value chain stakeholders).

3.1.1 Scenario 1 — Enabling environment

Scenario 1 envisages a more limited appetite on the part of government and steel buyers to directly bear the costs of supporting breakthrough steel. Government stops short of directly intervening in the costs of building breakthrough steel mills, focusing only on measures to create an enabling environment for their development and operation.

A key lever applied in Scenario 1 is a progressive carbon price regime that affects steel imports as well as domestic production. Over 2022, the prices of carbon allowances in the UK ETS fluctuated between £66 and £97/t CO_2.[xvi] Scenario 1 would require average carbon pricing to steadily increase, reaching £80/t CO_2 by 2030 and £95/t CO_2 by 2050. Crucially, the lever includes some form of UK CBAM to level the playing field for breakthrough steel relative to conventional production at home and abroad.

Effectively applied, the impact of even this modest carbon price rise is significant, turning the NPV of both the brownfield conversion and separate iron and steelmaking archetypes positive. While the assumed price trajectory could be seen as conservative (particularly relative to recent prices in the EU ETS), it was applied in this way given feedback from forum participants around the degree of uncertainty inherent to actual future prices. The crucial point would be that prices do not rise too quickly (and place an undue burden on incumbent steelmakers), but rise progressively and are applied effectively to iron and steel imports.

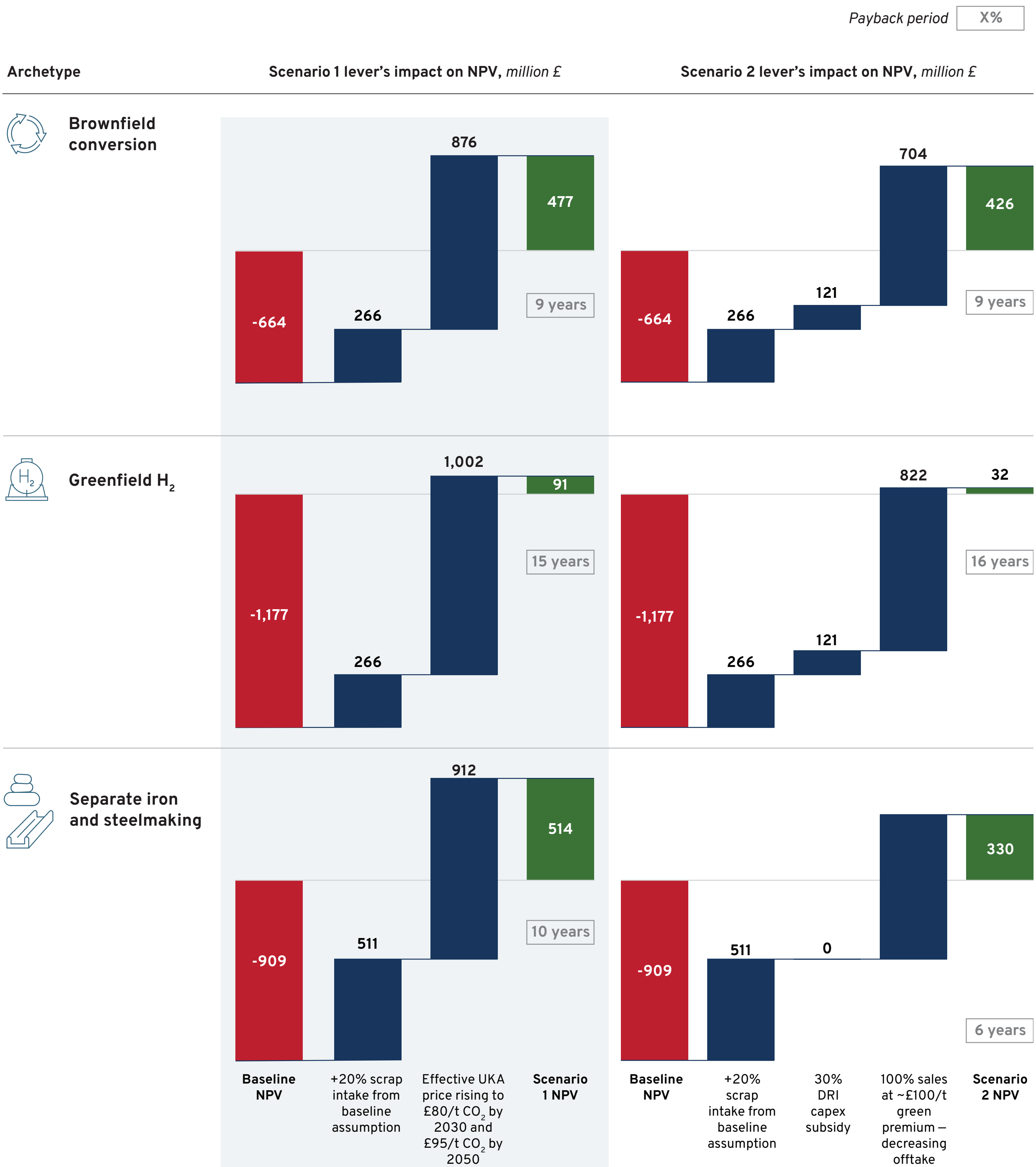
Although effective carbon pricing is enough to deliver a positive NPV for two archetypes, it falls short of giving them a payback period of 10 years of fewer, meaning further intervention is needed to strengthen the investment case. The practical implication of the scenario is that breakthrough steel would be

xvi Based on the price of UKAs as reported by ICE Futures Europe.

EXHIBIT 8

Impact of levers on the NPV of breakthrough steel archetypes

Plant size:	Scrap intake:	Plant lifetime:	Utilisation rate:	Debt-to-equity:	Equity IRR:	Average interest rate:	FID date:
2 Mtpa of HRC	0%	20 years	90%	1.5	8%	6%	2024



Note: Carbon pricing also assumes free allowances for steelmakers, declining over time and phased out by 2035. Assumptions remain the same as in Exhibit 3 unless otherwise stated.

Source: ETC analysis

sold almost entirely within UK or in markets subject to the same carbon pricing. Given that annual steel consumption in the UK totaled almost 9 Mt in 2020, it is not unreasonable to assume that the domestic market would be large enough to absorb the output of a first wave of breakthrough projects in the country. Moreover, if carbon pricing under the UK ETS is made to align with its EU counterpart, the EU would similarly offer a level playing field for breakthrough projects in the UK and a much larger market for their output.

The second lever applied in Scenario 1 is to increase the proportion of scrap in the ferrous input to production (from 40% to 60%). This lever was applied given the availability of scrap in the UK, which is underleveraged domestically and exported in large volumes (around 8 Mtpa). Scrap is currently underutilised in the UK because domestic steelmakers cannot simultaneously afford the high prices of the international scrap market as well as the high price of electricity required to process it. The high price of the material (projected at £280/t) is influenced by historical demand from scrap-based steelmakers in geographies that enjoy comparatively lower industrial electricity prices (such as Turkey and India) who can afford to pay more for scrap.

Under the scrap and electricity price assumptions in Scenario 1, increasing scrap intake offers a way for the industry to reduce production costs for breakthrough steelmaking at the outset. There is undoubtedly a role for government to play in maximising the impact of this lever, potentially through regulatory action to retain scrap for use within the UK or to reduce the cost of electricity associated with processing it. The lever also presents a trade-off: Increasing scrap intake lowers production costs but adds impurities that can prevent the resulting crude steel from being marketed toward higher-value applications. Upgrading of scrap-based crude steel can increase its quality, but this imposes an additional set of costs.

3.1.2 Scenario 2 — Steel-specific support

Scenario 2 envisages that government and steel buyers ascribe greater strategic value specifically to breakthrough steel and express more willingness to directly bear the costs of developing it as a result. Government ambition to provide targeted support specifically for breakthrough steel translates into a preference for providing direct project funding rather than taking far-reaching regulatory measures. This scenario applies the same scrap intake lever as Scenario 1, but replaces effective carbon pricing (namely a UK CBAM) with subsidies on project capital expenditures and offtake agreements with steel buyers paying a premium above market prices.

Greater government support in Scenario 2 manifests as a subsidy equal to 30% of the capital expenditure of a new DRI unit. This lever was applied because of the one-off nature of the support, which forum experts deemed more feasible than subsidising operational expenditures (such as electricity or green hydrogen) in a way that might require ongoing support over a long period of time. Moreover, there are already real-world examples of governments committing large dedicated amounts of funding to breakthrough steel projects in this way, such as the €1 billion of German state aid approved by the European Commission for the Salzgitter SALCOS project.

Alongside higher scrap intake and capital expenditure support, premium offtake is applied as a lever to tip the scales for the brownfield conversion and separate iron and steelmaking archetypes. The scenario sees a proposed breakthrough project initially being able to sell all of its output at a premium peaking at +£100/t (approximately +20% above market prices at the time). The competitive nature of wholesale steel markets might make any price premium seem ambitious. However, with HRC experiencing price volatility of around 15% on average in the UK over the past two decades (versus its 20-year average),[xvii] the premium applied in the scenario is close to the price swings typically experienced in these markets.

Crucially, the price premium peaks early, reflecting the initial value of scarce volumes of near-zero-emissions steel, but declines over time under an assumption that production with a comparable CO2 footprint becomes more widespread. If the premium achieved by the archetypes in this way were averaged out over their lifetime production, it would amount to a premium of +£50/t (+10% above market prices at the time).

Premium offtake is applied as a lever on account of a growing appetite among steel buyers to pay a premium to secure access to near-zero-emissions steel. Signals of this appetite were raised by forum experts, who highlighted mounting pressure on steel buyers to decarbonise their supply chains. The premium offtake in this scenario could materialise in the form of voluntary private sector demand but could equally be driven by green public procurement requirements on the part of government, or some combination of both.

3.1.3 Scenario sensitivity

The levers applied in Scenarios 1 and 2 should not be presumed to *guarantee* a positive business case for breakthrough steel. The economics of steelmaking are sensitive to a variety of operational and market conditions, changes to any one of which could markedly affect the business case for a breakthrough steel project (Exhibit 9, next page).

In both scenarios, shifts in operating parameters (such as utilisation rate and production capacity) and market

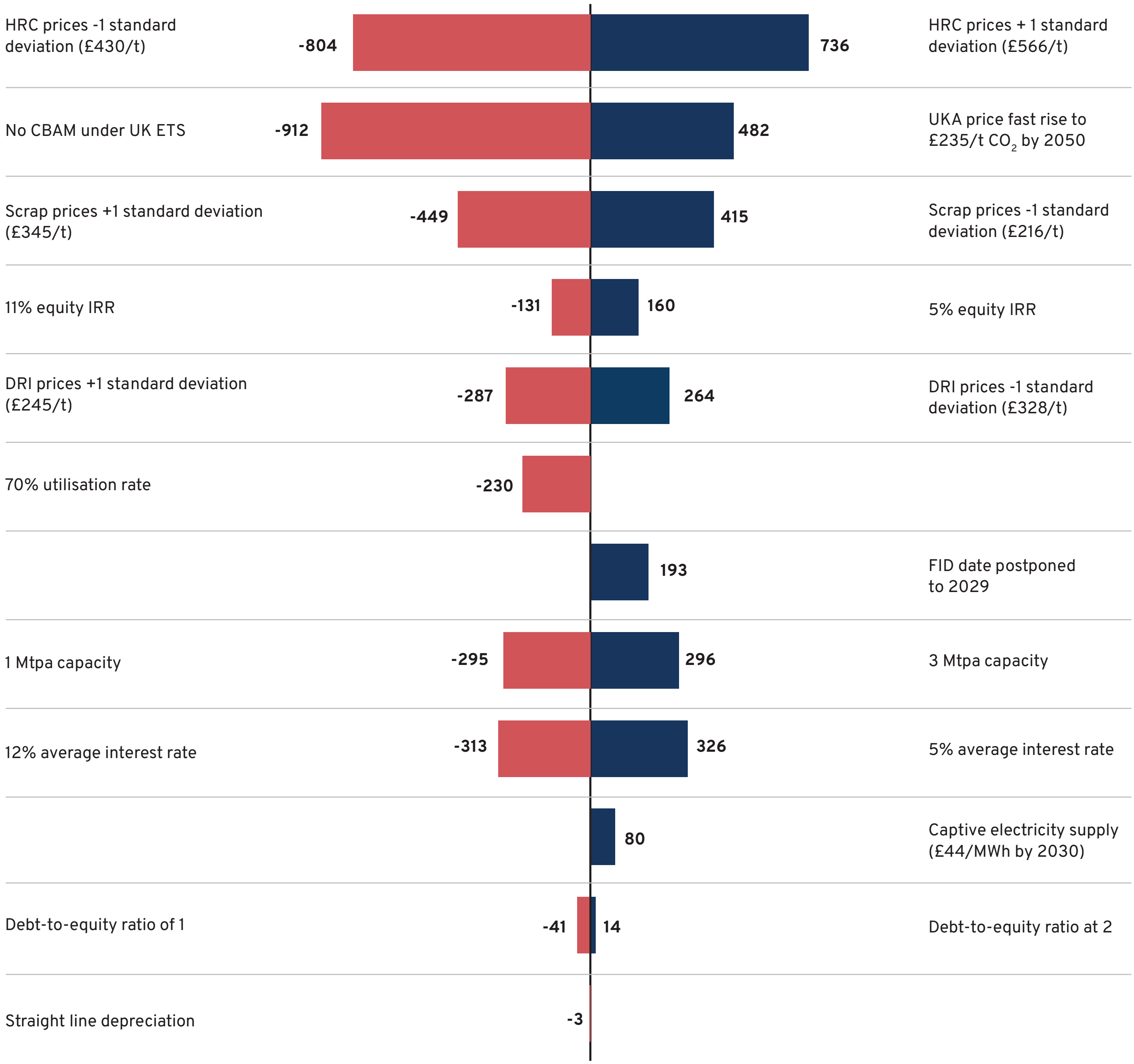
xvii ETC analysis based on HRC real price data from UN Comtrade. Average price volatility represents the standard deviation of prices from the mean between 2000 and 2020.

EXHIBIT 9

Sensitivity of breakthrough steel archetype NPV to operational and commercial factors

Separate iron and steelmaking

Impact of less favourable and more favourable conditions on scenario NPV, *million £*



Note: All other assumptions remain the same as in Scenario 1 unless stated otherwise.

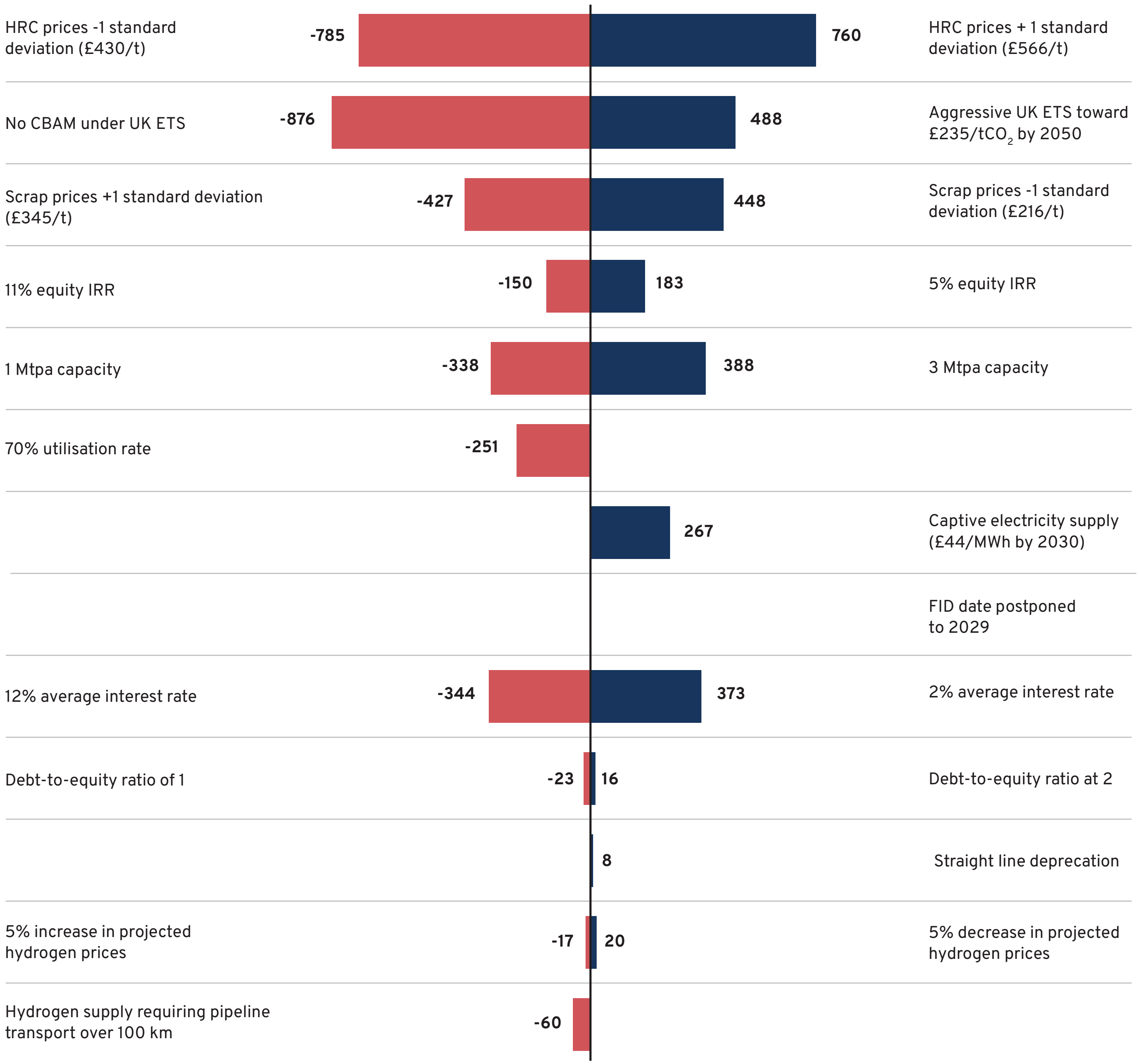
Source: ETC analysis

EXHIBIT 9

Continued: Sensitivity of breakthrough steel archetype NPV to operational and commercial factors

Brownfield conversion

Impact of less favourable and more favourable conditions on scenario NPV, *million £*



Note: All other assumptions remain the same as in Scenario 1 unless stated otherwise.

Source: ETC analysis

conditions (such as scrap and HRC prices) can make or break the business case.

The sensitivity of the scenarios to commodity prices highlights the risks and benefits of the archetypes relative to one another. The separate iron and steelmaking archetype crucially relies on imports of low-emissions HBI, which, even if initially available, could become constrained if other regions develop high demand for the product in a bid to decarbonise their steel industries. This development may lead to price swings much higher than we have assumed based on historical data. This risk could be mitigated by UK steelmakers setting up their own low-emissions HBI production abroad, while the brownfield conversion archetype circumvents the risk by retrofitting existing mills with DRI production and preserving low-emissions ironmaking in the UK. Another risk of a constrained HBI market is that steelmakers may switch to merchant pig iron to meet their need for ore-based metallics,[xviii] potentially risking new and complex forms of carbon leakage.

3.2 Additional Considerations for Achieving FID Status

Even if levers are applied to close the financial gap for breakthrough steelmaking, a positive *business case* does not guarantee a bankable *investment case*. To establish the latter and create the foundations for an FID, additional considerations must be taken into account, particularly around technology and project-specific risks.

Given the relative novelty of the breakthrough steelmaking technologies considered in this report, a project proposal in the UK centred on such technologies would likely be treated as a first-of-a-kind (FoaK) investment. Given higher levels of uncertainty commonly associated with new technologies, financiers normally expect additional guarantees to mitigate technology risks before making FIDs on FoaK investments, or else apply higher costs for their capital to balance those risks.

Lastly, an FID will be contingent on project-specific conditions that cannot be captured in an archetype-based assessment of an investment case. Factors such as the physical conditions of a target site or the financial health of its expected operator may present risks that can only be fully understood when project-specific assessments (such as feasibility studies) are carried out.

xviii Pig iron is the product of reducing iron ore in blast furnaces.

PART 4

CONCLUSIONS
AND RECOMMENDATIONS

Scenarios 1 and 2 demonstrate that unlocking an FID on breakthrough steel in the UK is within reach and can be achieved by different combinations of measures applied to different archetypes. However, the levers and additional considerations indicate there are prerequisites that would prove valuable under any scenario:

1. A progressive carbon price regime that affects steel imports as well as domestic production.
2. Availability of affordable scrap input and/or lower power prices for industrial customers to be able to process the scrap input without excessive cost.
3. Forward offtake agreements, potentially involving a premium on the first volumes of breakthrough steel. This demand could come from the private or public sectors or a combination of both.
4. Guarantees to manage the technology risk associated with a FoaK project, which the government is likely best placed to offer.

The impact of effective carbon pricing, applied to both domestic steel production and imports from abroad, on archetype NPV highlights its value as a foundation for the breakthrough steel investment case. Failing to properly lay this foundation could dampen even sizable efforts to enable breakthrough steelmaking in the UK. At the time of writing, the government is considering funding to support the country's existing integrated steelmaking sites to decarbonise their production.[xix] Transitioning to breakthrough technology would be a good use of this funding, but if the resulting breakthrough sites remain systematically uncompetitive with steel imports that face lower or zero carbon costs, the entire effort risks being undermined. An effective carbon price regime (including a UK CBAM) could be implemented by the government through its existing carbon price regulation in the form of the UK ETS.

Although large volumes of scrap steel are already available for domestic steelmakers, regulatory action on the part of government could make its usage more affordable in the context of breakthrough investments. While explicit trade controls to preserve scrap for use in the UK could be problematic (potentially resulting in the loss of revenues from scrap exports), measures to reduce electricity costs for steelmakers would make scrap intake more economical. The British Industry Supercharger, recently announced by government, takes a clear step in the right direction by proposing various measures to reduce electricity costs for industrial consumers, such as exempting them for certain green levies. However, with a consultation on the Supercharger due to open in the Spring of 2023, the government should also strongly consider additional measures, namely reducing or waiving network charges for industrial users, in order to bring arrangements in the UK more in line with peers in the EU.[xx]

xix *Government to offer £600m for green steel switch*, BBC, January 2023.

xx *Government action to supercharge competitiveness in key British industries and grow economy*, Department for Business and Trade & Department for Energy Security and Net Zero, February 2023.

Although offtake at a premium is only applied in Scenario 2, demand-side intervention in the form of forward offtake agreements would be a valuable tool to firm up revenues for prospective breakthrough projects and give financiers greater confidence in committing capital. The right demand signals could be achieved through an alliance of UK steel buyers, not unlike the First Movers Coalition or SteelZero efforts globally, but much more tailored to the specificities of UK steel-consuming sectors and underpinned by firm volume-based commitments. Alongside private sector demand, the power of green public procurement should not be underestimated. The UK government is expected to purchase over 8.4 Mt of steel over the coming decade.[xxi] A commitment from government to ensure even a portion of its steel procurement is met with near-zero-emissions steel, accepting a small initial price premium to meet this commitment, would go a long way toward underpinning the business case for a breakthrough steel project in the UK. Changes to UK content rules, such as requirements that bids for public tenders include greater proportions of domestically produced steel (for example, on critical infrastructure projects) could add further support in this regard.

The potential role of government as buyer, standard-setter, and strategic investor highlights how breakthrough steel is unlikely to become investable in the UK without clear government support. Given that the UK has not yet piloted any new ‘green’ steelmaking technologies at commercial scale, nor set any specific policy framework,[xxii] progressing breakthrough steel would require a clear shift in the government’s approach to the steel industry. The need for this shift was made particularly apparent by the government’s recent decision to approve a new coal mine in Cumbria; the first new coal mine in the UK for 30 years. Although the government has stated that coal from the mine will primarily be destined for export, its decision to approve coal production for steelmaking somewhat undermines its position on progressing steel decarbonisation at home. The Cumbrian coal mine highlights the extent of the change in government direction that is needed if it is judged that there is strategic value in preserving low-emissions steelmaking in the UK.

The steel-specific approach implied by Scenario 2 would require direct funding support from government at a scale beyond what has been proposed to date. Reviving and significantly extending plans for the £250 million Clean Steel Fund (that was announced in 2019 but has since seen uncertainty over its launch date) would be a step in the right direction.[xxiii] Crucially, this support need not be indefinite. Although support with operational expenditures, such as hydrogen subsidies, would also have a positive impact, the one-off nature of the capital expenditure subsidies applied in Scenario 2 would give breakthrough integrated steelmaking the push it needs to attract investment and succeed without resorting to ongoing government support.

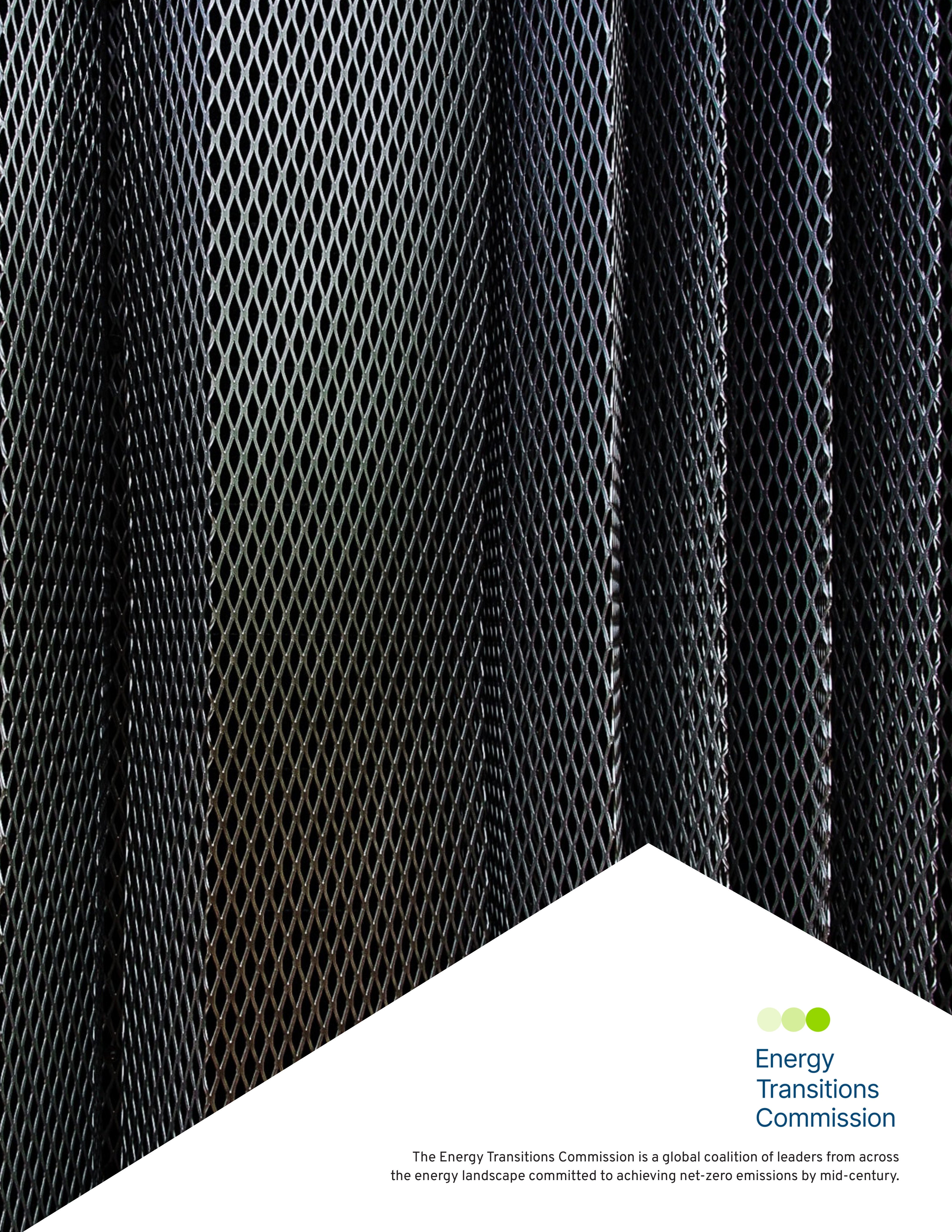
With relining decisions for domestic blast furnaces fast approaching, the absence of a clear decision on the future of UK steel from policymakers will be a decision in its own right, locking the UK into one of either carbon-intensive steelmaking or deeper import dependency. This time frame offers a narrow but clear window of opportunity. Action must be taken in the next two years if there is to be a revitalisation of the UK steel industry through breakthrough technology.

Should the pathway of breakthrough steel be chosen, an immediate priority would be the formation of a consortium of private sector stakeholders of the steel value chain (spanning energy suppliers, iron ore miners, steelmaking equipment manufacturers, steelmakers, buyers, and finance). Coalescing around a specific breakthrough project proposal, this consortium would be well placed to set out a robust case to government and swiftly act upon policy decisions. The power of novel industry consortia to advance breakthrough steel has already been evidenced elsewhere in Europe, such as the launch of GravitHy and its proposed green iron project in the south of France. A similar consortium in the UK could lay the best possible foundations to launch breakthrough steel in the UK and revitalise a vital and historic industry.

xxi ***Steel Procurement Pipeline 2022***, Department for Business, Energy & Industrial Strategy, July 2022.

xxii ***Green Steel***, Parliamentary Office of Science and Technology, May 2022.

xxiii ***Summary of Responses to the Clean Steel Fund Call for Evidence***, Department for Business, Energy & Industrial Strategy, December 2020.



Energy Transitions Commission

The Energy Transitions Commission is a global coalition of leaders from across the energy landscape committed to achieving net-zero emissions by mid-century.