Decarbonising Steel:

FORGING NEW PATHS TOGETHER

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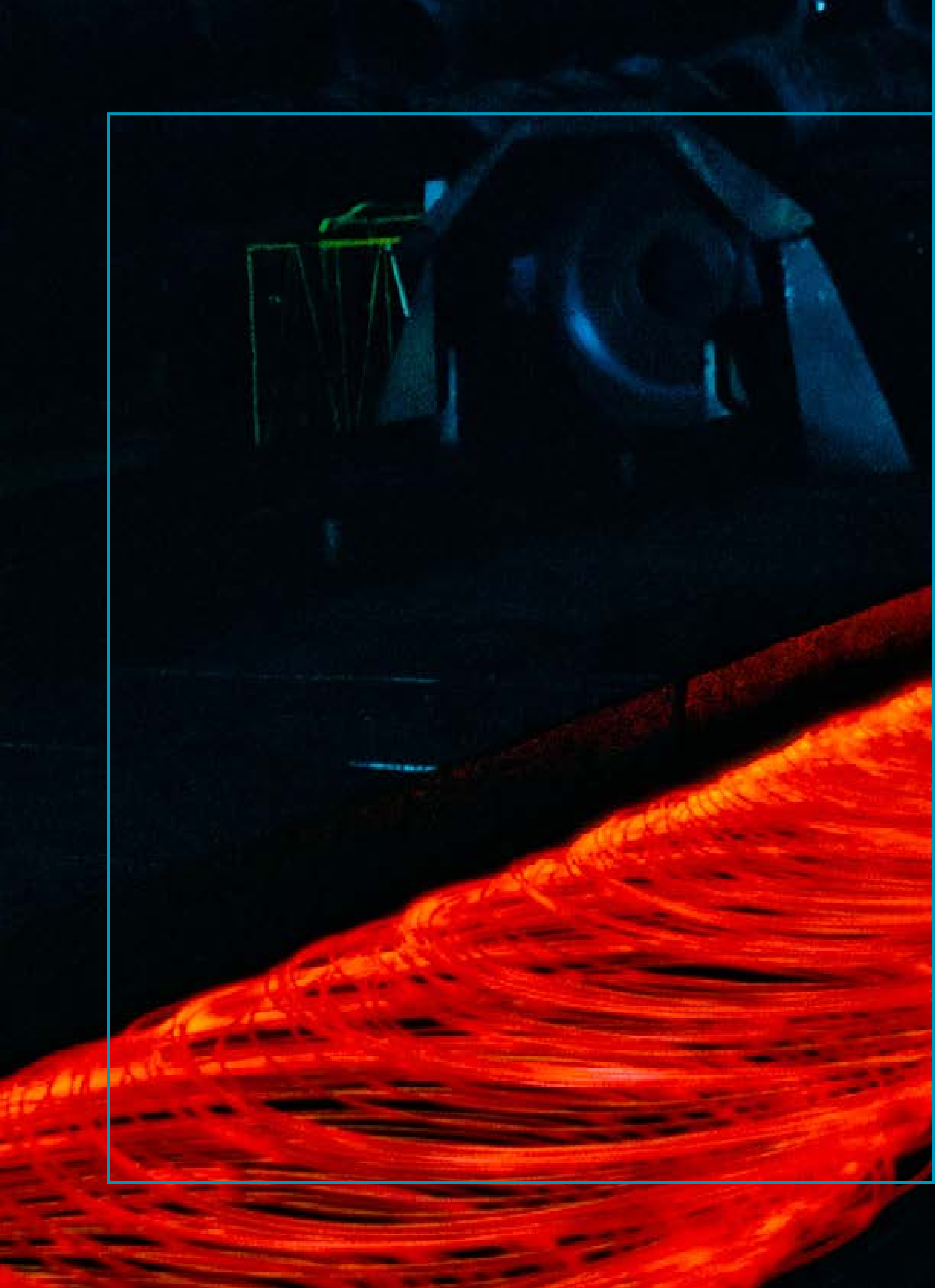

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Decarbonising Steel: Forging New Paths Together

1.1 FOREWORD

Steel is the world's most important engineering and construction material. Used in buildings, cars, ships, trains and tools, it appears in every area of modern life. Unsurprisingly, the world has developed a considerable appetite for it. Over the past 50 years, annual demand has tripled and is expected to reach a total of 1,840 million tonnes in 2022.[1]

While steel offers excellent formability and durability, there is a downside: the industry, from mining to production, has one of the highest carbon emission footprints. It generates more than three times the emissions of the aviation industry, over 45% more than the cement industry and 25% more than road freight.[2]

So how can such an energy- and carbon-intensive industry take the steps needed to reduce emissions, to help society make progress towards the goals of the Paris Agreement on tackling climate change?

Given the nature of steel processes, the vast range of steel products and their uses, and the complexity and fragmentation of the steel value chain, there is no simple or single solution to decarbonise the industry.

This report is the result of comprehensive interviews with experts from a wide variety of organisations involved in the entire steel value chain. Its purpose is to set out the major barriers to decarbonising steel and identify how to move forward with solutions. I would like to thank them all for their participation, enthusiasm and willingness in sharing their expertise and their views on how change can best be delivered.

Shell too is working hard to change. In 2021, we announced our goal to be a net-zero emissions energy business by 2050 or sooner and we want to help others reduce emissions too, and to that end we are working with customers across all industries including aviation, shipping, road freight and heavy industry.

Other companies and organisations have launched individual or joint projects aimed at reducing the carbon intensity of the steel industry and, as this report reflects, there are some promising technologies and processes that can enable the transformation.

Steve Hill
Executive Vice President,
Energy Marketing, Shell

There are several potential solutions to decarbonising steel, but to succeed one approach is crystal clear: if the industry is to cut carbon emissions at the speed and scale needed, all the elements within it must work together to deliver change. As we have seen in other industries, commercial coalitions with achievable goals are crucial to making the right progress, and alongside other core stakeholders along the value chain have an important role to play.

This is the fourth report we have published with the help of Deloitte on sectors where decarbonisation is harder to abate. It shows how much potential there is for change if we act without delay and chart a new path for the steel industry.

1.2 REPORT OBJECTIVES

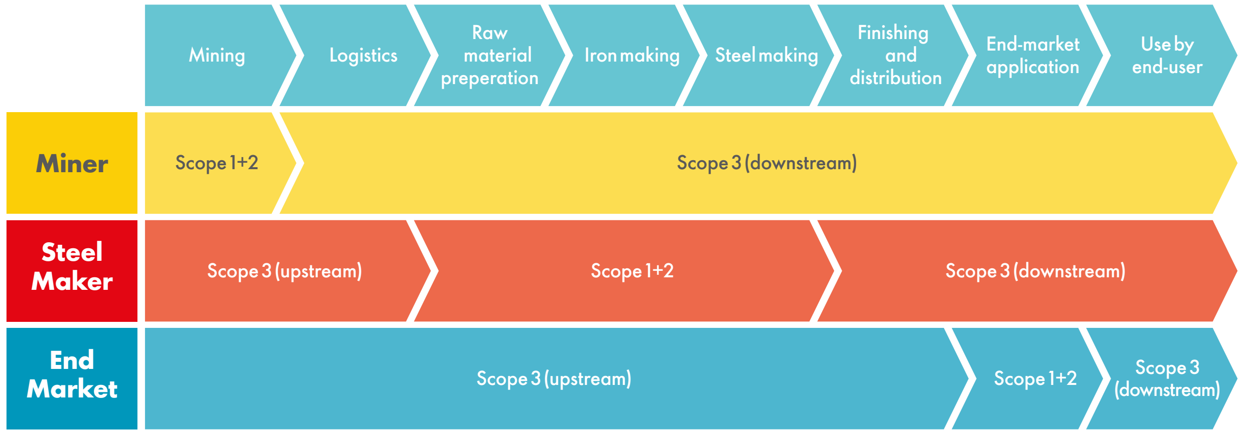
The research presented in this report was gathered in interviews with more than 100 executives and experts, representing 57 organisations involved in all aspects of the steel industry and its wider ecosystem. The report's goals are straightforward: they aim to reflect the views of the industry on how to accelerate decarbonisation and achieve net-zero emissions.

Taking a value chain view

The interdependence of organisations in any value chain, and especially harder-to-abate industries such as steel, needs to be taken into account to frame a comprehensive understanding of the challenges to decarbonisation. For sectoral decarbonisation to be achieved, a significant impact is made when companies commit to reducing their Scope 3 emissions, the indirect emissions associated with their value chain. This applies both to upstream (procurement of materials, assets, services, etc.) and downstream (including transport, waste disposal and processing). To tackle Scope 3 emissions, companies across the steel value chain are mutually dependent on one another to set firm emission reduction targets (see Figure 1).

A value chain assessment, like this report, reveals the key barriers to making progress, the solutions available and the crucial importance of cross-collaboration.

FIGURE 1: OVERLAPPING DECARBONISATION NEEDS OF THE VALUE CHAIN



Motivating sector interaction

Decarbonisation initiatives succeed best when collective momentum for change is achieved. For that to happen, it is essential to understand the unique motivations and challenges of different actors in the wider steel value chain and how these differ around the world. Collective action can then be taken that will accelerate in speed and grow in magnitude.

Activating the value chain

One of the main objectives of a cross value chain approach to a coalition is to enable a group of core participants to collectively map out a successful pathway that tackles the main barriers to decarbonisation and identifies the key solutions.

This report explores the insights participants shared with us in interviews and working sessions (see Figure 2). All engagements with interviewees were conducted in a manner that respects competition law boundaries.

FIGURE 2: RESEARCH PARTICIPANTS[3,4,5]

We interviewed 57 organisations...

5 Miners	**3** Shippers	**14** Steel producers	**6** Consumer Goods
3 Infrastructure	**4** OEMs	**7** Construction	**2** DRI asset suppliers
4 Financiers/traders	**3** Cert./Regulators	**4** Industry Assoc./Alliances	**2** Others

across multiple regions...

38 Europe	**5** Asia	**14** Rest of World

1.3 RESEARCH SUMMARY

1. The steel industry is considered harder-to-abate. It currently generates around 10% of global emissions, which could increase as demand is expected to rise by 10-35% by 2050 compared to 2019.[6] Iron and steel manufacturing is responsible for 95% of the emissions of the whole value chain, from ore mining to steel making.

2. The steel market is relatively concentrated, which offers opportunities for decarbonisation. If the 20 largest steel companies decarbonise their plants, the potential total emissions of the steel industry could be reduced by up to a third.[7]

3. To derisk decarbonisation investments, steel companies would need guarantees, in the form of low-carbon iron ore feedstock[8] and customer orders for green steel.[9]

4. This report highlights six key barriers to decarbonisation:

   - Lack of abundant and affordable green electricity [10] and green hydrogen;[11]
   - Absence of policy and regulatory incentives to promote global green steel standards enable fairer competition;
   - Limited availability of high-grade iron ore suitable for the direct reduced iron-electric arc furnace (DRI-EAF) decarbonisation route;
   - Shortage of a skilled workforce to support the decarbonisation transition across the value chain;
   - Limited capital available to invest in decarbonisation solutions;
   - Uncertainty of sufficient and long-term demand for green steel with green premiums.

5. To overcome these barriers, feedstock and production processes will have to change, driving transformations in the steel value chain. This could lead to a geographical separation of iron and steel making, with iron making moving to locations with low-cost green hydrogen availability.

6. Successful commercial coalitions are needed to help derisk investments by miners (to generate the right iron-ore grade), steel producers (to progress green steel production), end markets (to guarantee the purchase of green steel), energy providers (to ensure a growing supply of green electricity and hydrogen) and encourage policymakers to include low-carbon requirements in government tenders.

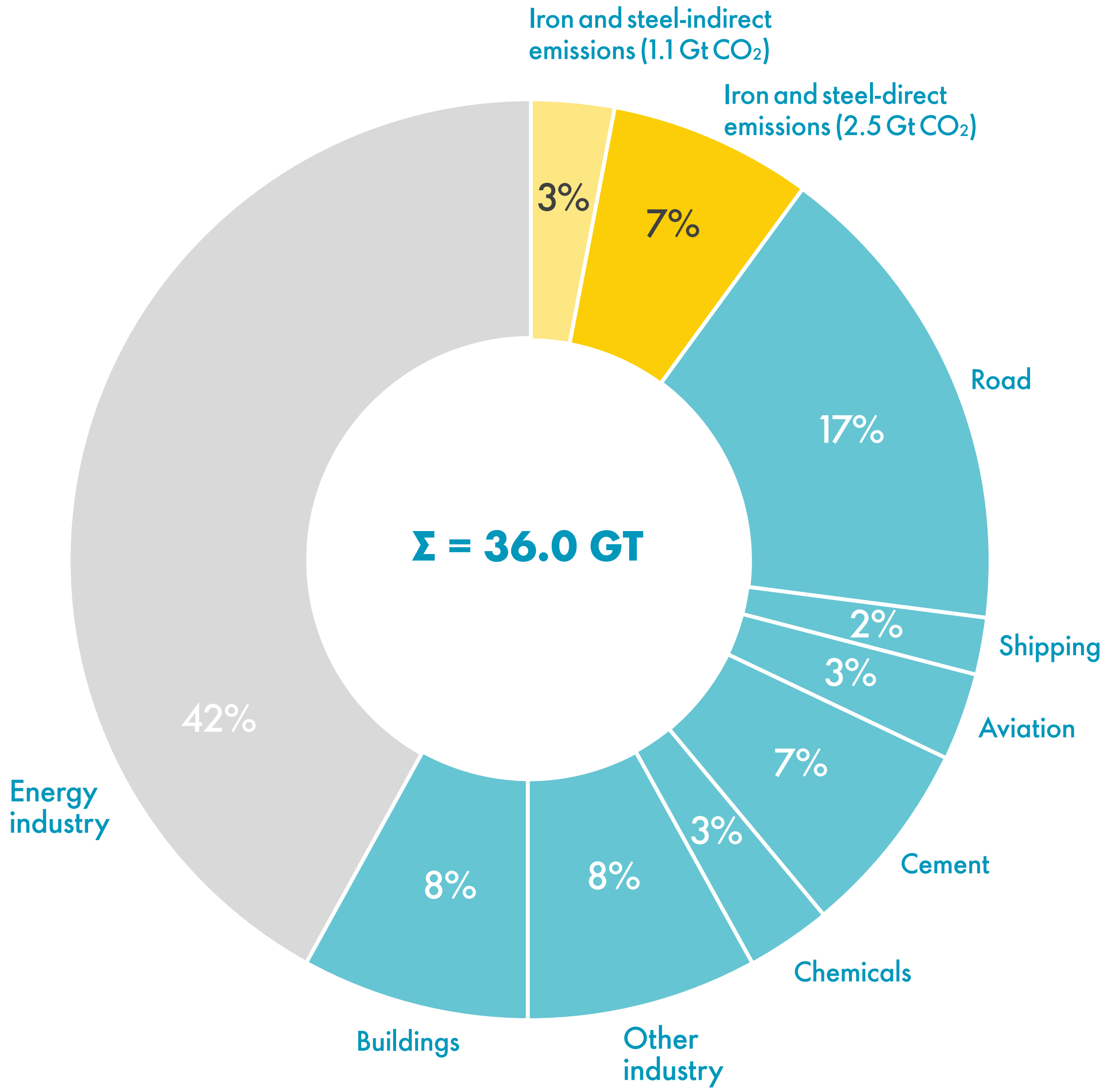
2 MOVING TOWARDS A CLEANER FUTURE: THE ROUTE FOR STEEL

Steel is a vital resource in society today. It is used by all industries and is crucial to the development of the global economy. However, its environmental impact is high, which occurs mainly through its production. But with increasing societal pressure to decarbonise, how can the industry meet the world's demand for steel while reducing the carbon intensity of its production to meet global climate change targets?

2.1 DECARBONISING STEEL IS CRITICAL TO ACHIEVING CLIMATE TARGETS

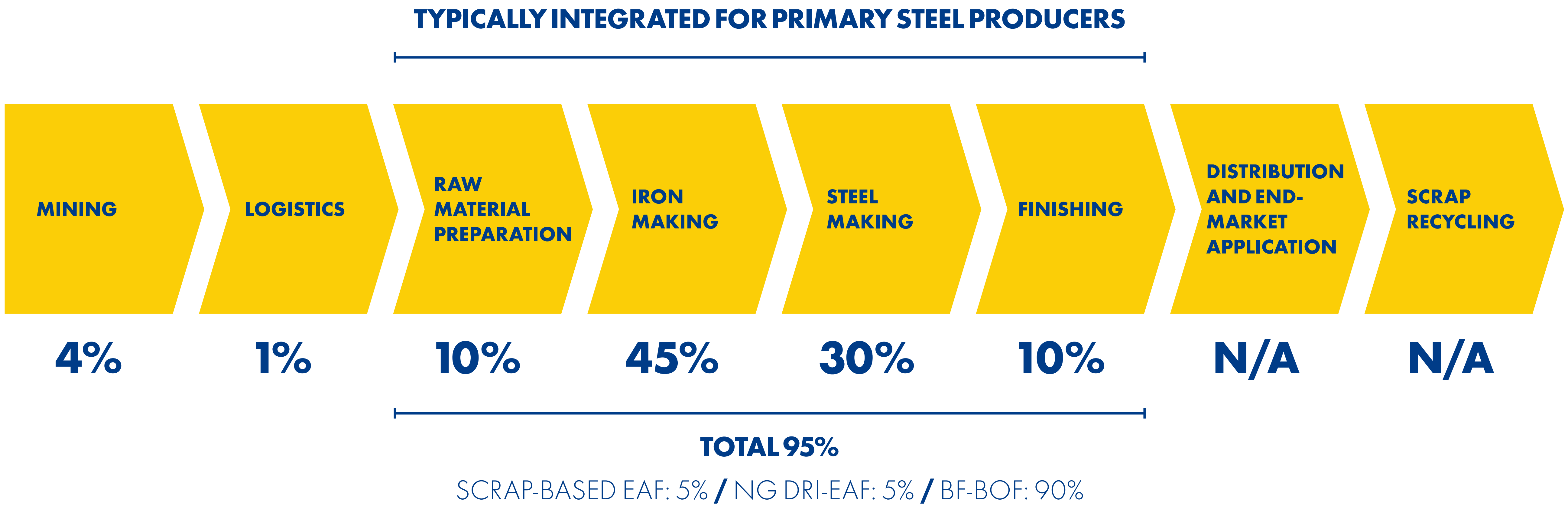
Progress towards the goals of the 2015 Paris Agreement on climate change requires major transitions in the key areas of energy production and consumption, food production and consumption, and materials sourcing and use. Steel has one of the highest emission footprints, accounting for around 10% of global carbon dioxide (CO_2) emissions. The long lifespan of steel production assets, combined with high asset replacement costs and high decarbonised energy requirements, make steel one of six harder-to-abate industries alongside road, cement, chemicals, aviation and shipping (see Figure 3).

FIGURE 3: GLOBAL CO_2 EMISSIONS BY SECTOR (2019)[12,13,14,15]



In the steel value chain,[16] steel production alone represents around 95% of total greenhouse gas emissions (see Figure 4), with the remaining proportion of emissions originating from mining (4%) and logistics (1%). Most of these emissions originate from the conventional blast furnace–basic oxygen furnace (BF–BOF) iron and steel making process to produce primary steel. Secondary steel production in scrap-based electric arc furnace (EAF) processes generates around 90% fewer greenhouse gas emissions than BF–BOF[17], as the iron-making step from iron ore is omitted, but there is insufficient scrap material to meet today's global demand for steel. By 2050, the International Energy Agency models that 46% of steel could be produced from scrap feedstock, compared to 32% in 2020, as more products reach their end-of-life.[18]

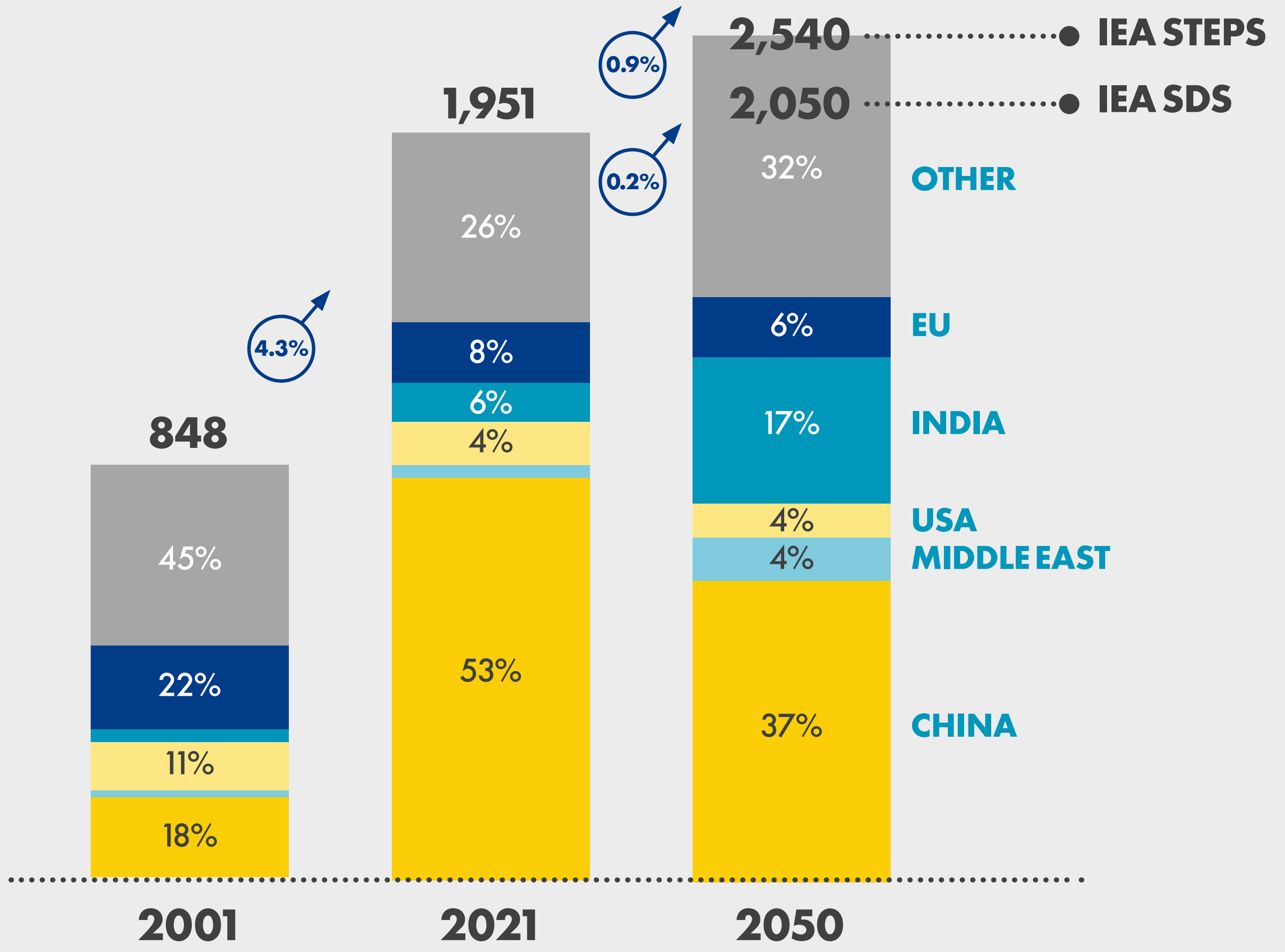
FIGURE 4: CO_2 EMISSIONS SPLIT BY VALUE CHAIN ACTOR[19]



In geographical terms, global steel production is relatively concentrated. For instance, some 20 companies account for around 37% of production, 12 of which are located in China.[20] In European steel-producing countries, the industry is consistently among the 10 largest emitters. As for China, it is not only the world's largest producer but also the largest consumer. This offers an opportunity: decarbonisation progress by a handful of major producers will have a far-reaching impact on reducing global emissions of the industry.

Steel production is expected to continue to grow to 2050 and beyond, although at a slower pace compared to the past two decades (see Figure 5). According to the International Energy Agency, average annual projected growth ranges from 0.2% to 0.9% due to demand from developing countries.[21] To a lesser degree, demand is also driven by the need for steel in building clean energy infrastructure such as wind and solar farms, power transmission networks and the electrification of plants and machinery.

FIGURE 5: STEEL DEMAND FORECAST (MT) 2021 OUTLOOK[22,23,24]



Take the emissions associated with developing an offshore wind plant, 71% of which originate from materials used.[25] According to the International Renewable Energy Agency (IRENA), the world will need an additional 775 gigawatts of offshore wind capacity from 2030 to 2050. This would require a significant growth in demand of about 140 million tonnes of steel, equivalent to 1% of total annual steel production, even when factoring in efficiency gains in wind technology.[26]

FIGURE 6: REQUIRED RENEWABLE ENERGY AND INFRASTRUCTURE

Wind power
Offshore wind farms

Electrolysers
Large scale production facilities

Solar power
New panels

Global H_2 infrastructure
Import/export terminals, storage

Power grid upgrades
Storage, new connections

Local H_2 infrastructure
Backbone refurbishment, pipeline extensions

2.2 COMPANIES ACROSS THE VALUE CHAIN DEPEND ON EACH OTHER TO DECARBONISE

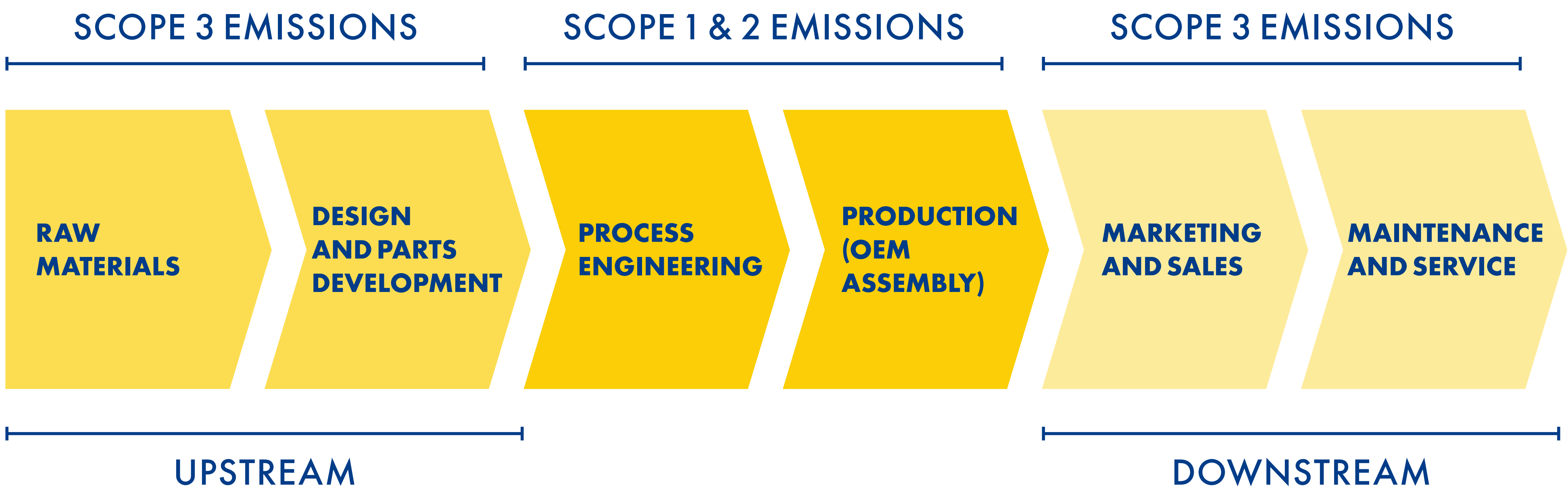
Most companies embark on their decarbonisation journey by setting targets for Scope 1 and 2 emissions which cover their own greenhouse gas emissions, from their use or assembly of products, vehicles, buildings or machinery.[27] By increasing energy efficiency, electrifying processes and using low-carbon or zero-carbon alternatives, companies can directly reduce their Scope 1 and 2 emissions. However, for sectoral decarbonisation to be achieved, the greatest impact is made when companies collaborate across the value chain.

This is especially the case for companies at the beginning of the steel value chain, such as iron ore miners, or at the end, including automotive and construction end users due to the concentration of emissions associated with iron and steel making. To lower their Scope 3 emissions, these companies are heavily dependent on the steel producers to reduce their greenhouse gas emissions. As one construction company stated:

"85% of our company's total emissions are Scope 3 emissions, of which the bulk originates from steel production".

Hence, if steel producers take action to decarbonise, it will enable all companies across the value chain to reach their climate targets and help to meet customer demand.

FIGURE 7: SCOPE EMISSIONS OF AN AUTOMOTIVE PRODUCER



EXAMPLE – AUTOMOTIVE OEM

"2021 saw a big rise in demand [for low-carbon steel]. Before this, it was sporadic requests, but now, we are bombarded with questions such as 'What is the CO_2 footprint of your steel? What plans do you have?' – especially from the automotive sector".

European steel producer

The mainstream emergence of electrical vehicles on roads across Europe, North America and China is reducing the Scope 3 emissions of automotive manufacturers because more of their cars are being powered by electricity instead of petrol or diesel. Electric vehicle manufacturers are now broadening their focus to include Scope 3 upstream emissions – those generated from the production of materials used in their cars, also referred to as embodied carbon (see Figure 7).[28] Steel typically makes up 54% of a vehicle (around 900 kg on average[29] and is therefore a priority material to decarbonise, to address Scope 3 emissions. This is especially the case in the high-end electric vehicle market, where manufacturers are actively trying to secure production of green steel from steel producers to use in their cars and where customers are willing to pay a green premium for more sustainable products. This, combined with the relatively small proportion of steel in the total cost of producing an electric vehicle, makes it economically viable for automotive manufacturers. For instance, according to the Mission Possible Partnership, using green steel[30] in a passenger car would add less than 1% to its showroom price, while also reducing material-related carbon emissions by up to 34%.[31]

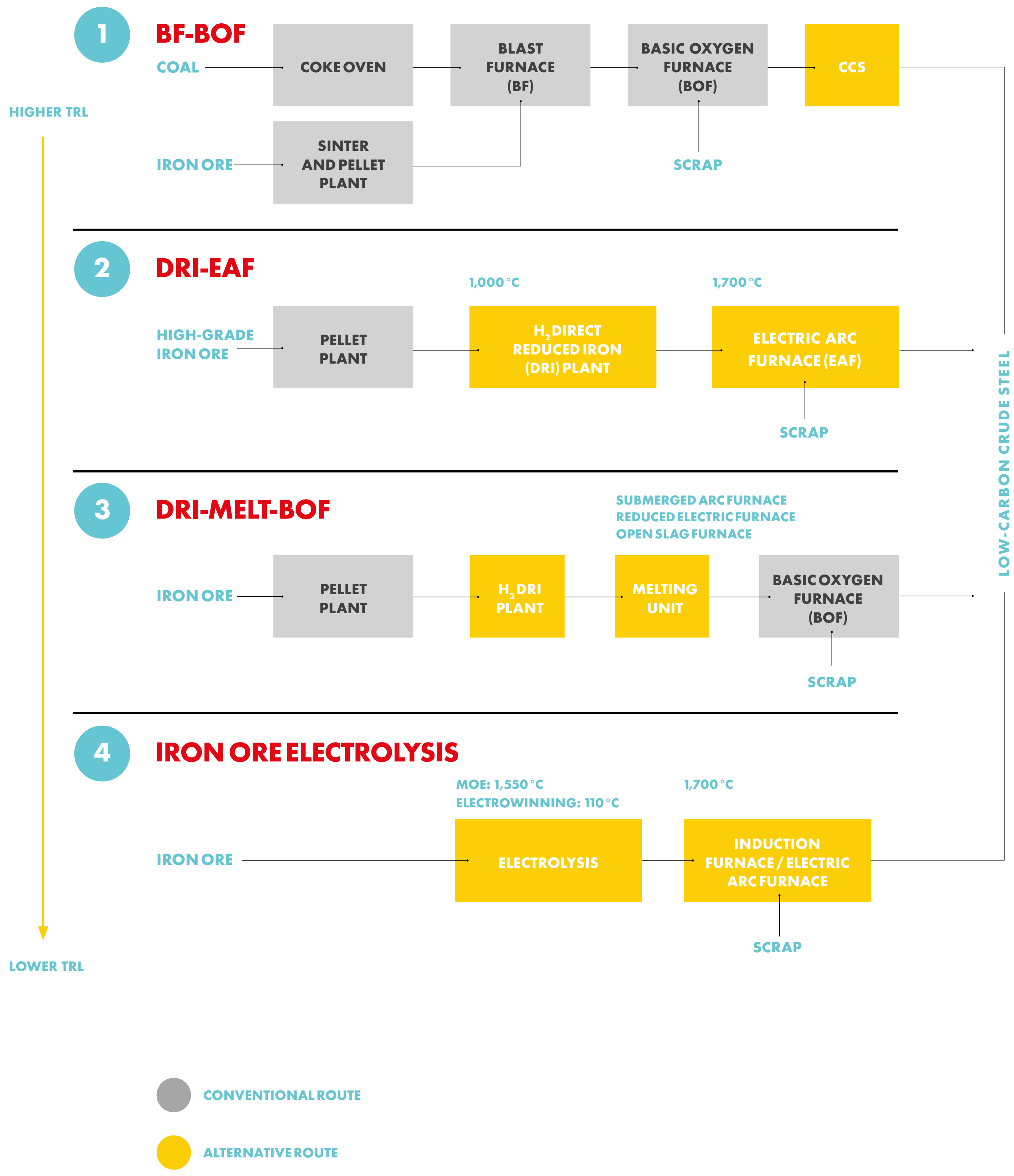
PATHWAYS TO DECARBONISING STEEL

Those interviewed in the research for this report identified four main pathways to develop low-carbon primary steel production, which are set out on the right (see Figure 8). If successfully deployed, these pathway solutions could result in a minimum total emissions reduction of around 60%. Many factors determine the most suitable decarbonisation solution for a specific plant, but the most common are the size, age, type and geographic location of the plant. Retrofitting newer plants in particular with carbon capture and storage, rather than replacing the blast furnace, will likely be used as a short to mid-term solution to prevent them from being stranded.

What all steel decarbonisation pathways have in common is that large capital investments are needed, especially to replace the blast furnaces. Globally, around $800 billion in capital investment is required by 2050 to decarbonise production, mainly for BF-BOF efficiency gains and carbon capture and storage, secondary steel production and hydrogen-based DRI-EAF.[32] To derisk investments, steel companies are largely dependent on their customers agreeing to purchase green steel. As one Chinese steel producer said:

"Furnaces are relatively new in China, so this is a problem. The cost of replacing them will be a challenge".

FIGURE 8: PRIMARY STEEL PRODUCTION PROCESS [33,34,35,36,37]



ROUTES TO LOW-CARBON STEEL

1.

Conventional iron- and steelmaking process including CCS.

2.

Alternative route to create steel using (natural gas or) H_2 as fuel, requiring high-grade iron ore.

3.

Alternative route that allows ongoing use of BOF plant, but with a DRI and melting unit plant, not requiring higher-grade iron ore.

4.

Innovative technology only using electricity to create iron/ steel directly from (non-premium) iron ore.

BF-BOF

Blast Furnace - Basic Oxygen Furnace

DRI-EAF

Direct Reduced Iron - Electric Arc Furnace

DRI-Melt-BOF

Direct Reduced Iron - Melt - Basic Oxygen

1

CARBON CAPTURE AND STORAGE FOR EXISTING BF–BOF PLANTS

Carbon capture and storage (CCS) is considered a short-term decarbonisation pathway – especially for newer BF–BOF plants. Within a typical plant lifetime of 40 years, the age of the existing global production capacity varies widely. In China for instance, the BF–BOF asset base is relatively new, so efficiency improvements and CCS measures are the most likely short-term transitional pathways.

CCS offers around 65-80% emissions reduction potential[38] and creates opportunities for other industries. For example, the captured can be used as a feedstock for green methanol production[39], a low-carbon fuel that can be used in shipping. However, the potential for CCS is limited to locations with sufficient storage potential, such as depleted North Sea gas fields, or with nearby petrochemical sites so that the CO_2 can be used as feedstock.

2

DRI–EAF WITH 100% GREEN ENERGY

Currently, a hydrogen-powered DRI plant combined with an EAF powered by renewable electricity is considered one of the most promising decarbonisation routes for steel. The DRI–EAF route is already operational at scale with natural gas in India and the United Arab Emirates. In the transition to green steel production, steel producers could use this proven technology to replace the blast furnace with a DRI plant fuelled by gas, and the BOF with an EAF.

> *"We aim to have our DRI operational by 2025 at 30% total capacity – it will first start with natural gas then increasingly hydrogen".*
>
> *European steel producer*

DRI technology using hydrogen instead of natural gas has not yet been proven on a commercial scale. The Swedish HYBRIT consortium[40] has shown that this approach to producing fossil-free steel is possible, but currently only on a smaller scale. Meanwhile, other companies, including ArcelorMittal,[41] Salzgitter[42] and Tata Steel,[43] are studying the potential of DRI using direct-injected hydrogen. A short-term, transitional approach is to blend hydrogen with natural gas in the DRI plant.

3

REPLACING THE BLAST FURNACE WITH A LOW-CARBON ALTERNATIVE, WHILE KEEPING THE BASIC OXYGEN FURNACE OPERATIONAL

Just a third of the world's iron ore supply is of high-grade quality.[44]

DRI–EAF production plants require higher-grade iron ore than BF–BOF production methods, because insufficiently dense iron ore can create acidic slag which can corrode the EAF assets and, in the longer term, lead to decreasing yields.

To mitigate this challenge, some European steel producers are also looking into DRI investments that use open slag bath furnaces (or reduced electric furnaces) with BOF, known as DRI–Melt–BOF. The open slag bath furnace acts as a melting unit before putting the iron into the BOF, which allows lower-grade iron ore to be used. At the same time, existing BOF assets can still be used. This pathway is less technologically mature than gas-powered DRI–EAF; however, once proven, DRI–Melt–BOF has the potential to be adopted quickly as it can partly use existing assets and would require less up-front investment.

4

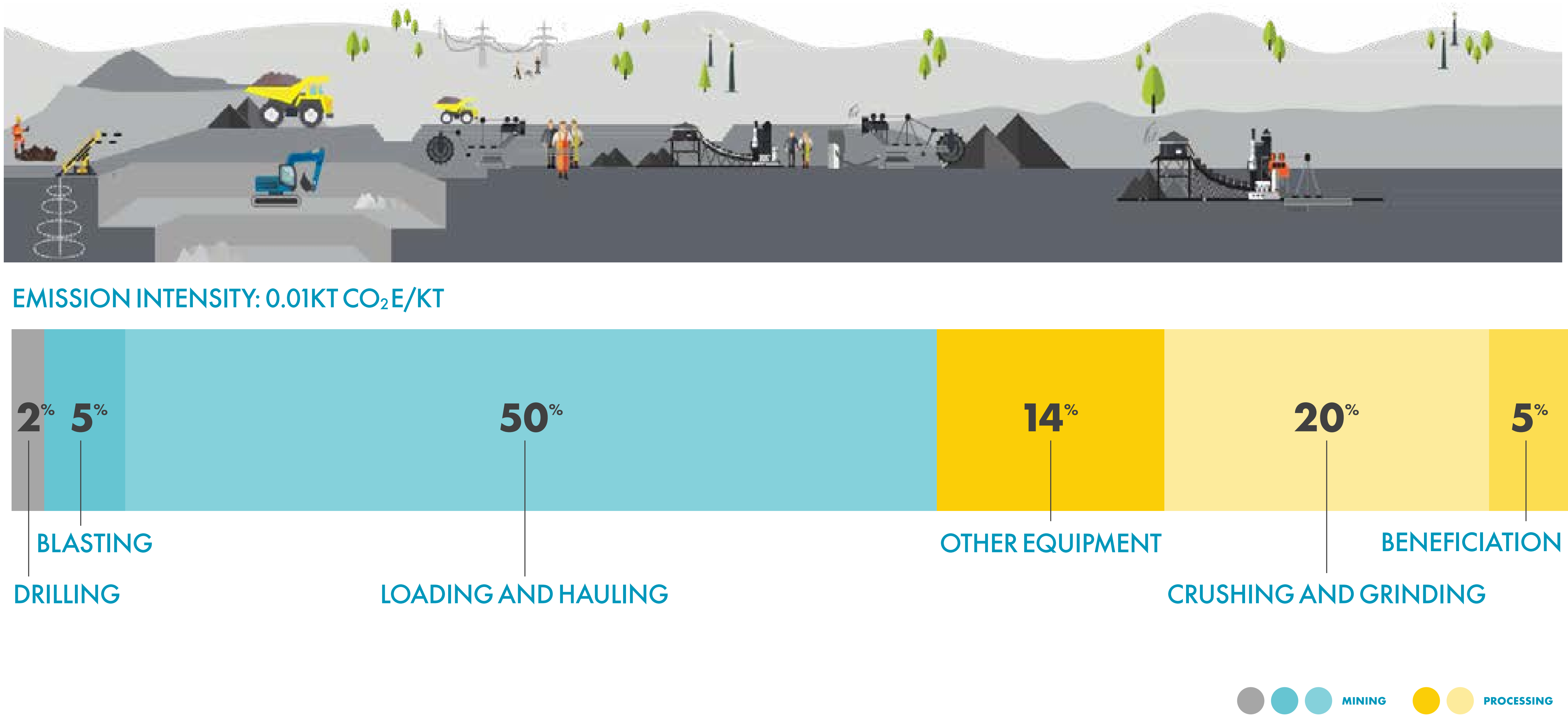
HARNESSING EXISTING TECHNOLOGIES FROM OTHER METALS

New green steel production technologies can potentially be developed through processes used to produce other metals. For example, a new technology is iron ore electrolysis – a process inspired by aluminium production – which is powered by renewable energy. For instance, Boston Metal[45] aims to use molten oxide electrolysis technology to run a zero-carbon facility at lower cost than a conventional BF–BOF plant. The company claims that the process can use a wider range of iron ore qualities than DRI–EAF plants, which removes the requirement for high-quality iron ore plants.

PATHWAYS TO DECARBONISING IRON ORE MINING

Iron ore mining accounts for about 4% of the emissions in the steel value chain, generating around 154 million tonnes of CO_2 in 2019.[46] Although considerably lower than emissions generated from steel making, the operational emissions and their abatement remain complex and varied for mining companies. Mining's Scope 1 and 2 emissions are largely attributed to the mine design, which includes location, (underground or open pit), the distance of loading and hauling materials, the properties of the mined product (ore grade, mineralogical properties) and the corresponding intensity of processing required. In general, 40–50% of emissions at site level are generated by mobile equipment running on diesel (see Figure 9). These emissions can vary up to twentyfold across mines, depending on the mine design.

FIGURE 9: ILLUSTRATION OF AUSTRALIAN OPEN PIT IRON ORE MINE[47]



TO DECARBONISE IRON ORE MINING, VARIOUS VIABLE PATHWAYS EXIST

1

INCREASING ENERGY EFFICIENCY

For both mining and ore processing, energy efficiency remains the starting point to achieve short-term emission reductions. Energy efficiencies can be realised through blast or haulage optimisation, asset upgrades and autonomous (highly automated) mining.

2

REDUCING ENERGY WASTAGE

To help decarbonise, mining operations should also focus on avoiding energy wastage. Some companies interviewed are exploring ways to do this by looking outside the industry for solutions, such as mechanical dewatering [48] or optimising the recovery of waste heat.[49]

3

TRANSITION TO LOW-CARBON ENERGIES

Using diesel to power mobile equipment accounts for the most emissions generated by iron ore mining. To reduce the use of diesel, operators could look at low-carbon fuels – such as sustainable aviation fuel, biodiesel, bioethanol and renewable compressed natural gas – or at fully electrifying their fleet of equipment (see Figure 10). Changes in infrastructure would be necessary to enable a large-scale transition to low-carbon energy sources through intelligent grid integration,[50] by reducing peak demand and generating renewable energy on-site.

4

CARBON-MANAGEMENT STRATEGIES

Where they cannot be avoided or reduced, the remaining emissions in the transition towards low-carbon mining could be tackled through carbon management strategies - such as carbon capture and storage, carbon sequestration or by using carbon offsets - until more solutions to avoid and reduce emissions are developed.

FIGURE 10: TECHNOLOGY DEVELOPMENTS NECESSARY FOR FLEET ELECTRIFICATION [51,52,53]

ELECTRIC

TROLLEY + DIESEL
1

TROLLEY + BEV
2

BEV
2-3

ELECTRIFICATION WILL REQUIRE TECHNOLOGY DEVELOPMENT GOING FORWARD

ALTERNATIVE FUELS

HVO
E-DIESEL
1-2

H_2
E-METHANE
2

Time Horizon 1: Commercially Available Today
Time Horizon 2: Commercially Available 2025-2030
Time Horizon 3: Commercially Available 2030+

3 OVERCOMING THE BARRIERS TO DECARBONISING STEEL

As the previous chapter describes, the steel industry is a major generator of greenhouse gas emissions. Decarbonising steel involves overcoming several challenges. In return, it offers far-reaching potential to progress the energy transition, mitigate the impact of greenhouse gas emissions and stimulate a lower-carbon economy.

3.1 THE SIX KEY BARRIERS TO STEEL DECARBONISATION

Through our interviews with companies and organisations across the steel industry we have identified key barriers to decarbonisation. The most significant are the lack of affordable green energy supply, underdeveloped environmental policies and the need for technological innovation to process varying iron ore quality.

To understand the barriers to decarbonisation and their significance, our research team spoke to people in 45 companies across the steel value chain, from miners to end users. We also spoke to representatives of 12 organisations that impact the industry, including financiers, technology providers and government and industry bodies. We then refined their responses in workshops with industry executives and senior management. Based on all responses, we have arrived at six barriers, which comprise the greatest challenges to decarbonising steel.

1

RENEWABLE ENERGY SUPPLY

An abundant, affordable renewable energy supply is needed to decarbonise the industry, whether green hydrogen to power DRI plants or renewable electricity to power EAF plants, iron ore production and transport operations. At present, the global green hydrogen economy is in the early stages of scaling up supply and infrastructure. In addition, existing mines and steel plants are often connected to electricity grids with limited capacity and are therefore not capable of supporting large-scale plant electrification without significant grid upgrades (see 3.2).

2

REGULATIONS, INCENTIVES AND STANDARDS

Policy and regulation, including incentives, is a powerful tool government bodies can use to accelerate decarbonisation. However, existing policies (as outlined in 3.3) are only expected to lead to a slight decline in emissions across the industry, which means greater global regulation across the industry is required to meet net-zero targets. In addition, many global and national standards for green steel and hydrogen have been developed or are emerging, but this proliferation can be confusing for end users as it inhibits transparency and comparability of green steel (see 3.3).

3

HIGH-GRADE IRON ORE

DRI–EAF steel production requires high-grade iron ore as feedstock. Multiple interviewees reported that they expect only a third of global iron ore to be suitable for current DRI–EAF processes. As one miner said:

"Estimations are that 66% of the global iron ore supply is not suitable for DRI–EAF operations".

Therefore, large-scale DRI–EAF production will require high-grade iron ore production or upgrading, and the development of low-carbon technologies that can use lower-grade iron ore (see 3.4).

The above three barriers were recognised by all interviewees and are expanded on in the following chapters. The following three barriers were mentioned by a smaller group of interviewees and were considered regional and locally specific. Because of this, we do not analyse them in greater detail.

4

ASSETS AND SKILLED LABOUR

A shortage of skilled labour (especially in Europe), and a limited number of manufacturers of DRI and EAF plants, poses another challenge to scaling up green steel production. Replacing iron and steel production plants, as well as upgrading the distribution infrastructure for hydrogen and electricity, involves large multi-year projects. This requires skill sets that are in demand across other sustainable initiatives, such as solar and wind farms, leading to greater competition for skilled people within regions.

5

FINANCING

Large-scale funding is required to decarbonise the iron ore and steel value chain, notably to replace existing steel production assets with newer and cleaner technologies. The steel sector is not known for high margins and hence, financing was identified as a barrier. However, the industry consensus is that financing could materialise if investments are derisked. For instance, financing would likely be more available if miners provide guarantees for high-quality iron ore supply, if energy suppliers commit to the supply of green energy, or if end users secure off-take agreements for green steel and regulators introduce viable policies and incentives.

"We are working with suppliers for low-carbon cement/steel. The problem is that we need so much, it is impossible to buy it all green/low-carbon".

Infrastructure construction company

6

END-MARKET DEMAND

Demand for green steel was ranked by interviewees as the least-pressing barrier because some niche markets are already keen to decarbonise their supply chains, particularly in Europe. Demand for affordable, green steel is expected to outpace supply until 2030, but is largely limited to specific business-to-consumer markets, such as automotive manufacturing, or those driven by green procurement policies, such as construction in the Netherlands. One banker responsible for metal and mining investments said:

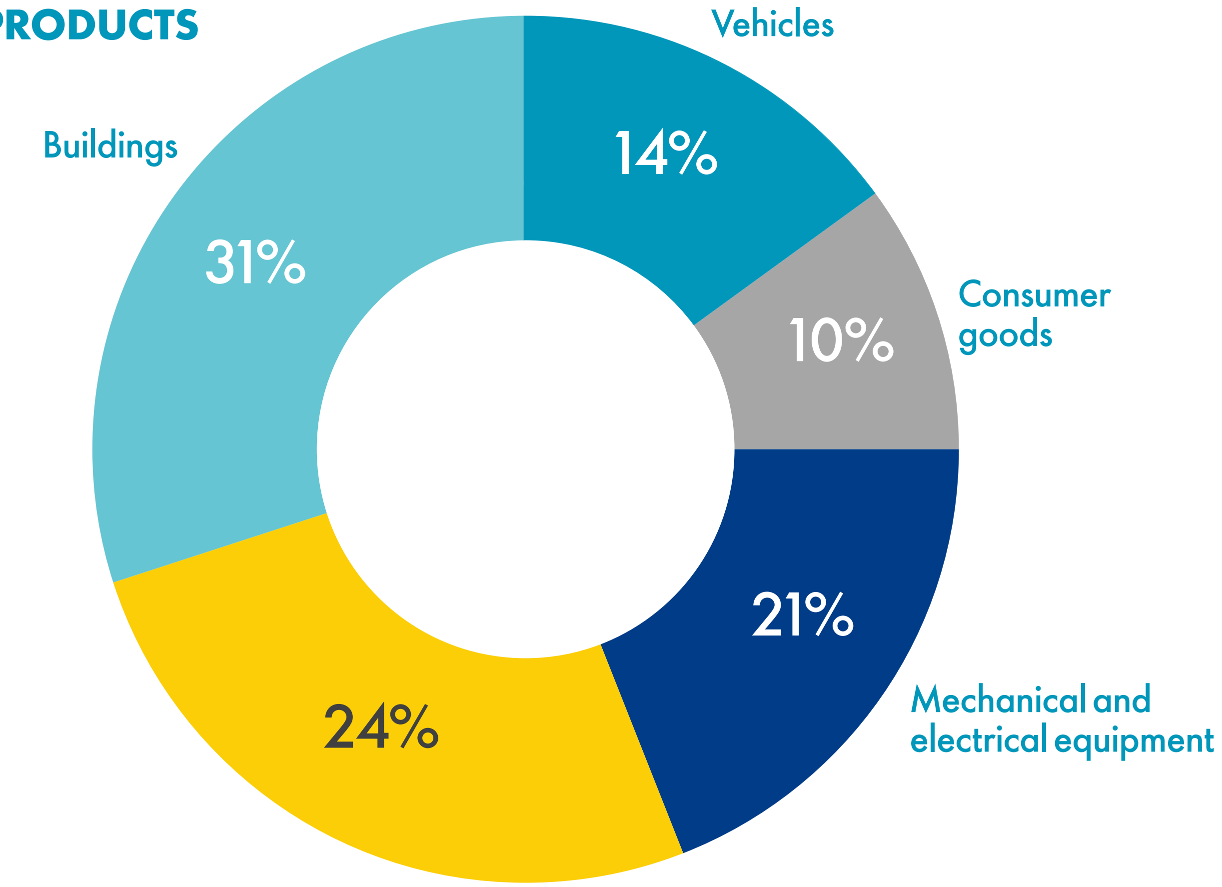
"Demand for green steel is already higher than people believe. Players who get in first will be the big winners".

For large-scale decarbonisation of steel to be viable, the demand for green steel needs to grow beyond niche markets. To derisk investment decisions, miners, steel producers and hydrogen suppliers will need order guarantees from large steel purchasers, especially infrastructure developers and construction companies, as they comprise more than half of the steel end market (see Figure 11). As a global consumer goods executive said:

"Transition can be financed if you get off-take guarantees. That is how you can get scale, and potentially lower the green premium".

FIGURE 11: MINING AND STEEL VOLUMES (MT, 2019)[54]

END PRODUCTS



3.2 THERE IS A NEED FOR ABUNDANT LOW-COST GREEN ENERGY

For green steel produced by hydrogen-powered DRI, the cost of renewable energy represents 50-70% of total production costs. This low-carbon process will only scale up if the cost of renewable energy drops sufficiently.

All interviewees mentioned that the limited availability of low-cost green energy, both green hydrogen and renewable electricity, is the key barrier to decarbonising steel. When modelling the cost of producing steel (excluding iron ore procurement), carbon price and energy emerge as the main cost-drivers (see Figure 12):

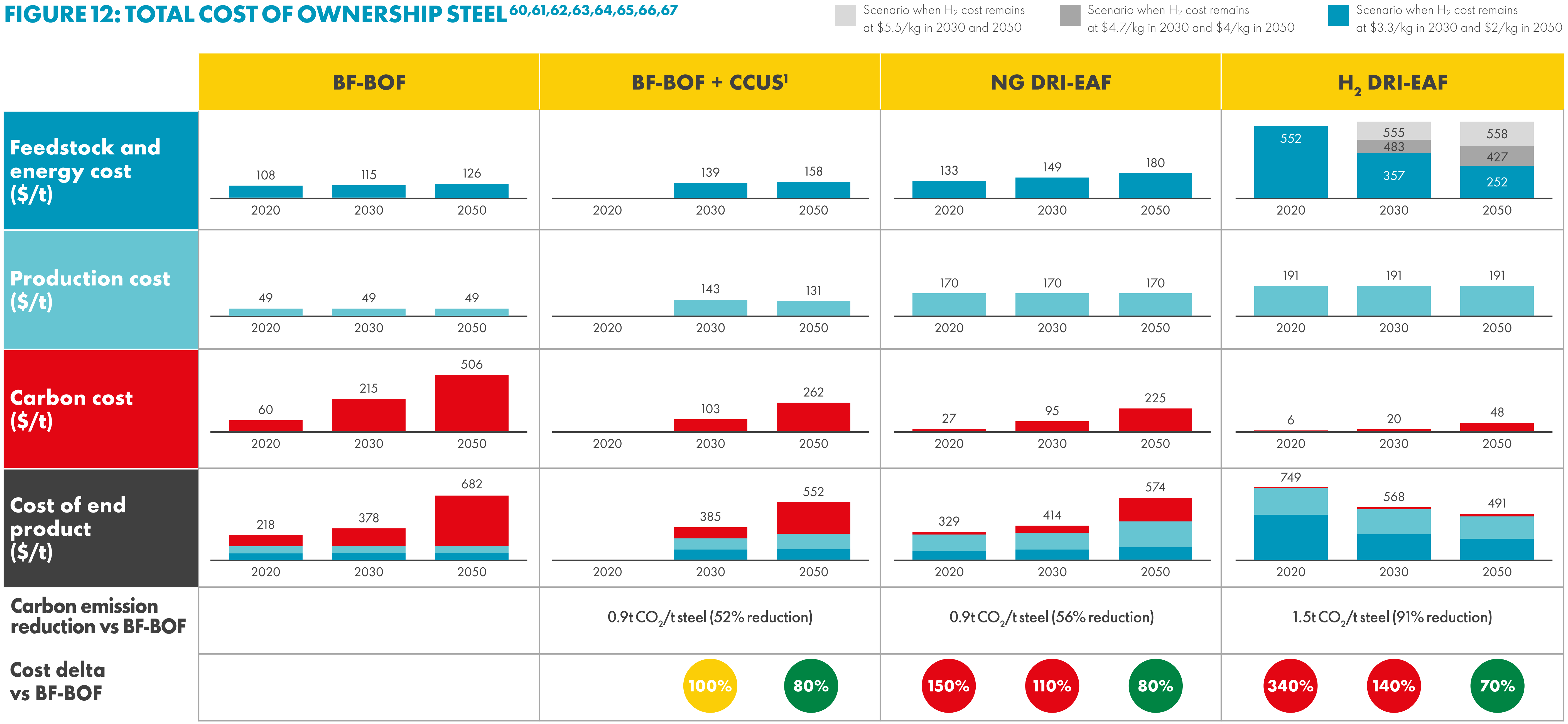
- For conventional BF–BOF, by 2050 the carbon price is expected to represent almost 70% of costs, based on an estimated carbon price of €300 per tonne.[55]
- For BF–BOF with carbon capture and storage, carbon capture costs are expected to result in higher costs in the short to mid-term compared to conventional BF–BOF. Even with carbon capture and storage, BF-BOF will likely face some carbon costs, but not as much, tipping the balance in favour of carbon capture capacity over the longer term.
- For DRI–EAF plants, regardless of whether they are running on natural gas or hydrogen, there are increased costs due to the high capital expenditure of building the core assets. In addition, gas-powered DRI production is also expected to generate some carbon costs, due to emissions from burning natural gas.
- For hydrogen-powered DRI plants, green hydrogen will likely be a major cost. Producing 1 tonne of green steel with hydrogen-powered DRI–EAF is estimated to require around 80 kg of green hydrogen and 0.6 megawatt-hours of electricity.[56] Based on 2021 green hydrogen prices, this could mean that the cost of producing green steel with this method could be two to three times higher than conventionally produced steel.[57] The cost of green hydrogen is expected to decrease over the coming decades, but the rate of decline is difficult to predict given the infancy of green hydrogen production. According to one of the scenarios outlined in Figure 12, the cost of green steel produced with green hydrogen could fall below conventional steel by 2050, as the carbon price increases and green hydrogen prices decrease. However, this ultimately depends on other factors, namely developments in gas and coal prices. It is also important to note that iron ore costs are not included in these three scenarios, and sourcing high-quality iron ore for DRI–EAF could further increase costs.

Overall, steel production costs are expected to more than double by 2050, with energy supply and carbon prices representing 53-74% of costs (see Figure 12). Abundant low-cost green hydrogen and renewable electricity are therefore crucial factors in making the business case for green steel. As a DRI equipment provider said:

"Nowadays, the availability of natural gas and hydrogen has a cost that is not viable for a single producer".

The projections do not take into account current geopolitical developments. In February 2022, Russia launched an invasion of Ukraine. Before the war, Russia and Ukraine together accounted for about 20% of EU imports of finished steel products. Many European steel producers relied on Ukraine for raw materials, such as metallurgical (coking) coal and iron ore. According to the London Metal Exchange, between February 23 and March 8, 2022, UK steel prices soared. The repercussions of the war have resulted in price increases due to uncertainty of supply. In parts of Europe, hot-rolled coil jumped from around €950 per tonne (around $1,040) before the invasion to more than €1,400 per tonne (around $1,533) in April, but fell back to trade at slightly more than €1,200 per tonne (around $1,314) in May.[58] In September, prices fell back further to around €800 a tonne due to rapidly-rising energy prices and lower consumer purchases.[59]

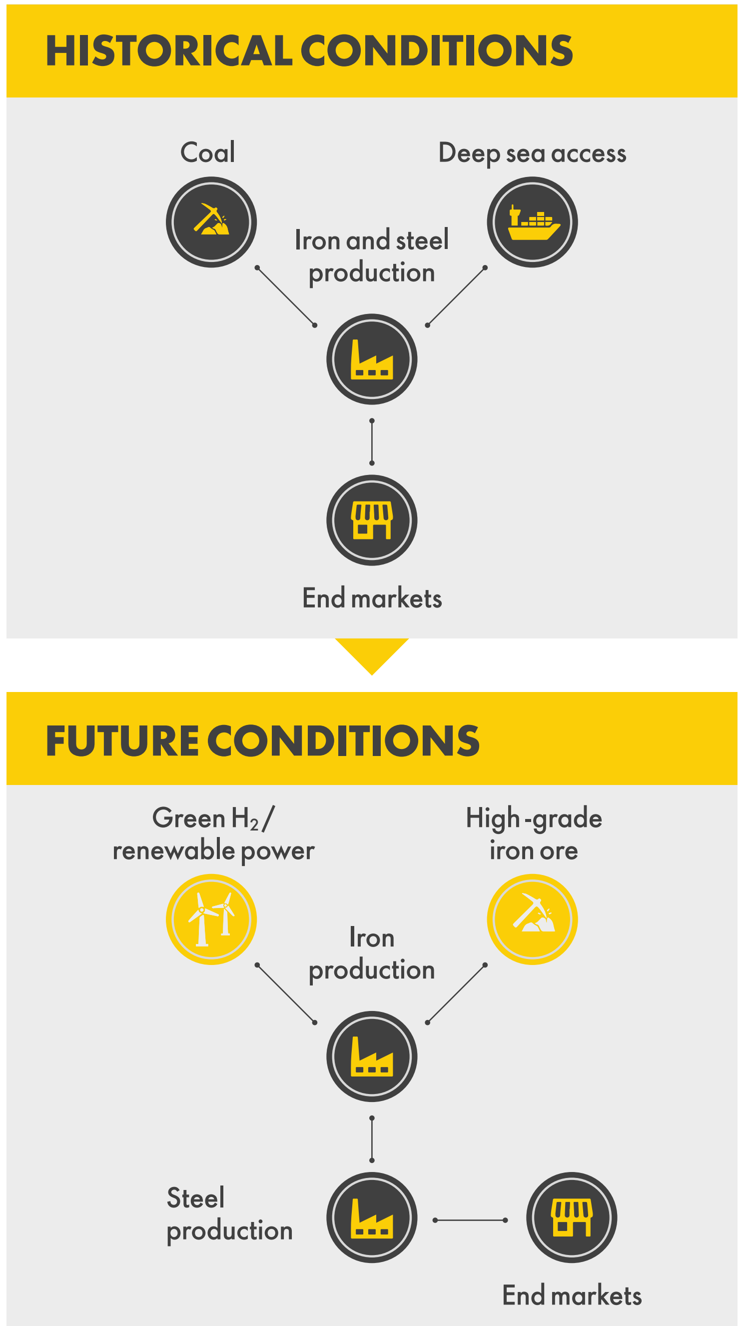
FIGURE 12: TOTAL COST OF OWNERSHIP STEEL[60,61,62,63,64,65,66,67]



BF-BOF	Blast Furnace - Basic Oxygen Furnace
DRI-EAF	Direct Reduced Iron - Electric Arc Furnace
DRI-Melt-BOF	Direct Reduced Iron - Melt - Basic Oxygen Furnace

COULD THE GEO-SPLIT MODEL BE A SOLUTION?

FIGURE 13: CRITICAL REGIONAL CONDITIONS THAT IMPACT STEEL DECARBONISATION



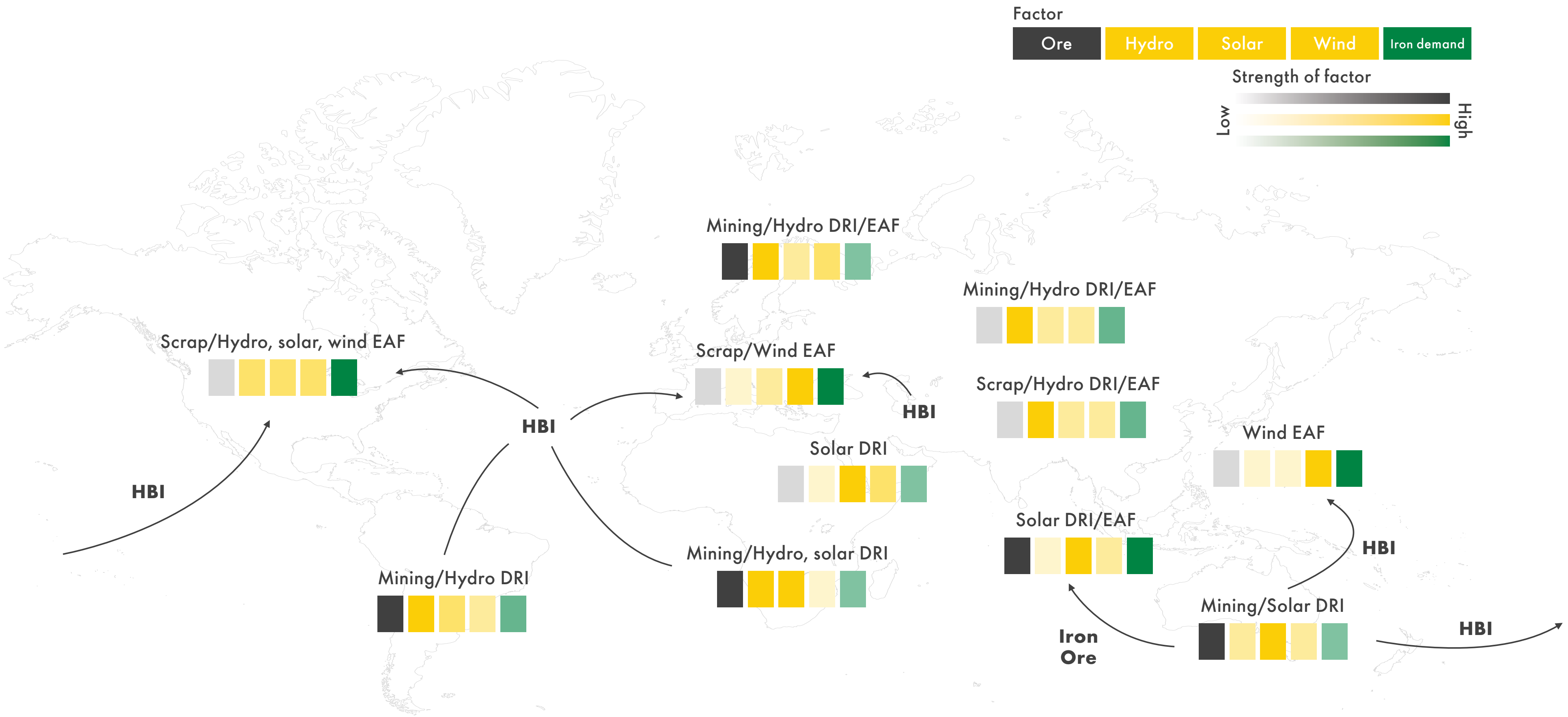
Proximity to an abundance of low-cost renewable power and green H_2 and high-grade iron ore will be future critical conditions for iron and steel production

The barrier of insufficient low-cost green energy in steel production could be mitigated by the emergence of green hydrogen production hubs.

The availability of affordable energy has always been a key determinant of the geographical location of steel plants. Historically, BF–BOF plants were built near coal mines or coal supply routes, and gas-powered DRI plants near gas fields. The iron ore, on the other hand, is shipped worldwide to both types of production plant. As energy demand shifts to green hydrogen and renewable electricity, these location patterns potentially make less sense and are likely to change.

Iron ore mines are often located in areas that offer renewable energy potential. This creates an opportunity to review and optimise the iron and steel making process, potentially splitting the process across several different geographies to achieve cost efficiency (see Figure 14).

FIGURE 14: POTENTIAL IRON (ORE) SHIPPING STEEL VALUE CHAIN 2050 | SIMPLIFIED



Brazil, Middle East, and Australia, regions with potential abundance of low-cost renewable power, could partially change the value chain by starting to produce HBI (premium DRI) and ship it globally

EAF steelmaking needs to remain close to finishing and end markets to meet customer demand for a wide variety of steel quality across thousands of stock-keeping units.[68] However, the DRI process could potentially move to locations that are well served by both high-quality iron ore and abundant low-cost renewable energy. In such a geo-split model, instead of shipping low-carbon iron ore, producers could ship low-carbon iron - in the form of hot briquetted iron (or sponge iron) - ready for EAF steel making. A banking executive active in the metals and mining industry said:

"I strongly believe in the splitting of iron and steel making, as the cost of energy is the most important driver".

And a leading DRI equipment supplier, who modelled the cost of steel making in a geo-split model, said:

"One could produce the hot briquetted iron at a DRI megahub in a low-cost green electricity region, and export it to Europe. We believe this is the most cost-efficient way of producing steel".

Despite the strong commercial arguments for separate iron and steel making locations, it is likely that national politics and resource security will drive some countries to maintain current processing locations. For miners and steelmakers, the shift in factors could potentially disrupt part or all of their business. Prioritising investment in EAF over DRI seems a low-risk choice for steelmakers located in areas without existing or planned large-scale hydrogen production, as it offers them future options for secondary – scrap-based – steel production, as well as the possibility to import hot briquetted iron. With the International Energy Agency predicting secondary steel use to increase in Europe, to make up 59% of European production by 2050, countries such as Austria, Germany and Slovakia might be better positioned to focus on EAF steel making only. This presents an opportunity for well-located iron ore miners to move downstream in the value chain towards the production of iron using DRI.

"Don't focus on the steel making, but on getting the hydrogen. We need to put the DRI next to the energy source".

Steel producer

For big steel customers, choosing between the geo-split model and the co-located model – where a steel plant and its energy resource are nearby one another – seems less of a concern than the availability, traceability and price of internationally recognised green steel. For instance, original equipment manufacturers are expected to support a geo-split model if it can speed up supply and allow them to become front-runners in using green steel.

3.3 PUBLIC POLICY AND INCENTIVES CAN MAKE THE TRANSITION LESS RISKY

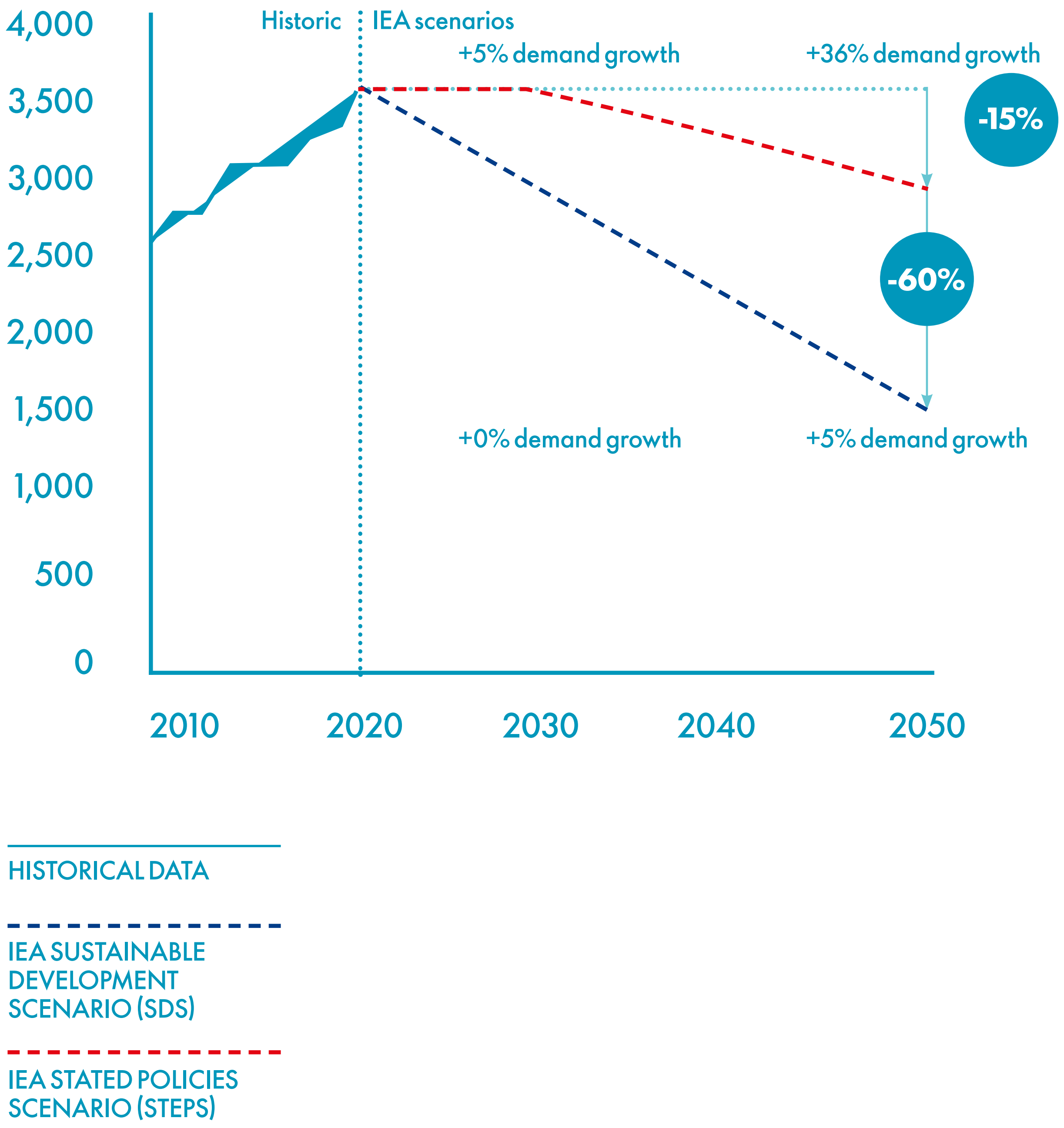
Government policy and regulatory incentives are crucial to decarbonise steel. The unification of green steel standards on a global basis is needed to reach net-zero emission targets.

According to the International Energy Agency's Stated Policies Scenario, a 15% decrease in CO_2 intensity and absolute emissions from global steel production is possible by 2050 if current efficiency policies worldwide are fully implemented. However, the agency goes further in its ambitious Sustainable Development Scenario, which predicts a 60% decrease could be possible with the widespread adoption of carbon capture, utilisation and storage, hydrogen-powered DRI plants and EAF production using renewable electricity (see Figure 15).[69] Progressive policies in some European countries have accelerated steel decarbonisation by putting a price on carbon emissions of both European and non-European[70] production and subsidy schemes for important decarbonisation initiatives.[71] In other regions and countries, such as South Korea, carbon pricing has been implemented as well to achieve their 2050 carbon-neutral strategies.[72] However, although expressing their ambitions to be carbon neutral by 2050, concrete policies are absent in many other geographies.

To further increase progress, interviewees singled out the following three initiatives from government organisations to stimulate the transition.

FIGURE 15: STEEL PRODUCTION CO_2 EMISSIONS, SCENARIOS (MT)[73,74,75,76]

IEA scenarios forecast stable to growing global steel demand 2020-2050 resulting in smaller total CO_2 emission declines.



1

STEEL-SPECIFIC INNOVATION FUNDING

On the supply side, increasing innovation funding for steel production could close the investment gap for steel companies looking to decarbonise. In Europe, for instance, the cost of replacing a 7 million tonne BF–BOF plant with a new hydrogen-powered DRI–EAF production facility is estimated to cost around €6-7 billion, excluding the cost of infrastructure for hydrogen, natural gas or renewable electricity supply.[77] While European governments have not yet made commitments, various European steelmakers indicated that they were expecting incentives to emerge in the coming years.

2

GREEN PROCUREMENT POLICIES

Alongside carbon pricing policies, governments can accelerate the transition to a lower-carbon energy system by implementing green procurement policies to support demand, particularly for construction and infrastructure projects. Sustainable practices in this sector are rarely low-cost in the short term. Implementing green procurement criteria can help counterbalance the impact of lowest-cost tendering processes. For instance, in the Netherlands, construction and infrastructure businesses report that green procurement processes have helped them deliver low-carbon projects using materials with a lower-carbon footprint while remaining competitive. A construction company involved in large European projects said:

"Governments are an end user of a large proportion of steel in the EU. They have to be willing to pay a premium and request it in their tenders and specifications for the construction sector to support the decarbonisation of steel. We are completely customer-driven, so if they are not putting it in the tender specification, we are not doing it".

3

GREEN STEEL STANDARDS

There is currently no clear standard for low-carbon or green steel. Existing green steel standards are based on emissions or production processes, and the qualifying thresholds for emissions intensity can vary from 2.5 tonnes CO_2 per tonne of crude steel to almost zero (see Figure 16). A certification company confirmed the widespread interest in steel standards:

"Green steel certification inquiries have really skyrocketed in the past two years".

Government policy can reduce the number of low-carbon standards, steel definitions and certifications, and guide buyers in their decision-making. A global consumer goods company expressed the need for independent standards:

"We need transparency across the value chain, to know where our steel comes from and how green it is".

For standards to be as relevant as possible, they should:

- Compare primary and secondary steel production. Secondary production is nearly carbon-free when using renewable electricity, but there is insufficient scrap metal to meet demand. This important factor drives the need for standards that take into account the percentage of scrap used. ResponsibleSteel™ is developing a standard that includes both primary and secondary steel.[78]
- Be technology-agnostic and base standards on carbon intensity. For instance, transitional methods such as natural gas and hydrogen-blending or carbon capture can help reach climate targets in the short term. Standards could, therefore, benefit by taking transitional decarbonisation into account.

Across the value chain, companies indicate that they expect governments and industry alliances to become active in narrowing down and aligning standards, definitions and certifications. However, until global standards have been set, objective comparisons between company ambitions and achievements will continue to make it difficult for buyers to make informed decisions.

FIGURE 16: LOW-CARBON PRIMARY STEEL CERTIFICATION[79]

CERTIFICATE	TERMINOLOGY	DEFINITION	INVOLVED COMPANIES
ResponsibleSteel™	Responsible steel production and sourcing standard	A standard based on emission intensity (0.5t CO_2/t crude steel) for primary and secondary steel production and sourcing, validated through third-party audits	ArcelorMittal, U. S. Steel, Tata Steel, BHP, Mercedes-Benz Group AG, Volvo, etc.
XCarb™	Green steel certificates	Aggregated and verified carbon emission savings from a BF, converted into certificates based on mass-balance approach	ArcelorMittal, DNV
bluemint®	Climate-friendly steel certificates	Two products with lower CO_2 emission intensity through use of HBI1 in BF (0.6 t CO_2/t, lower when using H_2 in long-run) and scrap (0.75 t CO_2/t)	thyssenkrupp, DNV, TÜV
ENVIRONMENTAL PRODUCT DECLARATION	Fossil free steel	Internationally comparable standard with emission intensity per tonne of steel	SSAB coalition, EPD

3.4 LOW-CARBON SOLUTIONS ARE NEEDED FOR BOTH HIGH AND LOW-QUALITY IRON ORE

With less than a third of global iron ore supply suitable as feedstock for DRI–EAF steel production, iron ore mining will play a key role in decarbonising the industry. Green steel production solutions using low-quality iron ore therefore need to be developed.

DRI–EAF production plants require higher-quality iron ore than BF–BOF plants, because insufficiently dense iron ore can create acidic slag which can corrode the electric arc furnace and, in the longer term, lead to decreasing yields.

The consensus among interviewees is that just 30% of global iron ore supply is currently suitable for DRI–EAF plants. Therefore, both miners and steel producers will need to invest in research and development and deliver new technologies to address this. A global mining executive said:

"Two-thirds of the world's iron ore supply doesn't love DRI–EAF. This is a value chain problem to solve".

One potential solution on the mining side is turning lower-grade iron ore into higher-grade iron ore – through grinding and purification processes – to reduce the silica content. The resulting iron ore would be of higher quality and suitable for DRI–EAF production.

Alternatively, on the steel production side, another solution is to develop ways to use lower-grade iron ore in low-carbon processes, such as large melting units, resulting in a DRI–Melt–BOF production process (See figure 8). Both types of technologies are still under development.

In its 2020 Iron and Steel Technology Roadmap, the International Energy Agency models that by 2050 around 20% of the world's steel production could be DRI–EAF based. This indicates that supply of high-quality iron ore is not expected to become the main limiting factor in decarbonising the steel industry in the short term.[80] In the longer term, availability may indeed become a limiting factor, but it will depend on the development of the processes mentioned above. And, the ability of refining lower grades of iron ore to suit DRI-EAF plants could provide a competitive advantage for some mining companies.

4 BUILDING COALITIONS TO ACCELERATE CHANGE

Finding solutions to overcome the barriers set out in Chapter 3 is a complex challenge, one that requires companies and organisations in the steel industry and wider ecosystem to work together. This is best achieved through creating coalitions to lead progress in specific areas, accelerating the goal of decarbonisation in the process. The vast majority of individuals interviewed for this report recognised this need for collaboration.

4.1 WORKING TOGETHER TO OVERCOME BARRIERS

Several coalitions have already been set up to drive the decarbonisation of the steel industry. They can be categorised by their objective: commercial, innovation or advocacy. Each has an important role to play in overcoming specific decarbonisation barriers.

- **Commercial** coalitions focus on commercialising specific decarbonisation pathways, as well as designing practices that can be replicated and scaled. One steel company researching multiple decarbonisation pathways said:

  "Companies that cannot produce DRI locally, due to limited availability of cheap and abundant green energy, will be looking for other partnership constructs".

- **Innovation** coalitions work jointly to develop new solutions and prove the effectiveness of new technologies. Often, this is achieved by providing funding for low-carbon solutions to remove or lower the financial barrier to innovation. Innovation coalitions often consist of a small number of companies and organisations with complementary knowledge and capability. As one global industry association said:

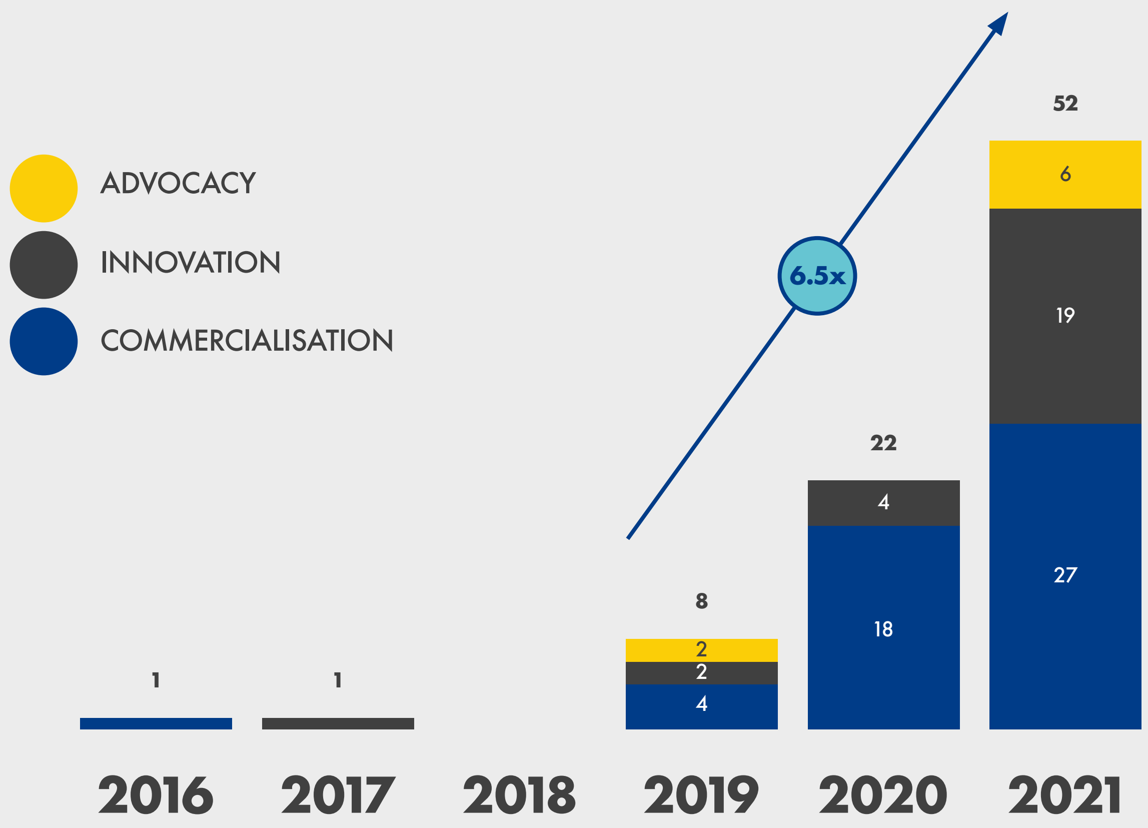
  "The next frontier is really forming partnerships that support technology transfer".

- **Advocacy** coalitions promote the development and implementation of policies to accelerate change and raise awareness of its importance. Typically, these alliances comprise a large membership that focuses on a specific topic. To decarbonise the steel industry, such alliances would concentrate on subsidies, green procurement policies, green steel certification or standards, or raising market demand in general. The more stakeholders involved, the greater the credibility of the alliance. One automotive original equipment manufacturer said:

  "When we create this sort of [broad] alliance, the voice we have in front of end customers and institutions is much higher".

All three types of coalitions have gained momentum since 2019 (see Figure 17), although commercial coalitions seem best-suited to accelerate steel decarbonisation because they focus on how to deliver more low-carbon iron ore and steel and how to deploy new technologies.

FIGURE 17: PARTNERSHIPS BY ANNOUNCEMENT YEAR AND FOCUS AREA | NON-EXHAUSTIVE [81]



4.2 COMMERCIAL COALITIONS ACCELERATE DECARBONISATION OF THE STEEL VALUE CHAIN

Three factors are critical for commercial cross-industry partnerships to succeed.

- The partnership should consist of a few members to ensure speed and maintain agility. In the words of one construction company executive:

  "The demand and green premium are there, but it is about making that transition [to decarbonised steel] with a small number of players. That is where the focus needs to be".

- Members should agree on a clear vision with intermediate goals as the purpose of the coalition and to guide decision-making. As a member of the International Council on Mining and Metals said:

  "If you have clarity on what your challenge is, you can then assess whether [potential coalition candidates] are also desperate to drive that change".

- The makeup of the coalition should offer complementary capabilities to deliver maximum breadth of knowledge.

One senior industry executive said:

"A great collaboration utilises the strengths of each of the players to mitigate the challenges within the sector".

Two other characteristics are important for coalitions working to decarbonise the steel industry.

- The coalition should be guided by an independent transition broker or orchestrator to facilitate the progress of members towards their joint vision and to interact with outside stakeholders including policymakers.[82] This was underpinned by a US-based construction company executive interviewed who said it was:

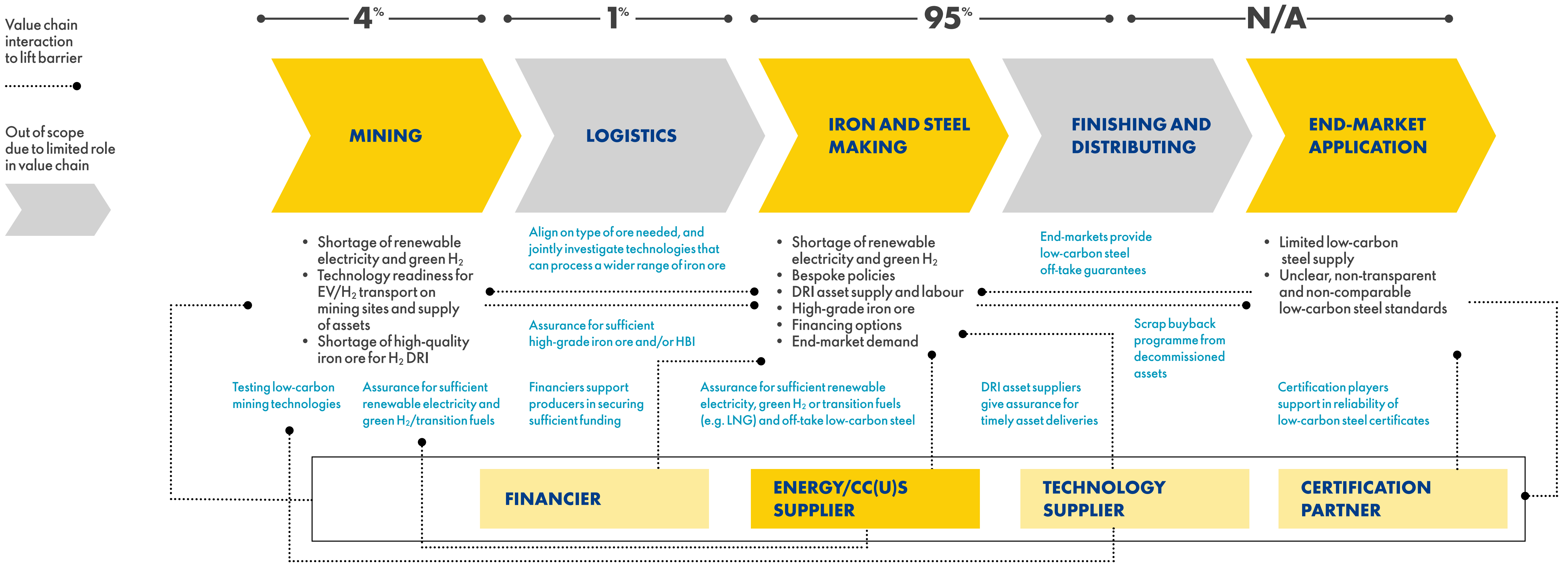
  "Disappointing to see that in decarbonisation initiatives, everyone just wants to do their own part. We need a player that coordinates everything".

- The coalition should be repeatable and scalable to build momentum in the transition to green steel.

4.3 A MINIMAL VIABLE COALITION IS NEEDED TO DECARBONISE THE INDUSTRY

Executives in the steel value chain identified four core stakeholders as the minimum number required to build a coalition to decarbonise steel successfully. As Figure 18 shows, each role – miners, steel producers, steel buyers, green energy producers and carbon, capture and storage companies – has several focus areas to work on to lift the barriers. In the wider ecosystem, four additional entities – financiers, technology providers, certification partners and governments – are regarded as enablers for success, but the consensus among interviewees was that they do not necessarily need to participate in a coalition.

FIGURE 18: VALUE CHAIN VIEW WITH KEY BARRIERS



Miners would be tasked with providing sustainably sourced, high-quality raw materials for green steel production. They could lower their emissions by shifting to low-carbon mining practices, such as electric or hydrogen-powered machines and equipment. Miners are essential to providing sufficient high-grade iron ore for DRI-EAF plants. However, they might also move downstream in the value chain and invest in DRI technology to provide low-carbon hot briquetted iron for EAF processes. As one mining executive said:

"We want to step into [green] sponge iron (production) to be in the value chain of fossil-free steel".

Steel producers are at the heart of steel decarbonisation. Their role is to advance the production of green steel by identifying, funding and implementing the best decarbonisation pathway for their plants. Setting up agreements with miners and energy providers to secure supply of the feedstock, and with end markets to ensure off-take, will help to derisk their investments. As a European steel producer spelled out:

"The largest challenges are around energy consumption for steel production, and partly around raw materials".

Alongside investing in new assets to drive the transition, steel producers can secure agreements with customers to buy their scrap steel to increase production of secondary steel.

The main role of **end markets** in steel decarbonisation coalitions is to guarantee sufficient demand for green steel to derisk investments upstream. These order guarantees, along with green premiums, would need to be established in larger markets. Supply and demand need to be aligned; at the moment demand is outpacing supply, as exemplified by a progressive European construction company:

"We are working with suppliers for low-carbon cement and steel. The problem is that we need so much and it is impossible to buy it all low carbon".

Besides guaranteeing demand, end market representatives can be crucial in giving the coalition a voice in local and regional policymaking.

The role of **energy providers and carbon, capture and storage companies** is to develop ways to provide sufficient affordable renewable energy and green hydrogen to power green steel production processes. In addition, they need to work with governments to build the associated infrastructure or carbon capture, utilisation and storage capability. Their trading divisions can help to reduce the long-term price risk across the value chain by developing bespoke bundled energy deals. And finally, they can support miners and steelmakers in the transition from fossil fuels to renewable energy.

ADDITIONAL ENTITIES THAT CAN SUPPORT COALITIONS

Technology providers can support coalitions by bringing expertise in design, engineering, procurement and construction, customising the decarbonisation pathway for a plant or mine.

Financiers are needed to fund investments across the value chain. One banker said:

"Decarbonising steel is the single biggest thing we are focusing on – it can only be done through collaboration".

All the banks we interviewed agreed on the importance of coalitions which can, over time, help to derisk their investment decisions. Next to providing funding, banks can contribute as they report on carbon emissions from investments and investments in greener practices help with their lower-carbon ambitions.

Independent certification bodies can enable end markets to charge green premiums by verifying and guaranteeing that green steel standards are met throughout the value chain.

Clear standards for green steel are often mentioned as an accelerator for commercialisation. A global classification company said:

"It is crucial that companies get to a consensus on the standards of low-carbon steel".

Support and clarity from **governments** is widely recognised as a key ingredient for making progress on decarbonisation. Especially in capital-intensive industries, a long-term government policy is essential for making investment decisions. With no clear policy from governments on decarbonisation in heavy industry, many participants remain hesitant to take action. Public-private partnerships offer a way to achieve clarity, derisk and speed up investments, and set standards for the wider ecosystem. This is also recognised by a Dutch regulatory body:

"For these large-scale projects, collaboration between companies and governments is needed. This concerns not just one government department, but several (infrastructure, permits, etc.)".

4.4 SETTING UP A COALITION FOR SUCCESS

The executives and senior managers we interviewed said that defining a long-term shared vision on creating possible coalition parties was relatively straightforward. However, translating this into a road map with short-term goals and actions – such as progressing discussions on investment and sharing commitment among the coalition participants – was more complex. These are the challenges coalitions need to overcome to succeed.

A coalition road map will help to set clear targets and actions for the next 10 years, including the use of transitional technologies. Decarbonising a steel plant involves high capital expenditure, so it is logical that investors are cautious about committing to a specific emerging technology without being certain that it will become the industry's technology of choice in the future – particularly if barriers or market conditions might change.

Definitions are an important aspect of the road map and help to ensure that all parties are referring to comparable decarbonisation goals – especially when they involve transitional technologies. One purchasing company said that making steel into a circular economy is an important sustainability target, although this was not part of the other purchasing companies' road map.

Agreeing on the purpose and short-term goals of the coalition – along with the corresponding actions for each coalition partner – depends largely on the participants and their mandates. Partners would benefit from deciding the framework on how to work together, how to derisk decarbonisation investments and how to create transparency into the coalition's decision-making processes.

It is important to recognise that opportunities, commitments and responsibilities will vary and reflect each coalition member's influence and impact on the value chain. The bigger the impact of a partner's actions, the higher the commitment needed from it. One Europe-based decarbonisation manager said:

"We need to act on the principle that the biggest shoulders should carry the largest weight".

It takes time to build a successful coalition, and individuals tasked with this important job need to bring trust, leadership and commitment, as well as patience and perseverance to the table.

5 SHELL PERSPECTIVES

Shell's target is to become a net-zero emissions energy business by 2050 or sooner. We have set out this ambition in our Powering Progress strategy which is aimed at contributing to a net-zero world, where society stops adding to the total amount of greenhouse gases in the atmosphere. It supports the ambitious goal to tackle climate change laid out in the Paris Agreement: to limit the rise in average global temperature to 1.5° Celsius.

Becoming a net-zero emissions business requires us to reduce emissions from our operations and from the fuels and other energy products we sell. A key part of this transformation involves the way we work with our customers. They come from many different sectors and several have announced targets to achieve net-zero emissions.

We believe that each sector will need to find its own way to achieve net-zero emissions – sectoral decarbonisation - and in each sector broad coalitions of businesses, governments and other parties are needed to identify and enable decarbonisation pathways towards a net-zero emissions future.

We have created a business – Sectors & Decarbonisation – that allows us to work more closely with our customers as they approach the decarbonisation barriers and opportunities ahead. Working with companies in each sector and with policy makers we hope to be able to increase ambition around reducing emissions, better enable infrastructure changes, and provide the low-carbon products and services to help our customers decarbonise.

Across the steel value chain, possible decarbonisation pathways in the various segments, from mines to end-markets, are becoming more technically and economically feasible. There is a strong movement towards transitioning to net-zero emissions steel production and completely removing embodied carbon across all end uses of this material.

Echoing some of the messages in this report, steel producers have highlighted to us their need to better understand the demand for green steel and the standards that automotive and construction end users are willing to accept. To ease the burden of investing in decarbonisation, they have expressed the need for financial support from governments.

Automotive and construction companies see embodied emissions from steel as a large part of their overall emissions. They are looking for stronger reassurance from the steel value chain that a sufficient and timely supply of green steel will be available to meet their needs.

In mining, since most emissions are Scope 3, mining companies have emphasised that the decarbonisation of steel is crucial to their own decarbonisation.

For energy providers such as Shell, long-term commitments from end consumers for low-carbon energy are necessary to underpin investments in new infrastructure, such as electrolysers, offshore wind farms, carbon sinks and pipelines.

A CALL TO ACTION

To enact change, one thing is certain: no one company can decarbonise alone. To successfully decarbonise, core stakeholders in the mining and steel production value chain must work together with end markets such as the automotive and construction industries. The companies and organisations interviewed for this report, as well as the conversations that Shell has had with customers and partners, all highlighted one key element to ensure change: the importance of a collaborative strategy to make significant decarbonisation progress.

A coalition with partners across the value chain, in addition to support from financial institutions and governments, will be required to trigger collective action, spark global and local conversations, drive increased public and private investment, and deliver tangible results.

Together with partners, customers and governments, we are focused on developing renewable energy hubs to help decarbonise industry, starting with Northwest Europe. Many industrial locations around the globe offer similar collaboration opportunities to develop clean energy hubs in other regions.

We now call on other committed organisations to join us and accelerate green steel production practices and demonstrate how these can be replicated around the world. We are ready to facilitate setting up a steel value chain coalition of first movers.

We believe that such a coalition can help to enable actions and investments by key companies and organisations. These include:

- Working towards a common approach to carbon accounting and standards in the value chain by developing standards that define what qualifies as "green".
- Creating a demand market for green products such as tenders specifying or qualifying the use of green materials. For instance, a tender to build a wind farm would score more points if it specifies using green steel and green cement.
- Seeking support from governments and authorities to accelerate permitting and gain financial aid to derisk the infrastructure needed for the decarbonisation value chain. As shown in Chapter 3, replacing a 7 million tonne BF-BOF plant with a new DRI–EAF plant in Europe is estimated to cost around €6 to 7 billion. Financial aid in the form of innovation funding could close the investment gap for steel companies.
- Advocating a level playing field in steel decarbonisation by adopting the carbon border adjustment mechanism (CBAM) in Europe. CBAM will help reduce the risk of carbon leakage by encouraging producers in non-EU countries to decarbonise their production processes.[83]

FORGING DECARBONISATION SOLUTIONS FOR STEEL CUSTOMERS

In the mining sector, Shell was chosen as one of eight winners (from an initial global response of 350 vendors) to develop a large-scale haul truck electrification system that could help decrease mining's reliance on diesel fuel and reduce carbon emissions. We are discussing piloting the integrated solution with eight mining companies in three different countries.

In steel making, we have a wide-ranging memorandum of understanding with Baosteel in China to purchase carbon-compensated steel[84] and green steel. The collaboration includes Shell electric vehicle charging points across Baosteel's facilities, as well as low-carbon solutions such as hydrogen and carbon capture and storage.

To deliver low-carbon pathways with steel producers, we have developed capabilities to model the complex relationships and interactions that occur between manufacturing processes, energy use and the associated emissions. These are developed from Shell's own experience in analysing data from its plants and using those data to make operations more efficient. We are also partnering with AVEVA and Schneider Electric to create a commercial service which combines this capability with their integrated digital engineering, operational process, and energy optimisation technologies.

In parallel, we are collaborating with several automotive manufacturers in Europe and North America on the implementation of their decarbonisation plans, by supplying biomethane and renewable power, among other solutions.

ENERGY SOLUTIONS FOR THE STEEL VALUE CHAIN

Natural gas

The first major step in the path towards green steel making is to move to gas-based combustion. Shell is present throughout the natural gas value chain, from upstream production to trading and wholesale supply. As the leading liquified natural gas supplier in the world, Shell is working hard to make gas available to steel producers to support their decarbonisation plans.

Although a hydrocarbon, natural gas emits between 45% and 55% lower greenhouse gas emissions than coal when used to generate electricity, according to the International Energy Agency. Gas also produces less than one-tenth of the air pollutants that coal does when used to generate electricity.

Renewable power

Electricity already plays a major role in steel production today through EAFs. With EAFs set to increase their share of global production as the industry decarbonises, it is increasingly important to source renewable power for their operation.

Shell is investing in both solar power projects and wind farms to diversify its energy offerings. For instance, as part of the CrossWind joint venture (Shell interest 79.9%) off the Netherlands coast, we are building a 760 megawatt (MW) offshore wind farm, Hollandse Kust (noord), that will start producing power in 2023. When operational, around a third of the power generated will be taken by an anchor customer to help deliver its decarbonisation plans. Some of the power will be for Shell's own use and for trading in the open market. The balance will power a 200 MW electrolyser which is set to be Europe's largest renewable hydrogen plant when it becomes operational in 2025.

Hydrogen production

Gaseous energy carriers are and will continue to be needed in sectors where electricity falls short, such as heavy goods transport by road, aviation and shipping. But this is mainly the case in industries such as those in the steel value chain. Hydrogen produced from renewable energy is, at present, the primary abatement solution that will lead the steel industry to carbon neutrality.

We have already started to produce green hydrogen at the Shell Energy and Chemicals Park Rheinland in Germany and, subject to a final investment decision, plans are now under way to expand capacity tenfold, supported by a grant from the European Climate, Infrastructure and Environment Executive Agency (CINEA).

In China, Shell has started operation of the 20 MW power-to-hydrogen electrolyser in Zhangjiakou, a joint venture between Shell (China) Limited and Zhangjiakou City Transport Construction Investment Holding Group Co. Ltd. It is currently one of the world's l hydrogen electrolysers and the companies have plans to scale up to 60 MW in the next two years in phase 2. Using onshore wind power, the project produces hydrogen for public and commercial transport in the Beijing-Tianjin-Hebei region, helping to decarbonise its mobility sector.

Elsewhere, we are partnering in the NorthH2 project in the Netherlands – one of the largest renewables-based hydrogen projects in Europe – with Gasunie, Groningen Seaports, RWE and Equinor. The project is expected to produce 4 gigawatts of green hydrogen by 2030, powered by wind farms in the North Sea.

Carbon capture and storage

When selecting decarbonisation pathways for the steel value chain, steelmakers have to consider multiple factors such as their ability to invest capital, the remaining lifespan of existing assets and the competitiveness of their steel products. With commercial-scale, 100% green hydrogen-based steel manufacturing many years away, solutions such as carbon capture and storage offer a path to reduce carbon emissions from existing processes.

We are already involved in two carbon capture and storage (CCS) projects. In Alberta, Shell Canada operates Quest, a CCS facility that captures, transports and stores more than 1 million tonnes of CO_2 every year from the Scotford Upgrader. On Barrow Island, off the northwest coast of Western Australia, Shell Australia holds a 25% interest in the Gorgon liquefied natural gas project which also uses CCS.

We are also involved in the development of several other carbon capture and storage projects. In the Netherlands, a joint venture called Porthos – between Energie Beheer Nederland (EBN), Gasunie and the Port of Rotterdam Authority – aims to transport CO_2 from industrial plants in the Port of Rotterdam and store it in empty gas fields beneath the North Sea.

The project aims to capture up to 2.5 million tonnes of CO_2 per year from 2024 and could make a significant contribution to meeting the Netherlands' climate ambitions. In 2021, Shell Netherlands, along with Air Liquide, Air Products and ExxonMobil, signed the final contracts with Porthos for the transport and storage of CO_2 from their installations at Rotterdam Port.

We are also involved in a collaboration between EBN, Gasunie, Shell and TotalEnergies – called Aramis – which is designed to use depleted gas fields beneath the Dutch North Sea for carbon storage. The project is expected to come on-stream as early as 2026 with 5 million tonnes of CO_2 stored in the launch phase with sufficient flexibility to facilitate future CO_2 sources and storage options for further expansion.

CO_2 and hydrogen transport

Through public-private partnerships with government and industry in the Netherlands and Germany, we are supporting the development of the Delta Corridor project by 2027. It comprises four pipelines between the Port of Rotterdam and , Chemelot in the Netherlands and the German Rhineland region to provide access to clean hydrogen and carbon capture and storage.

The Delta Corridor will unlock around 22 million tonnes of avoided and abated emissions a year. In addition, branches to the Delta Corridor could provide decarbonisation options in Belgium and other parts of Germany. The access will be essential in helping harder-to-abate industries in mainland Europe to meet the EU's 2030 climate targets.

ENERGY SOLUTIONS FOR THE MINING VALUE CHAIN

Shell has a portfolio of decarbonisation solutions for mining companies that span the entire mining value chain. The availability of these offerings differ around the world.

At Shell, we have been focusing on how to decarbonise diesel-powered mobile equipment which accounts for around 40-50% of mining's Scope 1 and 2 CO_2 emissions. Shell is investing in short and medium-term technologies to help mining companies reduce their emissions. Two examples of how we are helping to do this are low-carbon biofuels and electrification.

Low-carbon biofuels

Low-carbon biofuels are one of the only solutions available today for customers to decarbonise harder-to-abate sectors. Shell is already one of the world's largest traders and blenders of biofuels and our priority is to increase our low-carbon fuels production capacity by commercialising advanced technologies. Alongside our focus on new technology, we have invested in existing solutions to increase supply. For example, we are already one of the world's largest producers of bioethanol. In 2021, Raízen, our joint venture in Brazil with Cosan, produced around 2.5 billion litres of ethanol, from treated bagasse (a type of sugarcane juice) and straw.

Electrification solutions for mining

Together with our partners, we have developed a fully integrated electrification solution which can be used alongside existing technology at mines, offering the industry the potential to shift away from a long-standing reliance on diesel. The pilot project[85] combines a high-powered battery solution with ultrafast charging and a standardised micro-grid energy system which can be further decarbonised with renewable electricity generation on-site or through the grid.

The solutions are built around technologies from leading battery manufacturers, supercapacitor innovations, energy management systems and charging infrastructure, all of which help to support a mine operational and mobility needs.

SOURCES

1. World Steel Association (2022), World Steel in Figures
2. International Energy Agency (2020), Iron and Steel Technology Roadmap
3. OEM usually refers to original equipment manufacturers. In this report it refers to automotive and machinery and equipment manufacturers
4. Others include a research and analysis organisation and a decarbonisation technology developer
5. Regions refers to the organisation's headquarters; most of the organisations involved operate globally
6. World Steel Association (2022), World Steel in Figures; International Energy Agency (2020), Iron and Steel Technology Roadmap; World Steel Dynamics (2021), Strategic Insights from World Steel Dynamics.
7. World Steel Association (2021), Top steel-producing countries, 2021
8. The production of iron ore feedstock using technologies and processes that result in much lower emissions compared to conventional production
9. There is currently no agreed definition of what constitutes green steel. The World Steel Association regards it as low-carbon steel which is manufactured using technologies and practices that result in significantly lower emissions compared to conventional production. According to Klockner & Co, a metal solutions provider, green steel refers to steel produced using a low-carbon process
10. According to the European Environment Agency, green electricity refers to electricity produced from resources such as solar, wind, geothermal, biomass, and low-impact hydro facilities
11. Green hydrogen is the production process which is powered by renewable energy sources, such as wind or solar
12. Iron and steel emissions include steel production and finishing (downstream processes)
13. Iron and steel indirect emissions originate from power generation through combusting steel off-gases and/or grid off-take
14. Iron and steel direct emissions originate from fossil fuel combustion and industrial processes
15. Nature Communications (2021), Efficiency stagnation in global steel production urges joint supply and demand-side mitigation efforts; International Energy Agency (2020), Iron and Steel Technology Roadmap; Belfer Center Global Efficiency Intelligence (2019), How Clean is the U.S. Steel Industry?; International Energy Agency (2021), World Energy Outlook 2021; Deloitte analysis
16. Excluding some steel finishing and end-market applications
17. On average, CO_2 intensity for a BF–BOF plant is around 2.6 tonnes per tonne of steel and 0.2 tonnes per tonne of steel for scrap-based EAF (see Mission Possible Partnership (2021), The Net Zero Steel Sector Transition Strategy)
18. International Energy Agency (2021), Net Zero by 2050: A Roadmap for the Global Energy Sector
19. Nature Communications (2021), Efficiency stagnation in global steel production urges joint supply-and demand-side mitigation efforts; International Energy Agency (2020), Iron and Steel Technology Roadmap; Belfer Center Global Efficiency Intelligence (2019) How Clean is the U.S. Steel Industry?
20. World Steel Association (2021), Top steel-producing companies 2021
21. International Energy Agency (2020), Iron and Steel Technology Roadmap
22. STEPS refers to IEA's Stated Policies Scenario
23. SDS refers to IEA's Sustainable Development Scenario
24. World Steel Association (2022), World Steel in Figures; International Energy Agency (2020), Iron and Steel Technology Roadmap; World Steel Dynamics (2021), Strategic Insights From World Steel Dynamics
25. Siemens Gamesa (2022), A Clean Energy Solution - From Cradle to Grave
26. A 5-megawatt offshore wind turbine requires about 900 tonnes of steel for reinforced concrete foundations, rotor hubs and nacelles, and the tower
27. Definition according to Greenhouse Gas Protocol:
    Scope 1: CO_2-equivalent emissions from owned or controlled sources;
    Scope 2: CO_2-equivalent emissions from the generation of purchased electricity, steam, heating and cooling the reporting company consumes; and
    Scope 3: All other emissions that occur in a company's value chain, both upstream (procurement of materials, assets, services) and downstream (transport, waste disposal, processing, etc.)
28. Definition: CO_2 emissions associated with materials and construction processes throughout the whole life cycle of a building or infrastructure (see Carbon Cure, What is Embodied Carbon?)
29. World Steel Association, Steel in automotive
30. While there is no universally accepted definition of green steel, it refers to steel manufactured using technologies and practices that generate significantly lower greenhouse gas emissions compared to conventional production
31. Mission Possible Partnership, This is how the steel industry is forging a path to net-zero
32. World Steel Dynamics (2021), Strategic Insights from World Steel Dynamics
33. TRL refers to Technology Readiness Level
34. The steps within the iron ore electrolysis vary based on the electrowinning process
35. MOE refers to Molten Oxide Electrolysis
36. The cell interior temperature of the Molten Oxide Electrolysis is 1,550 °C
37. International Energy Agency (2020), Iron and Steel Technology Roadmap; Deloitte analysis
38. PBL (2019), Decarbonisation Options for the Dutch Steel Industry; Green Steel for Europe (2021), Technology Assessment and Roadmapping
39. Green methanol can be used as biofuel for transport or cooking as well as an energy carrier for storing renewable electricity. (Methanol Institute, 2022)
40. HYBRIT is a collaboration between SSAB, LKAB and Vattenfall to develop fossil-free steel in Sweden using hydrogen and green electricity in a DRI-EAF decarbonisation route
41. ArcelorMittal (2022), ArcelorMittal successfully tests partial replacement of natural gas with green hydrogen to produce DRI
42. Recharge (2022), Largest ever green steel investment | Salzgitter approves €723m spend on first stage of hydrogen-focused project
43. Tata Steel (2022), Tata Steel invests 65 million euro in next phase hydrogen route

SOURCES

44. Not all iron ore is equal. Geological processes have led to iron content levels of between 55% and 65% in some ores, which are considered high grade. In the DR furnace, iron oxide is reduced in situ, with temperatures sufficient to remove the oxygen, but not high enough to fully melt the ore. No fluxes are introduced to remove impurities from the final DRI either. For this reason, silica and alumina levels in iron ores entering the DR furnace need to be particularly low to avoid prohibitive cost escalation at the EAF steelmaking stage (see Fastmarkets (2021), Understanding the high-grade iron ore market
45. Boston Metal (2022), Transforming Metal Production
46. Nature Communications (2021), Efficiency stagnation in global steel production urges joint supply-and demand-side mitigation efforts.
47. Norgate et Al. (2010), Energy and greenhouse gas impacts of mining and mineral processing operations; Deloitte analysis'.
48. Mechanical dewatering is a process to separate water from solid rock to improve efficiency and reduce disposal volumes and water wastage
49. Diesel engines can convert around 40% of fuel into electricity, the rest is waste heat. Using waste heat recovery, diesel consumption can be reduced by about 7% (Mining.com, 2020)
50. A grid is fine-tuned to make optimal use of the resources available. A new, renewable resource should be integrated in a way to keep the grid efficient, reliable and economical (see IEEE, 2018)
51. HVO refers to Hydrotreated Vegetable Oil
52. BEV refers to Battery Electric Vehicle
53. Deloitte analysis
54. World Steel Association (2022), World Steel in Figures; International Energy Agency (2020), Iron and Steel Technology Roadmap; World Steel Dynamics (2021), Strategic Insights From World Steel Dynamics
55. Projections from a green hydrogen producer; De Jong et al. (2017, Cost optimization of biofuel production.
56. PBL (2019) Decarbonisation Options for the Dutch Steel Industry; Learn | OpenEnergyMonitor; Deloitte analysis
57. Based on mid-2021 gas and coal prices
58. Financial Times, May 14, 2022; X-rates, average EUR to USD rate at €1 = $1.095 (average rate for Feb, Mar, Apr and May)
59. MetalMiner (2022), HRC and CRC Steel Prices Stagnate Amid Energy Crisis
60. European view, European steel plants are typically more CO_2 efficient than the global average
61. CCS rate assumed 52%, based on 70% capture rate for BF and 23% for coke oven. 20% CCS cost reduction towards 2050, starting at $120/t CO2 captured
62. Calculations assume DRI-EAF co-located
63. Feedstock and energy costs exclude raw materials, H_2 costs: $5.5/kg in 2020
64. Production costs assume asset upgrade cost for BF-BOF and asset upgrade costs BF-BOF to DRI-EAF, written off over 20-year lifetime and include maintenance cost
65. Carbon price ranging from $38/t in 2020, to $324/t CO_2 in 2050, excludes EU ETS free allowances
66. Increase in cost of H2 DRI-EAF explained by increasing energy price
67. International Energy Agency (2020), Iron and Steel Technology Roadmap, BMWI; PBL; TSN IJmuiden (2021), Klimaatneutrale Paden TSN, ICF & Fraunhofer, EIB; ECB, Deloitte analysis
68. A stock-keeping unit is a unit of measure in which the stocks of a material are managed It often contains a scannable bar code which allows vendors to automatically track the movement of inventory
69. International Energy Agency (2020), Iron and Steel Technology Roadmap
70. Via the European Union Emissions Trading System and the recently adopted Carbon Border Adjustment Mechanism; Deloitte (2022), CBAM adopted by EU Parliament
71. Such as the Important Projects of Common European Interest
72. OECD (2021), Carbon Pricing in Korea
73. Including both direct and indirect emissions
74. The Sustainable Development Scenario (SDS) refers to an Ambitious IEA scenario to net-zero emissions for the energy system by 2070, includes widespread deployment of CC(U)S and/or DRI with hydrogen
75. In the Stated Policies Scenario (STEPS), BF-BOF remains dominant for producing steel towards 2050
76. World Steel Association (2022), World Steel in Figures; International Energy Agency (2020), Iron and Steel Technology Roadmap
77. Deloitte analysis.
78. ResponsibleSteel (2022) ResponsibleSteel International Standard Version 2.0
79. HBI refers to Hot briquetted iron:
Source: ResponsibleSteel GHG Emissions Requirements for 'Steel Certification'; ResponsibleSteel's Members and Associates; XCarb Green Steel Certificate; Bluemint Certification; Environmental Product Declaration Library
80. International Energy Agency (2020), Iron and Steel Technology Roadmap
81. Company announcements; Deloitte analysis
82. John Hagel III, Deloitte Center for the Edge (2021, The Journey Beyond Fear; John Kotter, Harvard Business Review (2012), The 8-step process for leading change
83. Jacqueline Cramer, Amsterdam Economic Board (2020), How Network Governance Powers the Circular Economy.
84. European Commission (2021), Carbon Border Adjustment Mechanism: Questions and Answers
85. Carbon-compensated steel is where emissions generated from steel manufacturing are offset using nature-based carbon credits
86. Shell (2022), Shell builds a winning consortium to accelerate the electrification of off-road mining vehicles

LEGAL DISCLAIMER

The companies in which Shell plc directly and indirectly owns investments are separate legal entities. In this report, Decarbonising Steel: Forging New Paths Together, "Shell", "Shell Group" and "Group" are sometimes used for convenience where references are made to Shell plc and its subsidiaries in general. Likewise, the words "we", "us" and "our" are also used to refer to Shell plc and its subsidiaries in general or to those who work for them. These terms are also used where no useful purpose is served by identifying the particular entity or entities. ''Subsidiaries'', "Shell subsidiaries" and "Shell companies" as used in this report refer to entities over which Shell plc either directly or indirectly has control. Entities and unincorporated arrangements over which Shell has joint control are generally referred to as "joint ventures" and "joint operations", respectively. "Joint ventures" and "joint operations" are collectively referred to as "joint arrangements". Entities over which Shell has significant influence but neither control nor joint control are referred to as "associates". The term "Shell interest" is used for convenience to indicate the direct and/or indirect ownership interest held by Shell in an entity or unincorporated joint arrangement, after exclusion of all third-party interest.

Forward-Looking Statements

This report contains forward-looking statements (within the meaning of the U.S. Private Securities Litigation Reform Act of 1995) concerning the financial condition, results of operations and businesses of Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management's current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Shell to market risks and statements expressing management's expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as "aim", "ambition", ''anticipate'', ''believe'', ''could'', ''estimate'', ''expect'', ''goals'', ''intend'', ''may'', "milestones", ''objectives'', ''outlook'', ''plan'', ''probably'', ''project'', ''risks'', "schedule", ''seek'', ''should'', ''target'', ''will'' and similar terms and phrases. There are a number of factors that could affect the future operations of Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this report, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell's products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, judicial, fiscal and regulatory developments including regulatory measures addressing climate change; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; (m) risks associated with the impact of pandemics, such as the COVID-19 (coronavirus) outbreak; and (n) changes in trading conditions. No assurance is provided that future dividend payments will match or exceed previous dividend payments. All forward-looking statements contained in this report are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional risk factors that may affect future results are contained in Shell plc's Form 20-F for the year ended December 31, 2021 (available at www.shell.com/investor and www.sec.gov). These risk factors also expressly qualify all forward-looking statements contained in this report and should be considered by the reader. Each forward-looking statement speaks only as of the date of this report, November 9, 2022. Neither Shell plc nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this report.

Shell's net carbon footprint

Also, in this report we may refer to Shell's "Net Carbon Footprint" or "Net Carbon Intensity", which include Shell's carbon emissions from the production of our energy products, our suppliers' carbon emissions in supplying energy for that production and our customers' carbon emissions associated with their use of the energy products we sell. Shell only controls its own emissions. The use of the term Shell's "Net Carbon Footprint" or "Net Carbon Intensity" are for convenience only and not intended to suggest these emissions are those of Shell plc or its subsidiaries.

Shell's net-zero Emissions Target

Shell's operating plan, outlook and budgets are forecasted for a ten-year period and are updated every year. They reflect the current economic environment and what we can reasonably expect to see over the next ten years. Accordingly, they reflect our Scope 1, Scope 2 and Net Carbon Footprint (NCF) targets over the next ten years. However, Shell's operating plans cannot reflect our 2050 net-zero emissions target and 2035 NCF target, as these targets are currently outside our planning period. In the future, as society moves towards net-zero emissions, we expect Shell's operating plans to reflect this movement. However, if society is not net zero in 2050, as of today, there would be significant risk that Shell may not meet this target.

Forward Looking Non-GAAP measures

This report may contain certain forward-looking non-GAAP measures such as cash capital expenditure and divestments. We are unable to provide a reconciliation of these forward-looking Non-GAAP measures to the most comparable GAAP financial measures because certain information needed to reconcile those Non-GAAP measures to the most comparable GAAP financial measures is dependent on future events some of which are outside the control of Shell, such as oil and gas prices, interest rates and exchange rates. Moreover, estimating such GAAP measures with the required precision necessary to provide a meaningful reconciliation is extremely difficult and could not be accomplished without unreasonable effort. Non-GAAP measures in respect of future periods which cannot be reconciled to the most comparable GAAP financial measure are calculated in a manner which is consistent with the accounting policies applied in Shell plc's consolidated financial statements.

The contents of websites referred to in this report do not form part of this report.

We may have used certain terms, such as resources, in this report that the United States Securities and Exchange Commission (SEC) strictly prohibits us from including in our filings with the SEC. Investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov.

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