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FORUM

Net-Zero Industry Tracker

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Contents

Foreword

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By 2050, the global economy is expected to accommodate and serve 25% more people,[1] 50% more city dwellers,[2] and 100% more purchasing power in the global middle class.[3] Such developments will have tremendous repercussions for the global industries that provide the basic materials and energy required to sustain modern society, from housing to consumer goods. These industries are today's most significant contributors to anthropogenic emissions. In business-as-usual scenarios,[4,5] through 2050, demand for energy and industrial products is projected to grow by 30-80%. Industries will continue to be vital to our future; the effective decarbonization of their processes and value chains is crucial to achieving our climate objectives.

While efforts are under way and commitments are being made, the reality of net zero for these industries is lagging and extrapolating from today's speed of progress will fall far short. Today's gap is considerable, and building transparency into this reality to elevate the discussion on how to structurally solve the challenge is key to addressing an under-served portion of the transition. While it is encouraging to see the adoption of standardization and monitoring of sustainability metrics at national levels in carbon-intensive sectors such as power generation, buildings and transport, significant gaps remain in heavy industries.

There have been multiple challenges; complex supply chains, multiple production processes, global fragmentation, etc. It is time to close the gaps with timely and consistent monitoring of industrial decarbonization. Progress tracking will help heavy industries determine the trajectory of their transformations, maintain a steady pace of progress and inform necessary course corrections.

The World Economic Forum has benchmarked countries' energy transition through the Energy Transition Index for ten years. We are leveraging our experience to lay the foundation of a robust cross-industry platform that will track sectors' journeys to net zero. Such a platform is needed now more than ever. The ongoing energy crisis, sky-high prices of energy and materials, and persistent risk of supply shortages are disrupting industrial value chains down to end consumers. This is the time for industries and governments to double down on efforts to accelerate the decarbonization of industrial processes, improve energy efficiency and reduce their dependence on fossil fuels.

There is much to be done. International standards need to define "low-emission" industries. Low-carbon production technologies need to demonstrate their value at commercial scale. Consumer awareness and acceptance must evolve to generate demand for low-emission products. Infrastructures required to develop and integrate low-carbon processes must be developed. Economically viable low-carbon markets need to emerge. Investments must be "de-risked" to accelerate capital inflows. Adequate policy frameworks can help enable and incentivize transformation. These and other objectives cannot be achieved without a paradigm shift in multistakeholder collaboration across extended industrial ecosystems. Neither can they be achieved without keeping equity and justice at the heart of industries' transformations. People's livelihoods and opportunities depend on it.

Industrial decarbonization may be one of the most daunting challenges of the energy transition. Yet, we want to be optimistic. Industry pathways to net zero have been charted; transparency is improving. If the global ambition and collaborative spirit witnessed at COP26 and at the 2022 World Economic Forum Annual Meeting in Davos spark concrete action, we could see this decade become one of the major breakthroughs for net-zero industries. The time for action is now.

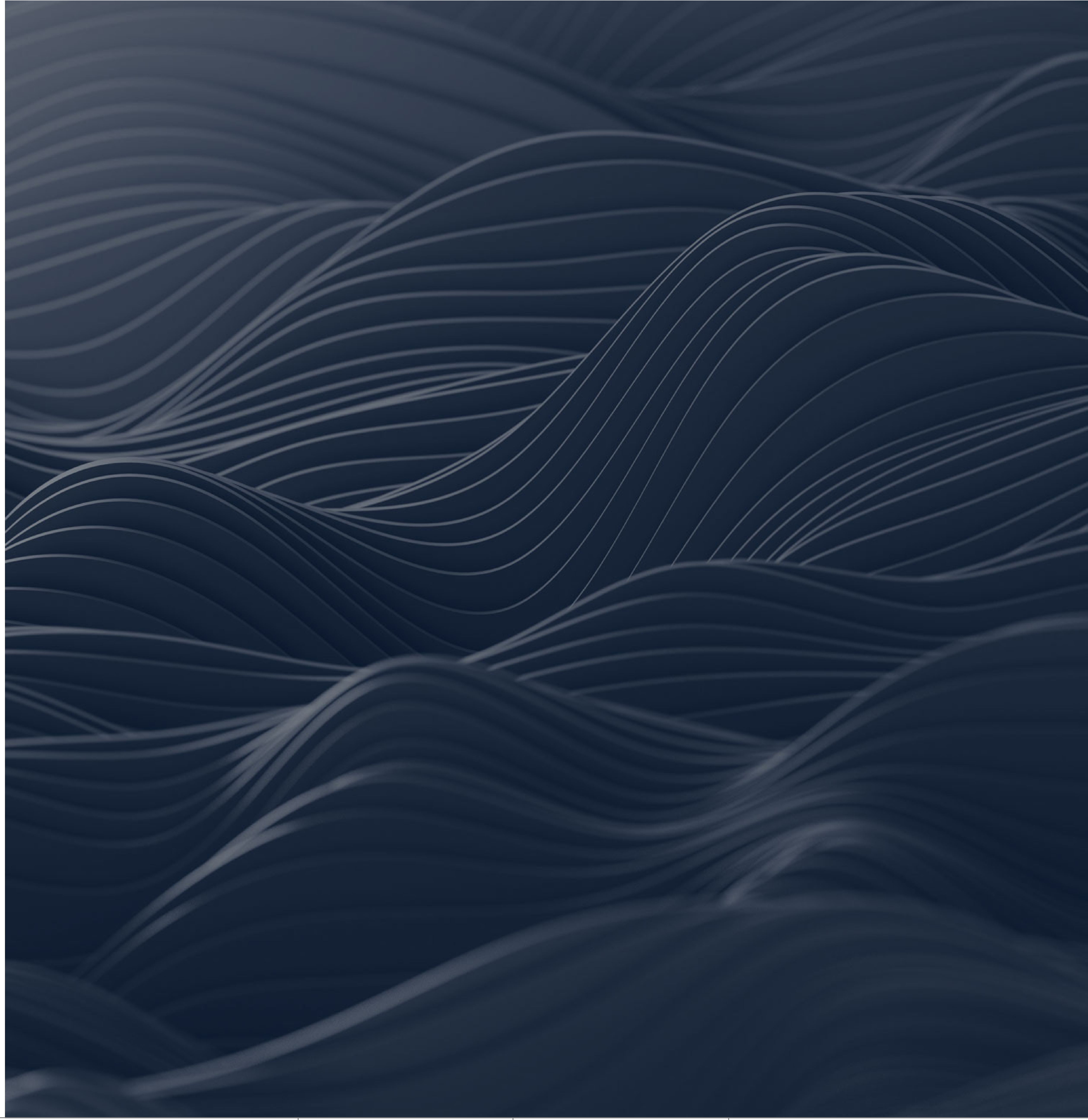
Executive summary

Industrial sectors account for nearly 40% of global energy consumption[6] and more than 30% of global greenhouse gas emissions.[7] The transformation of these sectors is pivotal to reaching net-zero emissions by 2050. This report by the World Economic Forum, in collaboration with Accenture and supported by expert input from over 40 organizations, establishes a new framework to monitor and support the progress of heavy industries towards net zero.

The challenges associated with industrial decarbonization are typically more complex than those of other carbon-intensive sectors (e.g. power, transportation, buildings, etc.). But they are also relatively less well understood. Gaps in data and discrepancies in key terminologies, definitions, and industry and emission boundaries contribute to a lack of visibility on progress. This tracking initiative aims to provide companies, policy-makers and consumers with the necessary transparency to ensure that action and investments are targeted and balanced.

The framework follows a holistic approach and is designed to concurrently track industries' "net-zero performance" and "net-zero readiness". It identifies a set of standard metrics to assess emissions reduction and energy efficiency to evaluate performance. It proposes emission intensity targets to inform sectoral net-zero transition strategies and highlights information gaps to improve transparency further. While industries differ in products, processes and business models, their transformation will rely on the evolution of common enablers that are often beyond the control of any single industry. The framework assesses sectoral readiness for net zero by evaluating key enablers such as the readiness of technology, access to the enabling infrastructure, the robustness of supporting policy frameworks, the strength of demand signals for low-emission products and the availability of capital for investments in low-emission assets. Efforts to improve industries' net-zero readiness across these dimensions are critical to progress industries' net-zero performance.

The report acknowledges that there are efforts under way. Net-zero commitments, decarbonization strategies, technology partnerships, low-carbon pilot projects, and discussions around green products and premiums have emerged. Despite this, no industry is anywhere near where it needs to be by 2050 and complex challenges within and across the industries remain. The report highlights sector-specific accelerators and priorities for six industries (steel, cement, aluminium, oil, natural gas and ammonia) and outlines seven cross-sectoral recommendations for immediate action.



1. **Industries' net-zero transformations require a new level of ambition in multistakeholder collaboration.** Breakthrough solutions are seldom found within a single firm or even industry. That's why industrial ecosystems need to join forces beyond traditional partnerships. Three archetypal partnerships, detailed in the recently released *Fostering Effective Energy Transition 2022* report,[8] should be built upon and replicated: collaboration between customers and suppliers (e.g. offtake agreements); collaboration among industry and cross-industry peers (e.g. CO_2 handling infrastructure); and collaboration across the broader ecosystem of industrial stakeholders, including governments, policy-makers, financiers, researchers and NGOs.

2. **Common standards for "low-emission" production thresholds need to be established for industrial companies to calibrate the transformation of their key production processes.** Net-zero targets are necessary but insufficient to drive the year-on-year progress required. Emission intensity trajectories at a product level (e.g. steel, cement) are essential to guide consistent and timely progress. Industry standards (e.g. Aluminium Stewardship Initiative[9] or Responsible Steel[10]), multistakeholder collaboration (e.g. *Achieving Net Zero Heavy Industry Sectors in G7 Members* report[11]) and product certification systems will be essential to define such trajectories.

3. **More full-scale demonstration projects need to be developed to accelerate the commercial readiness of low-emission technologies.** Many low-emission production technologies have already reached large prototype and even demonstration phases, and can drastically reduce emissions (e.g. -82% for natural gas, -95% for cement and steel, and -100% for ammonia). However, at the current pace, these technologies won't be commercially ready for industry adoption before the second half of the decade (e.g. 2025 for steel,[12] and 2030 or beyond for cement[13] and aluminium[14]).To accelerate the commercialization of these solutions and drive costs down, industrial firms need to double down on their efforts to develop full-scale demonstration or early commercial projects.

4. **Broad adoption of low-emission technologies will be at risk if the pace of investments in enabling infrastructures does not pick up drastically.** Most industry decarbonization pathways rely on low-carbon power, clean hydrogen (blue and green) and carbon capture. To meet the projected needs of the six focus sectors by 2050, capacities of global CO_2 storage and clean hydrogen production infrastructures need to grow 64-fold and 8-fold, respectively, from where they are today. Nearly 1,700 gigawatts (GW) of clean power will need to be added. This will require approximately $4.2 trillion in infrastructure investments over the next 30 years.

5. **Demand signals for low-emission products are emerging but must be strengthened and scaled up.** Decarbonizing the six industries could require over $2.1 trillion in capital expenditures in production assets. Such investments can only materialize if green premiums exist to grant producers and investors acceptable returns for their risk. Understanding end consumer demand and public and private buyers' commitments would help provide producers visibility on low-emission products' offtake volume and price (e.g. First Movers coalition[15]). Establishing adequate carbon footprint product labelling standards would help consumers make more informed decisions and advocate for new types of products.

6. **Public policy can reinforce all enabling dimensions and support the emergence of differentiated and economically viable low-emission markets for first movers.** The trade-exposed nature of commodity markets is particularly challenging to decarbonization. Stable policy frameworks are necessary to level the playing field for first movers that are willing to invest in higher-cost, low-emission production. Potential approaches limiting the risk of carbon leakage include but are not limited to a price on carbon combined with a border-adjustment mechanism, carbon contracts for differences, preferential public procurement (e.g. California Buy Clean Act[16]), material mandates, or quotas.

7. **Adequate risk-sharing mechanisms, supporting taxonomies and public financial support can accelerate the flow of private capital into low-emission industries.** Companies' investments in low-emission assets are riskier due to their dependencies on new technologies and infrastructure. Collaboration across industries and value chains can enable risk-sharing while providing direct market routes. Favourable taxonomies and public funding in the form of grants, low-interest and concessional loans, etc. can also reduce companies' risk exposure. Multilateral public-private partnerships to finance low-emission projects would help channel the necessary capital into the first commercial-scale assets.

Establishing net-zero roadmaps for industries is essential to keep the 2050 goal within reach. So is appropriately measuring progress and improving transparency along the way. This first edition of the Net-Zero Industry Tracker report sets the World Economic Forum's ambition to establish a robust tracking platform that supports the emergence of low-carbon industries by the decade's end. The current energy crisis presents an excellent opportunity to pick up the pace of industrial decarbonization. Now is the time to act.

1

Mission and methodology

MISSION STATEMENT

Establish a comprehensive tracker for all stakeholders (e.g. companies, investors, financial institutions, governments, policy-makers, etc.) to monitor and accelerate the net-zero transformation of industries.

KEY OBJECTIVES

Support the global effort around industry net-zero transformation by providing all stakeholders:

A **framework** and **methodology** to understand industrial emissions drivers and net-zero transformation enablers.

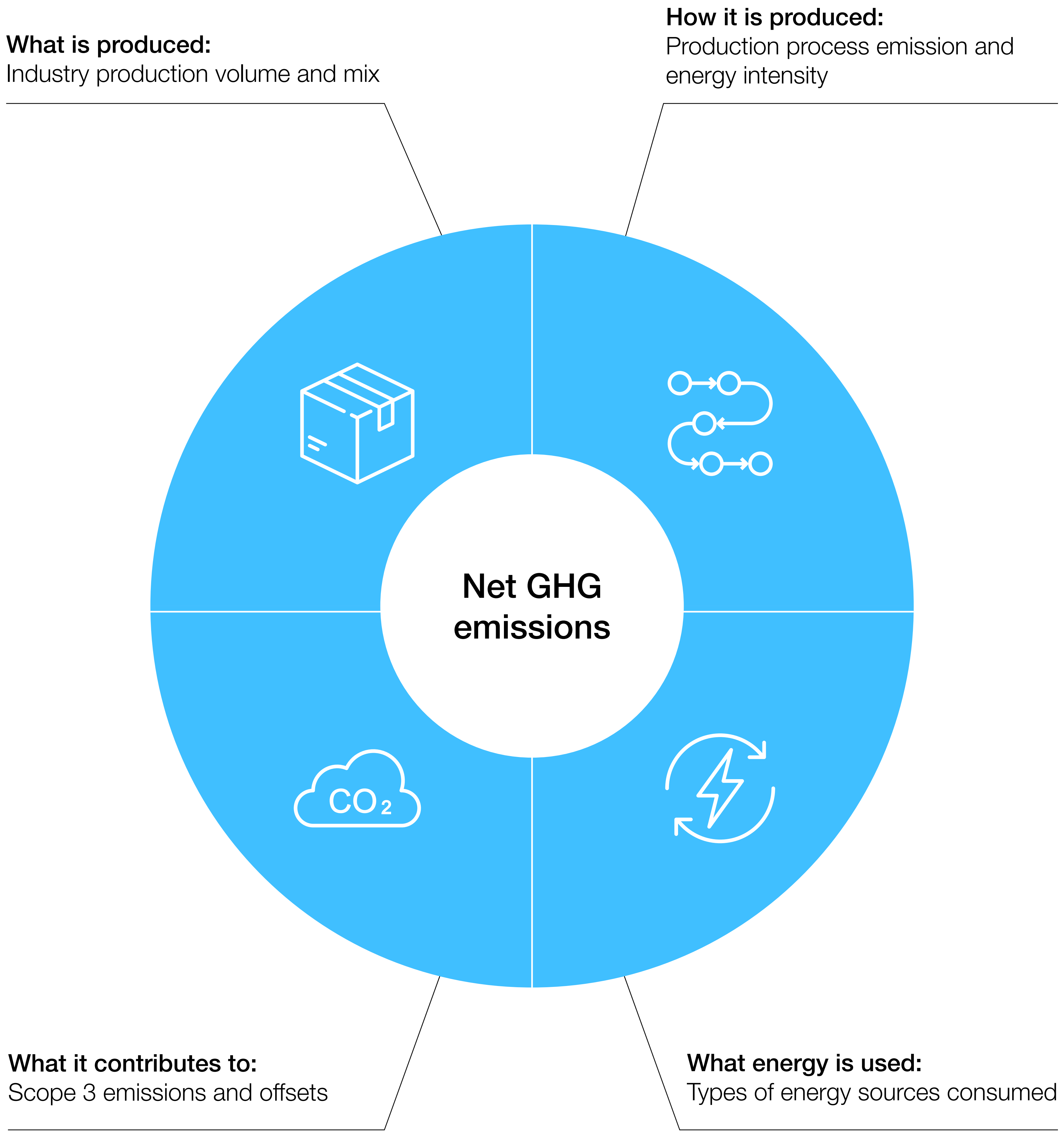
Quantitative and **qualitative scorecards** to track industry progress towards net zero over time.

Priority areas for industries to act upon and accelerate progress.

The Net-Zero Industry Framework combines two complementary lenses to track industries' progress on the ground.

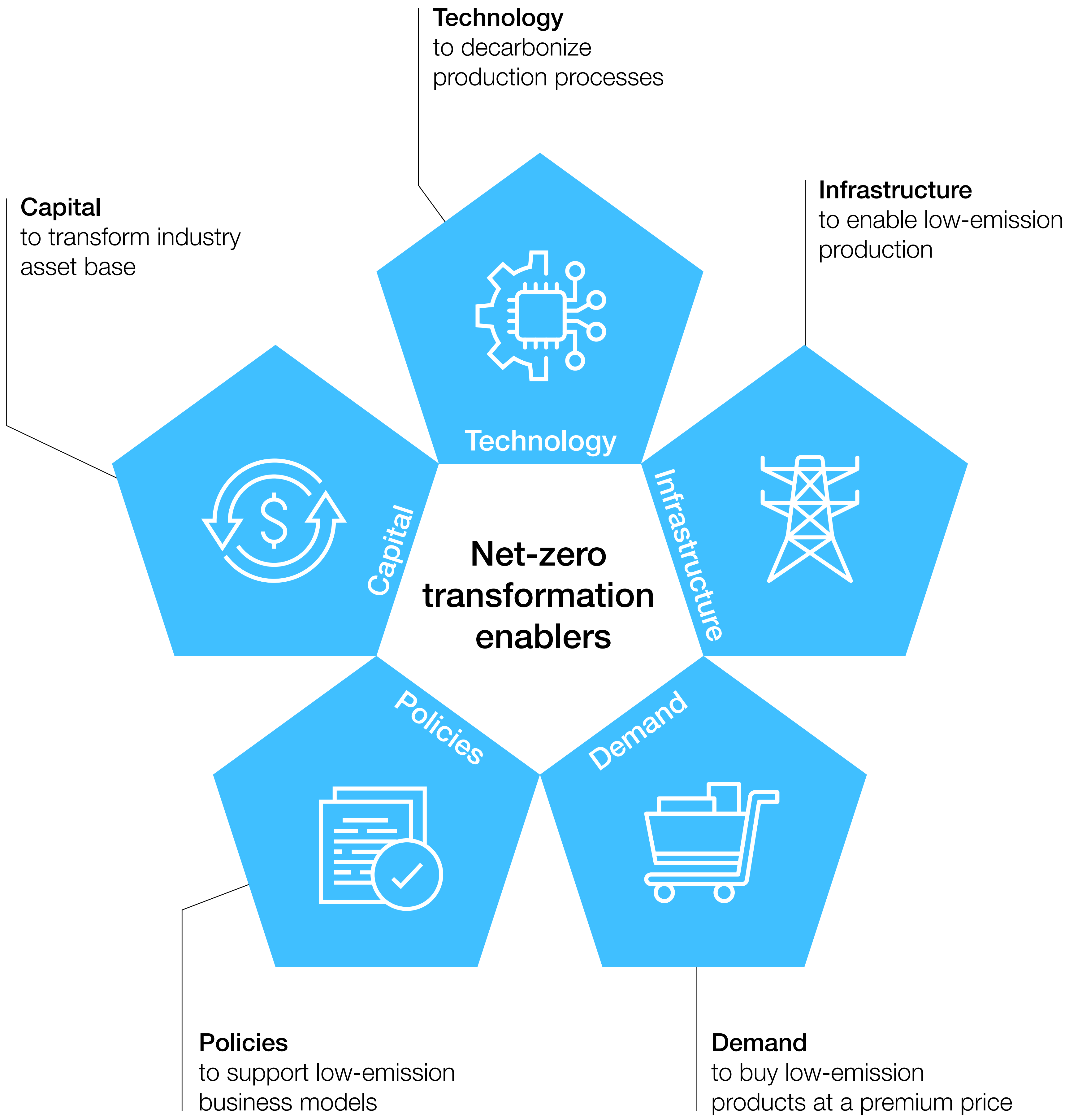
Net-zero industry performance

The four drivers of industry net greenhouse gas (GHG) emissions:



Net-zero industry readiness

The five enabling dimensions of industry net-zero transformation:



Industries' progress is assessed against production emission intensity trajectories from the International Energy Agency (IEA) Net Zero by 2050 Scenario.

Key messages

For aluminium, ammonia, steel and cement sectors, "low-emission" is defined as the average scope 1 and 2 production emission intensity required in 2050 in the IEA Net Zero by 2050 Scenario. For oil and gas, in the absence of corresponding data in the IEA Net Zero by 2050 Scenario, "low-emission" production is defined based on the potential of the best available technology (BAT) today.

"Reduced emission" is the average production emission intensity in 2030 in the IEA Net Zero by 2050 Scenario for all six industries.

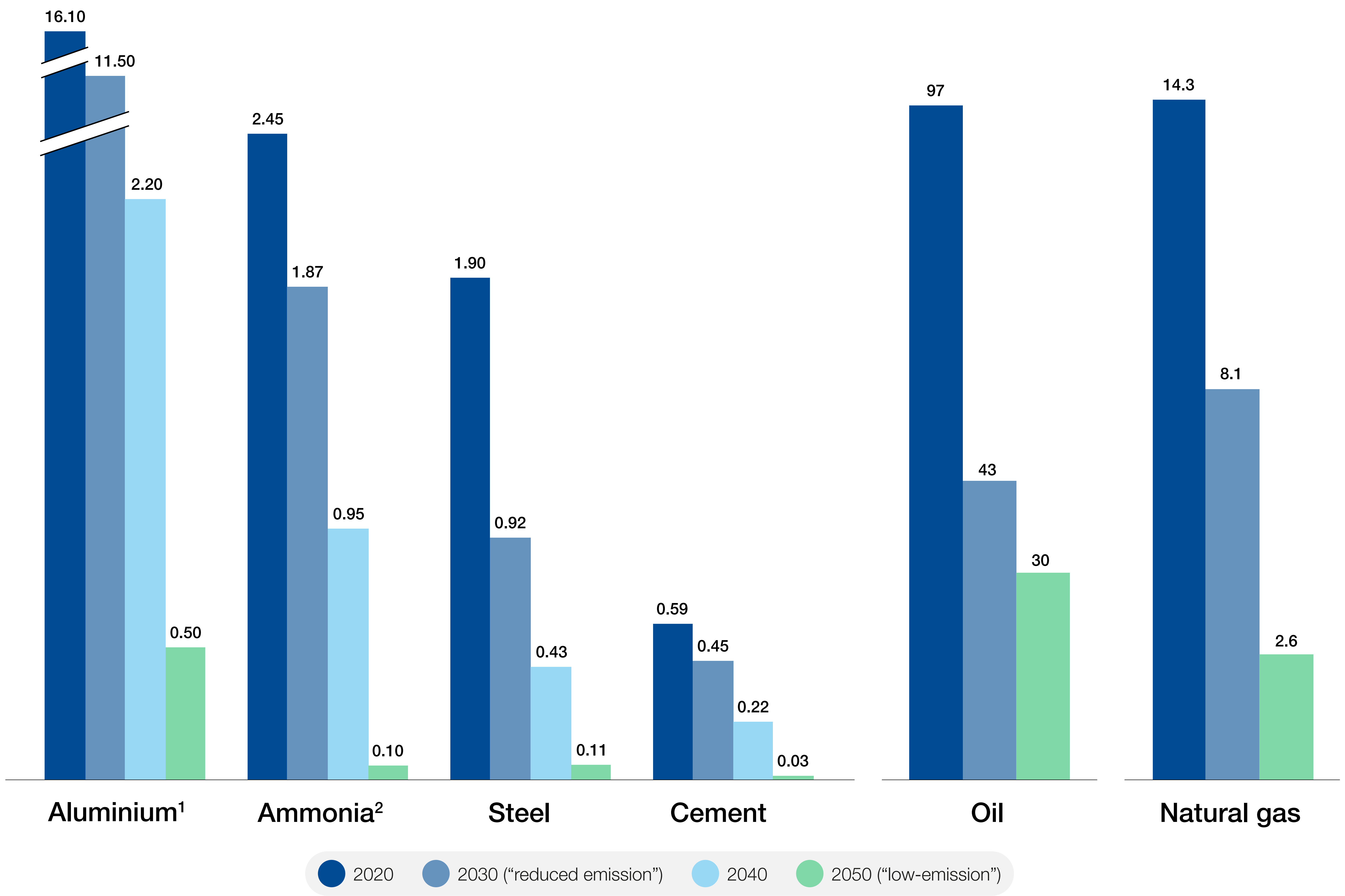
Emission intensity thresholds are industry average values and will not be met by all production, given multiple production routes and geographical constraints. While best performers will be below average, some individual sites will still produce above emission intensity thresholds.

These values are also subject to change as net-zero scenarios and projected industries' emission intensity trajectories evolve.[4]

Source: IEA, International Aluminium Institute (IAI)

Basic materials industry emission intensity trajectory (2020-2050) (tCO_2e/t production)[5]

Energy industry emission intensity trajectory (2020-2050)[3] ($kgCO_2e$/bbl and tCO_2e/MMcf)[6,7]



Notes: 1 Based on primary production routes only; **2** Based on overall primary chemicals industry trajectory; **3** Data for 2040 for oil and gas is not available, 2050 data for oil and gas is based on best available technology today; **4** IEA has started to develop "near-zero" emission intensity thresholds for steel (ranging from 50-400kg CO_2/t of steel depending on scrap steel content), and cement (ranging from 40-125kg CO_2/t of cement), however for this iteration of the report, the IEA Net Zero by 2050 emission thresholds are used for greater consistency across the industries; **5** Tonnes of CO_2 equivalent/tonne of production; **6** Kilograms of CO_2 equivalent/barrel of refined oil; **7** CO_2 equivalent/million cubic feet.

Transformation enablers are assessed against five stages of readiness.

Key readiness questions	**Technology** Is the technology to produce low-emission product at competitive cost available?	**Infrastructure** Is the infrastructure to enable use of low-emission technologies available?	**Demand** Can the market pay the required green premium for the low-emission product?	**Policies** Are supporting policies to enable the growth of a low-emission industry in place?	**Capital** Are returns sufficient to drive investments towards low-emission assets?
Stage 5	The low-emission production technologies are **fully available and competitive with high-emission alternatives.**	The necessary infrastructure required by the low-emission industry **is fully in place.**	**The whole market** can pay the required green premium.	Policies **fully** complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **all** CapEx[2] to flow towards low-emission production assets.
Stage 4	The low-emission production technologies are **largely commercial and competitive with high-emission alternatives.**	The necessary infrastructure required by the low-emission industry **is largely in place.**	**Most of** the market can pay the required green premium.	Policies **strongly** complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **most** CapEx to flow towards low-emission production assets.
Stage 3	The low-emission production technologies are **largely demonstrated in commercial conditions.**	The necessary infrastructure required by the low-emission industry **is partially in place.**	**Some of** the market can pay the required green premium.	Policies **moderately** complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **some of** CapEx to flow towards law-emission production assets.
Stage 2	The low-emission production technologies are **largely prototyped at scale.**	The necessary infrastructure required by the low-emission industry **is emerging.**	**A limited portion of** the market can pay the required green premium.	**Limited** policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **a minority of** CapEx to flow towards low-emission production assets.
Stage 1	The low-emission production technologies are **largely at concept or early prototype stage.**	The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**	**Only very early adopters** in the market can pay the required green premium.	**Very limited** policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Notes: "Low-emission" production is defined quantitatively for each industry in terms of product emission intensity (scope 1 and 2) as per IEA Net Zero by 2050 Scenario; **2** Capital Expenditure (CapEx).

The following criteria are considered when assessing readiness stages for transformation enablers.

Technology

Availability of technology

- Technology options for low-emission production
- Technology emission abatement potential
- Technology readiness level (TRL)
- Technology maturity timeline

Competitiveness of technology

- Technology impact on production cost

Technology deployment

- Technology adoption/deployment level

Infrastructure

Infrastructure requirements

- Infrastructure capacity required by 2050
- Infrastructure investments required by 2050

Infrastructure deployment

- Infrastructure deployment level

Demand

Market dynamics

- Size of market
- Historical price volatility
- Price elasticity of demand
- Availability and scalability of substitutes
- Green premium for direct customers/wholesale customers
- Green premium for end consumers

Effective green demand

- Market share of low-emission products
- Volume and strength of demand signals (e.g. regulation, public procurement)

Policies

Industry/Product specific policies

- Product specifications standards
- Product use standards
- Public procurement standards
- Product emission regulation/ penalties

General policies

- Carbon pricing
- Carbon border adjustment mechanisms
- Emission regulation
- Public action/projects
- Tax breaks
- Subsidies

Capital

Ability to attract capital

- Availability of adequate taxonomy
- Profitability/Level of returns
- Cash availability
- Credit rating
- Cost of capital
- Environment, sustainability and governance (ESG) rating

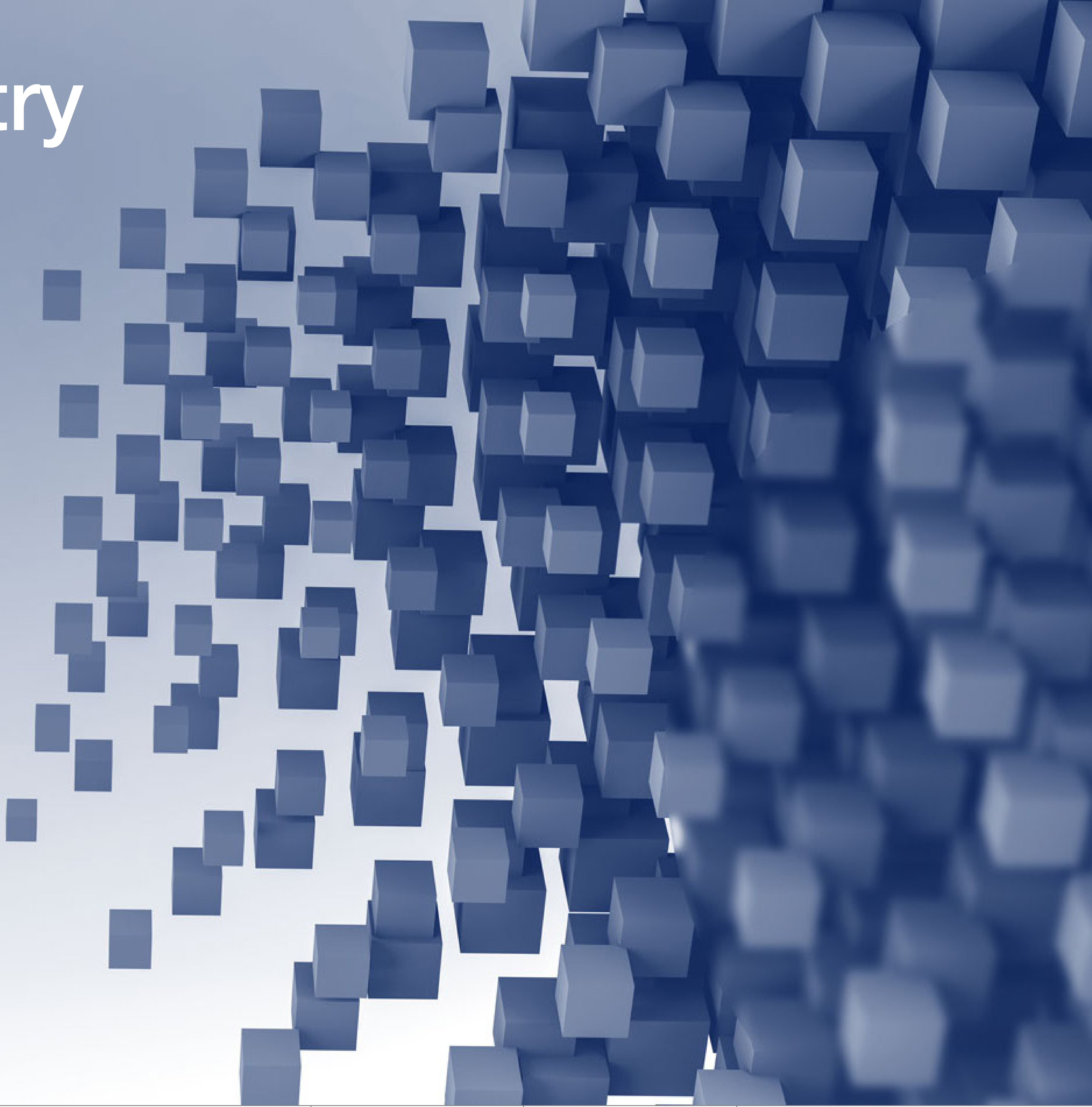
Capital deployment

- Scale of investments needed
- Number of projects invested
- Amount of green CapEx
- Amount of green bonds
- Amount of R&D investments
- Amount of venture capital investments
- Amount of government funding

Notes: Due to data availability constraints, not all criteria have quantitative indicators in the industry-specific trackers. This list is expected to evolve further with each iteration as data becomes available.

②

Cross-industry findings



Cross-industry findings: Net-zero performance

There is no net zero without industries; the deep decarbonization of six industrial sectors responsible for 80% of industrial emissions is necessary.

Key messages

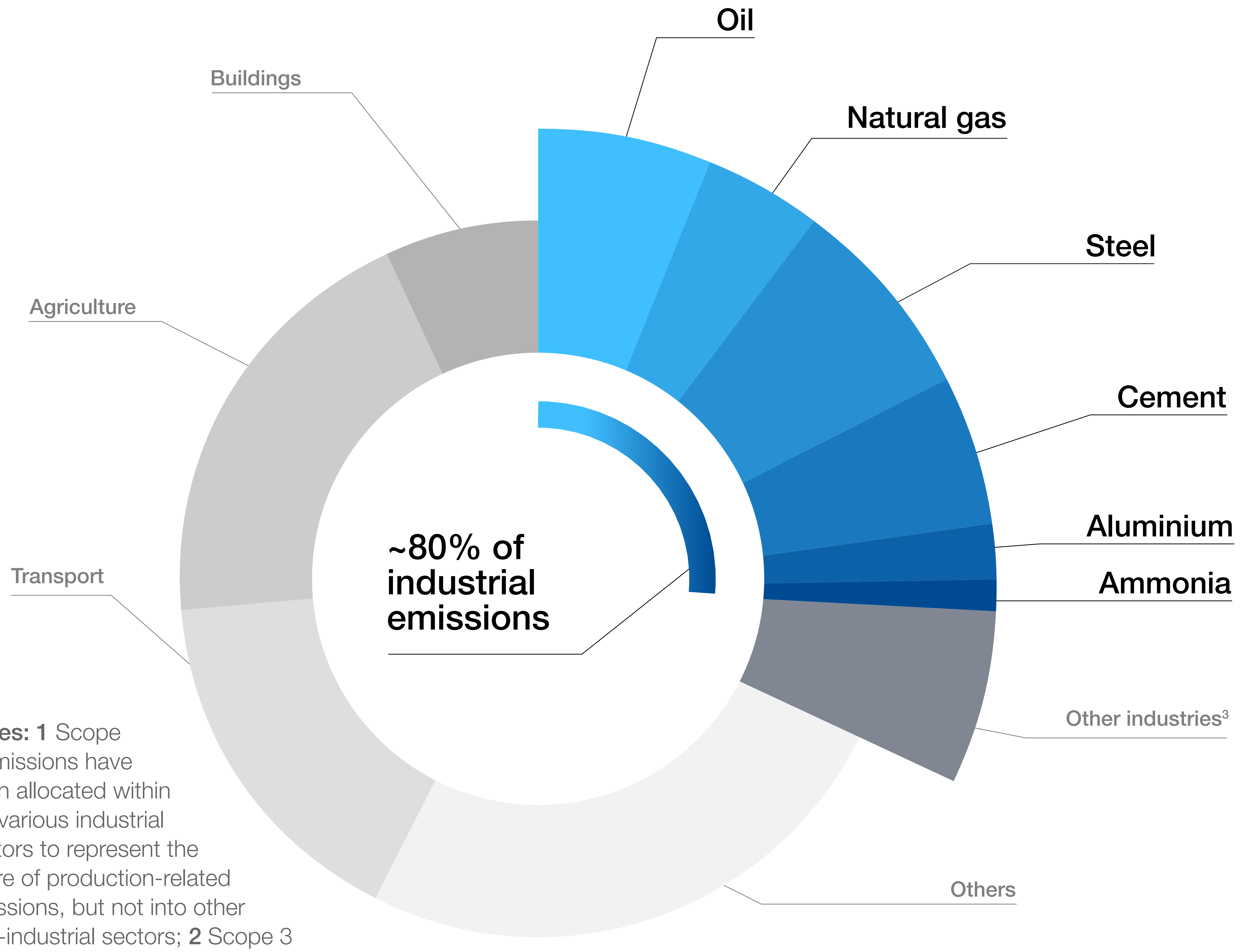
Industrial production-related emissions (scope 3 excluded) contribute to about 30% of global man-made greenhouse gas (GHG) emissions.

Six sectors are responsible for about 80% of industrial emissions[3] (scope 3 excluded).

While scope 3 emissions must also be addressed, particularly for the oil and gas sector, industrial firms must prioritize their scope 1 and 2 emissions, which they have the most control over.

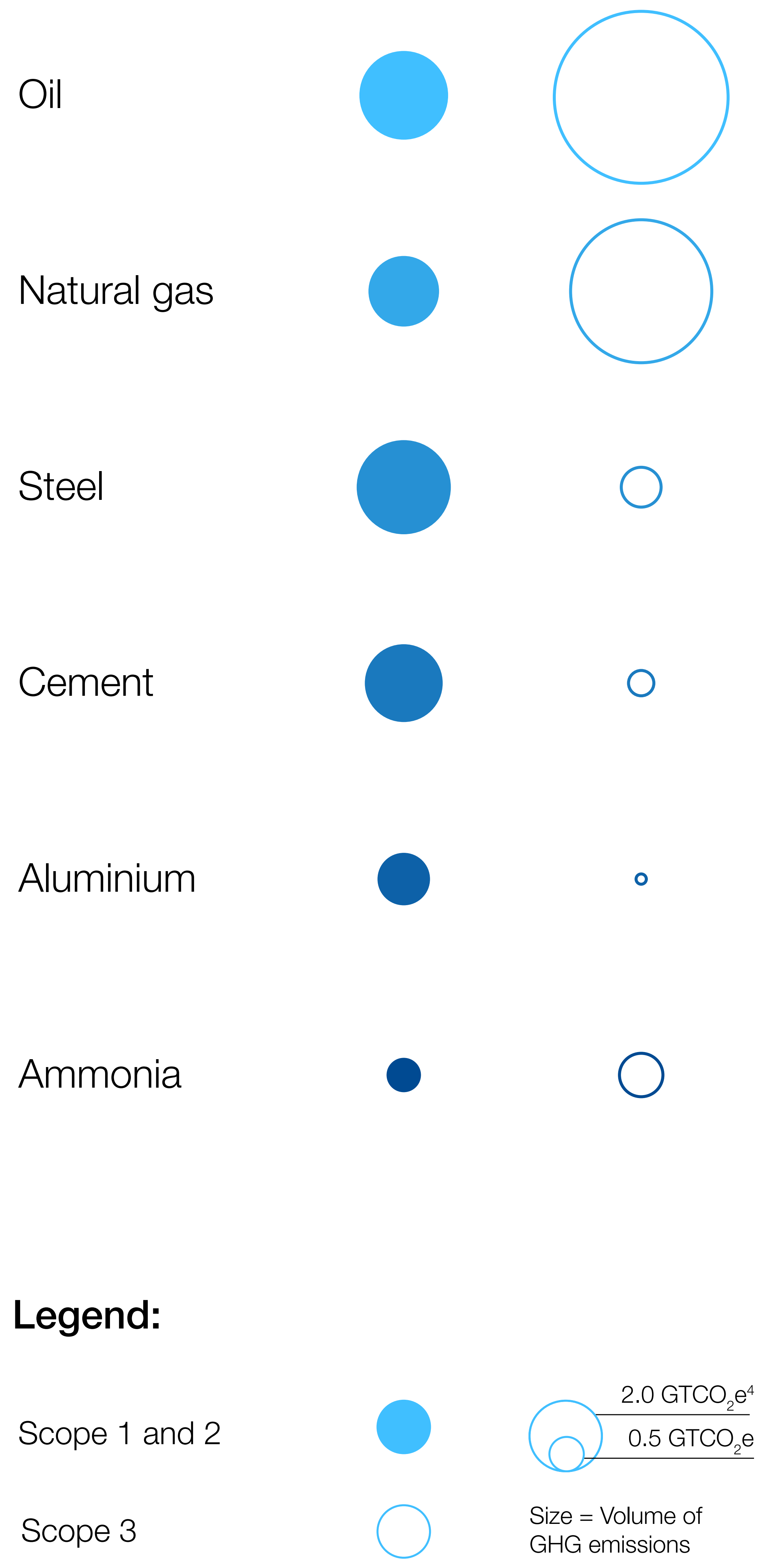
Source: IEA, IAI, World Steel Association (worldsteel), Global Cement and Concrete Association (GCCA), Accenture analysis

Global GHG emissions by sector (scope 1 and 2)[1]

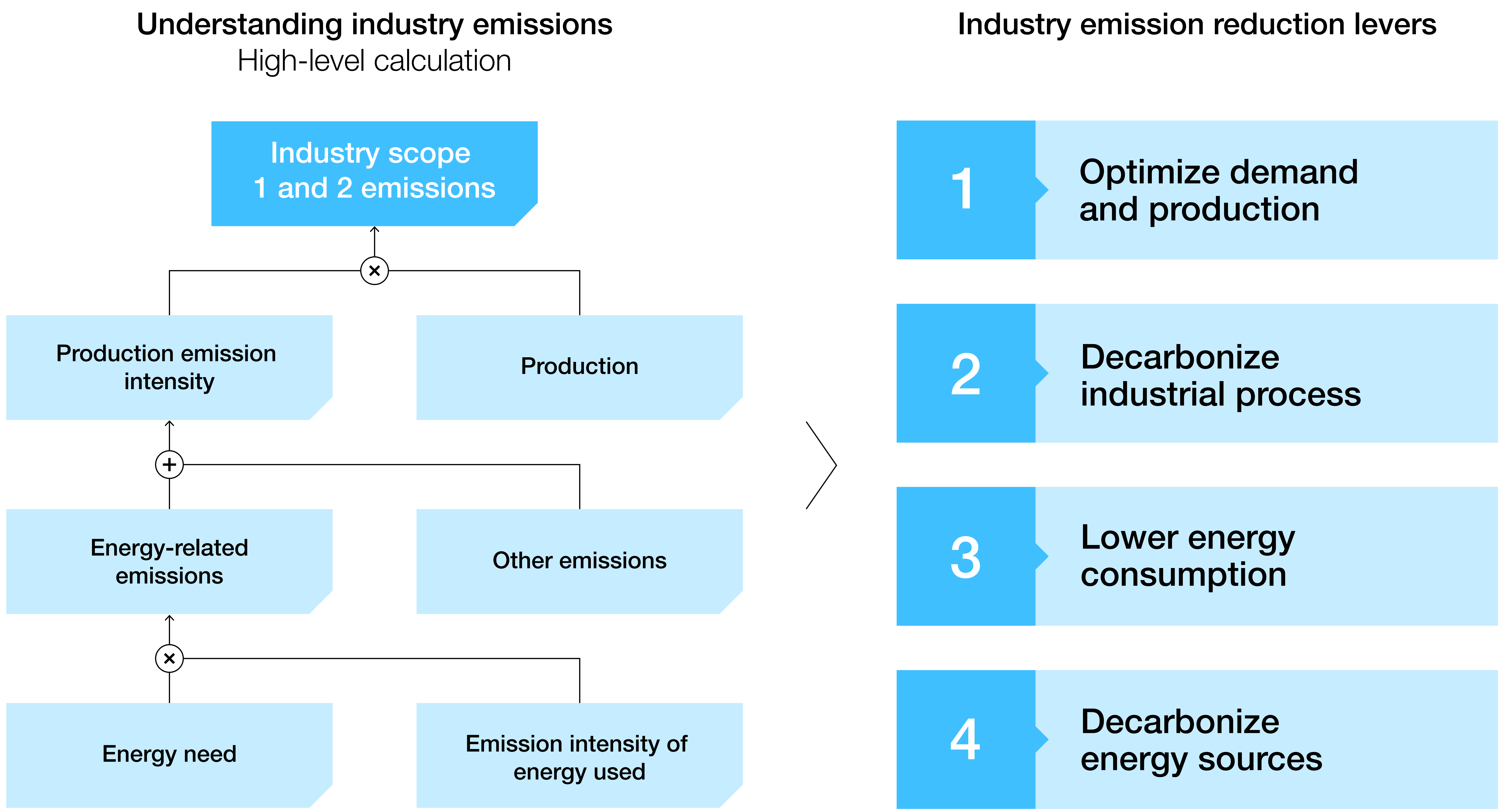


Notes: 1 Scope 2 emissions have been allocated within the various industrial sectors to represent the share of production-related emissions, but not into other non-industrial sectors; **2** Scope 3 emissions are based on GHG protocol scope 3 standards for each of these industries; **3** Other industries include petrochemicals, coal mining, paper and pulp, ceramics and others; **4** Gigatonnes of carbon dioxide equivalent ($GTCO_2e$).

Scope 1 and 2 vs scope 3 emissions[2]



Four levers can cut production-related emissions: demand and production optimization, industrial process decarbonization, energy efficiency and energy sources decarbonization.



Demand for industrial products is expected to grow significantly by 2050; significant demand-side efficiency gains must be realized to optimize production volumes.

1 Optimize demand and production

2 Decarbonize industrial process

3 Lower energy consumption

4 Decarbonize energy sources

Key messages

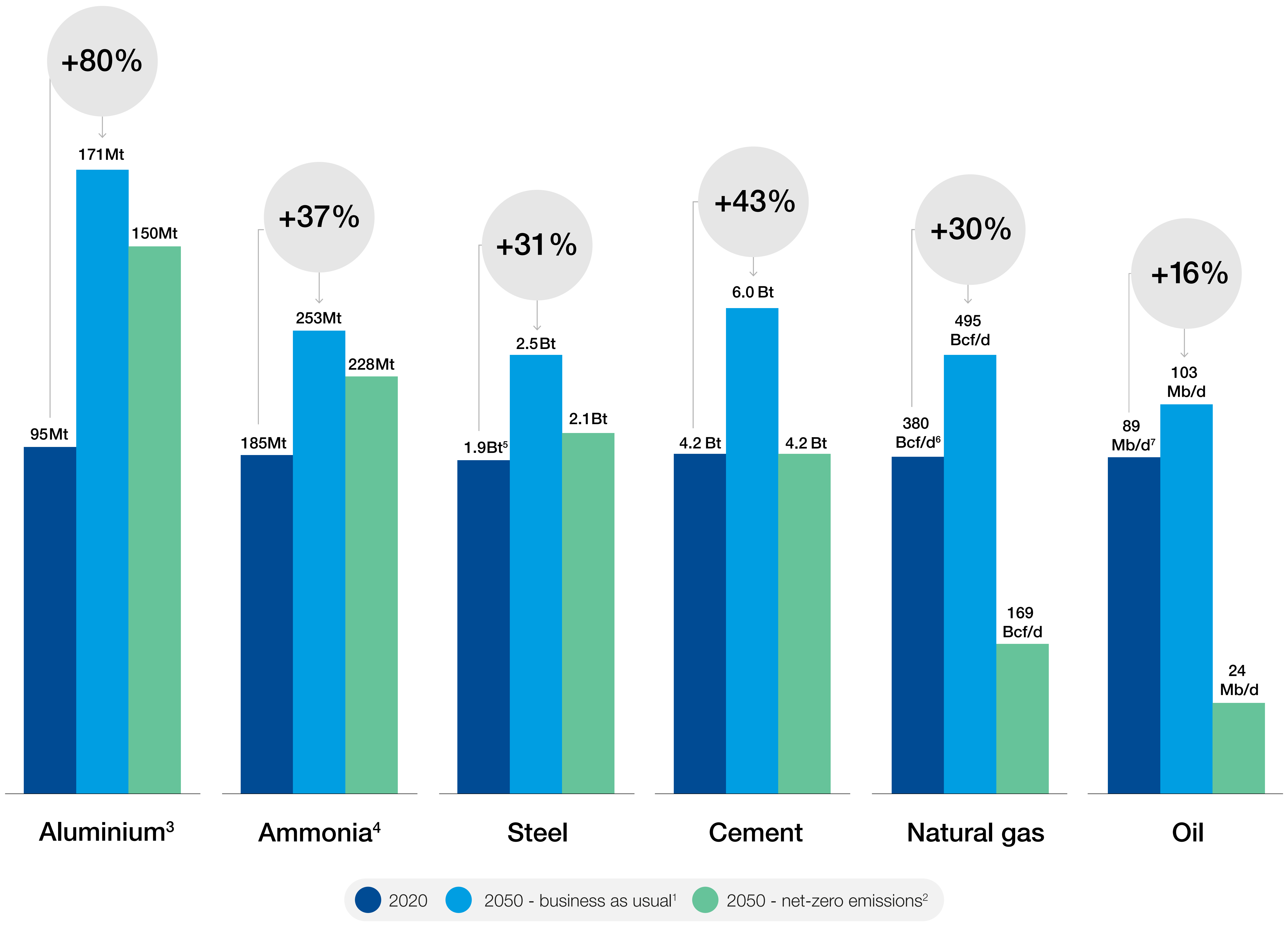
Basic materials and energy underpin numerous end products and services in modern society. Demand for these commodities is expected to grow significantly by 2050 in industry business-as-usual scenarios due to population, urbanization and economic growth.

Demand for basic materials increases in the International Energy Agency (IEA) Net Zero by 2050 Scenario. However, material efficiency (e.g. design regulations, incentives to promote longer lifetimes, circularity measures to improve recycling), demand management and substitutes could help optimize demand and production levels.

Significant investments will be required to decarbonize consuming sectors such as transport, buildings, industries and power to achieve a substantial reduction in fossil fuel demand and production as targeted by IEA Net Zero by 2050 Scenario.

Sources: IEA, IAI, GCCA and worldsteel

Production increase from 2020 to 2050 under business-as-usual (BAU) and IEA Net Zero by 2050 scenarios



Notes: 1 Based on IEA Stated Policies Scenario except for aluminium (International Aluminium Institute (IAI) 2050 BAU), **2** Based on IEA Net Zero by 2050 Scenario for all except aluminium (IAI 2050 1.5 Degree Scenario), **3** Production for aluminium based on 2019 data, **4** Ammonia projected demand does not include the use of ammonia as an energy carrier and is based on the overall primary chemicals production growth in IEA scenarios; **5** Billion tonnes (Bt); **6** Billion cubic feet per day (Bcf/d); **7** Million barrels per day (Mb/d).

Future demand for materials and energy depends on the pace of transformation in the transportation, buildings, agriculture, industries and power sectors.

1 Optimize demand and production

2 Decarbonize industrial process

3 Lower energy consumption

4 Decarbonize energy sources

Key messages

Products from the six industries have a wide range of end uses and are produced in large volumes, preventing them from being easily substituted.

The net-zero transformation of cities (buildings and structures) will be critical in shaping the future demand for cement and steel.

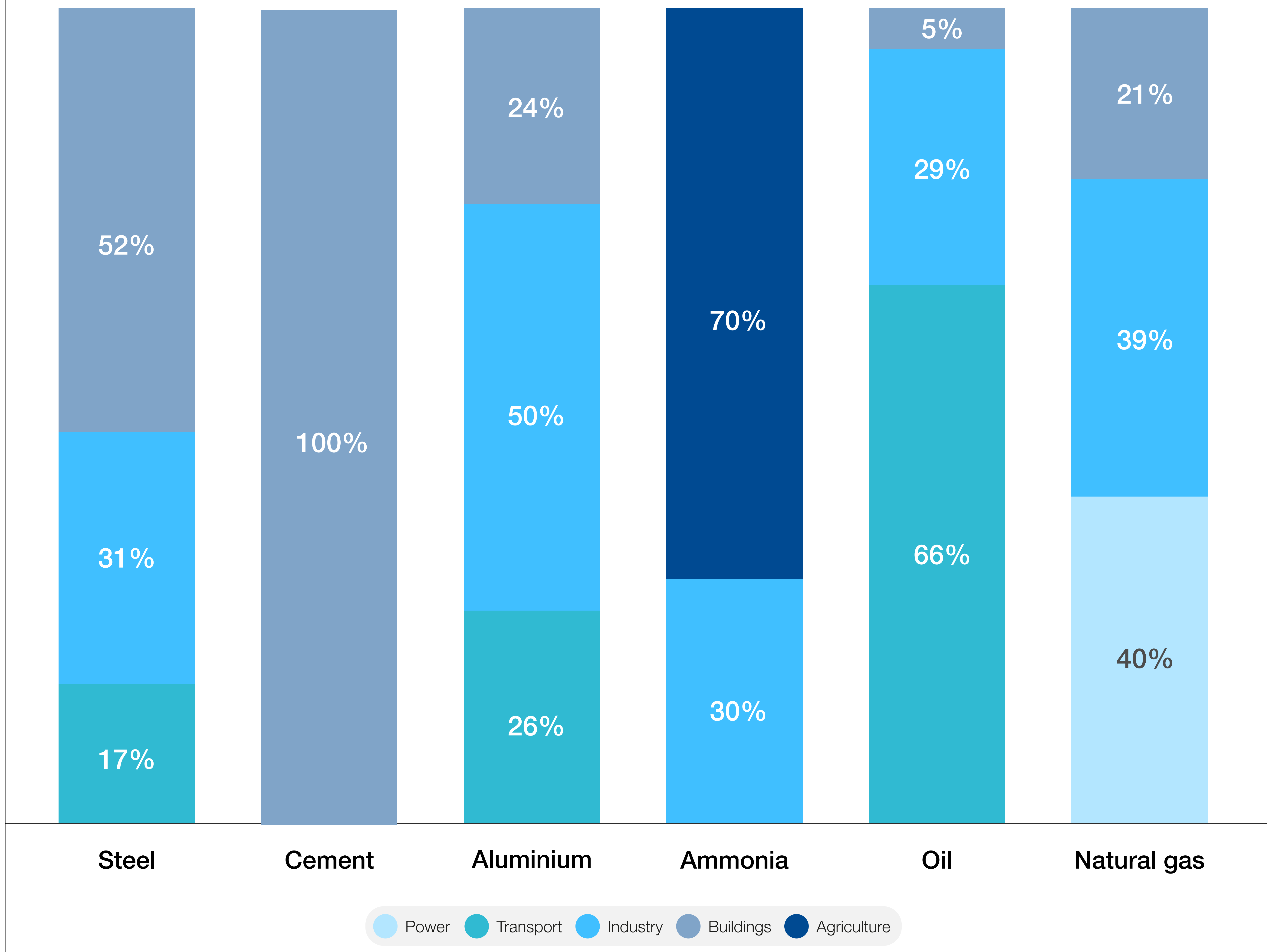
The agriculture journey towards net zero will determine the future demand for fertilizers and ammonia.

The decarbonization of transport and industries will significantly impact oil demand.

As a transition fuel, gas could see demand rising in the power and industrial sectors to replace coal in the medium term.

Sources: IEA, BP, Organisation for Economic Co-operation and Development (OECD), Statista

End-use consumption by sector



Decarbonizing extractive and manufacturing processes is highly complex due to the diversity and intensity of emission sources.

1 Optimize demand and production

2 **Decarbonize industrial process**

3 Lower energy consumption

4 Decarbonize energy sources

Key messages

These six sectors are considered “hard to abate” due to their complex and highly energy-intensive industrial processes. As a result, a significant shift from existing production routes to innovative new low-emission routes is required.

Sources: IEA, IAI, worldsteel, GCCA, Company reports, Accenture analysis

Sector	Energy emissions	Non-energy emissions
Steel	– Fossil fuels, including coke and natural gas, are used to reach the high temperatures required in blast furnaces and direct reduction. Electric arc furnaces require significant electric power.	– Metallurgical coke and natural gas are used as reducing agents to produce iron from iron ore, simultaneously releasing CO_2. Lime is also used.
Cement	– Coal and petcoke are typically burnt to reach the required high temperatures in cement kilns, releasing CO_2. – Energy emissions account for 40% of emissions.	– Oxidation of limestone under high heat forms calcium oxide (the desired product) and releases CO_2. – Process emissions account for 60% of emissions.
Aluminium	– Most emissions are due to the energy requirements of electrolysis to smelt aluminium.	– The consumption of carbon anodes during electrolysis also releases CO_2.
Ammonia	– Coal and natural gas are consumed in coal gasification and steam methane reforming processes to provide energy.	– In the same processes, methane, coal and water are converted into hydrogen gas, releasing CO_2.
Oil	– Fossil fuels are used in the extraction and transportation of oil. – Refining requires significant energy to process crude oil, typically powered by fossil fuels.	– Vented and fugitive methane emissions form 34% of oil industry emissions. – H_2 production and other refining processes also release CO_2 emissions.
Natural gas	– Energy is used to extract, process, and transport natural gas, typically from burning oil and gas.	– Vented and fugitive methane emissions form 66% of natural gas industry emissions. – CO_2 can also be released from raw gas streams.

Low-emission production technologies are emerging and can sharply reduce industries' emission intensity.

Key messages

Although at different technological maturity and commercial readiness, new low-emission production routes have been identified for the six sectors.

These new production routes can bring emissions in line with the net zero by 2050 goal.

Recycling steel and aluminium (secondary production) generates significantly fewer emissions than primary production.

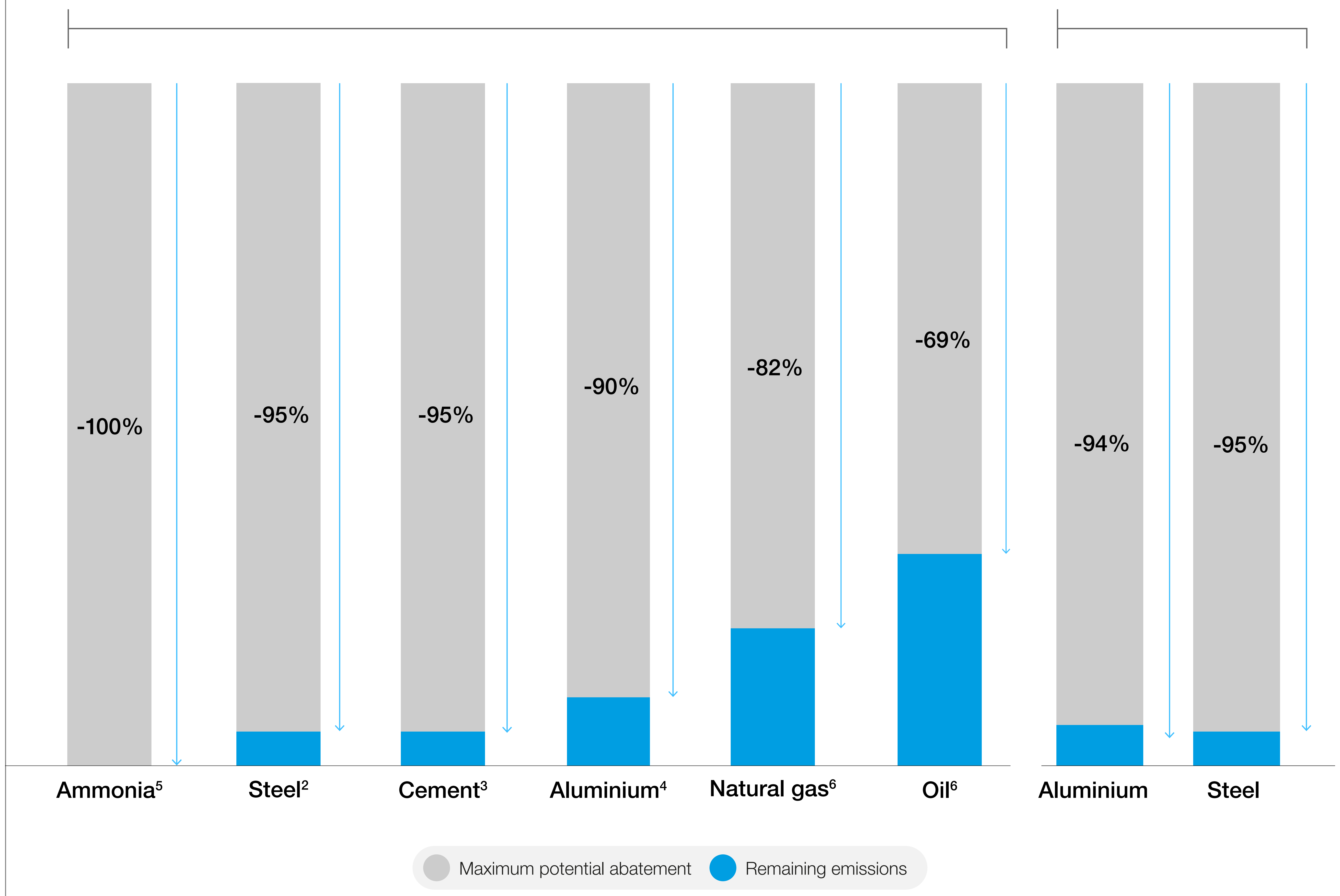
Secondary steel and aluminium production could reach near-zero emissions if fully powered by renewable electricity.

Around 85% of steel and 75% of aluminium are recycled at the end of their useful lifecycle.

Sources: IEA, Mission Possible Partnership (MPP), IAI

Maximum potential emission intensity reduction: primary production[1]

Maximum potential emission intensity reduction: secondary production



Notes: 1 Emission abatement is estimated based on the best technology expected to be commercially available by 2030 (for maximum emission reduction regardless of cost level) versus most common traditional production route; only includes primary production for steel and aluminium; includes scope 1 and 2 emissions; **2** With direct reduced iron-electric arc furnace (DRI-EAF) using carbon capture and storage (CCS); **3** Carbon capture with 95% CO_2 capture efficiency; **4** Green power, inert anodes and hydrogen boilers; **5** Electrolysis with green power; **6** Oil and gas routes require carbon capture, electrification and methane emissions reduction technologies.

Improving energy efficiency and adopting low-carbon energy sources can help companies reduce emissions.

1 Optimize demand and production
2 Decarbonize industrial process
3 Lower energy consumption
4 Decarbonize energy sources

Key messages

Today, all six sectors rely on fossil fuels as energy sources, feedstock or reducing agents.

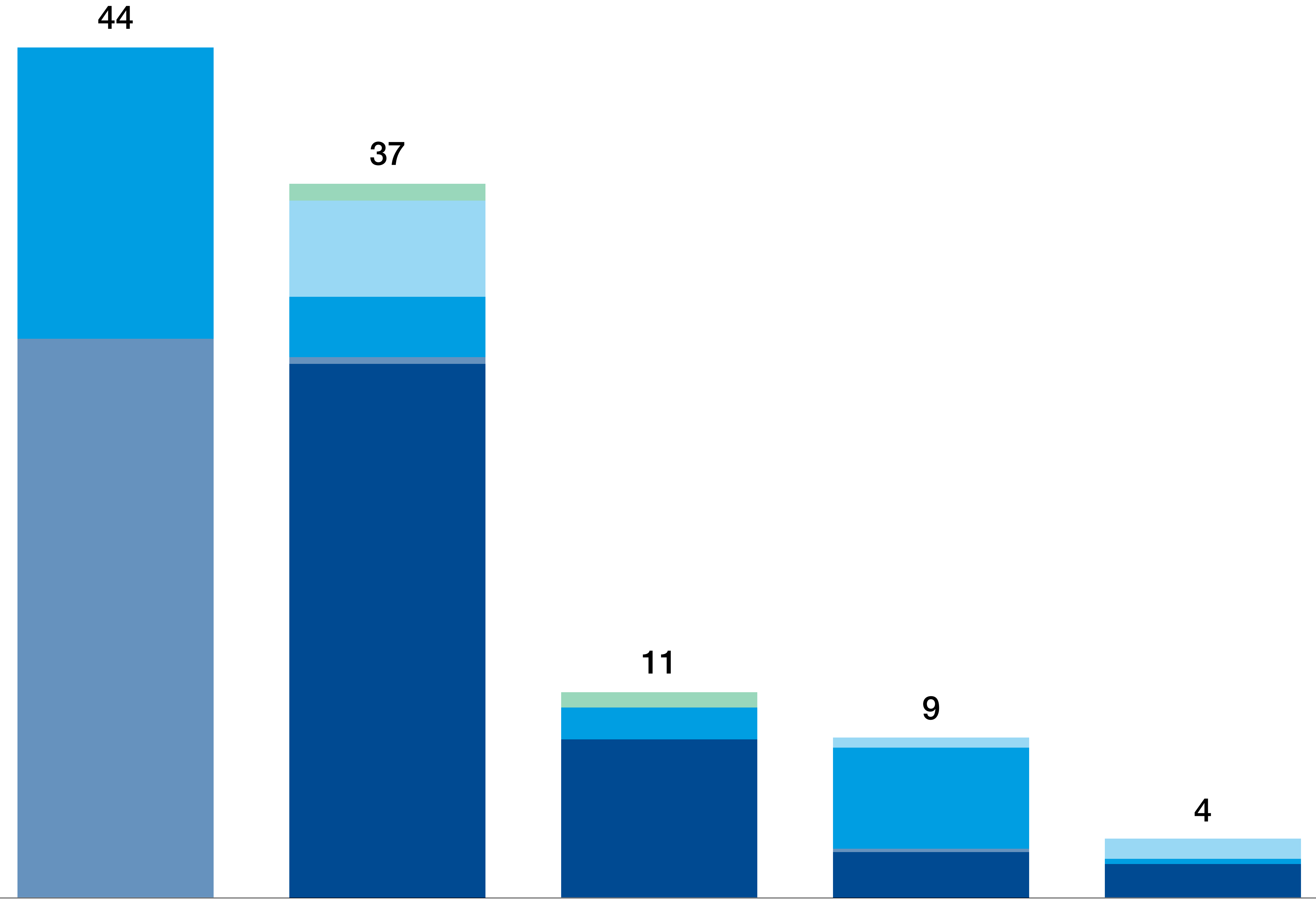
Further energy efficiency gains can be realized, but the nature of certain production processes may eventually cap progress.

Fossil fuel emissions can be mitigated through substitution with low-carbon energy sources (e.g. switching from coal to biomass from agricultural waste)

Electrification of plants and equipment wherever possible and greening the grid can also eliminate significant emissions from fossil fuels.

Sources: IEA, IAI, GCCA, worldsteel, US Energy Information Administration (EIA)

Energy consumption by sector (exajoules (EJ))



	Oil and gas	Steel	Cement[1]	Ammonia	Aluminium
Fuel mix intensity ($kgCO_2/GJ$)[2]	63	90	85	Data not available	59
Electrification of fuel mix (%)	–	13%	–	3%	25%

Notes: 1 Coal category for cement includes petcoke; **2** Gigajoule (GJ).

Besides aluminium, all sectors remain far from the emission intensity level required to align with the 2030 milestones of the IEA Net Zero by 2050 Scenario.

1 Optimize demand and production

2 Decarbonize industrial process

3 Lower energy consumption

4 Decarbonize energy sources

Key messages

Thanks to secondary aluminium production (33% of total production) and a high share of hydropower in primary aluminium production (25%), 65% of global aluminium production today is already below IEA 2030 emission intensity threshold.

Thanks to secondary steel production (22% of total production), 19% of global steel production today is already below IEA 2030 emission intensity threshold.

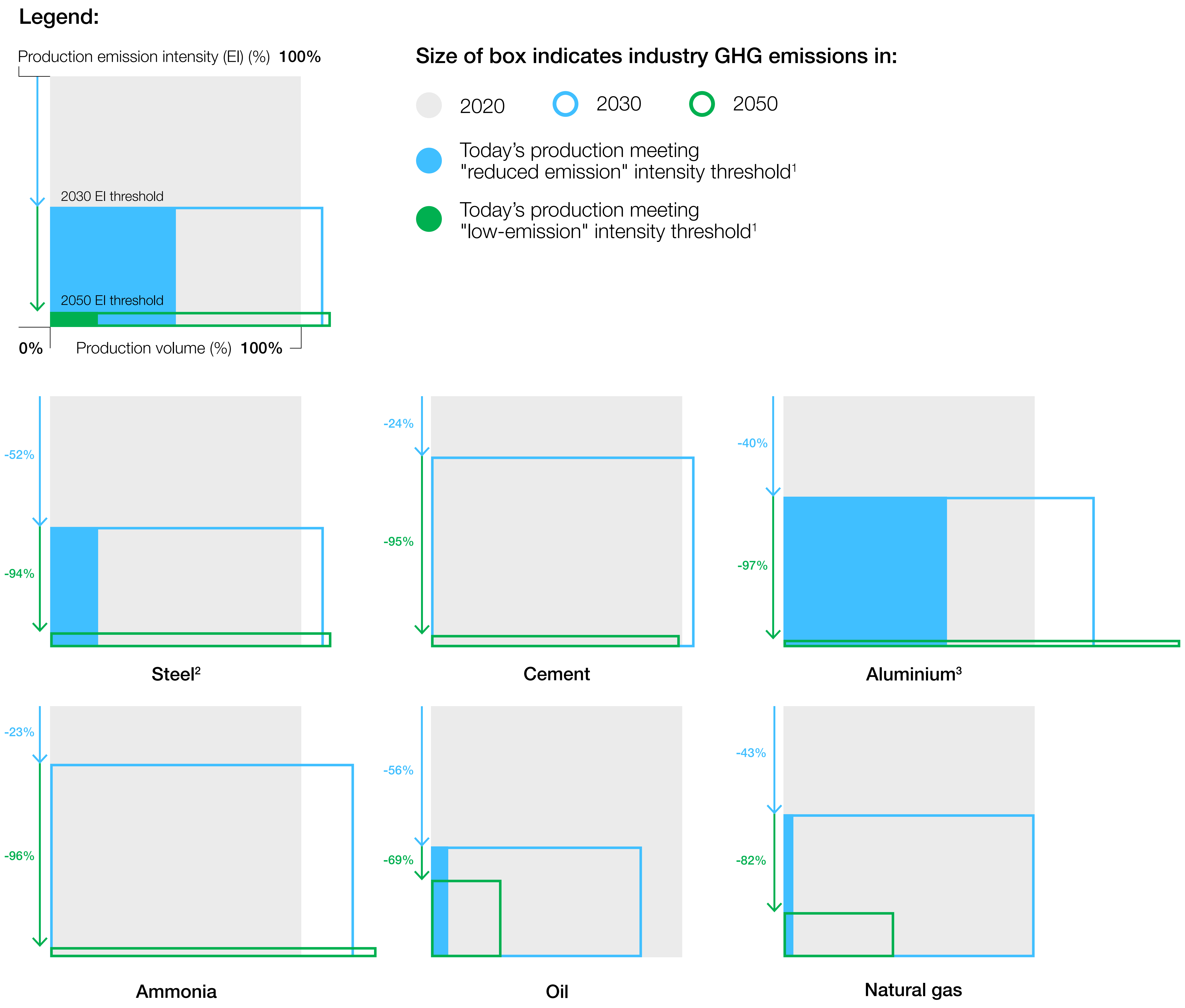
The development of blue and green ammonia, and carbon capture, utilization and storage (CCUS) in cement are encouraging signs for these industries' trajectory to net zero, however, adoption remains very limited.

Although oil and gas production volumes shrink by 73 and 55%, respectively in the IEA NZE 2050 Scenario, all producers should aim to meet the 2030 and 2050 emission intensity milestones. Low-emission producers could benefit from a strategic market advantage in the coming decades.

Sources: IEA, IAI

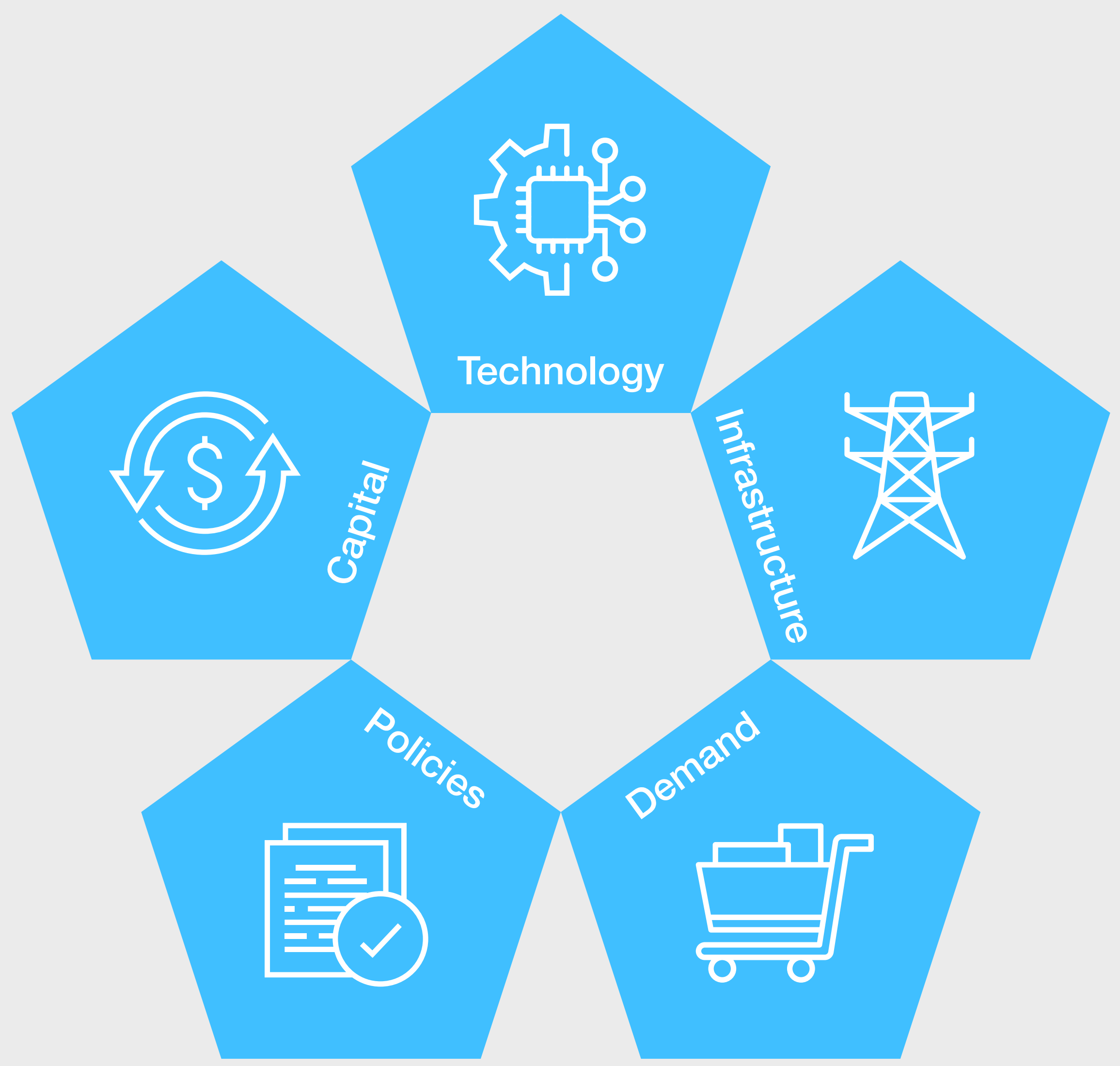
Notes: 1 Low-emission intensity is based on IEA Net Zero by 2050 Scenario trajectory for all except aluminium (IAI 2050 Net Zero)), and oil and gas (best available technology) for 2050 emission intensity; **2** Based on both primary and secondary production; **3** Based on both primary and secondary production.

Current industry performance against IEA Net Zero by 2050 trajectory for total emissions, emission intensity and production volume



Cross-industry findings: Net-zero readiness

Low-emission technologies have emerged, and demand signals are rising; however, more decisive action is required to progress the infrastructure, policies and capital enablers.



Key messages

Within each industry, unlocking a wide-scale decarbonization movement first requires key enabling dimensions to reach a high stage of readiness signifying that major barriers to transformation have been lifted.

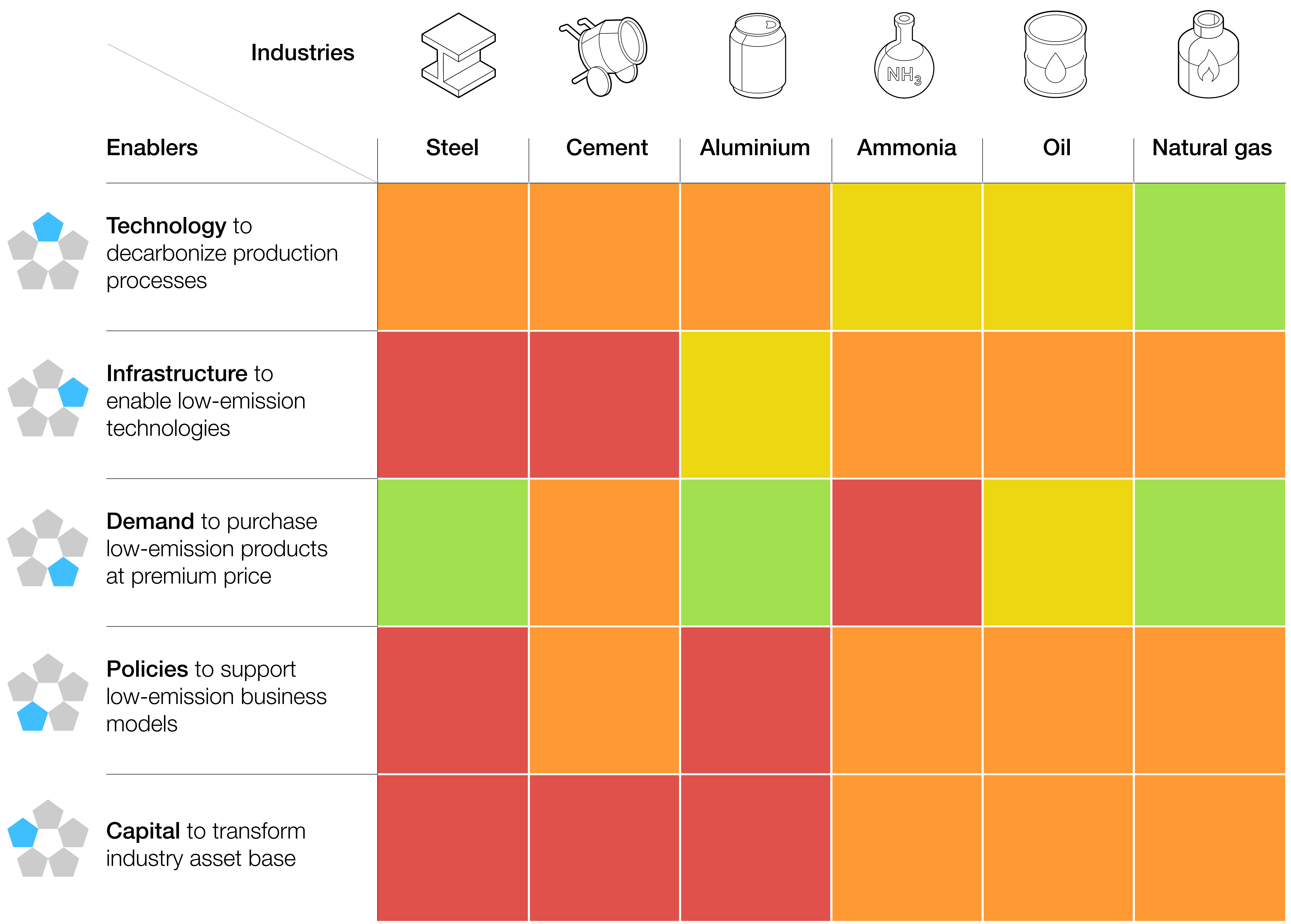
Good momentum is seen in the development of low-emission technologies; demand signals for low-emission products are also emerging and could scale rapidly in the coming decade.

The scale of the necessary enabling infrastructure is colossal, and the pace of development is greatly insufficient – this could lead to bottlenecks in the future.

The most pressing issue is accelerating capital inflows into full-scale demonstration and early commercial projects; supporting policies still need to significantly improve the business case for investments in low-emission industries and enable acceleration.

Source: Accenture analysis

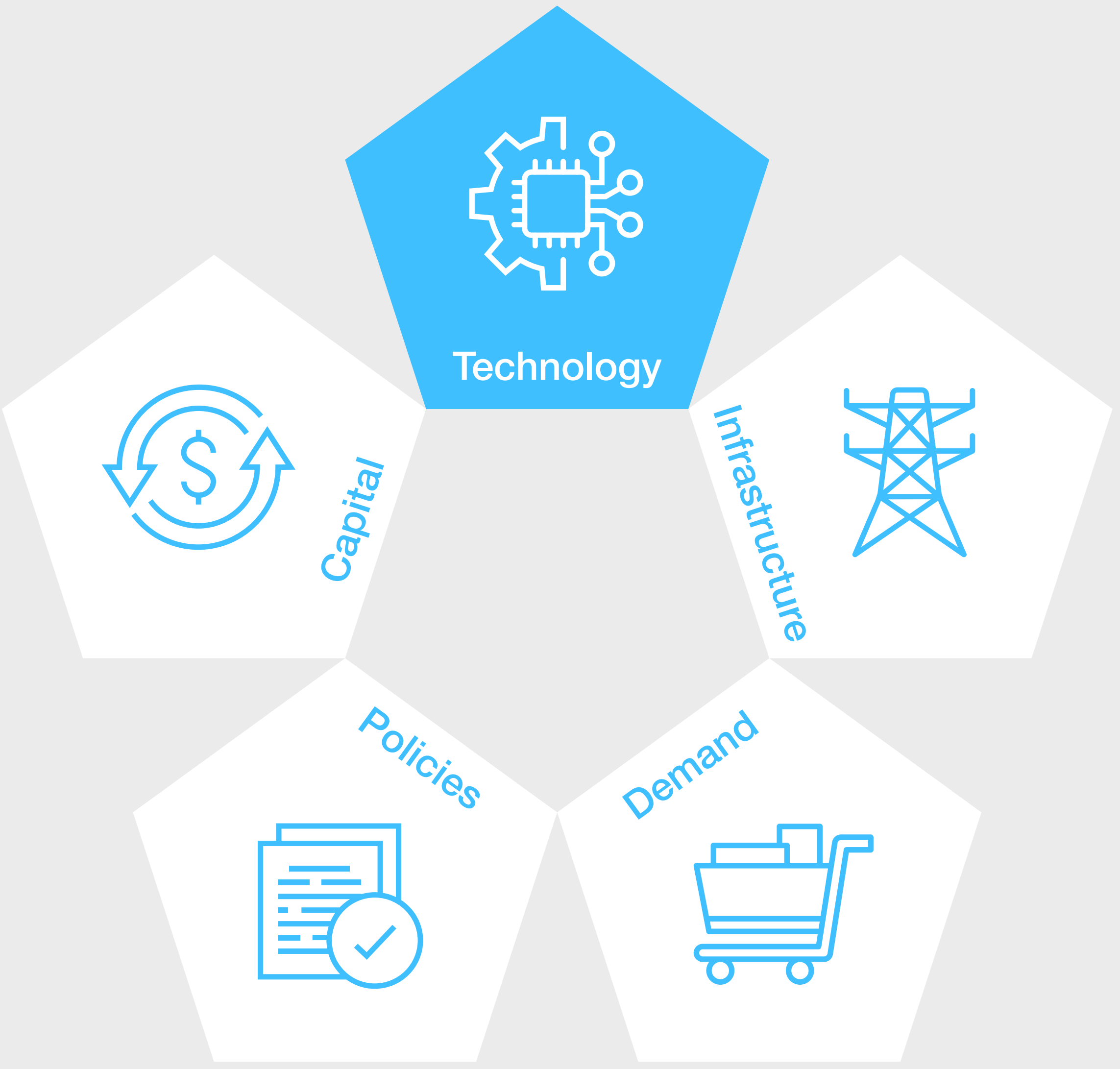
Heatmap of net-zero readiness stages across industries and transformation enablers



Note: "Low-emission" is defined in the "Mission and methodology" section of this report.

Readiness stages: Stage 1 Stage 2 Stage 3 Stage 4 Stage 5

Technologies to enable low-emission production are expected to reach commercial readiness by 2030; driving costs down to accelerate wide-scale adoption is the priority.



Key messages

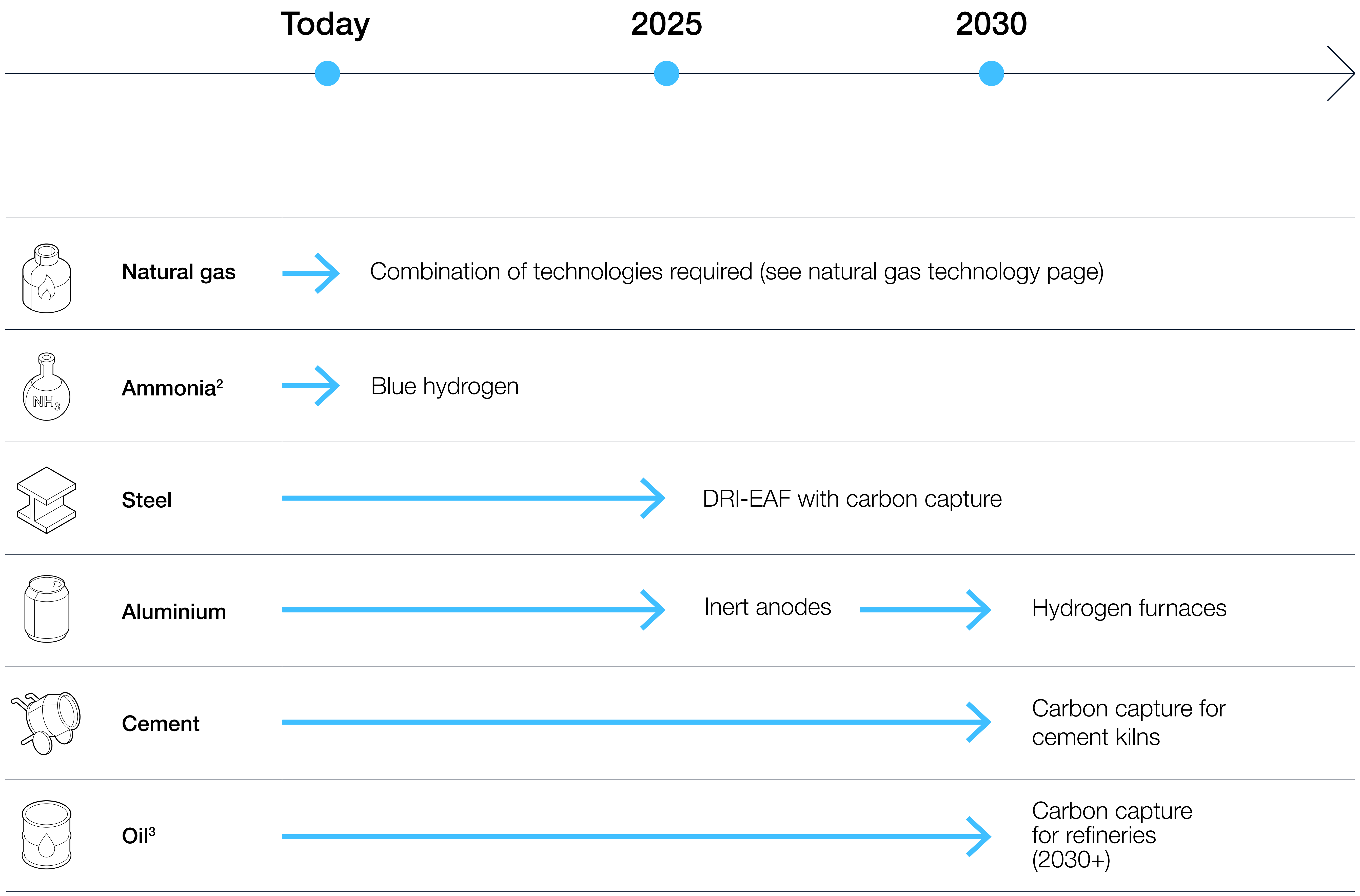
Technologies to decarbonize the natural gas value chain are mature and largely commercially competitive today (particularly upstream fugitive methane capture and venting elimination technologies).

Oil production can be decarbonized today, but technology to eliminate emissions from refining requires further development.

In other sectors, most transformative technologies are either yet to be proven at full commercial scale or too costly compared to existing alternatives. They are only expected to reach commercial readiness after 2025.

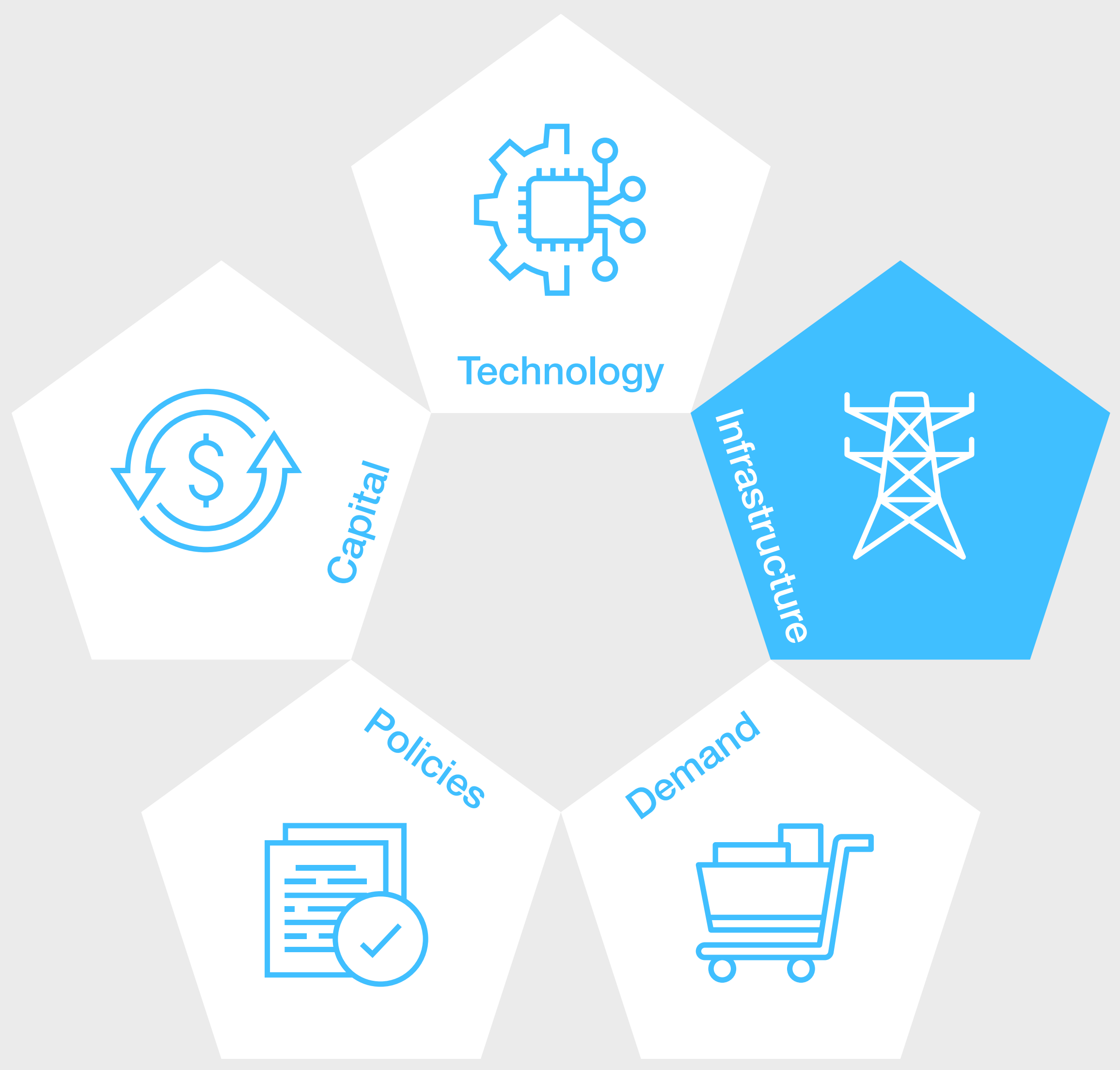
Sources: MPP (Energy Transition Commission) (ETC), Aluminium for Climate, Global CCS Institute, Sustainable Gas Institute, IEA, GCCA, Det Norske Veritas (DNV)

Year by which industries could commercially deploy technologies enabling them to reach their 2050 low-emission[1] intensity threshold



Notes: 1 "Low-emission" is defined in the "Mission and methodology" section of this report; **2** Only small-scale green hydrogen production is expected by 2025. **3** Refers to refined petroleum products.

Infrastructure to enable low-emission production must grow significantly to meet industry needs – risks of bottlenecks exist if investments lag.



Key messages

Most industries' low-emission production technologies involve either low-emission power, clean hydrogen (green and blue) or carbon capture.

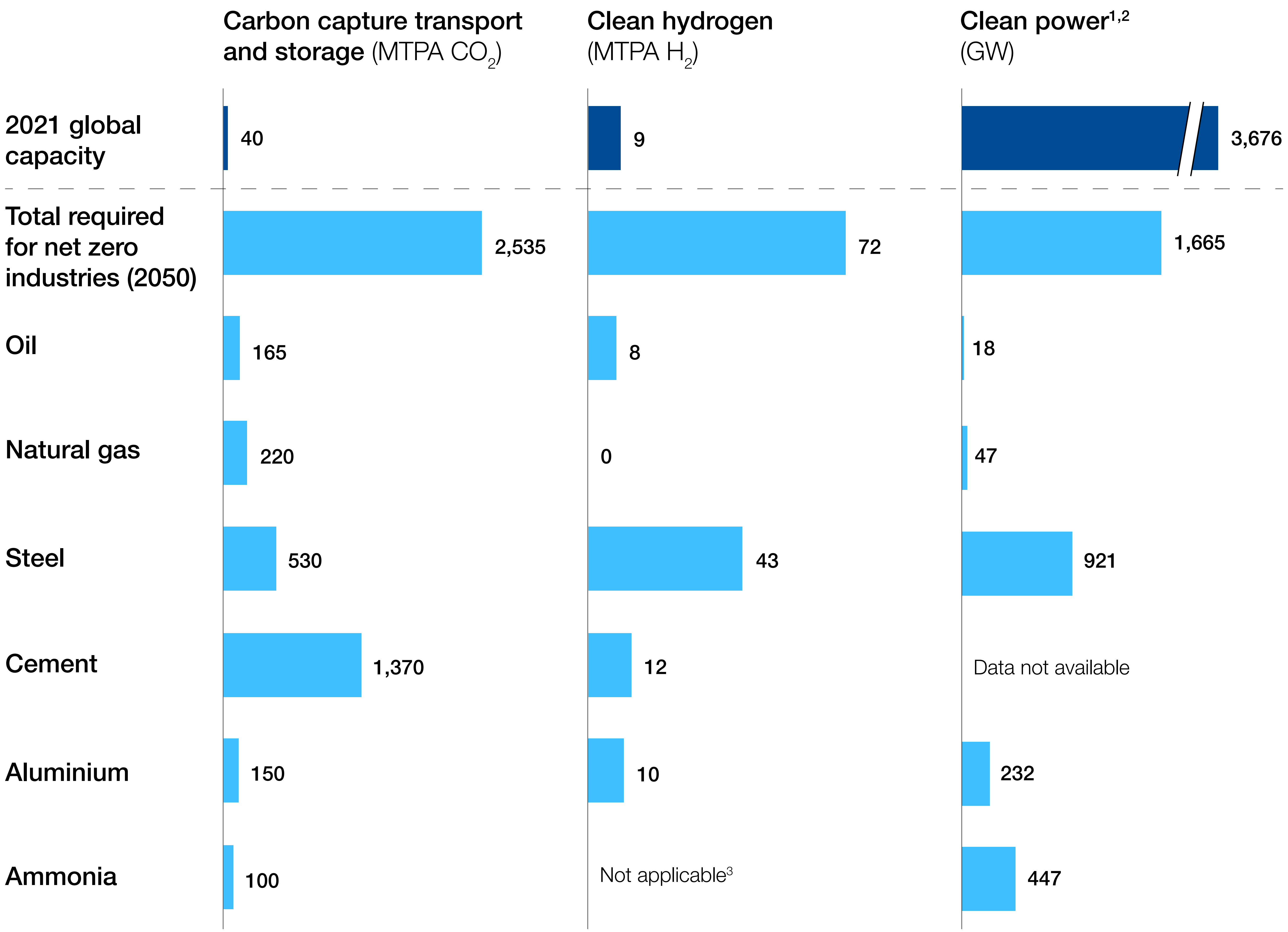
To ensure industries can rapidly deploy these technologies once mature and competitive, significant new capacity of low-emission power generation, clean hydrogen production and CO_2 storage must be made available.

Almost 290 gigawatts (GW) of renewable power capacity was added in 2021, a trend expected to accelerate, with China alone expected to contribute a total of 1,200 GW of wind and solar photovoltaics (PV) by 2026.

Deployment of carbon capture and storage (CCS) facilities has been slow, averaging only 3 million tonnes per annum (MTPA) last decade. The paradigm shift towards CCS networks led to significant momentum last year, with capacity in development increasing from 75 MTPA in 2020 to 111 MTPA by September 2021, a 48% increase.

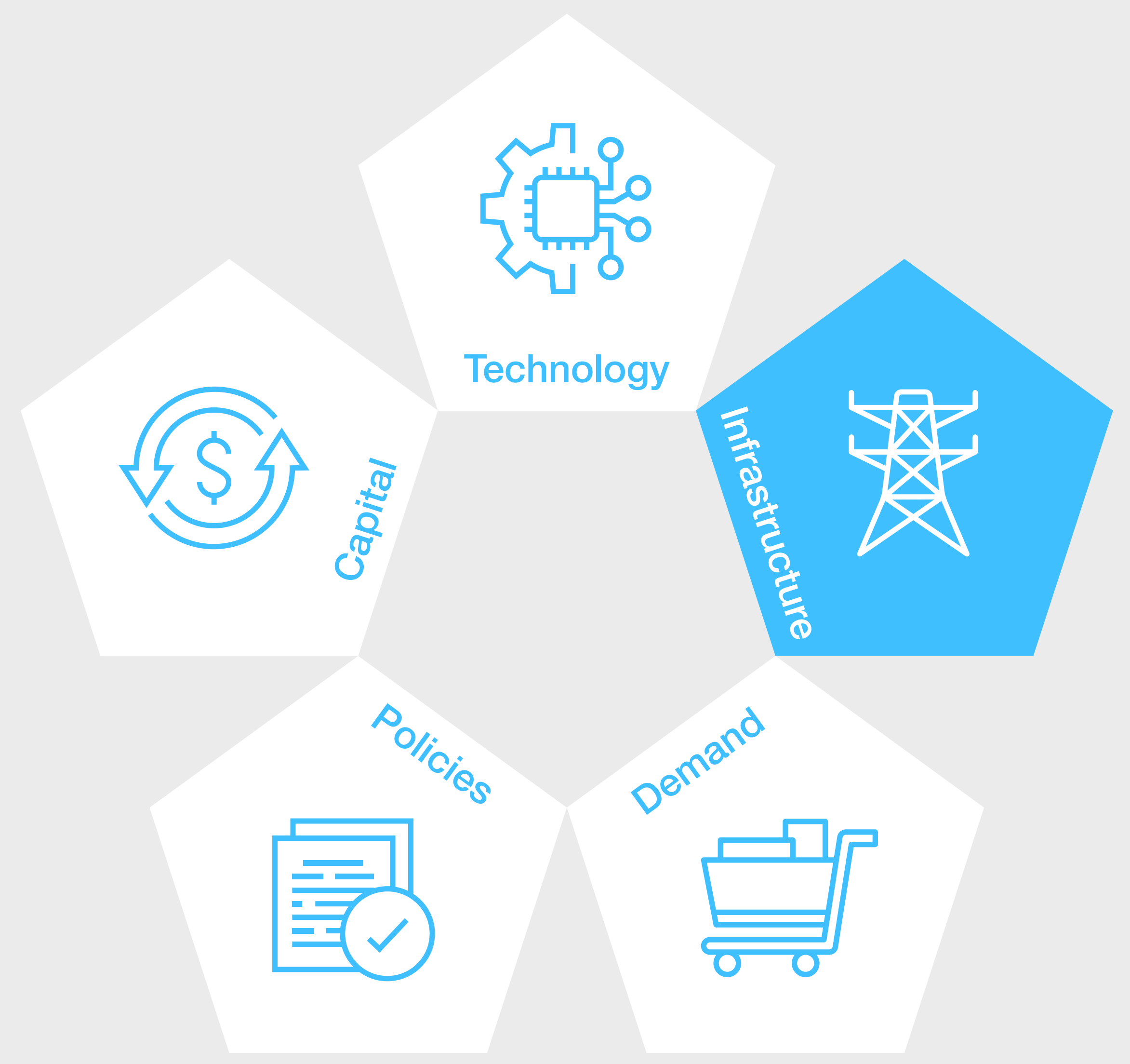
Sources: IEA, Accenture analysis

Enabling infrastructure capacity requirements for net-zero industries by 2050



Notes: **1** Includes nuclear, hydropower and other renewables; **2** Based on today's clean power load factor of 35%; **3** Hydrogen is not applicable as the production of hydrogen is part of the ammonia production process.

Enabling infrastructure for net-zero industries will require twice as much investment as production assets.



Key messages

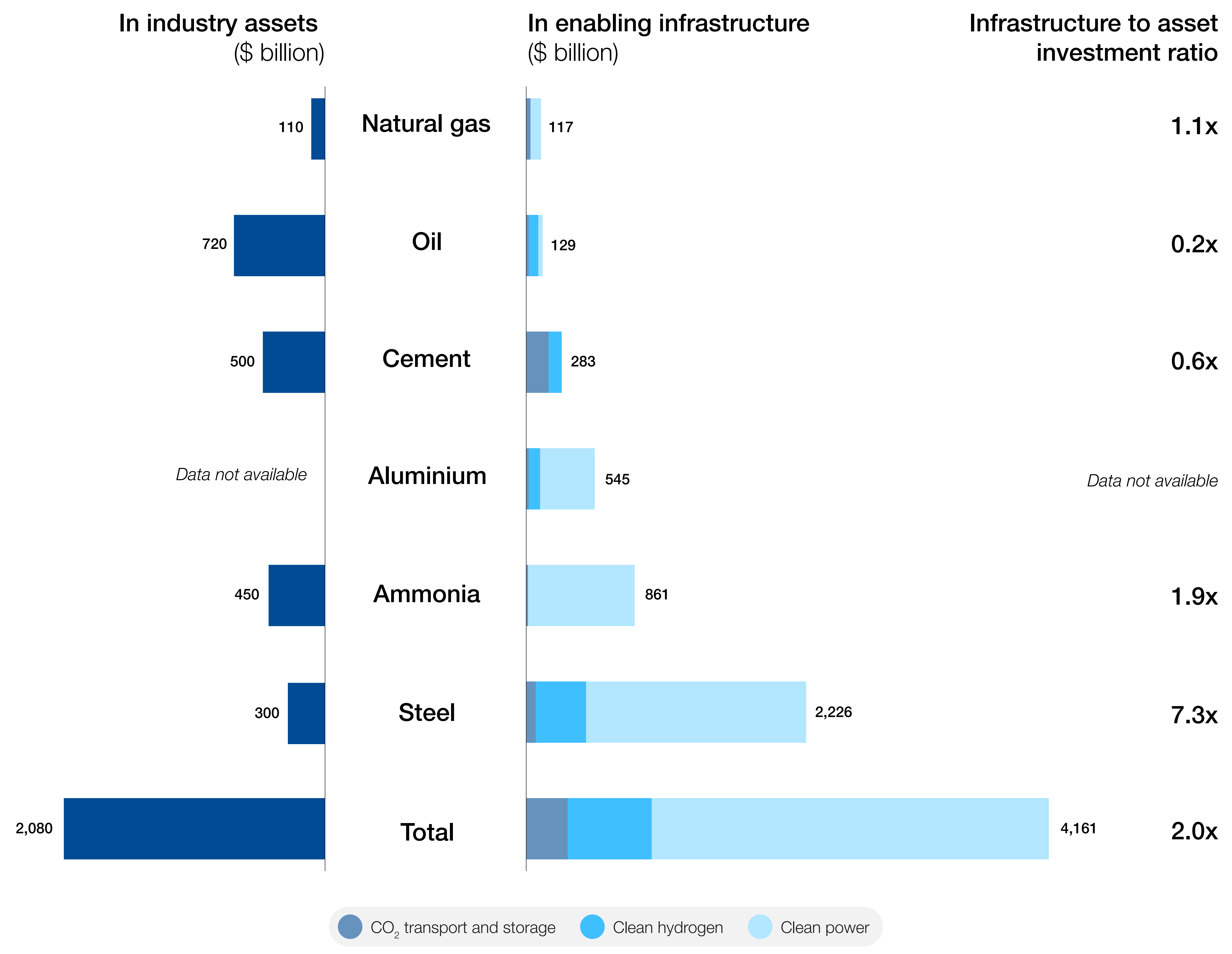
Industries will need to invest $2.1 trillion in low-emission production assets to decarbonize production in line with net-zero requirements.

In addition, $4.2 trillion of investment is needed to develop low-emission power, hydrogen production, and CO_2 transportation and storage to enable the low-emission production technologies/ assets. This is more than two times the global investments in energy of $1.9 trillion in 2021.[2]

In specific sectors such as steel, the investments required in the enabling infrastructure dwarfs those required in production assets and can be a more significant obstacle to the transformation.

Sources: IEA, Accenture analysis

Additional investments[1] required to reach net zero



Notes: 1 Additional investments refer to investments in addition to business-as-usual CapEx. Investments estimated based on demand requirements in IEA Net Zero by 2050 Scenario; **2** Based on IEA estimates.

Unlocking demand for low-emission products – despite green premiums – is critical to incentivize investments.

Key messages

If asset transformation costs were fully passed down the value chain, the B2B green premiums would range from 7-67%, while end consumer premiums could be smaller from 1-25%.

In isolation,[2] end consumer premiums are manageable over decades; however, aggregated premiums in "full green" products (e.g. a car with green steel, green aluminium, and an electric engine) could be much harder to absorb.

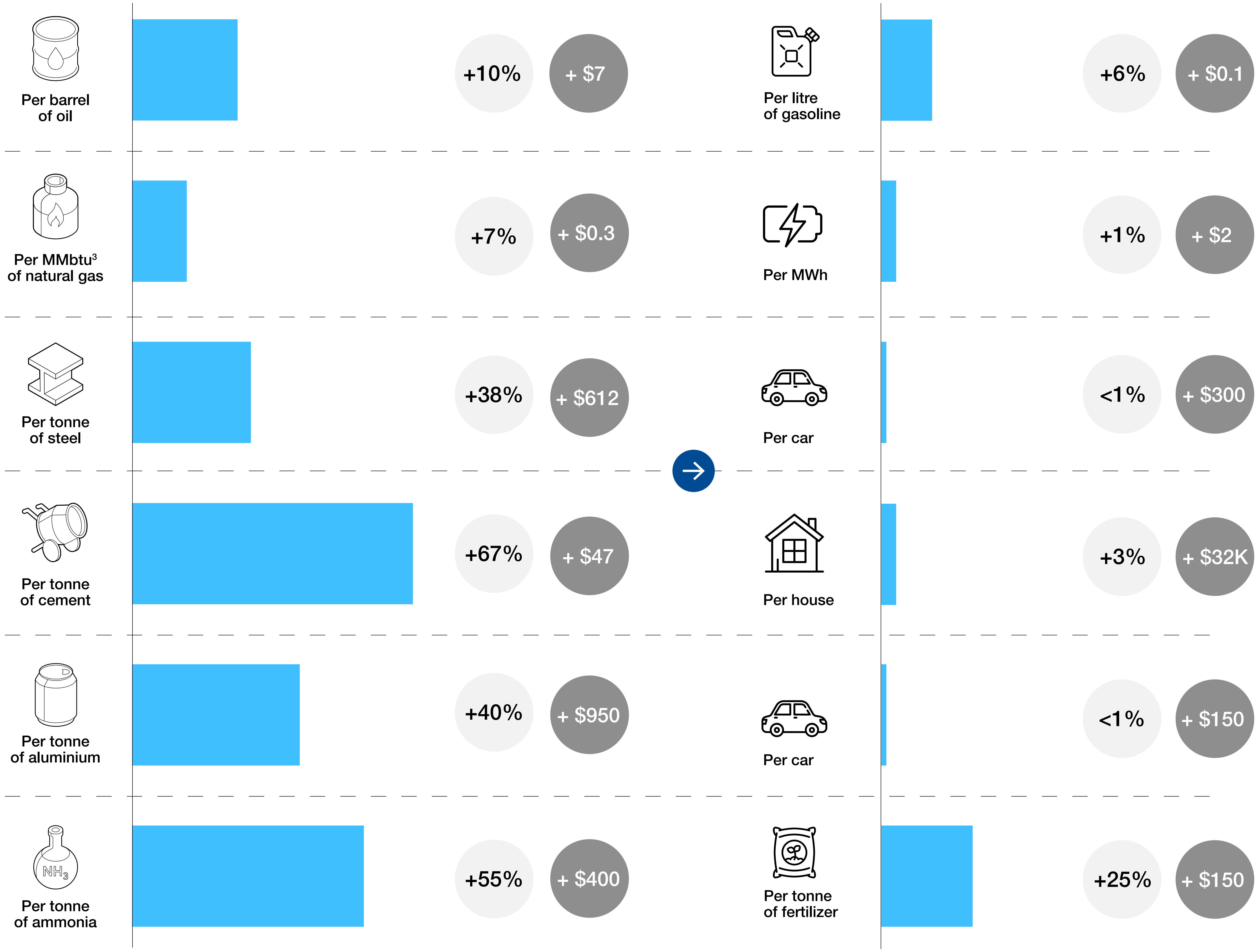
Increases in fertilizer and energy costs will significantly impact food and energy security, and governments will have to carefully monitor and balance these cost increases for a just transition.

More effort is required to incentivize B2B customers and end consumers to demand low-emission products.

Sources: GCCA, Aluminium-stewardship, IEA, Accenture analysis

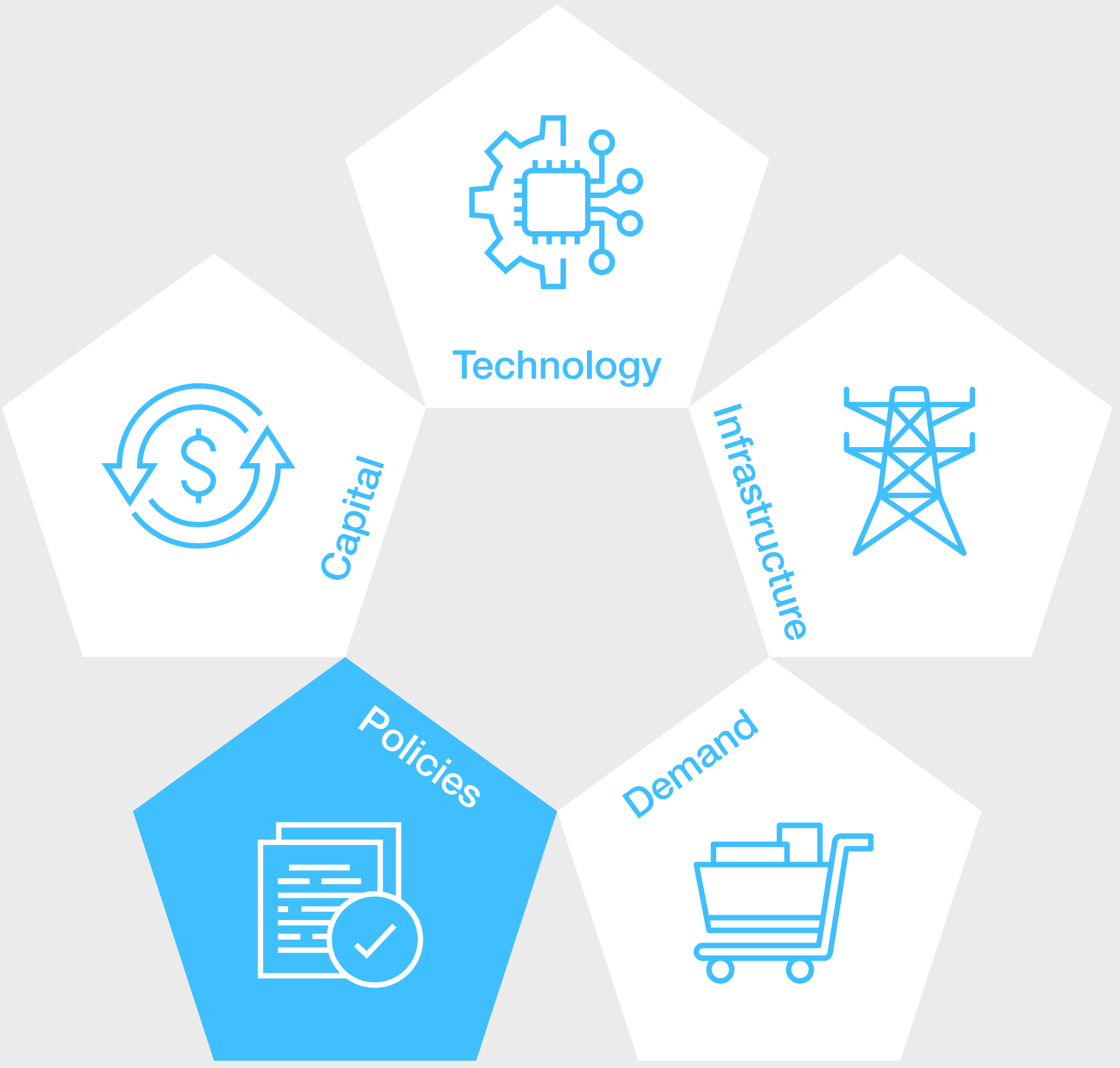
Average B2B green premium[1,2]

Average end consumer green premium



Notes: **1** Price analysis based on average costs paid by US consumers in 2021; **2** Green premiums have been calculated based on the estimated production cost increase using low-emission technologies while maintaining the same level of margins on sold products; **3** Million British thermal unit (MMbtu).

Targeted policy action by sector is required to level the playing field for low-emission producers.



Key messages

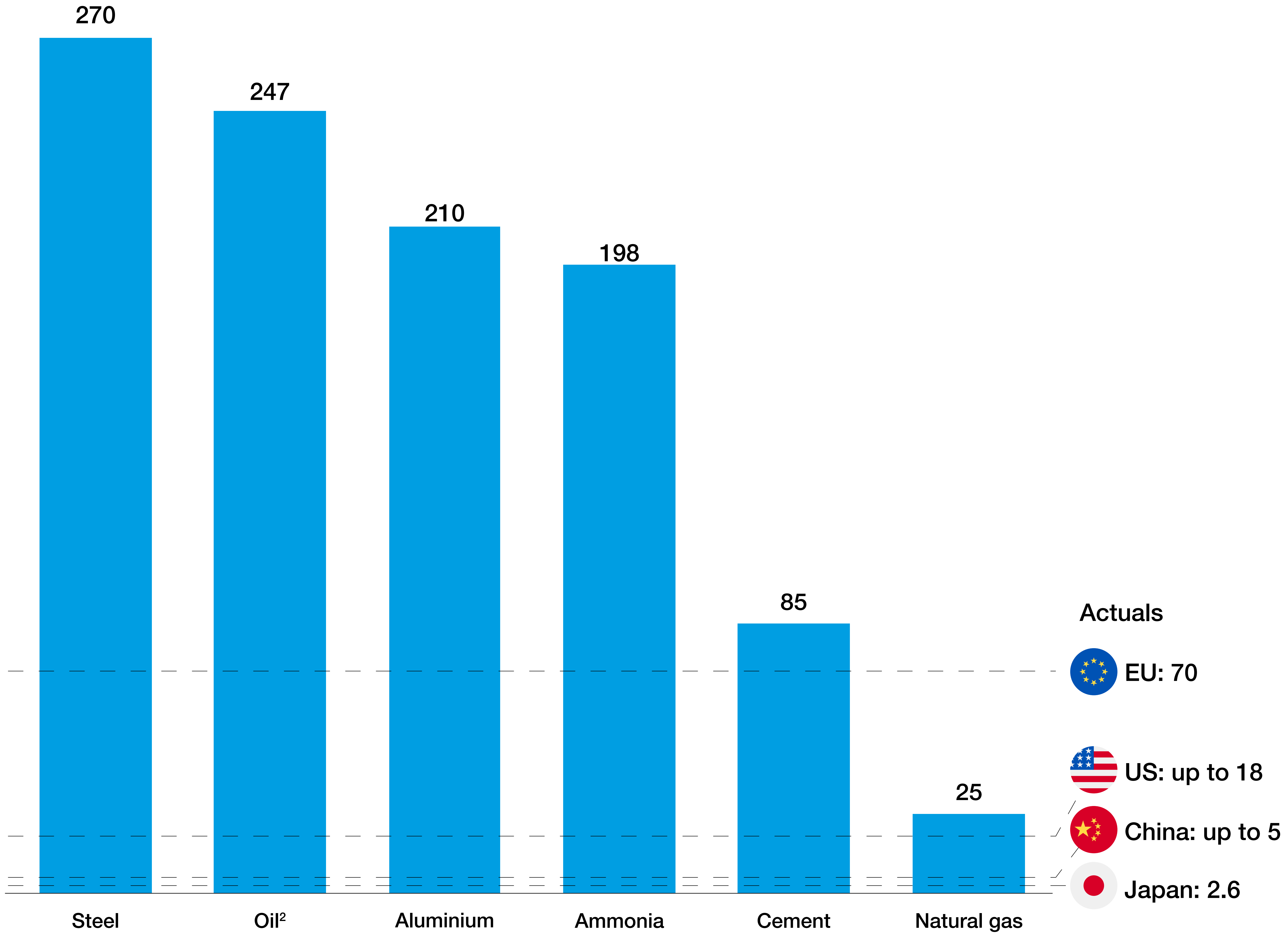
The figure illustrates the carbon prices considered necessary to incentivize the development of low-emission production technology (aligned with 2050 net-zero requirements).

Tailored non-pricing policy measures by sector (e.g. increasing the use of scrap steel, changing building construction standards to allow low-emission cement and public procurement for specific materials) can help achieve the adequate level of incentives for each industry.

Playing fields between competitors can be distorted due to different geographic carbon prices, and carbon border adjustment mechanisms could help prevent carbon leakage.

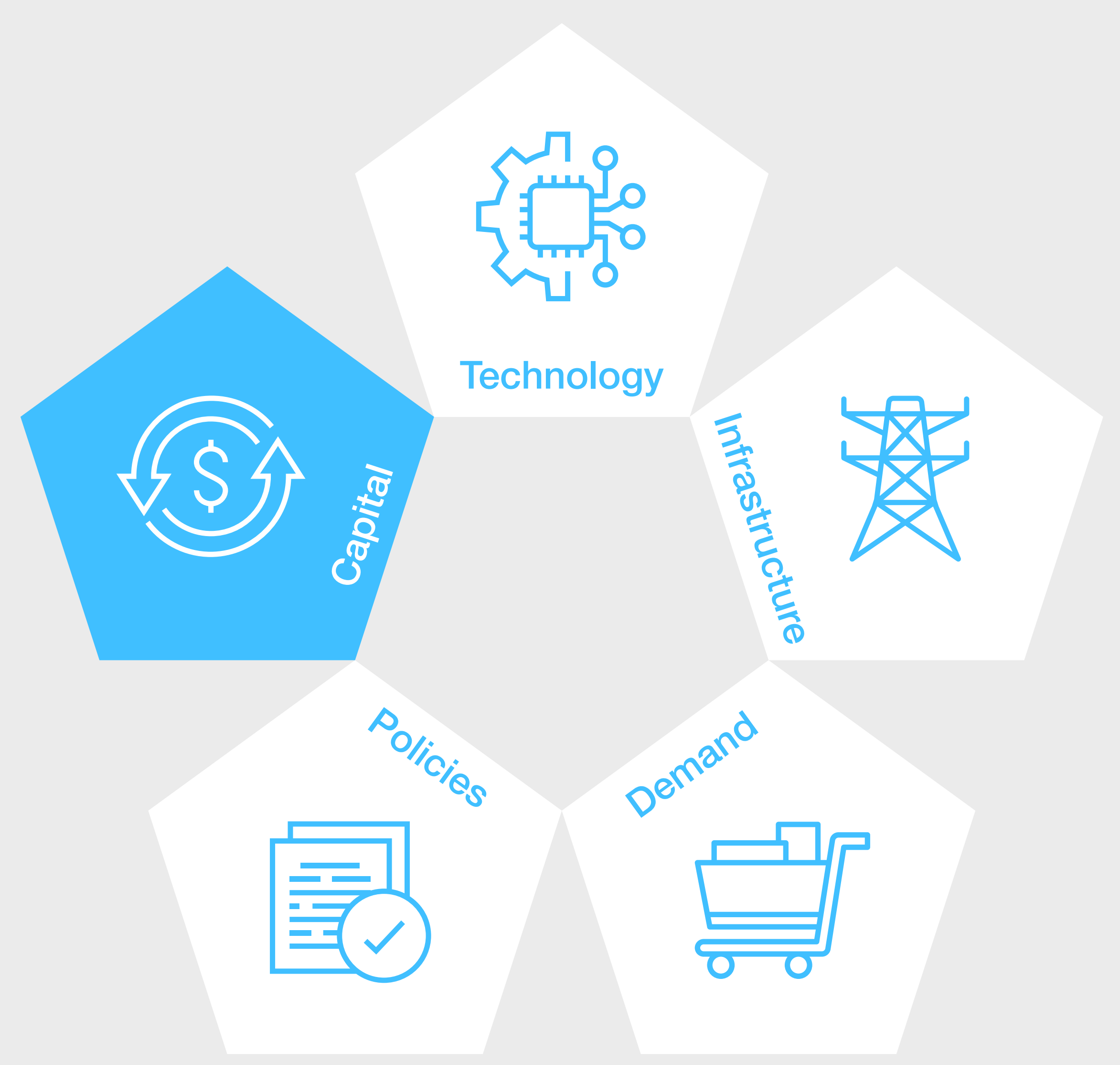
Sources: Accenture analysis, World Bank

Carbon price required to level the playing field for low-emission production vs actual carbon prices[1] ($/tCO$_2$e)



Notes: 1 Based on the estimated carbon price necessary to make "low-emission" product prices competitive with traditional product prices; **2** Refers to refined petroleum products.

Capital of about $2.1 trillion is needed to transform industries' asset base for net zero, but investment business cases are generally too weak to attract the required private funding.



Key messages

Developing low-emission production assets will require significant amounts of capital on top of business-as-usual investments, ranging from 20% of the current net property, plant and equipment (PPE) asset value in oil and gas to recapitalization of nearly seven times for the ammonia industry.

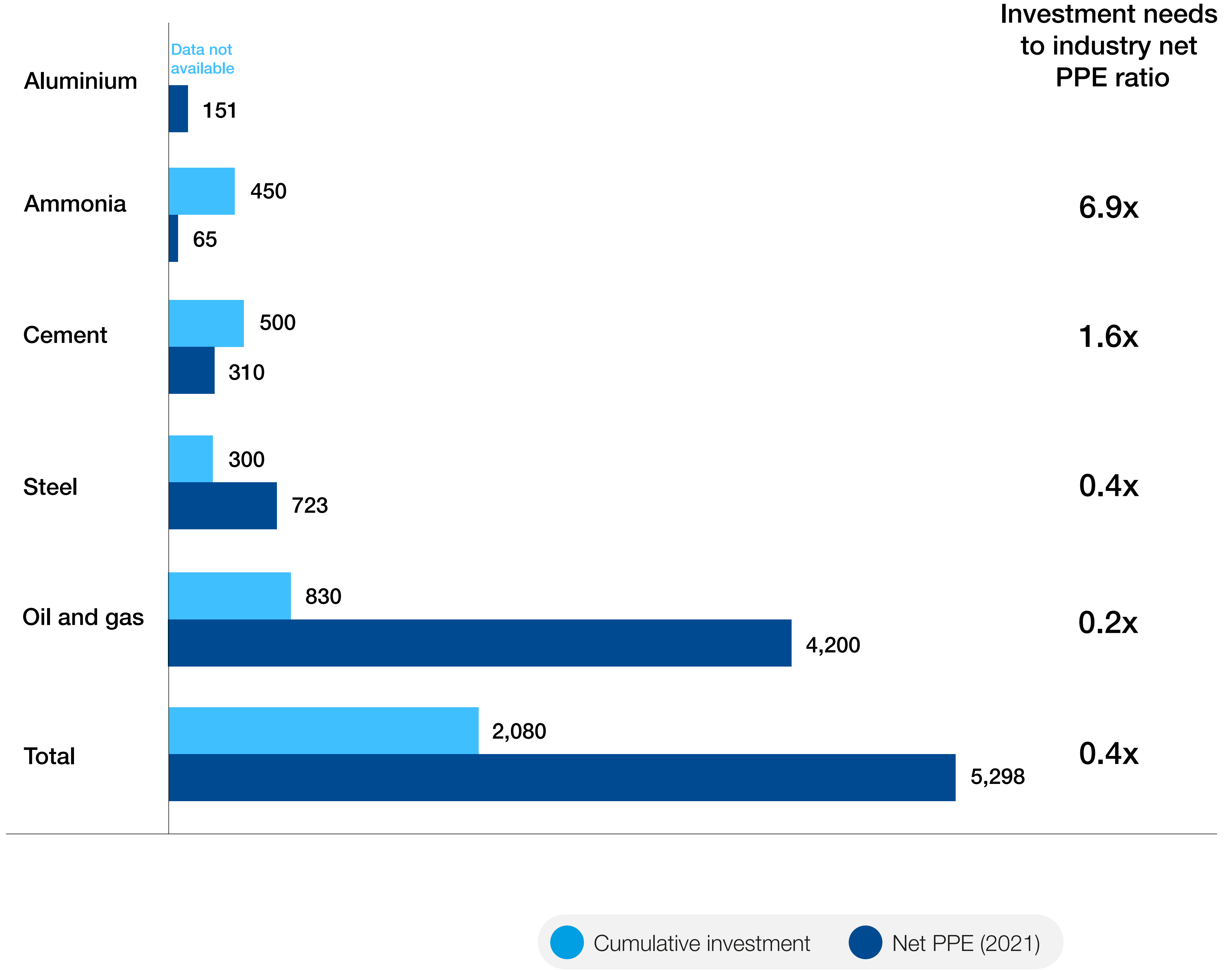
The current state of technology, infrastructure, demand and policy enablers generally lead to investment business cases that are not favourable for investments in low-emission assets.

Green bonds and other financing mechanisms are needed to attract capital; however, sector-specific criteria are often yet to be developed, with only 1% of Certified Climate Bonds issued in 2020 from these six industries.[1]

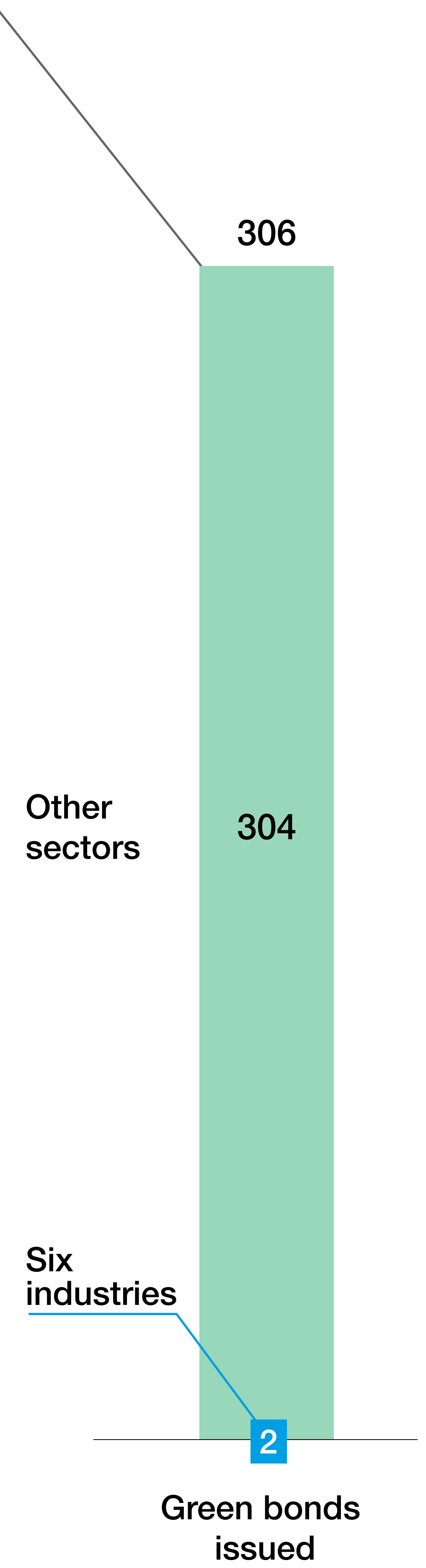
Additionally, public financing support can play a crucial role in reducing risk exposure for companies and help attract private capital in full-scale demonstration or early commercial projects.

Sources: Refinitiv, Climate Bond Initiative, Accenture analysis

Additional CapEx required vs net property, plant and equipment (PPE)[2,3] ($ billion)



Certified climate bonds 2020[1] ($ billion)



Notes: **1** Certified by Climate Bond Initiative, a third-party labelling scheme to align green debt with a 1.5 Degree Scenario; **2** Net PPE accounts for depreciation; **3** Excludes enabling infrastructure; Investments estimated based on demand requirements in IEA Net Zero by 2050 Scenario.

3 In-depth industry analysis

3.1

Steel industry
Net-zero industry tracker

Steel
Key highlights

Steel is the largest emitting manufacturing sector, generating 7% of all man-made emissions.

Steel demand could increase up to 30% by 2050 (~10% in IEA Net Zero by 2050 Scenario), risking a corresponding rise in emissions.

Three pathways exist to decarbonize primary steelmaking: carbon capture, hydrogen and electrochemistry.

Given the high costs of clean technologies, low-emission steel is expected to come with a green premium of 25-50% for steel buyers.

More than $2 trillion will need to be invested in low-carbon power, clean hydrogen and CO_2 handling infrastructure to enable clean technologies in steel production.

Demand signals from steel buyers and policies supporting low-emission steel production must improve drastically to incentivize investments.

Net-zero industry readiness

Readiness stage

2

Technology

The low-emission production technologies are **largely prototyped at scale**.

1

Infrastructure

The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**

4

Demand

Most of the market can pay the required green premium.

1

Policies

Very limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

1

Capital

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Net-zero industry performance

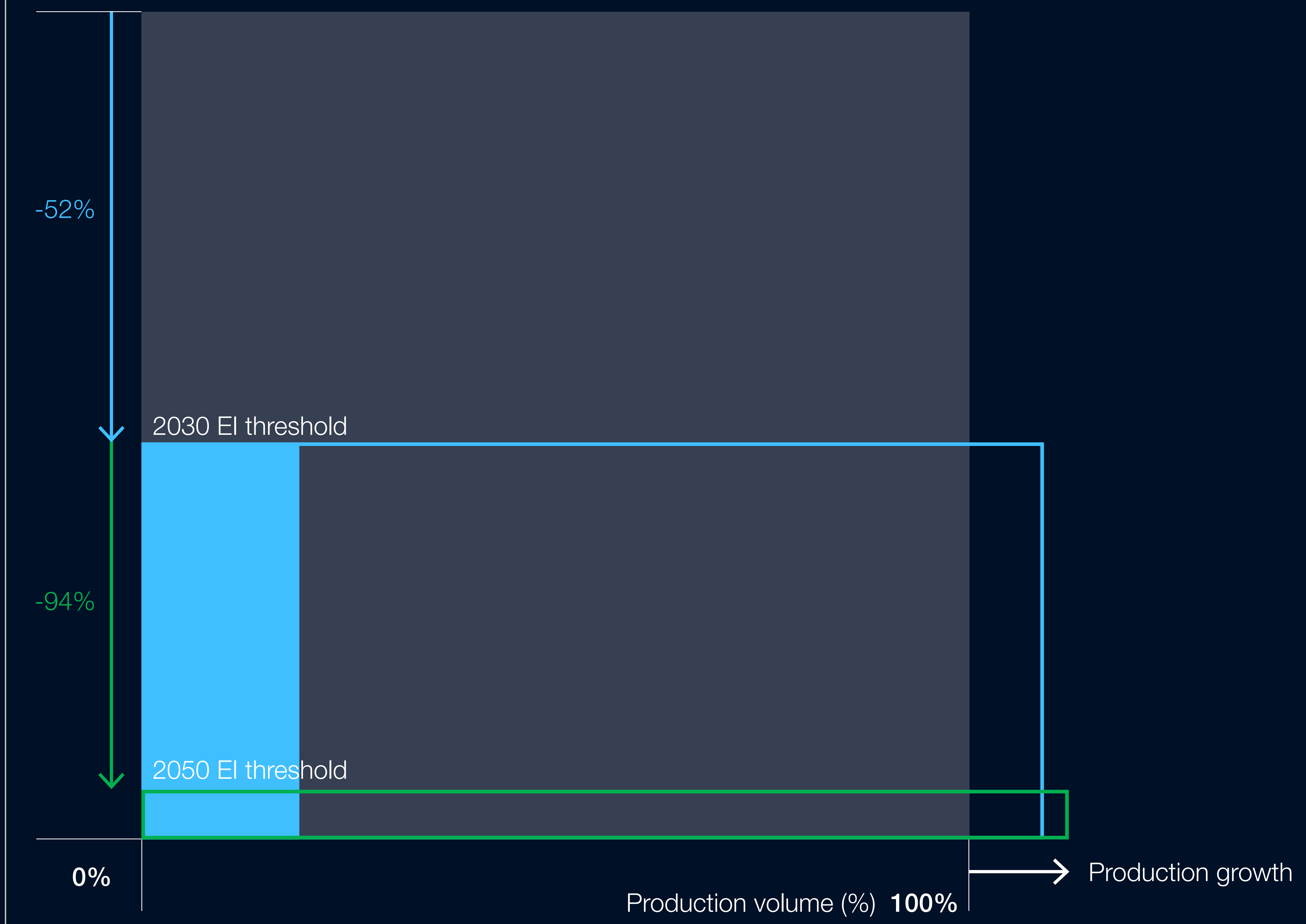
Size of box indicates industry GHG emissions in:

2020 | 2030 | 2050

Today's production meeting "reduced emission" intensity threshold[1]

Today's production meeting "low-emission" intensity threshold[1]

Production emission intensity (EI) (%) **100%**



Notes: 1 As defined in the "Mission and methodology" section of this report.

Steel
Executive summary

Steel is a fundamental material of modern society; it is used extensively in many sectors, including construction (50%), automobiles, shipping, aviation, machinery and countless metallic consumer goods – there are no scalable substitutes for steel as of today. Manufacturing steel requires highly energy-intensive processes to extract iron from iron ore and turn iron into steel – more than 85% of the energy used comes from fossil fuels. More than 50% of steel is made in China.

The steel industry generates about 7% of all man-made emissions – it is the largest emitting manufacturing sector. Steel demand is projected to rise 30% by 2050. Besides China, most regions, particularly India, Africa and South-East Asia, will see an increase in demand. Secondary steel production can be nearly carbon-neutral if powered by renewable electricity; it will play a significant role in decarbonizing steel supply. Primary steel will continue to be required to meet 60% of steel needs by 2050 and must be decarbonized.

Three pathways have been identified to decarbonize primary steelmaking: carbon capture, hydrogen and electrochemistry. Today, steelmaking using green hydrogen is seeing the most substantial momentum, with multiple projects under development worldwide. Technology costs for carbon capture and hydrogen use in the steel industry are expected to decrease over the decade but should remain at least 25-50% higher than traditional routes by 2030. Steelmaking via electrochemical processes is yet to be proven at scale and is not expected to become commercially available before 2035.

Besides investments in production assets, the technologies underpinning these three pathways will require at least $2 trillion in infrastructure investments in green hydrogen production, carbon transport and storage, and low-emission power generation – the latter is estimated at 921 GW, which is equivalent to today's European Union total capacity from all power sources combined. Low-emission steel is expected to reach the market by 2025 with a green premium of around 25-50% to steel buyers and below 1% to end consumers of steel products. To incentivize investments, demand signals from steel buyers are critical. This will require strengthening steel buyers' confidence in their ability to pass the premium to end consumers.

Public policy and international cooperation on carbon pricing, carbon border tax adjustments or product specification standards can help create a differentiated and economically viable market for first movers into the low-emission steel industry. Investments to decarbonize the steel industry are estimated at $300 billion on top of business-as-usual investments, i.e. approximately $10 billion per year until 2050. However, the current business case and returns on low-emission assets do not encourage mainstream investments from the industry.

We emphasize five priorities for the steel sector:

1. Implement efficiency levers to maximize emission reduction in existing processes.
2. Boost the number of low-emission projects to accelerate the learning curve, drive costs down and bring forward the commercial readiness of clean steel technologies.
3. Develop the renewable power capacity, green hydrogen production and CO_2 transport and storage infrastructure required to enable low-emission steel production.
4. Multiply demand signals for green steel to incentivize producers and investors to direct capital towards low-emission production assets.
5. Develop policies to support the four priorities above and strengthen the business case for low-emission steel production.

Steel Performance tracker

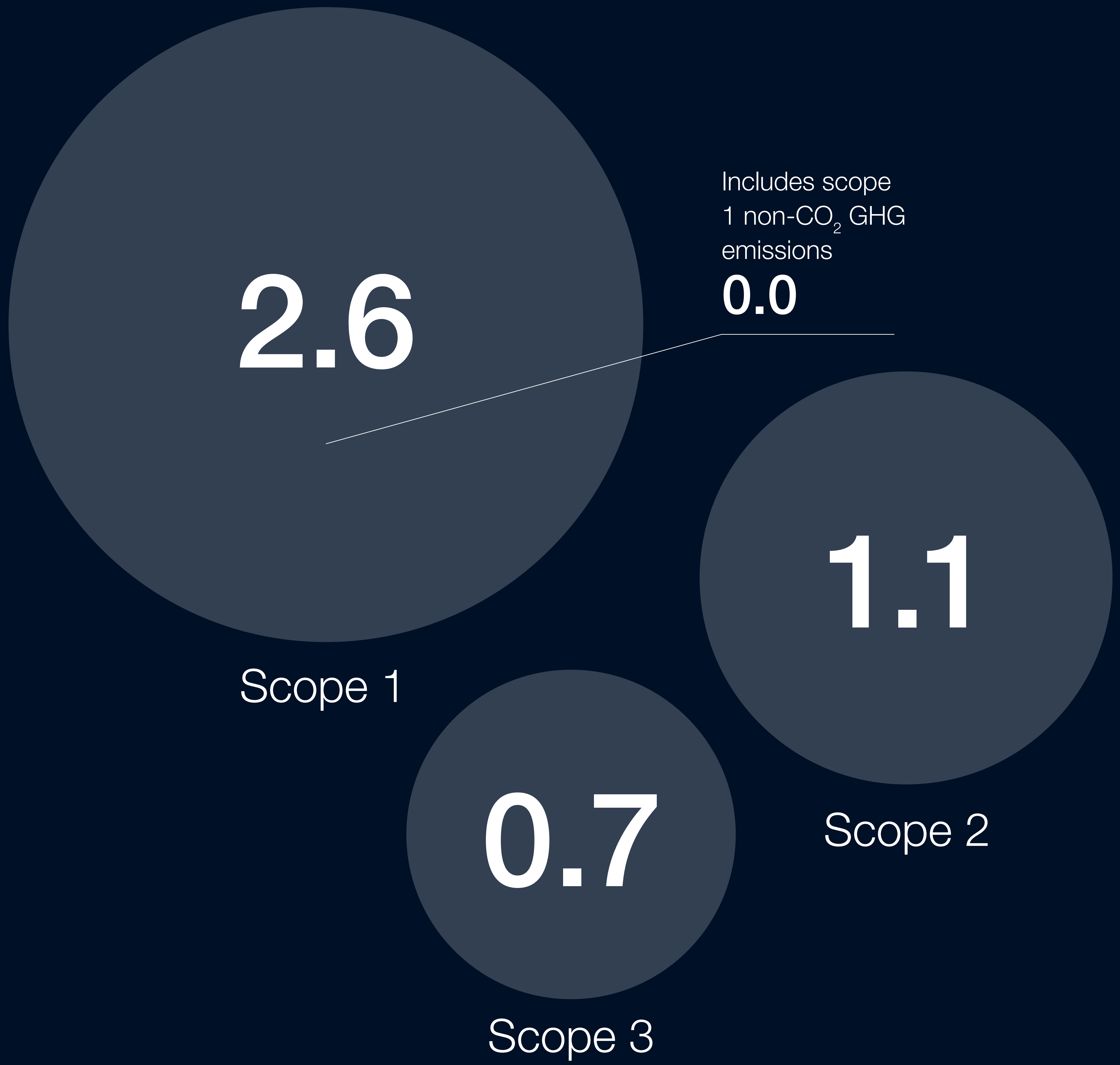
Steel is the largest emitting manufacturing sector, generating 7% of all man-made emissions. More than 85% of its energy consumption comes from fossil fuels.

Click here to see the full data:

Visual | Full data

What steel emits, captures and offsets

Scope 1, 2, and 3 GHG emissions (Gt CO_2e)



Total CCS (Gt CO_2e)

0.0008

Total offsets

Data not available

Steel
Summary

Steel benefits from promising technological pathways, but more decisive action is required to boost demand and investments in green steel.

Click on the enablers below to find out more.

Key messages

Low-emission production technologies are increasingly available but far from commercially competitive to be deployed at scale.

The cost of transforming steel assets is dwarfed by the cost of infrastructure needed – a significant bottleneck risk exists.

The green premium for end consumers is low, but steel buyers need to be incentivized to generate demand for producers.

Further decisive policy action can incentivize steel players into low-emission production.

Further de-risking and better returns will be needed to reorient larger investment flow towards the low-emission industry.

Technology

Readiness stage 2

The low-emission production technologies are **largely prototyped at scale.**

+25-50%

Production cost increase for low-emission production today

2025

Expected year of commercial readiness of first low-emission production.

Infrastructure

Readiness stage 1

The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**

$1,750 billion

Investments required in low-emission power generation

$222-586 billion

Investments required in low-emission hydrogen production

$35-109 billion

Investments required in CO_2 transport and storage

Demand

Readiness stage 4

Most of the market can pay the required green premium.

+25-50%

Expected green premium for steel buyers

+0.5-1%

Expected green premium for end consumers

Policies

Readiness stage 1

Very limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

$180-360/ tCO_2e

Carbon price equivalent required to level competitive landscape

Capital

Readiness stage 1

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

$300 billion

CapEx required to transform industry asset base by 2050 (~$10 billion/year)

Steel Technology

Three pathways exist to decarbonize primary steelmaking: carbon capture, hydrogen and electrochemistry. Green steel production costs could still be 25-50% higher by 2030.

The low-emission production technologies are **largely prototyped at scale.**

Home

Summary

Key messages

Scrap-based EAF production using 100% renewable electricity is the closest route to low-emission steel. However, 60% of primary steel is still expected to be needed to meet 2050 demand.

DRI-EAF with CCS is already available but not at a high carbon capture efficiency. Other processes leveraging carbon capture, hydrogen or electrochemistry are being developed. DRI-EAF with green hydrogen is seeing the most substantial momentum.

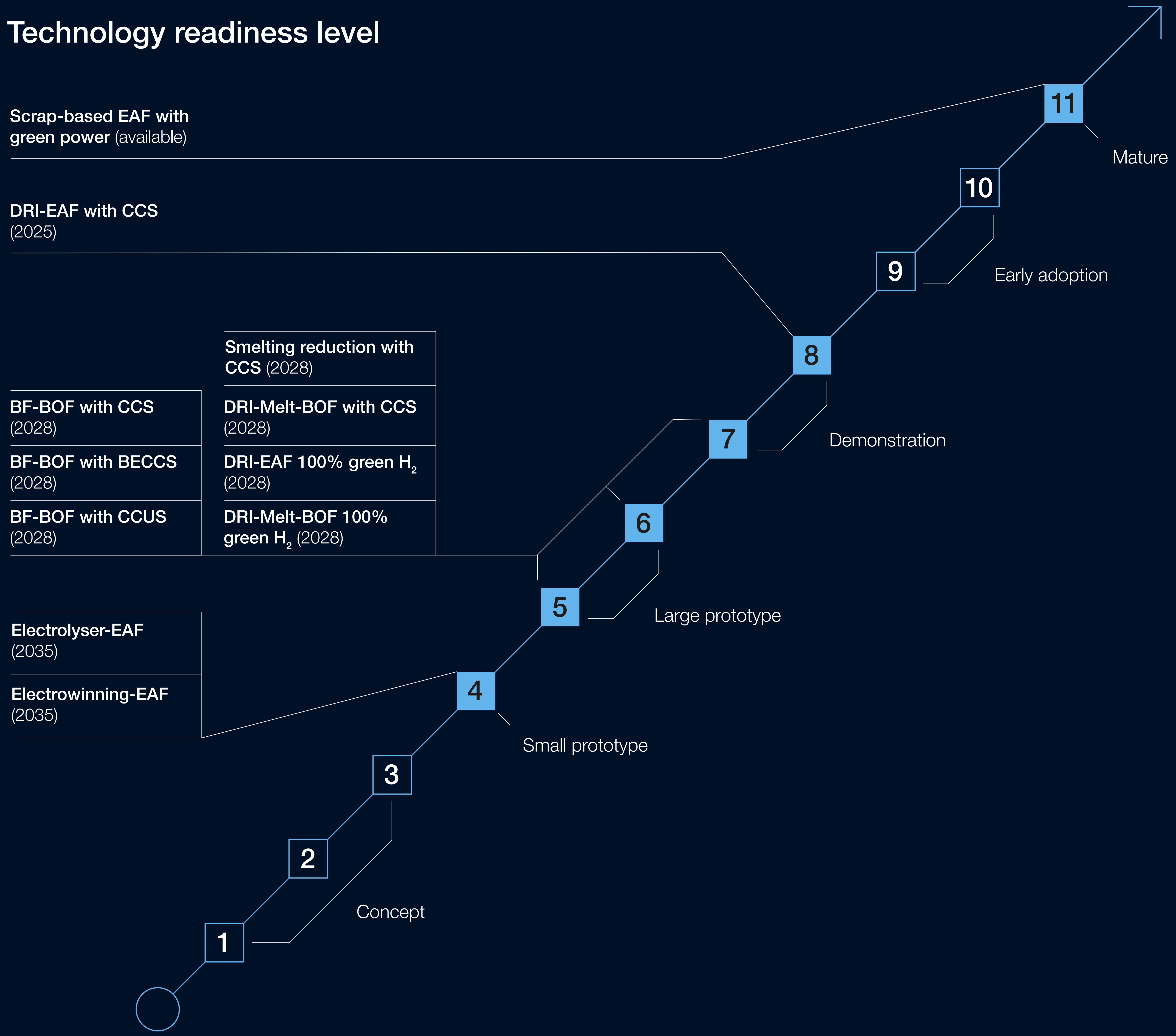
Most technologies are far from being commercially competitive today. Costs are expected to decrease over the decade but will remain 25-50% higher than traditional routes in 2030.

Sources: MPP (ETC), Green Steel Tracker, Global CCS Institute, Accenture analysis

Click here to see the full data:

Visual | Full data

Technology readiness level



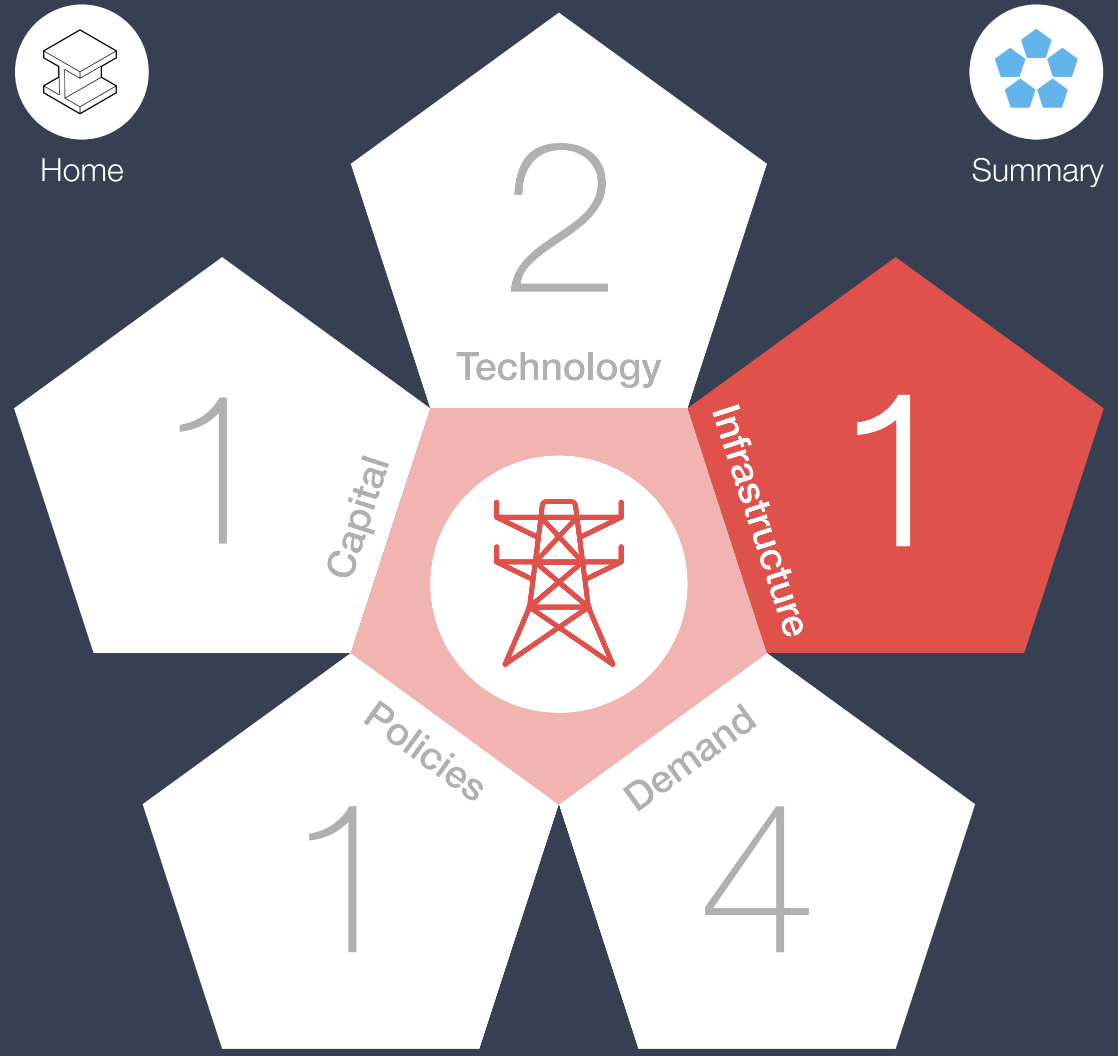
Steel
Infrastructure

More than $2 trillion will need to be invested in low-carbon power, green hydrogen and CO_2 handling infrastructure to enable low-emission technologies.

The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely**.

Home

Summary



Key messages

More than $2 trillion is required to scale the necessary low-carbon power, green hydrogen and CO_2 storage infrastructure over the next 30 years.

The steel industry will require a massive capacity of low-carbon power generation by 2050 – nearly equivalent to the EU's total electricity consumption today.

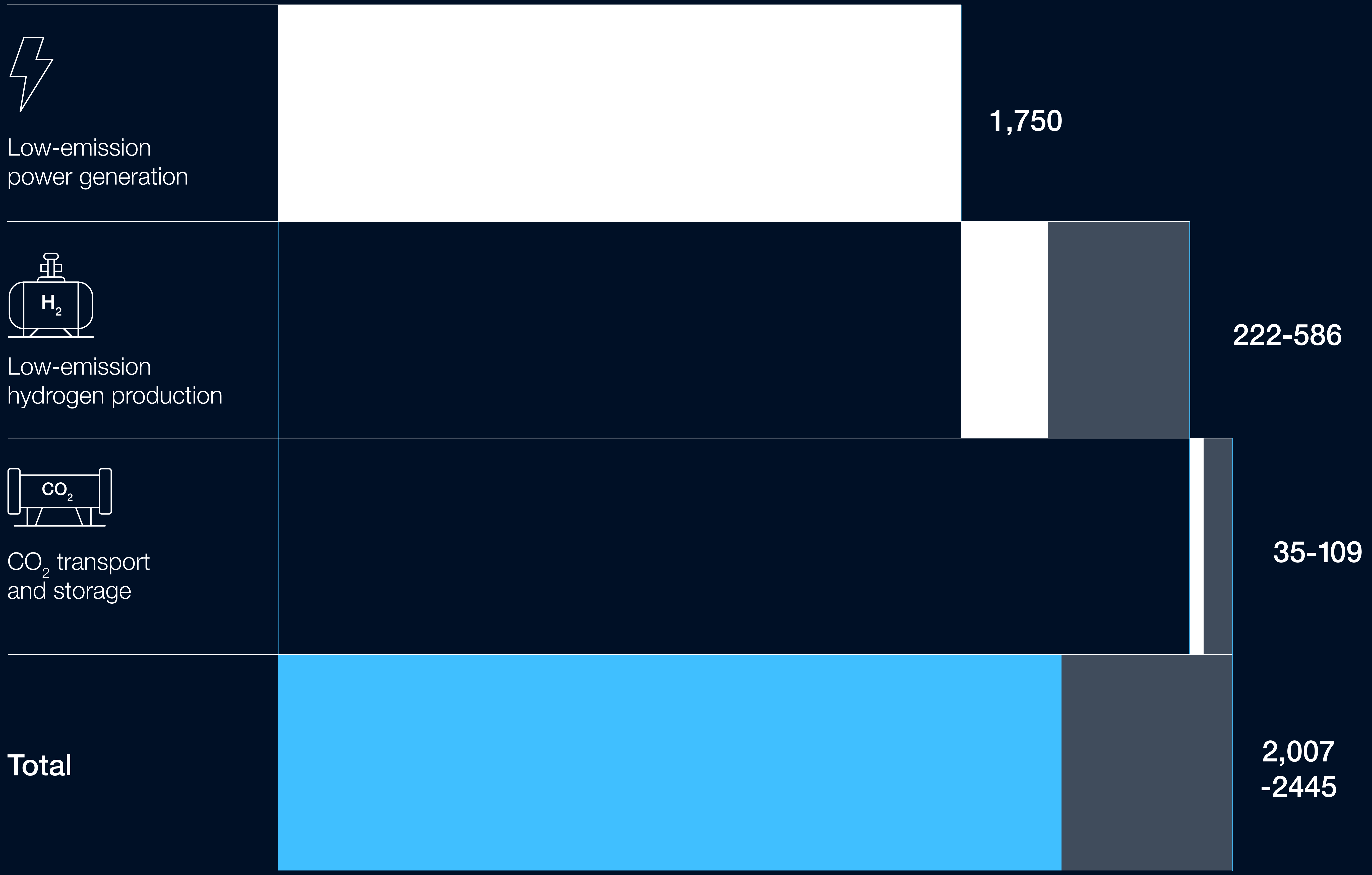
CapEx for low-emission power, green hydrogen and carbon storage are expected to go down with the learning curve; this could accelerate the development of the infrastructure needed by the steel industry.

Sources: MPP (ETC), Global CCS Institute, Accenture analysis

Click here to see the full data:

Visual | Full data

Investments required for enabling infrastructure ($ billion)



Steel
Demand

To boost demand signals, building steel buyers' confidence in their ability to pass their 25-50% green premium to end consumers is essential.

Most of the market can pay the required green premium.

Key messages

There is no low-emission steel available on the market today.

Low-emission steel is expected to arrive (in scarce quantity) on the market with a price premium of up to 50% and will be only available to buyers that have secured supply upfront with producers (e.g. bilateral offtake agreements).

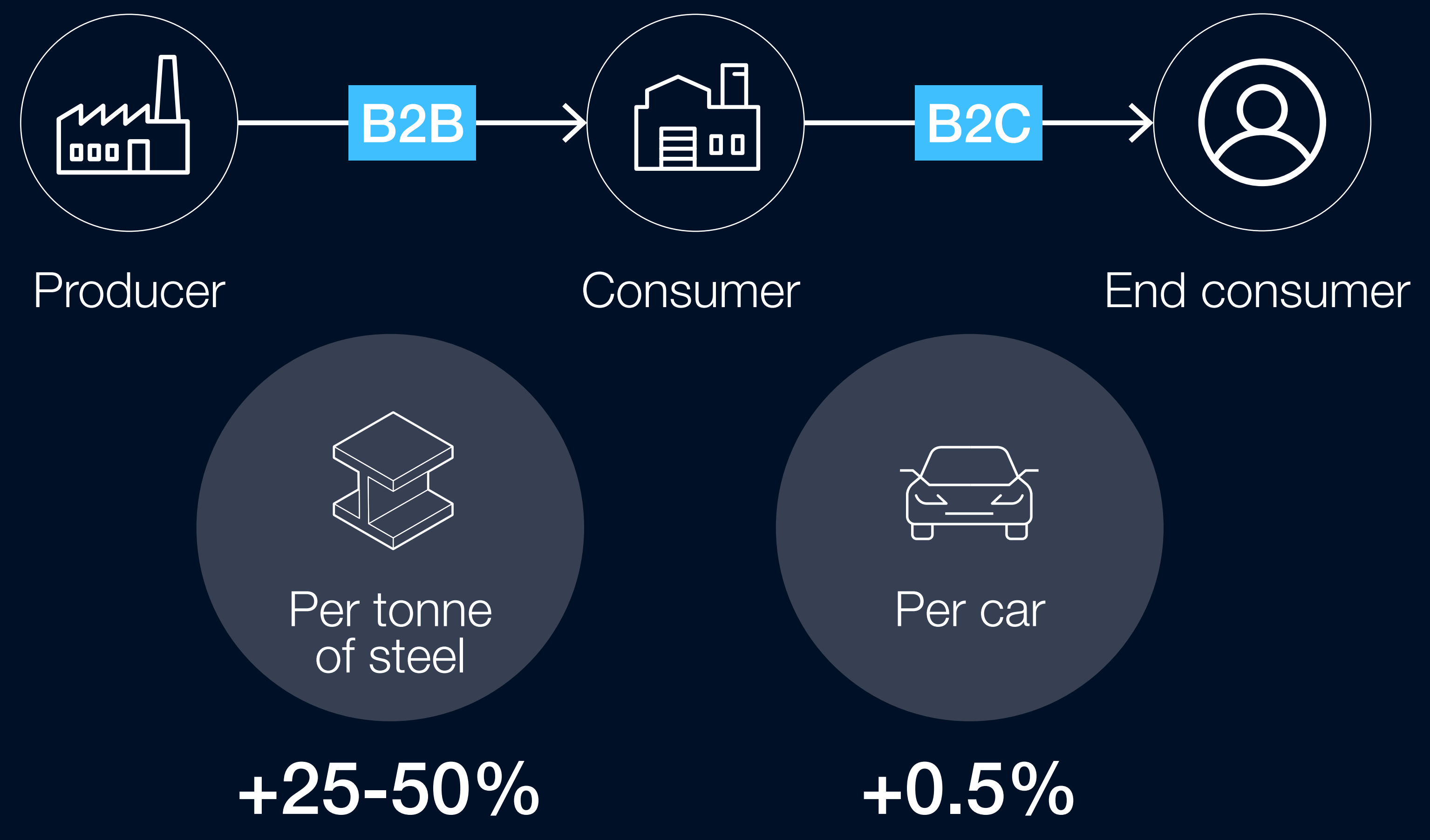
Provided low-emission steel comes in all necessary grades, products made of "green steel" could be made available to end consumers at a minimal green premium (+0.5-1%) while offering a strong competitive marketing advantage to sellers.

Sources: MPP (ETC), Global CCS Institute, Accenture analysis

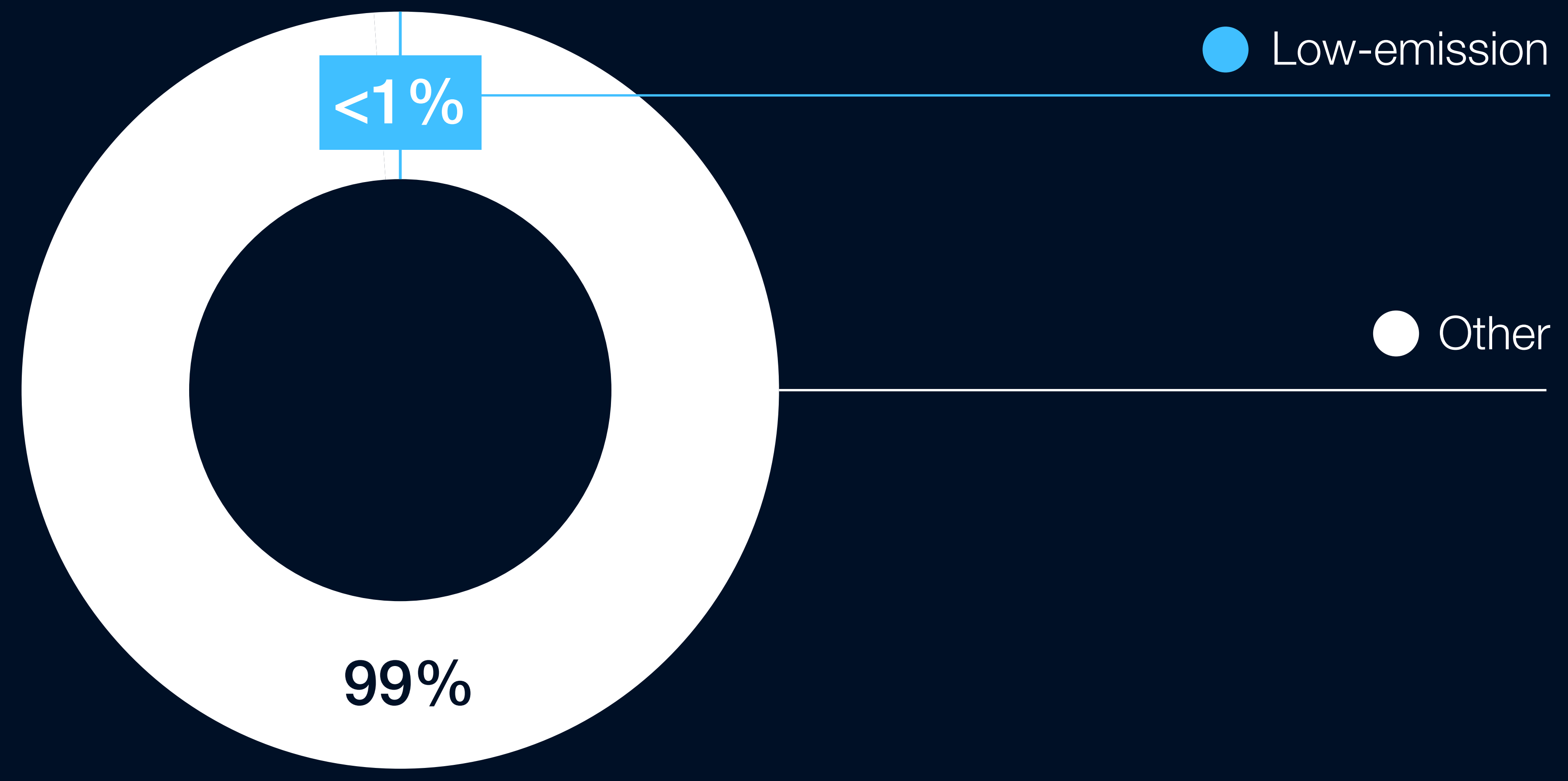
Click here to see the full data:

Visual | Full data

Green premiums



Market penetration



3.1.2 Steel readiness tracker

Steel
Policies

Further robust policy measures can help to create a differentiated and economically viable market for first movers into low-emission steel.

Very limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

Home

Summary

Key messages

Policies vary widely across geographies, and only examples of critical policies that have been recently introduced are included in this section.

To level the playing field for low-emission producers, an equivalent carbon price of $180-360/tCO_2e$ needs to be added to high-emission products.

An equivalent carbon price can be achieved through pricing policies or non-pricing policies such as product standards, public procurement standards or carbon border tax adjustments.

Current carbon prices are too low to incentivize a rapid growth of a low-emission industry.

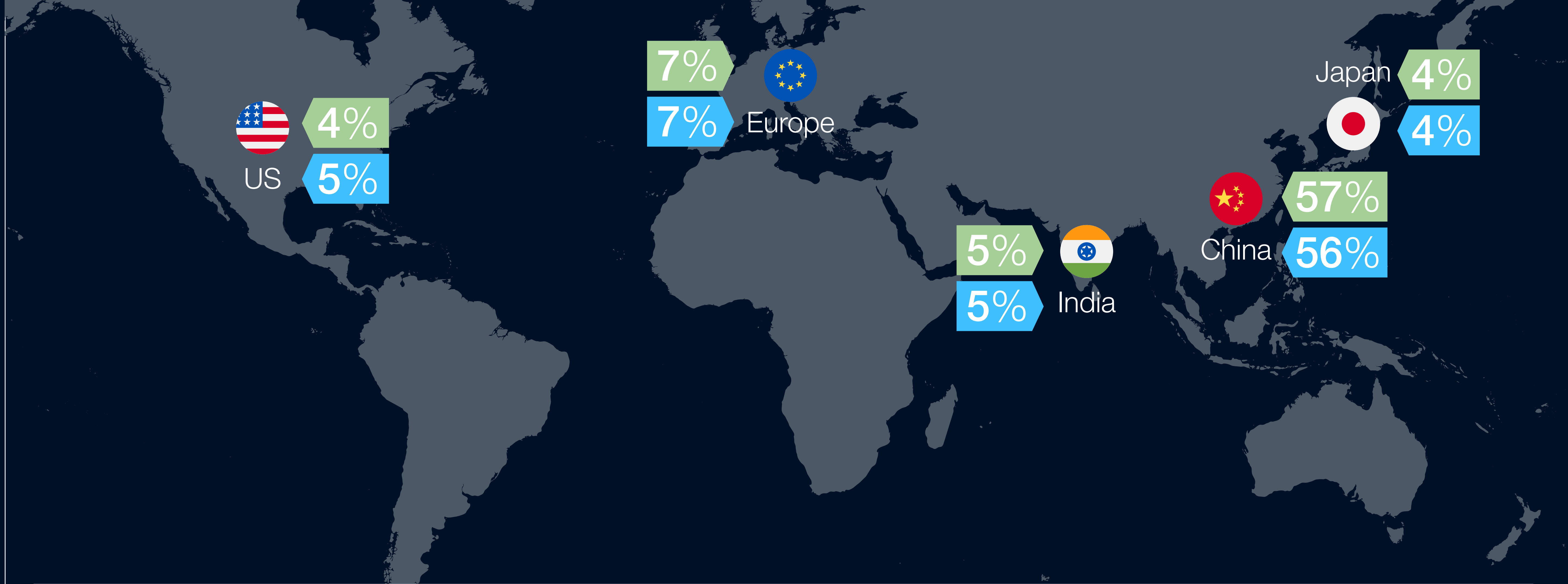
Sources: MPP (ETC), World Bank, ETC, government reports, Accenture analysis

Note: 1 Based on the estimated carbon price necessary to make "low-emission" product prices competitive with traditional product prices.

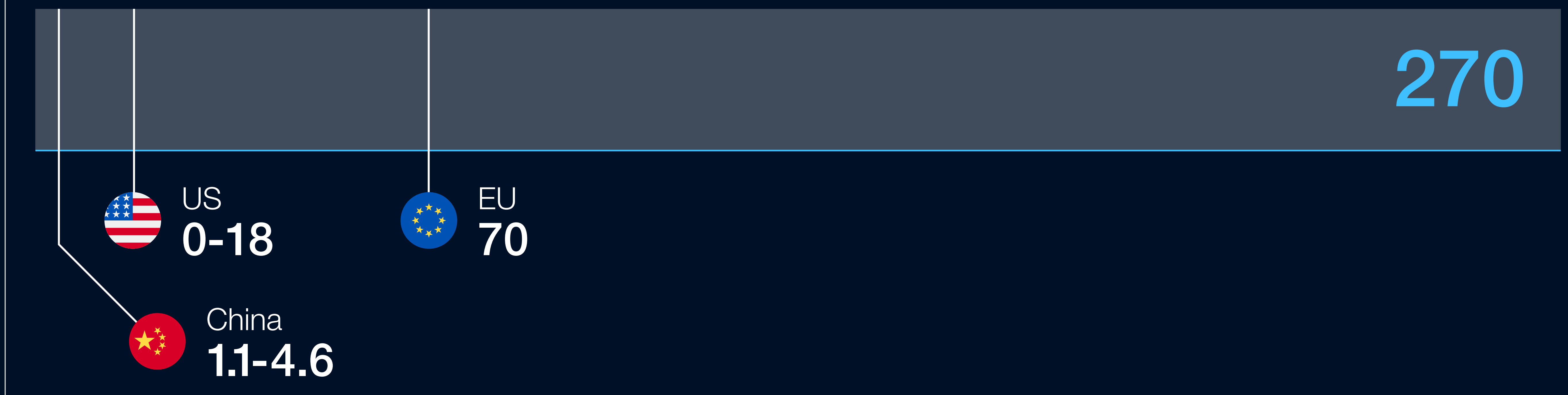
Click here to see the full data:

Visual Full data

Major producers and consumers of steel
(percentage of global production/consumption)



Average carbon price required to level the playing field for low-emission production vs actual carbon prices[1] ($/tCO_2e$)



3.1.2 Steel readiness tracker

Steel
Capital

An additional $300 billion is necessary to transform the steel industry asset base, but the current business case does not encourage investments.

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Home
Summary

Key messages

Additional investments of around $10 billion per year till 2050 are required to transform the industry asset base vs business-as-usual investments.

Major investment decisions for steel plants occur every 20-30 years on average (e.g. relining), providing rare opportunities to realize decarbonization investments. Half of all steel plants globally are due for their next major investment decision by 2030. Missing these opportunities may extend the life of high-emission assets to 2050.

The business case needs to improve significantly to attract and drive capital into low-emission steel assets.

Sources: MPP (ETC), Refinitiv, Accenture analysis

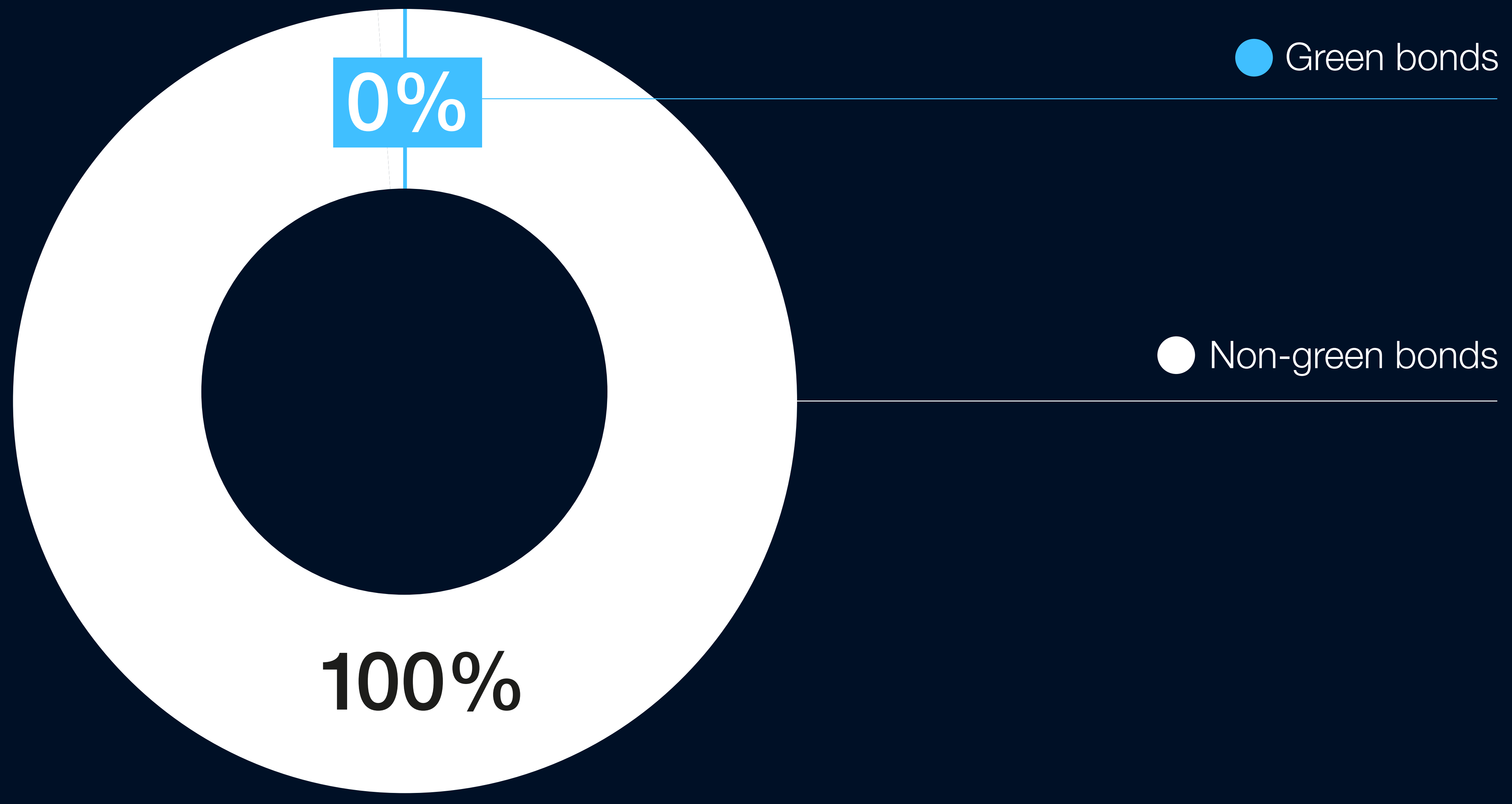
Click here to see the full data:
Visual | Full data

Assets and investments

Transformation investment required	$300 billion
Industry net property, plant and equipment (PPE)	$723 billion

= **0.4** Investment to PPE multiple

Debt issued (2020 bonds)



3.2

Cement industry
Net-zero industry tracker

Cement
Key highlights

Cement is the second largest emitting manufacturing sector – generating 6% of all man-made emissions.

Demand for cement could increase up to 45% by 2050 (0% in IEA Net Zero by 2050 Scenario), risking a corresponding rise in emissions.

Carbon capture is essential to the net-zero pathway for cement, but electrification and hydrogen could play supporting roles.

Given high costs of carbon capture, low-emission cement is expected to come with a green premium above 50%.

More than $185 billion will need to be invested in CO_2 handling infrastructure and clean hydrogen production to enable low-emission production in cement plants.

To incentivize investments, demand signals from cement buyers and supporting policies must improve drastically.

Net-zero industry readiness

Readiness stage

2

Technology

The low-emission production technologies are **largely prototyped at scale.**

1

Infrastructure

The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**

2

Demand

A limited portion of the market can pay the required green premium.

2

Policies

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

1

Capital

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Net-zero industry performance

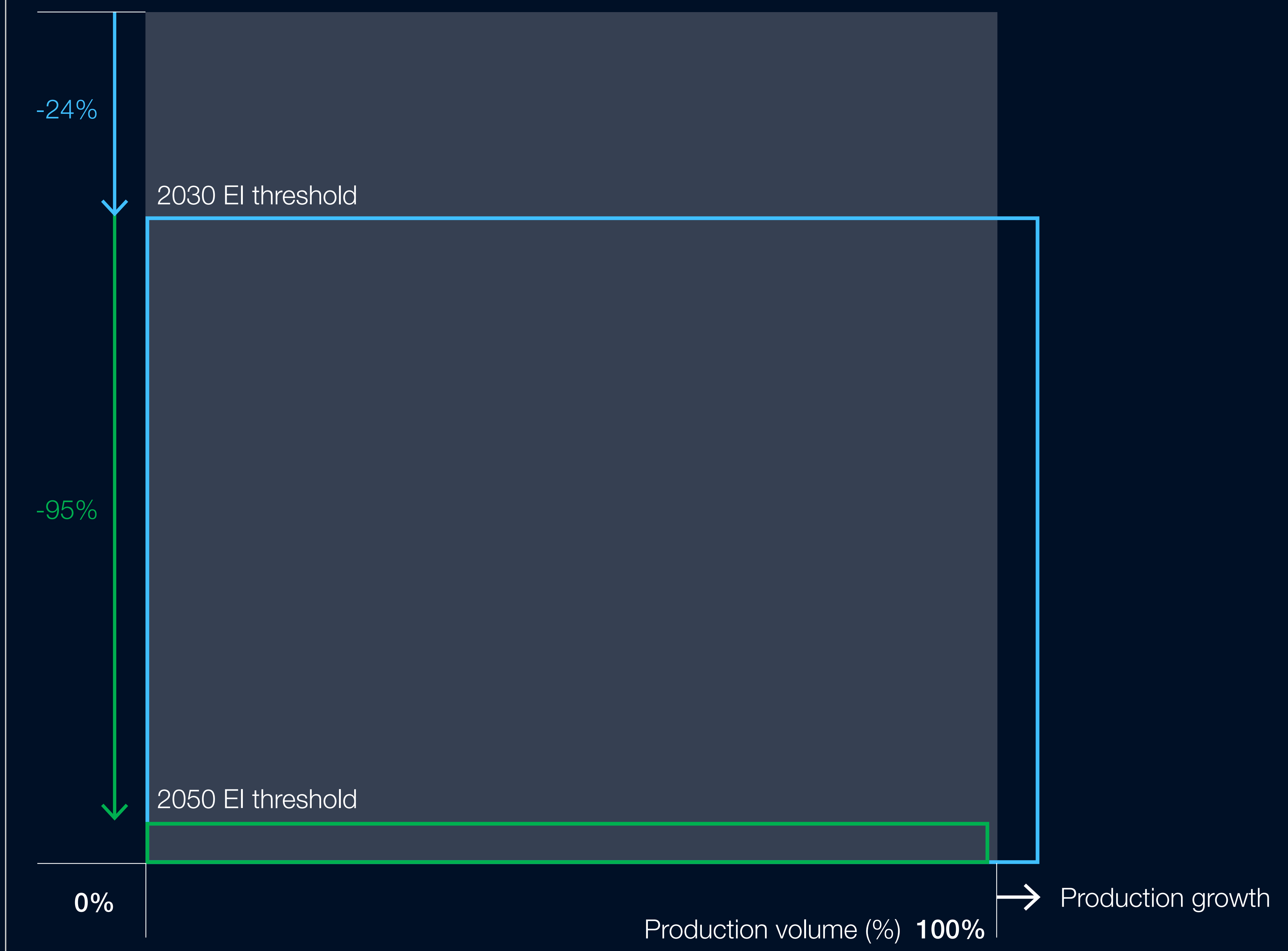
Size of box indicates industry GHG emissions in:

2020 2030 2050

Today's production meeting "reduced emission" intensity threshold[1]

Today's production meeting "low-emission" intensity threshold[1]

Production emission intensity (EI) (%) **100%**



Notes: 1 As defined in the "Mission and methodology" section of this report.

Cement
Executive summary

Cement is the second most consumed material in the world after water, with no scalable substitutes today. More than 50% is made in China. Manufacturing cement creates two sources of CO_2 emissions, about 40% comes from the burning of fossil fuels to heat kilns at 1300-1450°C, and about 60% is released during the thermal decomposition of limestone into carbon dioxide and lime, an essential element of clinker which is the main ingredient of cement (about 70%).

With 6% of all man-made emissions, cement is the second largest emitting manufacturing sector after steel. Societal needs and urbanization are expected to increase cement demand by 45% by 2050. Aligning with the Net Zero by 2050 pathway by IEA, however, requires limiting the increase to today's levels.

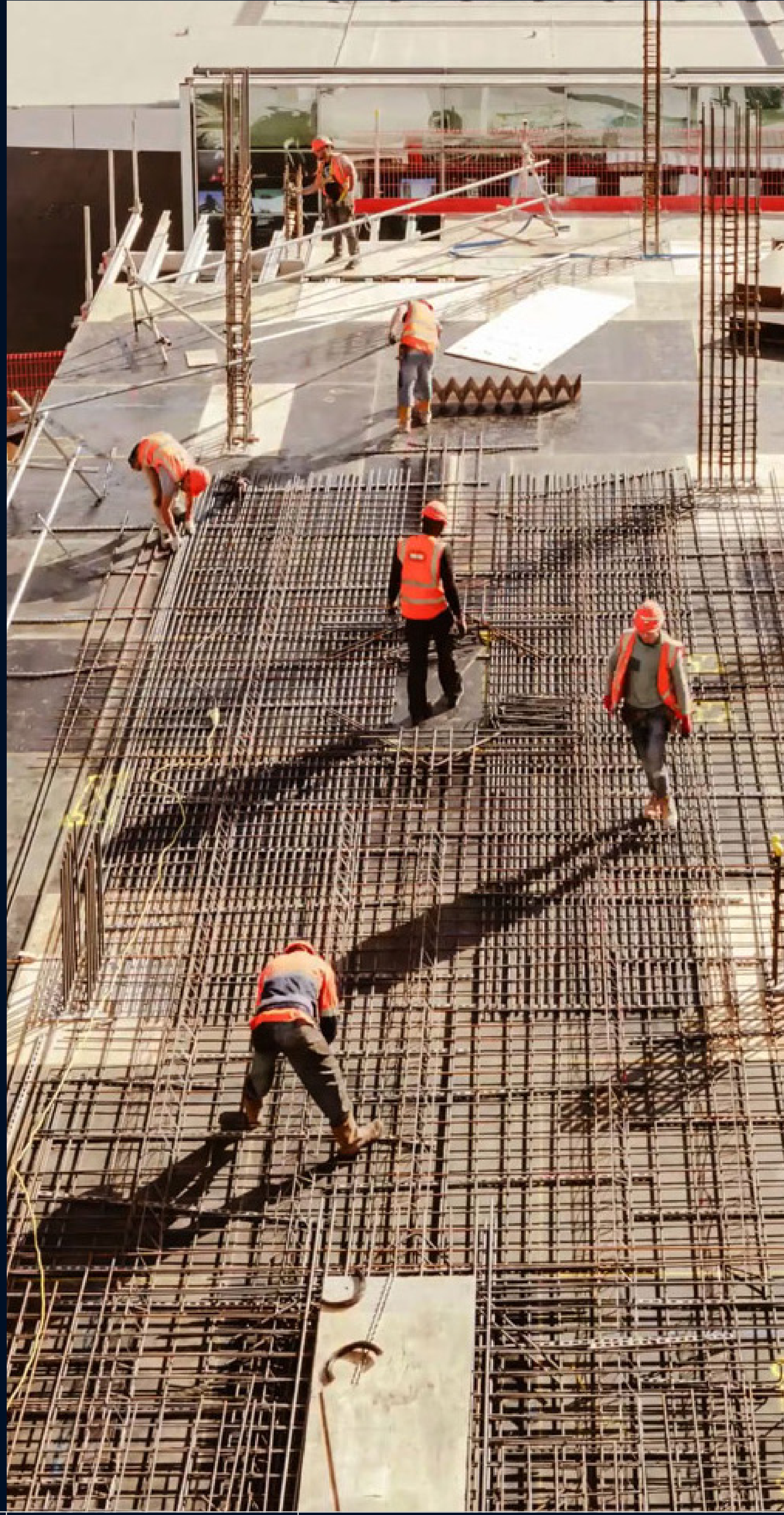
Without implementing transformative technologies, the cement sector can already cut emissions today with efficiency and circularity levers such as reducing clinker-to-cement ratio and using waste from other industries as alternative fuels. Deploying CCUS technology is the only known pathway to bringing sectoral emissions near zero. Today, its adoption could lead to a 50-85% production cost increase. The technology is expected to reach commercial stage by 2030.

Besides investments in carbon capture on production assets, investments of at least $185 billion are needed to develop the CO_2 transport and storage infrastructure to handle 1,370 MTPA of CO_2 (the most significant need after blue hydrogen in the IEA Net Zero by 2050 Scenario), as well as the low-emission power and hydrogen production infrastructure. Due to the high cost of carbon capture, low-emission cement is expected to reach the market with a green premium above 50%, which would lead to a 1-3% increase in housing prices. Demand signals for low-emission cement from the cement buyers are critical to incentivize investments. This will require strengthening cement buyers' confidence in their ability to pass the premium to end consumers.

International cooperation and more robust policy measures such as carbon pricing, carbon border adjustment mechanisms, circularity or product specification standards can help create a differentiated and economically viable market for first movers into the low-emission cement industry. The industry will require $500 billion to implement carbon capture technologies by 2050, i.e. $16 billion per year on top of business-as-usual investments. Access to green bonds through adequate taxonomy and ample public financing support will be instrumental to improving the business case.

We emphasize five priorities for the sector:

1. Implement efficiency levers to maximize emission reduction in existing processes and foster concrete recycling.
2. Boost the number of carbon capture projects to accelerate the learning curve, drive costs down and bring forward the technology's commercial readiness.
3. Develop the CO_2 transport and storage infrastructure required to enable low-emission cement production.
4. Multiply demand signals for low-emission cement to incentivize producers and investors to direct capital towards low-emission assets.
5. Develop policies to support the four priorities above and strengthen the business case for low-emission cement production.



Cement Performance tracker

Accounting for 6% of all man-made emissions, cement is the second largest emitting manufacturing sector after steel.

Click here to see the full data:

Visual | Full data

What cement emits, captures and offsets

Scope 1, 2, and 3 GHG emissions (Gt CO_2e)

Total CCS (Gt CO_2e)

<0.0001

Total offsets

Data not available

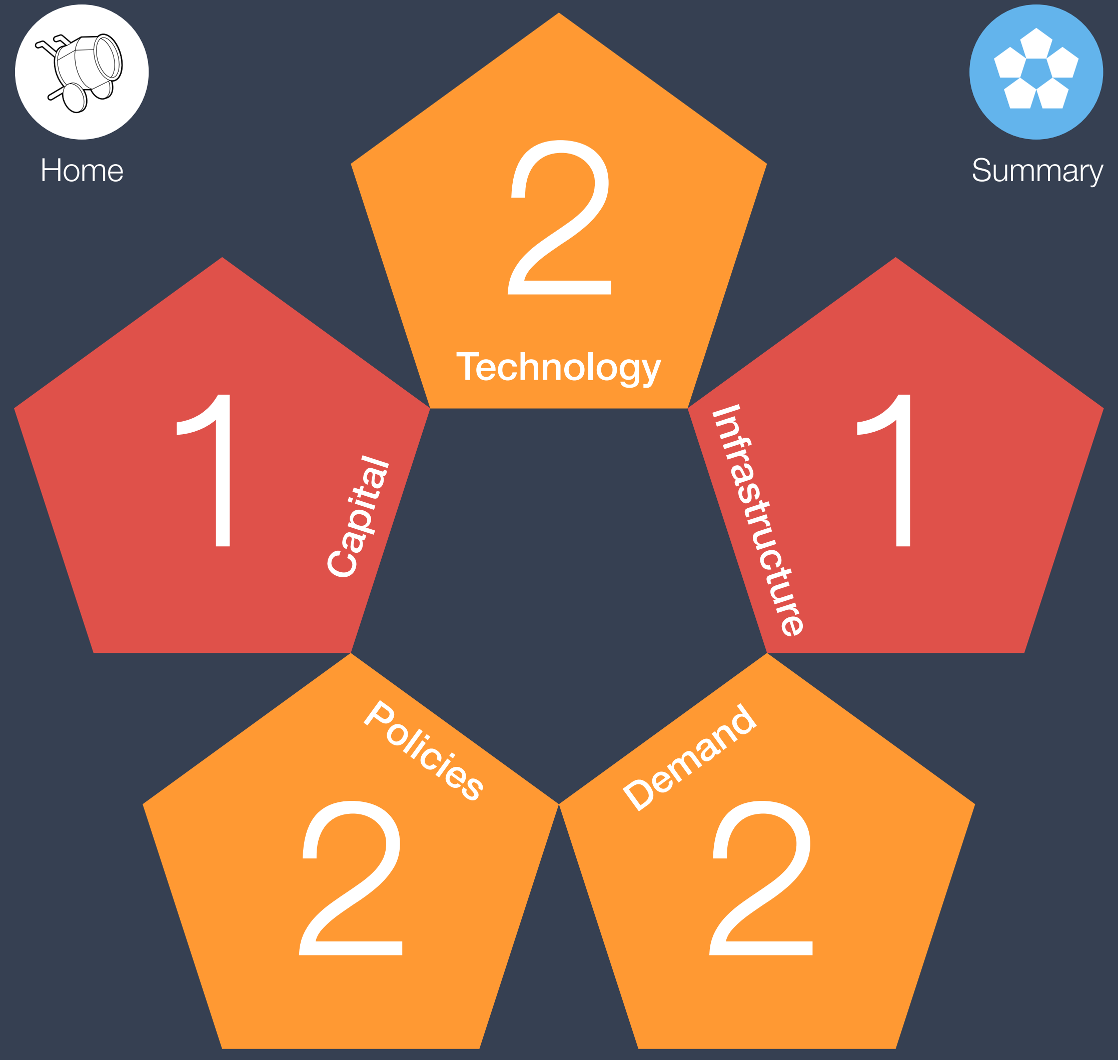
Cement
Summary

The path to net zero requires investing considerably more in CCUS technologies and CO_2 handling infrastructure, boosting demand and improving supporting policies.

Click on the enablers below to find out more.

Home

Summary



Key messages

As of today, carbon capture is the only technology that can bring the sector close to emissions compatible with a net-zero economy.

More than $185 billion will be required to develop the sector's carbon transport and storage needs.

Low-emission cement could reach the market with a significant green premium for cement buyers. While lower for end consumers, it could still represent a substantial amount in absolute terms for households and public spending limiting demand.

More decisive policy action is needed to incentivize cement players into low-emission production.

Technology costs and lack of policy/demand support result in unattractive returns, with limited CapEx for commercial-scale cement plants today.

Technology

Readiness stage 2

The low-emission production technologies **are largely prototyped at scale.**

+50-85%

Production cost increase for low-emission cement.

2030

Expected year of commercial readiness of first low-emission production.

Infrastructure

Readiness stage 1

The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**

Data not available

Investments required in low-emission power generation.

$75-140 billion

Investments required in low-emission hydrogen production.

$110-240 billion

Investments required in CO_2 transport and storage.

Demand

Readiness stage 2

A limited portion of the market can pay the required green premium.

+50-85%

Green premium for cement buyers.

+1-3%

Green premium for end consumers.

Policies

Readiness stage 2

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

$60-110 /t$CO_2$e

Carbon price equivalent required to level competitive landscape.

Capital

Readiness stage 1

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

$500 billion

CapEx required to transform industry asset base by 2050.

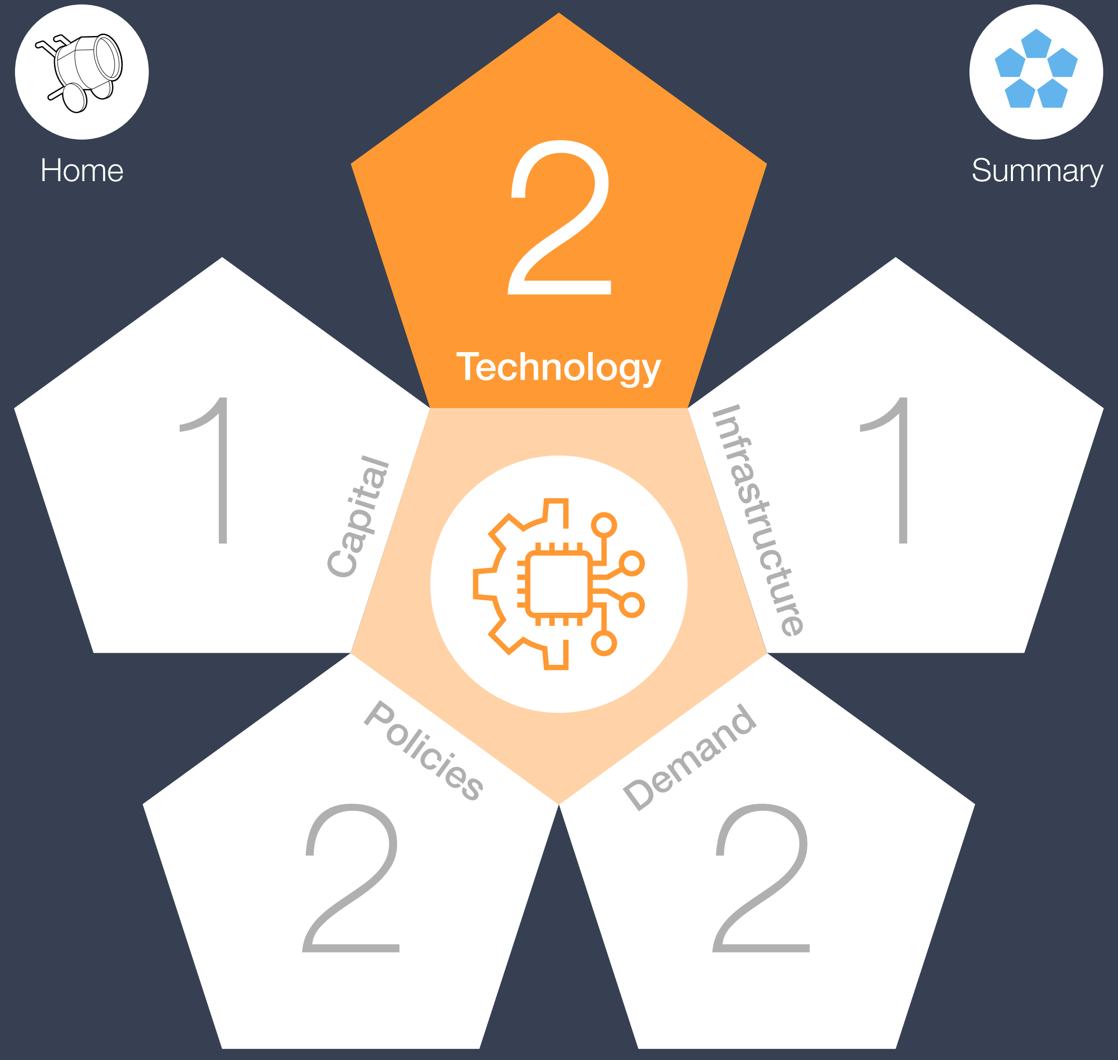
Cement
Technology

Efficiency levers can cut emissions by 25%, but only carbon capture can bring them near zero for a production cost potentially 50-85% higher.

The low-emission production technologies are **largely prototyped at scale.**

Home

Summary



Key messages

The cement sector can cut emissions by 25% today using efficiency levers in clinker production, cement production and decarbonizing power generation for quarrying, crushing, grinding and blending.

To get to low-emission cement, carbon capture is the only viable pathway today, but most projects are pilots/demonstrations with commercialization only expected in 2030.

Producing low-emission cement is expected to result in a +50-85% production cost increase.

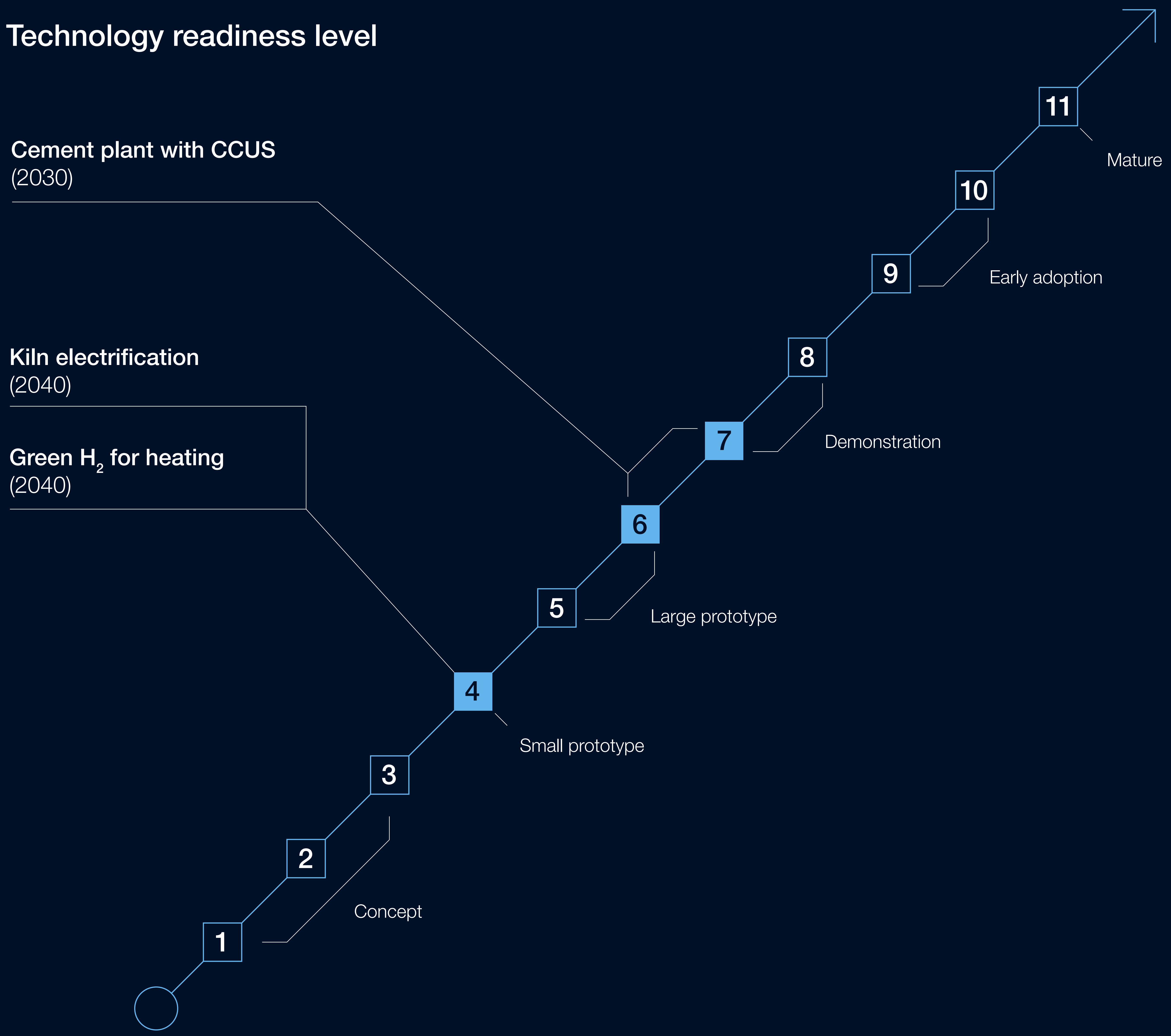
By 2040, electric kilns and green hydrogen could halve carbon capture requirements to process emissions only (by eliminating energy-related emissions).

Sources: GCCA, Global CCS Institute, Energies, Accenture analysis

Click here to see the full data:

Visual Full data

Technology readiness level



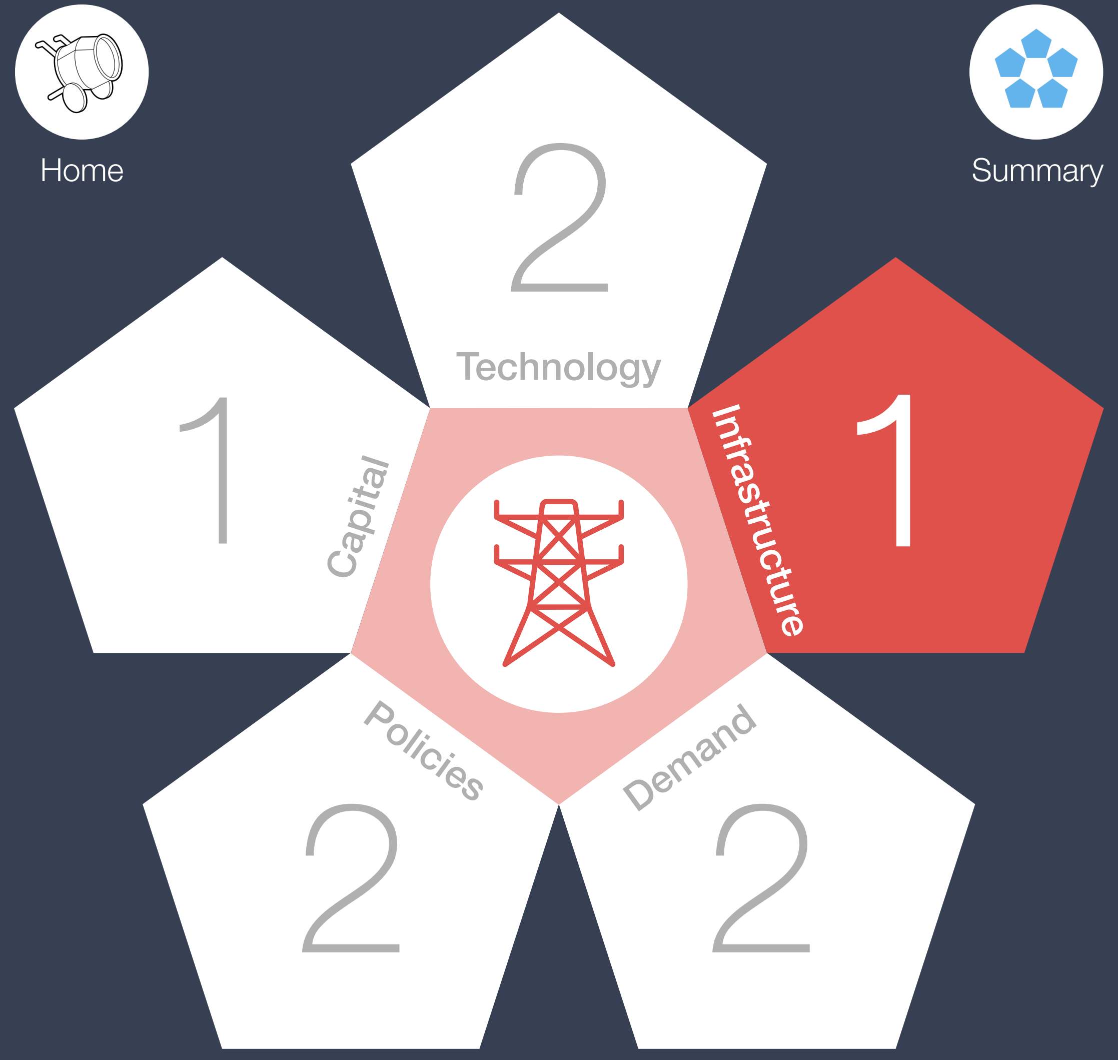
Cement Infrastructure

Carbon capture adoption could reach 85% of cement production by 2050 – provided more than $185 billion is invested in enabling CO_2 handling and clean hydrogen infrastructure.

The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**

Home

Summary



Key messages

The widespread deployment of carbon capture will require transport and storage of large volumes of CO_2, with an infrastructure investment of $110-240 billion needed. Currently, less than 1% of this infrastructure has been developed.

By 2040, to reduce the cement sector's carbon capture requirements, investments will also be required in green power and low-emission hydrogen infrastructure ($75-140 billion).

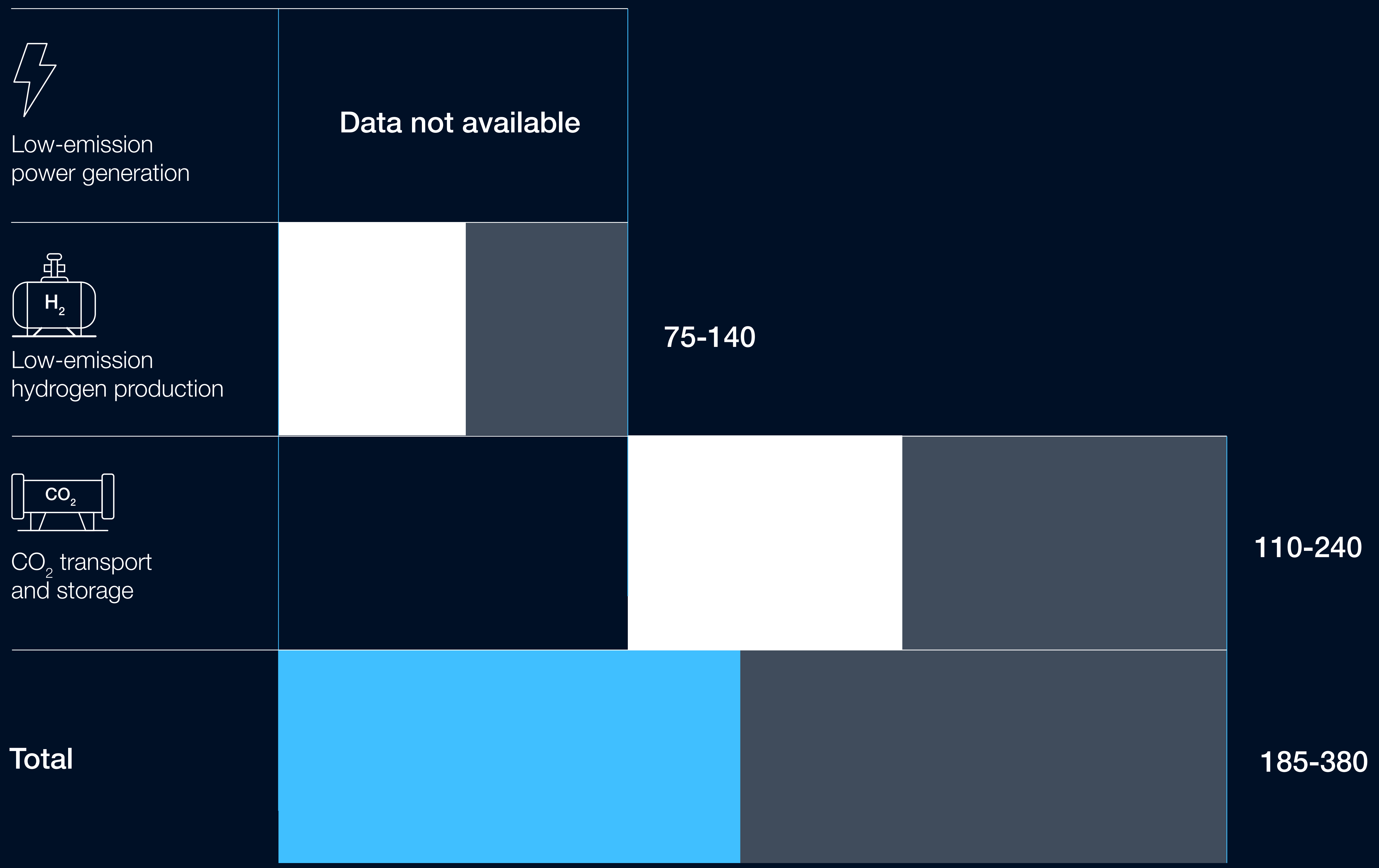
Infrastructure for concrete recycling and efficiency levers, such as alternative fuels availability or decarbonized raw materials is partially in place but needs further investments. These do not have the potential to bring the industry to near-zero emissions without CO_2 handling infrastructure.

Sources: GCCA, IEA, Global CCS Institute, Accenture analysis

Click here to see the full data:

Visual | Full data

Investments required for enabling infrastructure ($ billion)



Cement
Demand

To incentivize investments, building cement buyers' confidence in their ability to pass their 50%+ green premium to end consumers is essential.

A limited portion of the market can pay the required green premium.

Key messages

Given the high cost of CCUS today, the first low-emission cement is expected to reach the market with a significant green premium above 50% for cement buyers.

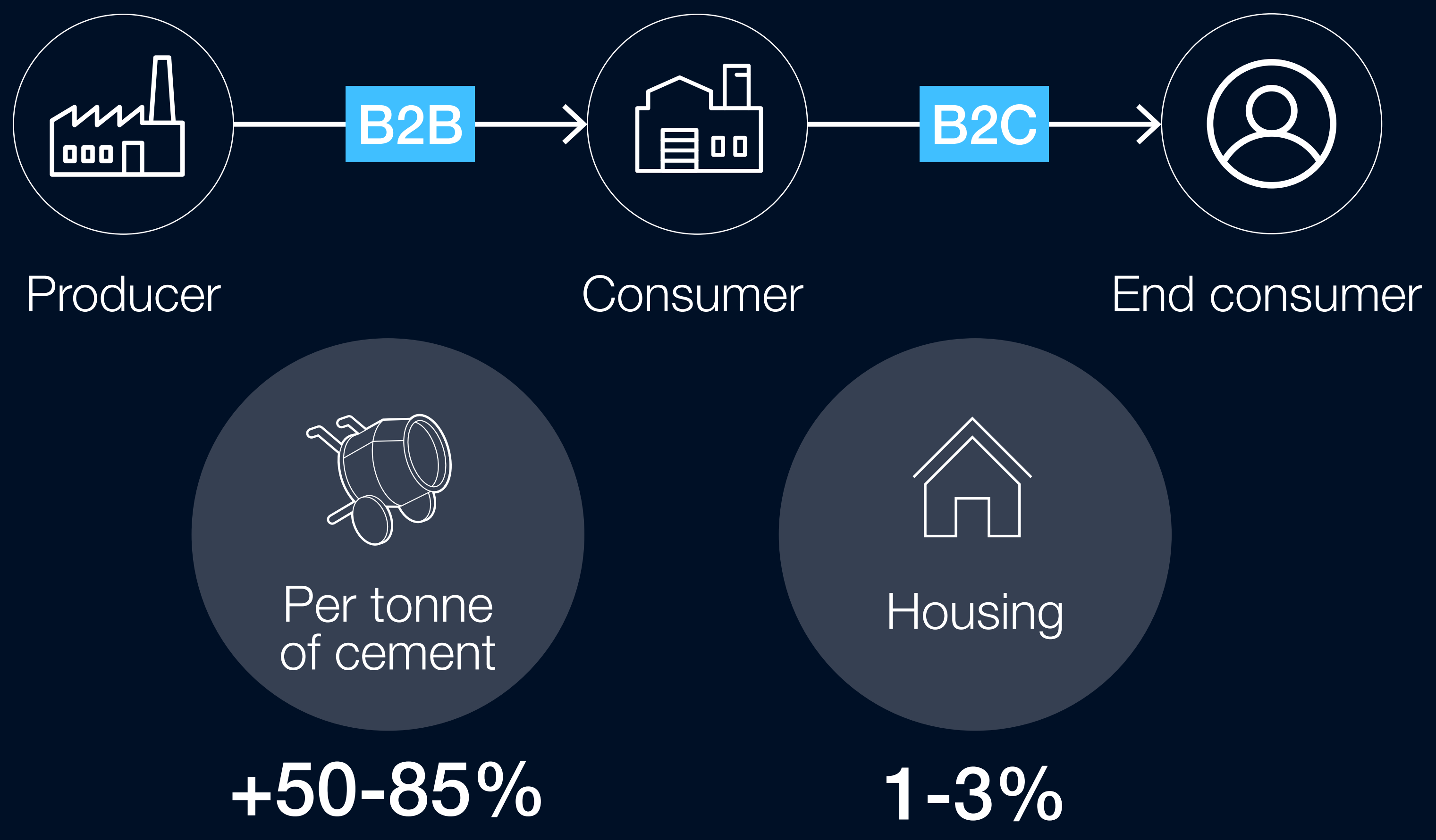
The green premiums on housing and infrastructure could be significantly lower – below 3%, but this could still represent a large amount in absolute terms for households and public sectors, limiting demand.

Sources: Bloomberg, GCCA, IEA, Global CCS Institute, Accenture analysis

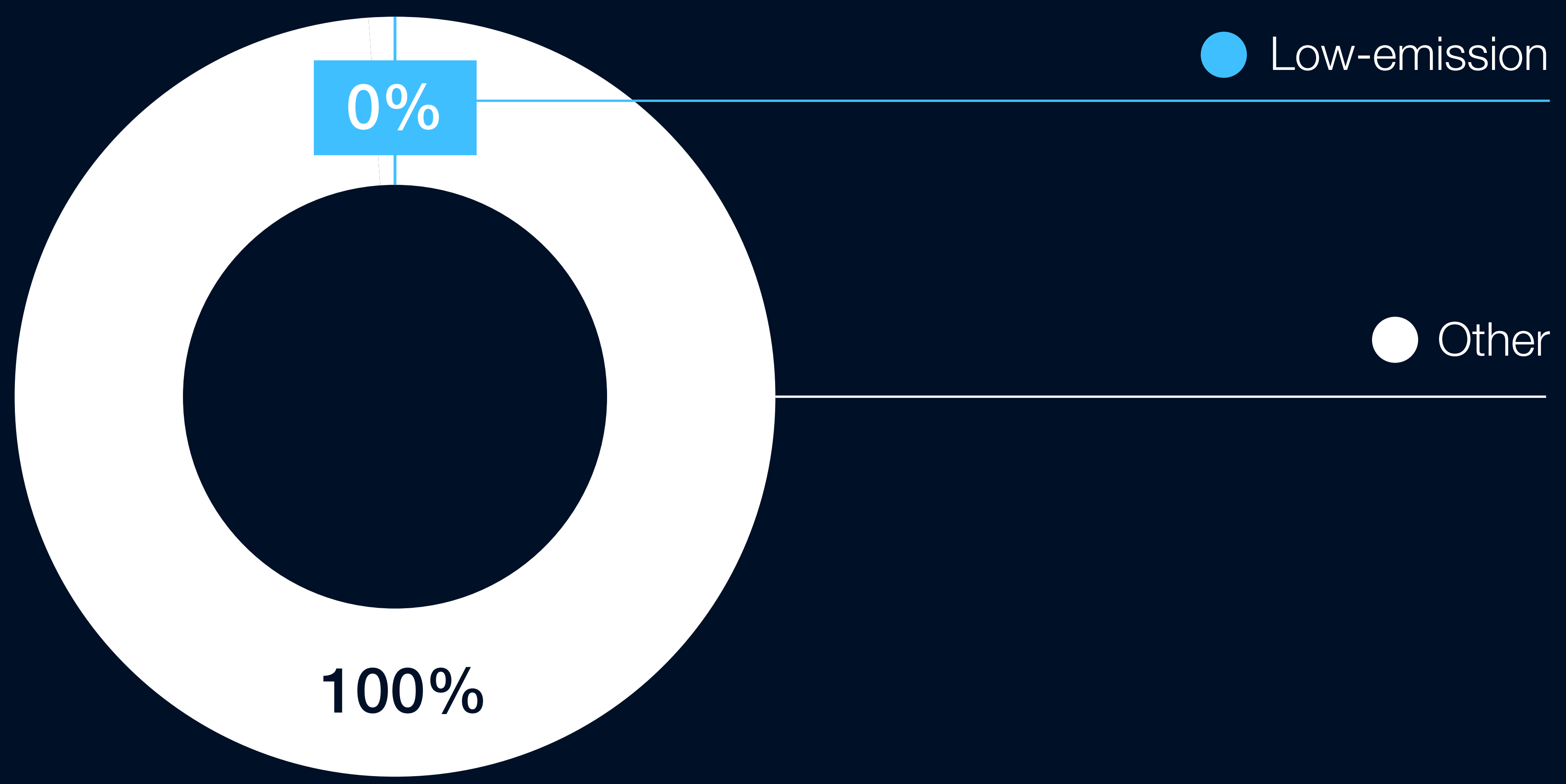
Click here to see the full data:

Visual | Full data

Green premiums



Market penetration



Cement
Policies

Further policy measures can help create a differentiated and economically viable market for first movers in low-emission cement.

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

Home

Summary

Key messages

Policies vary widely across geographies, and only examples of key policies that have been recently introduced are included in this section.

A $60-110/tCO$_2$e carbon price or equivalent policies (e.g. product standards, border tax adjustments) are required to level the competitive landscape.

Changes to building codes, concrete standards/recipes and public procurement could boost demand for low-emission cement/concrete.

Public procurement as detailed in the *Low-Carbon Concrete and Construction* report[1] could serve as a model to provide disclosure of embodied carbon and create incentives for low-carbon design.

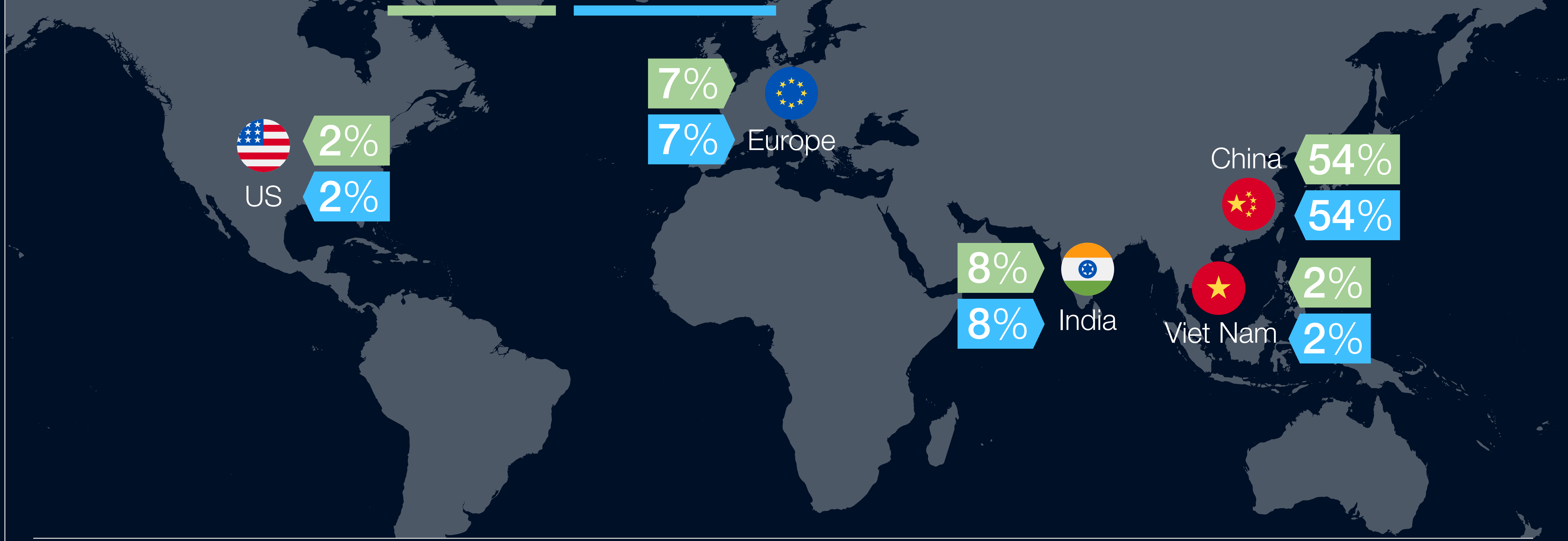
Sources: GCCA, Global CCS Institute, World Bank, Mission Possible Partnership (MMP), Various government reports, Accenture analysis, European Cement Association

Notes: **1** Mission Possible Partnership (MPP), Low-Carbon Concrete and Construction: A Review of Green Public Procurement Programmes, 2022; **2** Based on the estimated carbon price necessary to make "low-emission" product prices competitive with traditional product prices.

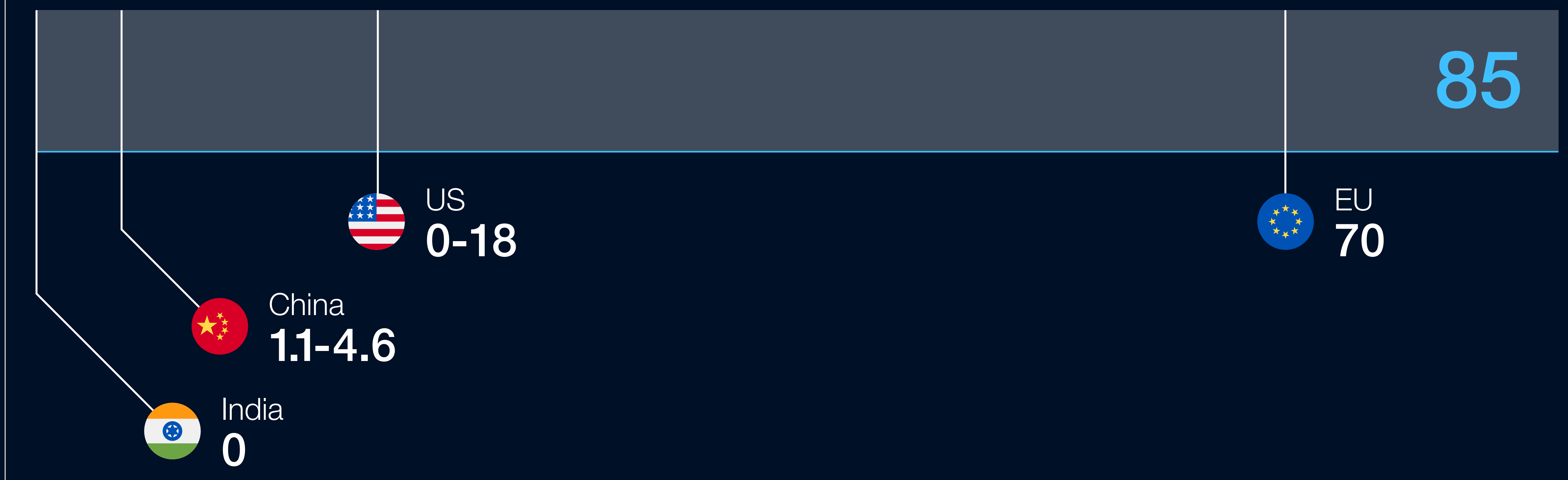
Click here to see the full data:

Visual | Full data

Major producers and consumers of cement
(percentage of global production/consumption)



Average carbon price required to level the playing field for low-emission production vs actual carbon prices[2] ($/tCO$_2$e)



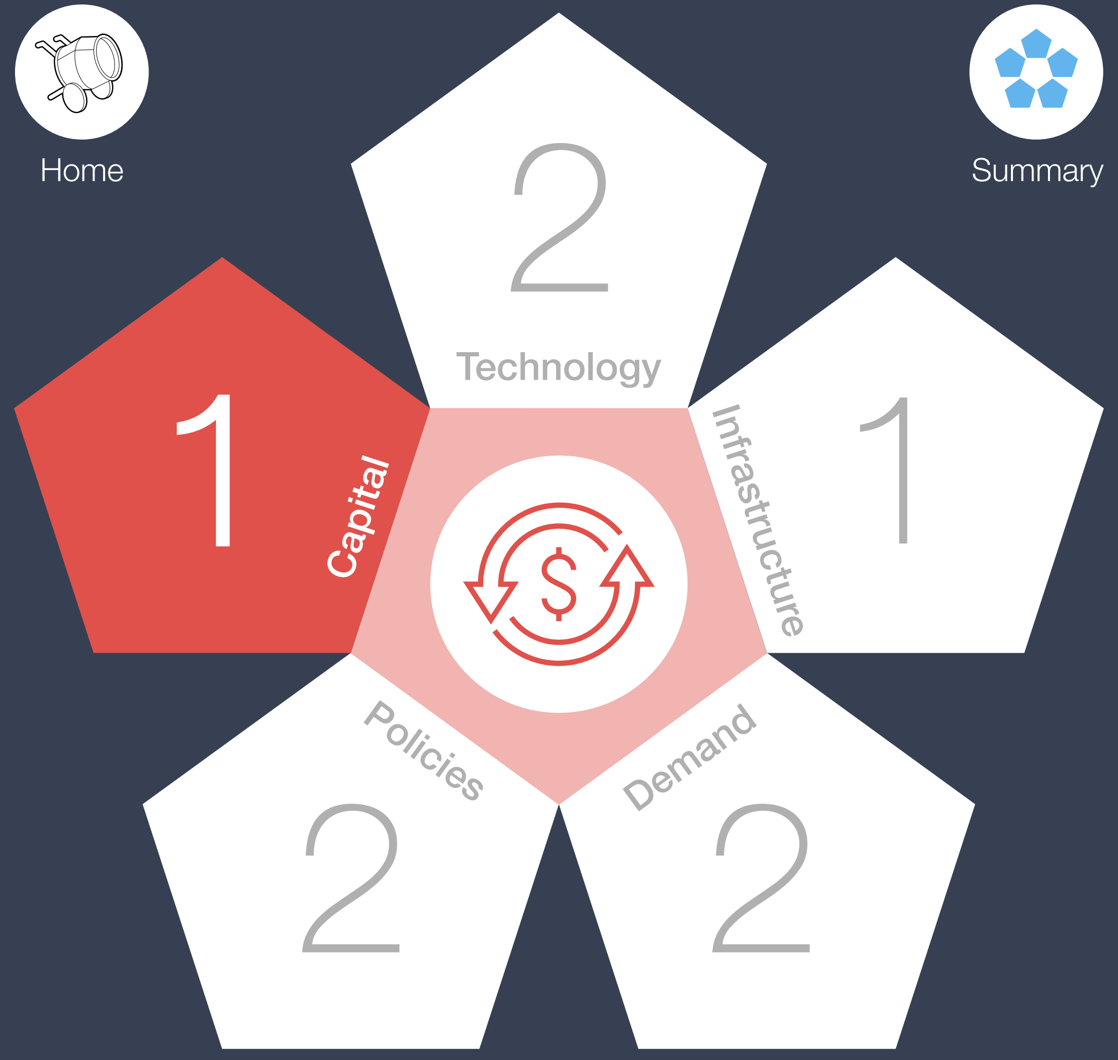
Cement
Capital

Five hundred billion dollars is necessary to transform the industry asset base with CCUS – current returns on low-emission assets do not encourage investments.

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Home

Summary



Key messages

Investments to transform asset base are estimated at $500 billion to retrofit cement plants with carbon capture.

The industry will also require capital to improve emission efficiency (e.g. alternative fuels, thermal efficiency).

An adequate taxonomy for the cement industry investments (equity and green bonds) is required to attract more capital for the industry transformation.

Targeted public finance and international cooperation could help lower the financial risks associated with low-emission technologies and contribute to the emergence of the low-emission cement industry.

Sources: Global CCS Institute, Refinitiv, Dialogue on European Decarbonization Strategies, Accenture analysis

Click here to see the full data:

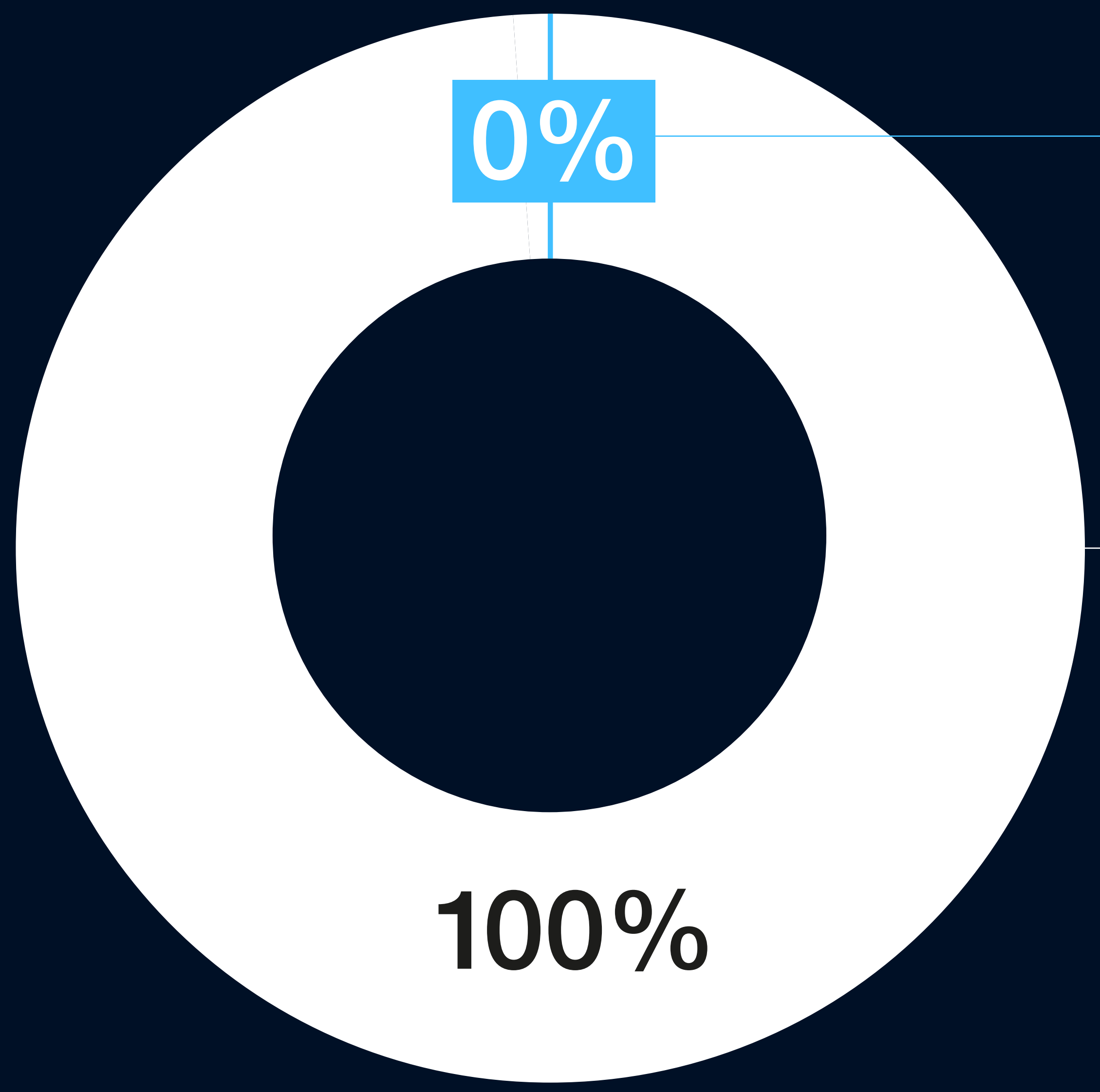
Visual | Full data

Assets and investments

Transformation investment required	$500 billion
Industry net property, plant and equipment (PPE)	$310 billion[3]

= **1.6** Investment to PPE multiple

Debt issued (2020 bonds)



Aluminium industry
Net-zero industry tracker

Aluminium
Key highlights

Aluminium is one of the most emission-intensive manufacturing sector – generating 2% of all man-made emissions.

Aluminium demand is projected to increase by up to 80% by 2050 (about 60% in International Aluminium Institute (IAI) Net Zero Scenario), risking a corresponding rise in emissions.

The main pathway to decarbonize aluminium production is a combination of electrification, transition to hydrogen and inert anodes – however, carbon capture is also being explored.

Given the high cost of clean technologies, low-emission aluminium is expected to come with a green premium up to 40% to wholesale buyers and 1-2% to end consumers.

More than $510 billion will need to be invested in low-carbon power, clean hydrogen and CO_2 infrastructure to enable clean technologies.

To incentivize investments, demand signals from aluminium buyers and supporting policies must improve drastically.

Net-zero industry readiness

Readiness stage

2

Technology

The low-emission production technologies are **largely prototyped at scale.**

3

Infrastructure

The necessary infrastructure required by the low-emission industry is **partially in place.**

4

Demand

Most of the market can pay the required green premium.

1

Policies

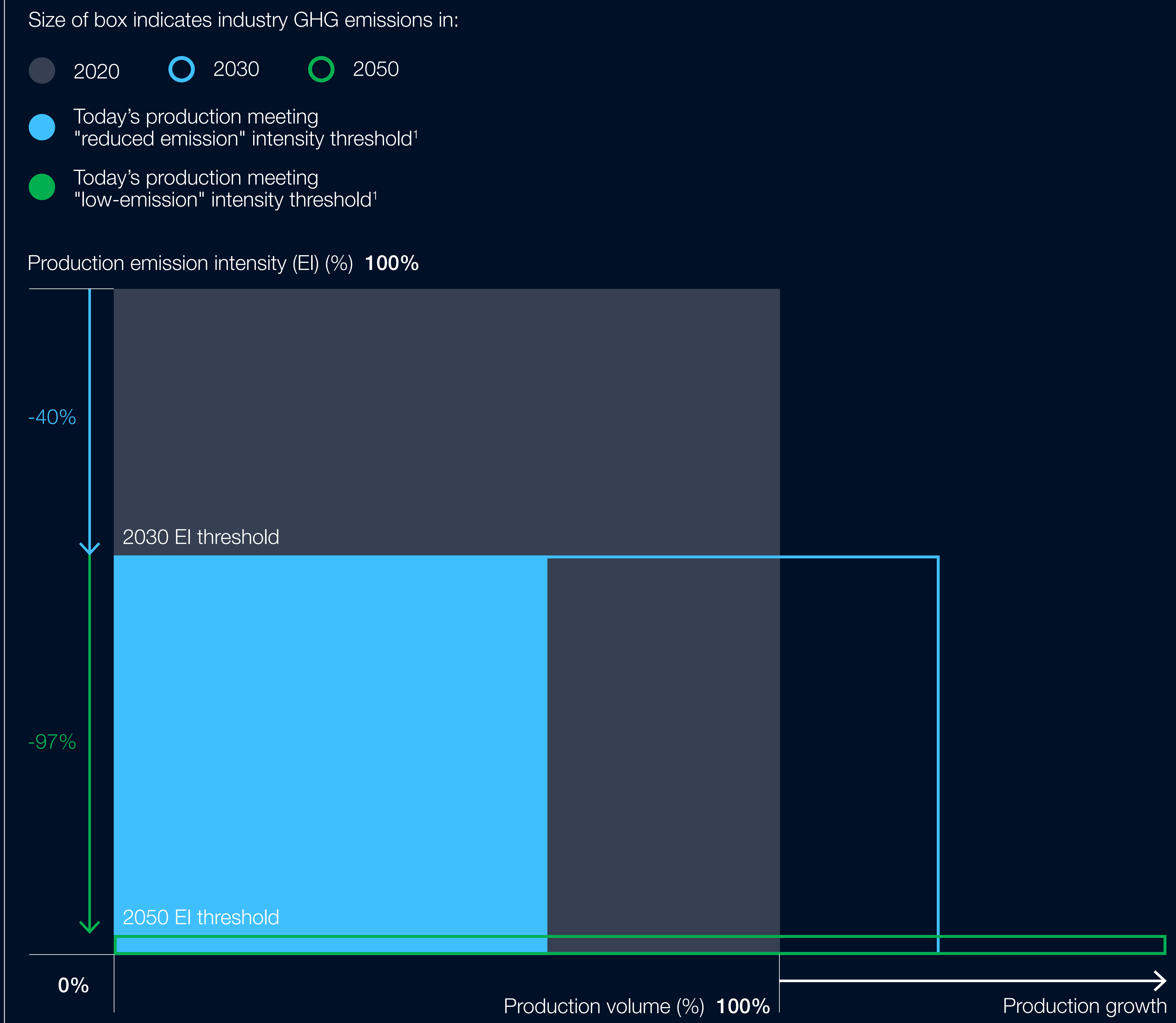
Very limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

1

Capital

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Net-zero industry performance



Notes: 1 As defined in the "Mission and methodology" section of this report.

Aluminium Executive summary

Aluminium is a lightweight, corrosion-resistant, highly malleable and infinitely recyclable material which finds usage in multiple industries, including construction (25%), transport (25%), electrical equipment, machinery and packaging; it has no scalable substitutes today, and its use in the renewable energy industry makes it a critical material for achieving net zero. Manufacturing aluminium requires highly energy-intensive processes to extract alumina from bauxite and turn it into aluminium. More than 70% of the energy used comes from fossil fuels, largely to produce captive electricity to run smelters (primary aluminium) and electric induction furnaces (recycled aluminium). Almost 50% of aluminium is made in China.

The aluminium sector generates about 2% of all man-made emissions – aluminium is one of the most emission-intensive industrial materials today (seven times that of steel). Partly because aluminium is bound to play a role in reducing emissions of other sectors (such as light-weighting cars and trucks), its demand is projected to rise by 80% by 2050. Aluminium recycling, i.e. secondary aluminium production, can be nearly carbon-neutral if powered by renewable electricity; hence it will be essential to decarbonize electricity supply. Demand cannot be met with recycled aluminium alone. Primary aluminium is projected to meet at least 50% of aluminium demand in 2050 and must be decarbonized.

The challenge for primary aluminium is twofold: decarbonize energy for refining and smelting and prevent CO_2 release to the atmosphere during the smelting process. The decarbonization pathway combines two building blocks: electrification with low-carbon power for refining and smelting, and hydrogen use for high heat. Carbon capture is also being explored but faces significant challenges (e.g. low CO_2 concentration). Today, decarbonizing power can already cut emissions by 60%, and up to 85% could be achieved with future electric boilers and inert anodes. Cost estimates for aluminium low-emission technologies are largely unknown due to their early stage of maturity, except for the use of CCUS for thermal energy and process emissions, which is estimated to raise production costs by 40%.

Besides investments in production assets, at least $510 billion in infrastructure investments in low-emission power generation, hydrogen production, and carbon transport and storage will be required. Low-emission aluminium is expected to reach the market by 2030

with a green premium of up to 40%. To incentivize investments, demand signals for low-emission aluminium from wholesale buyers should be multiplied. This will require strengthening aluminium buyers' confidence in their ability to pass the premium to end consumers, which shows encouraging signs.

Public policies and international cooperation on carbon pricing, carbon border adjustment mechanisms or product specification standards can help create a differentiated and economically viable market for first movers into the low-emission aluminium industry. The low maturity of most technologies makes it hard to size the investment required to transform the industry asset base. Moreover, current business case and projected returns on low-emission assets do not encourage mainstream investments.

We emphasize five priorities for the sector:

1. Promote and further expand aluminium recycling networks.
2. Boost the number of low-emission projects to accelerate the learning curve, drive costs down and bring forward the commercial readiness of clean technologies.
3. Develop the low-emission power capacity, clean hydrogen production and CO_2 transport and storage infrastructure required to enable low-emission aluminium production.
4. Multiply demand signals for green aluminium to incentivize producers and investors to direct capital towards low-emission production assets.
5. Develop policies to suport the four priorities above and strengthen the business case for low-emission aluminium production.

Aluminium Performance tracker

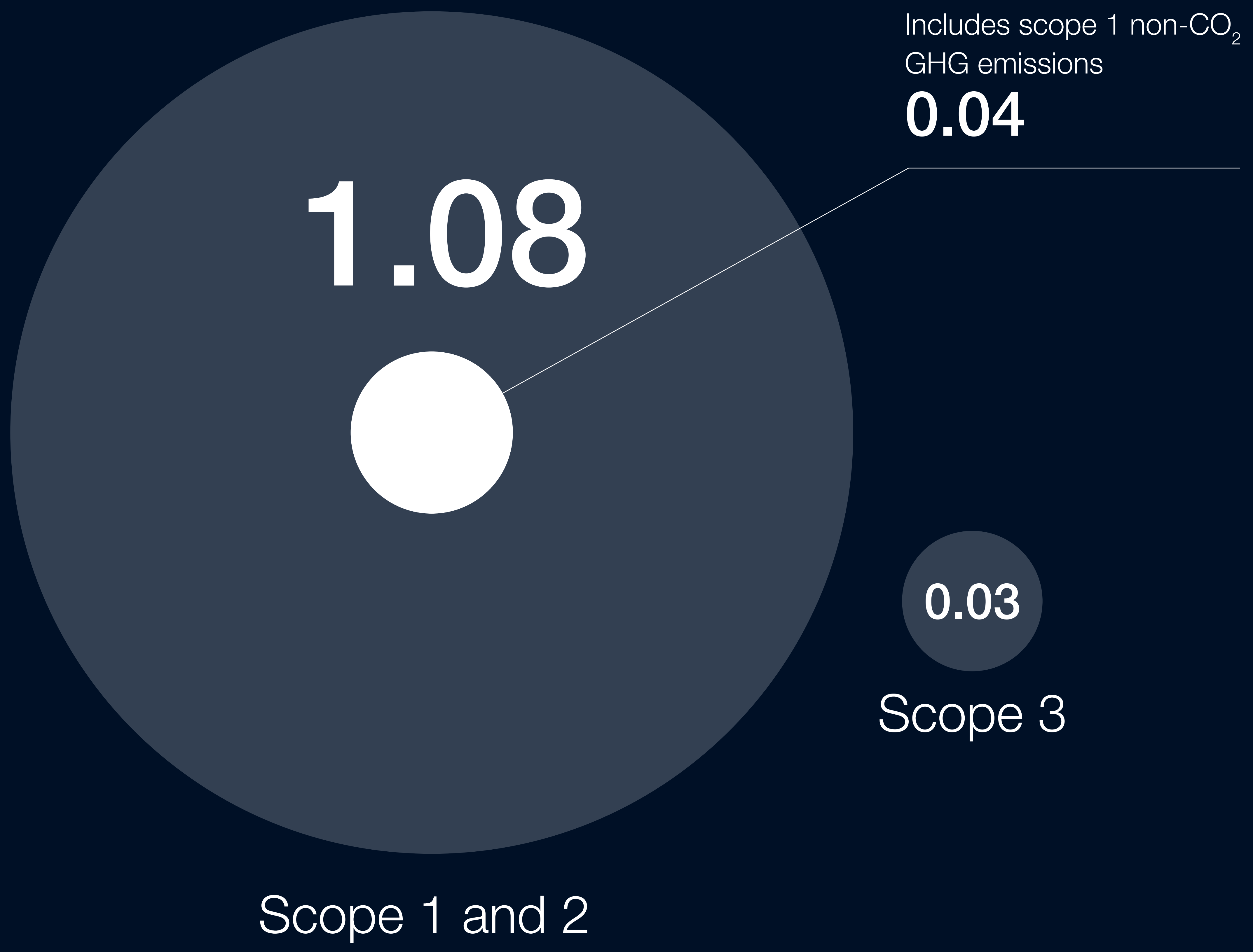
Aluminium is one of the most emission-intensive manufacturing sectors – generating 2% of all man-made emissions. More than 70% of its energy consumption comes from fossil fuels.

Click here to see the full data:

Visual | Full data

What aluminium emits, captures and offsets

Scope 1, 2, and 3 GHG emissions (Gt CO_2e)



Total CCS (Gt CO_2e)

0.00

Total offsets

Data not available

Aluminium
Summary

Aluminium benefits from a sizeable immediate decarbonization opportunity: low-carbon power. More decisive action is required to boost demand and investments in green aluminium.

Click on the enablers below to find out more.

Home

Summary

Key messages

Decarbonizing electricity already provides an immediate option to eliminate most sectoral emissions; the potential is even more significant with the addition of electric boilers and inert anodes.

Aluminium decarbonization would require a minimum investment of $510 billion in decarbonized power, clean hydrogen capacity and CO_2 transport and storage.

The green premium for end consumers is low, but aluminium buyers need to be incentivized to generate demand for producers.

More decisive policy action is needed to incentivize aluminium players into low-emission production.

Further de-risking and better returns will be needed to re-orient investment flow towards the low-emission industry.

Technology

Readiness stage 2

The low-emission production technologies **are largely prototyped at scale.**

+38%

Production cost increase for low-emission aluminium production.

2030

Expected year of commercial readiness of first low-emission production.

Infrastructure

Readiness stage 3

The necessary infrastructure required by the low-emission industry is **partially in place.**

$439 billion

Investments required in low-emission power generation.

$62-109 billion

Investments required in low-emission hydrogen production.

$12-26 billion

Investments required in CO_2 storage and transport.

Demand

Readiness stage 4

Most of the market can pay the required green premium.

38%

Green premium for aluminium buyers.

1-2%

Green premium for end consumers.

Policies

Readiness stage 1

Very limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

$210/tCO$_2$e

Carbon price equivalent required to level competitive landscape.

Capital

Readiness stage 1

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Data not available

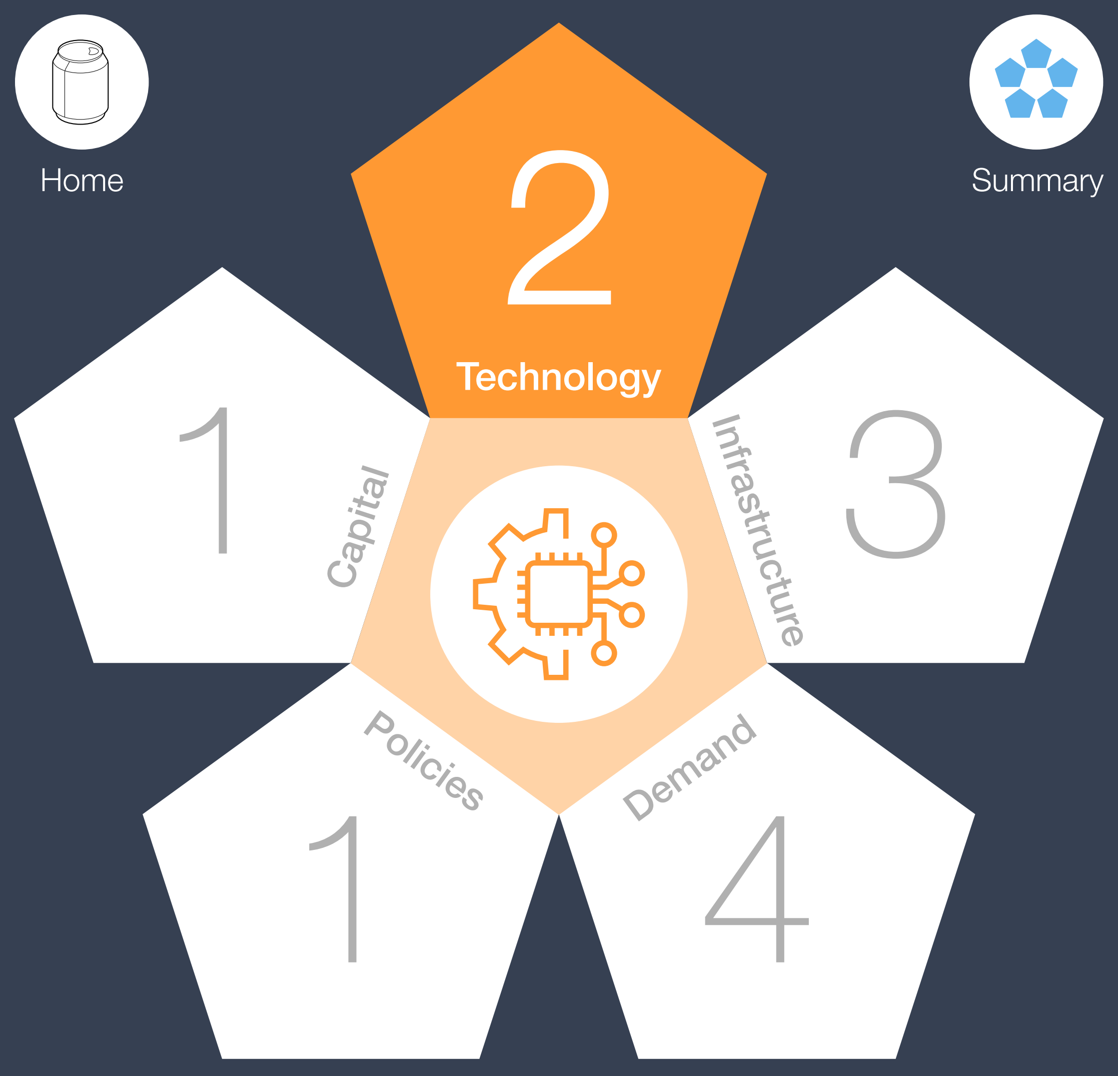
CapEx required to transform industry asset base by 2050.

3.3.2 Aluminium readiness tracker

Aluminium Technology

The main pathway to decarbonize primary aluminium combines electrification, hydrogen and inert anodes.

The low-emission production technologies are **largely prototyped at scale.**



Key messages

Scrap-based secondary aluminium production using 100% low-carbon power electric furnaces is the closest route to low-emission aluminium. Primary aluminium is still expected to be needed to meet at least 50% of 2050 demand.

Low-carbon power can decarbonize the sector by up to 62% of emissions. It could reduce up to 86% if electric boilers and inert anodes become available.

Besides power decarbonization and further plant electrification, hydrogen and CCUS pathways are also being explored for further results. Costs will become more apparent as technologies mature.

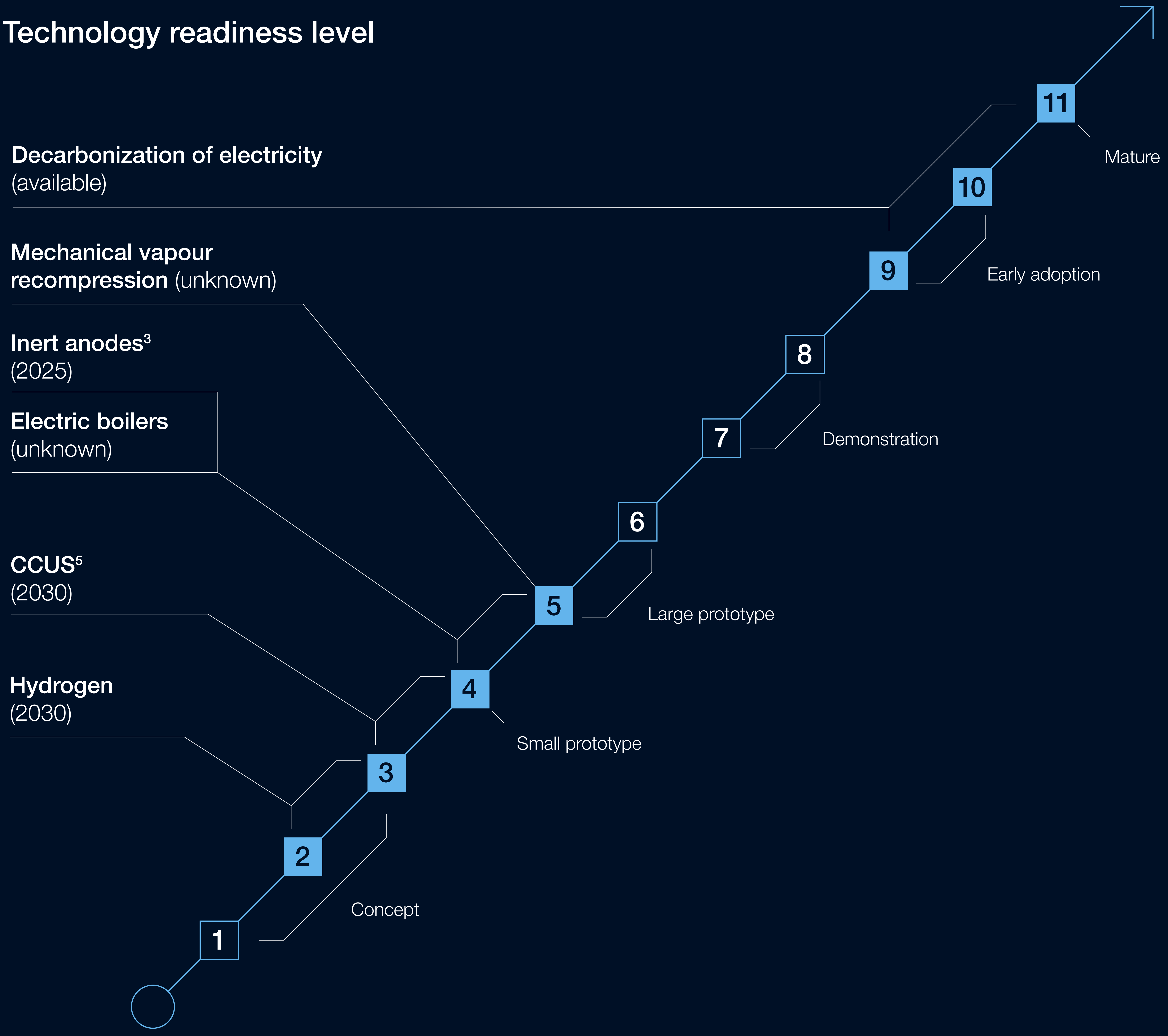
Currently, costs can only be estimated for the CCUS pathway, where low-emission production could cost 38% more – however, this path is the most unlikely.[5]

Sources: IAI, AFC, BloombergNEF, Hongqiao Group, Accenture analysis

Click here to see the full data:

Visual | Full data

Technology readiness level



Aluminium
Infrastructure

More than $510 billion will need to be invested in low-carbon power, clean hydrogen and CO_2 handling infrastructure to enable low-emission technologies.

The necessary infrastructure required by the **low-emission** industry is partially in place.

Home

Summary

Key messages

Hydroelectricity already powers 25% of primary aluminium production. Additional low-carbon power capacity of 231 GW is required, which will require a minimum investment of $439 billion.

Without electric boilers and mechanical vapour recompression, replacing fossil fuels for refining thermal energy with low-emission hydrogen would require a minimum of $60 billion in clean hydrogen production infrastructure.

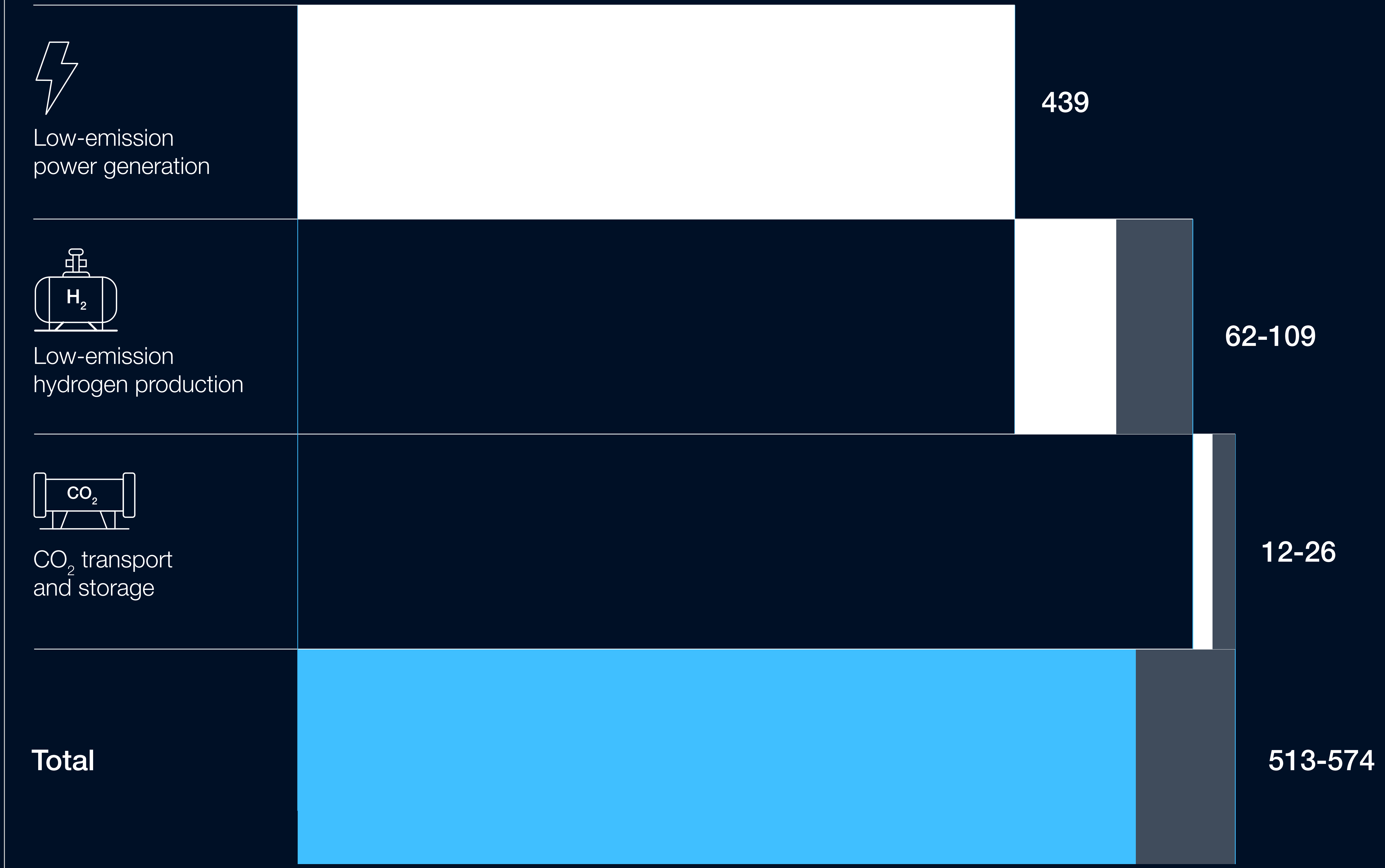
CO_2 transport and storage infrastructure may not be needed if inert anodes and hydrogen technologies are proven commercially successful.

Source: IAI, Global CCS Institute, IEA, Accenture analysis

Click here to see the full data:

Visual | Full data

Investments required for enabling infrastructure ($ billion)



Aluminium Demand

Building aluminium buyers' confidence in their ability to pass their 38% green premium to end consumers is essential to boost demand signals.

Most of the market can pay the required green premium.

Key messages

There is no low-emission aluminium in line with IEA Net Zero by 2050 Scenario available today. However, appetite is growing for reduced emission aluminium (made using green power), leading to minor green premiums around 1-2% to end consumers.

If such a technology pathway materializes, CCUS-based low-emission aluminium could arrive in the market with a price premium of up to 38% by 2030.

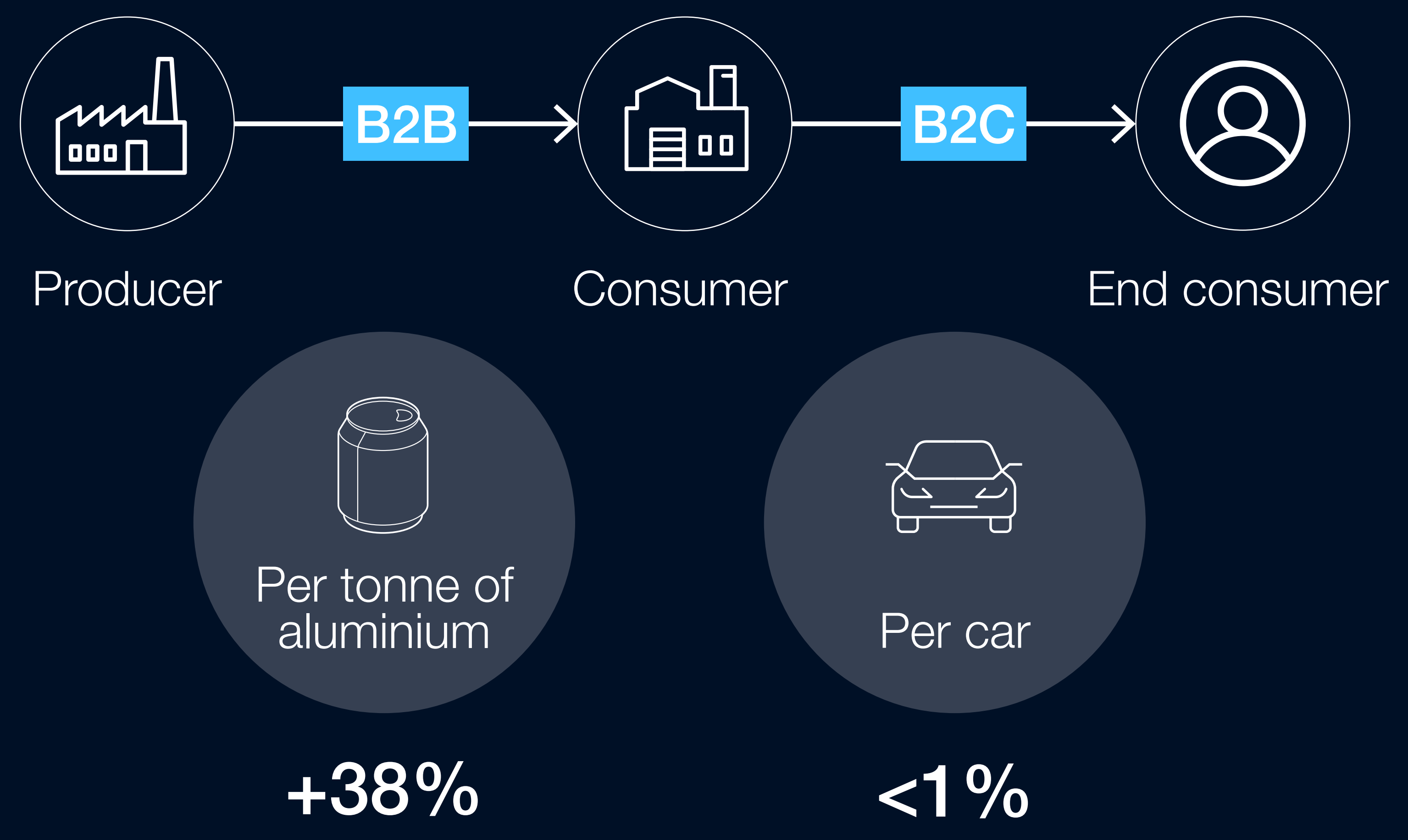
The extensive price elasticity of demand in recent years suggests aluminium buyers could take an approximate 40% green premium and pass it on to end consumers through a marginal price bump below 2% on finished products.

Sources: HARBOR Aluminium, LME, S&P Global, European Aluminium, Accenture analysis

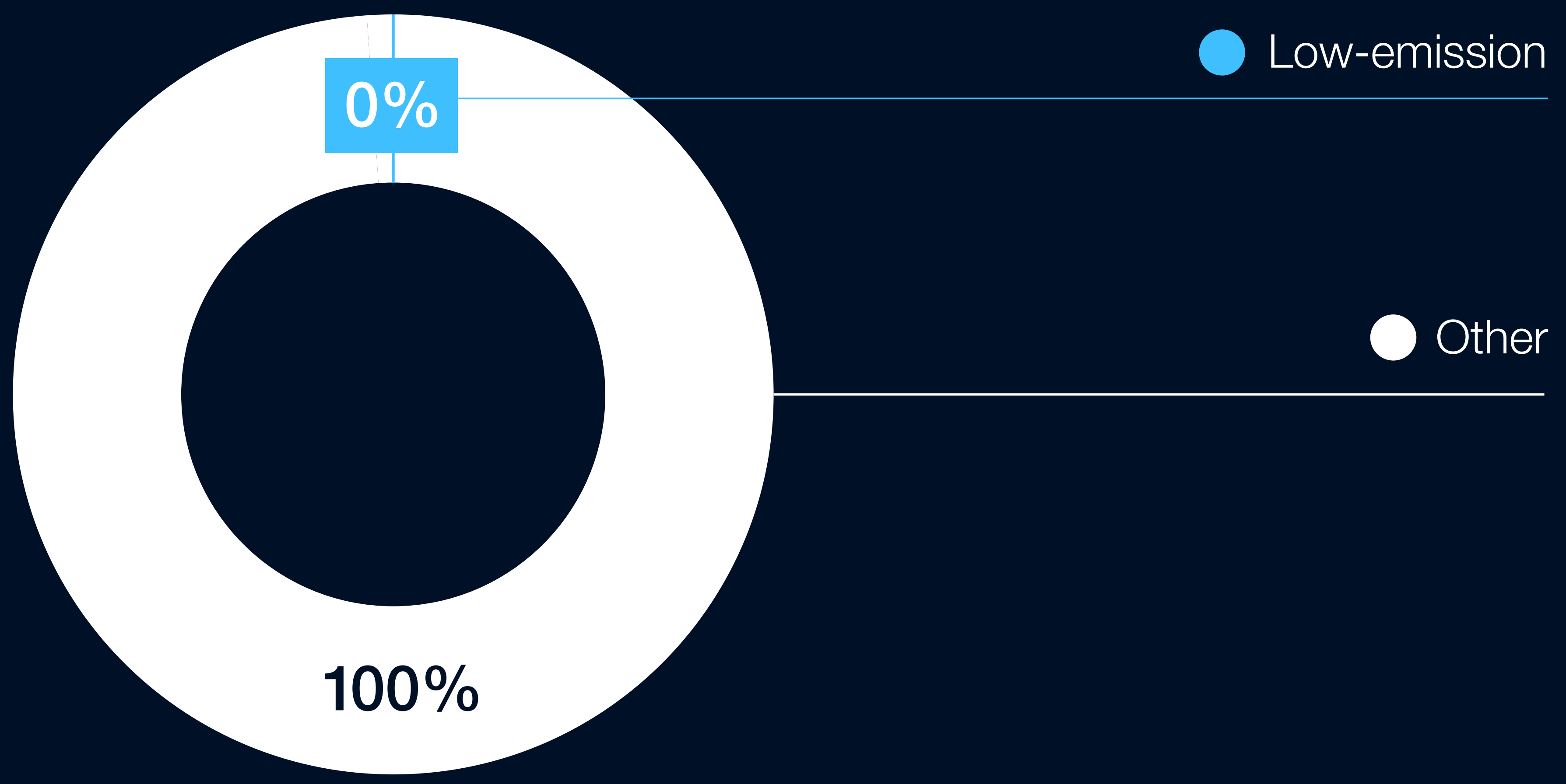
Click here to see the full data:

Visual | Full data

Green premiums



Market penetration



Aluminium Policies

More robust policy measures are needed to create a differentiated and economically viable market for first movers into low-emission aluminium.

Very limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

Key messages

Policies vary widely across geographies, and only examples of critical policies that have been recently introduced are included in this section.

The carbon price is only reflective of the CCUS technology cost in smelting due to low maturity levels and R&D confidentiality of other technologies.

A carbon price of \$210/t of CO_2 is required to incentivize the use of CCUS in smelting. This is significantly higher than the current carbon prices in major consuming countries. This could be achieved through pricing policies or non-pricing policies such as product standards, public procurement standards or carbon border tax adjustments which will require international cooperation.

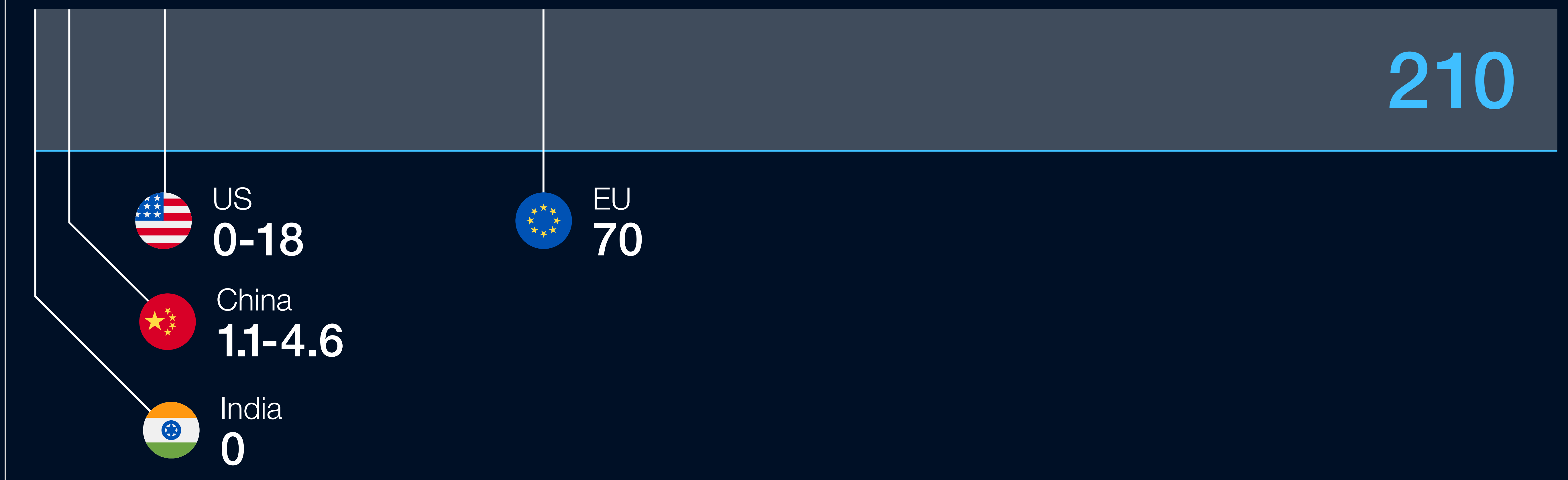
Sources: World Bank, ASI, Accenture analysis

Click here to see the full data:

Visual | Full data

Major producers of aluminium (percentage of global production)

Average carbon price required to level the playing field for low-emission production vs actual carbon prices (\$/tCO_2e)



Aluminium
Capital

It is still unclear how much capital will be required to transform the industry asset base, but the current business case does not encourage investments.

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Home
Summary

Key messages

Current technology maturity of low-emission production routes is too low to estimate CapEx requirements beyond electricity decarbonization.

The business case still needs to improve significantly to become attractive and drive capital into low-emission aluminium assets.

Sources: Refinitiv, Lightmetalage

Click here to see the full data:

Visual | Full data

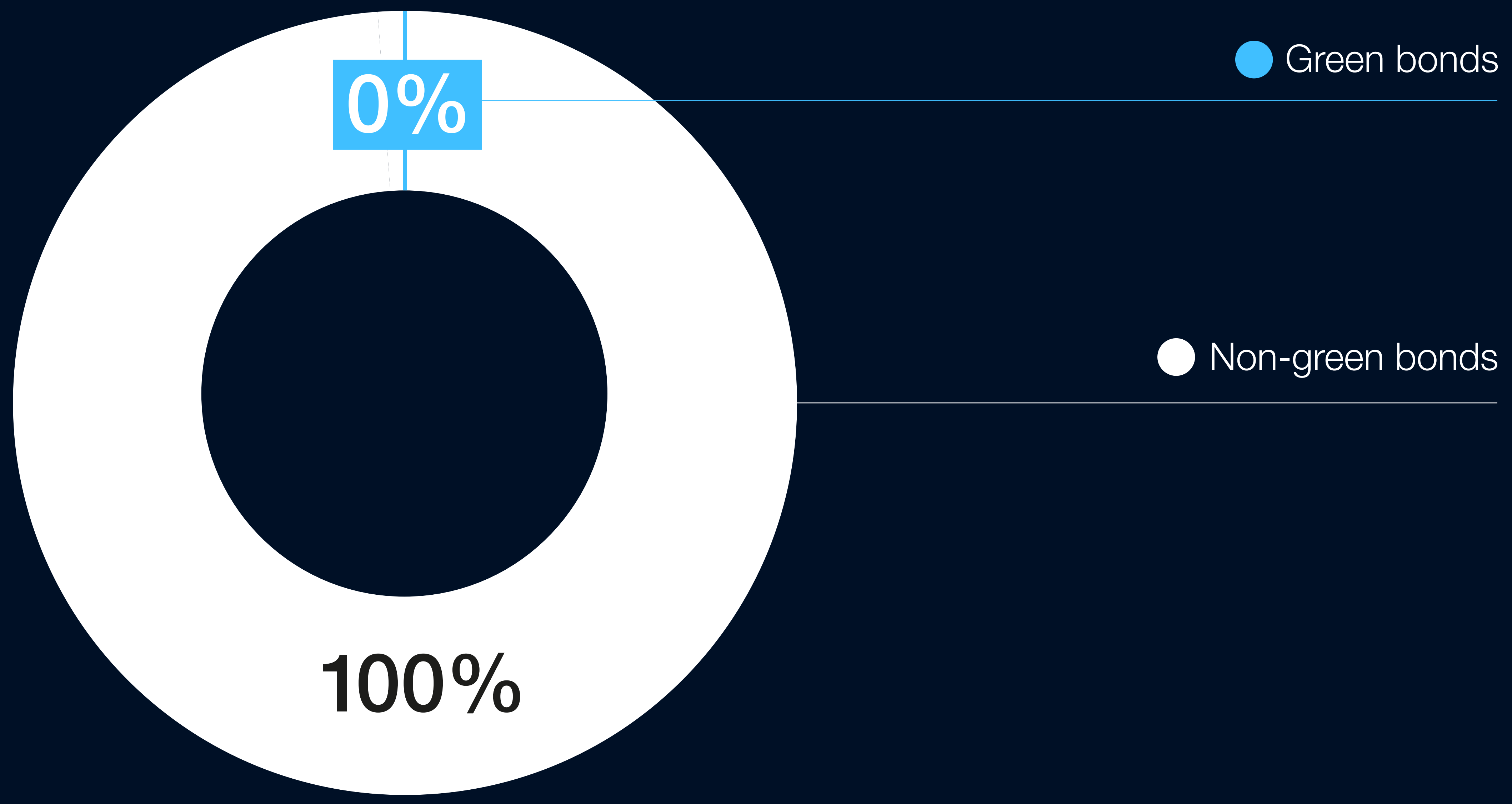
Assets and investments

Transformation investment required — Data not available

Industry net property, plant and equipment (PPE) — $151 billion

= Data not available — Investment to PPE multiple

Debt issued
(2020 bonds)



Ammonia industry
Net-zero industry tracker

Ammonia
Key highlights

Ammonia is the chemical sector's largest emitting product, generating 1.3% of all man-made emissions.

Ammonia demand for fertilizer and industrial use is projected to increase up to 37% by 2050 (23% in the IEA Net Zero Scenario), risking a corresponding rise in emissions.

The pathway to decarbonize ammonia production relies on developing blue or green hydrogen technologies.

Given the high costs of technologies, low-emission ammonia is expected to have a green premium of up to 100%.

More than $850 billion will need to be invested in low-carbon power and CO_2 infrastructure to enable green and blue hydrogen production.

Demand signals from ammonia buyers and supporting policies must improve drastically to incentivize investments.

Net-zero industry readiness

Readiness stage

3

Technology

The low-emission production technologies are **largely demonstrated in commercial conditions.**

2

Infrastructure

The necessary infrastructure required by the low-emission industry **is emerging.**

1

Demand

Only very early adopters in the market can pay the required green premium.

2

Policies

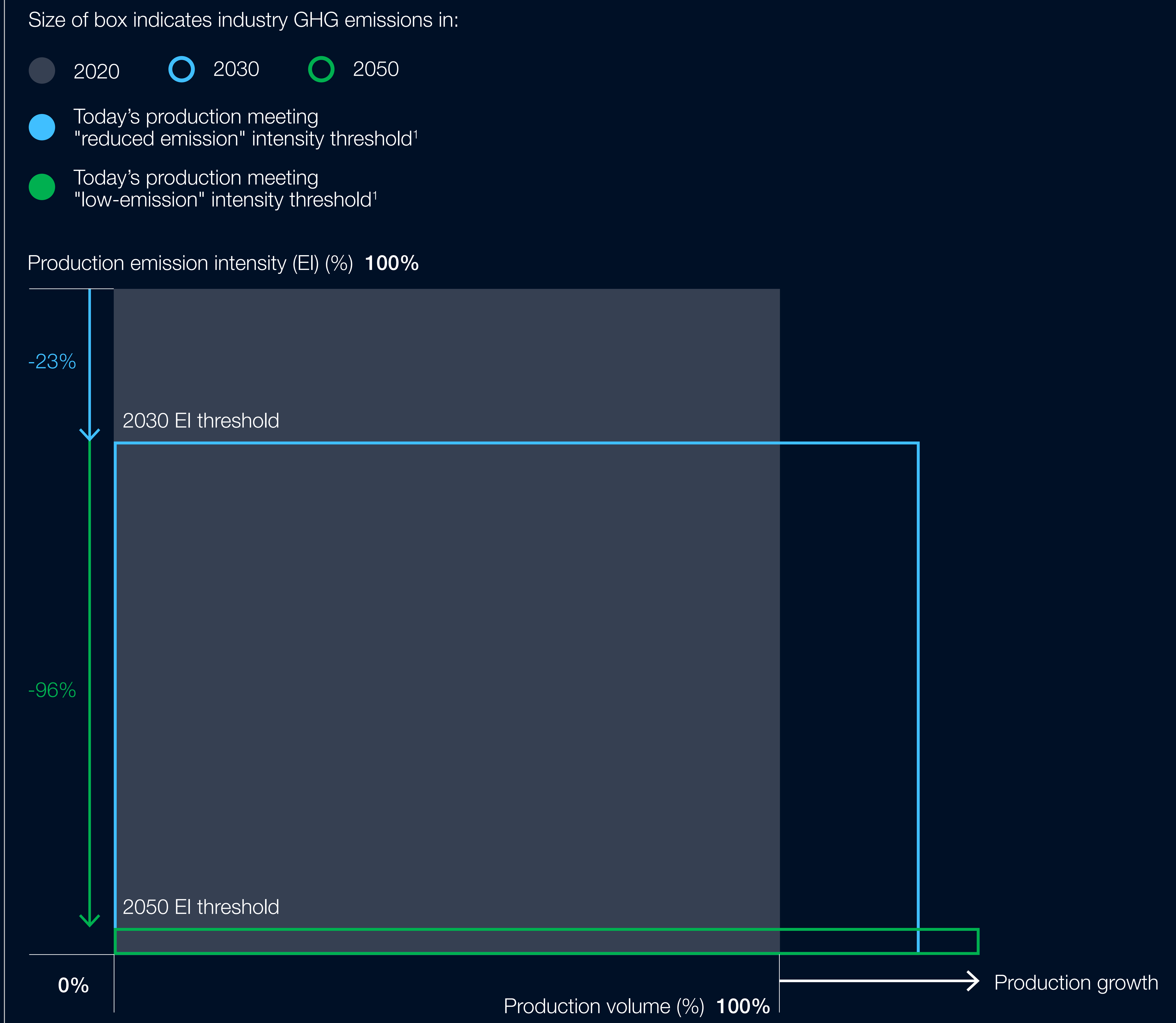
Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

2

Capital

Low-emission investments generate sufficient return for a **minority of** CapEx to flow towards low-emission production assets.

Net-zero industry performance



Notes: 1 As defined in the "Mission and methodology" section of this report.

Ammonia Executive summary

Ammonia is a primary chemical used as an intermediate and end-product for the fertilizer industry (70%) and other industries (30%). Ammonia is critical for the agriculture sector and global food security. It has also been identified as an energy carrier for clean hydrogen in the future. More than half of the world's ammonia is currently produced in four countries: China, US, India and Russia. 99% of ammonia production relies on coal gasification and steam methane reforming to make hydrogen. Hydrogen production generates 90% of total ammonia synthesis emissions.

With 1.3% of all man-made emissions, ammonia is the largest emitting product of the chemical sector (450 $MtCO_2$), ahead of high-value chemicals (250 $MtCO_2$) and methanol (220 $MtCO_2$). Demand for ammonia is projected to rise nearly 40% by 2050, driven by demand for fertilizers in Africa, Latin America, the Middle East and South-East Asia. Aligning with the IEA Net Zero by 2050 requires limiting the increase to 23%.

Two main pathways for low-emission ammonia exist, CCUS and electrolysis; both technologies are available today, however, blue and green hydrogen production costs typically range 10% and 40% higher, respectively, and require further cost reduction. Methane pyrolysis and biomass gasification are also emerging as potential technological alternatives.

Besides investing in production assets, a 50/50 green/blue ammonia supply in 2050 will require more than $850 billion in investments in decarbonized power and CO_2 infrastructure to be deployed – nearly 12 times the annual value of the ammonia market. Building ammonia and fertilizer producers' confidence to pass a green premium over 10% to farmers is essential to unlock demand and incentivize investments. Governments should be cautious of the impact on food price and food security due to the widespread use of mineral fertilizers and low margins in farming.

More robust policy measures and international cooperation on carbon pricing, carbon border tax adjustments or public procurement can help create a differentiated and economically viable market for first movers into the low-emission ammonia industry. $450 billion is necessary to transform the ammonia industry asset base – nearly seven times the value of the current asset base. This is expected to decrease over the coming decade as the cost of electrolysers and green power falls.

We emphasize five priorities for the sector:

1. Boost the number of green and blue ammonia projects to accelerate the learning curve, drive costs down and increase the competitiveness of low-emission ammonia technologies.
2. Prevent infrastructure bottlenecks by developing the low-emission power capacity, and the CO_2 transport and storage required to enable green and blue hydrogen production.
3. Multiply demand signals for low-emission ammonia and fertilizers to incentivize producers and investors to direct investments towards low-emission production assets.
4. Develop policies to support low-emission plants, infrastructure and demand, and strengthen the business case for low-emission ammonia production.
5. Ensure decarbonization of ammonia and fertilizer production does not impact food security for poorer households.

Ammonia Performance tracker

Accounting for 1.3% of all man-made emissions, ammonia production is the largest source of emissions within the chemical sector.

Click here to see the full data:

Visual | Full data

What ammonia emits, captures and offsets

Scope 1, 2, and 3 GHG emissions (Gt CO_2e)

0.45

Scope 1

Includes scope 1 non-CO_2 GHG emissions

Data not available

0.04

Scope 2

0.80

Scope 3

Total CCS (Gt CO_2e)

0.0036

Total offsets

Data not available

Ammonia Summary

Low-emission ammonia is a reality today, however, further cost reduction, stronger demand signals and supporting policies are needed to accelerate.

Click on the enablers below to find out more.

Home

Summary

Key messages

Low-emission production methods are emerging, including electrolysis, methane pyrolysis and carbon capture.

Delays in developing infrastructure risk creating bottlenecks in deploying electrolysis and CCUS technologies.

Increases in fertilizer costs could significantly impact food security around the world; governments would need to take measures to lessen the effect of green premiums.

More robust policies can support a differentiated and viable low-emission ammonia market.

Further de-risking and better returns will be needed to re-orient investment flow towards the low-emission industry.

Technology

Readiness stage 3

The low-emission production technologies are **largely demonstrated in commercial conditions.**

10-100%

Production cost increase for low-emission production today.

Available

Expected year of commercial readiness of first low-emission production.

Infrastructure

Readiness stage 2

The necessary infrastructure required by the low-emission industry **is emerging.**

$849 billion

Investments required in low-emission power generation, transmission and distribution.

$8-18 billion

Investments required in CO_2 transport and storage.

Demand

Readiness stage 1

Only very early adopters in the market can pay the required green premium.

+10-100%

Green premium for ammonia buyers.

+5-60%

Green premium for end consumers.

Policies

Readiness stage 2

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

$36-360 /t$CO_2$e

Carbon price equivalent required to level competitive landscape.

Capital

Readiness stage 2

Low-emission investments generate sufficient return for a **minority of** CapEx to flow towards low-emission production assets.

$450 billion

CapEx required to transform industry asset base.

Ammonia
Technology

CCUS and electrolysis technologies are available today, but production costs remain at least 10% and 40% higher, respectively.

The low-emission production technologies are **largely demonstrated** in commercial conditions.

Home

Summary

Key messages

Producing low-emission ammonia[3] will lead to cost increases of +10-100%.[6]

Low-emission ammonia production methods are emerging, including electrolysis, methane pyrolysis, and biomass gasification. While fossil-based routes with CCUS are currently available, adoption remains limited.

These emerging routes are typically 10-100% more expensive per tonne of ammonia, depending on energy prices and other regionally varying factors. However, costs are expected to drop significantly as the technology matures.

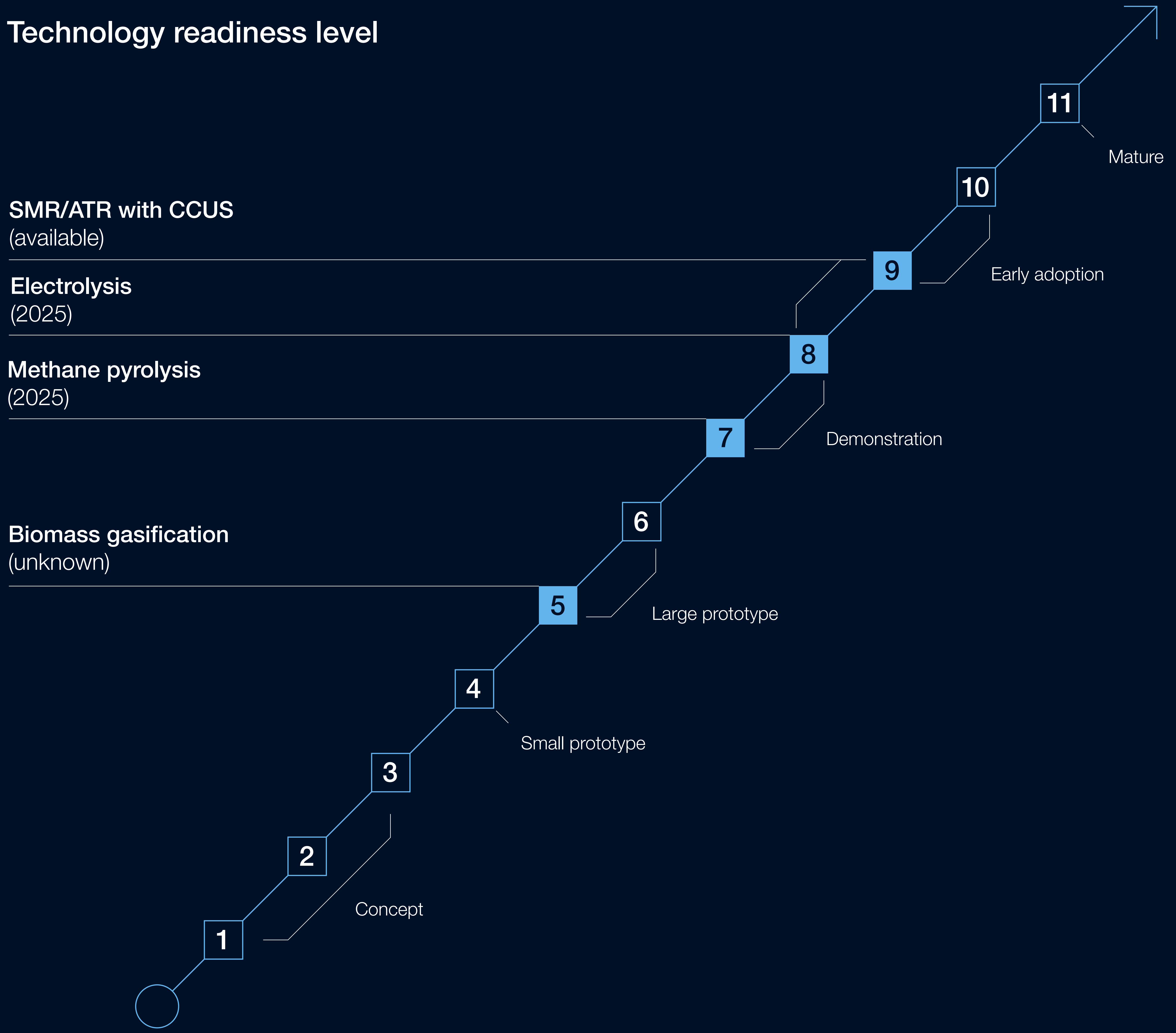
Current commercial production through steam methane reforming (SMR) can be retrofitted with CCUS, while new-build plants with CCUS will be autothermal reforming (ATR) based.

Sources: IEA, Global CCS Institute, Accenture analysis

Click here to see the full data:

Visual | Full data

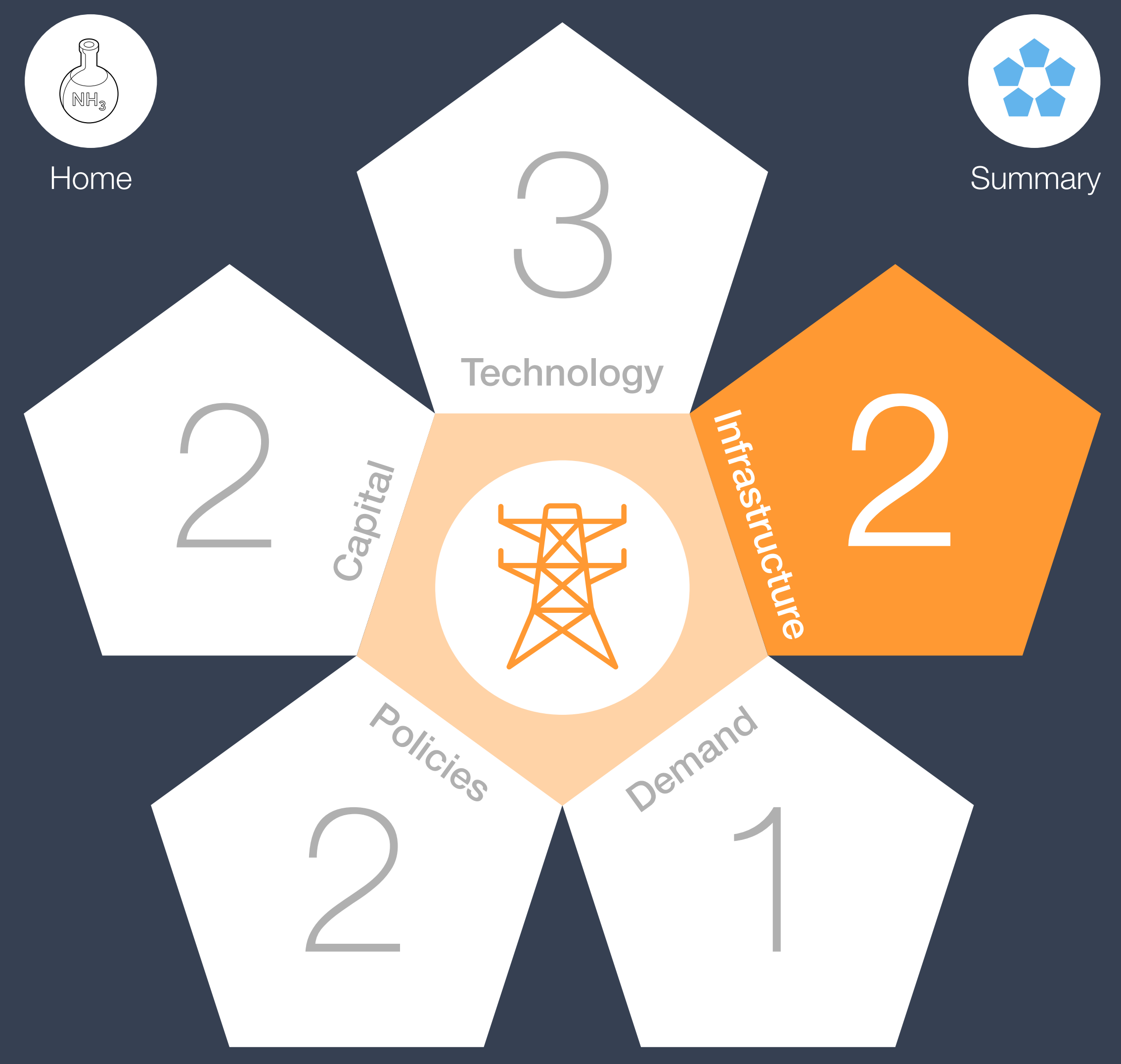
Technology readiness level



Ammonia Infrastructure

A 50/50 green/blue ammonia supply in 2050 will require more than $850 billion in investments in decarbonized power and CO_2 transport and storage infrastructure.

The necessary infrastructure required by the low-emission industry **is emerging.**



Key messages

More than $850 billion needs to be invested in CO_2 transport and storage infrastructure and green power capacity by 2050 to prevent bottlenecks in the deployment of electrolysis and CCUS technologies.

Only a small fraction (~1%) of the required green power has been developed for the ammonia industry.

The cost of low-carbon power and CO_2 transport and storage is projected to decrease, favouring infrastructure development.

Sources: IEA, Accenture analysis

Click here to see the full data:

Visual | Full data

Investments required for enabling infrastructure ($ billion)

Ammonia Demand

A green premium over 10% is too high to be passed on to farmers and consumers without impacting food security; further cost reduction is required to unlock additional demand.

Only very early adopters in the market can pay the required green premium.

Key messages

Low-emission ammonia could arrive on the market with a 10-100% premium[4] for ammonia buyers depending on regions and production routes.

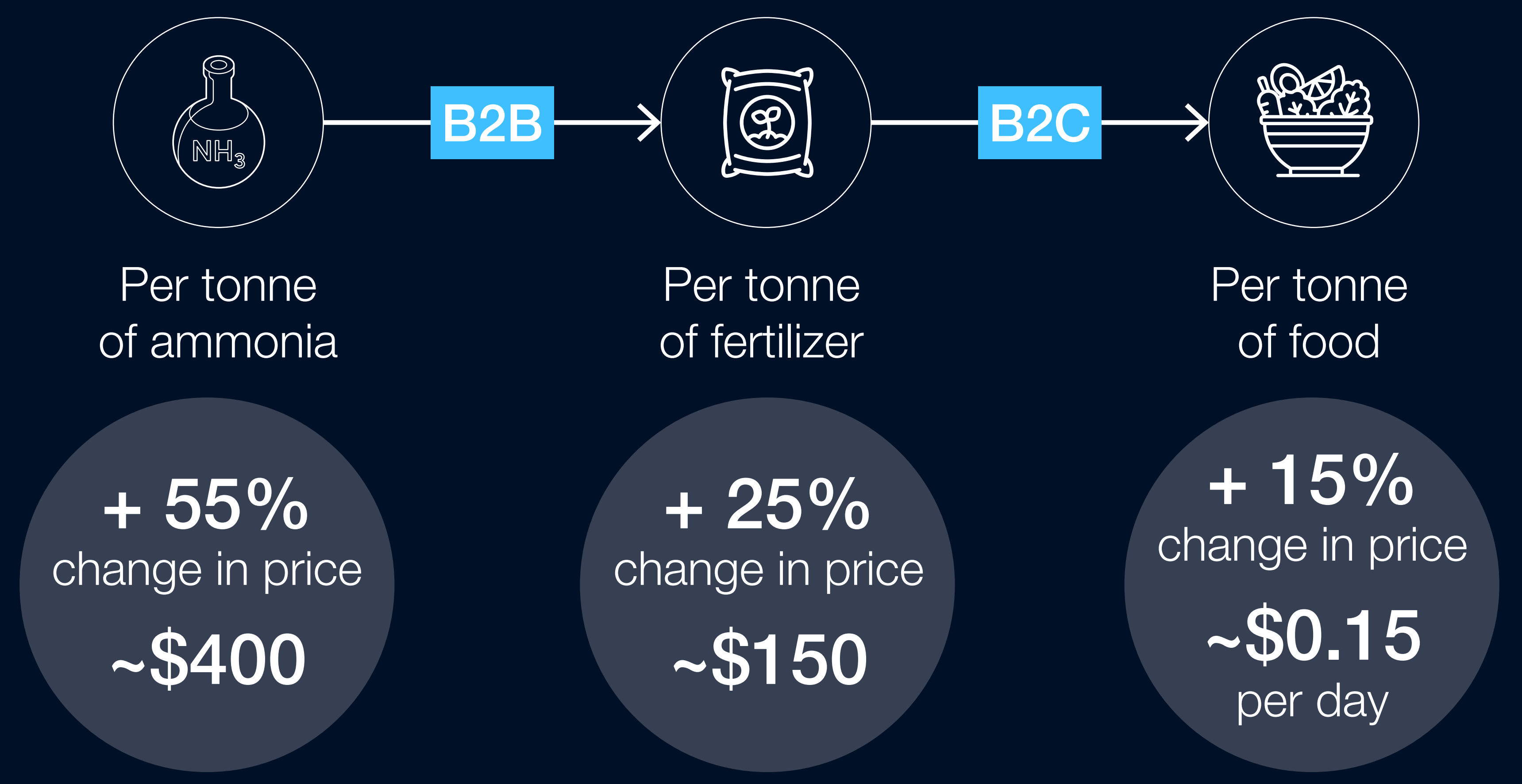
Passing the green premium to end consumers could result in a 5-60% increase in fertilizer cost. This could cause a rise in food prices by 3-26%, given the widespread use of fertilizers and the low margins in agriculture and farming. Governments will need to put cross-subsidies and other measurements in place to protect the food security of poorer households.

Sources: IEA, International Fertilizer Association (IFA), Polish Academy of Sciences, Leibniz University of Hannover, Accenture analysis

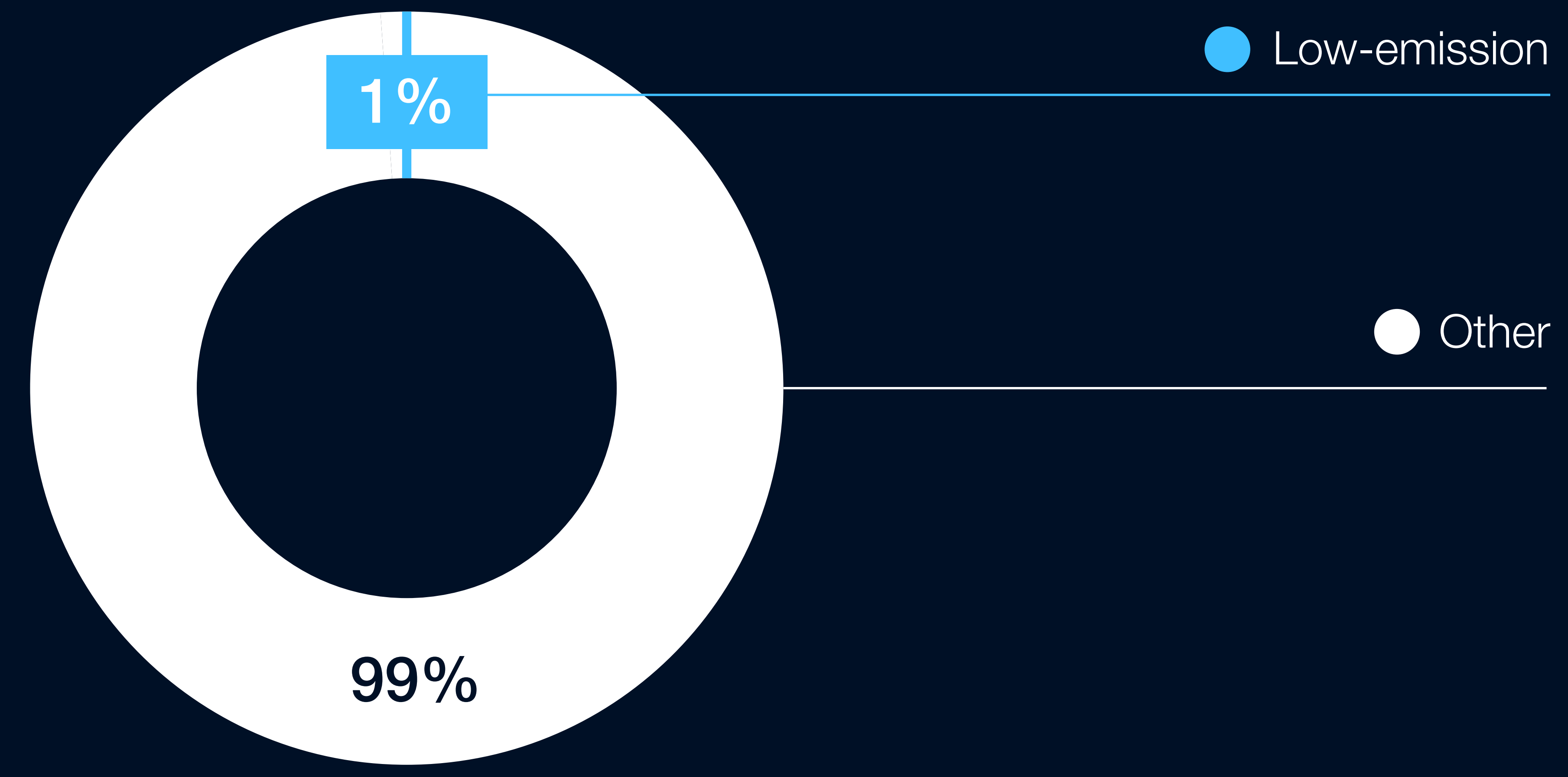
Click here to see the full data:

Visual | Full data

Green premiums



Market penetration



Ammonia Policies

Significant policy measures are needed to create a differentiated viable and economically viable market for first movers.

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

Key messages

Policies vary widely across geographies, and only examples of critical policies that have been recently introduced are included in this section.

A 36-360/tCO_2e carbon price equivalent is required to level the competitive landscape, depending on technologies and geographies, and "carbon border adjustment mechanisms" through international cooperation can help to prevent carbon leakage.

Long-term policies and financing mechanisms can support the deployment of carbon capture and electrolysers to produce low-emission ammonia and create a viable low-emission ammonia market.

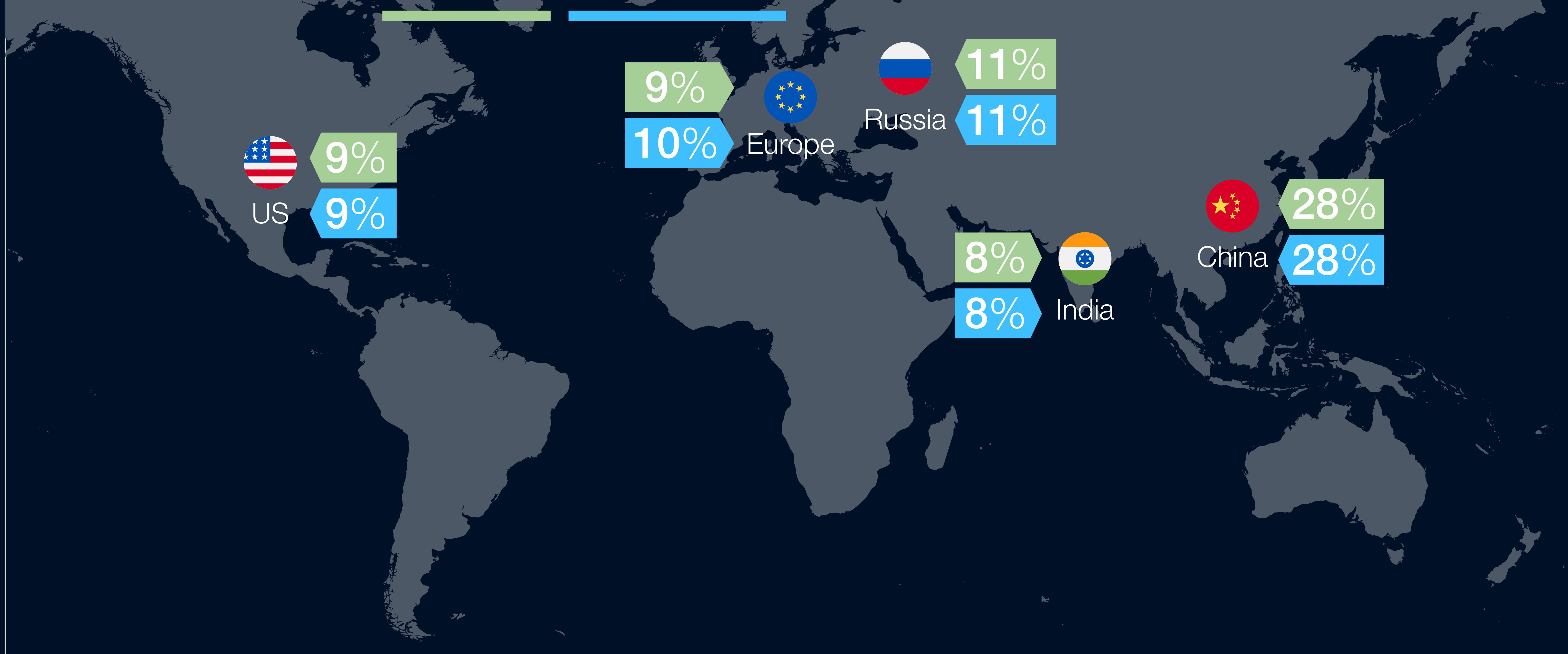
End-use policies can optimize fertilizer and application methods and manage the demand for ammonia-based fertilizers.

Sources: World Bank, IEA, Accenture analysis

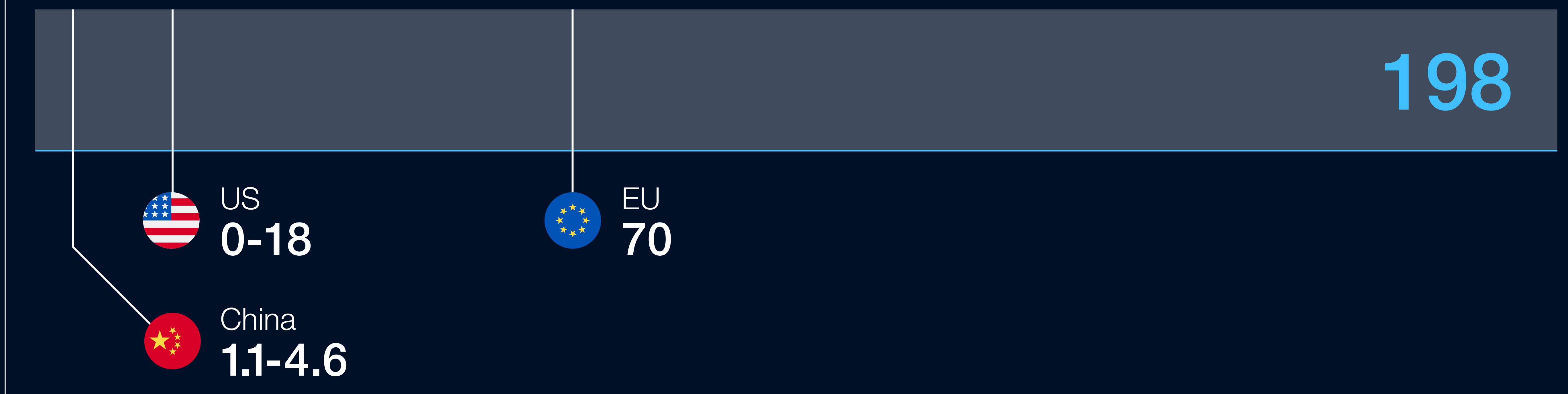
Click here to see the full data:

Visual | Full data

Major producers and consumers of ammonia (percentage of global production/consumption)



Average carbon price required to level the playing field for low-emission production vs actual carbon prices[1] ($/$tCO_2e$)



Ammonia
Capital

To transform the ammonia industry asset base, $450 billion would be needed. Despite the uncertainty on returns, some investment momentum exists.

Low-emission investments generate sufficient return for a **minority of** CapEx to flow towards low-emission production assets.

Key messages

Current ammonia production costs with low-emission technologies are too high to incentivize investments. Further de-risking and better returns will be needed to re-orient investment flow towards the low-emission industry.

More than $450 billion is required to transform the industry, this is nearly seven times more than the value of the current asset base. However, this required investment is expected to fall together with renewable and electrolyser costs.

No green debt was issued by the fertilizer industry in 2020 as the basic chemical specific criteria/taxonomy has yet to be developed.

Sources: MPP (ETC), Refinitiv, Accenture analysis

Click here to see the full data:

Visual | Full data

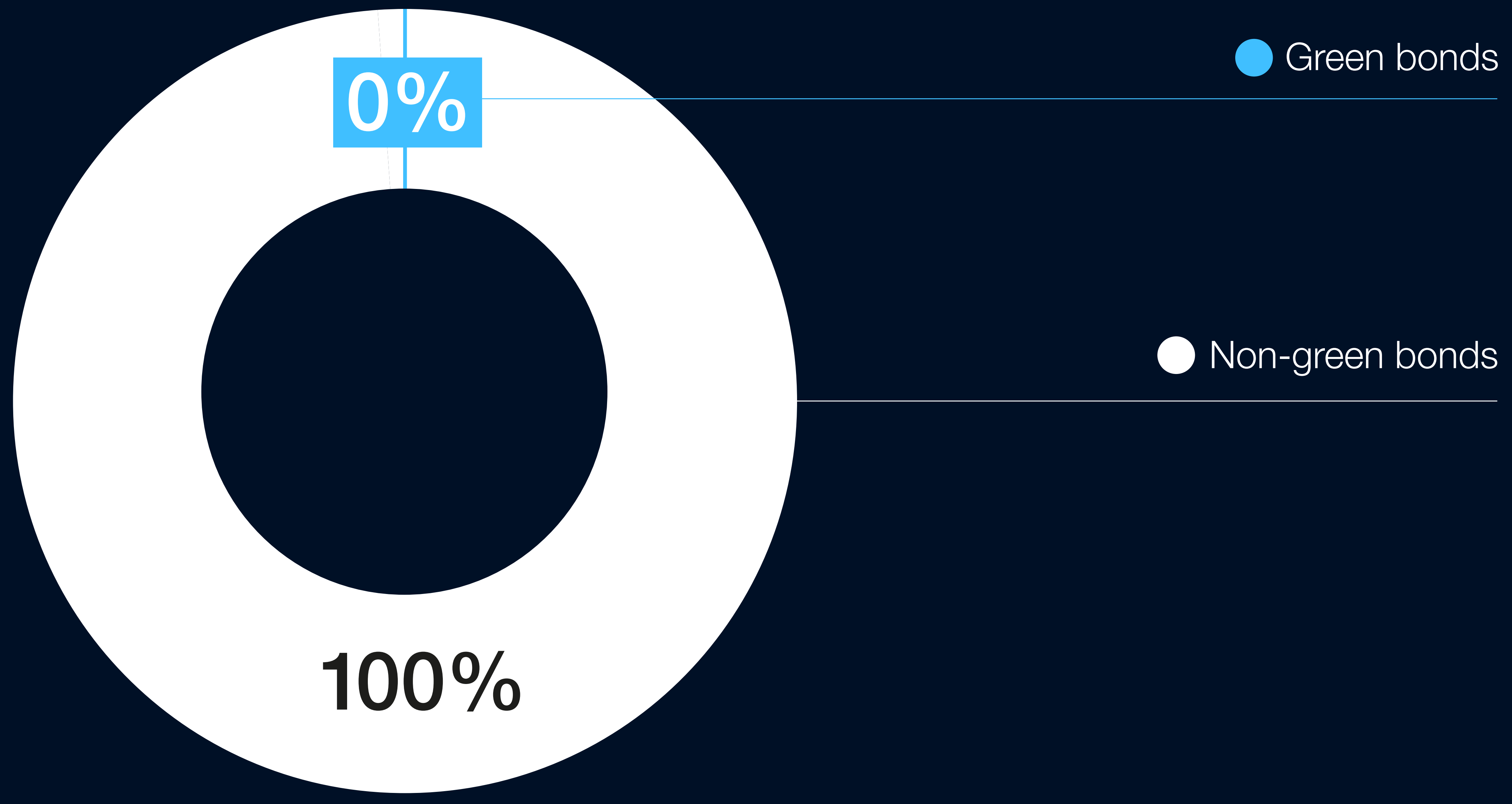
Assets and investments

Transformation investment required	$450 billion
Industry net property, plant and equipment (PPE)	$65 billion

=

6.9
Investment to PPE multiple

Debt issued
(2020 bonds)



Oil
Net-zero industry tracker

Oil
Key highlights

The oil sector is a significant consumer of fossil fuels and releases methane – generating directly 6% of all man-made emissions.

Oil demand is projected to increase by 17% by 2050 as per IEA Stated Policies Scenario, but should decrease by 73% for the world to reach net-zero in the IEA Net Zero by 2050 Scenario.

Decarbonizing the oil sector requires cutting methane and flaring emissions, energy-related emissions upstream, and energy and process-related emissions in refining.

35% of oil sector emissions are methane, 70% of which can be abated at zero or minimal costs today.

Technologies to decarbonize upstream are mature, but CCUS, hydrogen and electrification pathways are still being explored in refining.

Some substitutes for oil products are available; however, their availability and affordability remain a significant concern.

Net-zero industry readiness

Readiness stage

3 – **Technology**

The low-emission production technologies **are largely demonstrated in commercial conditions.**

2 – **Infrastructure**

The necessary infrastructure required by the low-emission industry **is emerging.**

3 – **Demand**

Some of the market can pay the required green premium.

2 – **Policies**

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

2 – **Capital**

Low-emission investments generate sufficient return for a **minority of** CapEx to flow towards low-emission production assets.

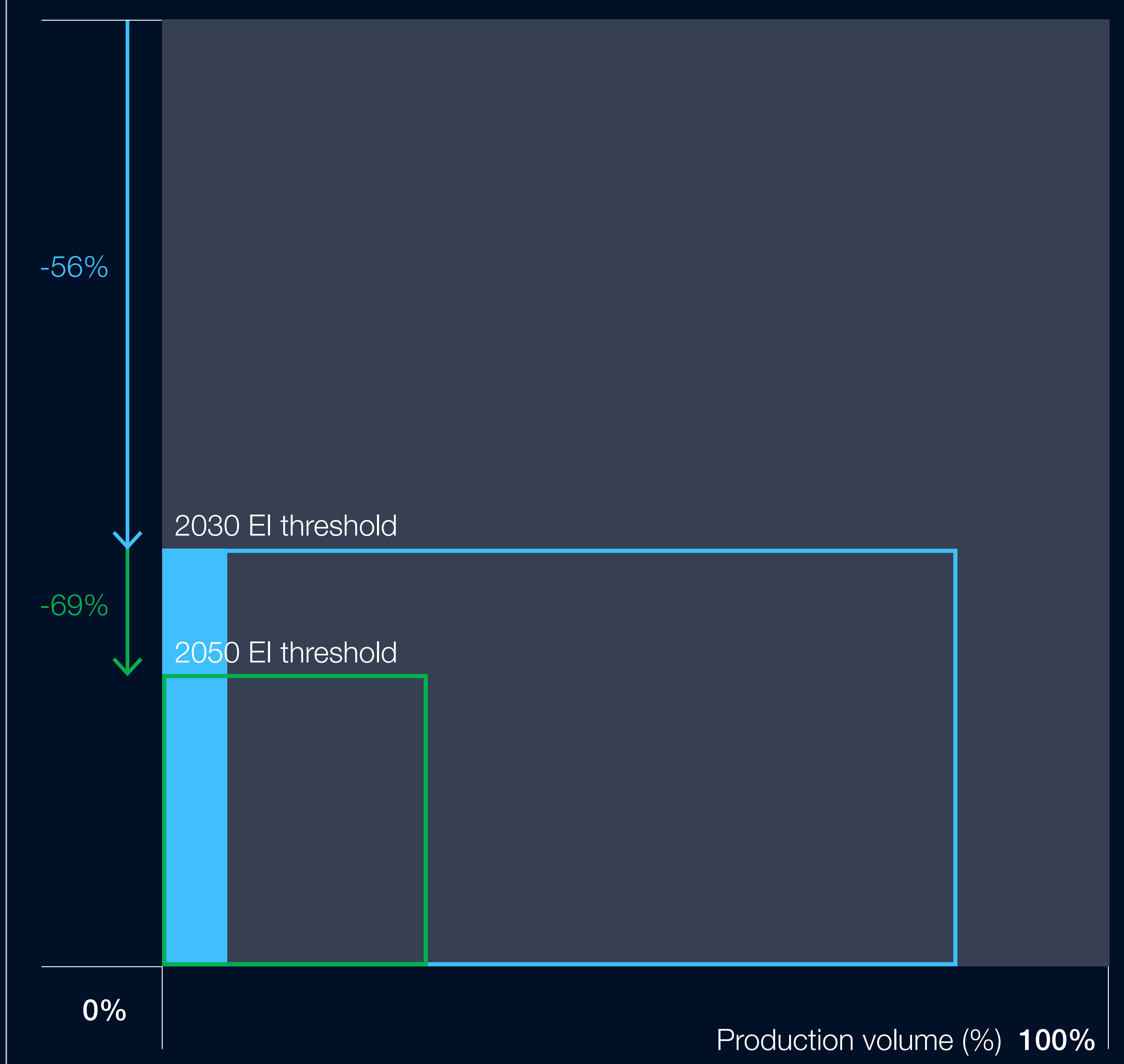
Net-zero industry performance

Size of box indicates industry GHG emissions in:

2020 2030 2050

Today's production meeting "reduced emission" intensity threshold[1]

Today's production meeting "low-emission" intensity threshold[1]



Notes: 1 As defined in the "Mission and methodology" section of this report.

Oil
Executive summary

Oil has been a driver of the global economy for the last 150 years. It is consumed as an energy source in the transportation sector (65%), industries (7%), buildings (5%) and used as feedstock (17%) in many industries including petrochemicals and plastics. Today, production is relatively concentrated with the US, Saudi Arabia, Russia and Canada producing nearly 50% of total supply. The oil industry relies on highly energy-intensive processes to extract crude oil and refine it into oil products. Nearly all the energy consumed is fossil fuel. The extraction of oil also releases methane in the atmosphere – 35% of these emissions are involuntary (fugitive methane) and 65% part of operational processes (vented). The combustion of oil products releases about four times more emissions (scope 3) than production (scope 1 and 2).

Including scope 3, oil is responsible for 30% of all man-made GHG emissions. However only a fifth (6% of total) is directly emitted by the industry – 35% in the form of methane. In the IEA Stated Policies Scenario, oil demand is projected to rise by 17% by 2050, with developing countries in Africa, the Middle East and Asia-Pacific seeing a sharp increase while China, Europe and the US seeing a decline. However, aligning with IEA Net Zero by 2050 Scenario requires a decrease in oil consumption by 73%.

Scope 3 emissions aside, the oil industry needs to address four sources of emissions: fugitive and vented methane, flaring, energy use in well delivery and production, energy use and processes in refining (e.g. steam methane reforming for hydrogen production). Technologies exist to reduce 70% of methane emissions at no or minimal cost to the industry considering the monetization of captured methane. Zero flaring technologies are commercially available. Well delivery and production can be electrified with low-carbon power. Reducing refining emissions remains a technological challenge; CCUS is well-placed and can be supported by electrification and hydrogen technologies. Overall, known technologies can reduce oil industry scope 1 and 2 emissions by up to 70% for an increased production cost of 8-10%.

Besides investing in production assets, such technologies will require more than $100 billion infrastructure investments in low-emission power generation, clean hydrogen production and carbon transport and storage – such amounts are relatively small compared to the over $300 billion spent on the upstream oil industry every year. Low scope 1 and 2 emission oil products are expected to reach the market with a green premium of 6-10%. To incentivize investments, demand signals for these products are critical. Governments will need to strengthen producers' confidence in their ability to pass the premium to end consumers, and in parallel, prevent poorer households from being hit by rising sustainability costs.

Policy measures and international cooperation on methane fees, flaring bans and carbon pricing can help create a differentiated and economically viable market for first movers into the low-emission oil industry. Investments to decarbonize the oil industry are estimated at $720 billion on top of business-as-usual investments, i.e. approximately $25 billion per year until 2050, which is also a minor amount compared to annual industry CapEx. The business case to invest in low-emission assets is already attractive in upstream but remains challenging on the refining side.

We emphasize five priorities for the sector:

1. Rapidly deploy existing technologies to drastically cut vented and fugitive methane and flaring emissions.
2. Boost the number of low-emission projects in refining to accelerate the learning curve, drive costs down and bring forward technology commercial readiness.
3. Develop the renewable power capacity, clean hydrogen production and CO_2 transport and storage infrastructure around production assets.
4. Multiply demand signals for low-emission oil to incentivize producers and investors to direct capital towards low-emission production assets.
5. Develop policies to support the previous four priorities and strengthen the business case for low-emission oil production.

Oil Performance tracker

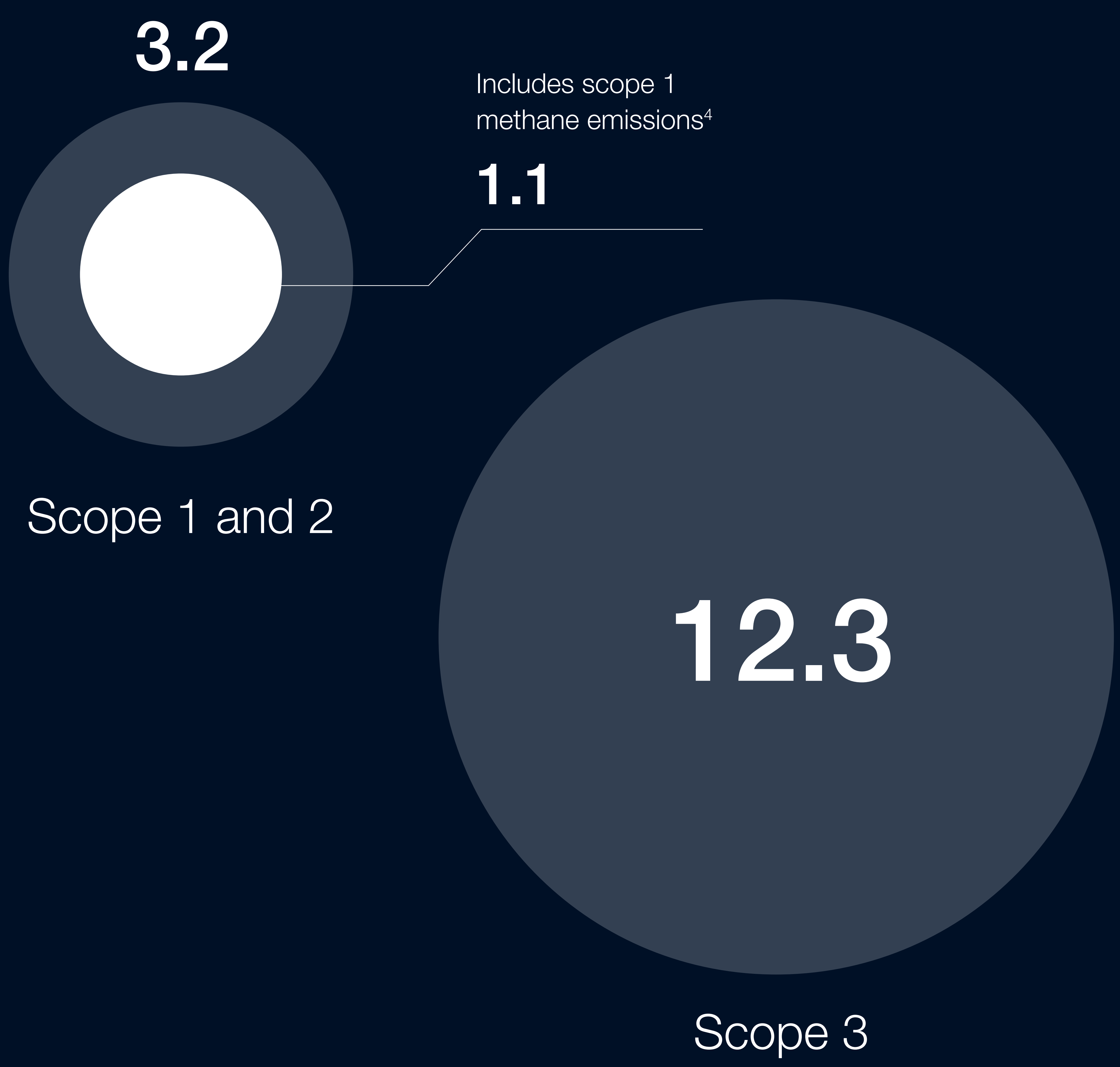
The oil sector generates directly 6% of all man-made emissions – 35% comes from methane emissions.

Click here to see the full data:

Visual | Full data

What oil emits, captures and offsets

Scope 1, 2, and 3 GHG emissions (Gt CO_2e)



Total CCS (Gt CO_2e)

~0.002

Total offsets

Data not available

Oil
Summary

The oil sector benefits from an immediate opportunity: cutting methane emissions. More decisive action is required to boost demand and investments in low-emission oil production.

Click on the enablers below to find out more.

Key messages

70% reduction in methane emissions can occur at effectively no cost to the oil companies (monetization of captured methane).

At least $90 billion are required to scale the necessary low-carbon power, green hydrogen and CO_2 handling infrastructure over the next 30 years.

Passing the 10% cost increase of switching to low-emission production will result in a 6-10% green premium to end consumers.

Due to the high cost of abatement in refining, a high carbon price of $247/t of CO_2 is required to level the competitive landscape for the low-emission oil industry today.

$720 billion is needed to decarbonize oil production (scope 1 and 2) in line with the projected demand of IEA Net Zero by 2050 Scenario.

Technology

Readiness stage 3

The low-emission production technologies **are largely demonstrated in commercial conditions.**

8-10%

Production cost increase for low-emission production today.

Data not available

Expected year of commercial readiness of first low-emission production.

Infrastructure

Readiness stage 2

The necessary infrastructure required by the low-emission industry **is emerging.**

$35 billion

Investments required in low-emission power generation.

$53-93 billion

Investments required in low-emission hydrogen production.

$13-29 billion

Investments required in CO_2 transport and storage.

Demand

Readiness stage 3

Some of the market can pay the required green premium.

+10%

Green premium for low-emission oil buyers.

6-10%

Green premium for end consumers.

Policies

Readiness stage 2

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

$247/t$CO_2$e

Carbon price equivalent required to level competitive landscape.

Capital

Readiness stage 2

Low-emission investments generate sufficient return for a **minority of** CapEx to flow towards low-emission production assets.

$720 billion

CapEx required to transform industry asset base.

3.5.2 Oil readiness tracker

Oil
Technology

Upstream decarbonization technologies are mature and competitive; however, the pathway for refining remains a challenge; low-emission oil production could cost 8-10% more.

Low-emission production technologies are **largely demonstrated in commercial conditions.**

Home

Summary

Key messages

Producing and refining a barrel of oil through a low-emission process could cost 8-10% more with today's technologies.

Reducing fugitive and vented methane is the fastest and most cost-effective way for the industry to cut emissions – a 70% reduction can occur at effectively no cost considering the value generated from recovered gas.

Upstream decarbonization technologies are already mature, while refining low-emission technologies are still under development.

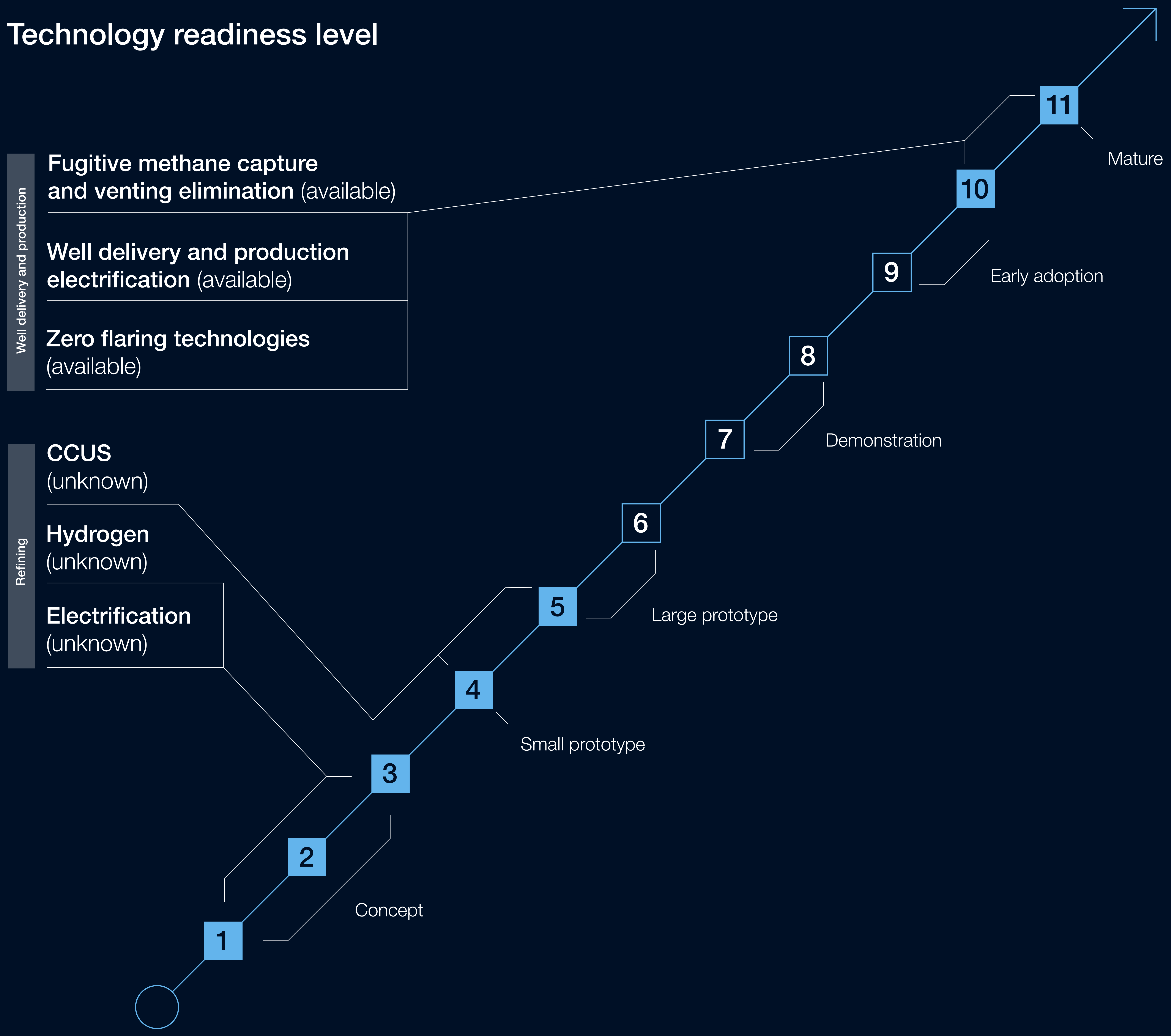
CCUS is likely to be a primary solution in refineries because of the ability to target emissions from burning waste fuel gases and petcoke (by-products of refining).

Sources: IEA, World Resources Institute (WRI), DNV GL oil and gas, Rystad Energy, University of Wyoming

Click here to see the full data:

Visual | Full data

Technology readiness level



3.5.2 Oil readiness tracker

Oil
Infrastructure

To enable low-emission technologies, $100-160 billion will need to be invested in low-carbon power, clean hydrogen and CO_2 handling infrastructure.

The necessary infrastructure required by the low-emission industry **is emerging.**

Key messages

Low-emission hydrogen infrastructure will cost $53-93 billion in investments, while CO_2 transport and storage infrastructure will require $13-29 billion in investments.

The infrastructure investment requirements are less than the annual CapEx of the industry, however only a small fraction exists today.

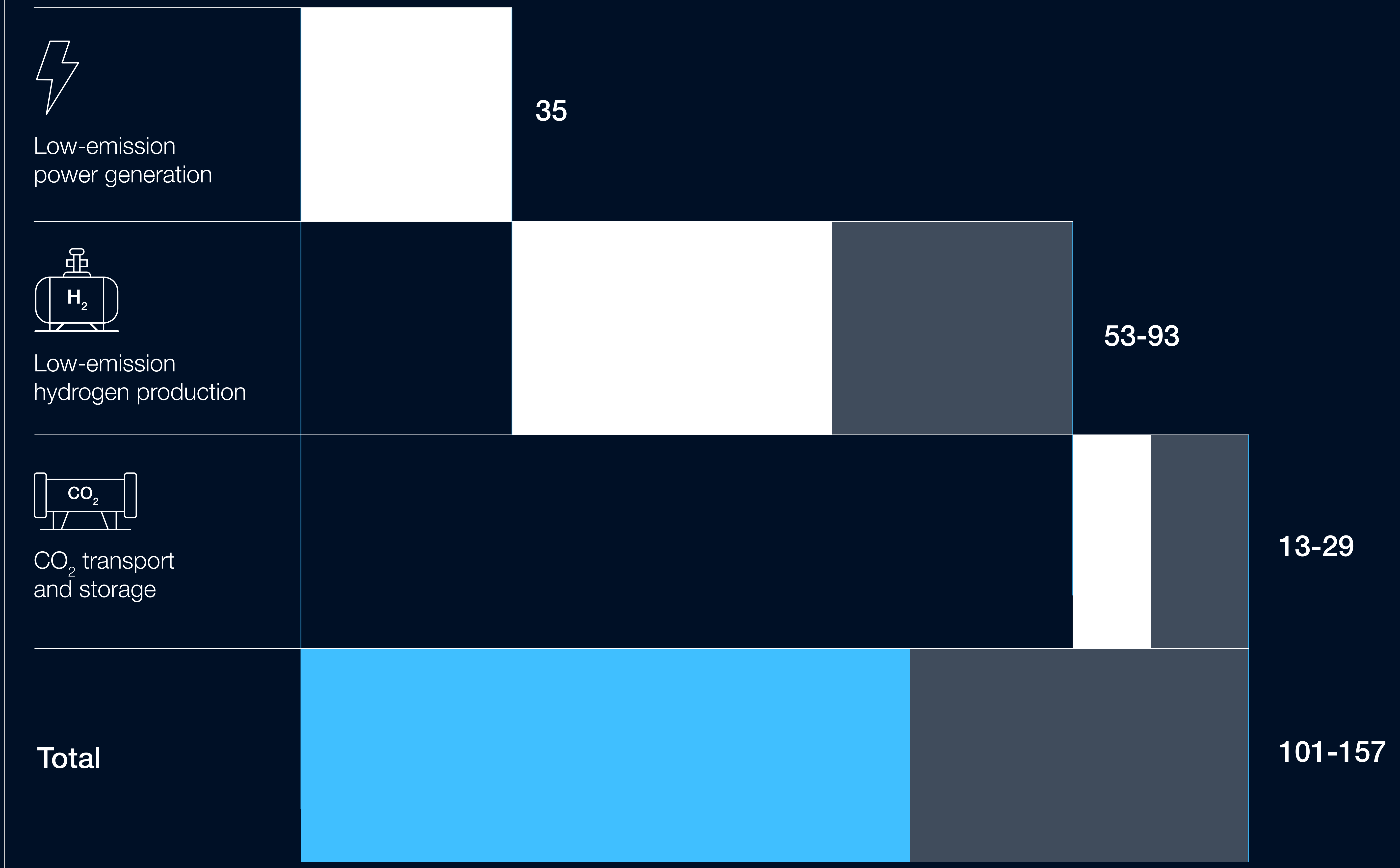
The figures in the table are aligned with IEA Net Zero by 2050 Scenario (i.e. 24 mb/d production). If this drastic decrease in production levels is not reached, further infrastructure investments will be required.

Sources: IEA, University of Wyoming, University of Georgia, Global CCS Institute, DNV GL oil and gas

Click here to see the full data:

Visual | Full data

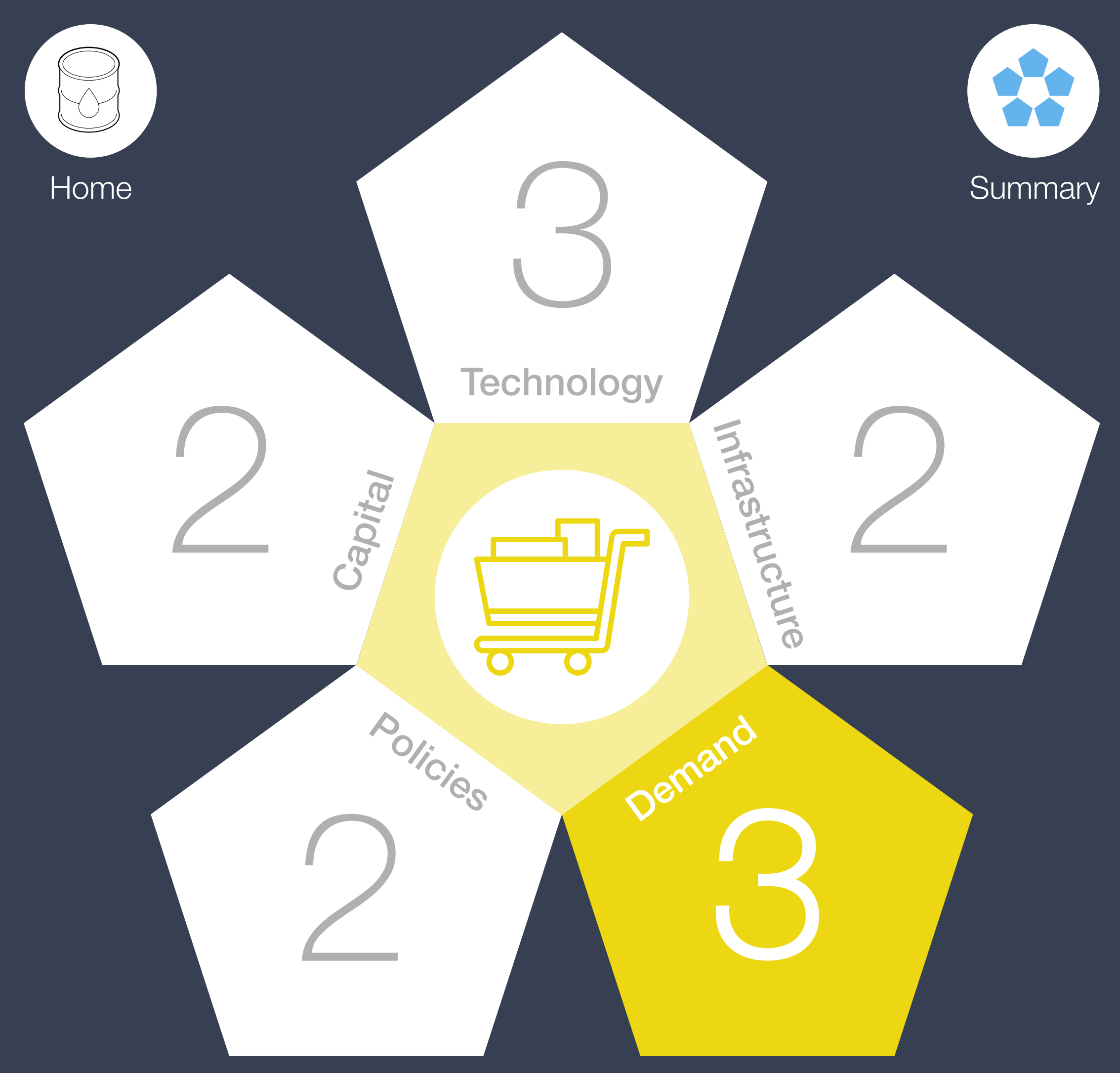
Investments required for enabling infrastructure ($ billion)



Oil
Demand

Governments will need to strengthen producers' confidence in their ability to pass a 6-10% green premium to end consumers while protecting poorer households.

Some of the market can pay the required green premium.



Key messages

Low (scope 1 and 2) emission oil does not exist on the market today – excluding the use of offsets.

Once available, the green premium for end consumers is expected to be 6%-10%. At this price point, substitutes like bio-diesel with a much lower overall emission footprint (because also reducing scope 3) will be more attractive (~15% premium only) provided they are available at scale.

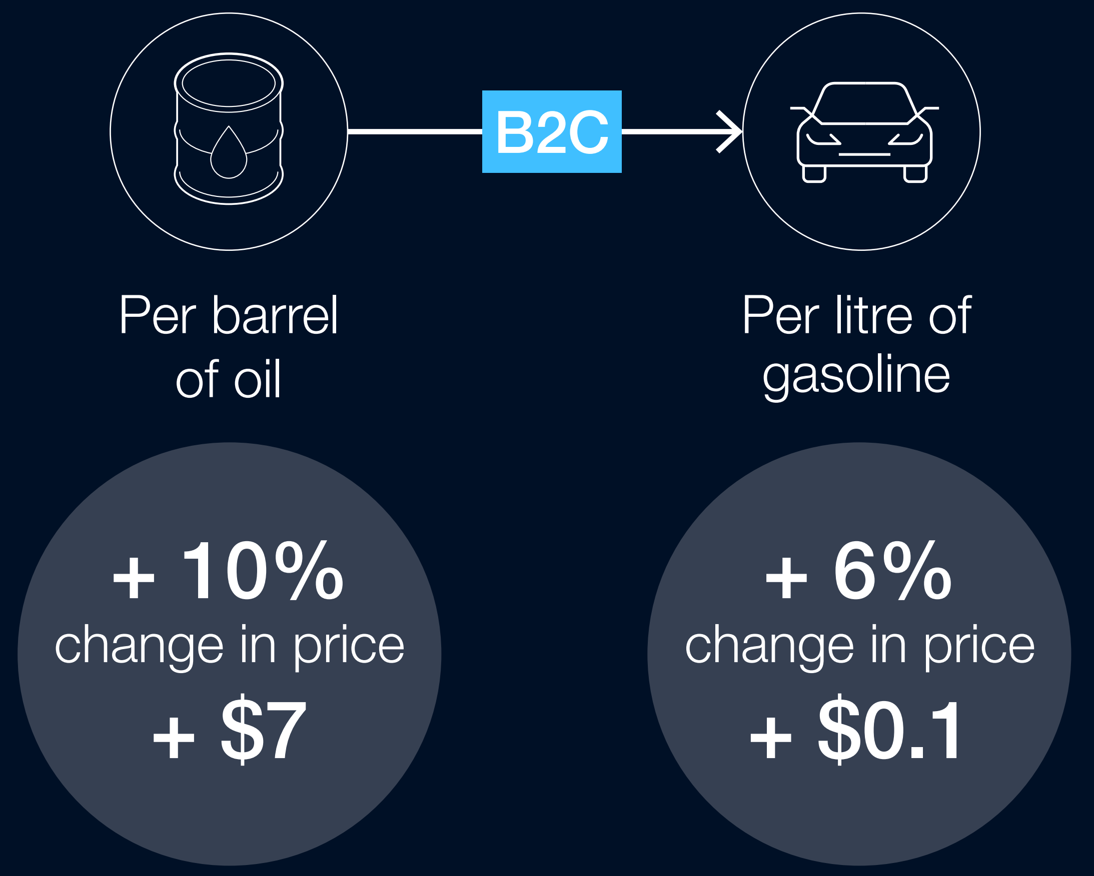
The limited price elasticity of demand seen in recent years suggests oil buyers could take a 10% green premium in the short term, but it might affect global product volumes in the long run.

Sources: Refinitiv, Accenture analysis

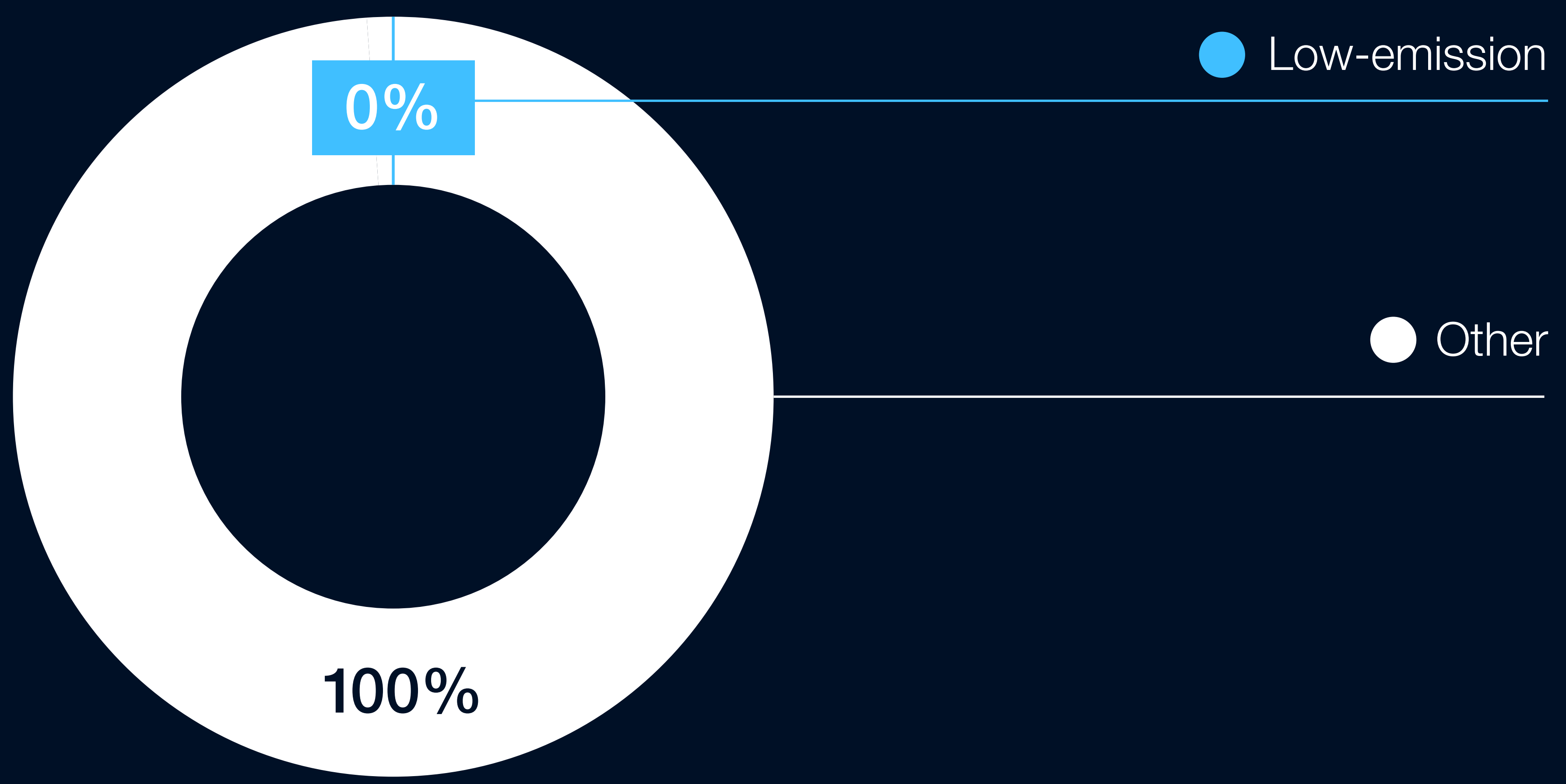
Click here to see the full data:

Visual | Full data

Green premiums



Market penetration



3.5.2 Oil readiness tracker

Oil
Policies

Stronger policy measures are needed to create a differentiated and economically viable market for first movers.

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

Home

Summary

Key messages

Policies vary widely across geographies, and only examples of key policies that have been recently introduced are included in this section.

The cost of carbon abatement in the oil production value chain is the highest in refining.

A carbon price of $247 per tonne of CO_2e is required to incentivize the use of low-emission technology in refineries (a lower price could be sufficient to incentivize upstream low-emission production).

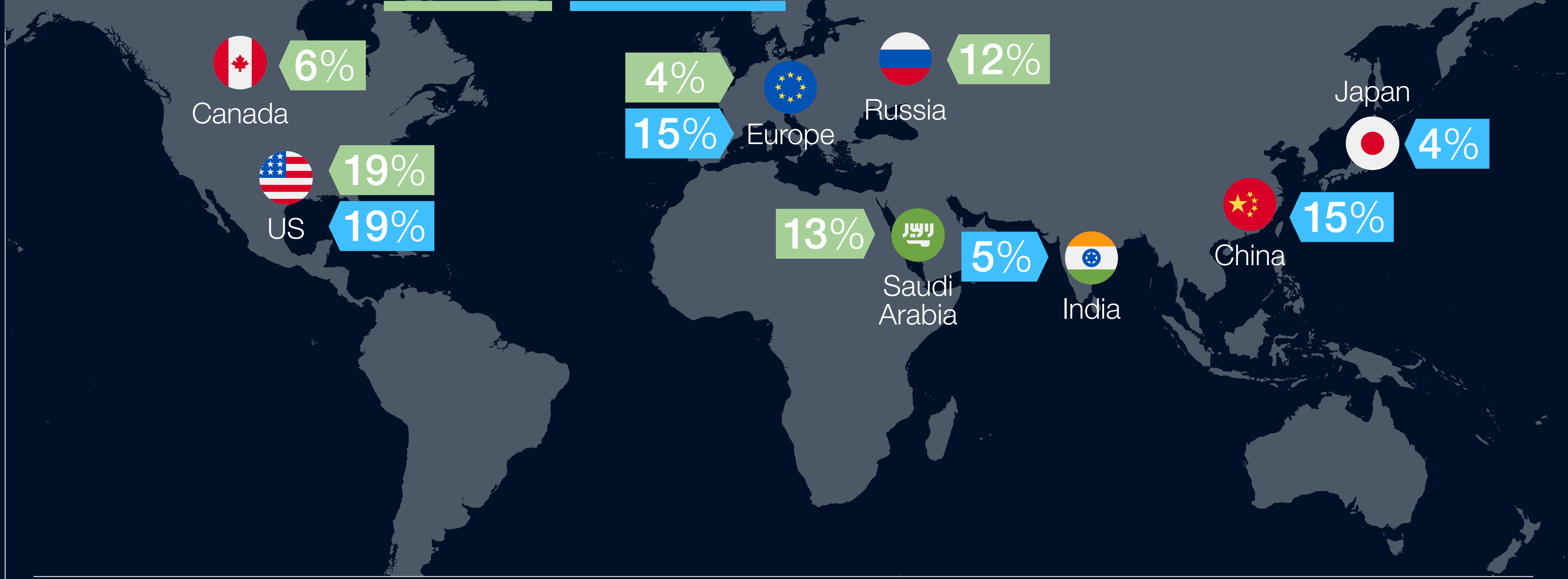
In addition to carbon pricing, methane fees could also incentivize oil companies to eliminate methane emissions.

Sources: World Bank, Various government reports, Accenture analysis

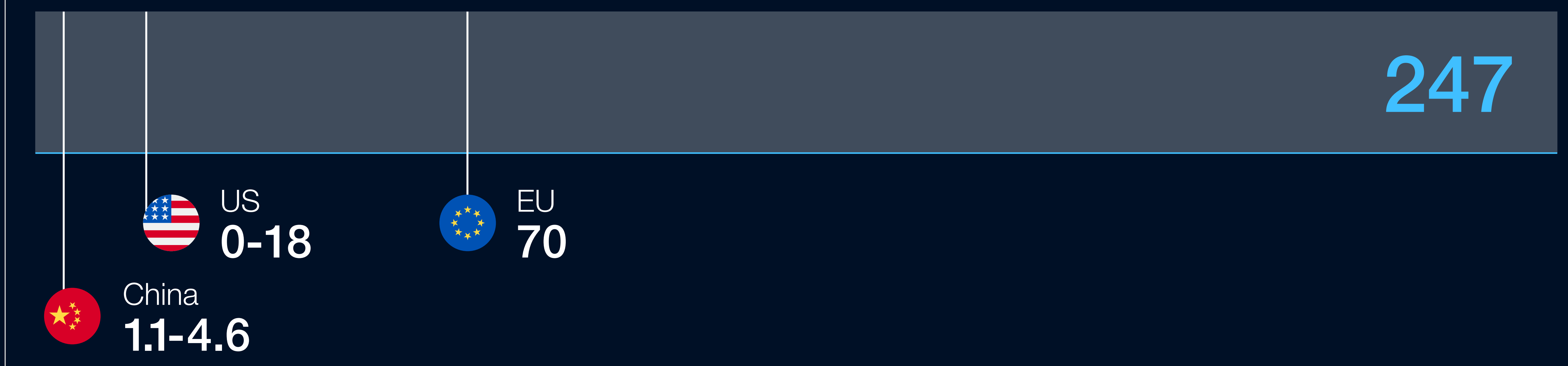
Click here to see the full data:

Visual | Full data

Major producers and consumers of oil
(percentage of global production/consumption)



Average carbon price required to level the playing field for low-emission production vs. actual carbon prices[1] ($/t$CO_2e$)



3.5.2 Oil readiness tracker

Oil
Capital

Approximately $25 billion is needed annually to transform the industry asset base by 2050. The business case is attractive in upstream but remains challenging for refining.

Low-emission investments generate sufficient return for **a minority of** CapEx to flow towards low-emission production assets.

Home

Summary

Key messages

Overall, $720 billion is needed to transform current oil production to low-emission (assuming oil demand reduction in line with IEA 2050 Net Zero Scenario)

To decarbonize upstream, $300 billion (approximately $10 billion per year) is required. This represents only 3% additional investments on annual CapEx of $350 billion spent in upstream in 2021, which can reduce industry emissions by 60%.

Investments in low-emission production in upstream provide a strong business case with sufficient profits recovered from the sale of captured methane. Business cases are weak today for investments in low-emission refineries.

Sources: Refinitiv, Accenture analysis, IEA, Statista, University of Wyoming, DNV GL oil and gas

Click here to see the full data:

Visual | Full data

Assets and investments

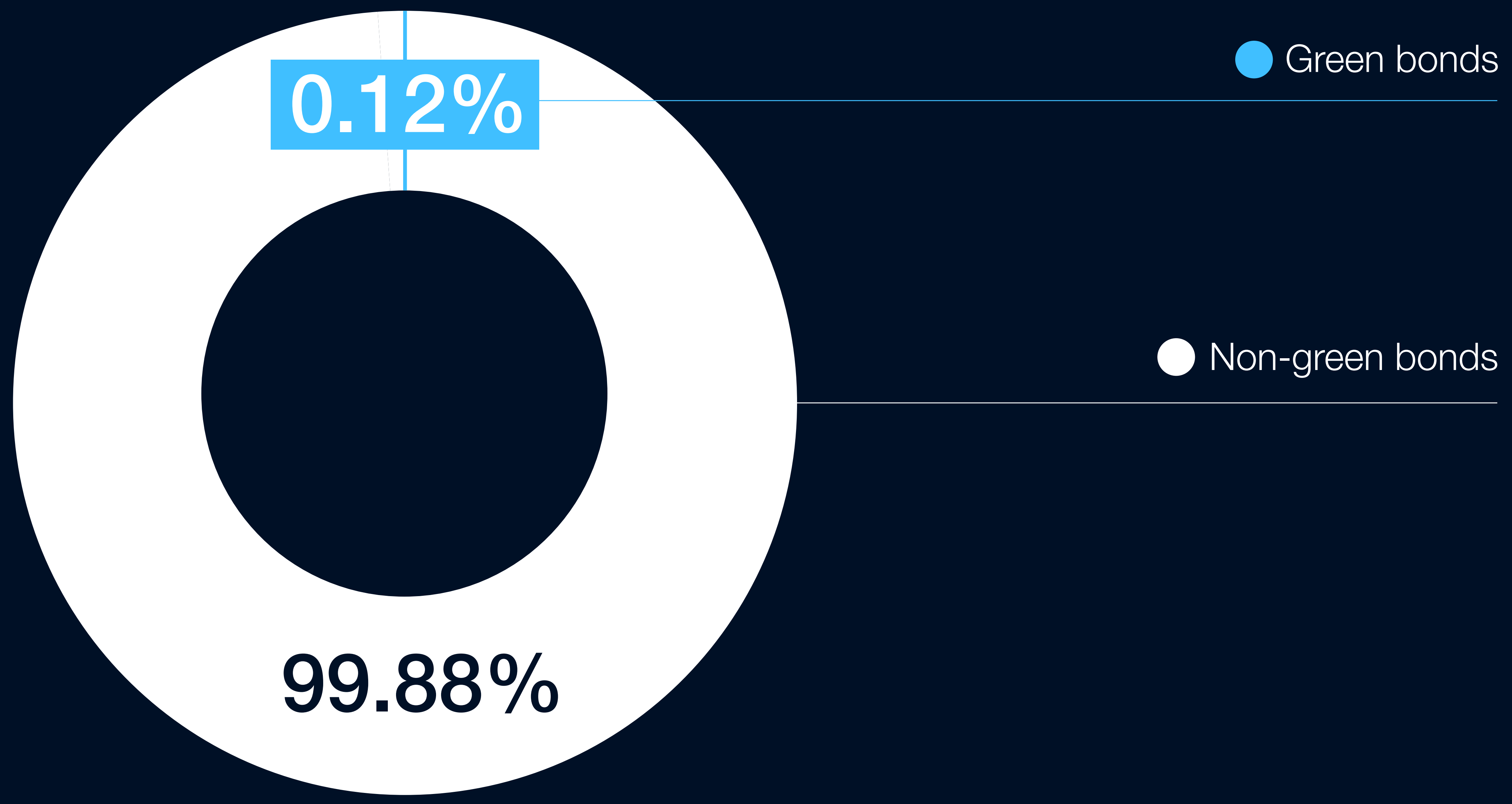
Transformation investment required **$720 billion**

Industry net property, plant and equipment (PPE) **$4.2 trillion**

=

0.2
Investment to PPE multiple

Debt issued
(2020 bonds)



Natural gas
Net-zero industry tracker

Natural gas
Key highlights

The gas sector is a major consumer of fossil fuels and releases methane – generating directly 4% of all man-made emissions.

Gas demand is projected to increase by 30% by 2050 in business-as-usual scenario (IEA Stated Policies Scenario), however, it would need to drop by 55% to reach net zero according to IEA Net Zero by 2050 Scenario.

Methane makes up 65% of emissions within the gas sector, of which 70% can be abated at zero or minimal costs today.

Mature technologies exist to abate 80% of gas sector emissions for about a 7% increase in production cost.

A green premium of 1-3% to end consumers could suffice incentivize low-emission production.

Policies to support the emergence of a low-emission gas market are needed to accelerate investments.

Net-zero industry readiness

Readiness stage

4

Technology

The low-emission production technologies are **largely commercial and competitive with high emission alternatives.**

2

Infrastructure

The necessary infrastructure required by the low-emission industry **is emerging.**

4

Demand

Most of the market can pay the required green premium.

2

Policies

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

2

Capital

Low-emission investments generate sufficient return for a **minority of** CapEx to flow towards low-emission production assets.

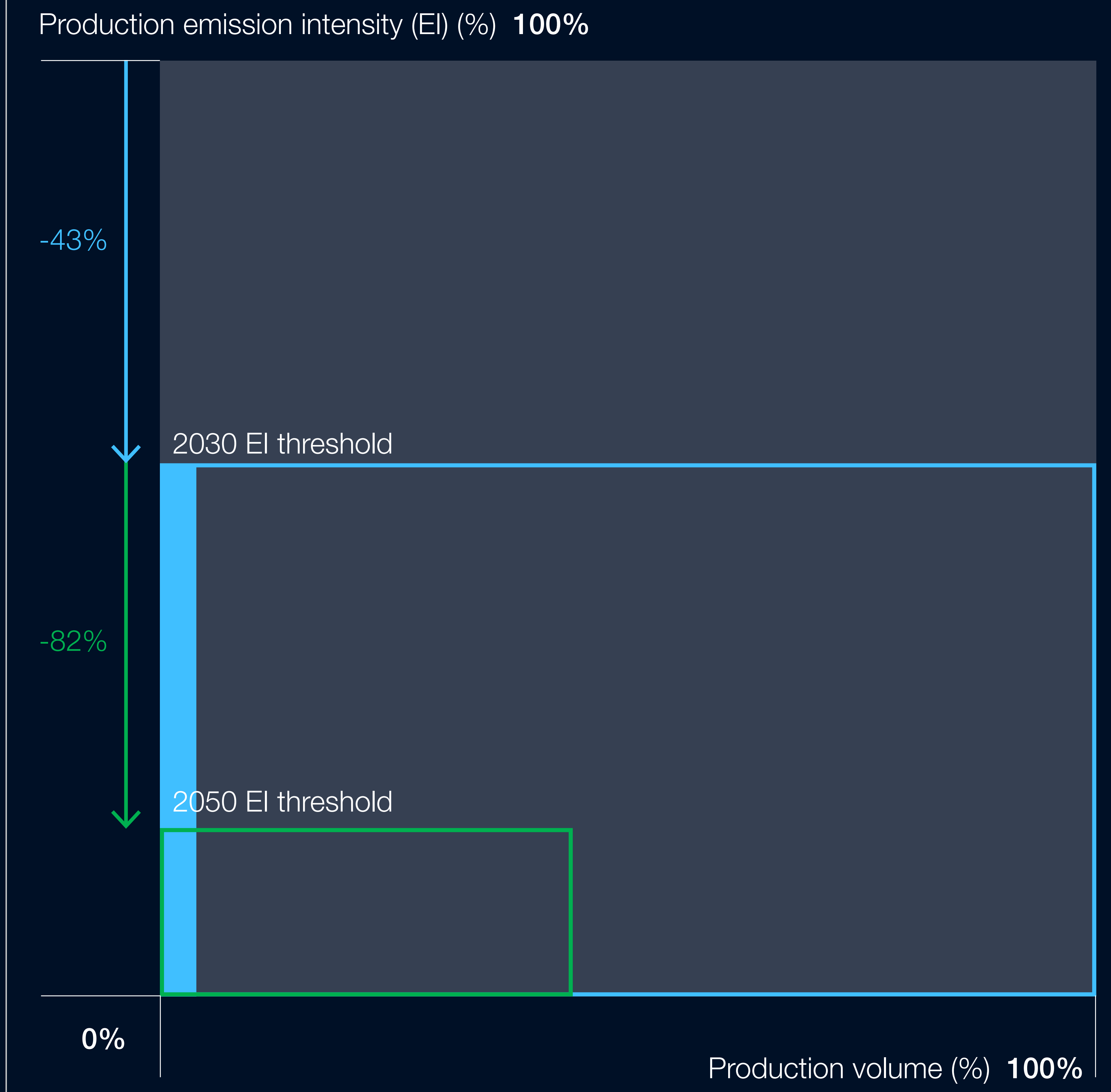
Net-zero industry performance

Size of box indicates industry GHG emissions in:

2020 2030 2050

Today's production meeting "reduced emission" intensity threshold[1]

Today's production meeting "low-emission" intensity threshold[1]



Notes: 1 As defined in the "Mission and methodology" section of this report.

Natural gas Executive summary

Natural gas is a major energy source of modern society used in power plants (40%), industries (35%), residential and commercial buildings (21%) and as feedstock for petrochemicals (4%). Today, production is relatively concentrated, with the US, Russia, Iran and Qatar producing over 50% of the global supply. The natural gas industry relies on highly energy-intensive processes to extract, process and deliver gas to customers – nearly all the energy used is fossil fuel-based. The combustion of gas (scope 3) releases four times more emissions than its production (scope 1 and 2).

Including scope 3, natural gas is responsible for 20% of all man-made GHG emissions. However, only a fifth (4% of total) is directly emitted by the industry – 65% in the form of methane. 45% of methane emissions are involuntary (fugitive), and 55% are part of operational processes (vented). In the business-as-usual scenario, gas demand is projected to rise by 30% by 2050, with developing countries in Africa, the Middle East and Asia-Pacific seeing a sharp increase while Europe and the US remain stable. However, aligning with the IEA Net Zero by 2050 requires a decrease in natural gas consumption by 55% by 2050, with the sharpest drops in North America (-55%), Europe (-96%) and Asia-Pacific (-71%).

Scope 3 emissions aside, the gas industry needs to address four sources of emissions: fugitive and vented methane, energy used in extraction, energy used in gas processing and energy used in liquified natural gas (LNG) processes. Technologies exist to reduce 70% of methane emissions at no or minimal cost to the industry, considering the monetization of captured methane. Extraction, gas processing and LNG processes can be electrified with low-carbon power, and CCUS is also well-placed to provide an alternative solution for gas processing emissions. Overall, known technologies can reduce gas industry scope 1 and 2 emissions by up to 80% for a production cost 7% higher.

Besides investing in production assets, such technologies will require more than $100 billion of infrastructure investments in low-emission power generation and carbon transport and storage, assuming the production level aligns with IEA Net Zero by 2050 Scenario (more if demand is higher) – such an amount is relatively small compared to the more than $300 billion spent in the upstream oil and gas industry every year. Low scope 1 and 2 emission natural gas could reach the market with a green premium of about 7%. To incentivize investments, demand signals for low-emission gas are critical. There are encouraging signs as the green premium for end consumers is expected to range from 1-3%, a relatively small impact that most end consumers could easily absorb. However, governments will need to prevent poorer households from being hit by rising costs.

Policy measures and international cooperation on methane fees, carbon pricing, emission standards, methane measurement and tracking regulations can help create a differentiated and economically viable market for first movers into the low-emission gas industry. Investments to decarbonize the gas industry are estimated at $110 billion on top of business-as-usual investments, i.e. approximately $4 billion per year until 2050, which is also small compared to the annual oil and gas industry CapEx. The business case to invest in low-emission assets is increasingly attractive; however, stronger demand and policy incentives are required to accelerate investments.

We emphasize five priorities for the sector:

1. Deploy existing technologies at scale to drastically cut vented and fugitive methane emissions.
2. Boost the number of low-emission projects to continue to accelerate the learning curve and drive costs down.
3. Develop the renewable power capacity and CO_2 transport and storage infrastructure required to enable electrification and CCUS for low-emission production.
4. Multiply demand signals for low-emission gas to incentivize producers and investors to direct capital towards low-emission production assets.
5. Develop policies to support the four previous priorities and strengthen the business case for low-emission gas production.

Natural gas Performance tracker

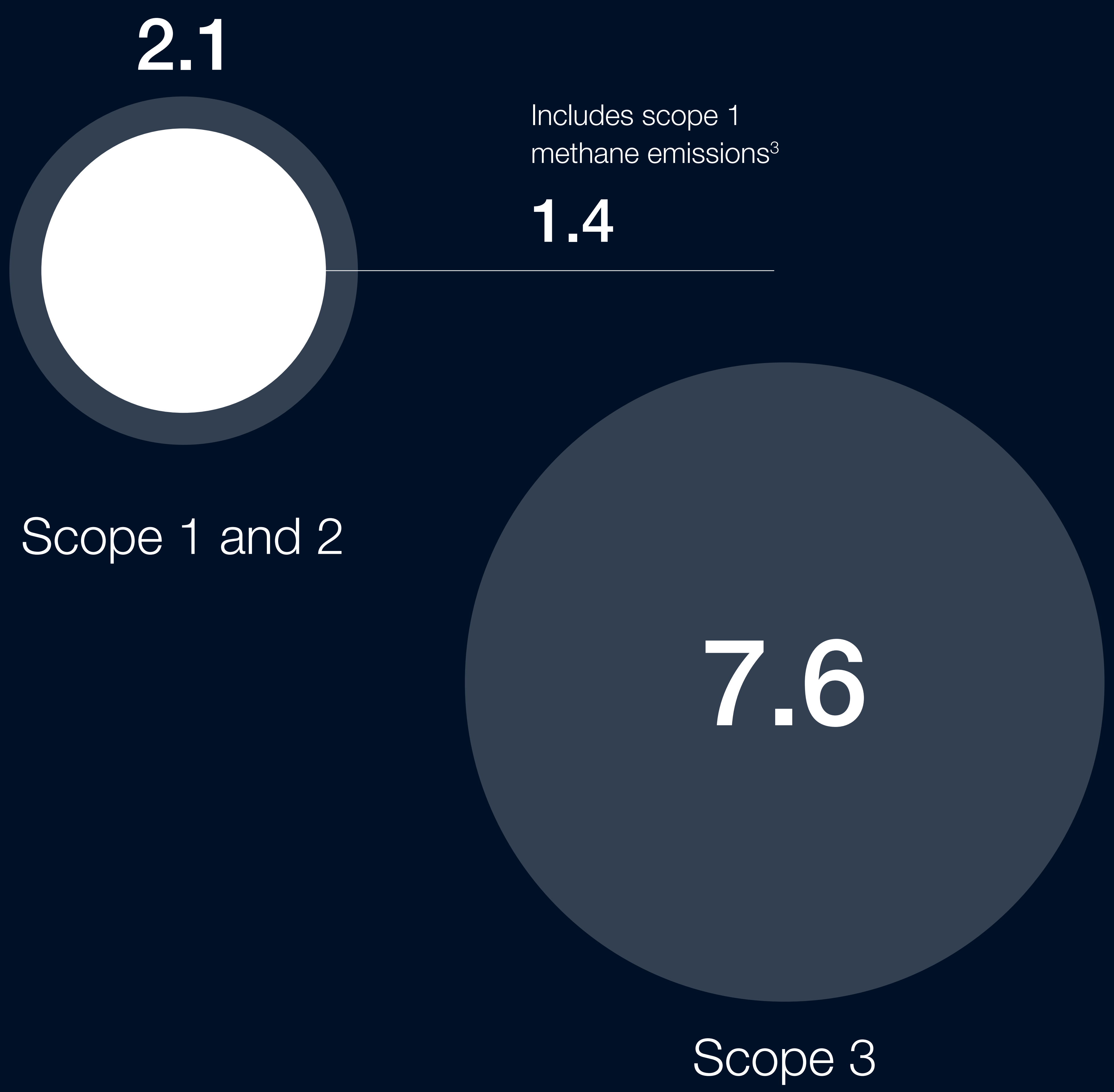
The natural gas sector directly generates 4% of all man-made emissions – 65% in methane emissions.

Click here to see the full data:

Visual | Full data

What natural gas emits, captures and offsets

Scope 1, 2, and 3 GHG emissions (Gt CO_2e)



Total CCS (Gt CO_2e)

0.0285

Total offsets

Data not available

3.6.2 Natural gas readiness tracker

Natural gas Summary

The gas sector benefits from an immediate opportunity: cutting methane emissions. More decisive action is required to boost demand and investments for low-emission gas production.

Click on the enablers below to find out more.

Key messages

70% reduction in methane emissions can occur at effectively no cost to oil and gas companies (monetization of captured methane).

More than $100 billion is required to scale the necessary low-carbon power and CO_2 handling infrastructure over the next 30 years.

Passing the 7% cost increase of switching to low-emission production will likely result in a minor green premium of 1-3% to end consumers.

More decisive policy action can incentivize gas players into low-emission production.

$110 billion is needed to decarbonize gas production (scope 1 and 2) in line with the projected demand of IEA Net Zero by 2050 Scenario.

Technology

Readiness stage 4

The low-emission production technologies are **largely commercial and competitive with high emission alternatives.**

+7%

Production cost increase for low-emission natural gas.

Available

Expected year of commercial readiness of first low-emission production.

Infrastructure

Readiness stage 2

The necessary infrastructure required by the low-emission industry **is emerging.**

$89 billion

Investments required in low-emission power generation.

$18-38 billion

Investments required in CO_2 transport and storage.

Demand

Readiness stage 4

Most of the market can pay the required green premium.

+7%

Green premium for low-emission natural gas buyers.

+ 1-3%

Green premium for end consumers.

Policies

Readiness stage 2

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

$20-30/t$CO_2$e

Carbon price equivalent required to level competitive landscape.

Capital

Readiness stage 2

Low-emission investments generate sufficient return for a **minority of** CapEx to flow towards low-emission production assets.

$110 billion

CapEx required to transform industry asset base by 2050.

Natural gas Technology

Decarbonization technologies are largely mature and competitive, and deployment could lead only to a 7% increase in production cost.

The low-emission production technologies are **largely commercial and competitive with high-emission alternatives.**

Key messages

Low-emission technology is currently available and could result in a 7% increase in production cost.

Fugitive and vented methane drive 65% of natural gas emissions across the entire value chain. Reducing these emissions is the quickest and most cost-effective way for the industry to cut emissions. 70% reduction can occur at effectively no cost when also considering the value generated from recovered gas.

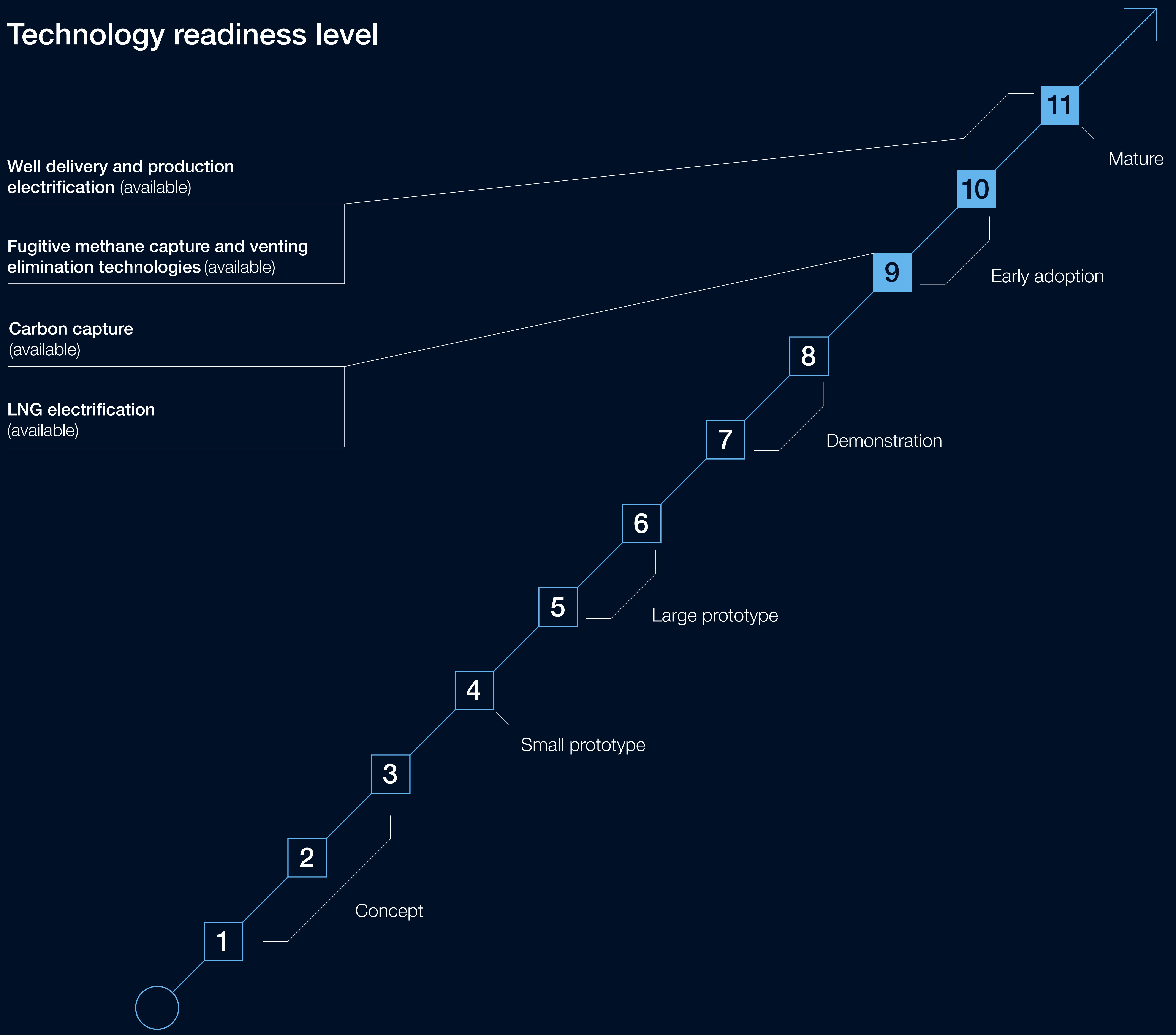
Decarbonization technologies for gas processing and LNG include CCUS and electrification, which are already commercially available and can be deployed at little incremental production costs.

Sources: Sustainable Gas Institute, IEA, World Bank

Click here to see the full data:

Visual | Full data

Technology readiness level



Natural gas Infrastructure

More than $100 billion will need to be invested in low-carbon power and CO_2 handling infrastructure to enable low-emission technologies.

The necessary infrastructure required by the low-emission industry **is emerging**.

Key messages

Under the IEA Net Zero by 2050 emission scenario, natural gas production is expected to drop from 380 to 169 Bcf/d from today to 2050.

The low-carbon power and CO_2 infrastructure required to decarbonize the remaining gas production is emerging and will need at least $100 billion of investments by 2050. Nearly 30 Mt of CCS capacity has already been developed for natural gas.

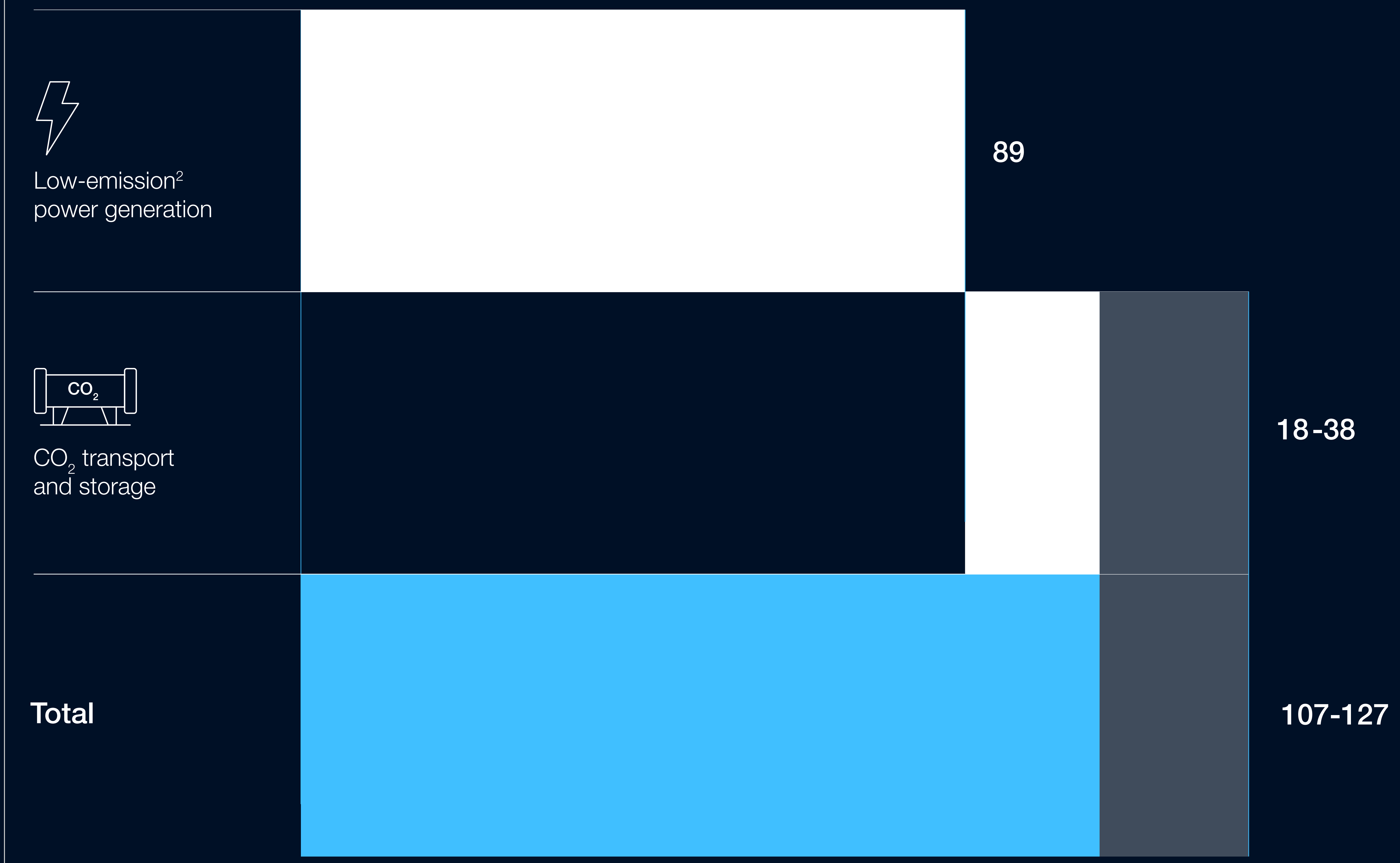
The investment required to decarbonize will be proportionately higher if gas production levels do not fall to the IEA Net Zero by 2050 Scenario levels.

Sources: Global CCS Institute, IEA, Accenture analysis

Click here to see the full data:

Visual | Full data

Investments required for enabling infrastructure ($ billion)



Natural gas Demand

Producers could pass a green premium of 1-3% to end consumers; however, governments should be cautious of this cost impact on poorer households.

Most of the market can pay the required green premium.

Home

Summary

Key messages

Low-emission natural gas (scope 1 and 2) does not exist in the market today (excluding the use of offsets).

Once available, the green premium for wholesale gas buyers is expected to be about 7%. Passing this 7% premium to end-users will result in a price increase of 1-3%.

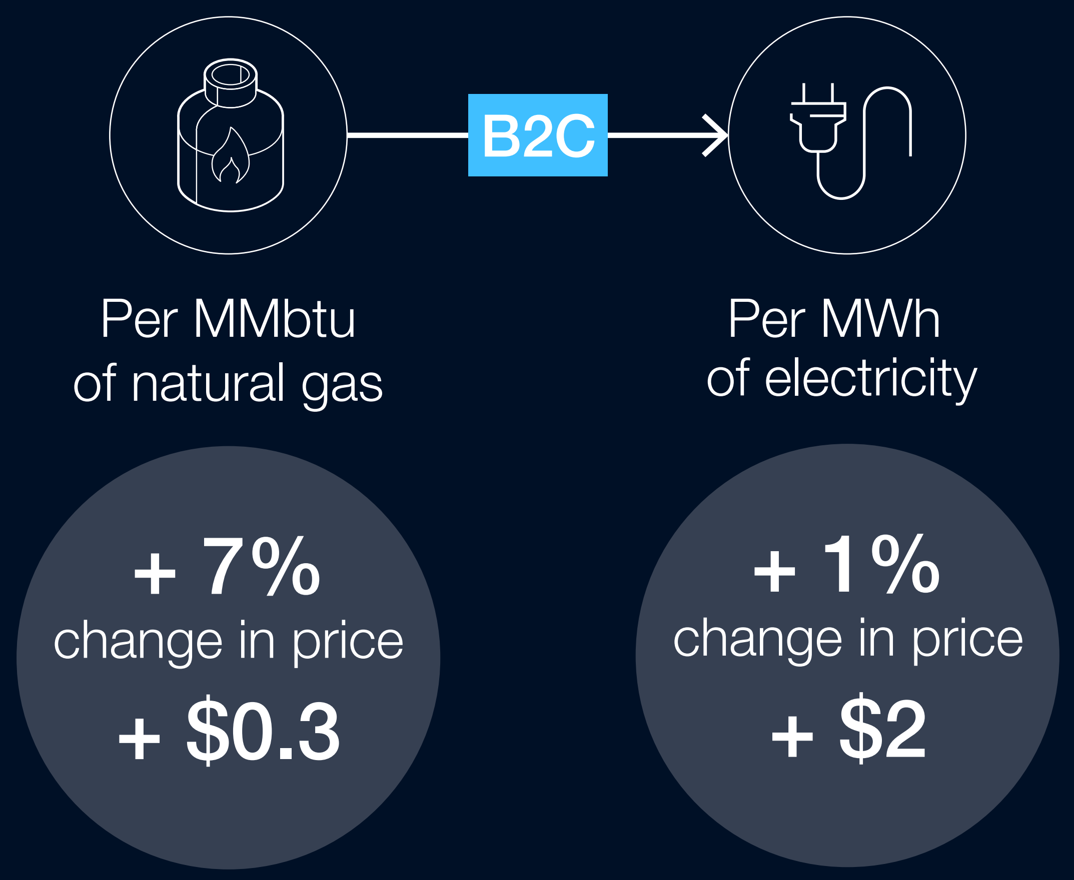
The limited price elasticity of demand seen in recent years suggests both wholesale and end-use gas buyers could take these minor green premiums. Still, governments should protect the poorer households as necessary.

Sources: IEA, EIA, Refinitiv, Accenture analysis

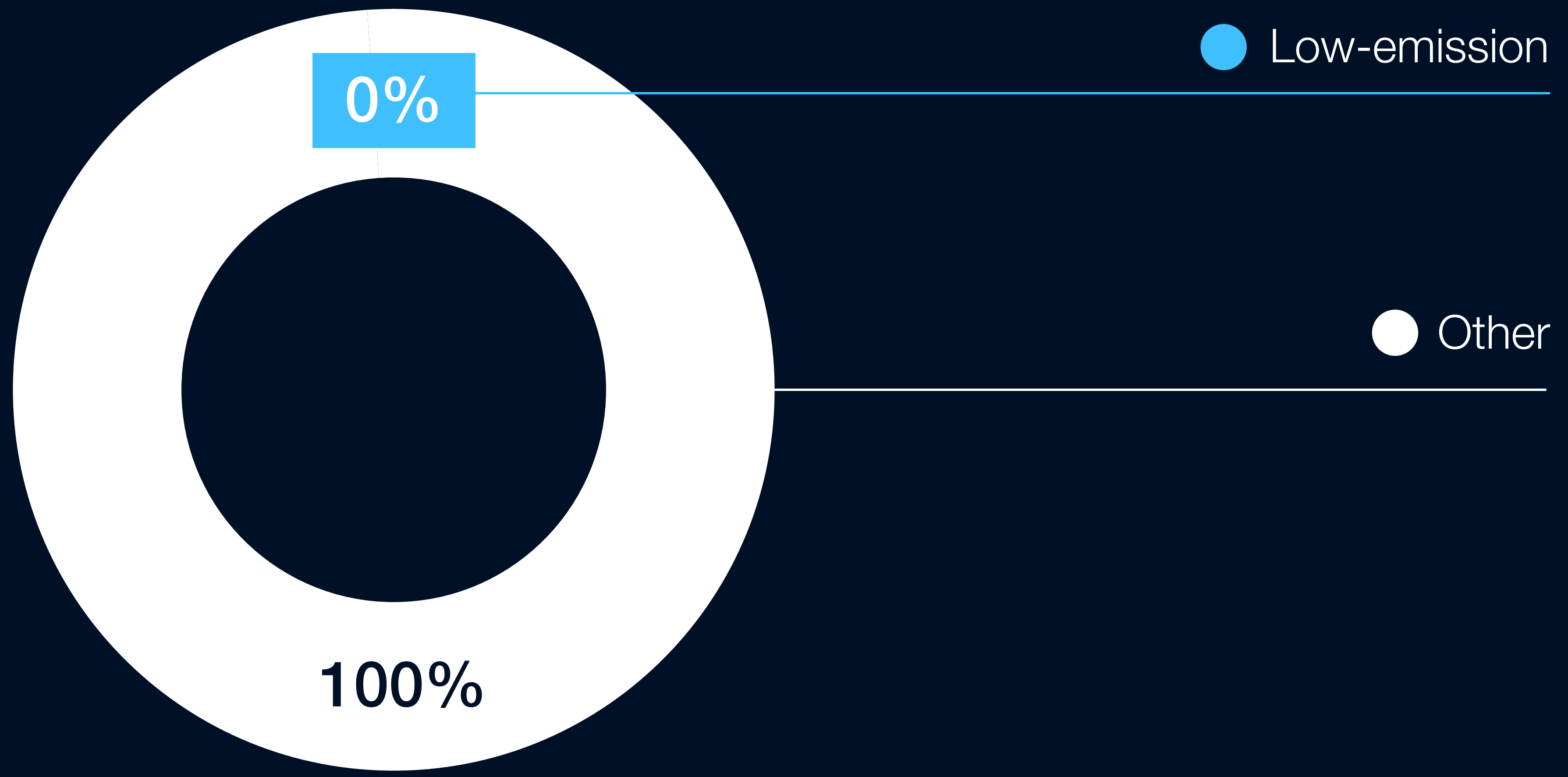
Click here to see the full data:

Visual | Full data

Green premiums



Market penetration



Natural gas
Policies

Policy measures can help create a differentiated and economically viable market for first movers.

Limited policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.

Home

Summary

Key messages

Policies vary widely across geographies; only examples of critical policies that have been recently introduced are included in this section.

The abatement cost in the gas production value chain is the highest for gas processing.

A carbon price of $20-30/ tCO_2e is required to incentivize low-emission technology in gas processing.

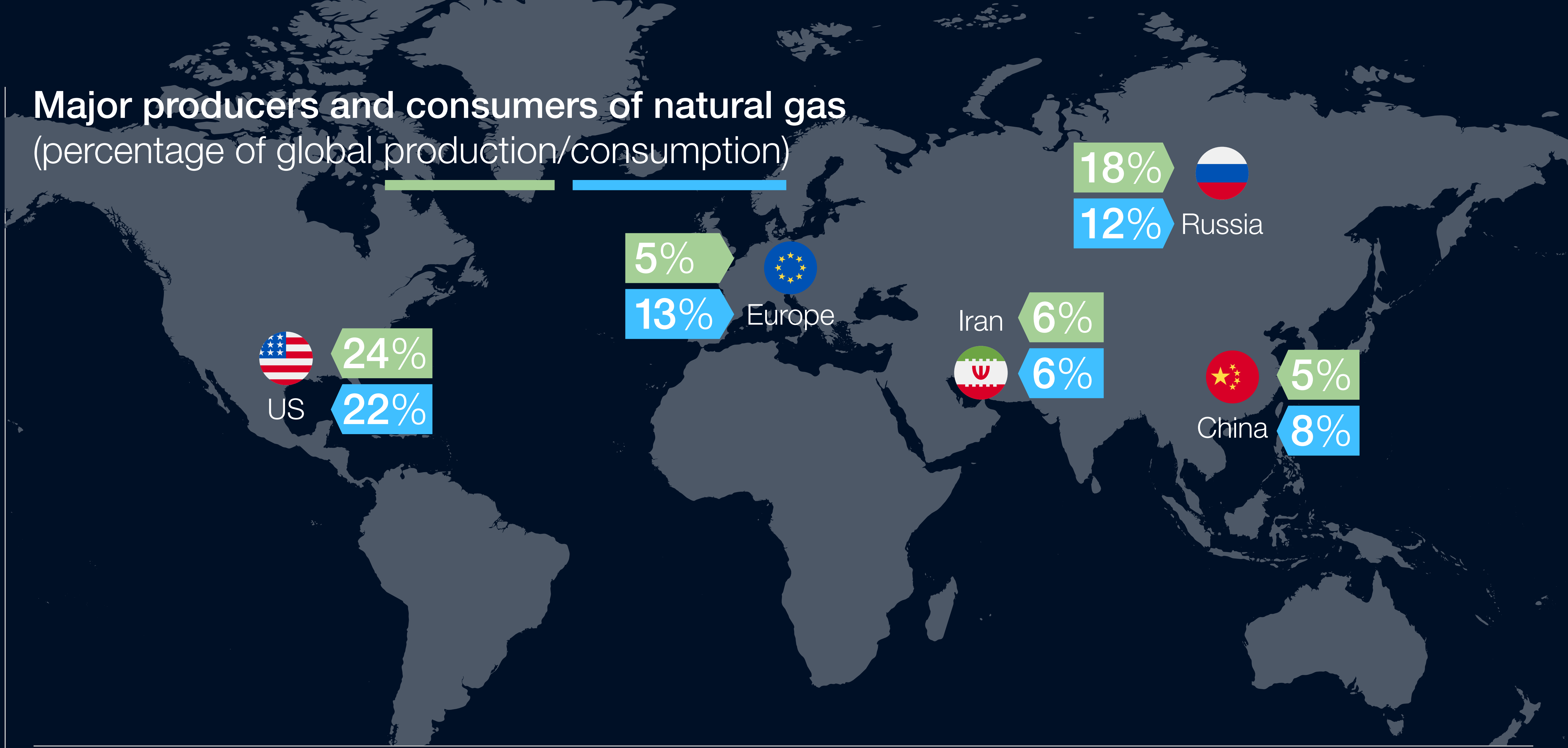
In addition to carbon pricing, methane fees could also incentivize oil and gas companies to eliminate methane emissions.

Sources: IEA, World Bank, Various government and UN reports, Accenture analysis

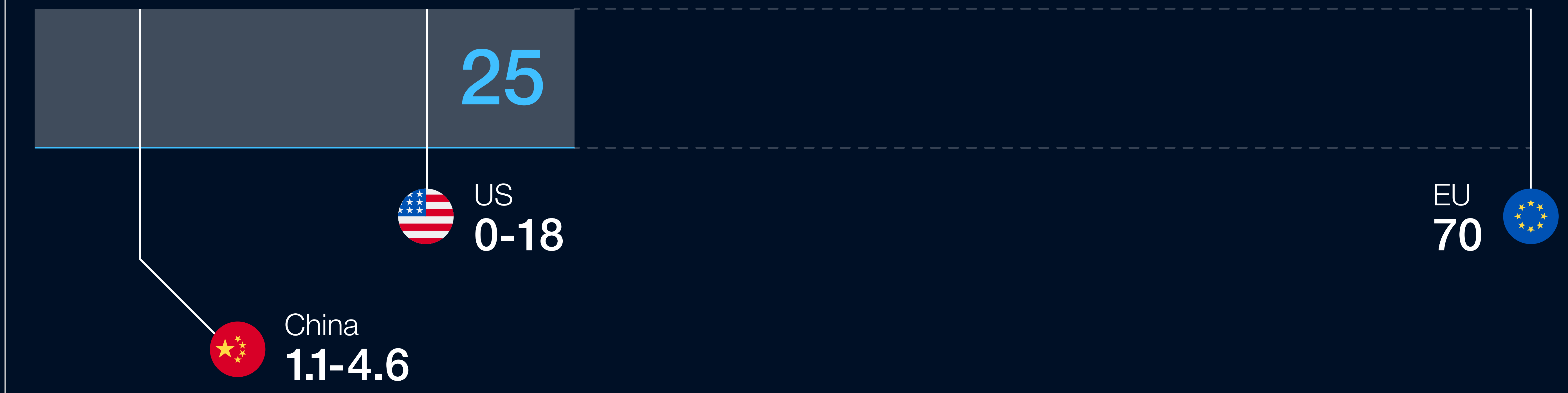
Click here to see the full data:

Visual | Full data

Major producers and consumers of natural gas (percentage of global production/consumption)



Average carbon price required to level the playing field for low-emission production vs actual carbon prices[1] ($/$tCO_2e$)



Natural gas
Capital

Approximately $4 billion is needed annually to transform the industry asset base by 2050 – in some locations, returns on low-emission assets are already attractive for investments.

Low-emission investments generate sufficient return for a **minority of** CapEx to flow towards low-emission production assets.

Key messages

$110 billion is needed to transform current production assets into low-emission assets, in line with IEA 2050 Net Zero Scenario's demand for gas.

Returns from recovering fugitive/vented methane are sufficient for companies to take action to eliminate emissions from 43% of assets, with regulations in some regions further incentivizing emission reduction.

Oil and gas companies raised $380 million in green debt in 2020, a fraction of the total debt issued. $6.5 billion for renewable energy was raised in the same period.

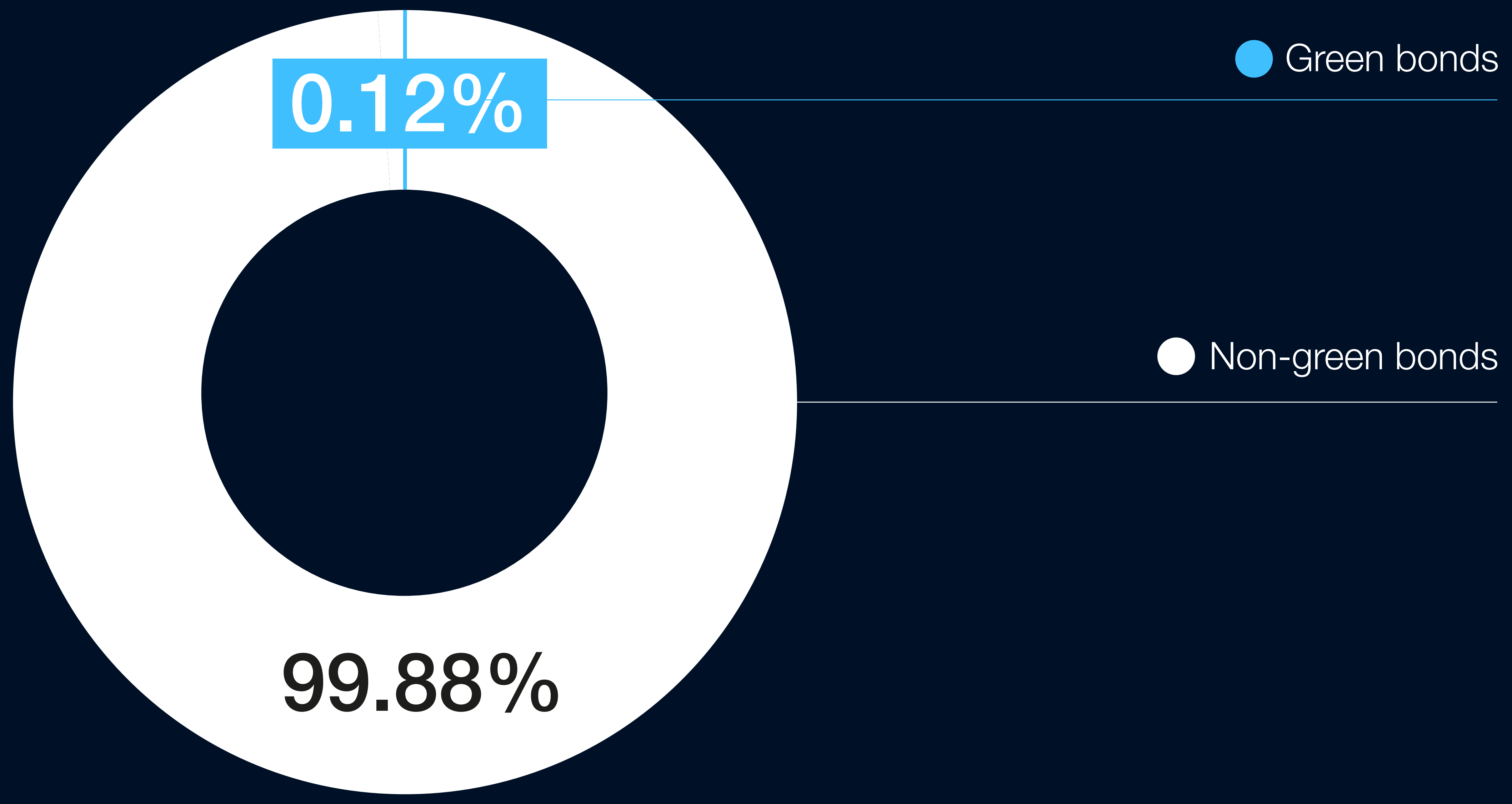
Sources: Refinitiv, EIA, Accenture analysis

Click here to see the full data:

Visual | Full data

Assets and investments

Debt issued
(2020 bonds)



Appendix

A.1

Industry process overview

Steel
Process overview

Steel is used extensively in many sectors and has no scalable substitute. It is manufactured through energy-intensive processes, and 50% is made in China.

Industry boundaries – value chain

	Mining/scrap sorting	Iron production	Steel production	Casting and finishing
Description	Iron ore is a mixture of iron oxides. Magnetite (Fe_3O_4) and hematite (Fe_2O_3) are the most common. Scrap steel is collected, sorted and sent for remelting.	Iron ore is reduced to pig iron in a blast furnace at 1400-1500°C using carbon as a reducing agent. In the direct reduced iron process, iron ore is reduced into iron using a reducing gas at a high temperature. Not applicable.	In the basic oxygen furnace, oxygen is injected to lower the carbon content of pig iron to produce the desired grade of steel (scrap is also added). Reduced iron is melted in an electric arc furnace with oxygen injection to produce steel. Scrap is melted in electric arc furnaces, sometimes with directly reduced iron.	Liquid metal is purified, alloyed to specification and then cast into slabs, billets and blooms.
Source of emissions	Emissions come from diesel and fuel oil combustion to extract and haul the mined ore and waste. Emissions come from the electricity generated to run sorting, crushing and grinding equipment.	Emissions come from the use of coke as reducing agent and fuel combustion to heat and reduce the iron ore. Emissions come from the use of natural gas as reducing agent and fuel combustion for heat.	Emissions mostly come from burning dissolved carbon in the pig iron (hot metal). Emissions come from the electricity generated to run the electric arc furnace, electrodes consumption and slag formers.	Emissions come from both fuel and electricity use in casting and finishing.

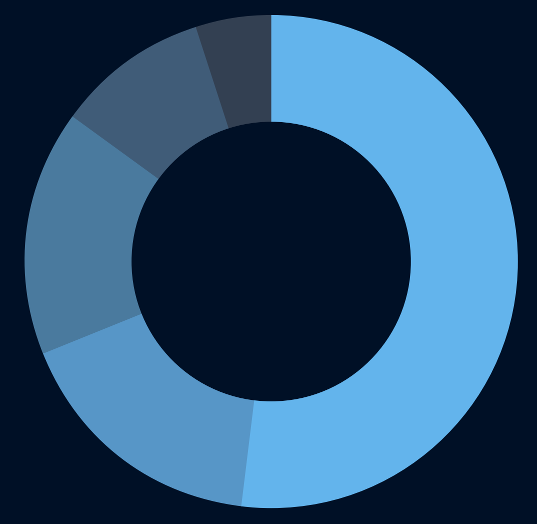
BF-BOF[1] route (88% of industry scope 1 and 2 emissions)
DRI-EAF[2] route (4% of industry scope 1 and 2 emissions)
Scrap-EAF (8% of industry scope 1 and 2 emissions)

Notes: 1 Refers to blast furnace-basic oxygen furnace; **2** Refers to direct reduced iron-electric arc furnace.

Sources: worldsteel, IEA, Statista

Steel consumption

End consumer sectors (global)



Construction	52%
Transport	17%
Mechanical equipment	16%
Metal products	10%
Others	5%

There are more than 3,500 different grades of steel with many different physical, chemical and environmental properties used in various sectors and applications.

Half of the world's steel is used to construct buildings and infrastructure. The other major consuming sectors are equipment manufacturing, automobiles and other transport, and metal products.

A.1 Industry process overview

Cement
Process overview

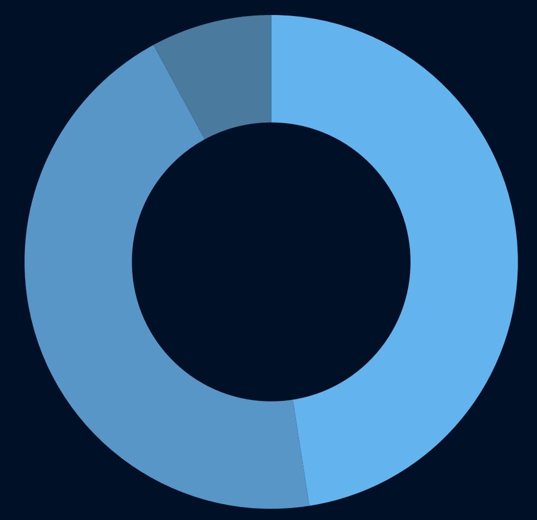
Cement is the second most consumed man-made resource in the world after water; its production releases both energy-related (40%) and process-related CO_2 emissions (60%).

Industry boundaries – value chain

	Quarrying, crushing and grinding	Raw material preparation	Clinker calcination	Cement grinding
Description	– Raw materials (limestone, clay, marl) are quarried and transported.	– Raw materials are homogenized through an electric grinding mill, crushers and other equipment.	– The limestone and clay mixture is heated/sintered in a rotatory kiln to form clinker (1,300-1,450°C).	– Clinker is further ground into powder, and other constituents (gypsum, blast furnace slag) are added to give different properties, forming ordinary Portland cement. – Cement is packed, then trucked or shipped.
Source of emissions	– Emissions come from diesel and power used for trucks and other heavy equipment.	– Emissions come from the electricity used to power heavy machinery to blend materials.	Emissions come from: – Energy (~40%): coal and petcoke are typically burnt to reach the required high temperatures, releasing CO_2. – Process (~60%): the heating decarbonizes limestone to form calcium oxide (desired product) and CO_2, which is released into the atmosphere.	– Emissions come from the electricity used for machinery and diesel for transport.

Cement consumption

End consumer sectors (global)



Infrastructure	47%
Structures	45%
Industrial equipment	8%

Cement is used as a binder for concrete and other construction materials (e.g. grout, mortar).

For concrete, cement is mixed with water to form a paste which binds the aggregate formed by sand, gravel or crushed stone, which can also be recycled from concrete wastes. One cubic metre of concrete consists of approximately 280kg of cement, 175 litres of water and two tonnes of aggregates.

Across all end uses of concrete, a lower bound estimate is that approximately 20% of CO_2 released into the atmosphere can be reabsorbed by concrete in a recarbonation process.[1]

Notes: 1 Tier 1 of the IVL methodology allows for 20% uptake in the use phase of concrete.

Sources: IEA, OECD, Swedish Environmental Research Institute

Aluminium Process overview

Aluminium is used extensively in many sectors and has no scalable substitute. It is manufactured through energy-intensive processes, and 50% is made in China.

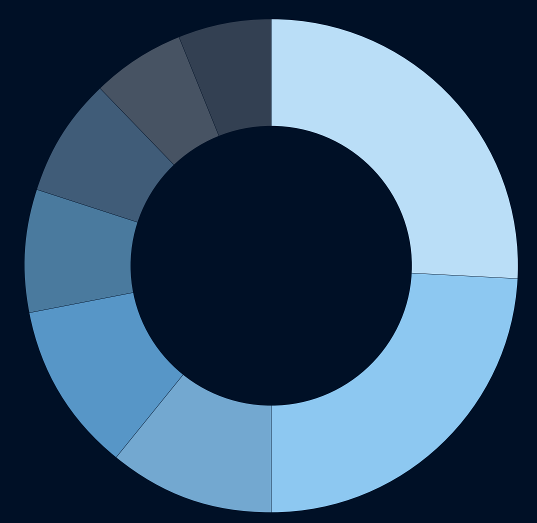
Industry boundaries – value chain

	Mining/scrap collection (1% of scope 1 and 2 emissions)	Alumina production (16% of scope 1 and 2 emissions)	Aluminium production (82% of scope 1 and 2 emissions)	Casting and semis production (1% of scope 1 and 2 emissions)
Description	– Bauxite is mined in tropical and sub-tropical areas such as Australia and the West Indies. – Aluminium scrap is sorted and then sent for remelting.	– Alumina (aluminium oxide) is extracted from bauxite through a refining process. – Step not required in secondary aluminium production process using scrap aluminium.	– Primary aluminium is produced by an electrolytic process called smelting, which reduces aluminium oxide to liquid aluminium. – Secondary aluminium is produced by remelting aluminium scrap.	– Liquid metal is purified, alloyed to specification and then cast into ingots. – Ingots can be directly sent to end-users or turned into semi-finished products such as sheets, strips, wires, tubes, plates, rods and bars.
Source of emissions	– Emissions come from diesel fuel and fuel oil combustion to provide the energy required to extract and haul the mined ore. – Emissions come from the electricity used to run magnets and other sorting equipment.	– Emissions during the refining process come from fuel combustion to generate heat.	– The majority of emissions come from the energy used to produce electricity and heat for smelting. The remaining is released during the consumption of carbon anodes. – Emissions come from the energy used to heat scrap in remelting.	– Emissions in casting come from fuel combustion to melt aluminium and fit into casts. – Emissions in semi-finished production come from fuel combustion to heat aluminium casts along with electricity required to run rolling and other equipment.

Source: IEA

Aluminium consumption

End consumer sectors (global)



Transport	26%
Construction	24%
Machinery	11%
Electrical	11%
Packaging	8%
Foil stock	8%
Consumer durables	6%
Others	6%

Aluminium is a lightweight, corrosion-resistant, highly malleable and infinitely recyclable material which finds usage in multiple industries.

Half of the world's aluminium is used in the construction and transport sectors. Other major consuming sectors are machinery, electrical equipment and consumer goods.

Ammonia Process overview

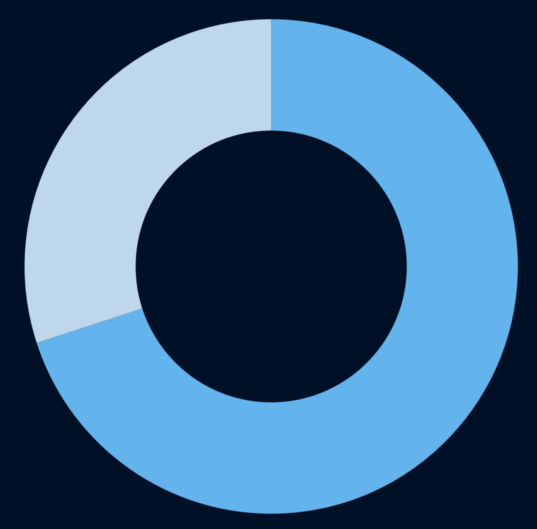
Ammonia is a critical feedstock used for fertilizers and other chemicals. It requires producing hydrogen as a main process.

← Industry boundaries – value chain →

	Natural gas and coal production	Hydrogen production (~90% of scope 1 emissions)	Ammonia production (~10% of scope 1 emissions)
Description	– The fossil fuel industry extracts natural gas and coal.	– Different routes exist to produce hydrogen – common routes are coal gasification and steam methane reforming (SMR), while water electrolysis is a nascent technology. – Released CO_2 may be captured to be used to produce urea (CO_2 and ammonia combination).	– Atmospheric nitrogen is reacted with hydrogen to form ammonia in the Haber process. – Ammonia is transported to be further processed into fertilizer or industrial chemicals.
Source of emissions	– Methane emissions are released across the natural gas value chain and during coal mining operations. – Energy-related emissions in the extraction process also contribute to a lesser extent.	– Significant process and energy emissions are released: – In coal gasification, coal is oxidized with water and oxygen to produce CO_2 and H_2. – In steam methane reforming, natural gas is reacted with water releasing H_2 and CO_2.	– Limited emissions come from energy requirements to power motors and equipment for compression and cooling (the exothermic reaction itself maintains high temperatures of 400-500°C).

Ammonia consumption

End consumer sectors (global)



Nitrogen fertilizer	-70%
Industrial uses	-30%

Most ammonia is used to manufacture nitrogen fertilizers[1] (urea is the most common) or is sold to speciality chemical companies for other uses (e.g. explosives).

Fertilizer is transported and distributed to farmers, and emissions are released when fertilizer is applied – CO_2 is released when urea is applied; additionally, excessive fertilizer leads to N_2O being released. The agriculture industry transitioning away from urea fertilizer will lead to decreases in fertilizer scope 3 emissions.

Notes: 1 Fertilizer plants may be collocated with ammonia and hydrogen production.

Source: IEA

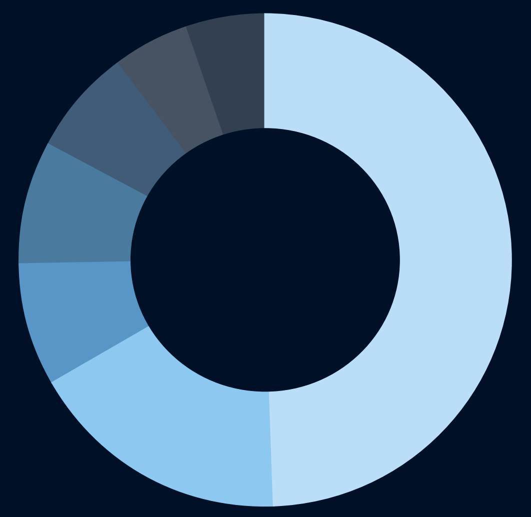
Oil
Process overview

Oil is used extensively in many sectors; its production consumes considerable fossil energy and releases methane into the atmosphere.

Industry boundaries – value chain

	Well delivery and production (56% of scope 1 and 2 emissions)	Crude transport and storage (6% of scope 1 and 2 emissions)	Refining (34% of scope 1 and 2 emissions)	Oil products distribution (4% of scope 1 and 2 emissions)	Oil products consumption (four times total scope 1 and 2 emissions)
Description	– Oil wells are drilled to extract oil and put on production using either the natural pressure of reservoir or artificial lift.	– Extracted crude oil is transported to refineries and storage depots mostly using pipelines, sometimes trucks, and ships in case of international marine movements.	– Crude oil is refined into end consumer use products such as diesel, gasoline, jet fuel by using multiple processes including distillation, cracking, coking and reforming.	– After refining, oil products are distributed to the gas stations or airports for end use. Preferred mode of transport is generally rail or road transport.	
Source of emissions	– Vented and fugitive methane as well as flaring are the two main sources of emissions in this phase. – Other emissions come from energy used to power drilling equipment, production pumps, water injection and the use of steam and electricity.	– Pipeline pumps and fuels for trucks and ships generate the bulk of emissions during this phase.	– Around 70% of emissions in refining stage come from fuel combustion for heating, and from the disposal of waste fuel generated during refining. – Around 30% process emissions come from catalyst regeneration, hydrogen, electricity and steam production, with emissions varying by type of crude oil.	– Emissions come from the fuel use in transportation.	

End consumer sectors (global)



Road transport	49%
Non-energy use	17%
Aviation	8%
Shipping	8%
Industry	7%
Residential	5%
Others	5%

Almost half of the refined oil is used in road transport in the form of gasoline and diesel.

Aviation and shipping are the second and third biggest users of energy products from oil.

Some of the refined oil products are also used for non-energy uses such as feedstock for petrochemicals industry or bitumen for roads construction.

Emissions from combustion (scope 3) are four times scope 1 and 2 emissions.

Source: IEA, BP

Natural gas Process overview

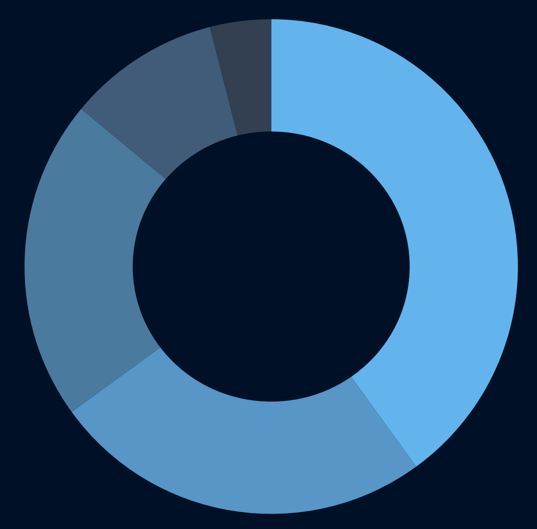
Natural gas is primarily used as a source of electrical and heat energy. Its production consumes considerable fossil energy and releases methane into the atmosphere.

Industry boundaries – value chain

	Well delivery and production (29% of scope 1 and 2 emissions)	Processing (33% of scope 1 and 2 emissions)	Pipeline transport and storage (31% of scope 1 and 2 emissions)	LNG[1] processes (7% of scope 1 and 2 emissions)
Description	– Wells are drilled to extract natural gas from underground gas reservoirs. – Gas can also be produced jointly from oil reservoirs (associated gas).	– Raw natural gas is piped to processing plants to remove impurities, contaminants and higher mass hydrocarbons before it is ready to be transported in pipelines.	– Pneumatic pumps transport processed natural gas across pipelines extending long distances directly to consumers. – Natural gas can also be stored underground before final consumption in some cases.	– Natural gas is liquified in liquefaction plants through cryogenic heat exchange before being transported in large ships and re-gasified at the destination port to export natural gas across oceans.
Source of emissions	– Most methane emissions come from operational processes (vented) or involuntary leaks (fugitive) in equipment such as storage tanks or compressor seals. – Other emissions come from energy used to power drilling equipment, production pumps, water injection, and steam and electricity.	– CO_2 forms the bulk of emissions; it comes from fossil energy to process gas and from the CO_2 present in raw gas streams. – Vented and fugitive methane emissions contribute to a lower extent in this phase.	– Vented and fugitive methane emissions contribute to the bulk of total emissions in this phase.	– Emissions are energy-related. The energy-intensive thermodynamic refrigeration cycles in liquefaction plants are powered by natural gas.

Natural gas consumption (four times total scope 1 and 2 emissions)

End consumer sectors (global)



Power generation	40%
Industry	25%
Residential and commercial	21%
Oil and gas industry	10%
Others	4%

Natural gas is combusted to generate electricity and produce thermal energy, with power plants typically consuming 40% of natural gas.

25% of natural gas is consumed by industrial plants, with about 4% used as feedstock for chemicals, mainly ammonia and methanol.

Note: 1 Liquified natural gas.
Source: IEA

A.2

Industry demand overview

Steel
Demand

Steel demand could rise 30% by 2050 pulled by India, Africa and South-East Asia. Recycling will be key but insufficient to curb industry emissions.

Key messages

Demand for steel is projected to increase by 30% by 2050 in the MPP business-as-usual scenario. The MPP high circularity scenario projects a demand decreasing by 21% by 2050 and an increase in circularity to achieve net zero.[1]

India, South-East Asia and Africa economies are expected to see the largest increase in demand for steel.

Producing secondary steel from scrap will play a crucial role in reducing industry emissions, it is four times less emissive than primary steel today and could achieve near carbon neutrality if powered with green electricity. Secondary steel is limited by scrap availability.

Scrap share in steel making is expected to increase from 30% today to 40% by 2050 in MPP business-as-usual scenario, but it rises to 70% in the high circularity scenario enabled by a lower demand and greater scrap recirculation.

Today around 85% of steel is recycled at the end of its useful lifecycle.

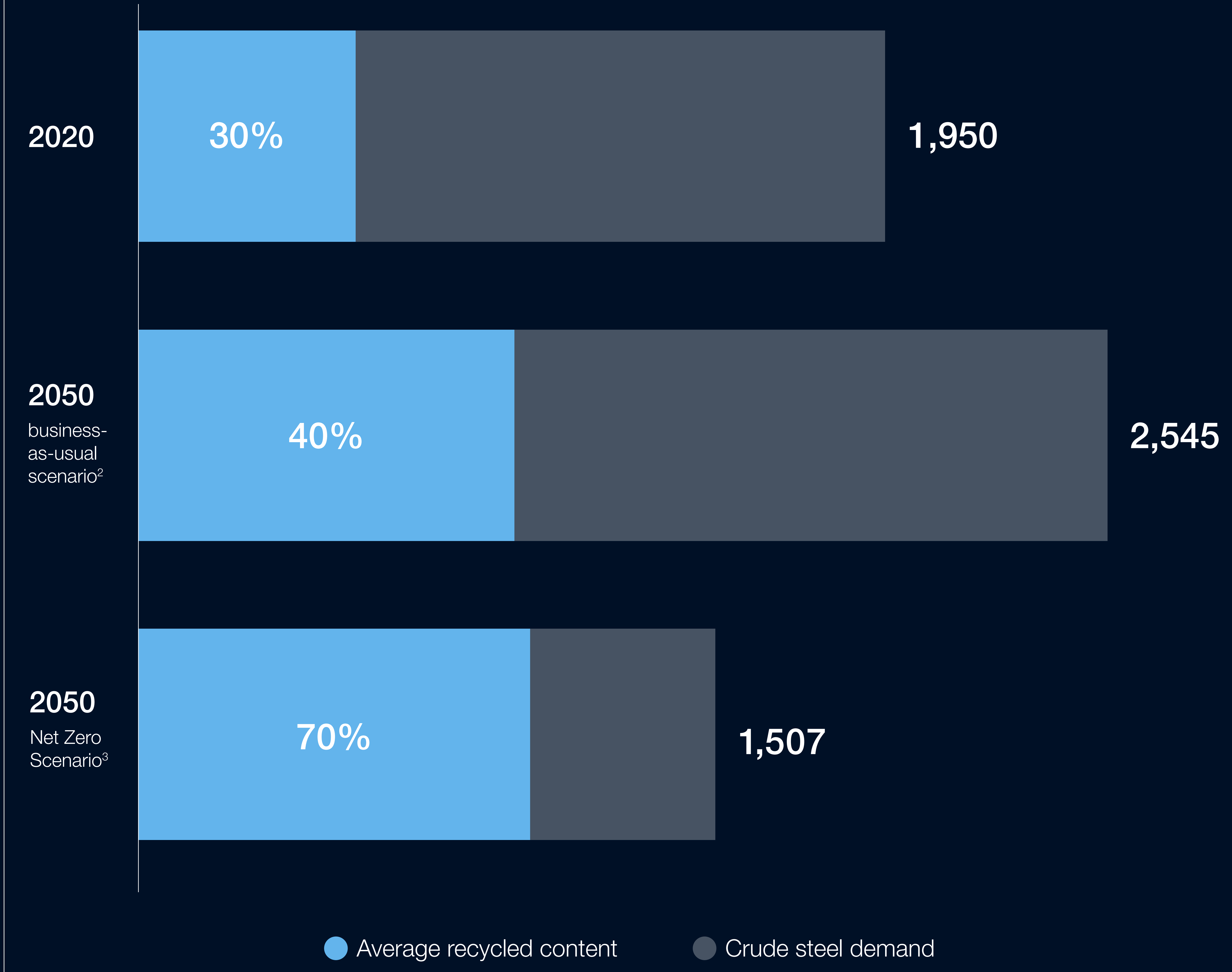
China is projected to see a major jump in steel recycling driven by the increased availability of scrap steel in the country.

Sources: MPP (ETC), Accenture analysis

Click here to see the full data:

Visual | Full data

Crude steel demand vs average recycled content (Mt)



Cement
Demand

Cement demand could rise by 45% by 2050, but the IEA Net Zero by 2050 Scenario calls for it to remain steady.

Key messages

Demand for cement is expected to increase by 45% by 2050 in the business-as-usual scenario due to rising population, urbanization patterns and infrastructure development needs, but aligning with the IEA Net Zero by 2050 pathway requires limiting demand to today's levels.

While China has the excess cement production capacity and is expected to cut back, India and other developing countries are set to increase domestic production.

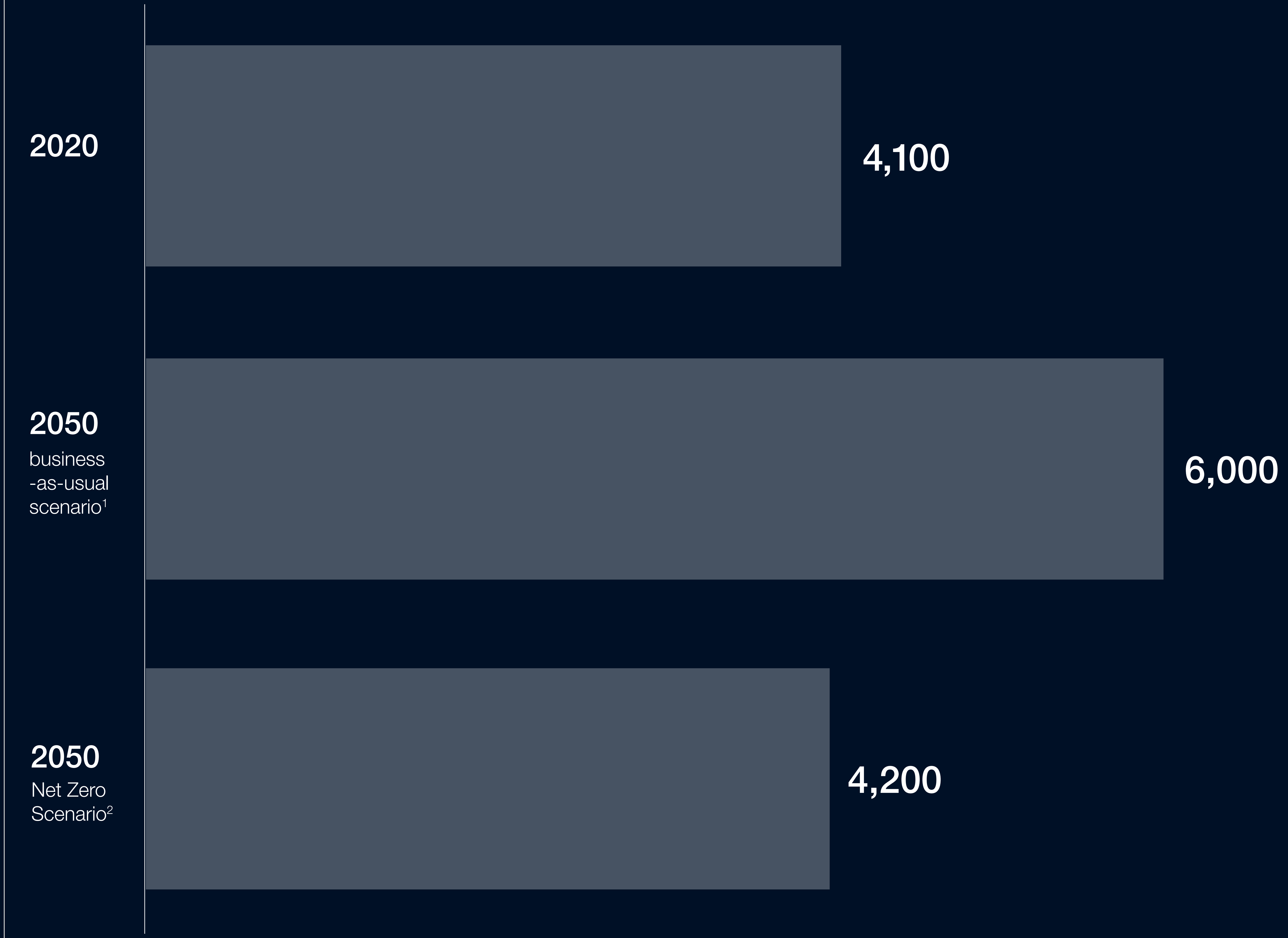
Optimizing concrete demand through efficiency in design and construction is a crucial lever in reducing the need for new concrete and cement.

Sources: US Geological Survey, IEA, GCCA

Click here to see the full data:

Visual Full data

Cement production (Mt)



Aluminium Demand

Aluminium demand could rise 80% by 2050, partly pulled by the needs of the energy transition itself – recycling will be crucial but insufficient to curb industry emissions.

Key messages

Demand for aluminium is expected to increase by 80% by 2050 in the IAI business-as-usual scenario but aligning with the IAI 1.5 Degree Scenario requires limiting the increase to 60%.

Producing secondary aluminium from scrap (recycling) will play a crucial role in reducing industry emissions. Recycled aluminium is more than ten times less emissive than primary aluminium today and could near carbon neutrality if powered with decarbonized electricity.

However, recycled aluminium is limited by scrap availability. Around 75% of aluminium is recycled at the end of its useful life cycle.

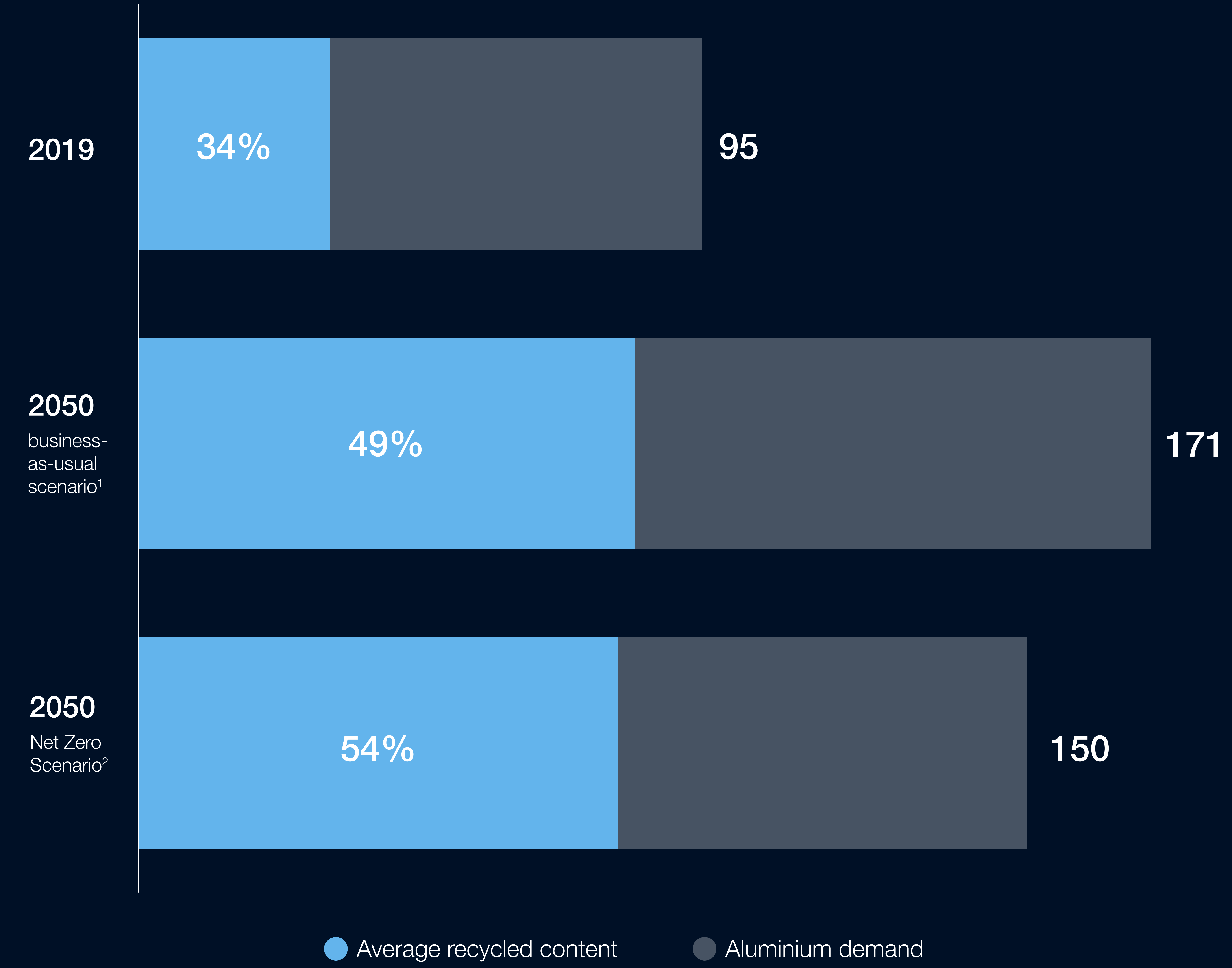
Average recycled content in total aluminium production is projected to rise from 34% today to nearly 50% by 2050.

Sources: IAI (demand predictions based on IAI Reference Scenarios), CRU

Click here to see the full data:

Visual | Full data

Aluminium demand vs average recycled content (Mt)



Ammonia Demand

Ammonia demand could rise by 37% by 2050. Aligning with the IEA Net Zero by 2050 Scenario requires limiting the increase to 23%.

Key messages

Increased demand for nitrogen fertilizers, driven by population growth and higher protein consumption, sees ammonia production grow 37% by 2050 in the business-as-usual scenario (IEA Stated Policies Scenario). Aligning with the IEA Net Zero by 2050 requires a limited increase of only 23%.

Currently, production is dominated by Asia-Pacific (47%), with China alone accounting for 30% of global production. In IEA Net Zero by 2050, Asia-Pacific share declines to 42%, with China reducing to 16%, India growing to 15%, and South-East Asia reaching 8% of total production.

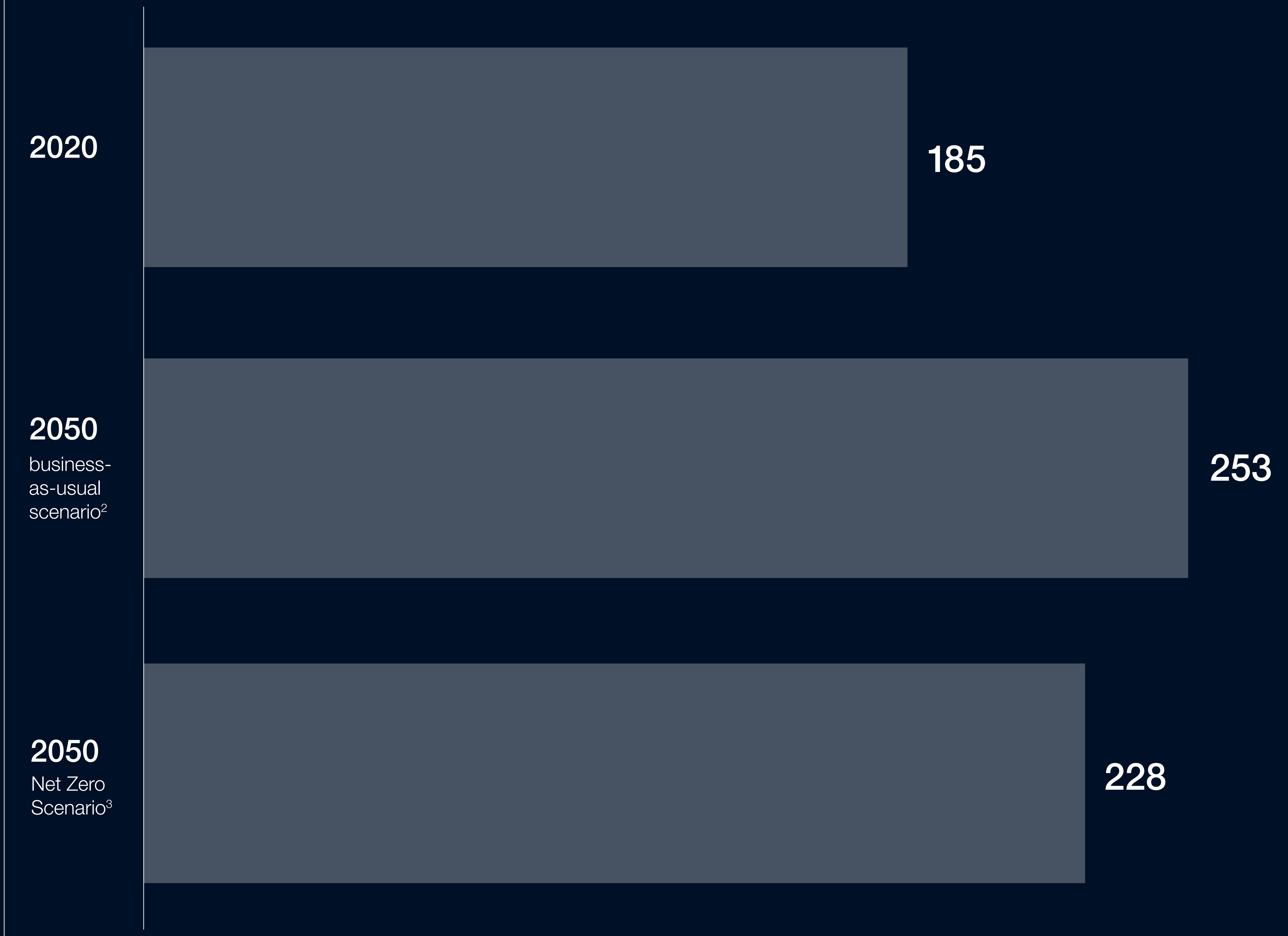
The ammonia market could evolve drastically with the use of blue or green ammonia as a hydrogen fuel carrier for multiple sectors such as shipping or the power sector (not included in this ammonia industry tracker).

Source: IEA

Click here to see the full data:

Visual | Full data

Ammonia production (Mt)



Oil
Demand

Oil demand could increase by 17% by 2050 pulled by Asia-Pacific, Africa and the Middle East, but demand must decrease sharply for the world to reach net zero.[1]

Key messages

Oil demand is projected to increase by 17% in 2050 in the IEA Stated Policies Scenario. While the demand in developed countries is expected to decrease, the overall net increase in demand originates from the rising needs of developing countries in Africa, the Middle East and Asia-Pacific.

The IEA Net Zero by 2050 pathway calls for a decrease in oil consumption by 73%, with the biggest drops required in the US (-82%), Europe (-90%) and China (-74%).

Share of OPEC in global oil production is expected to increase from 37% to 52% by 2050 (IEA Net Zero Scenario).

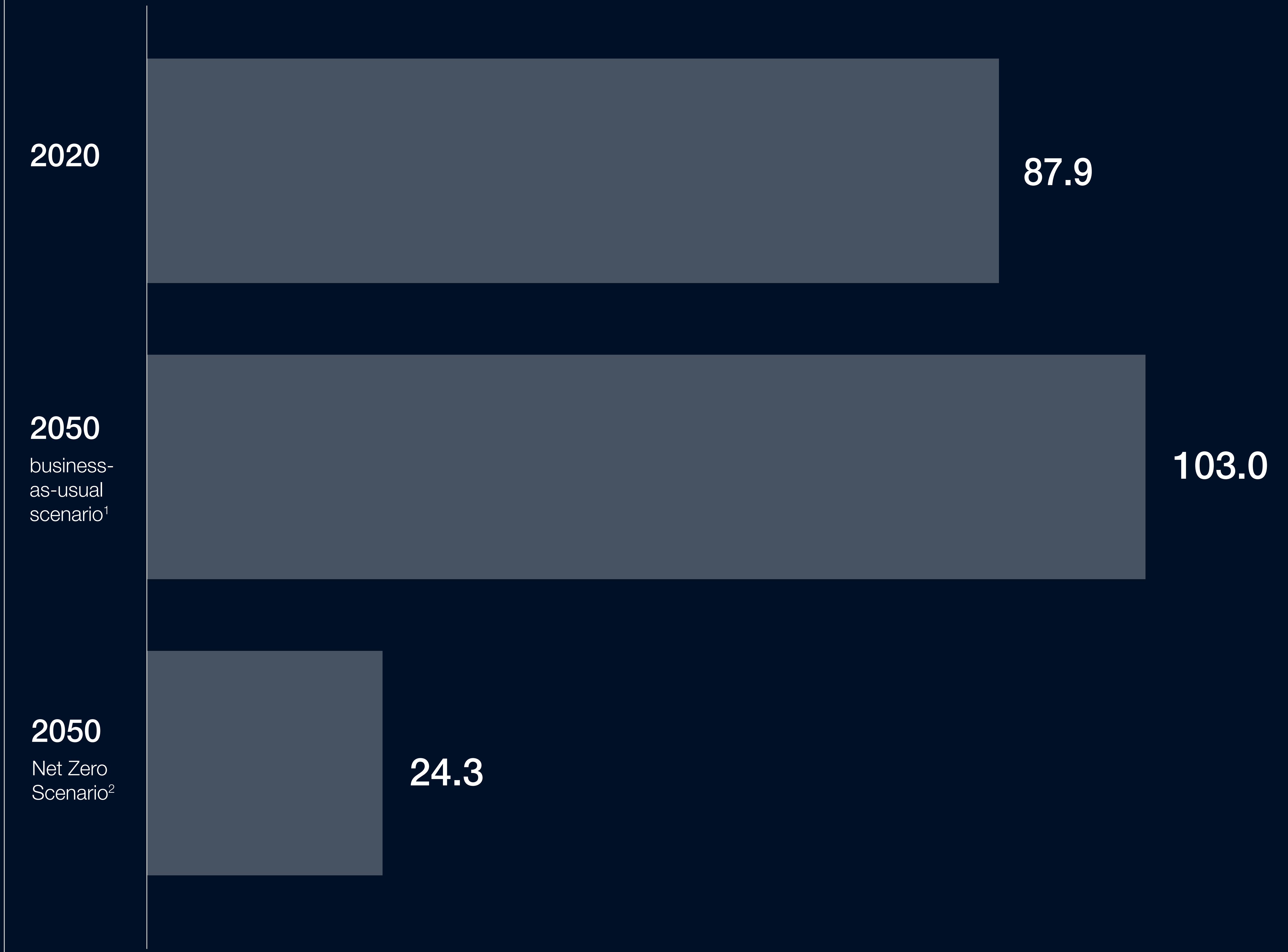
Production of substitutes like biofuels and sustainable synthetic fuels must also increase from current 0.1 thousand barrels of oil equivalent per day (mboe/d) to 6.2 mboe/d by 2050 to achieve net zero.

Source: IEA, BP

Click here to see the full data:

Visual | Full data

Crude oil demand (Mb/d)



Natural gas Demand

Natural gas demand could increase 29% by 2050 under the IEA Stated Policies Scenario but will require a steep decrease for the world to reach net zero.

Key messages

In the IEA Stated Policies Scenario, natural gas demand is projected to increase by 29% in 2050. While demand in Europe and North America is expected to remain stable, the increase in demand originates from the rising needs of emerging countries in Africa, the Middle East and Asia-Pacific.

However, aligning with the IEA Net Zero by 2050 Scenario requires a decrease in gas consumption by 55%, with the most significant drops required in North America (-55%), Europe (-96%) and Asia-Pacific (-71%).

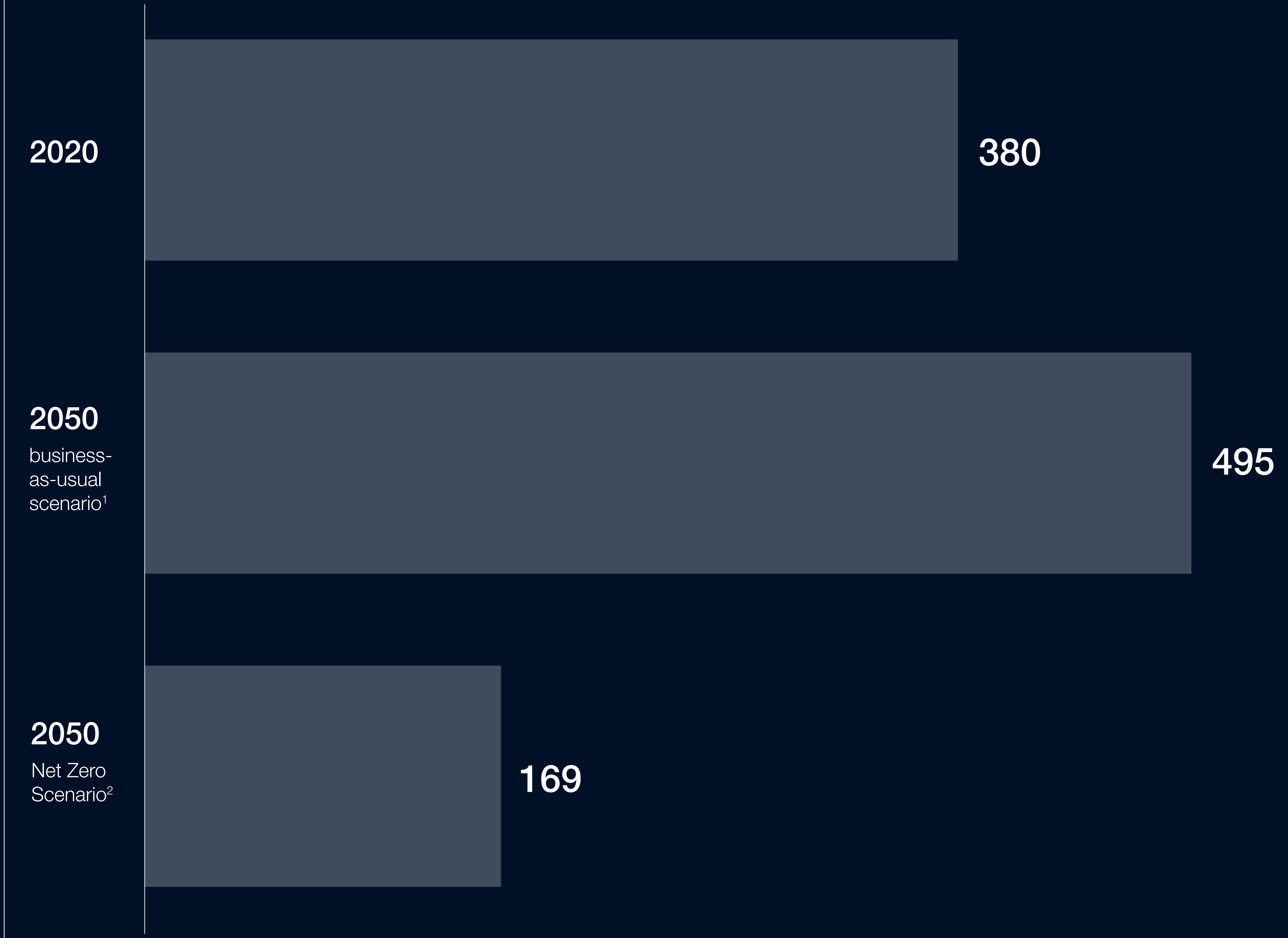
In the IEA Net Zero by 2050 Scenario, no new oil and natural gas fields are required beyond those approved for development. Production is relatively concentrated in a few major producing countries such as the US, Russia, Iran and Qatar, representing over 50% of global production.

Source: IEA

Click here to see the full data:

Visual | Full data

Natural gas demand (Bcf/d)



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Data sources

Aluminium Stewardship Initiative, Aluminium For Climate, BloombergNEF, CRU Group, Det Norske Veritas (DNV), Environmental Protection Agency, Energy Information Administration, European Aluminium, Global Cement and Concrete Association, Global CCS Institute worldsteel, Green Steel Tracker, HARBOR Aluminium, International Aluminium Institute, International Energy Agency, International Fertilizer Industry Association, International Renewable Energy Agency, Leibniz University of Hannover, Lightmetalage, London Metal Exchange, Mission Possible Partnership, OECD, Polish Academy of Sciences, Refinitiv, Statista, Sustainable Gas institute, S&P Global, Swedish Environmental Research Institute, University of Georgia, University of Wyoming, US Geological Survey, World Resources Institute, World Bank, Various company reports

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Tracker data sheet

Click here to access detailed sources for all data points in the report

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Endnotes

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Endnotes from Foreword and Executive summary only

Abbreviations and acronyms

AFC	Aluminium for Climate
ASI	Aluminium Stewardship Initiative
ASTM	American Society for Testing and Materials
ATR	Autothermal reforming
AUD	Australian dollar
BAT	Best available technology
BAU	Business-as-usual
BBL	Barrel of crude oil
Bcf/d	Billion cubic feet per day
BECCS	Bio energy with carbon capture and storage
BF-BOF	Blast furnace-basic oxygen furnace
Boe/d	Barrel oil equivalent per day
BP	British Petroleum
Bt	Billion tonne
CAD	Canadian dollar
CapEx	Capital expenditure
CCS	Carbon capture and storage
CCUS	Carbon capture, utilization and storage
CIS	Commonwealth of Independent States
CO_2	Carbon dioxide
CO_2e	Equivalent carbon dioxide
DNV	Det Norske Veritas
DRI-EAF	Direct reduced iron-electric arc furnace
EAF	Electric arc furnace
EBITDA	Earnings before income tax, depreciation and amortization
EIA	US Energy Information Administration
EPA	US Environmental Protection Agency
EScerts	Energy saving certificates
ESG	Environment, social and governance
ETS	Emissions trading scheme
EU	European Union
GCCA	Global cement and concrete association
GHG	Greenhouse gases
GJ	Gigajoule
Green H_2	Hydrogen produced from electrolysis using renewable electricity
Gt	Gigatonne or billion tonne
GW	Gigawatt
GWP100	Global warming potential over 100 years
H_2	Hydrogen
IAI	International Aluminium Institute
IEA	International Energy Agency
IFA	International Fertilizer Association
IRS	Internal Revenue Service (USA)
kg	Kilograms
LDAR	Leak detection and repair
LME	London Metal Exchange
LNG	Liquified natural gas
Mb/d	Million barrels per day
Mboe/d	Million barrels oil equivalent per day
MMBtu	Million British thermal unit
MMcf	Million cubic feet
Mn	Million
MPP	Mission Possible Partnership
MPP (ETC)	Mission Possible Partnership (Energy Transition Commission)
MRV	Measurement, reporting and verification
Mt	Million tonnes
MTPA	Million tonnes per annum
MVR	Mechanical vapour recompression
N_2O	Nitrous oxide
NH_3	Ammonia
PPE	Plant, property and equipment
R&D	Research and development
S&P	Standard & Poor's
S1, S2, S3	Scope 1, scope 2, scope 3 emissions
SDS	IEA sustainable development scenario
SMR	Steam methane reforming
STEPS	IEA Stated Policies Scenario
t	Metric tonne
tCO_2	Tonnes of carbon dioxide
tCO_2e	Equivalent tonne of carbon dioxide
Tn	Trillion
TRL	Technology readiness level
UN	United Nations
WACC	Weighted average cost of capital
WRI	World Resources Institute

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