2025 Whitepaper

outokumpu

THE EVOLUTION OF MATERIALS

Stainless Steel Insights 2025

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KATI TER HORST

President & CEO at Outokumpu

"Climate systems are edging past safe planetary boundaries, reshaping coastlines and supply chains alike. At the same time the share of people aged over sixty-five is on course to double in many developed economies, stretching hospitals, pensions and even the geometry of homes and transit hubs. Technology will morph and political winds will shift, yet one constant runs through every scenario: societies will still need vast expanses of resilient, low-impact infrastructure and energy.

Materials sit at the heart of that task. Behind every policy target or market forecast lies a physical choice – which alloy, polymer or composite will carry the load or store the energy? The decision rarely makes headlines, but it is exactly where grand ambitions succeed or stall. The UK National Audit Office estimates that design consumes only 0.3–0.5% of a project's whole-life budget yet influences up to 85% of it.[1]

And if geopolitics, capital flows and consumer taste feel unpredictable, other forces remain stubbornly certain. Ageing bridges must still be replaced, and coastal cities will demand corrosion-proof defenses and buildings. In addition, recent studies suggest average temperatures increases may accelerate the rate of corrosion propagation in infrastructure.[2] By 2100, the European Commission expects climate change induced corrosion repair costs to range from €76bn in current climate scenarios, up to €883bn in a severe scenario.[3]

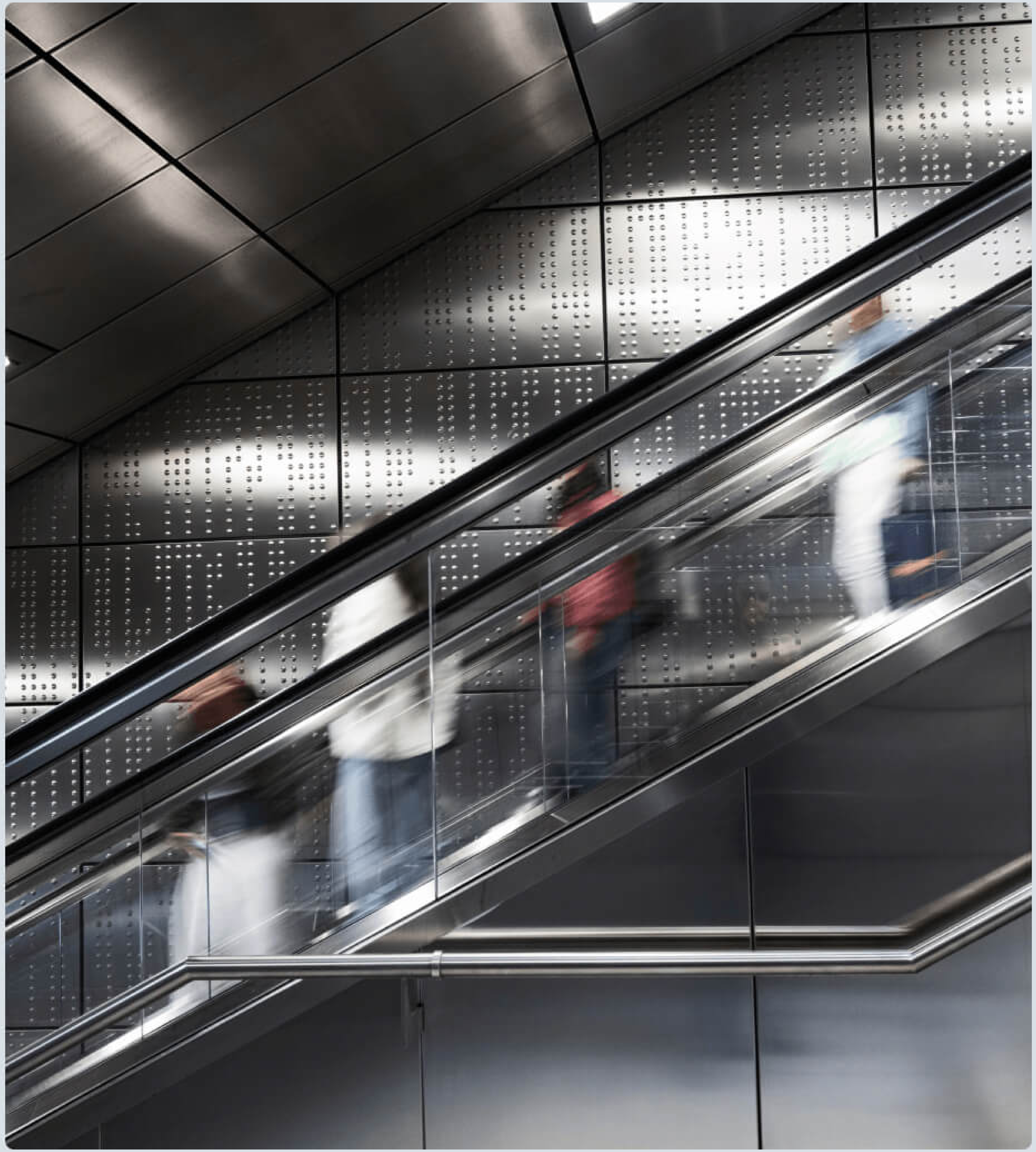
This means manufacturers will seek materials that can cycle through multiple lives without downgrading performance and risk over time. Those certainties invite a fresh look at metals that combine longevity, strength, and genuine circularity."

[1] Getting Value for Money from Construction Projects through Design, National Audit Office, 2013.
[2] Landi et al. 2025. Europe's reinforced concrete structures: Corrosion rates in a changing climate.
[3] Dimova et al, 2024. Impact of climate change on the corrosion of the European reinforced concrete building stock, Publications Office of the European Union

STAINLESS STEEL AND THE EVERLASTING ERA

Our earlier white paper, Five Shifts Shaping the Steel Industry[1] (Sept, 2024), framed this moment as the dawn of an **"Everlasting Era"**, an age that prizes artefacts designed to outlast fashions – and perhaps their first owners. Few substances fit that brief as neatly as stainless steel.

As we enter the Everlasting Era, the underlying economics and demography change the brief for design. The winning aesthetic is not novelty but endurance: objects and equipment that earn trust day after day, with surfaces that age gracefully. Stainless steel fits this shift because it makes durability legible: cleanable, corrosion-resistant, and endlessly recyclable.



[1] https://expertise.outokumpu.com/futureofsteel

Anyone who has ever parked a bicycle or left patio furniture outside for too long has witnessed how ruthlessly weather erodes unprotected metal. For most of steel's two-hundred-year story, engineers waged an endless war against rust.
In the 1910s however, the problem was finally solved on two parallel fronts. In 1912, Krupp engineers patented steel alloy with high levels of chromium and nickel – they called it Nirosta (abbreviated German for "never rusting"). Almost simultaneously, in Sheffield, England, Harry Brearley's 1913 breakthrough produced a "non-rusting" chromium-rich steel that the New York Times soon celebrated with the headline **"A Non-Rusting Steel. Sheffield Invention Especially Good for Table Cutlery"**. Each laid the foundation for steel grades still used today: Nirosta became the first **Austenitic** steel, particularly well-suited for extreme corrosion resistance and Brearly's stainless is today known as **Martensitic** steel – specifically adapted for tough environments that require high hardness.

A NON-RUSTING STEEL.

Sheffield Invention Especially Good for Table Cutlery.

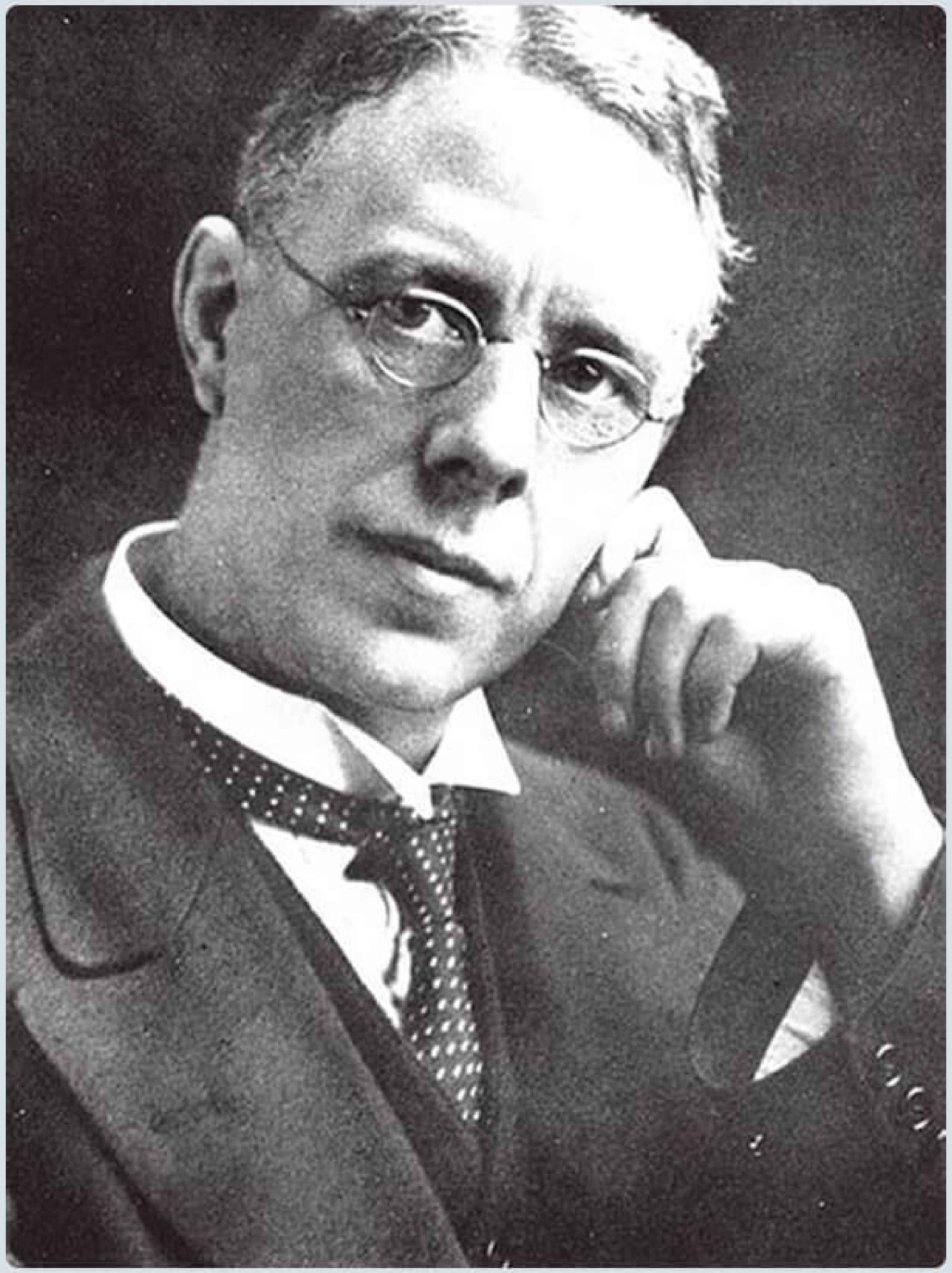
According to Consul John M. Savage, who is stationed at Sheffield, England, a firm in that city has introduced a stainless steel, which is claimed to be non-rusting, unstainable, and untarishable. This steel is said to be especially adaptable for table cutlery, as the original polish is maintained after use, even when brought in contact with the most acid foods, and it requires only ordinary washing to cleanse.

"It is claimed," writes Mr. Savage in the Commerce Reports, "that this steel retains a keen edge much like that of the best double-sheer steel, and, as the properties claimed are inherent in the steel and not due to any treatment, knives can readily be sharpened on a 'steel' or by using the ordinary cleaning machine or knifeboard. It is expected it will prove a great boon, especially to large users of cutlery, such as hotels, steamships, and restaurants.

"The price of this steel is about 26 cents a pound for ordinary sizes, which is about double the price of the usual steel for the same purpose. It also costs more to work up, so that the initial cost of articles made from this new discovery, it is estimated, will be about double the present cost; but it is considered that the saving of labor to the customer will more than cover the total cost of the cutlery in the first twelve month."

Figure 1: The original 1913 New York Times article that presented stainless steel to the world.

Figure 2: Portrait of Harry Brearley



DECARBONIZATION THROUGH DURABILITY

A century on, the same alloys have definitely progressed beyond cutlery. By adding elements like molybdenum which increases resistance to sea water, we have progressed to engineering stainless for extremely specialized and well-adapted situations. Innovation in stainless has been marked by the creation of new alloys, better surface engineering, hardening techniques and even powder metallurgy for additive manufacturing.

Today, stainless steel is at the core of the food (storage tanks, appliances), energy (offshore structures, renewables) and process (chemical, metallurgy, pulp and paper) industries and can even be found in rockets and satellites. Its value proposition remains surprisingly simple: a self-healing surface that shrugs off salt, acid and thermal shocks; high mechanical strength in a lightweight profile; hygienic, easy-clean finishes that need neither toxic paint nor constant maintenance.

Stainless steel is 100% recyclable without loss of quality. On average, some 60 percent of the metal in new production is recycled scrap,[1] and industry leaders such as Outokumpu already melt grades with up to 95 percent recycled material content, cutting the carbon footprint by as much as 75% versus the global industry average.[2]

Today, stainless steel is produced in multiple specialized grades all adapted to very precise applications. Duplex grades are – with their excellent combination of corrosion resistance and high strength – extending lifespans for coastal bridges and rail stations. They anchor offshore wind turbines where conventional carbon steel would corrode away its safety margin; stainless tie-rods and flow plates in green-hydrogen electrolyzers handle caustic chemistries while keeping embedded emissions low. In short, stainless meets the moment's twin imperatives: net-zero and longevity.

[1] https://bssa.org.uk/bssa_articles/environmental-aspects-of-stainless-steel/
[2] https://www.outokumpu.com/en/about-outokumpu/in-brief

STAINLESS STEEL BENEFITS IN A NUTSHELL

Stainless steel isn't just strong and shiny – it's a powerhouse of performance and sustainability. From its exceptional durability and corrosion resistance to its full recyclability, stainless steel offers a wide range of benefits that make it a smart, future-proof choice for industries looking to reduce environmental impact and boost long-term value.

PROPERTY	Exceptional corrosion resistance	High strength-to-weight ratio	Wide temperature tolerance	Cleanability and hygiene	Formability and weldability	Aesthetic durability	Magnetic and non-magnetic options	Fire and impact resistance	Fully recyclable
WHY IT MATTERS	The chromium-rich passive film self-repairs instantly when damaged, so rust and pitting are minimal even in harsh, wet or chloride-rich environments – if the appropriate stainless steel grade is selected.	Austenitic and duplex grades deliver mechanical strength comparable to or higher than carbon steel while allowing thinner sections, trimming weight without sacrificing safety.	Can be used for liquid hydrogen at −253 °C and maintains strength/oxidation resistance up to ~1150 °C (good for heat exchangers, turbines).	A smooth, non-porous surface sheds contaminants and withstands aggressive cleaning agents, ideal for food (leaves no taste), pharmaceutics, medical equipment and other surfaces that need to be fully sterile.	Most grades can be formed, machined, laser-cut, and welded without post-treatment, simplifying fabrication and repair.	Natural luster resists staining and fading; brushed, mirror, or colored finishes last decades with minimal upkeep.	Ferritic/martensitic grades provide magnetism where needed; austenitic grades remain non-magnetic – useful for sensors, MRI suites, etc.	High melting point (~1 400 °C) and energy absorption make it reliable in structural and safety-critical roles.	Scrap retains full value; typical stainless products contain ≥40% recycled content (on average, 60%), lowering life-cycle emissions. Even up to 95% recycled content can be found in some grades today.

KNOW YOUR ENEMY: THE COST OF CORROSION

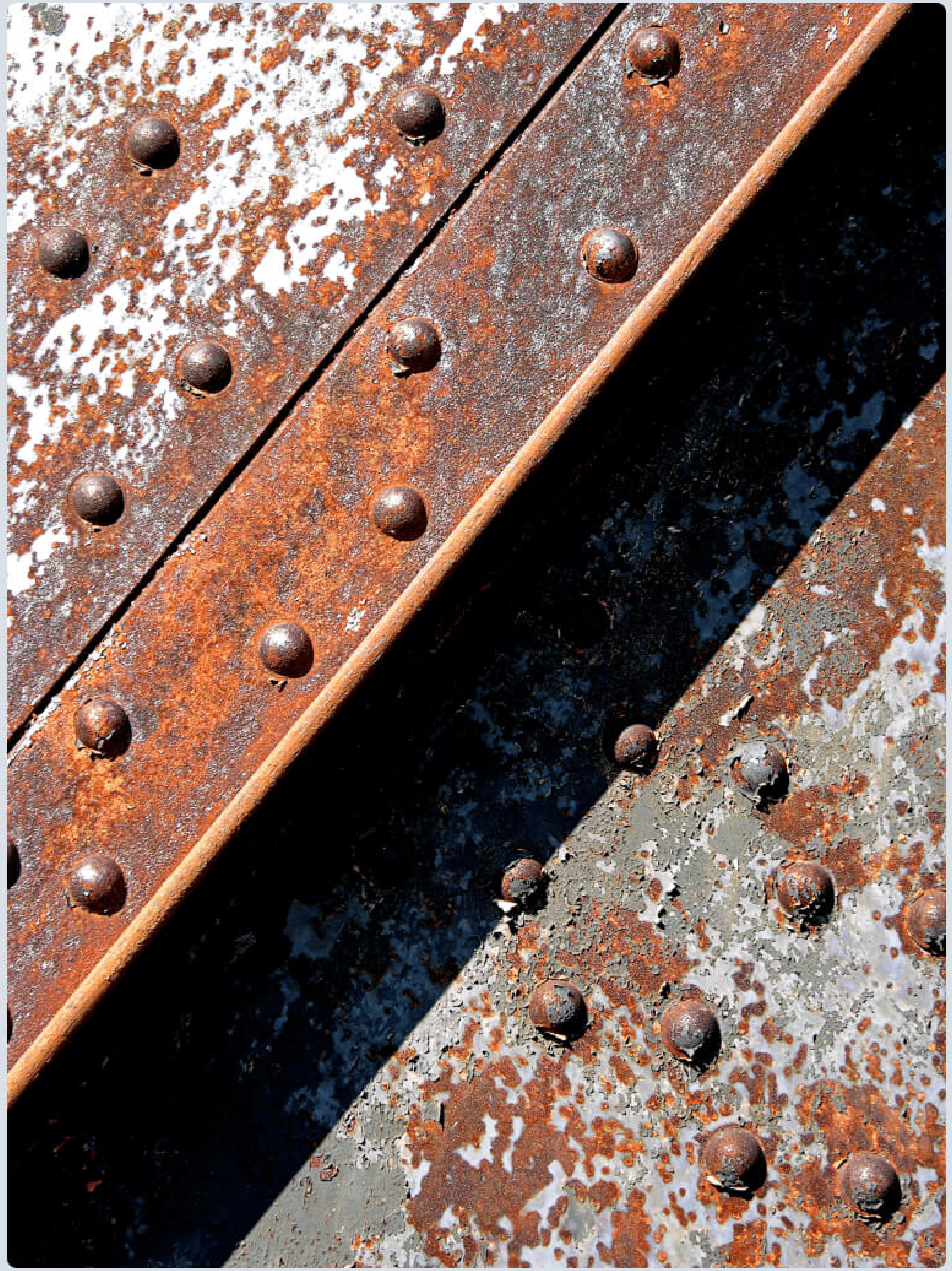
Corrosion is a natural process that degrades materials, typically metals, when they react with their environment.

Its economic toll is enormous. A landmark assessment from the National Association of Corrosion Engineers (NACE) in 2016 put the direct cost of corrosion at around US$2.5 trillion annually (about 3.4% of 2013 world GDP), with regional burdens ranging from ~1% of GDP in Japan to ~5% in Arab countries.[1] Beyond purely financial losses, depletion of essential resources (e.g. water), damage to infrastructure, and productivity impacts – for example, when bridge failures prevent people from reaching work and services.

There is also a climate cost, since replacing corroded steel could account for 4.1–9.1% of total CO_2 emissions by 2030 under climate targets[2]. The encouraging part is that applying established corrosion-control practices can reduce losses by around 25–30%,[3] which translates into global savings on the order of US$375–875 billion annually and underscores why material selection and design matter[4].

Switching to life cycle cost analyses helps factor in these costs during planning more systematically, and in this context, materials such as stainless steel are more competitive as their service is usually much longer[4].

[1] Kania, 2023, Corrosion and Anticorrosion of Alloys/Metals: The Important Global Issue. Coatings.
[2] Iannuzzi & Frankel, 2022, The carbon footprint of steel corrosion, Materials Degradation.
[3] Bender et al, 2022, Corrosion challenges towards a sustainable society, Materials and Corrosion.
[4] https://www.outokumpu.com/en/about-outokumpu/in-brief



"A major game changer for the industry would be to incentivize engineering, procurement, and construction (EPC) partners to prioritize total cost of ownership over initial manufacturing cost. If we can get this crucial benefit fully recognized in the procurement process, it represents a massive win for long-term value and sustainability."

CARMEN PINO
Senior VP of Commercial
Outokumpu

CORROSION'S KRYPTONITE

Stainless steel is unique because it forms a few nanometres-thin, protective layer on the surface, known as the passive layer. This thin, invisible layer of chromium, iron oxides and hydroxides acts as a barrier, protecting the metal from direct contact with corrosive elements (acids, salts, pollutants, etc) in the environment forms simultaneously when stainless steel has a high-enough chromium content (10.5%). Oxygen in air or water continually rebuilds this film if it is scratched. As long as this layer remains intact, the stainless steel effectively resists corrosion. Higher chromium content generally leads to better oxidation resistance, as well as the addition of some other alloying elements (Ni, Mo, N, Cu) which can enhance the resistance in different environments.

A wide range of stainless steel grades are developed to optimize the resistance in different settings. The protection might fail if the environment is too aggressive for the selected material, like when chlorides are found in concentrated amounts (seawater, de-icing salt), when oxygen is scarce (tight crevices, deposits, stagnant water), or when heat and pollutants destabilize the passive layer, leading to pitting, crevice attack, or stress-corrosion cracking rather than uniform rust. Today, we are able to circumvent and prevent this in most situations by matching the grade of stainless to the exposure – for example, using more highly alloyed steels with molybdenum and/or nitrogen for salty environments, or duplex or ferritic grades where chloride cracking is a risk. Material selection guidance is given in Corrosion Handbooks.

JORI MÄÄTTÄNEN

Sales Director Stalatube Oyj

"While our core markets remain strong, the future of stainless steel lies in shifting perspectives. We still encounter outdated myths about stainless steel being a complex material to weld or process, but that's simply no longer the case. The real game-changer is when we move the conversation beyond the material itself. By providing deep expertise in areas like corrosion and application, we help clients unlock long-term value. Looking ahead, sustainability will be more important in the coming years – and the moment when CO_2 is assigned a tangible cost, the superior lifecycle and durability of stainless steel will not just be an engineering choice, but a clear economic and environmental imperative."

STRATEGIC STAKES FOR 21ST CENTURY INFRASTRUCTURE

History's great transitions have always been written in stone, timber, concrete and steel. From the Pyramids to the Burj Khalifa or the Golden Gate bridge, infrastructure has been used as one defining reference point for historical periods. The net-zero transition will be no different – except that durability and circularity will decide the winners. Singapore's Garden by the Bay and Copenhagen's Copen-Hill may provide first glimpses of working with infrastructure for sustainable development. Today, Saudi Arabia's announced flagship infrastructure project Neom aims to build a sustainable city fully centered around public transport rather than car use. Whether it will manage to make its way into history's famous landmarks remains to be seen.

Stainless steel already meets the benchmarks for these types of undertakings. Its technical virtues map point-for-point onto the constraints now reshaping capital spending: tighter climate regulation, scarcer public funds and an expectation that assets should serve for half a century before re-entering a closed-loop scrap stream – preferably one of high value nonetheless.

The chapters that follow examine the industry through two lenses: **a peek at the industry today and forward and a glimpse into where the alloy is poised to surface next.**

The strategic question is no longer whether stainless can deliver, but whether regulators, designers and capital markets **will recognize a change-maker hiding in plain sight and deploy it at the scale this warmer and more interconnected century demands.**

Chapter 1.

THE STATE OF STAINLESS STEEL TODAY

FOUR KEY INSIGHTS

Stainless steel sits at an unusual crossroads. On one hand, it remains a mature, widely-traded alloy family with well-established supply chains. On the other, tightening climate policy, disruptive geopolitics and fast-moving end-markets are forcing producers and buyers alike to revisit long-held assumptions about where, how and why they use the metal.

From May 5 to 20, 2025, research consultancy Kairos Future, on behalf of Outokumpu, conducted a global online survey of senior decision-makers from 70 companies, totaling the annual revenue of ~428.85 billion USD (2024) – including some of the world's largest stainless steel consumers. The questionnaire included single-choice, open-ended, and Likert-scale items. Quantitative and qualitative data were collected and analyzed by Kairos Future, yielding 49 completed responses (70% response rate). To complement the survey, in-depth interviews were conducted with selected companies and Outokumpu experts.

Respondents represent a broad swath of the economy: energy, automotive, consumer goods, construction and infrastructure, transport equipment, food & beverage, pharmaceuticals, chemical/petrochemical processing and specialized distribution. Geographically, respondents break down into Europe (41%), United States (24%) and those operating globally (35%) – a mix that provides a reasonably balanced view of regional priorities and pain-points.

FOUR MAIN INSIGHTS EMERGE FROM THE STUDY

1. **MOMENTUM BUILDS ACROSS MARKETS**

2. **GEOPOLITICS IS REDEFINING SOURCING PLAYBOOKS**

3. **COST STAYS FRONT-OF-MIND, BUT LIFE-CYCLE METRICS ARE SPREADING**

4. **SUSTAINABILITY CLAIMS GAIN QUANTITATIVE WEIGHT**

First, demand momentum is positive: two-thirds expect to buy more stainless steel over the coming five years.

Second, geopolitics is already shaping procurement decisions; recent tariffs and trade frictions have prompted many firms to rethink sourcing strategies and diversify supply bases.

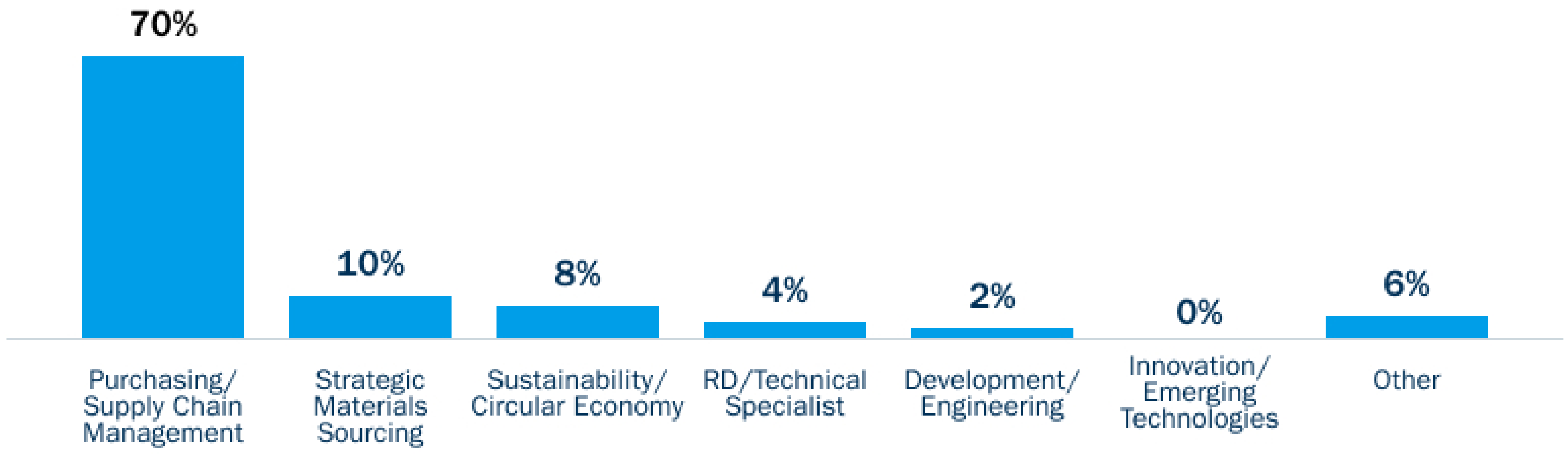
Third, cost remains the primary gatekeeper, but life-cycle-cost (LCC) methodologies are beginning to shift conversations away from price alone.

Finally, sustainability has moved from reputational add-on to quantitative metric; respondents found stainless to be a generally greener material than its common competitors; than competing materials and is increasingly valued for its ability to cut Scope 3 emissions (all indirect greenhouse gases from a company’s upstream and downstream value chain activities).

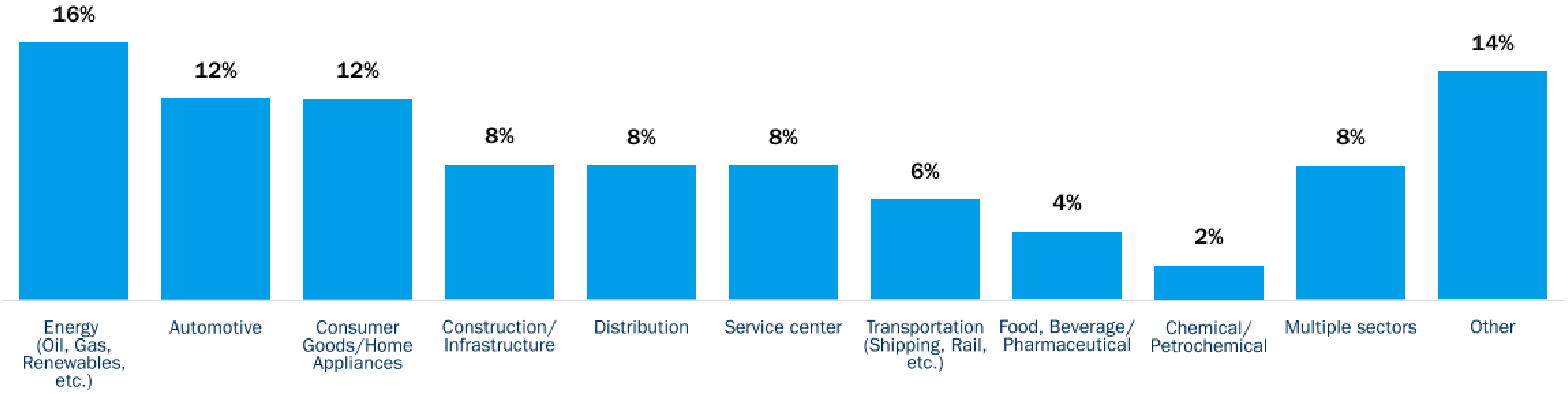
THE SECTIONS THAT FOLLOW EXAMINE EACH INSIGHT IN TURN

While the findings are necessarily a snapshot, they highlight the structural forces – demand growth, geopolitical realignment, life cycle cost perspective and environmental scrutiny – that will define stainless-steel markets through the rest of the decade.

Which of the following best describes your role in your organization?



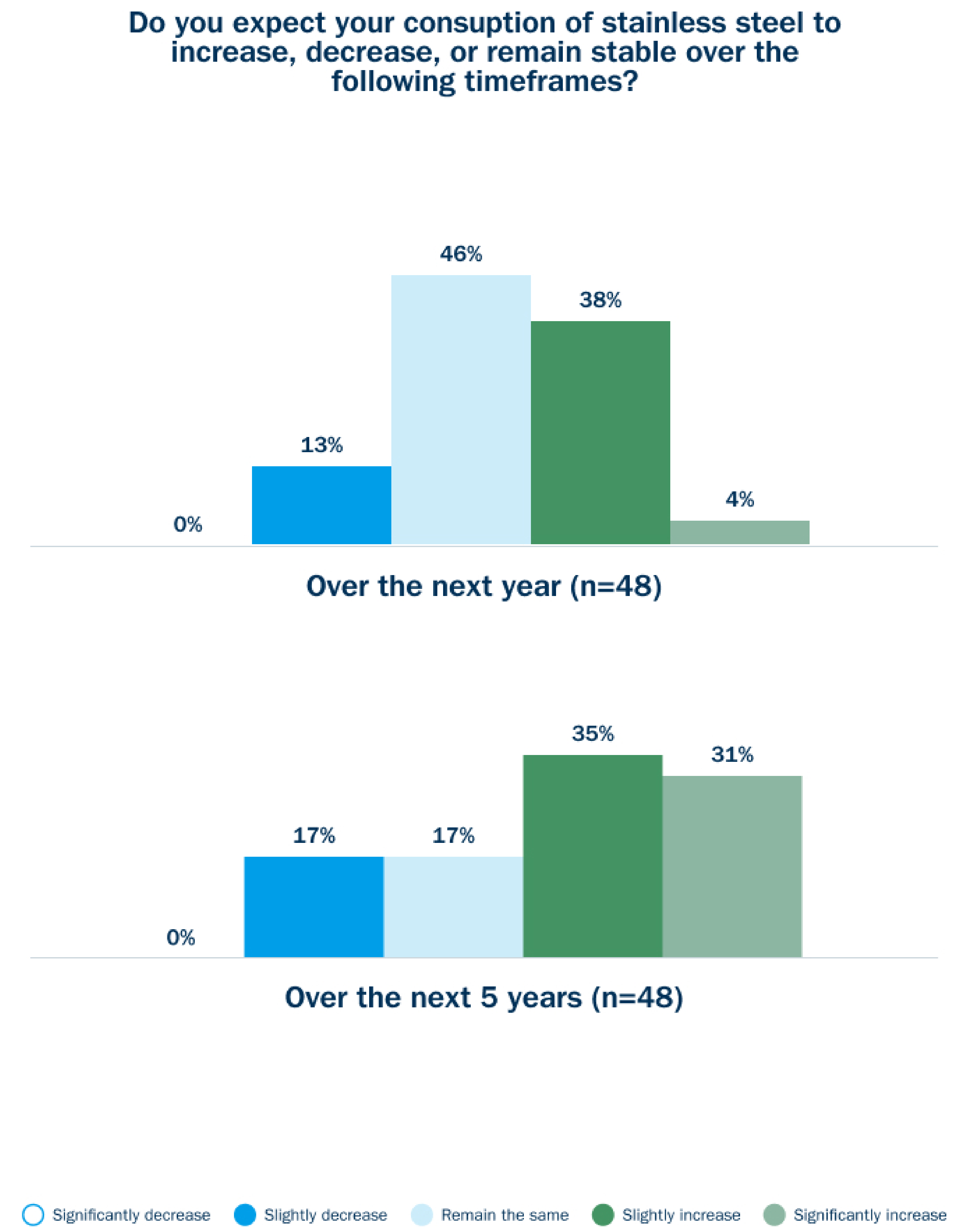
Which sector best describes your organization's main activities?



INSIGHT 1: MOMENTUM BUILDS ACROSS MARKETS

Survey data point to a broadly expansionary stance among large stainless consumers: respondents overwhelmingly expect their stainless steel consumption to increase. Two respondents in three anticipate higher stainless-steel intake over the next five years, and one in three predicts a “significant” rise. Even on a twelve-month horizon, just under half the sample expect volumes to tick up, while none foresee a material decline.

Several drivers may explain this optimism. Growth sectors such as infrastructure, defense and energy rely on stainless grades that combine corrosion resistance with mechanical strength. Regulations that reward longevity may also tilt specifications toward stainless in many cases. The momentum is stronger on the U.S. and Global markets, while European respondents indicate more cautious growth going forward.



"While the overall growth per annum for stainless steel in the US market is projected, according to analysts, at 2–3%, I see opportunities that are emerging in key sectors. Defense, aerospace, and the burgeoning hydrogen economy for instance – particularly along the Gulf Coast, where existing infrastructure can be repurposed. Furthermore, the massive energy requirements for new technologies like AI and data centers will fuel growth in the energy production sector. However, the steel industry's reliance on temporary tariffs masks a deeper challenge: our investments in sufficient capacity and capabilities as well as decarbonization span decades and are highly vulnerable to economic and geopolitical shocks. The industry requires a stable and predictable regulatory framework that prioritizes long-term vision over short-term survival."

TAMARA WEINERT
President for Business Area Americas
Outokumpu

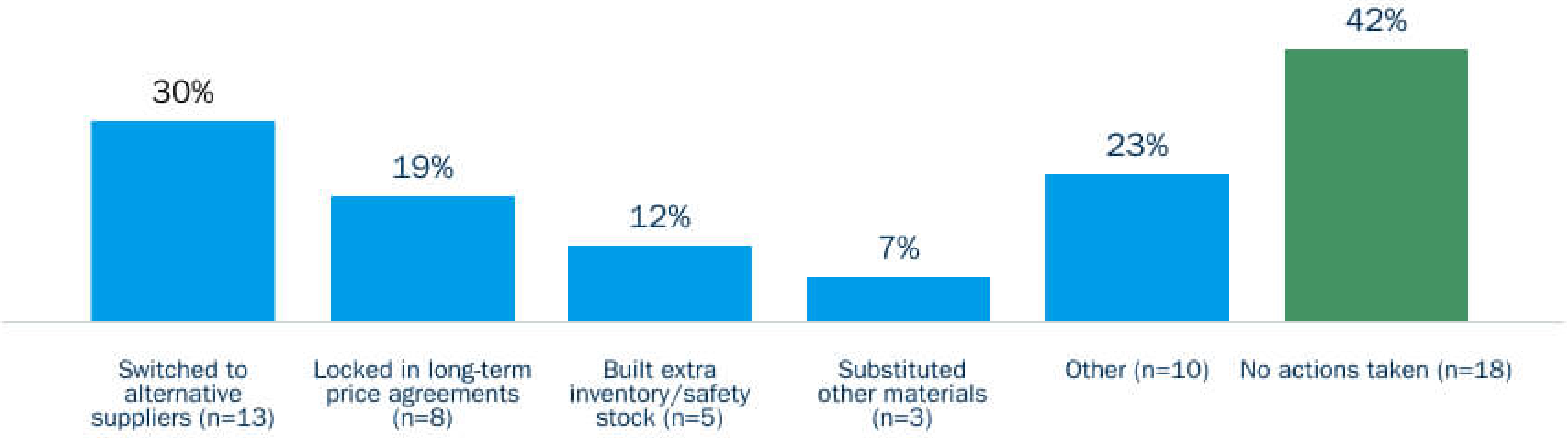
INSIGHT 2: GEOPOLITICS IS REDEFINING SOURCING PLAYBOOKS

At the time of the survey collection (May 5–20th, 2025), economic uncertainties related to trade and tariffs started to increase significantly. April saw the introduction of broad U.S. tariffs on nearly all its trading partners, ranging from 10% to 97% increases for some countries. Reponses were not uniform: while some countries chose to enter negotiations on their announced tariffs, others retaliated with their own. The results from this survey are therefore to be understood as occurring during a particularly turbulent period.

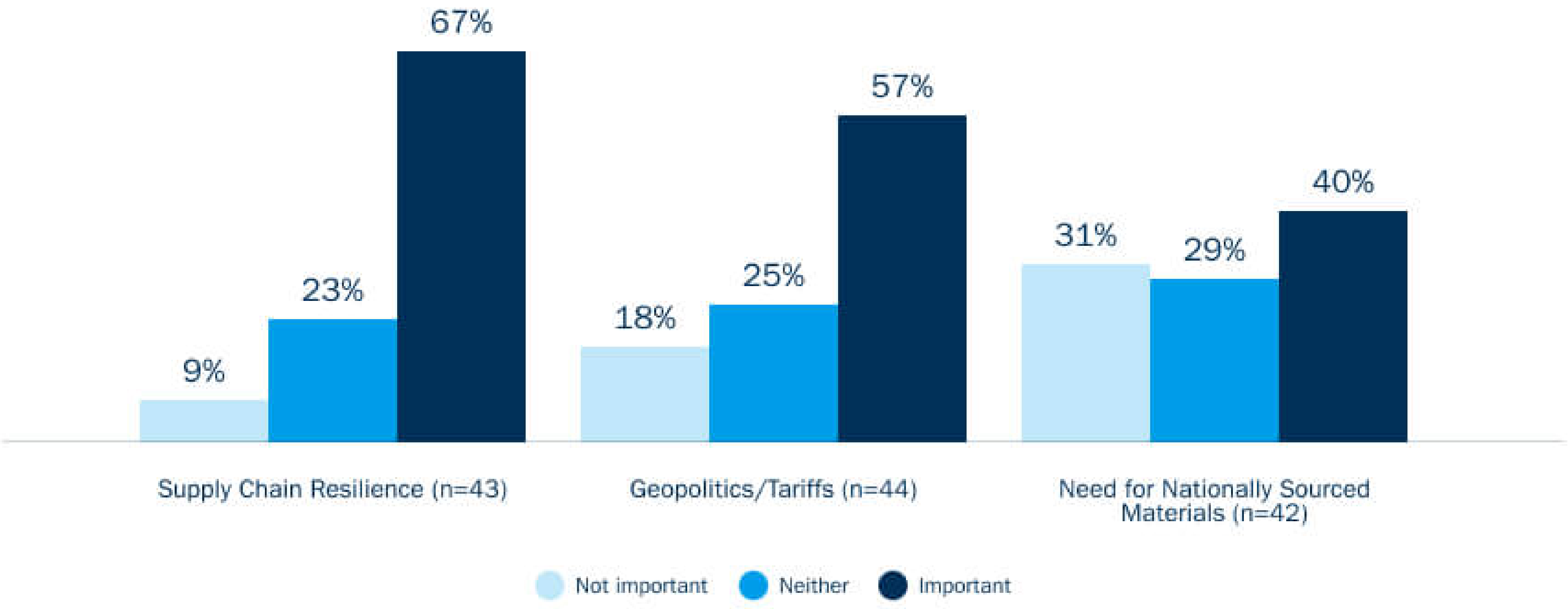
One in three organizations reported having already paused or delayed orders because of tariff rounds; and 30% responded by switching suppliers. Just over half were re-evaluating their entire sourcing strategy. The survey indicates that actors on the U.S. market have generally been faster to take action than the European, and while many U.S. companies responded by locking in prices long-term, more European respondents claim to have built extra inventory.

It is unclear if this geopolitical turbulence is expected to persist, but with nearly 70% reporting supply-chain resilience as an important driver of future stainless demand, and an even larger share of respondents on the North American and global markets, something is clearly changing. The working assumption seems to be that diversification costs less than shutdowns.

Which of the following actions has your organization taken in response to steel tariffs?



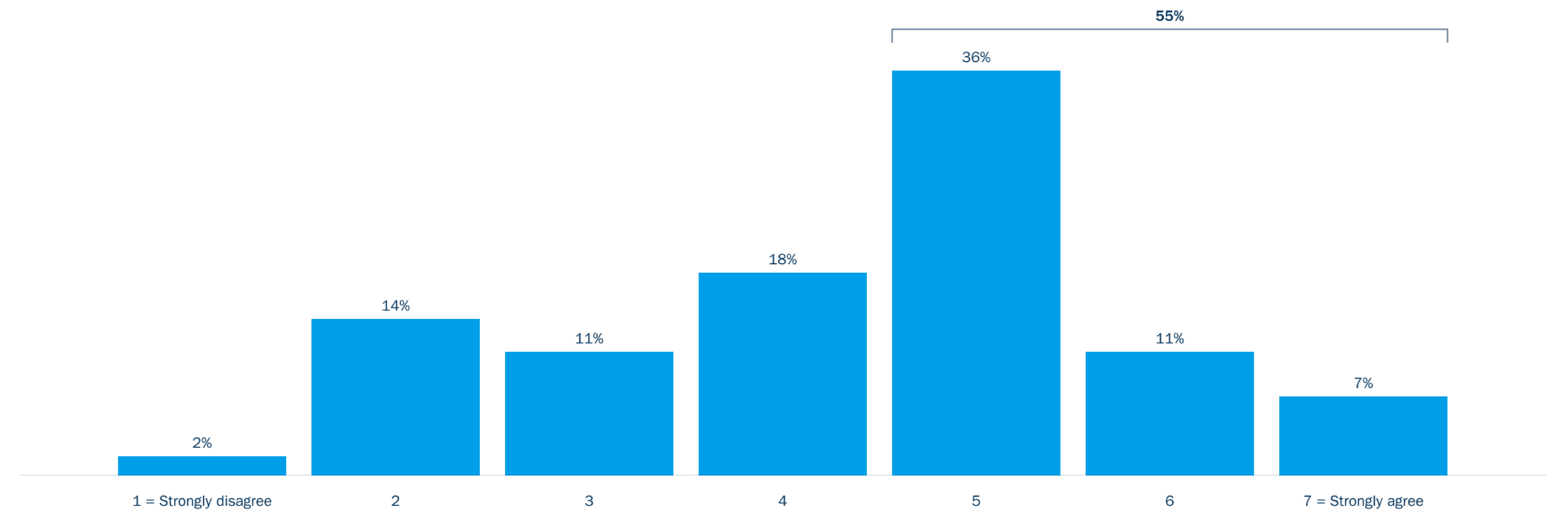
How important will each of the following factors be in driving your organization's demand for stainless steel over the next 5 years?



INSIGHT 3: COST STAYS FRONT-OF-MIND, BUT LIFE-CYCLE METRICS ARE SPREADING

One in four respondents name life-cycle cost (LCC) as the principal reason to choose stainless, and 40% say they now run LCC analyses, albeit with varying levels of rigor. Nearly 60% believe stainless offers better overall value than substitutes and well over half say high scrap value of stainless contributes to offsetting higher upfront cost, the latter being a widespread conception among European respondents. Price is still a key factor in material selection, but the increase in methodologies that factor in longer-term thinking is growing, especially in Europe.

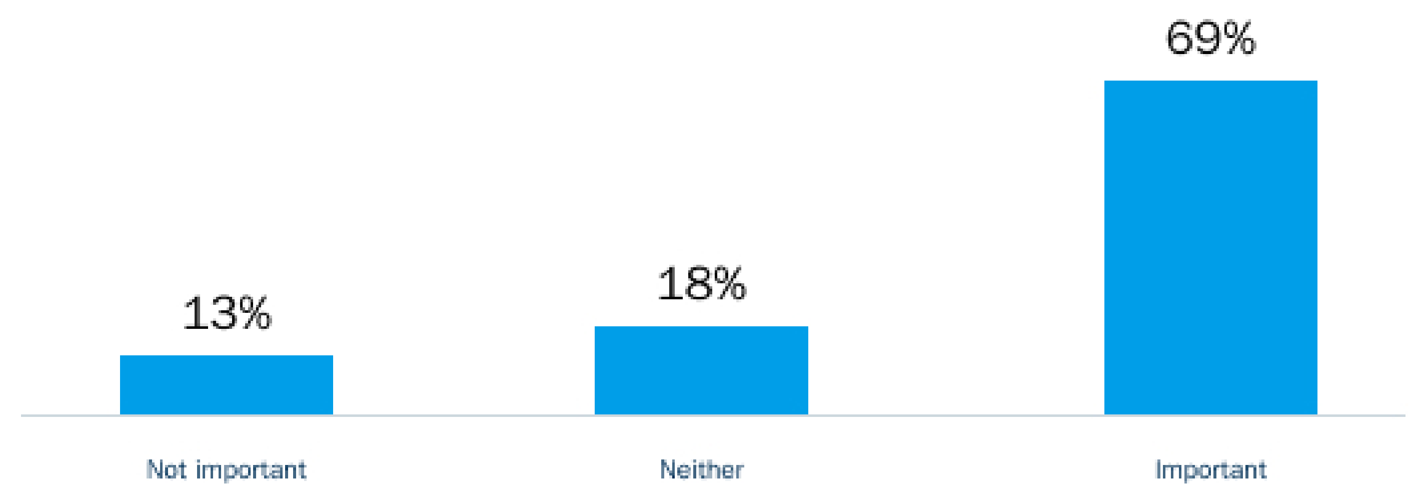
The ability to recover significant scrap value at end-of-life offsets a higher upfront cost for stainless steel (n=44)



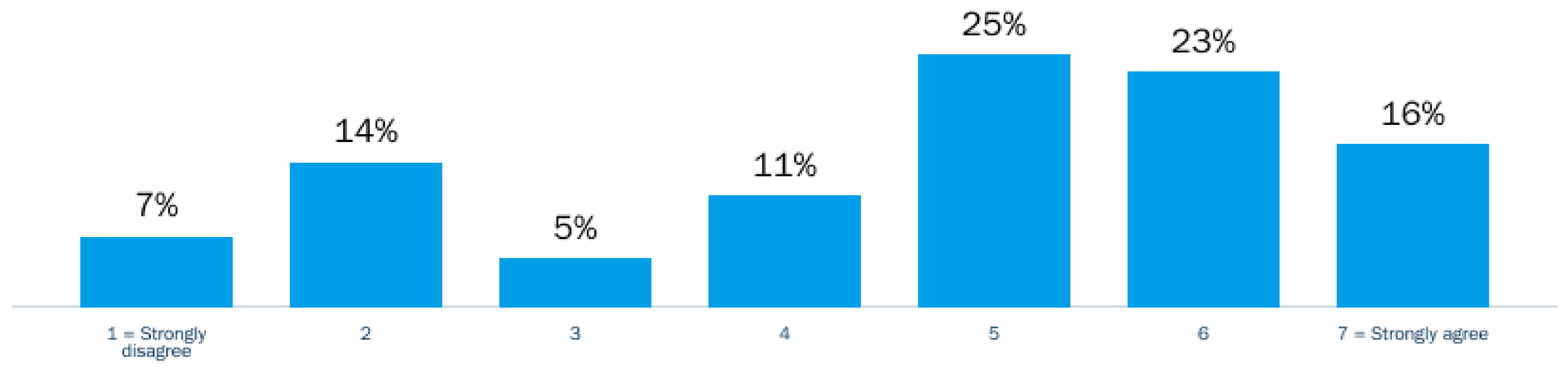
INSIGHT 4: SUSTAINABILITY CLAIMS GAIN QUANTITATIVE WEIGHT

Seven in ten respondents deem stainless more sustainable than alternatives; a similar share link the alloy directly to Scope 3 emission reduction goals. Two thirds expect green stainless – scrap-rich or produced with renewable energy – to be important to their organizations within five years, with European respondents being especially keen on this idea. With the rise of net-zero oriented industries – of which many rely on stainless properties (e.g. offshore wind) – the Scope 3 benefits are even clearer, as these industries can't claim offering net-zero technologies and benefits to their clients without themselves moving towards net zero in their own scopes.

How important is stainless steel's durability and recyclability (e.g. longer lifespan, fewer replacements, etc.) in reducing your overall Scope 3 emissions?



Green or low-carbon stainless steel will be important to our organization in the next 5 years (n=44)



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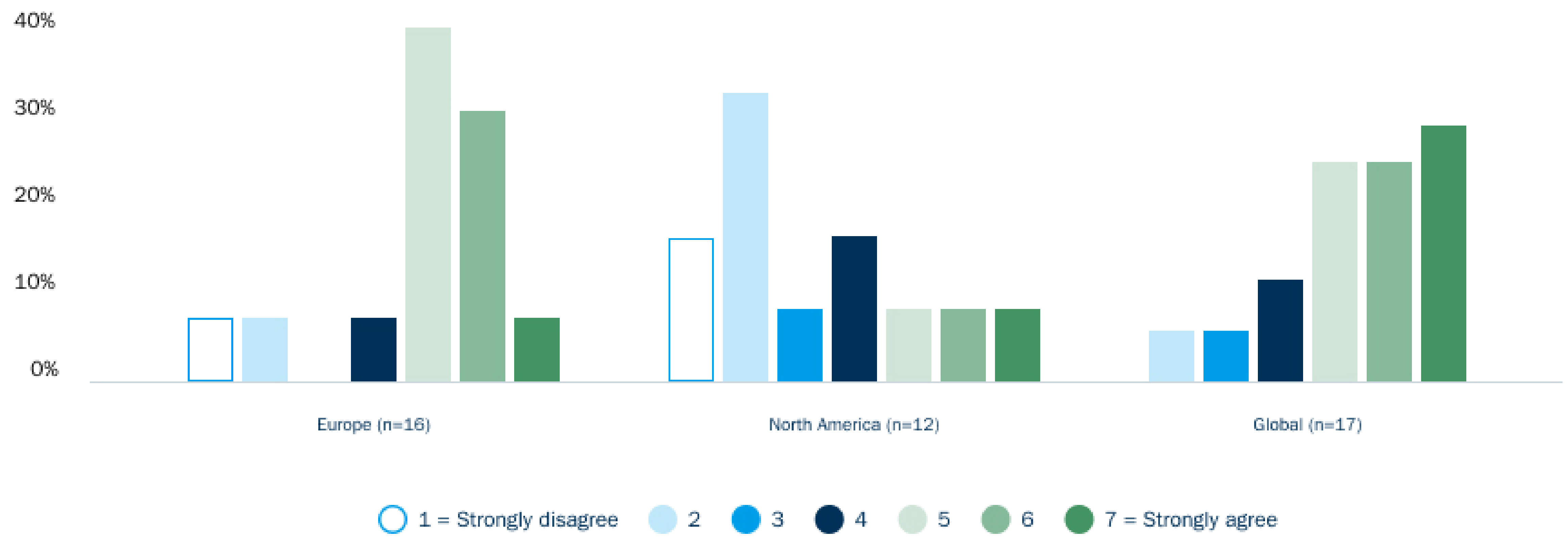
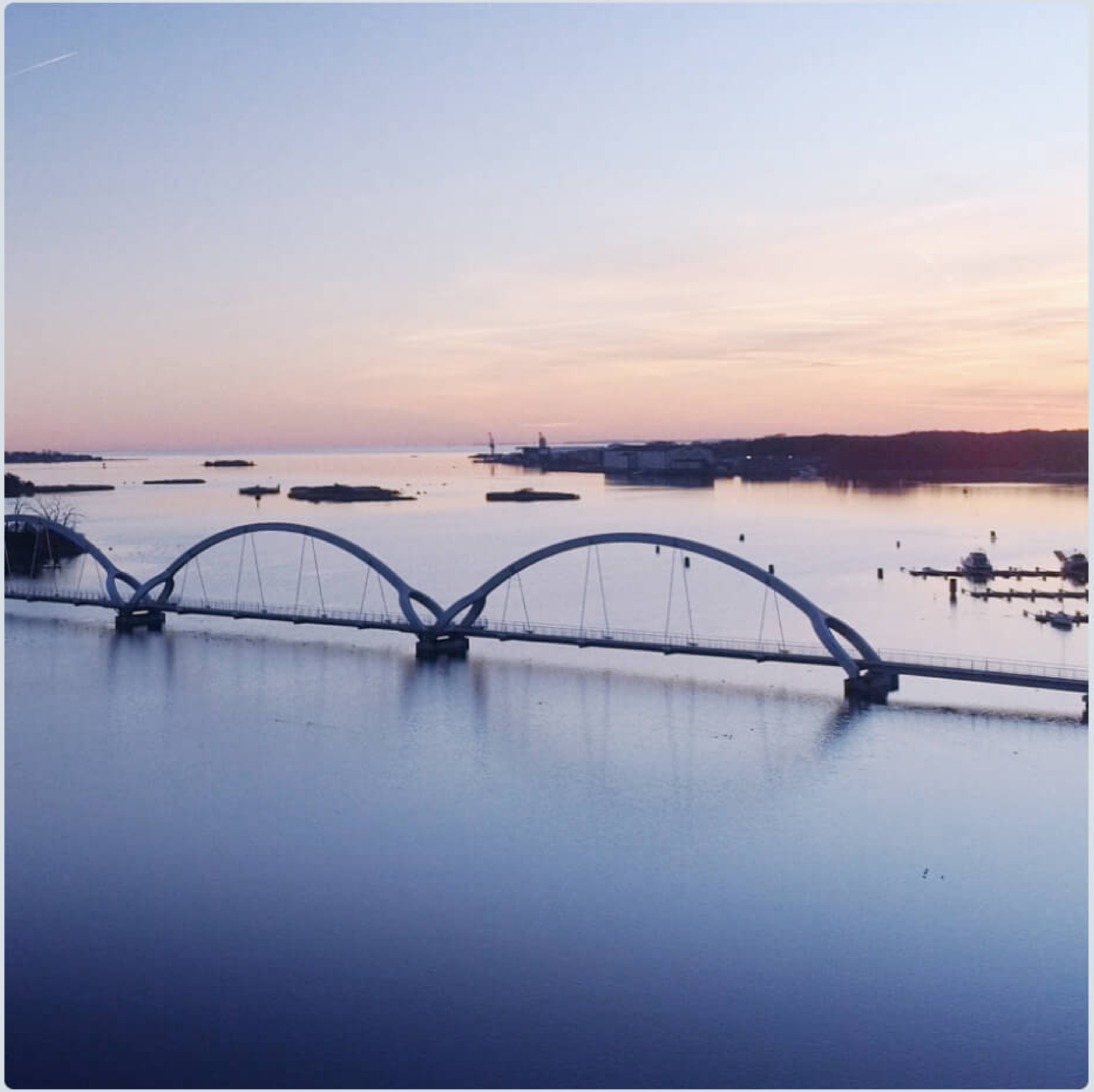


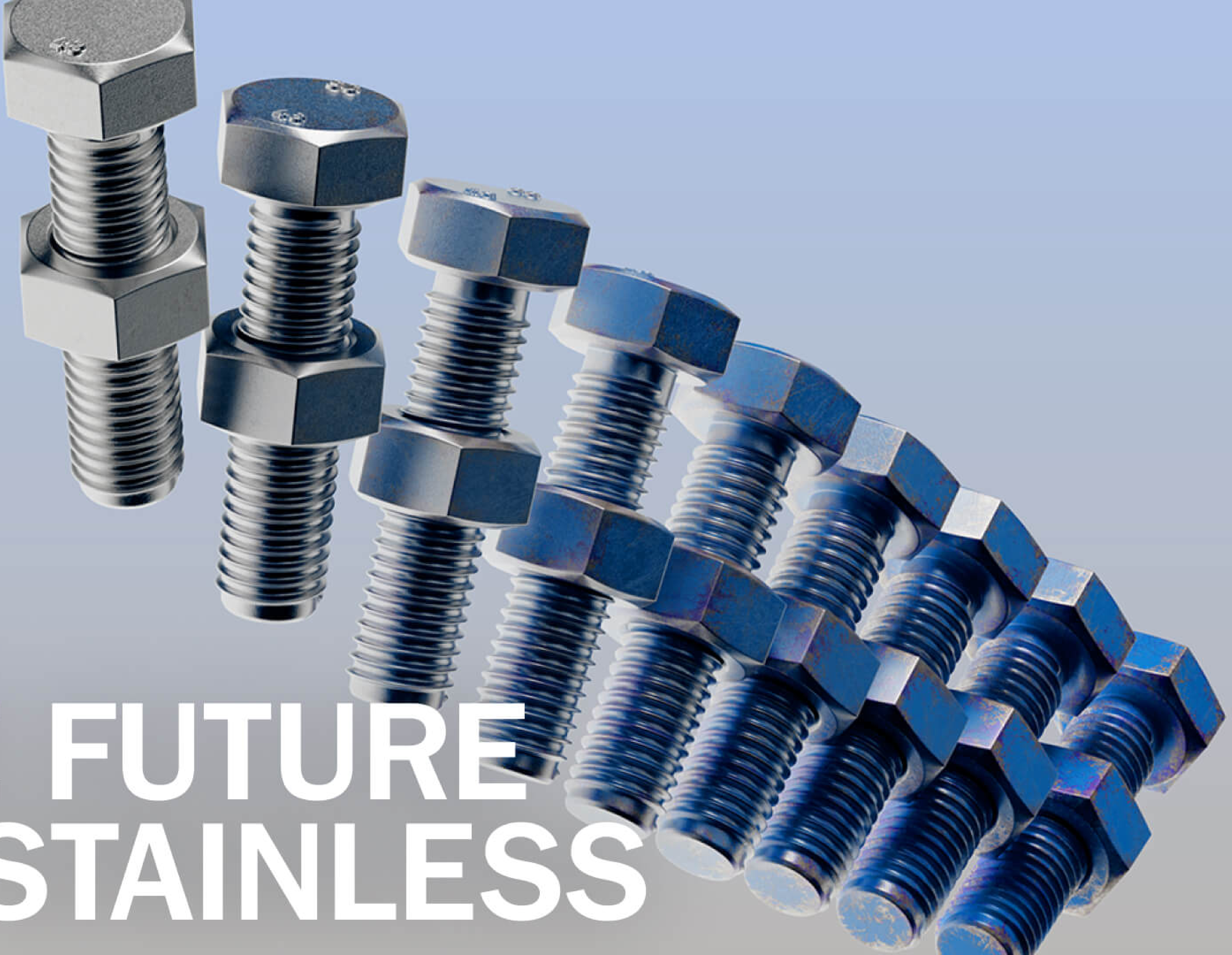


WHAT DOES THIS MEAN?

Large stainless users are leaning into growth while rewriting sourcing for resilience. In our survey of 49 senior decision-makers across Europe, the U.S. and global operators, two-thirds plan to buy more stainless over the next five years. Geopolitics and supply-chain risks are pushing many to diversify suppliers and hold selective inventory.

Cost still has the final say, but the conversation is shifting from price-per-tonne to total cost over service life, especially in Europe. Sustainability is now measurable: product-level CO_2 data, recycled content and renewable power use are quantifiable purchase criteria, with verified “green stainless” expected to matter for most organizations within five years.

Taken together, the market is growing, regionalizing and professionalizing. Stainless wins where durability, reliability and low embedded carbon intersect.



Chapter 2.

THE FUTURE OF STAINLESS

GROWTH SECTORS & NEW APPLICATIONS

Stainless steel is a niche by volume but heavyweight by impact. Global demand for stainless steel flat products reached 43.4 million tons in 2024, a 5.2% rise on the previous year (CRU Stainless Steel Flat Products Market Outlook August 2025). Measured against total crude-steel production of 1.88 billion tons, stainless represents just over 3% of global tonnage, yet its share of value is several times higher.

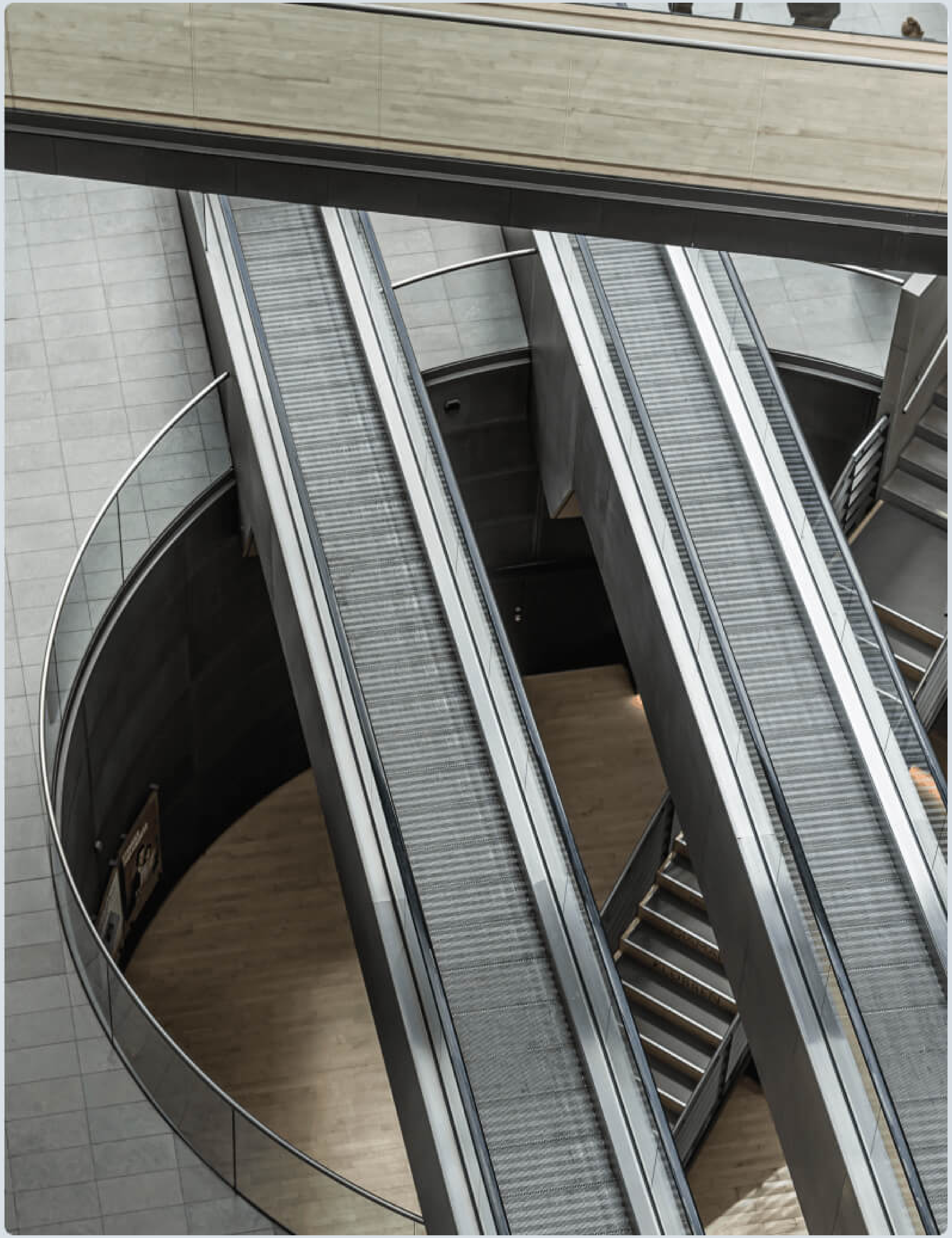
Over the past decade stainless output has grown roughly one percentage point faster than carbon steel, propelled by sectors that prize its unique combination of corrosion resistance, mechanical strength, low-maintenance, hygiene, temperature stability and near-infinite recyclability. A significant part of this growth has come from Asian markets. As mentioned previously, ≥40% (on average, 60%) of stainless globally is already scrap, and the industry-leaders are able to utilize even up to 95% of recycled content. The alloy retains its properties each time it is melted, making it a cornerstone of circular-economy thinking.

The survey data indicate that stainless steel's closest rivals are other metals – carbon steel and aluminum – each cited by a similar proportion of respondents. Further down the list are plastics, pointing to substitution in cases where light weight, shaping flexibility, or a lower upfront price are priorities. Copper, titanium, and composites appear less frequently but still hold ground in specialized applications. The relatively strong showing for coated steels highlights that corrosion resistance can be engineered through alternative material solutions.

THE PARADIGM IN THE EU

The European stainless steel industry, however, stands at a critical crossroads, where its commitment to sustainability is being undermined by conflicting trade policies and regulatory inconsistencies. EU needs economic resilience to guarantee Europe's energy, climate, and environmental transition, and the correct trade defense measures will protect Europe's competitiveness.

The Carbon Border Adjustment Mechanism (CBAM), taking effect in 2026, is a cornerstone of the European Union's climate regulation and a key element of the Clean Industrial Deal. CBAM aims to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries. CBAM is also closely linked to the EU's Steel and Metals Action Plan, which aims to decarbonize hard-to-abate sectors while maintaining industrial competitiveness. A timely and thorough Implementation of CBAM is critical as the current carbon leakage measures (free allowances) will be phased out in the period when CBAM will be phased in.



A LOOK AT THE COMPETITIVE FIELD

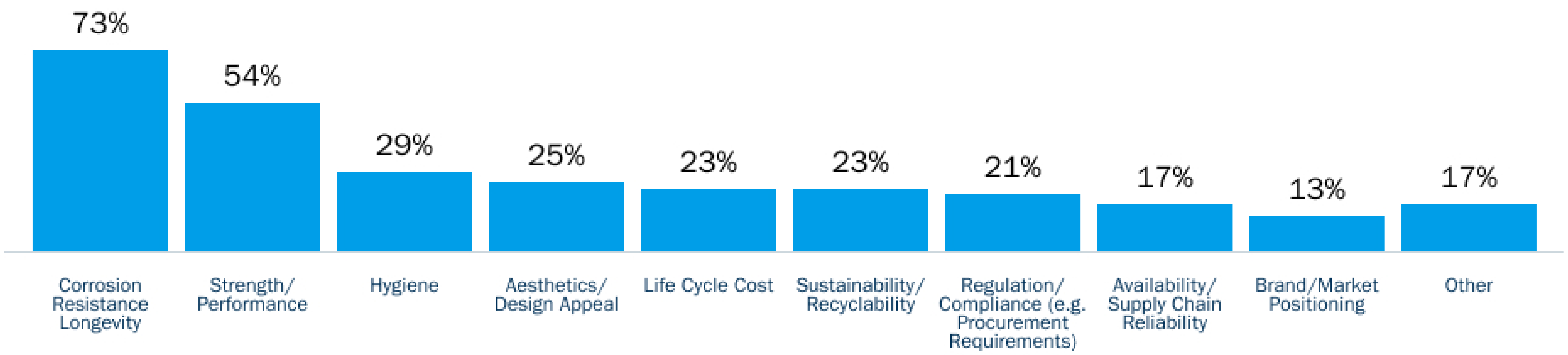
CARBON AND LOW-ALLOY STEELS	ALUMINUM	COPPER AND NICKEL ALLOYS	CERAMICS	PLASTICS AND COMPOSITES	TIMBER AND OTHER BIO-BASED MATERIALS	CONCRETE
Dominate construction, electric and mechanical equipment as well as automotive, being cheap and weldable. Their weakness is durability: paint, galvanizing or other forms of protection and coatings are required to fend off corrosion, driving up maintenance costs over a structure's lifetime. Some paints can also leak toxins and microplastics over time.	Offers superior lightness and good corrosion performance in many environments. However, it is softer, more expensive per unit strength and energy-intensive to smelt. In food-grade or high-temperature service, it often yields to stainless.	Excel in extreme chemical or thermal environments but carry a price-premium multiples above stainless and are generally harder to weld.	Provide exceptional hardness, wear and corrosion resistance, and retain properties at very high temperatures. However, they are brittle and difficult to machine and join as well as sensitive to thermal shocks.	Deliver weight and design freedom but suffer from lower heat limits, (very) limited recyclability and, in some cases, permeability to gases or solvents.	Store carbon and enjoy favorable policy treatment, yet struggle with long-term moisture, fire resistance and structural predictability.	Dominates civil works thanks to low cost, ubiquity, fire resistance and strong compressive capacity. However, it is heavy, weak in tension (requiring steel reinforcement), prone to cracking and permeability durability issues (e.g. freeze–thaw).

"Today's society and competitiveness is very often about the next quarter, the next year, maximum the next five years, but and not the next 35 or even 60 years, which is ironic in a period where we must care about our future and the green transition. Though governments have a four to five-year horizon; those who sit on budgets have their constraints, and therefore they usually try to prefer the low-cost solution, which in many cases is carbon steel whereas stainless steel is the better choice considering the total costs over the lifecycle."

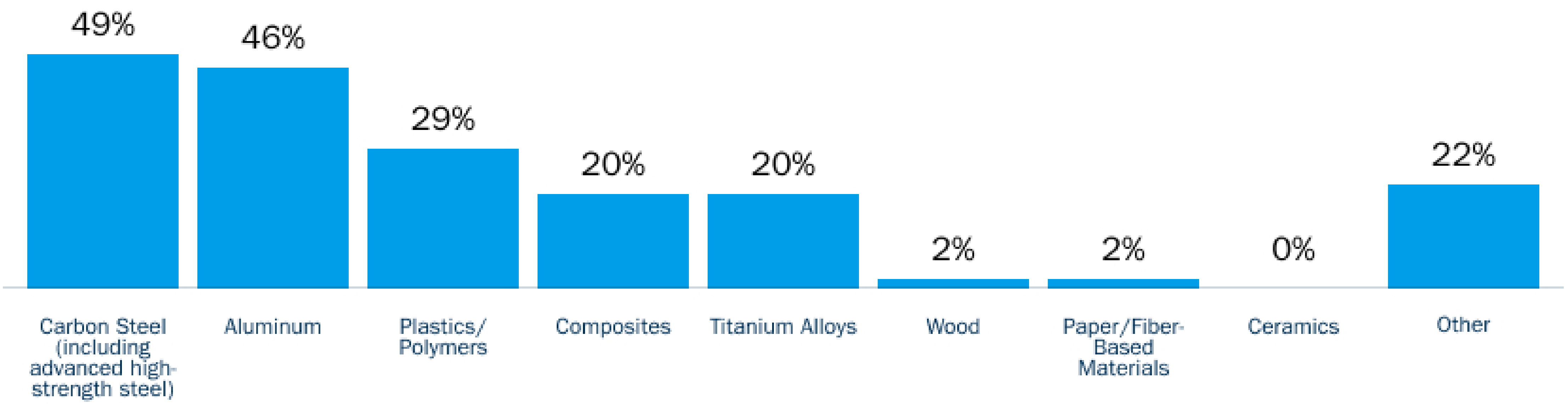
JÖRG MÜLLER
Senior Vice President, Business Line Europe
Outokumpu

Against its competition, the properties of stainless are central. Survey responses show corrosion resistance is the clear standout reason why stainless steel is specified, followed closely by strength and mechanical performance. Other drivers – such as hygiene, low maintenance, and recyclability – are important in certain sectors like food, beverage, and pharmaceuticals but are secondary for most buyers. Aesthetics and ease of fabrication rank lower overall, suggesting that stainless is chosen first for technical durability rather than appearance. The spread of responses points to a segmented market: while all value corrosion resistance, different industries weigh additional benefits differently, creating opportunities for more targeted messaging and grade positioning.

What are the main reasons stainless steel is used in your products or operations?



Which materials most closely compete with stainless steel in your products or processes?



Stainless steel is moving beyond its traditional industrial niches into roles where longer lifespans, easy cleaning, and harsh working conditions now matter more than the price. Car manufacturers are good examples: gas-vehicle exhausts still need stainless to survive heat and salt, but emerging safety concerns are also steering electric-vehicle to consider stainless steel battery boxes because the metal keeps its shape in case of a fire far longer than aluminum. Shippers and port operators are switching their chemical tank to stainless, finding that the higher upfront cost is offset by years without repainting or corrosion-related shutdowns.

The energy transition is another catalyst. Hydrogen plants and solar farms, but even traditional offshore oil lines face extreme pressure, temperature, and chemicals; the advanced stainless grades highlighted by experts handle all three while remaining fully recyclable – a point financiers increasingly factor in. Cities and architects are adopting stainless pedestrian bridges, floodgates, and façades for the same maintenance-free promise, while farmers, brewers, and medical suppliers value tanks and tools that never rust or shed coatings. Even defense programs and emerging space firms rely on stainless armor and rocket parts for toughness under fire and in re-entry heat.

Across these arenas, durability, safety, and sustainability rise on decision-makers' checklists make stainless steel's role central.

"To secure our future, we should change our perspective and thinking from forecasts to scenario planning. This requires us to look beyond the traditional use cases for stainless steel and leverage deep market intelligence to pioneer new opportunities. We see immense potential in the burgeoning energy sector, particularly in nuclear power plants, renewables and medium to long term hydrogen systems where stainless steel is a critical enabler. Significant growth will also be driven by the essential renewal of urban infrastructure, from aging pipelines to entire water supply systems. Additionally, we expect positive business development for precision tubes in electrical measurement and control technology through digitalization and automation."

ROLAND MERTENS
Chief Sales Officer
Schoeller Werk

1. ENERGY — ENGINEER FOR CORROSION & HEAT

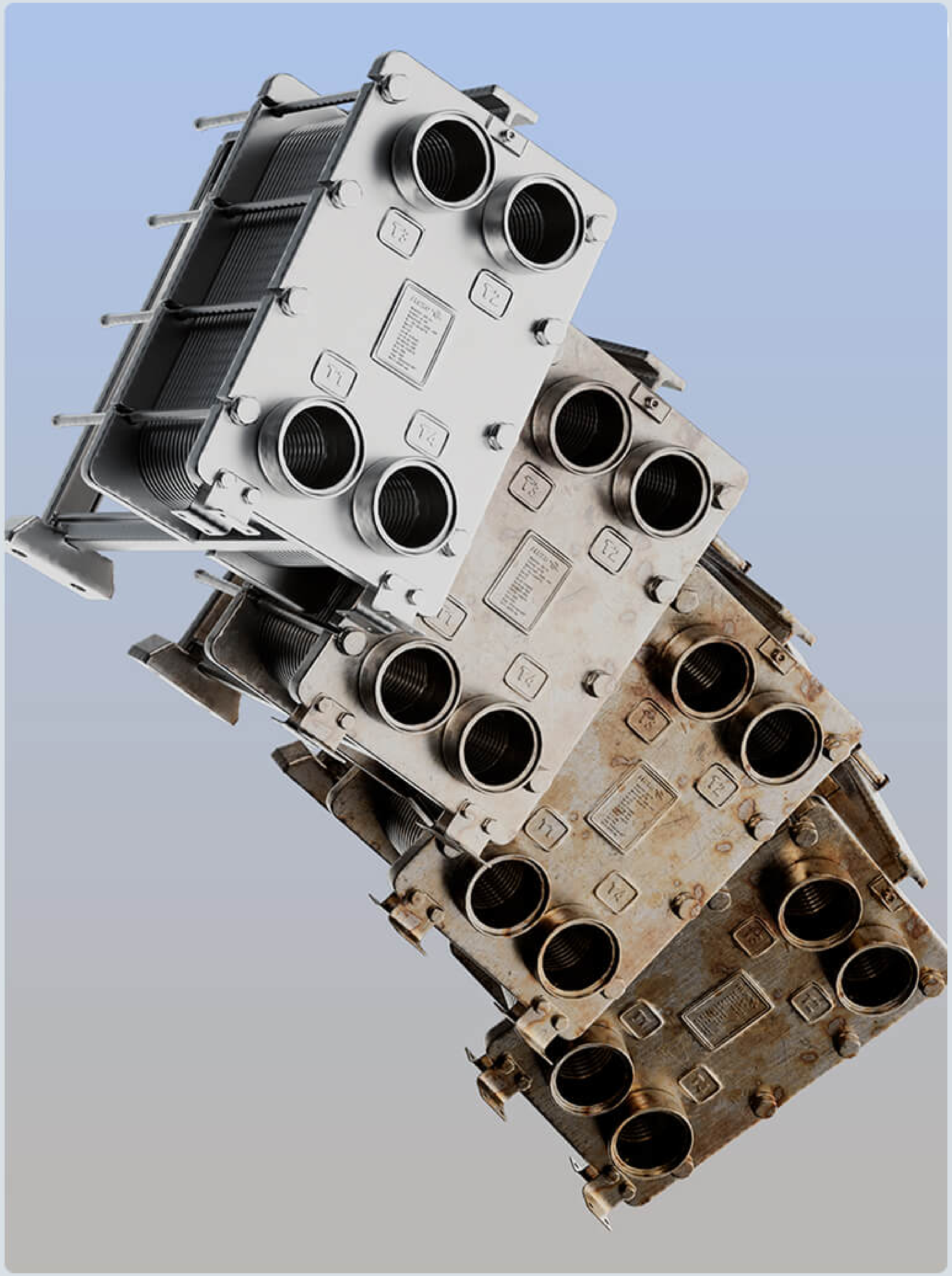
Stainless steel is positioned to be integral in emerging and established energy systems. Momentum around the hydrogen economy – particularly blue-hydrogen projects in North America that leverage existing natural-gas assets – favors stainless alloys for pipelines, reformer tubing and storage, as they resist hydrogen embrittlement and withstand the elevated pressures required for large-scale transport. In Asia and Europe green hydrogen is expected to grow significantly, with both geographic locations expected to become large net consumers of hydrogen.[1]

Along the U.S. Gulf Coast, where oil-and-gas infrastructure can be repurposed, these properties allow a relatively low-cost transition to hydrogen service while maintaining safety margins. More broadly, the push for lower-carbon processes is accelerating adoption of electric arc furnaces, nuclear plants and other high-temperature equipment that depend on stainless grades for oxidation resistance and mechanical stability.

Beyond hydrogen, stainless steel's corrosion resistance and strength continue to underpin its use in harsh operating environments, from offshore subsea lines and downhole oil-and-gas components to digesters and bleaching towers in pulp-and-paper mills. In each case its durability reduces maintenance frequency and extends asset life, aligning with corporate efforts to cut both operating costs and lifecycle emissions.

As industries switch from crude oil to renewables like used cooking oil, animal fats, and pyrolysis oils, they also take on extra oxygen, acids, and tiny amounts of salts. When heated, these impurities turn into harsh chemicals that can eat through ordinary carbon steel in a matter of months. To keep plants running, refineries, biogas sites, and chemical facilities are moving to higher-grade stainless steels. Specialized stainless grades are well-adapted to these chemicals and stay strong at operating temperatures. And because stainless can be recycled again and again without losing quality, it both protects equipment and supports the circular-economy goals behind bio-based fuels and chemicals.

[1] https://www.mckinsey.com/industries/oil-and-gas/our-insights/global-energy-perspective-2023-hydrogen-outlook



There is also renewed momentum behind nuclear power. Hyperscaler buyers have long pursued 24/7 clean electricity have widened their options to include nuclear: Microsoft's 20-year PPA with Constellation tied to restarting Three Mile Island Unit 1 is a prominent example. In Europe, France's EPR2 program – six new reactors plus life-extensions – reaffirms nuclear as a core pillar of its energy strategy. These moves signal durable demand and a multi-decade investment cycle with knock-on implications for permitting, supply chains, and materials (e.g., nuclear-grade stainless for piping, heat exchangers, and seawater systems).

Offshore wind farms need miles of walkways and platforms that live in salty spray and tough weather. Swapping the traditional galvanized steel for duplex stainless steel in these gratings can cut weight by up to 40%, making towers easier to install and upgrade while keeping loads down. Duplex stainless shrugs off corrosion without paint or galvanizing, so it needs far less maintenance over a 20+ year life and avoids coating repairs when pieces are cut on site. It also installs quickly with bolted connections and, at end of life, is fully recyclable – reducing waste and improving the project's overall footprint and total cost of ownership.

Decarbonization initiatives and the need for resilient materials in corrosive or high-temperature service suggest steady growth for stainless steel across the energy landscape over the next decade.

"Stainless steel already has a strong role to play in the green materials sector. Its extended life, resistance to degradation, and full recyclability make it one of the most sustainable materials available, reducing the need for frequent replacement and thus reducing resource and energy requirements. Beyond its use in everyday infrastructure and advanced technologies, stainless steel is also a key enabler of nuclear fusion reactors and at MPI we have already produced these low reactivity materials at scaled production levels. By combining longevity with innovation, stainless steel embodies the shift toward a truly sustainable future."

ANDY RICHARDSON
Business Development Lead, Green Metals
The Materials Processing Institute

2. DEFENSE AND AEROSPACE — DESIGN FOR EXTREMES

Heightened geopolitical tensions and record defense spending announcements may lead to renewed interest in stainless steel.

As the EU's €800 billion ReArm Europe plan prioritizes "resilience and sustainability criteria" in defense spending, advanced stainless grades offer extended equipment lifecycles while supporting the military's transition to low-carbon infrastructure. The convergence of security and climate objectives positions sustainable stainless steel as essential for Europe's defense industrial base, supporting everything from renewable-powered military installations to energy-efficient surveillance systems that operate indepen-dently of vulnerable fossil fuel supply chains.

In aerospace, stainless finds a different niche, coping with extremes of temperature rather than combat abrasion. Reusable rocket bo-dies, cryogenic fuel tanks and hot aircraft ex-haust ducts could favor the alloy because for its strength retention in negative and extreme re-entry temperatures, allowing designers to dispense with heavy insulation layers or active cooling.

Additive manufacturing is widening these opportunities: finely atomized stainless powders fed into 3D printers are already producing complex structures that would be impossible to mill or forge. Although volumes remain modest compared with other categories of stainless, these high-margin, critical parts give stainless a resilient foothold in two sectors that prize performance and reliability over raw material cost. Aerospace is increasingly leaning on Additive Manufacturing to make lighter parts with shapes that are difficult to machine such as compact heat exchangers or turbine blades. Stainless-steel powders fit well here: they stand up to corrosion and hard use, and when the powder is round and uniform the printer can deposit consistent layers that build reliable parts. That lets engineers trim weight by putting material only where it matters, without trading away safety. Stainless is expected to become the most used feedstock in additive manufacturing in 2027 – surpassing titanium and nickel alloys. Some powders now even come from recycled stainless, shrinking the overall footprint. [1]

[1] https://www.metal-am.com/ampower-releases-2025-additive-manufacturing-market-report/

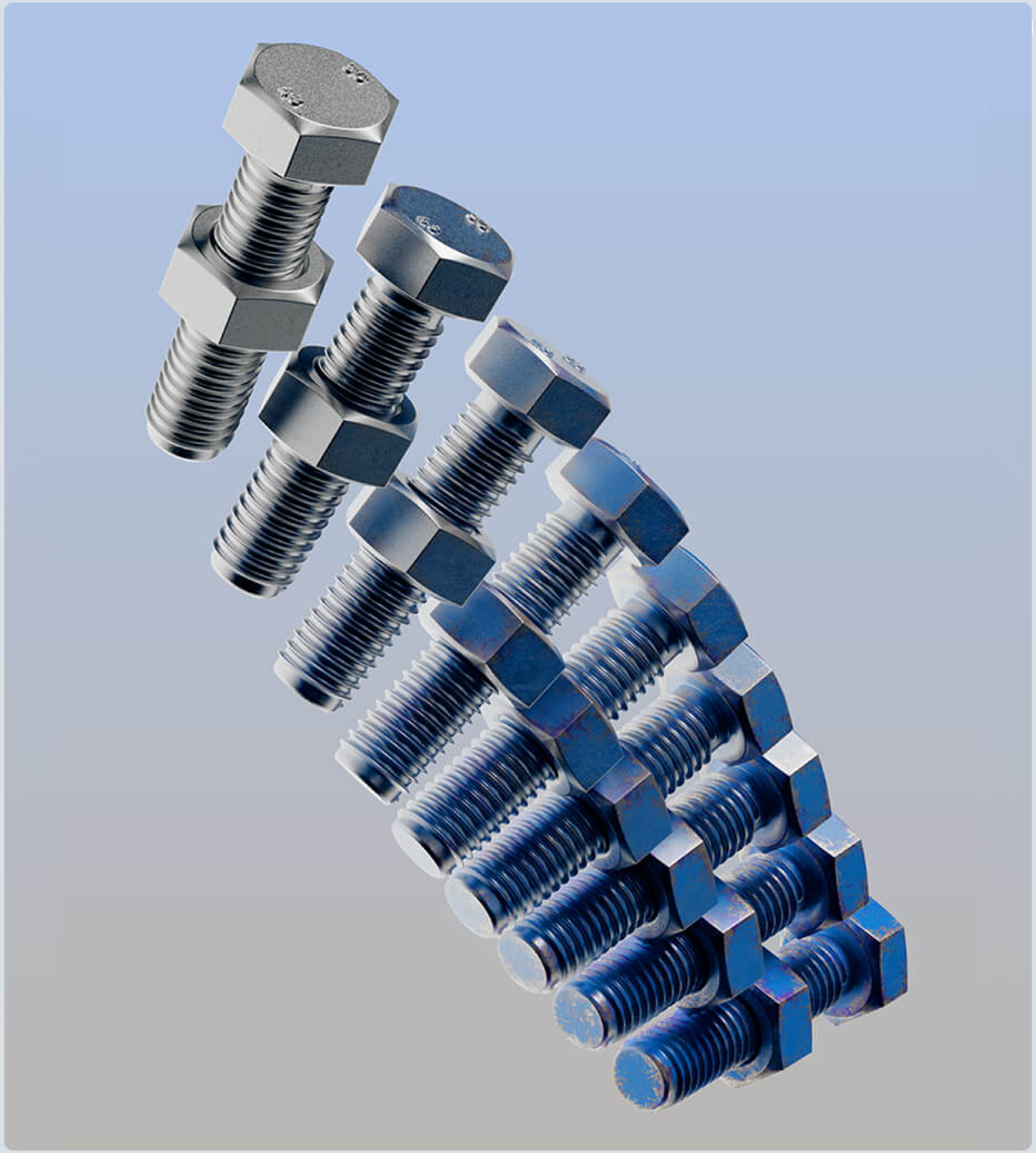
"One of the things we are starting to see, if you imagine the world with rising sea levels, is a much greater requirement for materials that do not corrode under seawater conditions. A large part of the world's buildings and cities are in low-lying areas or are coming close to the waterline. Consequently, you could see parts of the building and construction industry moving more towards stainless steel. There's also a greater need for marine structures, like floodgates, that must be built to protect cities against being flooded. Stainless steels' benefits and future potential lies in aggressive environments – places where you need high strength, high corrosion resistance, high pressure resistance, and high temperatures."

BRITTA WARNKE
Senior VP of Commercial
Outokumpu

3. BUILDINGS & CIVIL INFRASTRUCTURE — BUILD FOR LONG LIFE

As fleets electrify, use-phase emissions shrink, so materials and durability matter more. Buildings and infrastructure show this even more clearly: with efficiency and cleaner energy, the big impacts come from the materials we install and how often we replace them (the “embodied” part). That favors long-life, low-maintenance, recyclable choices – like stainless steel for façades, roofs, water and ventilation systems and bridges – where corrosion resistance and hygiene cut upkeep for decades.

Elevator and escalator manufacturers, for instance, continue to specify austenitic grades because the alloy combines the wide range of patterns and decorative surfaces available, with a durable, easily polished surface that resists scuffs in crowded lobbies and transit hubs. With growing urbanization around the world, the markets are expected to keep growing.



Pipe-and-tube producers serving water grids, district heating, and oil-and-gas gathering lines likewise report steady orders, as stainless welds reliably and extends service intervals – benefits that outweigh its higher upfront price when shutdowns are costly. There is even potential of moving from cast-iron and copper piping altogether favoring stainless, which could push maintenance from occurring with significantly longer intervals.

Climate exposure provides an additional tailwind. Rising sea levels and more frequent coastal flooding are leading engineers to adopt stainless rebar, cladding, and fasteners for seawalls, piers, and shoreline buildings, avoiding the accelerated corrosion that shortens carbon-steel asset life. The same logic is reshaping bridge design after a series of corrosion-related shutdowns in Europe: stainless reinforcement and plating can deliver service lives approaching a century, reducing disruptive repairs. As The Guardian eloquently framed it: **“Rust in peace: why are Germany’s bridges and schools falling apart?”**

Aesthetic considerations matter, too. Architects value stainless for façades and interiors because it can be mirror-polished, brushed, or color-treated while keeping its finish without repainting – paintings that can sometimes leak toxins and microplastics into soils. Some of the world’s most remarkable landmarks are made of steel – the Golden Gate or the Tokyo Sky Tree – but would cost taxpayers a lot less if that steel was stainless and wouldn’t need to be repainted frequently. The Golden Gate costs taxpayers ca. $300 000 per year[1] and the Eiffel Tower has maintenance cycles of around 18 months at an average of €3 million.[2] Protection from rust is expensive. And the 60 tons of paint needed to coat the “Iron Lady” have an environmental impact as well that is likely not priced in today.

[1] https://www.sfgate.com/local/article/myth-about-sf-golden-gate-bridge-16848740.php
[2] https://www.ipcm.it/en/article/the-corrosion-of-the-eiffel-tower.aspx

CASE STUDY: EIFFEL TOWER

What if the iconic Eiffel tower, made of wrought iron, was replaced with stainless steel? What would be the emissions for 100 years timespan?

Emissions in total (construction phase & use phase*):

21,060t CO_2

Needs to be painted 14,3 times. The paint forms a barrier between the wrought iron and the environment, thereby preventing rust formation and weakening of the structure.

*) Total emissions in the construction phase (raw material, total wrought iron used for outer structure 7300 t): 2.13tCO2/t. Total emissions in the use phase (14,3 times repainted, total amount of paint used 857.1 t): 6.43tCO2/t.

Final conclusion:

64% CO_2 reduction

if using stainless steel (25% less material) compared to wrought iron.

Emissions in total (construction phase & use phase**):

7,665t CO_2

No painting needed. The stable and self-healing oxide layer on the surface of stainless steel provides protection against rust and corrosion. Painting and other surface treatments are therefore not needed.

**) Total emissions in the construction phase (raw material, total amount of stainless steel used for the outer structure 5475 t): 1.4tCO2/t. Since the stainless steel grade used for comparison is stronger than wrought iron, the assumption is that 25% less stainless steel would be needed in the construction stage.

Methodology: Calculation EN 15804 and emissions factors GWP 100. Stainless steel used: Outokumpu stainless steel, 1,4t CO2/t (2024).

"In imagining the evolution of architectural design, I'm convinced we need to bridge the knowledge gap around materials like stainless steel. It's a reality that architects, while visionary, often rely on engineers for the granular specifics, meaning the ultimate material decisions can fall outside their direct purview. This suggests a significant opportunity: to craft more compelling narratives that illuminate the full spectrum of stainless steel's properties, tailored specifically for the architectural community. When architects are genuinely informed, rather than just presented with options, they can integrate materials like stainless steel into their designs, leading to more innovative and informed outcomes. And for the architecture of the future, stainless steel isn't just a material; it's the embodiment of permanence, chosen for projects where we invest in tomorrow, where durability and responsibility are paramount."

BEATRICE GALILEE

Curator on Architecture & Design

Founder and Executive Director of the World Around

Beatrice Galilee curates contemporary architecture, a role that places her in constant dialogue with architects and designers. She delves into the future of construction, exploring where the industry is headed, how we should be building, and the materials we'll need to create a safer tomorrow.

The Laakso Joint Hospital in Helsinki, Finland for example, is sourcing plate heat exchangers made with lower-emission stainless and steel, cutting the equipment's embodied carbon by supplier-reported ~60%. This points to stainless growth in HVAC and district-energy hardware where durability and low footprint both matter.

Finally, duplex stainless grades are gaining traction in road and rail bridges, but also in modular pedestrian and cycle bridges. British Network Rail's AVA bridge is a new kind of railway footbridge built in a factory like a kit, then quickly bolted together on site.[1] It uses rust-resistant stainless steel sheets that are cut and folded into strong parts, reducing heavy welding and on-site work. The result is faster installation, less disruption for passengers, and a bridge that will need less maintenance over time.

Stainless' combination of strength and corrosion resistance supports lighter, factory-fabricated spans that install quickly and need little maintenance – with the added bonus of making cities look like the current world's most livable city of Copenhagen.

This indicates a steady role for stainless steel in the built environment, driven by longevity, lifecycle cost savings, and design flexibility rather than raw tonnage alone.

[1] https://www.outokumpu.com/en/expertise/2024/a-bridge-designed-for-manufacture-ava-bridge

4. AUTOMOTIVE & MOBILITY — OPTIMIZE TOTAL COST OF OWNERSHIP & SAFETY

Stainless steel is expected to maintain – and in certain segments grow – a meaningful role across mobility and transport applications as market dynamics and policy requirements evolve. In the automotive sector, the recent slowdown in electric-vehicle sales and the partial rebound of internal-combustion models (at least in some parts of the world) favor components where stainless steel has long been established, such as exhaust systems, fuel rails, and selected chassis parts.

In the electric vehicle market, aluminum has established an early lead in battery casings despite stainless steel offering critical safety benefits, among others. For instance, in the event of a fire or thermal self-ignition of the batteries, a stainless steel battery case can save the structure due to its thermal resistance properties up to 15 minutes compared to less than 3 minutes for an aluminum one. This underscores the need for strategic positioning to better communicate and capitalize on these unique advantages in new applications.

European circular economy rules that mandate higher recycled content in new cars also align with stainless steel's high recyclability, enhancing its appeal in future material selections.

If robotaxis scale and mobility shifts from ownership to service, lifecycle costs may move from households to fleet operators, who optimize for total cost of ownership, uptime, and risk which could result in less planned obsolescence and more lasting cars. Higher annual mileage and liability would push designs toward durability and safety, favoring targeted use of stainless where failure is costly: for example, battery enclosures, in tougher strike protection and high-touch interior hardware that must withstand frequent cleaning.

CASE STUDY: AUTOMOTIVE MATERIALS

What if a passenger car's outer body, made of aluminium, was replaced with stainless steel? What would be the emissions for 15 years timespan (average life of a car)?

Emissions in total (construction phase*):

~1052 kg CO_2

*) A rough simplified calculation of an outer car body. Total emissions in the construction phase calculated based on raw materials: aluminium (8,42 kg CO2/kg with 125 kg, -1/3 density of steel)

Final conclusion:

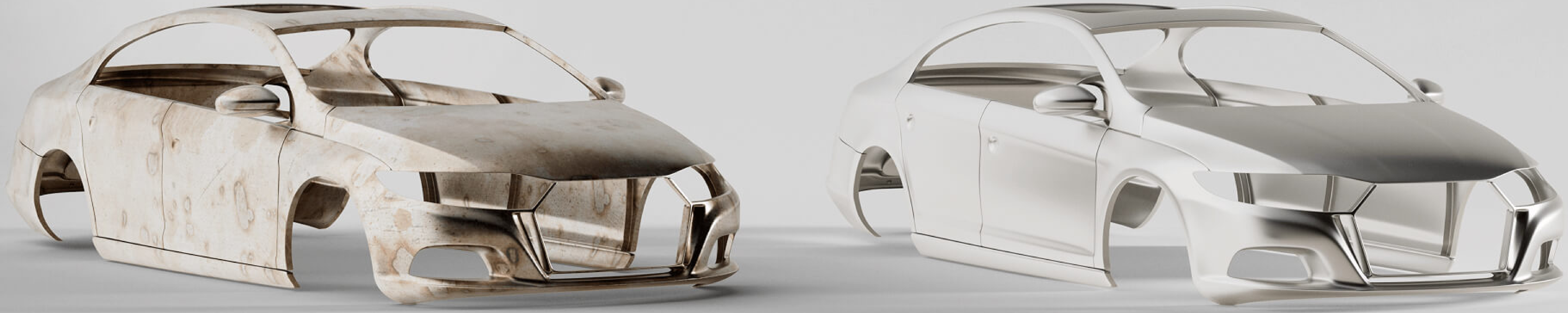
83% CO_2 reduction

if using aluminum compared to stainless steel.

Emissions in total (construction phase**):

~175 kg CO_2

**) Total emissions in the construction phase calculated based on raw materials: Outokumpu stainless steel (1,4 kg CO2/kg, replacing the 125 kg for aluminum).



Methodology: LCA calculation and emissions factors GWP 100.

Beyond passenger cars, rail and heavy-duty truck manufacturers are increasing their use of stainless steel in car bodies, tankers, and refrigerated trailers. The corrosion resistance and strength allow thinner gauges, fewer welds, and longer service life, helping offset higher initial material costs through lower lifecycle expenses. Growth in chemical and cold-chain logistics reinforces this trend, as stainless steel meets stringent hygiene and durability requirements for tanks and insulated cargo units.

Together, these factors suggest steady, selective growth for stainless steel in mobility and transport over the coming decade, driven by a combination of safety performance, circular economy compliance, and total-cost-of-ownership considerations rather than headline material cost alone.

5. CONSUMER & LIFESTYLE — CHOOSE DURABLE HYGIENE

In household appliances, demand has softened alongside fewer new-home starts, yet stainless retains its place in refrigerators, dishwashers, and cooking ranges: consumers value its hygienic surface, scratch resistance, and "premium" appearance, features that do not fluctuate with the construction cycle. In kitchens, stainless has been the norm for professional kitchens. Media features on EuroCucina and other 2024 trade shows describe a "retro-futurist" revival in brushed or mirror-polished stainless islands and cabinetry, confirming that the material still signals quality to homeowners – particularly on the premium front. As awareness around microplatics, PFAS and other chemical grow, more households may start ditching their non-stick pans for stainless cookware – and perhaps plates and glasses as well. Breaking a glass may increasingly be a thing of the past.

Durability is also increasingly embedded in revenue models. Start-ups and appliance makers testing "product-as-a-service" plans – from appliances to entire kitchens as exemplified by Dutch Chainable's "kitchen-as-a-service" – could favor stainless housings and base materials because they withstand the repeated transport, sanitizing and refurbishment cycles that keep assets in circulation.

Outdoors, furniture retailers may start to use stainless for all types of furniture: picnic tables, benches and patio sets. Stainless' ability to resist all types of harsh outdoor conditions could help individuals and even cities ensure their outdoor furniture stay impeccable forever. Just look at how Australian parks have chosen to install stainless steel barbecues[1] – the public barbie.

[1] https://theconversation.com/the-public-barbie-an-aussie-icon-frozen-in-time-95441

"Stainless isn't just a material – it's a mindset. It reflects how we approach challenges, build partnerships, and shape the future. We source with purpose, lead with vision, and collaborate with heart. Every quote we deliver reflects our commitment to innovation, agility, and the kind of strategic sourcing that doesn't just meet expectations – it redefines them. This isn't just stainless it's our "Forever" vision."

DONNIE HOLDER

VP Strategic Sourcing & Global Trade Affairs

Webco

CONCLUSION

Despite what may at times feel like a tumultuous period, this century is being decided in the quiet places where design meets durability. Climate targets are drifting, and the physics is unsentimental – warmer, wetter, saltier conditions accelerate many corrosion processes; storms compress maintenance windows; budgets face more frequent, unplanned repairs. What we choose to make permanent now will either compound reliability – or compound risk.

History shows both paths. After a catastrophic North Sea flood in the mid-20th century, the Netherlands launched a decades-long program of dams, dikes, surge barriers, and polders. That effort – best known through the Afsluitdijk and the Delta Works – ended up doing even more than hold back water. It reclaimed land, stabilized an economy, and embedded a culture of thinking ahead. On the other hand, Kim Stanley Robinson's novel New York 2140 imagines a very different lesson: a future Manhattan after significant sea-level rise, a city of canals and elevated life where adaptation happens post-crisis.

It's fiction, but its point is practical: if we delay hard choices, we still adapt, just with fewer options and higher costs. As we near potential tipping points – such as a disruption of the Atlantic Meridional Overturning Circulation, an ocean current that transports warm water northwards – the steep costs of adapting to a much colder Europe make the case of investing in durability wise.[1]

This white paper's findings point to the same fork in the road. Demand for long-lived materials is edging up. Supply chains are being diversified in response to geopolitics. Cost decisions are slowly shifting from sticker price to life-cycle cost and sustainability is becoming measurable – product-level CO_2 data, recycled content, and renewable power are showing up in procurement. **In brief: the market is learning to value what keeps working.**

[1] https://www.economist.com/leaders/2025/08/14/the-shutdown-of-ocean-currents-could-freeze-europe

That is the heart of the Everlasting Era – a design mindset that builds to last. Instead of assuming frequent replacement, it assumes long service lives, low maintenance, and circular recovery at the end. In an Everlasting Era, a “winning” product or structure is one that keeps its properties in real exposures and can be inspected, upgraded, and eventually remade without downgrading quality.

To make the Everlasting Era practical, two things matter in particular:

1. **Procurement that counts the whole life.** Treat life-cycle cost and downtime risk as primary metrics. Factor inspection access into the tender.

2. **Finance that values avoided loss.** The cheapest option may often look expensive once maintenance and closures are evident. Instruments that monetize avoided damage and reduced maintenance (and that recognize recoverable material value) align hard cash with physics.

So what should we actually build? And how do we make it a landmark good enough for the history books?

We need a family of infrastructures – coastal and inland – that are dependable, repairable, and multipurpose. The Coastal Commons is one clear expression of this idea: protective sea walls that double as public space and utility corridors. Tidal gates that, on ordinary days, function as promenades and bike routes, as a core part of a city’s infrastructure.

An imaginations of the Coastal Commons, the defining structure of the 21st century.

Why could the Coastal Commons become the signature project type of this century? Because it solves several problems at once. It buys safety without giving up the shoreline. It creates public space in cities that are short of it. It carries utilities that must be upgraded anyway. It can be built in segments and adapted as projections change. And at the end of its service, much of its material can re-enter the melt shop or be remanufactured, preserving value rather than externalizing waste. That combination of protection, everyday use, modularity, and circularity is rare, and it's exactly what a warmer, more populous, more urban world needs. A structure built with the future in mind.

The 20th century's emblems were highways (like the U.S. Interstates) and hydro dams (like the Hoover or Three Gorges Dams). **The 21st century is still open to be defined, hopefully with the Everlasting Era in mind. A structure that lasts forever with little to no maintenance may be the signature worth leaving.**

ABOUT THIS REPORT

This research report was commissioned by Outokumpu and conducted by Kairos Future between May–September 2025.

OLIVIER ROSTANG
Strategic Foresight Consultant
at Kairos Future

Outokumpu is accelerating the green transition as the global leader in sustainable stainless steel. Our business is based on the circular economy: our products are made from 95% recycled materials, which we then turn into fully recyclable stainless steel. This steel is utilized in various applications across society, including infrastructure, mobility, and household appliances. We are committed to 1.5 °C target to mitigate climate change, and with up to 75% lower carbon footprint than the industry average, we support our customers to reduce their emissions. Together, we are working towards a world that lasts forever. Outokumpu Corporation employs approximately 8,700 professionals in close to 30 countries, with headquarters in Helsinki, Finland and shares listed in Nasdaq Helsinki. Read more: www.outokumpu.com

Kairos Future is a Swedish consultancy specializing in strategic intelligence, foresight, and scenario planning. Through trend analysis, innovation, strategy, and software support for AI-driven analytics, we help our clients understand and shape their future. Founded in 1993, Kairos Future is headquartered in Stockholm and has offices and partners around the world. www.kairosfuture.com

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