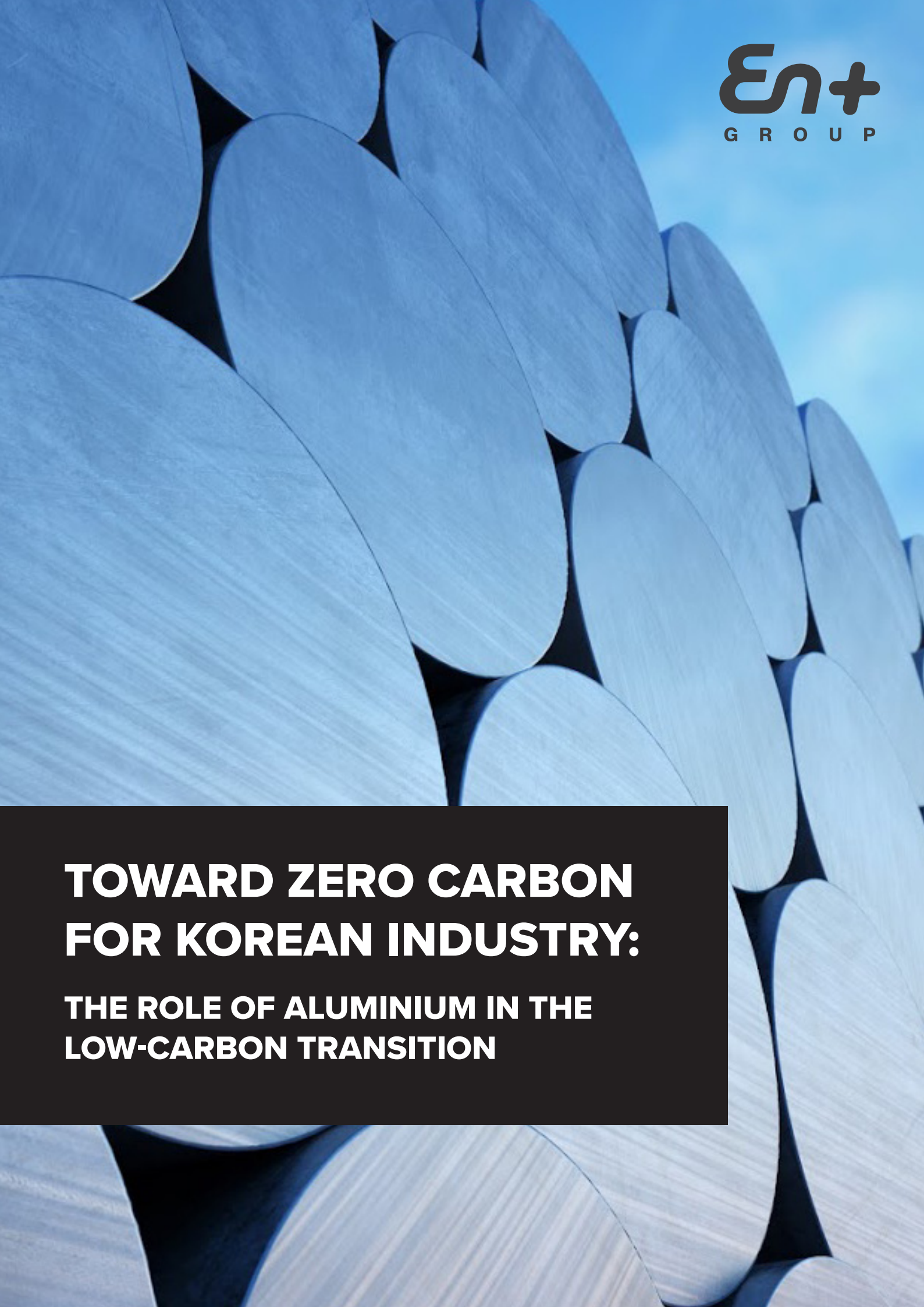


TOWARD ZERO CARBON FOR KOREAN INDUSTRY:

THE ROLE OF ALUMINIUM IN THE LOW-CARBON TRANSITION

CONTENTS

ABBREVIATIONS

BREEAM – Building Research Establishment Environmental Assessment Method

CT – Carbon Trust

EV – Electric vehicle

IAI – International Aluminium Institute

ICE – Internal combustion engine

GHG – Greenhouse gas

GPP – Green public procurement

GRK – Government of the Republic of Korea

G-SEED – Green Standard for Energy and Environmental Design

KEITI – Korea Environmental Industry & Technology Institute

K-ETS – Korean Emissions Trading Scheme

LEED – Leadership in Energy and Environmental Design

MoE – Ministry of Environment of the Republic of Korea

MOLIT - Ministry of Land, Infrastructure, and Transport of the Republic of Korea

MOTIE - Ministry of Trade, Industry and Energy of the Republic of Korea

NDC – Nationally determined contribution

UNEP – United Nations Environment Programme

WEF – World Economic Forum

WGBC – World Green Building Council

ZEB – Zero-energy building

EXECUTIVE SUMMARY

In its Carbon Neutral Strategy to 2050, the Korean government set out an ambitious roadmap for decarbonisation that will channel public and private funds into areas such as electric vehicles, green buildings and distributed renewable energy. However, with major investment pouring into the green transition, there is a risk that the raw materials used in this monumental economic shift come with significant embedded emissions. Without addressing these hidden climate impacts, Korea's transformation would undermine its own objective, driving pollution abroad to build green industries at home.

Aluminium: A building block of the low-carbon economy—but not all is born equal

While Korea does not have a primary aluminium industry, it is a major importer of the metal, which is processed by downstream aluminium producers for use across a breadth of sectors. Aluminium is primed to play a major role in the green transition:

- In Korea's automotive sector, where its lightweight properties are key to improving the efficiency of electric vehicles, aluminium demand is set to rise 27% between 2020 and 2025.
- The construction industry similarly values aluminium's lightweight properties, alongside its durability, reflectivity, and ease of extrusion. Demand for aluminium from construction growth in Korea is set to increase 18% between 2020 and 2025. This will be further stimulated by the increased integration of distributed renewable energy infrastructure into residential and commercial buildings under Korea's Carbon Neutral Strategy, given aluminium accounts for approximately 85% of solar panel components.

Behind the opportunity, however, lies a challenge for Korea's downstream aluminium industry. The high energy intensity of aluminium production means raw materials imported to Korea can have vastly different embedded emissions. Primary aluminium produced using renewable energy, for example, can have an emissions intensity of less than 4 tonnes of CO2 per tonne of aluminium (tCO2/tAl) compared to a global average of 12.6 tCO2/tAl, while innovative processes such as inert anode production are offering even lower figures.

A challenge and opportunity for Korea's downstream aluminium producers

The gulf between average and low-carbon aluminium presents both risks and opportunities for Korea's downstream producers. As Korea begins to implement its decarbonisation plans, demand for low-carbon materials will be driven particularly strongly by the country's sophisticated tools for green public procurement, a proposed increase in emissions disclosure standards and the integration of lifecycle assessments into the Carbon Neutral Strategy's green stimulus. Moreover, trends among the customers of the downstream aluminium industry show a growing preference for low-carbon sourcing. In the automotive industry, for example, companies are increasingly looking to compete on the basis of emissions. Currently, 83% of global automakers have stated commitments to reduce the lifecycle emissions of their vehicles, while almost three-quarters have set numerical targets. Meanwhile, in Korea's construction industry, demand for low-carbon materials is being driven by increased adoption of the G-SEED building standards, which allocates 20% of points based on materials and resources.

Recommendations

Korea's downstream aluminium producers are faced with a choice. By acting proactively to source low-carbon materials they can get ahead of demand and gain a competitive advantage among customers increasingly looking to cut their climate impacts. In contrast, sticking with the status quo could leave some producers reacting too late to customer expectations and losing out to earlier movers in the industry. To guide them towards the opportunities that lie in the green transition, this paper makes a series of recommendations to downstream aluminium producers. These include for them to:

1. Work with suppliers to enhance emissions disclosure for the supply chain
2. Set phased decarbonisation pathways that encourage suppliers to transition to low-carbon production models
3. Accelerate decarbonisation efforts by coordinating research and development, investment, and advocacy across the value chain

The paper also recognises that, with major investments in the creation of a thriving green economy, the Korean government has an opportunity to ignite significant growth in its downstream aluminium sector. To help unlock this potential, it suggests policymakers consider:

1. Setting standards for disclosing embodied emissions and providing support to businesses on compliance
2. Establishing benchmarks for what constitutes low-carbon aluminium in line with benchmarks set by organisations such as the Carbon Trust. Korean authorities can lead on this process by integrating standards into the mechanisms for public procurement
3. Implementing differentiated import tariffs low-carbon aluminium

With effective systems for sustainable certification coupled with burgeoning green industries, Korea provides a strong environment from which the country's aluminium producers can seize the opportunity of a global low-carbon transition. Those that successfully get ahead of demand for low-carbon materials will enjoy a win-win—what is right for profits and what is essential for our planet.

INTRODUCTION
KOREA'S LOW-CARBON TRAJECTORY
FROM ADAPTIVE REDUCTION TO PROACTIVE RESPONSE

"2050 carbon neutrality has become a global common goal to address climate change a new international economic order. Korea should also join this paradigm shift and move from 'adaptive GHG emissions reduction' towards 'proactive climate response'" (GRK 2020, 128)

At the conclusion of its landmark Carbon Neutral Strategy, the Korean government signalled a fundamental shift in its approach to combatting the climate crisis. The country had already experienced accelerated warming, with average temperatures rising 1.4°C over 30 years (GRK 2020, 6), and average rainfall increasing nearly 160mm compared to a century before (GRK 2020, 16). However, Korea's 2050 strategy was about much more than mitigating the worst impacts of a changing climate. Its latest Nationally Determined Contribution (NDC) commits the country to cut greenhouse gas (GHG) emissions to 24.4% below 2017 levels by 2030, with an even more ambitious target due to be announced in the second half of 2021 (Lee 2021). At the same time, the Korean government is also aiming to grow its economy into global green superpower.

It is clear from the Carbon Neutral Strategy that part of the transition to a green economy will be driven by market solutions, such as carbon pricing. National authorities would set rules and regulations to which the private sector should respond with solutions determined to be most efficient. Korea's carbon trading scheme, the K-ETS, has seen the price of carbon increase steadily from KRW 8,000 per ton in 2015 to approximately KRW 20,000 today (GRK 2020, 38). The government also committed in the Carbon Neutral Strategy to increasing the share of auctioned credits to 10% by 2030, which will continue to steadily increase the carbon price over the coming years (GRK 2020, 38).

Alongside these market mechanisms, the Korean government sees a more active role for itself in steering the economy towards a low-carbon future. As stated in the Carbon Neutral Strategy, the government believes "the public sector is in the best position to show its commitment to and progress in GHG emissions reduction." (GRK 2020, 110). A track record of public sector leadership already exists—the country has operated a GHG emissions Target Management System since 2011 (GRK 2020. 110). However, through the commitment to mobilise KRW 73.4 trillion under last year's Green New Deal, the government is changing gear in its drive for a low-carbon economy (GRK 2020, 111).

The proactive direction of government efforts towards the green transition will have a profound impact on the shape of the Korean economy. The Korean government has placed innovative green industries at the heart of its vision. This drive for innovation is emphasised again and again throughout the Carbon Neutral Strategy, most notably in the government's vision statement:

"Korea will harness green innovations and advanced digital technologies to create synergies between the Green New Deal and the Digital New Deal, the two pillars of the Korean New Deal. Korea will also take decisive action especially in supporting and investing in the development of innovative climate technologies to achieve carbon neutrality." (GRK 2020, 7)

This approach is given greater specificity later in the strategy, with the government stating:

"Korea's highly developed ICT and leading technologies of electric vehicles (EVs) and Energy Storage System (ESS) provide an enabling environment for a convergence between green innovations and Industry 4.0 technologies. Such convergence is expected to give rise to a new wave of the low-carbon industry that will replace conventional energy-intensive industry." (GRK 2020, 24)

The government has already given significant backing to this plan. For example, the Ministry of

Environment announced at the end of last year that loans designed to nurture future-oriented green industries would increase by over 50% from KRW 200 billion in 2020 to KRW 311.1 billion in 2021 (MoE, 2020a). It is also actioning the strategy on a global level, announcing in April of this year that it would halt public financing of overseas coal-fired power plants (Lee 2021).

Government action is partially being driven by a rallying of consumer sentiment behind green industries. Unlike in other developed markets, the COVID-19 pandemic barely made a dent in the number of Koreans saying their next car purchase would be a vehicle without an internal combustion engine. At 57%, the proportion of Koreans saying they would make this choice is now higher than in the US, India, Germany, China and Japan, providing legitimacy to the government's ongoing support for the EV sector (Deloitte, 2021). Similarly, increasing activism against single-use plastics has helped push the government towards a 2030 target of cutting plastic waste in half and doubling recycling rates. To deliver on this pathway, the Ministry of Environment is now engaging directly with the private sector to drive circularity. For example, in January this year, it launched a Reverse Recycling Scheme with the Korea Cosmetic Association and Korea Packaging Recycling Cooperative that will enable consumers to return cosmetics packaging to shops, department store and hypermarkets (Lim 2021).

Korea's green transition will have a profound impact beyond the small set of innovative sectors targeted by government stimulus. Supply chains will have to adapt to new demands—from how raw materials are sourced to the establishment of a circular economy. Moreover, if the establishment of a low-carbon economy is to be consistent with the ultimate objective of combatting the global climate crisis, green industries will be increasingly directed by corporate leaders, public officials and their customers to ensure the full lifecycle of their products are sustainable.

This study explores these potential impacts through the prism of Korea's downstream aluminium industry. Korea's aluminium industry relies on imports of unwrought metal from around the world, which is then made into finished materials for both domestic and export markets. From electric vehicles to green buildings, recyclable packaging to renewable energy infrastructure, this aluminium is a vital input for businesses in the green economy. However, the position of Korean producers in the middle of the supply chain presents a challenge. These businesses will increasingly face pressure from their customers in green industries to supply low-carbon materials. To meet this expectation, however, they will have to influence actors further up the supply chain. ***The systems needed to identify, source and verify the credentials of low-carbon materials cannot be established overnight, making it imperative for Korean producers to begin engaging with their suppliers well ahead of an accelerating green transition.*** While this will be a collaborative effort, this paper illustrates the significant rewards available to those able to differentiate their materials on the basis of their low carbon footprint.

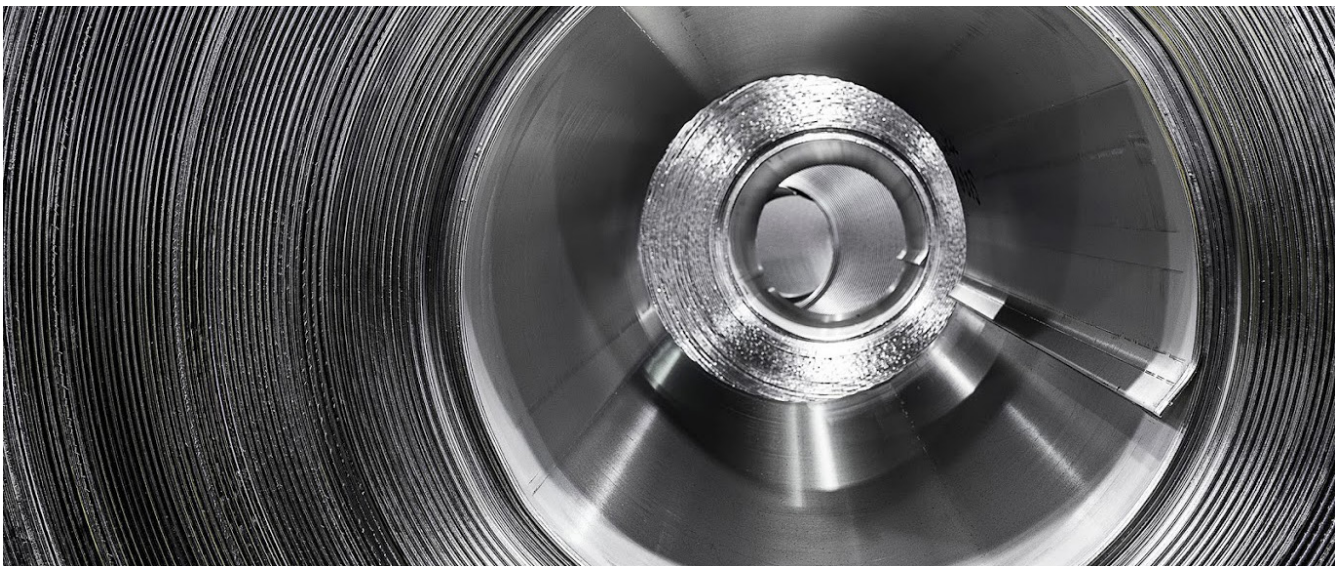
Chapter 1 begins by illustrating the spike in aluminium demand forecast as a result of the green transitions underway around the world and in Korea. It then highlights the potential damage to the climate that could occur if this demand for aluminium continues to be met with materials made using high-carbon power sources. It establishes how we might identify what constitutes low-carbon aluminium and highlights that green variants of the metal are already available at scale.

Chapter 2 analyses the drivers of low-carbon aluminium demand. It begins by highlighting the ways in which public sector procurement practices are, in general, reinforcing the principle of low-carbon sourcing in the Korean economy. It then focuses on the transformational shifts underway in the automotive and construction industries, illustrating the impact this will have on aluminium demand and the growing push for this demand to be met with low-carbon materials.

Finally, chapter 3 provides some brief recommendations to Korean aluminium producers on how they might work with their suppliers to transition to low-carbon sourcing, as well as discussing ways policymakers may support the industry as it shifts to this sustainable footing.

While this paper focuses on the aluminium industry, many of its findings are applicable across a range of materials essential to the low-carbon economy. Fundamentally, it points to a win-win scenario for the economy and environment, in which Korean manufacturers are both able to seize the opportunity of the green transition and spread influence up their supply chains to secure a more sustainable future.

CHAPTER 1:
LOW-CARBON ALUMINIUM IN THE GREEN TRANSITION



Shifting the source of emissions rather than eliminating them could have severe consequences that undercut the objectives of Korea's green transition.

Ensuring raw materials match up to green ambitions

The Korean government has committed to a green transition focused on "harnessing environmental technologies and green industry as a new growth engine for the national economy" (GRK 2020, 36). While the rise of green innovations provides a compelling headline, the devil is in the detail. With increased demand from rapidly scaling industries, there is a risk that raw material inputs do not match up to the low-carbon credentials of their end-products. In this scenario, Korea's green transition would be half-baked. To the observer, Korea would be a country of clean energy, clean cars and clean cities. However, many of the emissions these innovations would look to have saved would be partially reversed by pollution in other countries. Away from the eyes of the general public, high-polluting industries would continue to impact our climate in order to supply the raw materials needed for ostensibly green products.

Shifting the source of emissions rather than eliminating them could have severe consequences that undercut the objectives of Korea's green transition. Prosperity from the low-carbon economy would be enjoyed but not sustained. Emissions released anywhere have consequences everywhere, causing the global climate to continue its steep decline. While green industries would mitigate some of the emissions contributing to the climate crisis, they would not be enough on their own to prevent worsening extreme weather events. This scenario would leave the Korean peninsula at risk of dangerously high temperatures, increased flooding and more destructive typhoons, which have the potential to wipe out huge amounts of economic value and dramatically impact the lives of Korean citizens.

The only way to avoid this scenario is to ensure the demands of the low-carbon economy are met using low-carbon materials and for businesses to engage the whole way up their supply chains in a process of collaborative decarbonisation.

Rising demand for aluminium

The aluminium industry in Korea presents a compelling case study for the risks of hidden emissions and the opportunities from a transition to low-carbon materials.

Around the world, the green transition is driving aluminium demand to unprecedented levels. As the International Aluminium Institute (IAI) notes:

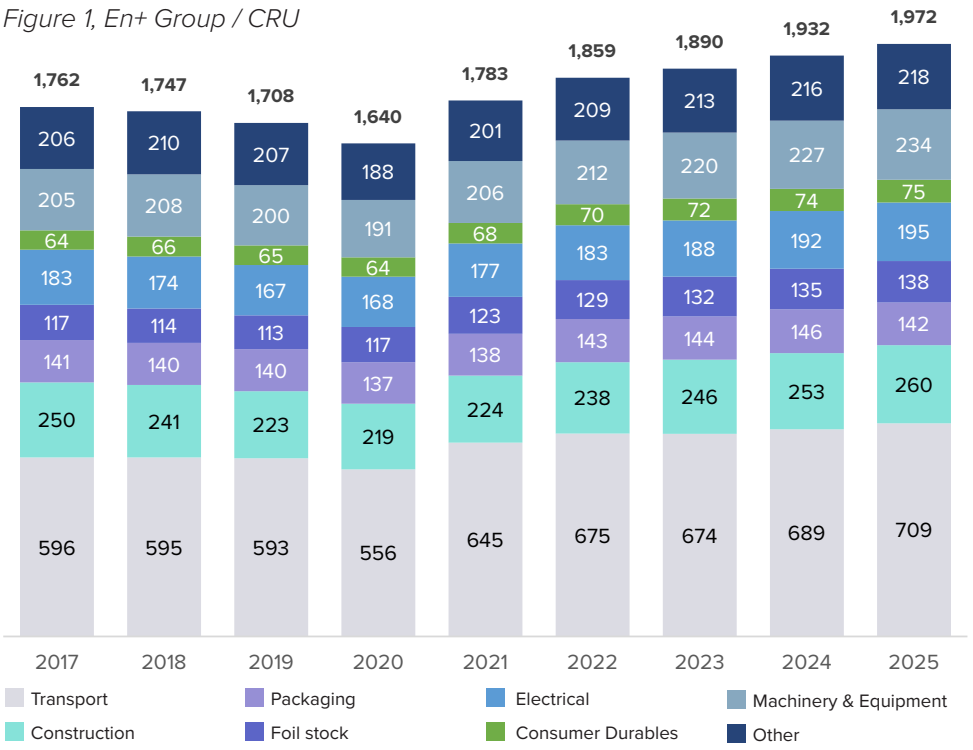
> ***Lightweight, strong, durable, conductive and recyclable, aluminium products are essential enablers of a low carbon future. They provide energy-efficient and carbon-saving solutions to high emitting but critical service-providing sectors, including energy, transportation, buildings and food & pharmaceuticals.***
>
> **IAI 2021a, 1**

In 2018, global demand for aluminium was 95 million tonnes, of which two thirds was met with primary materials and one third recycled (IAI 2021b, 8). However, with aluminium playing a central role across the low-carbon economy, the acceleration of green transitions around the world—coupled with increasing global GDP and a rising population—means demand for the metal is set to grow 80% by 2050 (IAI 2021b, 3). While the supply of recycled aluminium is set to increase over this period, between 75 to 90 million tonnes per year of primary aluminium will still be required to meet demand (IAI 2021b, 9).

This global growth is reflected in demand trends for South Korea. Driven in particular by shifts in the automotive industry, demand for aluminium semis is set to rise 20% from 1640 kt in 2020 to 1972 kt in 2025. To put this into perspective, between 2017 and 2019, demand fell slightly from 1762 kt to 1708 kt (En+ Group / CRU 2021.[1] The Korean aluminium industry is therefore moving from a relatively stable demand trend to one of acceleration as the both the national and global economy shifts at an increasing rate towards a low-carbon footing.

S.Korean al semis consumption by end-use dynamics, kt

Figure 1, En+ Group / CRU



1 Unless otherwise stated, demand trends cited in this paper for aluminium in Korea were compiled by En+ Group using data from CRU

1.1

gigatonnes of greenhouse gas per annum produced by aluminium industry

2%

of all global anthropogenic emissions

The rising demand for aluminium presents a potential contradiction in the growth of the low-carbon economy. Production of the metal is energy intensive, requiring highly charged anodes to convert aluminium oxide (alumina) into aluminium. According to data from the IAI, approximately 60% of this power comes from coal-powered energy sources.[2] The result is that the aluminium industry as a whole produces approximately 1.1 gigatonnes of greenhouse gases per annum, accounting for 2% of all global anthropogenic emissions (IAI 2021b, 3). In a business as usual scenario, this figure could reach 1.6 gigatonnes by 2050 (IAI 2021b, 7), whereas a scenario compatible with the United Nations' pathway for global warming below 2°C would require a reduction in emissions to 250 megatonnes (IAI 2021b, 8). While some of the emissions reduction required by the aluminium industry could be achieved by increasing recycling rates, the IAI projects that between 75 and 90 million tonnes of primary aluminium will be needed each year by 2050 (IAI 2021b, 9).

Currently, the average emissions intensity of aluminium imports to South Korea are high for a country that has also shown strong public support for climate action. The average scope 1 and 2 emissions intensity for primary aluminium used in South Korea (both alloyed and non-alloyed) is 11.4 tonnes of CO2 per tonne of aluminium (tCO2/tAl).[3] While the country has in recent years increased its sourcing of recycled metal (including scrap), this still only brings down the average emissions intensity of all aluminium imported into the country to 6.86 tCO2/tAl (En+ Group / CRU 2021).

Fortunately, clear pathways already exist for the decarbonisation of primary aluminium. Since more than 60% of emissions released by the aluminium industry come from its use of electrical energy, switching to renewable power sources has a dramatic effect on producers' climate impact (IAI 2021b, 10). Aluminium produced in this way is already available at considerable scale, with international producers including Hydro, Rio Tinto, Alcoa and Rusal offering metal with a carbon footprint below 4 tCO2/tAl (CT 2020, 3) compared to a global average of 12.6 tCO2/tAl. While slightly different methodologies are used by each company to calculate these footprints, the Carbon Trust notes that these largely align with the IAI's level 1 guidelines, which include emissions from aluminium electrolysis, aluminium ingot casting, anode/paste production, as well as emissions from generating electricity and heat consumed in these processes. This paper therefore follows the Carbon Trust's precedent by defining low-carbon aluminium as any metal made with an emissions intensity below 4 tCO2/tAl as measured according to level 1 of IAI guidelines.

As the integration of renewable energy into aluminium production continues to progress, downstream aluminium producers in Korea face an increasingly stark choice between low-carbon and high-carbon forms of primary aluminium. As the next chapter will establish, the public and private sector forces driving the green transition are set to not only elevate overall demand for aluminium but provide Korean producers with an opportunity to differentiate their products on the basis of low-carbon sourcing.

2 IAI, Primary Aluminium Smelting Power Consumption, https://www.world-aluminium.org/statistics/primary-aluminium-smelting-power-consumption/#data
3 Information on the emissions intensity of imported unwrought aluminium was compiled by En+ Group using data from CRU

CHAPTER 2:
THE EMERGENCE OF LOW-CARBON ALUMINIUM AS A DIFFERENTIATOR

Low-carbon materials for a low-carbon economy

As the world embraces green innovations, governments, businesses, and consumers are increasingly supporting a parallel drive to ensure the materials used for this revolution are consistent with their environmental values. This movement is already underway in Korea but is set to accelerate over the coming years as the Korean government implements its Green New Deal and low-carbon industries continue to mature.

This chapter will highlight the existing policies established by the Korean government to drive a general transition towards low-carbon materials. It then uses specific examples from the automotive and construction sectors to illustrate the increasing rate at which low-carbon aluminium will become a differentiator for Korean producers selling to these businesses.

Driving demand for low-carbon materials: The impact of public sector procurement

As previously noted, the Korean government has clearly indicated its belief that "the public sector is in the best position to show its commitment to and progress in GHG emissions reduction." (GRK 2020, 110). This commitment is already underpinned by a strong system for directing public procurement towards low-carbon materials—an approach that has significant knock-on impacts for the broader economy.

Passed in 2005, Korea's Act on Promotion of Purchase of Green Products is globally recognised as a best practice example of green public procurement (GPP) (UNEP, KEITI 2019, x). The act requires government agencies to submit annual GPP implementation plans to the Korea Environmental Industry & Technology Institute (KEITI), setting voluntary targets and reporting on GPP performance. These agencies are given fiscal incentives to improve GPP, including large budgets and performance bonuses. In addition, the Ministry of Environment is mandated every five years to publish an Action Plan for Promotion of Purchase of Green Products. To support the implementation of

USD 759m
KOREA GPP 2006

USD 2,945m
KOREA GPP 2017

GPP across the public sector, Korean authorities have established a series of green product standards and certifications, ranging from the Carbon Footprint Labelling mark, which requires disclosure of a product's lifecycle emissions, to the Low Carbon Products label, which identifies products with lower-than-average emissions, and the Good Recycled Mark.

Korea's system for GPP has achieved considerable success from both an environmental and economic perspective. Between 2006 and 2017, GPP rose from USD 759 million to USD 2,945 million, with green product procurement as a percentage of total expenditure reaching 47.5% (UNEP, KEITI 2019, x). Over the same period, the number of certified products increased from 2,721 to 14,647 (UNEP, KEITI, 26). The strategy has also been extended to consumers through the Green Credit Card, rewarding the 20 million Koreans who have signed up to the scheme for spending on certified products.

"Korea's GPP policy could "create macroeconomic benefits in the range of USD 56 million to USD 117 million"

The success of the current system for GPP is likely to spur further development of the Korean government's approach. As noted in a study by the United Nations Environmental Program (UNEP) and KEITI, Korea's GPP policy could, by 2030, "create macroeconomic benefits in the range of USD 56 million to USD 117 million in terms of costs savings from GHG mitigation." An indication of growing ambition can be seen in Seoul, where authorities are aiming to reach 90% GPP by 2022.

As well as increasing GPP, the Korean government has set out plans in the Carbon Neutral Strategy to direct more private capital to green products, businesses and projects. The government is committed to developing a green taxonomy similar to that proposed by the European Union, which would help investors identify sustainable investment opportunities and dismiss greenwashing. Moreover, the Carbon Neutral Strategy sets out plans for realigning "the environmental information disclosure system and encouraging businesses, especially listed ones, to disclose their environmental information" (GRK 2020, 120).

"A comprehensive assessment of overall environmental impacts needs to be conducted in developing low-carbon technologies."

Importantly for considering the consequences of the green transition on demand for low-carbon materials, the Korean government makes it clear in the Carbon Neutral Strategy that its policies will be underpinned by a lifecycle approach to considering climate impacts. It notes that "a comprehensive assessment of overall environmental impacts needs to be conducted in developing low-carbon technologies." Building on this, the government sets out plans for "a common [Lifecycle Assessment] model to assess overall environmental impacts of the technologies at R&D state so that it could be used in developing R&D strategies as well as in policymaking for promoting technologies" (GRK 2020, 124).

Putting lifecycle assessments at the heart of GPP policy and disclosure standards will make low-carbon material sourcing a key part not only of winning government contracts but also of attracting private investment and continued revenues. As disclosure of lifecycle emissions move further into the mainstream, Korea's aluminium producers will, like every other business, be expected to report the climate impacts of their supply chains, arming investors and customers with new data to inform selection of the most sustainable materials.

Demand for low-carbon aluminium in the age of zero-emission vehicles

Charting a sustainable future for transportation is a major challenge for societies around the world. Transport currently accounts for approximately a quarter of global CO2 emissions, with road transport alone contributing 18% (Winkler et al. 2020, 4).

14%
decline in overall car sales

In response to the climate crisis, auto manufacturers are moving inexorably away from the internal combustion engine and towards new forms of transport—in particular, electric vehicles (EVs). In 2020, EVs defied a 14% decline in overall car sales to achieve 40% sales growth and a record market share of over 4% (Gorner & Paoli 2020). As

McKinsey noted in September last year: "If the current tailwinds for EVs in China and Europe persist, electric mobility could emerge from the COVID-19 crisis in an even stronger position than pre-crisis estimates had predicted" (Gersdorf et al. 2020). On the back of this growing demand, annual EV sales are expected to reach 23 million in 2030, compared to 3 million last year, while the total number of EVs on the road will hit 130 million (Gorner & Paoli 2020).

Helping to drive the growth of EVs is a willingness from consumers to pay a premium for zero-emission vehicles. In a global survey, Deloitte found 40% of people would be willing to pay up to EUR 2,500 more for an EV (Deloitte 2020, 30). This figure increased for individuals from Gen Y/Z, almost 20% of whom said they would be prepared to pay over EUR 2,500 (Deloitte 2020, 31).

The share of non ICE vehicles has quadrupled over the past three years

These global trends are reflected in Korea's domestic market. Over the past three years, the share of non-internal-combustion-engine (ICE) vehicles has quadrupled (GRK 2020, 42). In 2020, EV exports rose 60.1% to 121,825, while domestic sales rose 62% to 25,691 (MOTIE 2021). The domestic market looks set for further growth, with 57% of Koreans saying that plan to buy a non-ICE vehicle for their next car (Deloitte 2021, 5).

1/3

new vehicle sales EVs and hydrogen fuel cell vehicles by 2030

With transport accounting for 14% of Korea's GHG emissions (GRK 2020, 9) and 13% of airborne particulate matter (GRK 2020, 74), the transition to zero-emission vehicles forms a central pillar of the Korean government's green transition plans. In the Carbon Neutral Strategy, the government set the goal of establishing "the world's most competitive future mobility industry by 2030… [by] intensively investing in technology innovations in green vehicles production while coming up with various incentive programmes to boost domestic demand for eco-friendly vehicles" (GRK 2020, 42). Over the past five years, subsidies for EV purchases have increased almost nine-fold to KRW 6,330 million (GRK 2020, 42), while more than KRW 1.2 trillion has been set aside in 2021 to help subsidise EVs and charging infrastructure (MoE 2021a). The government has said these vehicles will make up 80% of new public sector purchases, while private companies will be encouraged to sign up to a K-EV100 project to convert 100% of their fleets to low- and zero-emission vehicles (MoE 2021b). The end goal for the Korean authorities is for EVs and hydrogen fuel cell vehicles to make up one third of new vehicles sales by 2030, with 3 million EVs and 0.85 million hydrogen vehicles on the road (GRK 2020, 76).

To achieve this goal, the Korean government is also making major investments in EV charging infrastructure, with the aim of having 500,000 charging stations by 2025 (Kang 2020). From 2022, new buildings will also be required to install a set number of charging stations for prospective residents (Kang 2020).

0.5x

weight of aluminium compared to steel - saving 13-23 tn C02 over a vehicle's lifetime

The global transition to EVs is set to become a major driver of aluminium demand, due in large part to the metal's lightweight properties. Every 1 kg of aluminium used in car production is able to replace 2 kg of steel (Fitzpatrick, Synagowitz & Snowdon 2020, 9)—an important factor considering that for every 100 kg of weight saved, an EV's milage increases by 10-11% and battery costs fall by 20% (Stall 2020). From a climate perspective, the lightweight properties of aluminium mean every tonne of the metal used to replace heavier materials can save between 13 and 23 tonnes of CO2 over a vehicle's lifetime (Fitzpatrick, Synagowitz & Snowdon 2020, 9), with the environmental impact becoming more pronounced as the size of the vehicle increased. A combination of these factors means that the average amount of aluminium used in an EV is 30% higher than in an ICE vehicle (Desai 2020).

Aluminium demand from the automotive sector could nearly double between 2020 and 2025

The higher volumes of aluminium required by EVs will have a significant impact on demand dynamics. Wood Mackenzie forecasts that aluminium demand from the automotive sector could nearly double between 2020 and 2025, with the auto industry consuming 3.3% of all primary material (Desai 2020). This growth trend is set to accelerate in the latter half of the decade, with aluminium demand from car manufacturers projected to

27%
predicted rise of alumunium semi consumption in Korea by 2025

be 10 times higher in 2030 than it was in 2017 (Dinsmore 2018). In this scenario, the road transport sector could account for approximately a quarter of total demand growth for aluminium between now and the end of the decade (Jones et al. 2019, 19). The aluminium demand trends seen at a global level are reflected in the domestic Korean market, where consumption of aluminium semis by the automotive sector are set to rise over 27% between 2020 and 2025 to 709 kt (En+ Group / CRU 2021).

Accelerating aluminium demand from the automotive sector could have severe climate impacts if low-carbon materials are not specified. Currently, materials production is responsible for 18% of emissions in the automotive industry. However, as noted by McKinsey, the decline in tailpipe emissions resulting from the transition to EVs means "emissions from vehicles' materials will increase both absolutely and relatively and soon become a larger share of life-cycle emissions." McKinsey estimates that "the growing market share of battery electric vehicles that have higher baseline material emissions—and the changing energy mix required to power them—will boost material emissions from 18 percent of vehicles' life-cycle emissions today to more than 60 percent by 2040" (Hannon et al. 2020).

"The growing market share of battery electric vehicles that have higher baseline material emissions—and the changing energy mix required to power them—will boost material emissions from 18 percent of vehicles' life-cycle emissions today to more than 60 percent by 2040"

While rising emissions from materials use in the automotive sector is a significant risk, effective and practical pathways exist for mitigating the potential climate impact. Analysis by McKinsey shows the industry could abate 66% of emissions from materials production at no extra cost by 2030. It notes that 60% of these costs-positive decarbonisation approaches involve aluminium or plastics, with the potential to abate more than 73% of emissions linked to aluminium through use of recycled materials or sourcing from low-carbon smelters (Hannon et al. 2020). A major impact could come from inert anode smelting technology, currently being developed by companies such as En+ Group and a joint venture between Rio Tinto and Alcoa. This approach to smelting uses anodes made from platinum or graphite rather than carbon, meaning they do not degrade during the aluminium production process. As a result, oxygen is created as a by-product rather than carbon dioxide. The potential of this technology as an industrial scale solution was shown in April of this year, with En+ Group producing aluminium that had process emissions of just 0.01 tCO2/tAl (En+ Group 2021). McKinsey predicts that rollout of inert anode technology could eliminate 0.4 tonnes of CO2 per vehicle. With the cost of transitioning to low-carbon materials shown by McKinsey to be relatively low for automotive manufacturers, only a small incentive will be required for these companies to begin making demands of their suppliers.

90%
of consumers deem sustainable materials and important factor for EVs

The incentive for change is already apparent in consumer sentiment. In a global survey by McKinsey, over 90% of consumers said they deem sustainable materials an important factor for EVs, with approximately 60% describing the issue as moderately or extremely important (Garibaldi et. al 2021). This trend was reflected in Asia, where sustainable materials were ranked as important by a higher proportion of respondents than low-emission manufacturing and end-of-life recycling (Garibaldi et. al 2021). At the opposite end of the spectrum, failure to demonstrate sustainable sourcing could reinforce existing resistance to EV adoption by the 39% of consumers who believe EVs have a comparable or worse impact on the environment compared to ICE vehicles (Deloitte 2020).

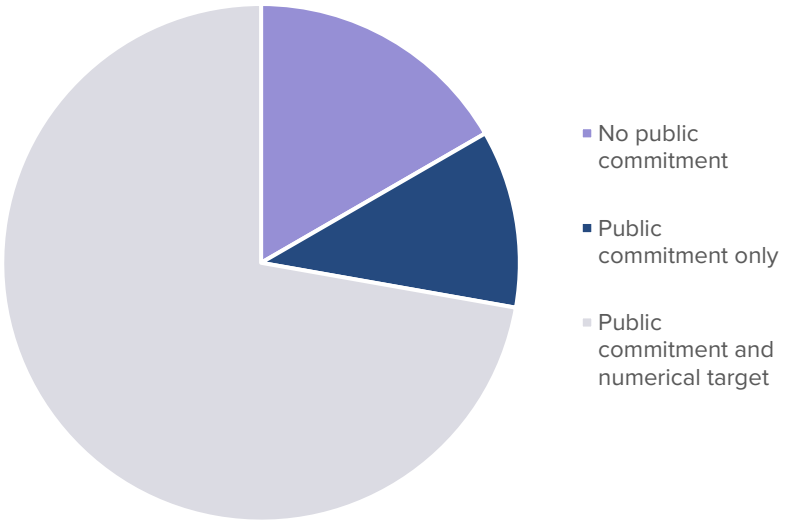
Recognising the direction of consumer sentiment, automotive executives are rapidly shifting their approaches to sourcing—a transition that will have significant implications for aluminium producers in Korea aiming to remain competitive in the coming decades. In a global survey of automotive executives, KPMG found 98% believe sustainability is a key differentiator (KPMG 2020, 25). Moreover, 48% of executives said they view sustainability as a product feature, meaning it is integral for the product itself, rather than marketing, to demonstrate sustainability credentials (KPMG 2020, 24). If the product itself is viewed as core to differentiation on the basis of sustainability, the implication is

that vehicles will need to be sustainable throughout their lifecycle, or risk being accused of greenwashing. This view is supported by research conducted by Capgemini, which found sustainable supply chains ranked in the top five priorities for global automotive executives (Winkler et al. 2020, 11).

83%
manufacturers committed to addressing lifecycle impact of their cars

Around the world, we are seeing this executive sentiment translating into tangible actions designed to shift automotive supply chains towards low-carbon materials. In a review for this paper of sustainability policies at global automotive manufacturers, 83% were found to have specific commitments to addressing the lifecycle impact of their cars. Moreover, almost three quarters had numerical commitments on this issue.[4]

Commitments by global OEMs to tackling lifecycle emissions



In a clear signal of the industry's trajectory, companies such as Jaguar Land Rover and Daimler have committed to carbon neutral supply chains. Meanwhile, in an interview with Business Green, Polestar's head of sustainability, Fredrika Klarén, stated the manufacturer's intention to achieve full sourcing transparency, transition to renewable energy throughout its supply chain and move to circular and innovative materials. Klarén stated: "We will not wait for customers to demand solutions—but instead take a proactive approach to educate and deliver attractive, sustainable offers to them" (Klarén 2021).

To back up these long-term commitments, automotive manufacturers are acting now to increase their proportion of sustainable sourcing, with numerous initiatives specifically targeting aluminium. In January of this year, Audi became the first car manufacturer to be awarded the Aluminium Stewardship Initiative's Chain of Custody certificate (Audi 2021). Its German rival, BMW, announced at a similar time this year that it would be sourcing aluminium made using solar electricity as part of its aim to reduce emissions in its supplier network by 20%. The company believes aluminium made using renewable energy can cut 2.5 million tonnes of CO2, equivalent to 3% of its supply chain emissions (BMW 2021). Jaguar Land Rover, meanwhile, has said it plans to use recycled aluminium from drinks cans and end-of-life materials to reduce its emissions by up to 26% (Mace 2020). Volvo is pursuing a similar approach, launching a partnership with aluminium roller Novelis to create a closed-loop recycling system it hopes will cut the footprint of its aluminium sheet by 78% (Bloxsome 2019).

These trends extend to Korea, where, in December 2020, Hyundai Sungwoo, the main

4 OEMs studied include Toyota, Volkswagen, BMW, Volvo, GM, Mitsubishi, Ford, Honda, Daimler, Hyundai, Nissan, Mazda, Suzuki, JLR, Stellantis, Renault, Tata Motors and Mahindra

partner of Hyundai Motors Group, named low-carbon aluminium producer Rusal as its preferred long-term supplier of primary aluminium alloys (Rusal 2021). GM, which has major manufacturing operations in the country, has committed to use at least 50% sustainable material content in its vehicles by 2035.[5] Meanwhile, Renault, which holds an 80% stake in Korean manufacturer Renault Samsung Motors, pledged to cut the lifecycle emissions of its vehicles by 25% between 2010 and 2022 and is aiming for net zero by 2050.[6]

The international mix of automotive manufacturers committed to sustainable sourcing initiatives is particularly important for Korean aluminium producers, for whom export markets are often as important as domestic customers. In 2020, sales of plate and strip aluminium, which account for 81% of production, were 597 kt for the domestic market and 426 kt for export (En+ Group / CRU 2021). Even for aluminium producers not involved in exports, the trend in the automotive industry towards sustainable materials will only grow among domestic automotive and automotive parts manufacturers, who will be expected by customers both in Korea and worldwide to match the climate actions of their global peers.

"The benefits of lightweighting alone will not enable aluminium to compete on carbon footprint with steel equivalents."

For aluminium producers in Korea selling into the automotive sector, the impetus to source low-carbon aluminium is further strengthened when considered in the context of competition with the steel industry. As previously noted, aluminium has previously held an advantage over high strength steel in terms of its lightweight properties, meaning it has replaced the heavier metal in some auto parts. However, as focus shifts onto the carbon footprint of materials, favour could swing back towards steel, given its lower average emissions intensity. Only low-carbon aluminium has a carbon footprint competitive with steel. This has the potential to become an environmental performance advantage for low-carbon aluminium once automakers factor in that they will need less batteries—and therefore less high-polluting battery components—given the lighter weight of their vehicles. The key determinant in this equation will be the low-carbon origin of the primary material—without this, the benefits of lightweighting alone will not enable aluminium to compete on carbon footprint with steel equivalents.

The rapid growth of the EV industry both in Korea and internationally presents a major growth opportunity for the aluminium industry over which producers around the world will be competing. It is clear from recent initiatives launched by automotive manufacturers that low-carbon materials will become a key differentiator. It is therefore imperative for Korea's aluminium producers to engage with their supply chain to ensure they have the low-carbon inputs they need to remain competitive at home and abroad.

Low-carbon aluminium at the foundation of a green building boom

As we progress towards the middle of the century and the world's population approaches 10 billion people, the global building stock is expected to double in size (Adams et al. 2019, 7). With buildings currently responsible for 39% of global energy-related carbon emissions, this steep increase in new building could have a profound impact on the state of the planet. In response to the climate crisis, the World Green Building Council (WGBC) is putting pressure on the construction companies to realise the 84 gigatonnes of CO2 savings possible across the industry by 2050.[7]

28%
buildings-linked emissions embodied in construction materials

While there is considerable focus on the potential for energy efficiency to deliver reductions in operational emissions from buildings, tackling the climate impacts embodied in construction materials is also critical. In total, approximately 28% of emissions linked to buildings come embodied in construction materials, accounting for 11% of total global energy related carbon emissions worldwide (Adams et al. 2019, 16). This figure is rising, with embodied emissions forecast by the WGBC to be responsible for half of the entire carbon footprint of new construction between now and 2050 (Adams et al. 2019, 17). As a result, the WGBC is leveraging its global network of green

5 See General Motors, "Sustainability", https://www.gm.com/citizenship/sustainability.html
6 See Renault, "Carbon Footprint", https://group.renault.com/en/our-commitments/respect-for-the-environment/carbon-footprint/
7 See World Green Building Council, "The benefits of green buildings", https://www.worldgbc.org/benefits-green-buildings

building councils to push for a 40% reduction in embodied carbon emissions by 2030 and for buildings, infrastructure and renovations to reach net zero embodied carbon by 2050 (Adams et al. 2019, 16).

Surveys of both decision makers in the construction industry and consumers in numerous countries suggests an alignment with the World Green Building Council's vision for reduced embodied emissions. Collecting information from specifiers, installers and distributors in the construction industry, Saint-Gobain found 76% want their suppliers to be transparent about the impact of their products and 72% want manufacturers to provide sustainable products (Saint-Gobain 2018). Meanwhile, in a survey of consumers in the United Kingdom, United States and Germany, En+ Group found over half of people in these countries believed governments should deny new building requests to projects with higher carbon footprints (En+ Group 2020, 10).

10,000
G-SEED certified buildings between 2002-2018

The global trend towards green building is reflected in the Korean market. Recognising that the building sector is responsible for approximately 7% of total emissions (GRK 2020, 10), Korean authorities have established an effective system for encouraging green construction projects. At the heart of this is the country's own certification scheme, G-SEED, which provides points to buildings based on everything from energy efficiency and low-carbon materials to water management and sound insulation. Performance on G-SEED is linked to incentives including building property and registration tax reductions and support for environmental improvement costs. According to KEITI, 10,000 buildings were certified by G-SEED between its creation in 2002 and 2018. By 2019, the rate of certification of multi-residential buildings had reached 28%, with rates of 27% and 15% respectively for schools and commercial facilities (Kim et al. 2020, 2).

25%
target reduction of carbon emissions by buildings

The growth of green building in Korea is set to accelerate over the coming decade. Under the country's Third Basic Building Policy Plan for 2021 to 2025, the Ministry of Land, Infrastructure, and Transport (MOLIT) is aiming to reduce carbon emissions from buildings by 25% (MOLIT 2021a). A key part of this is increasing the construction of 'Zero-Energy Buildings' (ZEBs)—an approach to architecture that prioritises energy efficiency and self-sufficient power generation. Starting from 2020, all new public buildings will be built to ZEB standards and, from 2030, private buildings over 500 m2 will have to be certified (GRK 2020, 10). In support of the self-sufficiency aspect of ZEBs, the government is also targeting a 40% increase in the use of distributed energy resources by 2040 (GRK 2020, 61). Moreover, a ZEB Innovation Organisation composed of the Korea Land and Housing Corporation, Korea Real Estate Agency, Korea Energy Corporation and Korea Institute of Construction Technology has been established to drive R&D in areas such as solar panel installation and energy consumption analysis. For existing buildings, the Korean government is exploring tax cuts and grants for green retrofits. Public authorities will lead the way in this area, retrofitting 225,000 public housing units, 2,890 school buildings, 2,000 medical centres and 1,000 cultural facilities using renewable energy solutions, improved building insulation and "eco-friendly" construction materials (GRK 2020, 111).

As global construction continues to expand, demand for aluminium is forecast to rise, with the green building movement likely to direct sourcing increasingly towards low-carbon materials. Lightweight, easy to extrude and durable, aluminium is a go-to material in areas such as curtain wall framing, windows, and partitions. Aluminium's reflective properties also make it popular for cladding in energy efficient buildings. The reflective cladding can help manage natural light in ways that reduce the need for electric lighting, keep the building cool when sunlight is strong and provide an insulating layer for cold weather. Moreover, aluminium foil is a popular component in insulation, offering both the ability to reflect infrared heat and an impermeable barrier to light and moisture.

24%
of aluminium demand from buildings

As a result of aluminium's versatile uses, buildings account for 24% of all demand for the metal (WEF 2020, 9). In Korea, demand from the construction industry is set to increase

over 18% between 2020 and 2025, reaching 260 kt—the largest source of demand after the automotive industry (En+ Group / CRU 2021). Use of aluminium will rise yet further as a result of the Korean government's focus on energy self-sufficiency for ZEBs. The metal accounts for 85% of most solar panel components (WEF 2020, 9), making it an essential element for the installation of renewable generation capacity in new and existing buildings.

42%
total embodied carbon emissions in wood-framed buildings made up of aluminium

As with the rise of EVs, the increased demand for aluminium from a growing construction sector presents a potential contradiction to Korea's aspirations for a green transition. Currently, aluminium manufacturing is the third highest source of GHG emissions in the construction materials sector (BioNova 2020, 8). However, recent research by BioNova has suggested that significant abatement can be achieved through the specific selection of low-carbon aluminium. It found that aluminium can account for 42% of total embodied carbon emissions in wood-framed buildings, but that switching to a low-carbon variant of the metal could reduce this climate impact by up to a fifth (BioNova 2020, 2). BioNova found similar potential for commercial buildings, where low-carbon aluminium could reduce emissions by 7% (BioNova 2020, 11), and in retrofits, where emissions fell 11% (BioNova 2020, 3). The BioNova study also examined the embedded emissions of individual building components made from aluminium. For partition walls, curtain walls and windows, replacing conventional aluminium with low-carbon aluminium reduced embedded emissions by 29%, 32% and 43% respectively (BioNova 2020, 16-18).

20%
G-SEED certification system made up of points for materials and resources

The emissions reduction potential of low-carbon materials is already reflected in Korea's green buildings standards, meaning that, as uptake of this certification system increases, it will be ever more important for aluminium producers to secure low-carbon primary metal. Currently, points for materials and resources make up just below 20% of the G-SEED certification system (Wang et al. 2019, 5). This makes low-carbon materials particularly important for winning government procurement contracts, for which building materials are the largest share at almost 50% of total GPP (UNEP/KEITI 2019, 26). Ensuring emissions embodied in materials are as low as possible will also be essential for Korean aluminium producers aiming to export to global customers in the construction sector. As BioNova points out: "Measuring and optimizing embodied carbon is a standard requirement in green building rating systems" and is "particularly true of international systems, such as LEED and BREEAM" (BioNova 2020, 12).

Through the continued growth of the construction sector and the increasing importance of energy efficiency and distributed power generation, Korean aluminium producers can secure a strong market for their materials. However, with green building practices becoming ever more embedded in the approaches taken by the public and private sector, producers will have to differentiate themselves, ensuring they have the low-carbon materials to match visions of a more climate-conscious society.

CHAPTER 3:
CONCLUSION & RECOMMENDATIONS

From the rise of electric vehicles to a boom in green building, the green transition provides an unprecedented opportunity for aluminium producers around the world. The dynamics in Korea are favourable, with the government setting clear commitments to a low-carbon economy and building on established systems for innovation and public procurement. Within this context, downstream aluminium producers in Korea are well-placed to reap the benefits of a burgeoning domestic market and growing demand from green industries around the world. However, as illustrated by moves in the automotive and construction industries to address lifecycle sustainability and embedded emissions, Korean producers will need to ensure the climate impacts of their metal aligns with the environmental vision of their customers, governments and consumers around the globe. Fail to act fast enough and they risk being left behind.

Recommendations for Korean aluminium producers

1. Work with suppliers to enhance emissions disclosure across the supply chain

Tackling emissions in the aluminium supply chain will not be easy. It will require collaboration up the supply chain and a clear articulation to customers that, while change cannot happen overnight, a plan is in place that aligns decarbonisation of materials with the journey towards a low-carbon economy. A starting point will be for downstream aluminium producers to ask for transparency on carbon emissions from their suppliers. As recommended by the Carbon Trust, this should begin with a requirement for emissions disclosure in line with the IAI Level 1 guidelines, which cover emissions from aluminium electrolysis, aluminium ingot casting, anode/paste production, as well as emissions from generating electricity and heat consumed in these processes (CT 2020, 14). Disclosure requirements could then be expanded over the course of a few years until they encompass full lifecycle emissions, giving upstream producers time to collect the information they need to make these sometimes-complex calculations.

2. Set phased decarbonisation pathways that encourage suppliers to transition to low-carbon production models

In parallel with the phased expansion of disclosure, a decarbonization pathway might be collaboratively agreed between downstream aluminium producers and their suppliers. This would begin with the areas that are easiest to control at the smelter and company-owned energy assets while providing more time for upstream producers to engage with external energy providers as well as suppliers of alumina or bauxite. A clear requirement that metal is not produced using coal-based electricity could be considered by companies as a steppingstone to more sophisticated requirements based on emissions intensity and, eventually, integrated assessments of overall sustainability such as Aluminium Stewardship Initiative certification.

Engagement with suppliers is preferable, as it will ensure the aluminium industry successfully transitions to low-carbon modes of production. However, where suppliers do not provide any pathway to decarbonisation, Korean aluminium producers will be able to clearly signal their support for a green transition by sourcing low-carbon materials widely available from numerous international suppliers.

3. Accelerate decarbonisation through collaboration across the value chain

Progress on decarbonisation could be accelerated through richer collaboration between Korean aluminium producers and their suppliers. This could include joint research and development, channelling investment to promising innovations and coordinating advocacy in areas such as renewable energy expansion or recycling infrastructure. Such initiatives could be given further weight by drawing in aluminium customers to support efforts. A potential model for this coordination could be the 100+ Accelerator founded by AB InBev and supported by major companies such as Unilever, Coca-Cola and Colgate-Palmolive. By collaborating across the value chain, the initiative is helping fund and develop everything from circular packaging innovations to renewable heat solutions.[8]

Recommendations for policymakers

While there is a market incentive for aluminium producers in Korea to engage with their suppliers, there are also actions policymakers in the country can take to help with this transition.

1. Set standards for disclosing embodied emissions and provide support on compliance

First, Korean authorities can make it easier for purchasers of aluminium to distinguish low-carbon from conventional materials. This could begin by setting suggested or mandatory guidelines on emissions disclosure for companies above a certain size. These should include requirements relating to embodied emissions and come with guidance for companies on how to make these calculations. Such a policy could be implemented in phases, beginning with key exporting industries that have high embodied emissions, such as the automotive industry. Guiding these companies towards more comprehensive disclosure would incentivise action on embodied emissions in the industries where it matters most while also ensuring exports are able to compete in a global low-carbon market.

2. Establish benchmarks for what constitutes low-carbon aluminium through public procurement and eco-labels

Authorities could also use public procurement rules to set clear benchmarks for what constitutes low-carbon aluminium. For example, Korea's Lifecycle Inventory Database (LCI DB) is currently used to help with the calculation of lifecycle emissions by providing average emission intensities for different products. The database currently includes specific fields for aluminium ingots and chips made from recycled materials and could be expanded to include calculations for low-carbon aluminium. This addition to the

8 See AB InBev, "Accelerator 100+", https://www.100accelerator.com/

database would help highlight the extent of emissions savings from using low-carbon aluminium, as well as providing a reference against which businesses can evaluate their current aluminium sourcing.

In addition to expanding the LCI DB, Korean authorities could consider integrating specific benchmarks for low-carbon aluminium into the existing standards for the Low-Carbon Products label and the upcoming green taxonomy. For consistency, these benchmarks should follow the recommendations made by the Carbon Trust, setting a carbon footprint of 4 tCO2/tAl according to the IAI's Level 1 guidelines as the initial standard for low-carbon aluminium and expanding the scope of mandatory disclosure over a three year period.

Taken together, the policies above would support the establishment of a distinct market for low-carbon aluminium. The creation of such a market would empower Korean businesses to source low-carbon materials while having to invest considerably less time and effort identifying which suppliers meet the right standard.

3. Implement differentiated import tariffs low-carbon aluminium

Finally, Korean authorities could make low-carbon aluminium easier to source for both the country's aluminium producers and end-users of the metal by removing tariffs on imports of primary materials that align with the benchmarks described above. Currently, tariffs on aluminium imports from countries not covered by trade agreements range from 1% for non-alloyed aluminium to 8% on wire rods.[9] Lowering or removing tariffs for low-carbon aluminium would not only make it cheaper for Korean industries to purchase but also send a signal to primary metal producers, incentivising them to decarbonise and increasing the overall availability of sustainable materials.

The green wave is set to sweep away many of our old polluting systems and in their place leave something new—a tide of innovations with incredible potential to enhance livelihoods, nurture the planet and enhance economic prosperity. However, achieving a truly sustainable transition will require collaboration beyond the headline projects of EVs and green buildings. From green innovation will come a surge in demand for materials like aluminium, which, if not sourced in a sustainable manner, could undo much of the good work instituted through climate policies. The importance of a lifecycle approach to decarbonisation is increasingly recognised across governments and by international businesses. With effective systems for sustainable certification coupled with burgeoning green industries, Korea provides a strong environment from which the country's aluminium producers can seize the opportunity of a global low-carbon transition. Green businesses are set to be a driver of growth for the Korean aluminium industry; however, with sustainable businesses increasingly demanding materials to match their low-carbon vision, producers will need to collaborate with their suppliers to meet this need. Failure to align with the climate goals of customers, be they in the private or public sector, could leave producers out in the cold. However, those that successfully get ahead of these demands and have low-carbon materials ready to supply will enjoy a win-win—what is right for profits and what is essential for our planet.

9 ITC, "Market Access Map", https://www.macmap.org/

REFERENCES

Adams, Matthew, Victoria Burrows, Stephen Richardson, James Drinkwater, Christine Collin, Xavier Le Den, Lars Ostenfeld Riemann, Samy Porteron, Andreas Qvist Secher, “Bringing embodied carbon upfront”, World Green Building Council, 2019, London, UK

Audi, “Audi is the first car manufacturer to be awarded the Chain of Custody – the certificate of the Aluminium Stewardship Initiative”, 1 April, 2021, Ingolstadt, Germany, https://www.audi-mediacenter.com/en/press-releases/audi-is-the-first-car-manufacturer-to-be-awarded-the-chain-of-custody-the-certificate-of-the-aluminium-stewardship-initiative-13543

BioNova, “Low-Carbon Aluminium: Solutions for Sustainable Construction & Renovation”, 2020, Helsinki, Finland

Bloxsome, Nadine, “Novelis and Volvo Cars Create Automotive Closed-loop Recycling System”, Aluminium International Today, 13 December, 2019, Redhill, UK, https://aluminiumtoday.com/news/novelis-and-volvo-cars-create-automotive-closed-loop-recycling-system

BMW, “Harnessing the power of the desert sun: BMW Group sources aluminium produced using solar energy”, 2 February, 2021, Munich, Germany, https://www.press.bmwgroup.com/global/article/detail/T0325353EN/harnessing-the-power-of-the-desert-sun:-bmw-group-sources-aluminium-produced-using-solar-energy?language=en

Carbon Trust, The Case for Low Carbon Primary Aluminium Labelling, 2020, London, UK

Deloitte, “2020 Global Automotive Consumer Study”, 2020, New York, US

Deloitte, “2021 Global Automotive Consumer Study”, 2021, New York, US

Desai, Pratima, “Auto parts makers shine spotlight on aluminium’s role in electric vehicles”, Reuters, 27 July, 2020, London, UK, https://www.reuters.com/article/us-aluminium-electric-autos-analysis-idUSKCN24S1QM

Dinsmore, Eoin, “Electric vehicles to transform aluminium demand”, CRU, 15 February, 2018, London, UK, https://www.crugroup.com/knowledge-and-insights/insights/2018/electric-vehicles-to-transform-aluminium-demand/

En+ Group, “Carbon Clarity”, 2020, Moscow, Russia, https://enplusgroup.com/en/company/glance/carbon-clarity/

En+ Group, “En+ Group Metals segment produces record-breaking high purity aluminium with world’s lowest carbon footprint”, 13 April 2021, Moscow, Russia, https://enplusgroup.com/en/media/news/press/en-group-metals-segment-produces-record-breaking-high-purity-aluminium-with-world-s-lowest-carbon-fo/

Fitzpatrick, Liam, Bastian Synagowitz, Nick Snowdon, “The hidden value in RIO’s Canadian aluminium business”, Deutsche Bank Research, 2020, Frankfurt, Germany

Garilbaldi, Matias, Eric Hannon, Kersten Heineke, Emily Shao, “Mobility investments in the next normal”, McKinsey, 4 March, 2021, New York, US https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mobility-investments-in-the-next-normal

Gersdorf, Thomas, Russell Hensley, Patrick Hertzke, Patrick Schaufuss, “Electric mobility after the crisis: Why an auto slowdown won’t hurt EV demand”, McKinsey, September, 2020, New York, US, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/electric-mobility-after-the-crisis-why-an-auto-slowdown-wont-hurt-ev-demand

Gorner, Marine, Leonardo Paoli, “How global electric car sales defied Covid-19 in 2020”, International

Energy Association, 28 January, 2021, Paris, France, https://www.iea.org/commentaries/how-global-electric-car-sales-defied-covid-19-in-2020

Government of the Republic of Korea, Carbon Neutral Strategy of the Republic of Korea, 2020, Seoul, Republic of Korea

Hannon, Eric, Tomas Nauclér, Anders Suneson, Fehmi Yuksel, "The zero-carbon car: Abating material emissions is next on the agenda", McKinsey, 18 September, 2020, New York, US, https://www.mckinsey.com/business-functions/sustainability/our-insights/the-zero-carbon-car-abating-material-emissions-is-next-on-the-agenda

International Aluminium Institute, Aluminium Sector Greenhouse Gas Pathways to 2050, executive summary, 2021a, London, UK

International Aluminium Institute, Aluminium Sector Greenhouse Gas Pathways to 2050, position paper, 2021b, London, UK

Kang, Yoon-seung, S. Korea to build more EV charging stations, offer incentives for purchases, Yonhap, 2020, Seoul, Republic of Korea, https://en.yna.co.kr/view/AEN20201030002500320

Kim, Han Kee, Sang-Sub Jeon, Amina Irakoze, Ki-young Son, "A Study of the Green Building Benefits in Apartment Buildings According to Real Estate Prices: Case of Non-Capital Areas in South Korea", Sustainability, MDPI, 12(6), 2206, 2020, Basel, Switzerland

Klarén, Fredrika, "Reinventing the car industry: Transparency as a driver for change", Business Green, 16 February, 2021, London, UK, https://www.businessgreen.com/opinion/4027232/reinventing-car-industry-transparency-driver-change

KPMG, "Global Automotive Executive Survey 2020", 2020, Toronto, Canada,

Lee, Heesu, "South Korea Shuns Coal-Power Financing Amid Rising U.S. Pressure", Bloomberg, 22 April, 2021, Seoul, Republic of Korea, https://www.bloomberg.com/news/articles/2021-04-22/south-korea-shuns-coal-power-financing-amid-rising-u-s-pressure

Lim, Amanda, "'Reverse recycling': Korea actions new scheme to aid goal of recycling 10% of cosmetic packaging by 2025", Cosmetics Design Asia, 13 January 2021, https://www.cosmeticsdesign-asia.com/Article/2021/01/13/Korea-actions-new-scheme-to-aid-goal-of-recycling-10-of-cosmetic-packaging-by-2025

Mace, Matt, "Recycled aluminium could help Jaguar Land Rover reduce emissions by a quarter", edie, 21 August, 2020, East Grinstead, UK, https://www.edie.net/news/5/Recycled-aluminium-to-help-Jaguar-Land-Rover-reduce-emissions-by-a-quarter/

Ministry of Environment of the Republic of Korea, "2021 Ministry of Environment Budget and Fund Set at 11 Trillion 171.5 Billion Korean Won", 2 December, 2020a, Seoul, Republic of Korea, https://eng.me.go.kr/eng/web/board/read.do?pagerOffset=10&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=461&orgCd=&boardId=1427370&boardMasterId=522&boardCategoryId=&decorator=

Ministry of Environment, "2021 Government Affairs Report: 'Recovery, Inclusion, and Leaping Forward of Korea 2021 -Tangible Achievements for People, Carbon Neutrality for the Future'", 1 December, 2020b, Seoul, Republic of Korea, https://eng.me.go.kr/eng/web/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=461&orgCd=&boardId=1431530&boardMasterId=522&boardCategoryId=&decorator=

Ministry of Land, Infrastructure, and Transport of the Republic of Korea, "We will increase the value of everyday life and create a city where life is happy through architectural policy", 16 February, 2021a, Seoul, Republic of Korea, http://www.molit.go.kr/USR/NEWS/m_71/dtl.jsp?lcmspage=7&id=95085181

Ministry of Land, Infrastructure, and Transport of the Republic of Korea, “Established a dedicated organization (TF) for Zero Energy Building (ZEB) innovation”, 2 February, 2021b, Seoul, Republic of Korea, http://www.molit.go.kr/USR/NEWS/m_71/dtl.jsp?lcmspage=10&id=95085140

Ministry of Trade, Industry and Energy of the Republic of Korea, “Green car exports, domestic sales hit record high in 2020”, 14 January, 2021, Seoul, Republic of Korea, https://english.motie.go.kr/en/pc/pressreleases/bbs/bbsView.do?bbs_seq_n=826&bbs_cd_n=2&currentPage=1&search_key_n=&search_val_v=&cate_n=

Rusal, “Rusal becomes a preferred supplier to Hyundai Sungwoo”, 17 December, 2020, Moscow, Russia, https://rusal.ru/en/press-center/press-releases/rusal-becomes-a-preferred-supplier-to-hyundai-sungwoo/

Saint-Gobain, “SCORE by Saint-Gobain”, 2018, Paris, France

Stall, Robert, “How advancing mobility will disrupt the mining and metals sector”, EY, 2020, London, UK

United Nations Environment Programme, Korea Environmental Industry & Technology Institute, Green Public Procurement in the Republic of Korea: A Decade of Progress and Lessons Learned, 2019, Paris, France

Wang, Seongjo, Sungho Tae, Rakhyun Kim, “Development of a Green Building Materials Integrated Platform Based on Materials and Resources in G-SEED in South Korea”, Sustainability, MDPI, 11(23), 6532, 2019, Basel, Switzerland

Winkler, Markus, Caroline Segerstéen Runervik, James Robey, Philippe Vié, Sebastian Tschödrich, Florent Andrillon, Amol Khadikar, Jerome Buvat, Shahul Nath, Gaurav Aggarwal, “The Automotive Industry in the Era of Sustainability”, Capgemini, 2020, Paris, France

World Economic Forum, “Aluminium for Climate: Exploring Pathways to Decarbonize the Aluminium Industry”, 2020, Geneva, Switzerland