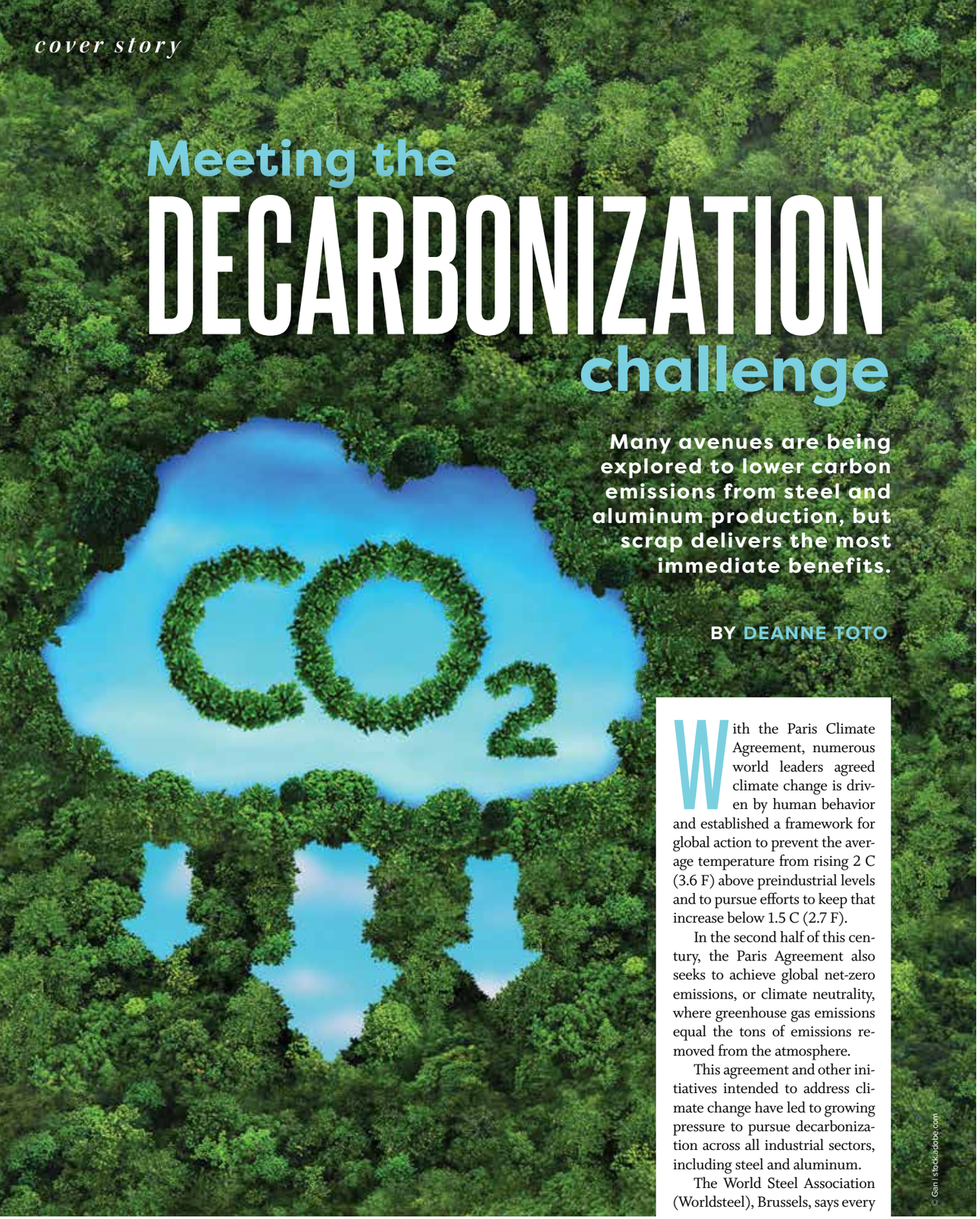

Meeting the DECARBONIZATION challenge

Many avenues are being explored to lower carbon emissions from steel and aluminum production, but scrap delivers the most immediate benefits.

BY DEANNE TOTO

With the Paris Climate Agreement, numerous world leaders agreed climate change is driven by human behavior and established a framework for global action to prevent the average temperature from rising 2 C (3.6 F) above preindustrial levels and to pursue efforts to keep that increase below 1.5 C (2.7 F).

In the second half of this century, the Paris Agreement also seeks to achieve global net-zero emissions, or climate neutrality, where greenhouse gas emissions equal the tons of emissions removed from the atmosphere.

This agreement and other initiatives intended to address climate change have led to growing pressure to pursue decarbonization across all industrial sectors, including steel and aluminum.

The World Steel Association (Worldsteel), Brussels, says every

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metric ton of steel produced in 2020 emitted 1.89 metric tons of CO_2 into the atmosphere. That year, Worldsteel says 1.86 billion metric tons of steel were produced, releasing 2.6 billion metric tons of CO_2, representing between 7 percent and 9 percent of global anthropogenic, or human-caused, CO_2 emissions.

Global steel demand is forecast to increase by 30 percent through 2050, according to the World Economic Forum, highlighting the need for emissions reductions in the sector.

"The modern world is made of steel, and steel is a primary material that will make a lower-carbon future possible," says Philip K. Bell, president of the Steel Manufacturers Association (SMA), the Washington-based group that represents the electric arc furnace (EAF) steel industry. "Reducing carbon emissions in the manufacturing of steel will be essential to meeting global greenhouse gas [GHG] emissions reduction."

Aluminum, which also is used in technology that enables the energy transition, such as solar panels, is another significant source of CO_2 emissions. According to the Paris-based International Energy Agency (IEA), aluminum production emitted nearly 270 million tons of CO_2 in 2022, about 3 percent of the world's direct industrial CO_2 emissions.

The London-based International Aluminum Institute (IAI) estimates aluminum demand could rise 80 percent by 2050 from the 2018 baseline of 95 million metric tons, illustrating the need to address the sector's emissions.

As these sectors work to lower their carbon footprints while increasing their production, scrap is playing a larger role as it is among the most immediate ways to realize a decrease in emissions. Other technologies, including renewable energy, used in combination with scrap could further reduce CO_2 emissions.

LOWER ENERGY, LOWER EMISSIONS

Aluminum and steel production are energy-intensive processes. Subodh Das, Ph.D., CEO of Clayton, Missouri-based Phinix LLC, says "decarbonization" is just another way to say less energy is being used in metal production.

"It takes lots of energy of all forms—electrical, thermal, hydro—to make aluminum," Das says.

Phinix offers research, development and technical and marketing consulting in process and product development and commercialization and recycling for light metals, electronics, municipal solid waste and rare earth elements.

Das says much of the energy—roughly 70 percent—used to produce primary aluminum is consumed in the third stage of the process when aluminum oxide is transformed into aluminum metal.

"Also, more than 70 percent or 80 percent of the energy required to make aluminum from alumina is mostly coal-based, with the exception of hydro-rich countries such as Canada or Iceland or Norway," he adds.

However, using recycled aluminum to make new aluminum requires only 5 percent of the energy used in primary aluminum production, while recycling ferrous scrap uses 75 percent less energy than processing iron ore.

"Scrap-based steelmaking in [EAFs] has 75 percent lower GHG emissions than steel produced by extractive integrated steelmaking, which requires vast amounts of iron ore and coal and is much more energy-intensive," Bell says.

In addition to using scrap, professor Chenn Zhou, Ph.D., of Indiana's Purdue University Northwest (PNW) says improving energy efficiency in steel production will lead to CO_2 reductions but adds that decarbonization also will involve transitioning to alternative energy sources that use less carbon. (For more on PNW's research into steel decarbonization, see the online version of this article at www.RecyclingToday.com/article/decarbonizing-aluminum-and-steel-production.)

THE EAF TRANSITION

While EAF steel production dominates in the U.S., comprising roughly 70 percent of the market, the ratio is reversed globally. However, given the lower emissions associated with EAF steelmaking, companies around the world have announced plans to transition from blast furnace(BF)/basic oxygen furnace (BOF) to EAF steelmaking.

Luxembourg-based steel producer ArcelorMittal is investing 1.7 billion euros ($1.95 billion) in Fos-sur-Mer and Dunkirk, France, to install EAFs in both cities and an accompanying direct reduced iron (DRI) plant in Dunkirk.

The board of Luxembourg-based steelmaker Ternium SA has approved construction of a 2.6 million-ton-per-year EAF steel slab production facility in Mexico to be complemented and supported by its new hot rolling mill that began operations at Pesquería in mid-2021.

The supervisory board of Austria-based Voestalpine AG approved 1.5 billion euros ($1.6 billion) to install EAF technology at two of its steel mill sites that use BF/BOF technology in Linz and Donawitz, Austria.

Australia-based BlueScope and its New Zealand Steel business unit are spending $198 million to convert its Glenbrook, New Zealand, BF/BOF steel mill to an EAF.

Algoma Steel Group Inc., Canada, is constructing two EAFs in Sault Ste. Marie, Ontario, to replace its BF/BOF

steelmaking operations.

Wood Mackenzie says EAF steel production is predicted to reach near parity with BF/BOF production by 2050.

"However, EAFs do not directly utilize iron ore inputs, are increasingly competing for a limited global pool of scrap and require high-quality iron ore inputs for ore-based metallics like DRI," Wood Mackenzie says, adding that a multitechnology approach that incorporates steelmaking routes beyond EAF production will be needed.

Bell says scrap scarcity should not be a concern. "There is more than enough scrap to meet the global transition to cleaner steelmaking [processes], and free and fair trade in scrap ensures that it gets where it needs to go," he says. "The U.S. exports about 20 million tons of ferrous scrap every year, for instance," he says.

"Companies in the U.S., Canada, the United Kingdom, Germany and other countries are investing billions of dollars in scrap-based steelmaking, and they wouldn't do that if they had any worries about scrap availability."

INCREASING SCRAP'S BENEFITS IN STEELMAKING

While scrap use alone considerably reduces emissions from steel production, Bell says, "Other promising low-emissions steelmaking processes—especially in combination with EAF scrap-based steelmaking—involve direct-reduced iron, hydrogen, carbon capture and storage and renewable energy production, including nuclear power. Some of these, such as on-site solar power, are already a significant part of day-to-day operations for many SMA members."

Charlotte, North Carolina-based Nucor Corp. offers one example, having committed to a 35 percent combined reduction in Scopes 1 and 2 GHG intensity by 2030, using 2015 baseline goals. This would take its CO_2 emissions down to 77 percent less than 2020's global steelmaking average, Nucor says.

"We are the North American leader in sustainable steelmaking, and these targets further highlight our leadership role in developing clean solutions for the entire steel industry, as well as empowering our customers to meet their business and environmental goals successfully," President and CEO Leon Topalian said.

In pursuit of this goal, Nucor is using renewable energy—noting it was the largest buyer of renewable energy in 2023—improving its energy efficiency; exploring carbon capture and sequestration; and evaluating long-term technologies that can transform steelmaking.

In the fall of last year, Nucor announced its collaboration with fusion power company Helion Energy Inc. to develop a 500-megawatt fusion power plant, offering baseload zero-carbon electricity from fusion directly to a Nucor steelmaking plant. The steelmaker is investing $35 million in Helion, which is based in Everett, Washington.

"This is the first fusion energy agreement of this scale in the world and will pave the way for decarbonizing the entire industrial sector," Nucor says. It estimates that deploying fusion at one of its largest mills could reduce its Scope 2 emissions by 500,000 tons annually.

Fort Wayne, Indiana-based EAF steelmaker Steel Dynamics Inc. (SDI), which also has a goal to be carbon neutral by 2050, has signed a renewable product purchase agreement with a subsidiary of NextEra Energy Resources LLC for 308 megawatts of energy to be produced by a new wind farm project in Scurry County, Texas, calling the agreement the largest of its kind for the steel industry in North America.

The project is expected to produce 1.1 million megawatt hours of electricity per year, equivalent to 16 percent of SDI's steel mills' electricity usage in 2022.

Steelmakers with significant BOF capacity also are exploring ways to lower their carbon footprints. Last fall, Pittsburgh-based U.S. Steel Corp., which operates BOF and EAF steel mills, signed a nonbinding memorandum of understanding with CarbonFree Chemicals Holdings LLC, San Antonio, to pursue the capture of CO_2 emissions from U.S. Steel's Gary Works manufacturing plant in Indiana using CarbonFree's SkyCycle technology. If a definitive agreement is reached, the project could capture and mineralize up to 50,000 metric tons of CO_2 annually.

U.S. Steel also is collaborating with the U.S. Department of Energy's National Energy Technology Laboratory to test an advanced membrane technology to capture CO_2 emissions at its Edgar Thomson Plant in Braddock, Pennsylvania.

Ohio-based Cleveland-Cliffs has ambitions to reduce its Scopes 1 and 2 GHG emissions by 85 percent by 2030, using 2017 as the baseline, by using hydrogen and green energy in addition to direct-reduced hot briquetted iron in its blast furnaces and increasing its use of prime ferrous scrap.

CEO Lourenco Goncalves has said using HBI in its BFs yields "enormous" benefits. "That material goes to the blast furnace prereduced, so the oxygen portion of that iron has already been removed." Therefore, no coke is needed, resulting in less carbon emissions.

Cliffs also is maximizing scrap use in

its BOFs. "The normal charge of scrap in a BOF is between 10 and 18 percent," Goncalves said. "In our plant, we use between 25 and 30 percent. So, we are using the same amount of pig iron, therefore the same amount of coke, therefore generating the same amount of CO_2 to produce more steel."

Cliffs also is looking to capture the CO_2 it generates, though Goncalves has said, "Hydrogen is coming first. We need to reduce the CO_2 emissions and then capture the rest with carbon capture."

Additionally, Cliffs has an agreement with EDP Renewables in Houston to purchase 7 percent of its electricity companywide from a wind farm in Indiana and is exploring self-generated electricity.

THE US' ALUMINUM ADVANTAGE

According to data from the IAI, total GHG emissions from the global aluminum sector did not grow in 2022 despite growth in aluminum production. The association reports this is the first time production increased without GHG emissions rising.

Data from 2022, the latest available, show aluminum production growing by 3.9 percent from 104.1 million metric tons to 108.2 million metric tons. However, GHG emissions declined slightly from 1.13 billion metric tons of CO_2 equivalent (CO_2e) to 1.11 billion metric tons of CO_2e, and the GHG emissions intensity of primary aluminum production has been declining since 2019.

Intensity declined by 4.4 percent from 15.8 metric tons of CO_2e per metric ton in 2021 to 15.1 metric tons of CO_2e per metric ton in 2022.

IAI Secretary General Miles Prosser says rather than be prescriptive about the reductions needed, the organization is encouraging aluminum producers to set those targets because they are the ones that will be carrying out those actions and making those investments. "What we've done is tried to create a framework and environment where corporate decarbonization strategies and target-setting can be better done," he says.

That includes developing trajectories for the industry and establishing guidance to ensure companies are measuring their carbon emissions and reporting them in a consistent way, Prosser says.

"Most recently we've worked on developing the transparency framework that creates the means by which companies can make it clear what their ambitions are and report on those over time," he says.

Prosser says that while progress is being made, the industry is still early in its decarbonization journey. "We knew from the start that a lot of what was needed was going to be the development of technology and then the implementation of that technology once it's been developed."

However, he says three pathways are available to the industry to decarbonize: decarbonizing the electricity supply, reducing direct emissions related to the consumption of anodes and fuels used in transport and increasing recycling rates.

"It won't be a single technology" that leads to decarbonization of the industry, he says. "We need to progress all of those pathways; one of them on its own won't be enough."

The industry's reduction in GHG emissions thus far is a result of investment in research, development and implementation of new technologies, innovative techniques and changes in energy supply, the IAI says, having tracked more than 50 projects across the industry that are contributing to this trend.

Of note are changes in the electricity supply used in aluminum smelting, the most significant component of the aluminum industry's GHG emissions, Prosser says. China, the world's largest aluminum producer, has shifted toward using more hydropower, while other regions are embracing renewable energy, including the Middle East and Australia.

"We're very conscious of the size of the challenge ahead of us," Prosser says. "But we are pleased to see that at least the early stages of investment in emissions reduction technologies are starting to show in the data that we're observing on a global level."

Das says recycling is playing the primary role in reducing emissions from aluminum production in the U.S., which is home to only four primary aluminum smelters with the shutdown of the Magnitude 7 Metals plant in Missouri.

According to the Congressional Research Service, in 2021, more than 75 percent of U.S. aluminum was made

by secondary smelters. However, Das says secondary smelters are producing nearly all aluminum in the U.S., estimating that primary aluminum was only 1 percent, or 750,000 tons, of U.S. production in 2023. The U.S. recycled 3.3 million tons of aluminum scrap that year, of which about 55 percent (1.8 million tons) came from preconsumer scrap and 45 percent (1.5 million tons) from postconsumer scrap.

"Scrap is the new primary," Das says of U.S. aluminum production, adding that while other countries are focusing on increasing the energy efficiency of primary aluminum production because they have less scrap, the U.S. must focus on capturing and upgrading scrap.

Aluminum companies are investing in scrap sorting, with Atlanta-based Novelis having taken a minority position in Sortera Alloys Inc. of Fort Wayne, Indiana, establishing a long-term commercial agreement. Norway-based Hydro partnered with Padnos, a Michigan-based recycler, to commercialize Hydro's proprietary sorting technology, HySort, in the U.S. to help feed its new facility in Cassopolis, Michigan.

The companies have formed a 50/50 joint venture, Alusort LLC, to install a Hysort sorting machine at Padnos' existing facility in Grandville, Michigan.

Despite the significant volume of additional scrap-based aluminum production capacity planned for the U.S., Duncan Pitchford, president of Hydro Aluminum Metals, does not foresee a long-term scrap shortage looming. "More aluminum is being used and more scrap eventually will be generated," he says. "We see that balanced in the long term and that scrap will be available."

With that, he acknowledges the need to use more postconsumer scrap going forward—potentially types of scrap it has not used in the past for billet production. He says Hydro is looking into maximizing its postconsumer scrap use.

Das says it is necessary to find the highest and best use for aluminum scrap. While mechanical separation that employs cameras, sensor sorters and X-ray technology can address contaminants that are not part of the metal's atomic structure, addressing those that are, such as iron, manganese, magnesium, zinc, copper and silicon, is more difficult. He is researching methods to recover those elements from aluminum.

Scrap will continue to play a leading role in decarbonizing the aluminum and steel sectors, particularly in the U.S. Making the most of these recovered resources will become essential. **RT**

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