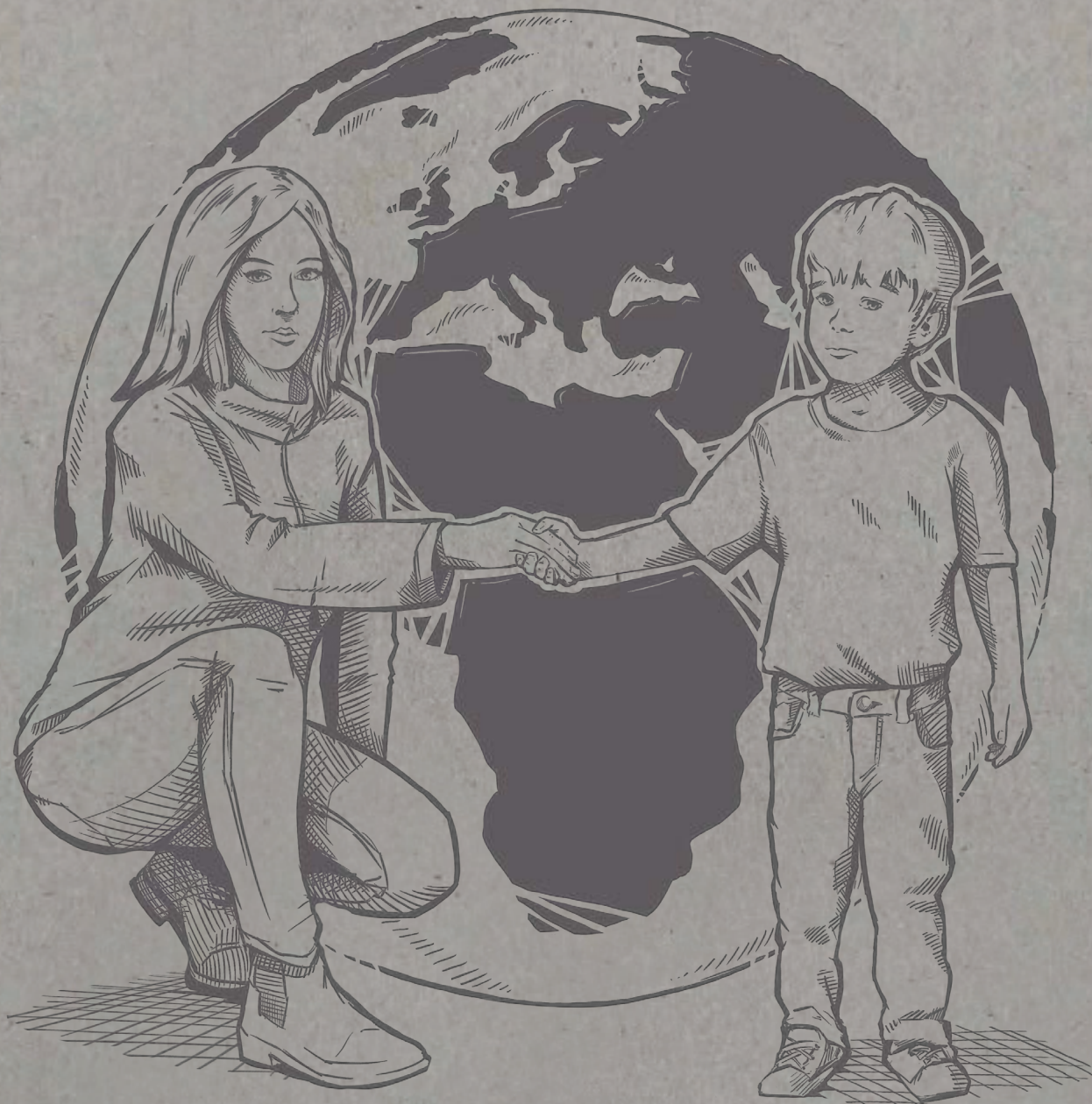


ISSUE 09 | JANUARY 2020

METALS MAGAZINE

INNOVATION AND TECHNOLOGY FOR THE METALS INDUSTRY



ONE PLANET.
ONE FUTURE.
ONE MISSION.

“ If you have children, you will have an even more acute sense that we have only one planet to hand over to the next generation—and that we therefore must look after it.”



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EDITOR'S COLUMN

DEAR READER,

Just this morning, before coming to work, I went for a ten-mile run. It is something I do regularly—something that helps me to think and to problem solve. I feel quite fortunate to live right next to a large nature reserve in the south of Linz. My favorite trail leads through woods and fields, and continues alongside a river and a lake. There is no traffic and I usually only cross paths with the odd dog walker. For an area so close to one of Austria's major cities, it could not be more peaceful. Even more than the exercise, I relish the opportunity to spend time outdoors. To breathe the clean air and to feel the wind. To hear the birds and the rushing of the water. But only a few decades ago, the area wasn't nearly as pristine. Particularly in the fall and winter, vast amounts of smog would build up. People would complain and long for change. This was before the local steel producer and other companies installed the highly effective environmental technologies they are using today. These green solutions made a night and day difference—and the smog was lifted.

Taking responsibility for the environment is crucial, and the benefits of living in relative harmony with nature are tremendous. If you have children, you will have an even more acute sense that we have only one planet to hand over to the next generation—and that we therefore must look after it. It is precisely this duty to protect nature and to ensure that future generations will be able to lead safe and stable lives that inspired this issue of Metals Magazine. We wanted to draw attention to all the things the steel industry can do—and is doing—to further enhance its relationship with nature. And we know that we are certainly not the only ones that care. At Primetals Technologies, we know just how much steel producers all around the world are genuinely concerned about sustainability. We know that, like us, they unquestionably want to do their bit for the planet. In this magazine issue, we look at innovative ways to make an impact: to turn night into day.

Yours sincerely,



Dr. Tom Widter
Editor-in-Chief of Metals Magazine
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DR. TOM WIDTER
EDITOR-IN-CHIEF OF METALS MAGAZINE



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We explore what's next in the world of metals. We innovate so that metals producers can realize their ambition to protect nature. Our solutions are designed to support the steel industry in its transition to a greener, low-carbon future.

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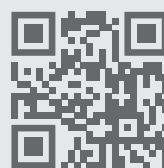
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METALS MAGAZINE WEB ARCHIVE

Whether you're at work, at home, or traveling, you can always find a complete archive of Metals Magazine issues at meta.ls/magazine.



MESSAGE FROM THE CEO

DEAR CUSTOMER,

There is a reason why this edition of Metals Magazine is titled "One planet, one future, one mission." When it comes to nature and environmental protection, we at Primetals Technologies have a very clear ambition. We know that mankind has only **one planet** and must care for it. Therefore, whenever we design new solutions for our customers, we do so in line with the global needs shared by the world's societies. This is especially important because we all share **one future**, and we therefore must prepare for it together. To me, this preparation doesn't just mean anticipating what's to come. Rather, it's about taking proactive steps. I always encourage my engineers to find new ways of shaping the future—by developing innovative technologies that will form the basis of steel production in 2030 and beyond. In that sense, Primetals Technologies has only **one mission** when it comes to environmental matters: it is to pioneer the solutions that will make even greener metals production a reality.

Our green technologies are the biggest lever we have as a company in terms of facilitating change. We certainly also aim to make our operations greener, and have committed to supporting the United Nations' Sustainable Development Goals—especially Goal 13 on global climate action. Our locations around the world do their very best to continually address their carbon footprint and to promote a lifestyle among their workforces that is geared toward greater sustainability. But while these efforts do matter, it is through our products that we will make the biggest positive long-term environmental impact.

Imagine a production line for thin-slab casting and rolling that uses only 55 percent of the energy required by a traditional line, and that reduces CO₂ emissions by 39 percent. A line that is not only more energy efficient and environmentally friendly but also more technologi-

cally advanced and much more compact. A line that can produce "cold-rolled substitute" strip as thin as 0.6 millimeters. Well, this solution is already here, and it is called Arvedi Endless Strip Production.

Imagine sintering, but with 99 percent of all emissions filtered from the off-gas: the fine dust particles, nitrogen compounds, dioxins, sulfur, mercury, lead, and more. This is already a reality, and the name of the solution that makes this possible is MEROS. We expect that the 12 MEROS plants ordered to date will have filtered a total of one million tons of pollutants by 2024.

Imagine an electric arc furnace that helps to save energy by preheating 100 percent of the scrap it uses with its own off-gas. Or waste-heat recovery systems that ensure consistently optimal energy use. Cold mills that enable the production of thinner and lighter strip, which is then used by the automotive industry for the manufacture of lighter and more economical cars. Automation systems that power down parts of the steel plant that aren't in active use, or that comprehensively streamline each and every part of the production process.

All the technologies I have described thus far are already available. They are just a few examples of the larger portfolio of green-production solutions from Primetals Technologies. But I also care deeply about the innovations that are still ahead of us. A few decades from now, hydrogen will likely have become an important energy source in many areas of our lives, including steel production. New technologies will transform the image of the steel industry as one of the world's major CO₂ emitters. And Primetals Technologies, together with its customers, will continue to pioneer the future of metals production—with green innovations that will help to safeguard our planet for generations to come. ●



SATORU IIJIMA
CEO of Primetals
Technologies

“ Whenever we design new solutions for our customers, we do so in line with the global needs shared by the world’s societies.”

Satoru Iijima
CEO of Primetals Technologies and Chairman of the Board



— WITH —


PRIMETALS TECHNOLOGIES

Primetals Technologies supports steel producers all over the world with innovative solutions. Find out how—in our project and company news.



- | | |
|-----------------------------------|-----------------------|
| 1. Monclova, Mexico | 8. Linz, Austria |
| 2. Braddock, Pennsylvania, U.S.A. | 9. Smederovo, Serbia |
| 3. Monlevade, Brazil | 10. Dilovasi, Turkey |
| 4. Port Talbot, Wales, U.K. | 11. Mariupol, Ukraine |
| 5. IJmuiden, Netherlands | 12. Sanmenxia, China |
| 6. Düsseldorf, Germany | 13. Wuzhou, China |
| 7. Dortmund, Germany | 14. Tangshan, China |

Geographic locations of the project news topics discussed in this section



The new 150-ton
RH plant can handle two million
tons of liquid
steel per year.

MEXICAN PRODUCER AHMSA ISSUES FAC FOR NEW 150-TON RH VACUUM-DEGASSING PLANT

AHMSA is now capable of producing low-hydrogen-content steels for the oil and gas industries.

1. MEXICO: Mexican steel producer Altos Hornos de Mexico, S.A.B. de C.V. (AHMSA) has issued the final acceptance certificate (FAC) for a twin RH vacuum-degassing plant supplied by Primetals Technologies. The 150-ton RH plant was installed in AHMSA's converter melt shop No. 2 in Monclova. It can handle 50 charges per day—the equivalent of about two million tons of liquid steel per year. The new RH plant employs a dry mechanical vacuum-pump solution, which yields excellent metallurgical results in terms of degassing and decarburization and reduces operational costs. The plant enables AHMSA to produce steels with a very low hydrogen content for the oil and gas industries. Primetals Technologies supplied the mechanical vacuum pumps, the structural steel construction, and the treatment station, which incorporates a combined-vessel ladle-lifting system to allow for vessels to be lifted into places inaccessible to cranes. The scope of supply also included the electrics and automation equipment for the RH plant.



Arvedi ESP stands for combined thin-slab casting and rolling at a compact plant size.

PRIMETALS TECHNOLOGIES TO SUPPLY ARVEDI ENDLESS STRIP PRODUCTION LINE TO U.S. STEEL

2. USA: Primetals Technologies is to supply an Arvedi Endless Strip Production (Arvedi ESP) line to United States Steel Corporation (U.S. Steel) for its “Edgar Thomson” plant in Braddock, Pennsylvania. It will be the first Arvedi ESP line to be built in the U.S.A. The combined casting and rolling plant will have an annual capacity of 2.5 million tons of steel. The Arvedi ESP line is designed to produce high-quality ultra-thin strip at thicknesses ranging from 0.8 to 6 millimeters and widths from 965 to 1956 millimeters, making it the widest Arvedi ESP line to date. Primetals Technologies will be responsible for the engineering of the plant and will supply mechanical equipment, media-control systems, technological packages, and Level 1, Level 2, and Level 3 automation systems. With this project, U.S. Steel will be able to boost its production of advanced high-strength steels and improve its environmental performance, energy efficiency, and overall carbon footprint. The first coil is expected to be produced in 2022.

Primetals Technologies was responsible for the engineering, planning, equipment and material supply, demolition, and erection—all of which were accomplished during an ambitiously short downtime in late 2018.

DESULFURIZATION AND DEDUSTING SOLUTION FOR AM MONLEVADE

3. BRAZIL: A new desulfurization station and a new dedusting system were successfully put into operation at Brazilian steel producer ArcelorMittal Monlevade. The desulfurization station combines a volumetric dosing device for magnesium and a pressure dispenser for calcium oxide injection. It can achieve sulfur levels of less than 50 ppm in the hot metal. To



learn more, watch the video by scanning the QR code or by pointing your web browser to meta.ls/ammondes.



The new desulfurization station at ArcelorMittal Monlevade is now operational.



Tata Steel Europe turned to Primetals Technologies for a comprehensive modernization of Blast Furnace No. 5 at Tata's Port Talbot steelworks.

TATA STEEL RESTARTS REVAMPED BLAST FURNACE AT PORT TALBOT SITE

4. UNITED KINGDOM: Tata Steel Europe had Primetals Technologies execute a blast-furnace revamp at the Port Talbot steelworks in South Wales, U.K. The aim of the modernization project was to extend the lifetime of the plant's Blast Furnace No. 5. Primetals Technologies was responsible for the engineering, planning, equipment and material supply, demolition, and erection—all of which were accomplished during an ambitiously short downtime in late 2018. The main areas of work included the replacement of a furnace-shell ring, cooling elements inside the shell, the waste-gas downcomer, and parts of the carbon hearth refractories. Shell modifications and general furnace-lining repairs were also realized. Before the revamp, Blast Furnace No. 5 had been running for 15 years and produced some 30 million tons of iron. The project was a continuation of a long-standing partnership.



Tata Steel Europe has tasked Primetals Technologies with the harmonization of its Level 2 automation systems controlling the continuous casters at Tata's IJmuiden plant.

HARMONIZATION OF LEVEL 2 AUTOMATION SYSTEMS FOR CONTINUOUS CASTERS AT TATA STEEL IJMUIDEN

5. NETHERLANDS: Tata Steel Europe and Primetals Technologies have commissioned a new Level 2 automation system completely remotely via an online connection. It is the first startup of its kind in 50 years of mutual history between the two companies. The project's success was based on a detailed definition of all relevant interfaces and intensive preparations of both companies' specialists, all of whom contributed vast amounts of technical and metallurgical expertise while establishing a relationship based on mutual trust. The new automation system replaced the existing solution at continuous caster CC21 of Tata Steel's plant in IJmuiden, Netherlands, after 20 years of operation. One important reason for the upgrade was that the steel producer wanted to harmonize all caster-automation systems used at the IJmuiden plant—namely, for caster CC21, CC22, and CC23. The latter is currently in the process of being constructed by Primetals Technologies and will feature the same automation as CC21. Over the course of the commissioning of CC21, the teams involved gained valuable experience, and as a result preparations for the implementation of CC23 were significantly easier. In particular, the coupling of the new automation solution to Tata Steel's existing IT infrastructure at the IJmuiden plant can be re-used, which will substantially reduce the effort required to start up the new continuous caster.



GERDAU PARTNERS WITH PRIMETALS TECHNOLOGIES FOR REALIZATION OF NEW DIGITALIZATION STRATEGY

6. GERMANY: Steel producer Gerdau and Primetals Technologies signed a strategic partnership agreement for their digitalization journey at METEC 2019. The cooperation's main goal is the development and realization of a digitalization roadmap for Gerdau, which strives to be one of the global steel industry's pioneers in the implementation of digital innovations. The focus of the cooperation is on the execution of digitalization projects, joint development efforts, and the creation of new business models. The steering committee was formed of experts from both Gerdau and Primetals Technologies.

MITSUBISHI HEAVY INDUSTRIES AND PRIMETALS TECHNOLOGIES ACQUIRE ABP INDUCTION SYSTEMS

7. GERMANY: Mitsubishi Heavy Industries (MHI) and Primetals Technologies have acquired ABP Induction Systems (ABP), a global manufacturer and servicer of induction furnaces and heating systems. ABP offers a variety of best-in-class products and comprehensive services to blue-chip customers that include leading automotive OEMs and suppliers, industrial manufacturers, independent foundries, as well as steel plant manufacturers and steel producers. Future business activities will be conducted under the leadership of Primetals Technologies.



VOESTALPINE REPLACES EXISTING CASTER AUTOMATION WITH SYSTEM FROM PRIMETALS TECHNOLOGIES

8. AUSTRIA: A new Level 2 process-automation system from Primetals Technologies was successfully put into operation at voestalpine Stahl's CC8 continuous slab caster at the company's Linz location. It replaced a system originally supplied in 2018 by a third party. As a result, the continuous casters operated by voestalpine in Linz, Austria, now exclusively use the same Primetals Technologies Level 2 system, thereby simplifying maintenance and the allocation of staff to any of the company's casting facilities. Specialized metallurgical models such as DynaGap Soft Reduction and Dynacs 3D secondary cooling are now available at all of voestalpine's casting plants in Linz.



HBIS Serbia's LD (BOF) converter No. 2 will be replaced by Primetals Technologies.

HBIS SERBIA PLACES ORDER FOR NEW LD (BOF) CONVERTER

9. SERBIA: Primetals Technologies has received an order from HBIS Group Serbia Iron & Steel LLC (HBIS Serbia) to replace LD (BOF) converter No. 2 at HBIS Serbia's production site in Smederovo. The aim of the project is to improve the steel-production process and to raise the plant's capacity. This will be achieved by increasing the converter vessel's shell volume. The critical outer dimensions of the converter, however, will remain unchanged so that the adjacent interfaces will not have to be changed. No modifications of the BOF pedestal or revamping of civil works will be required. The new converter will have a tapping weight of 105 tons. The scope of supply includes the new vessel featuring a detachable BOF bottom part, the trunnion ring, the Vaicon Link 2.0 suspension system, new supporting bearings with housings, a new tilting drive including a pneumatic emergency drive system, a bottom-stirring system, a dart machine for slag retention, as well as the implementation of slag-splashing technology. Primetals Technologies will also supply the electrics and automation for the new tilting drive and existing melt shop equipment, execute the construction process, and provide advisory services. The removal of the old BOF and the installation of all new equipment is expected to complete within 55 days.

The aim of the converter replacement is to improve the production process and to raise the plant's capacity.



Industry 4.0-ready automation helps to achieve the desired steel grades.

Primetals Technologies will be upgrading one of Çolakoğlu's VD plants to the largest VOD plant ever built.

ÇOLAKOĞLU ORDERS LARGEST VOD PLANT EVER CONSTRUCTED

10. TURKEY: Turkish steelmaker Çolakoğlu Metalurji (Çolakoğlu) has placed an order with Primetals Technologies to upgrade an existing vacuum degassing (VD) plant in its Dilovası meltshop to a vacuum oxygen decarburization (VOD) plant. With a heat size of 295 tons, the VOD plant will be the largest worldwide. The aim of the modernization project is to enable the production of special steels such as interstitial-free grades, ultralow-carbon grades, and stainless steels. This will help Çolakoğlu to broaden its product range and enter additional markets. Primetals Technologies is responsible for the engineering and will supply all the core components. These include valve stands, the oxygen blowing lance system, as well as filters and a filter-cleaning system installed ahead of the vacuum pumps. The scope also encompasses the modernization of the existing automation system. The main products of the Çolakoğlu plant, one of the largest electric steel plants in the world, are slabs for further processing in a hot rolling mill and billets for the production of reinforcing steel bars and anchor bolts. The current modernization project marks another step in the business partnership of Çolakoğlu and Primetals Technologies. The new VOD plant is expected to be operational in March 2020.

PJSC ISSUES FACS FOR TWIN LADLE FURNACE AND ALLOYING STATION

11. UKRAINE: Ukrainian steel producer PJSC "Ilyich Iron and Steel Works of Mariupol" (MMKI) has issued Primetals Technologies with the final acceptance certificates (FACs) for a 2-strand continuous slab caster, a twin ladle furnace with an alloying station, and the associated dedusting system. The 2-strand caster CC4 is designed to produce 2.5 million tons of slab per year. It increases MMKI's annual production capacity to around four million tons and helps MMKI to enhance and expand its product portfolio to high-carbon, ultrahigh-carbon, and ultralow-carbon steels. A Level 3 heat-pacing solution coordinates the site's steel production with its casting operation. Thanks to the Industry 4.0-ready automation systems, the desired steel grades and the correct temperatures can be set via pre-selectable process models at the twin ladle furnace and the alloying station.

The new aluminum mill will be capable of processing all aluminum alloys in groups 1xxx to 8xxx, which includes alloys used in the aerospace and automotive industries.



BaoWu has placed an order with Primetals Technologies for the construction of a 300,000-ton aluminum hot-rolling mill in Sanmenxia, China.

PRIMETALS TECHNOLOGIES TO SUPPLY ALUMINUM HOT-ROLLING MILL TO BAOWU

12. CHINA: Primetals Technologies will be supplying BaoWu Aluminium Technology Ltd. (BaoWu) with a combined aluminum hot-rolling mill for the production of heavy plate and strip. The new mill will be built in Sanmenxia, Henan province, to an annual production capacity of 300,000 tons. It will be capable of processing all aluminum alloys in groups 1xxx to 8xxx, which includes alloys used in the aerospace and automotive industries. Primetals Technologies' SmartCrown system will ensure that the profile and flatness of the hot strip will stay within the narrow tolerance range of the specifications. The rolling mill will comprise a combined roughing and heavy-plate line that is capable of producing either transfer bars or plates. Primetals Technologies will be training BaoWu's staff on the new equipment. Commissioning of the rolling mill is scheduled for the second half of 2020.

WUZHOU YONGDA TO RECEIVE EAF QUANTUM AND LADLE FURNACE

13. CHINA: Primetals Technologies has received an order from Chinese steelmaker Wuzhou Yongda Special Steel Company to supply an EAF Quantum electric arc furnace and a ladle furnace for a greenfield project in Wuzhou city, in Guangxi Zhuang Autonomous Region. This marks the tenth EAF Quantum for China. The EAF Quantum furnace is designed to handle steel scrap of very varied composition and quality. The electrical energy requirement of the electric arc furnace is extremely low because all scrap is preheated. This reduces both operating costs and CO₂ emissions. The twin ladle furnace sets the desired steel grades and the correct casting temperature. Primetals Technologies will supply all process-relevant mechanical and electrical equipment as well as automation solutions. The new furnaces are scheduled for commissioning in early 2020.



To date, no fewer than ten EAF Quantums have been sold to Chinese producers.



PRIMETALS TECHNOLOGIES OPENS NEW METALLURGICAL SERVICES WORKSHOP IN CHANGXING, CHINA

14. CHINA: On May 30, 2019, Primetals Technologies officially celebrated its Changxing branch opening in Changxing, Huzhou City, Zhejiang Province. The service workshop commenced operation in April 2019 and will further enhance the capabilities of Primetals Technologies' Metallurgical Services organization in China. Guests from the Changxing government and customer representatives participated in the opening ceremony. Hiroshi Ogawa, CEO of Primetals Technologies China, said: "The establishment of our Changxing service workshop is a major milestone in the development of Primetals Technologies in China. It allows us to provide better services that match customer requirements and a changing market environment." Karl Purkarthofer, Head of Primetals Technologies' global Metallurgical Services business, added: "The Changxing service workshop is a state-of-the-art service facility designed in line with Industry 4.0 principles. It will provide an excellent platform to support our customers in China in the best possible way, and it demonstrates our leading position in China in terms of technology-based services." An important aspect to the workshop's mission is to further digitalization. With the implementation of smart manufacturing, lean production processes, and environmental and energy-saving solutions, Primetals Technologies will be able to provide reliable services at great speed, of the highest quality, and at competitive prices.



PRIMETALS
TECHNOLOGY

PIONEERING A **GREENER FUTURE**

At Primetals Technologies, we care about the environment. We never stop to innovate for nature. We create new solutions that will ensure the long-term sustainability of the steel industry. Our technologies are designed to make greener steel production a reality. We go where our customers are, and we make a point of taking our green-production solutions with us. When it comes to nature, we have only one planet, one future, and one mission.

DISCOVER THESE TOPICS:

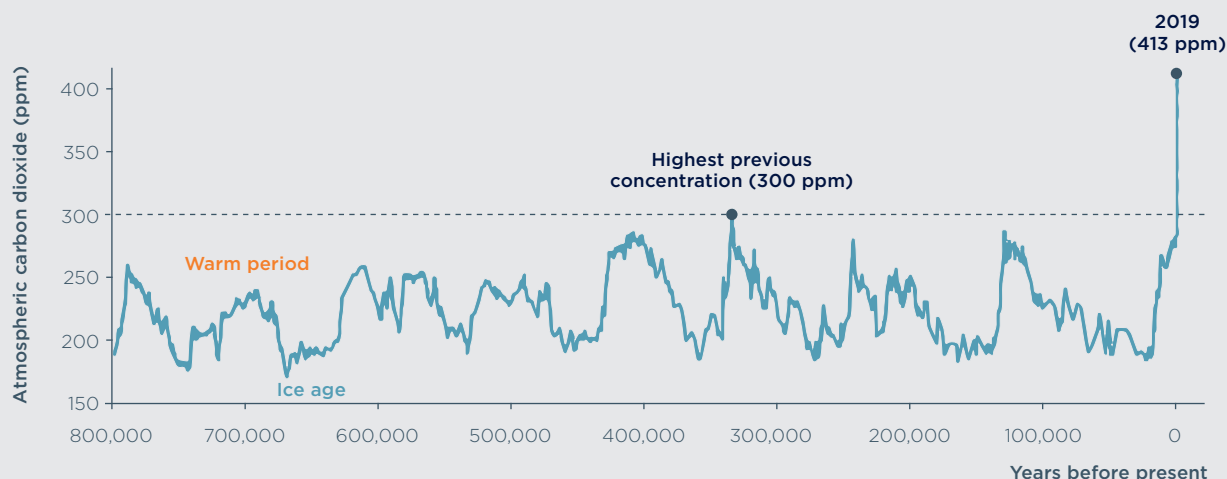
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GLOBAL WARMING

101

A RECAP ON THE SCIENCE THAT IS FUELING GLOBAL CLIMATE ACTION



ATMOSPHERIC CARBON DIOXIDE

This data, provided by the U.S. National Oceanic Atmospheric Administration (NOAA), shows CO₂ levels in the atmosphere for the last 800,000 years. Since no direct measurements exist, the respective information was derived from ice cores—via the European Project for Ice Coring in Antarctica (EPICA). Atmospheric CO₂ is measured in parts per million: 413 ppm equals 0.0413 percent.

Whenever you read about global warming or climate change, you'll often come across two things: updated measurements of the CO₂ content found in the earth's atmosphere, and projected future scenarios, generated by climate models, that seem nothing short of apocalyptic. Often overlooked, however, are the simple foundations, the core of the science behind global warming.

At Metals Magazine, at the time of writing, we have spent almost half a year researching global warming. While this has certainly not made us experts, we have always aimed for objectivity and have spoken with university professors, ph.d physicists, journalists, teachers, and, of course, numerous colleagues from Primetals Technologies. We have also had discussions with members of the public who consider themselves critical thinkers. What we found is that quite a few of them—even some of the strongest advocates of stringent governmental climate action—were lacking the most basic understanding of the theory behind global warming.

TWO HARD QUESTIONS

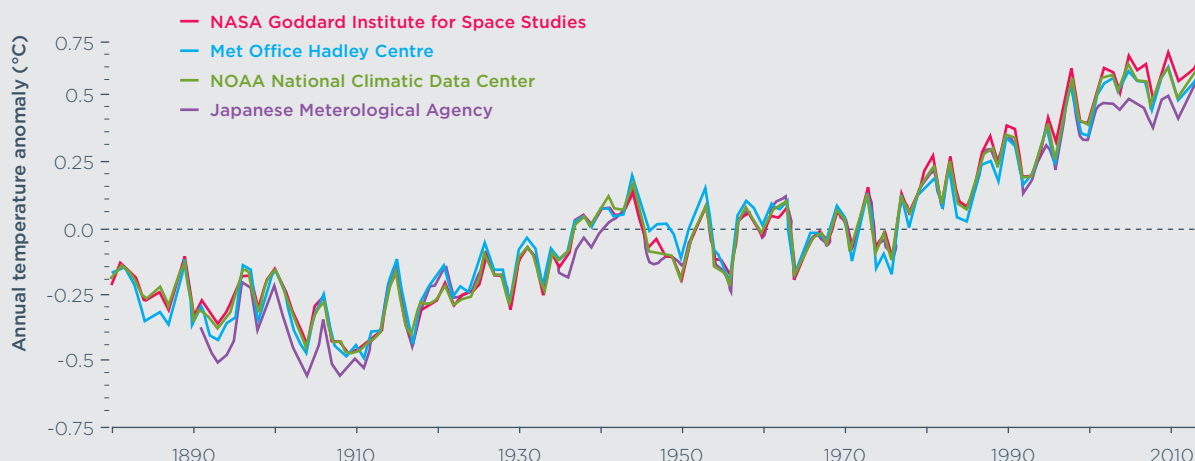
The Metals Magazine team asked two fundamental questions to start the conversations. First, "Are you convinced that climate change is a reality, and that it is entirely man-made," to which the vast majority of interviewees would say yes. This was then followed by our second question: "What percentage of the earth's atmosphere is currently made up of CO₂?" Surprisingly, as essential as this piece of information might be to a well-founded stance on climate change, hardly anyone had any idea. Is it 12 percent? 15 maybe? Could it be more? And how much might CO₂ levels have increased over time?

Our second question was, of course, a trick question. The proportion of CO₂ in the atmosphere is usually measured in parts per million, rather than by percentage. Prior to the Industrial Revolution, 0.028 percent (equal to 280 ppm) of the air we breathe consisted of CO₂, and today it is approximately 0.0413 percent (413 ppm, figure from early 2019). Clearly, the fact that we're not even close to reaching one percent is no reason to doubt the reality of climate change. But the deficits in knowledge uncovered by our conversations does indicate that more education might be required to make informed decisions on how to tackle the potentially greatest problem faced by future generations.

TOO MUCH OF A GOOD THING

So let's get into our 101 of global warming. In a nutshell, it is the result of "too much of a good thing." Without the earth's atmosphere, our planet's surface would be all but frozen. As sunlight enters the atmosphere, it is absorbed by oceans and continents, which warm up. Much of the heat is then radiated back toward space in the form of energy-rich infrared light. This is where "greenhouse gases" come into play. These gases—mainly water vapor, CO₂, and methane—interact with the infrared light and keep it from leaving the atmosphere as it heads for space. As a consequence, the "good thing" happens: the atmosphere retains the heat. It's just that too much of the warming effect has negative consequences—it is getting too warm.

As indicated, the amount of CO₂ in the atmosphere has risen from 280 to 413 ppm since the Industrial Revo- ➤



A GLOBAL RISE IN TEMPERATURE

The Goddard Institute for Space Studies (GISS), part of the U.S. National Space Agency (NASA), has accumulated temperature measurements from 6,300 metrological stations worldwide. GISS has used data from NASA itself, the U.S. National Oceanic Atmospheric Administration (NOAA), the Japanese Meteorological Agency, and the U.K.'s Met Office Hadley Centre. The graph depicts annual temperature anomalies, and while there are minor variations from year to year, the overall rise in average temperatures is clearly evident. NASA's explanation for the leveling off between the 1940s and 1970s is that aerosols, generated by rapid economic growth after the Second World War, introduced cooling effects.

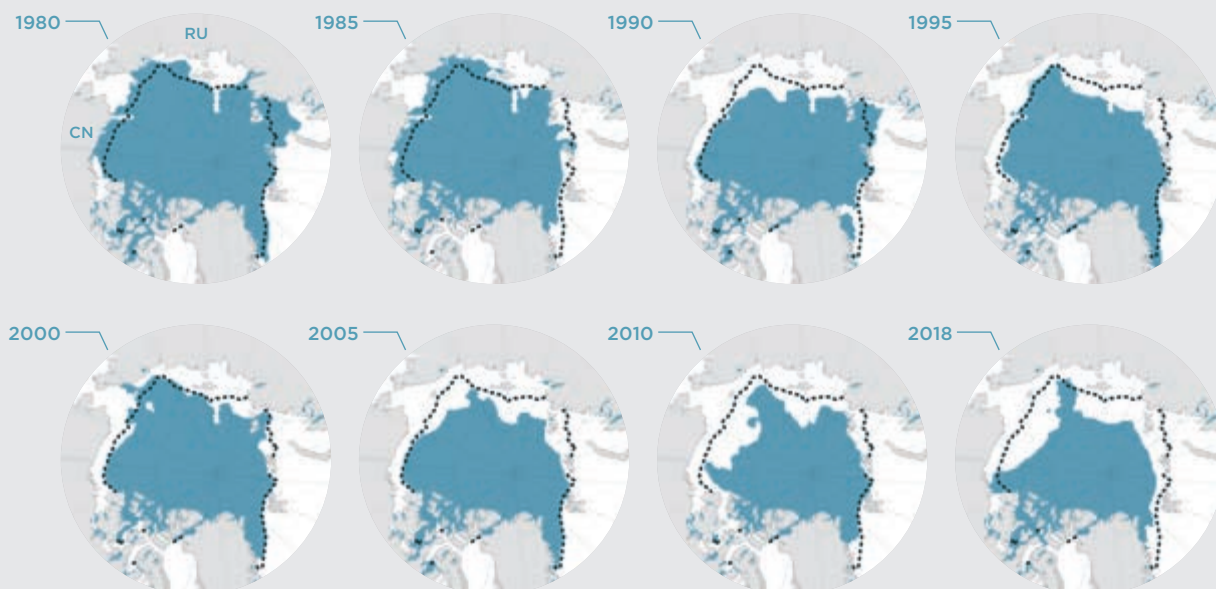
lution. Carbon dating shows that this increase is indeed connected to the burning of fossil fuels—coal and oil. During the same period, average global temperatures have been reported to have risen by 1 degree Celsius. This is according to ground-based measurements; satellite-based measurements suggest a less pronounced increase in temperature, especially in the tropical troposphere (the troposphere being the lowest part of the atmosphere, where most weather-related activity takes place). The International Panel of Climate Change has acknowledged this discrepancy in its fifth assessment report by attributing a 95 percent confidence rating to the assumption of the 1 degree Celsius increase.

SERIOUS CONSEQUENCES

While 1 degree might not seem like much, it is believed that any further increase could have dire consequences. Climate models predict more frequent extreme weather events, extended droughts, encroaching deserts, increasing wildfires, far-reaching effects on wildlife, as well as changing rainfall and agricultural patterns. However, these climate models are highly complex

and, to a non-scientist, nothing short of “black boxes.” What's less complicated and more obvious is what happens when ice melts. In this context, 1 degree can make a big difference: disappearing sea ice, receding glaciers—and in turn a rise in sea levels, which is currently measured at 3.3 millimeters per year on average. Based on this trend, a reduction in habitable coastal areas is inevitable.

The melting of the ice has further ramifications. An icy surface is highly reflective (50–70 percent), while the earth's oceans are highly absorbent (only 8 percent reflected, the rest absorbed) of the sunlight's energy. As arctic ice melts it is replaced by ocean, further adding to the planet's warming. Another complication is the future of the permafrost soil in northern latitudes. Vast stretches of permafrost contain great quantities of CO₂ and methane. Once thawed, these gases would be released into the atmosphere and would further amplify the greenhouse effect. To avoid the thawing of the permafrost regions, scientist believe that global warming must be kept below the 2 degree Celsius mark.



ARCTIC SEA ICE DECLINE

Data provided by the U.S. National Snow and Ice Data Center shows that arctic sea ice has declined since the 1980s. Arctic ice tends to build up in winter and melt in summer; the illustrations above reflect the ice's state in the month of September of the respective year, with the dotted line indicating the statistical average. Sea ice is thought to affect the mean global sea level, which on average has risen by 3.3 millimeters per year since 1993. The rise in sea level has been a matter of contention: in late September of 2019, the journal "Nature" retracted a disputed study that suggested a sea level rise of 91 centimeters by the end of the century. The study had also warned that certain hundred-year floods would become yearly events.

The arguably largest and most unsettling consequence of global warming is mass migration. Once certain regions are no longer habitable, people—millions of them—would be forced to relocate. The question is, to where? These "climate refugees" could pose the largest ethical challenge mankind has ever seen. Would the world's nations accept them with open arms, or regard them as a national security and military concern? Previous refugee crises suggest that migration of this proportion has the potential to cause great disunity, if not major disarray, even in highly developed countries.

GLOBAL CLIMATE ACTION

So what now? Some of the solutions for tackling climate change have long been evident—mankind's dependence on fossil fuels will have to cease. The trend of a global rise in energy consumption will have to be reversed. More powerful means of sourcing renewable energy will have to be developed and implemented on an enormous scale. New breakthrough technologies will have to be pioneered. The biggest issue, however, will be to achieve global consensus about the need to act.

Symbolic actions will have to be replaced by a comprehensive, honest and smart, top-down agenda. Only if the world's leaders can truly unite on global climate action will mankind be able to embark on a new and different journey—toward greener lifestyles and a world economy driven by sustainability. At Primetals Technologies, we are ready to make our contribution to a greener future, with our innovative solutions and our deep commitment to protecting our planet. ●

JOIN THE CONVERSATION

At Primetals Technologies, we care deeply about the environment, our planet, and the long-term sustainability of steel production and our societies at large. But global warming to many is an emotional topic and certainly not a simple subject matter. Therefore, we would like to hear your views. To let us know your thoughts, simply send an email to the Metals Magazine team:

metalsmagazine@primetals.com



PIONEERS AT HEART

We explore what's next in the world of metals.
Our solutions are designed to support the steel
industry in its transition to a low-carbon future.
We innovate so that steel producers have the
technologies they need to protect nature.





INNOVATING **FOR NATURE**

THE GREEN-PRODUCTION SOLUTIONS OF PRIMETALS TECHNOLOGIES ARE DESIGNED TO MAKE STEEL PRODUCTION MORE SUSTAINABLE.

At Primetals Technologies, we care about the environment. We innovate for nature—by creating new solutions that will contribute to the long-term success of the steel industry. Since different regions in the world have their own different environmental objectives, we strive to provide steel producers with the ideal combination of green-production technologies for their particular situation.

Steel producers—especially multinational ones—are constantly monitoring the situation in the countries they operate in, as they base their technological and strategic decisions on future requirements.

Global climate action has become a top priority in many of the world's societies, prompting the steel industry to channel even more resources toward greater sustainability. Steel has always been a "green" base material thanks to its high recyclability. But the production of steel is still energy-intensive, especially in the upstream area. It also requires off-gas cleaning technologies to minimize the overall environmental impact.

Depending on where in the world a steel producer is located, environmental regulations will vary. The same is true for the direction individual countries are taking in terms of climate action. Data provided by the World Bank [see pgs. 30–31] shows that Japan, for instance, has implemented a carbon tax, but no national carbon-trading scheme. In Australia, the situation is the exact opposite. China has not implemented either measure to date, but is planning the introduction of a trading scheme. Mexico has established a carbon tax, but this tax does not cover industrial production.

AMBITIOUS TARGETS

To date, no fewer than 77 countries—including the U.K., France, and Germany—are planning to lower greenhouse-gas emissions to zero by 2050. Finland, for example, intends to become carbon neutral by 2035. Norway is targeting 2030 and will prohibit the registration of new diesel and gas-powered cars by 2025. And while the U.S. government has not committed to any similar goal thus far, a number of states—California, Colorado, New Mexico, and Washington—are all planning to shift their energy mix to 100 percent renewables.

Because of these discrepancies between regions, steel producers—especially multinational ones—are constantly monitoring the situation in the countries they

operate in, as they base their technological and strategic decisions on future requirements. The green-production solutions of Primetals Technologies are designed to enable producers to achieve long-term sustainability, irrespective of their location. And thanks to its extensive R&D program, Primetals Technologies will be further extending its portfolio of innovative green solutions while aiming to provide the technologies that will define the future of steel production for decades to come—in a greener, more environmentally conscious world.

TACKLING CARBON EMISSIONS

On average, the steel industry produces approximately 1.8 tons of CO₂ per ton of steel, which—according to worldsteel figures—equates to some 7 to 9 percent of global carbon emissions. The lion's share of the steel industry's CO₂ emissions is generated in the upstream area, both directly, as a consequence of chemical reactions, and indirectly, through the consumption of electrical energy. But even in the less energy-intense downstream area, energy savings and higher environmental compatibility are possible, and desirable. Primetals Technologies has developed solutions that address both areas and significantly lower the overall CO₂ emissions occurring during steel production—from ironmaking all the way to rolling and processing.

One technology with a particularly competitive carbon footprint is Arvedi Endless Strip Production. This technology combines continuous thin-slab casting and rolling in one compact plant layout—and is the only solution on the market that offers real endless operation. Compared to a standard production line, Arvedi ESP delivers unparalleled performance at 39 percent lower CO₂ emissions. Energy consumption is also reduced, by a staggering 45 percent. The strip produced with Arvedi ESP is on par with high-quality »

cold-rolled strip, and thicknesses as low as 0.6 millimeters can be achieved. Thanks to its powerful, green, and future-oriented properties, Arvedi ESP has been attracting significant customer interest. To date, Primetals Technologies has sold a total of 10 Arvedi ESP lines, and is expecting further orders.

HIGHER ENERGY EFFICIENCY

Electric steelmaking is also becoming greener—with solutions such as the EAF Quantum, the electric arc furnace of choice, available only from Primetals Technologies. The EAF Quantum employs custom-designed scrap-charging and -retaining systems. The retaining system preheats 100 percent of the scrap using the

furnace's own off-gas, which significantly increases energy efficiency and consequently reduces the environmental impact. The furnace also features outstanding tap-to-tap times of just 33 minutes. As a number of steel producers in China and other countries move from the integrated production route to electric steelmaking, the EAF Quantum has seen a steep increase in orders. Primetals Technologies expects that, by the spring of 2021, no fewer than 11 recently purchased EAF Quantum will commence operation. Together, they will produce a combined 13 million tons of steel per year.

Energy recovery is another cornerstone of green production. It comes in various shapes and sizes and the

SELECT GREEN-PRODUCTION TECHNOLOGIES



MEROS ...

... is arguably the world's most advanced off-gas cleaning solution for sinter and pelletizing plants. It reduces emissions by 99 percent and removes fine dust particles, sulfur, nitrogen compounds, dioxins, mercury, lead, as well as volatile organic compounds from the off-gas for greener agglomeration.

ARVEDI ESP ...

... stands for "Arvedi Endless Strip Production" and represents the only solution worldwide that is capable of real endless thin-slab casting and rolling, all in one compact plant layout. Arvedi ESP saves 45 percent of the energy required by a standard production line and lowers emissions by 39 percent.

result is a diverse set of technologies. Prominent examples are waste-heat recovery systems for electric arc furnaces and top-gas energy recovery solutions for the blast furnace. Dry slag granulation, a technology that is still in development, recovers heat energy from blast-furnace slag, and lots of it—approximately 1.7 gigajoules per ton of slag. All of these solutions, directly or indirectly, lower the amount of CO₂ released into the atmosphere by a steel plant. The same is true for Selective Waste-Gas Recirculation (SWGR): it improves a sinter plant's carbon footprint by a remarkable 10 percent. SWGR also cuts the amount of sinter-plant waste gas in half, and leads to lower operational costs when it is implemented together with Primetals Technologies' MEROS system.

TACKLING THE WASTE-GAS

Which leads us directly to MEROS, arguably the world's most powerful gas-cleaning solution for sinter and pelletizing plants. It is a six-in-one off-gas cleaning solution, capable of dedusting, desulfurization, denitrification, and of removing dioxins and volatile organic compounds as well as mercury and lead. All of these processes combined result in a reduction in emissions of no less than 99 percent—perfect for environmentally friendly agglomeration. Over the last 15 years, MEROS has thoroughly proven its merits. It has been ordered 12 times, by steel producers in Europe, India, China, and Japan. The success of MEROS has inspired its creators to extend its reach into the fields of ironmaking and steelmaking— »



EAF QUANTUM ...

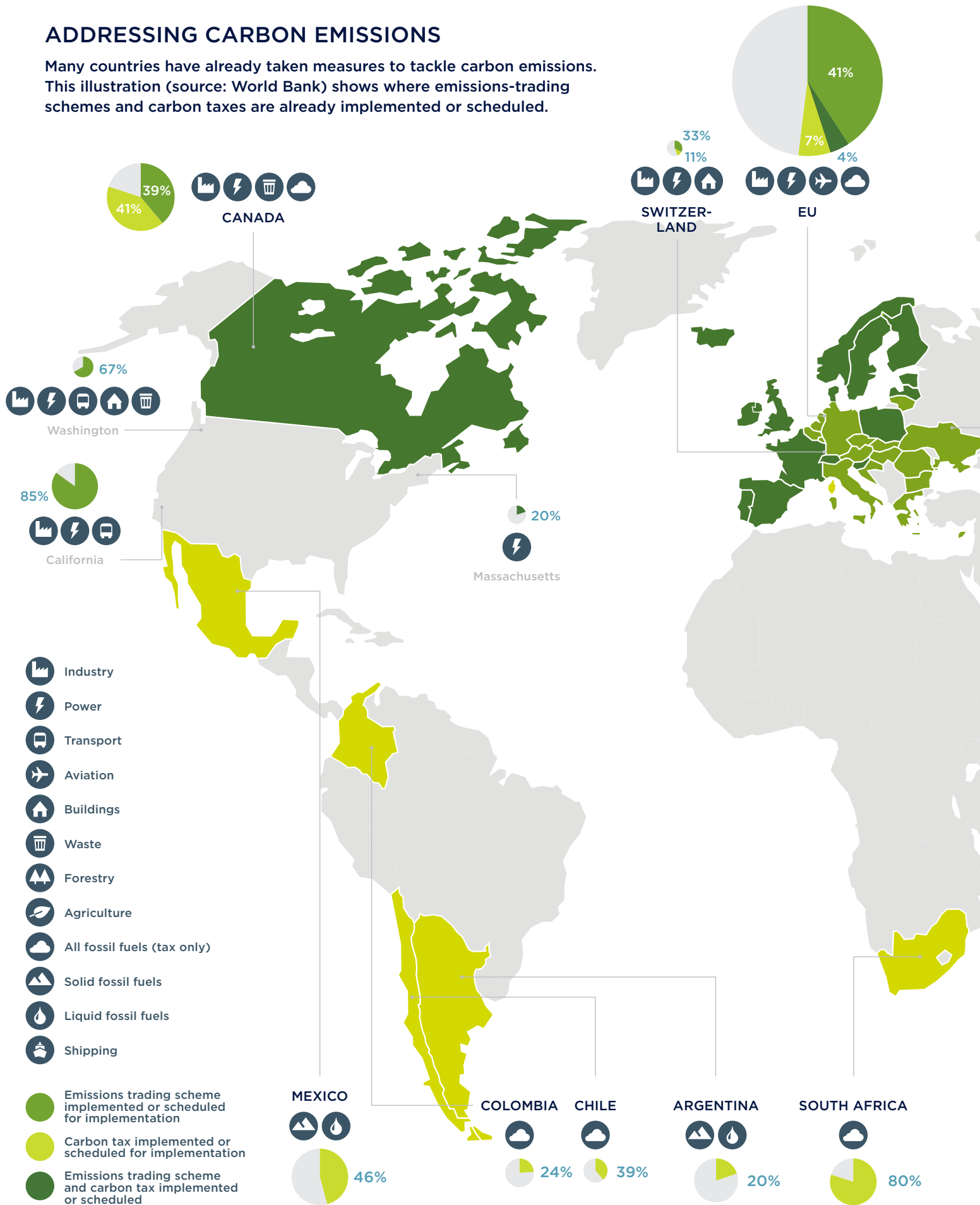
... is the next generation of electric arc furnaces. The EAF Quantum uses its own off-gas to preheat 100 percent of the scrap before charging. The furnace's innovative design results in significant energy savings and greater environmental compatibility. Tap-to-tap times are at only 33 minutes.

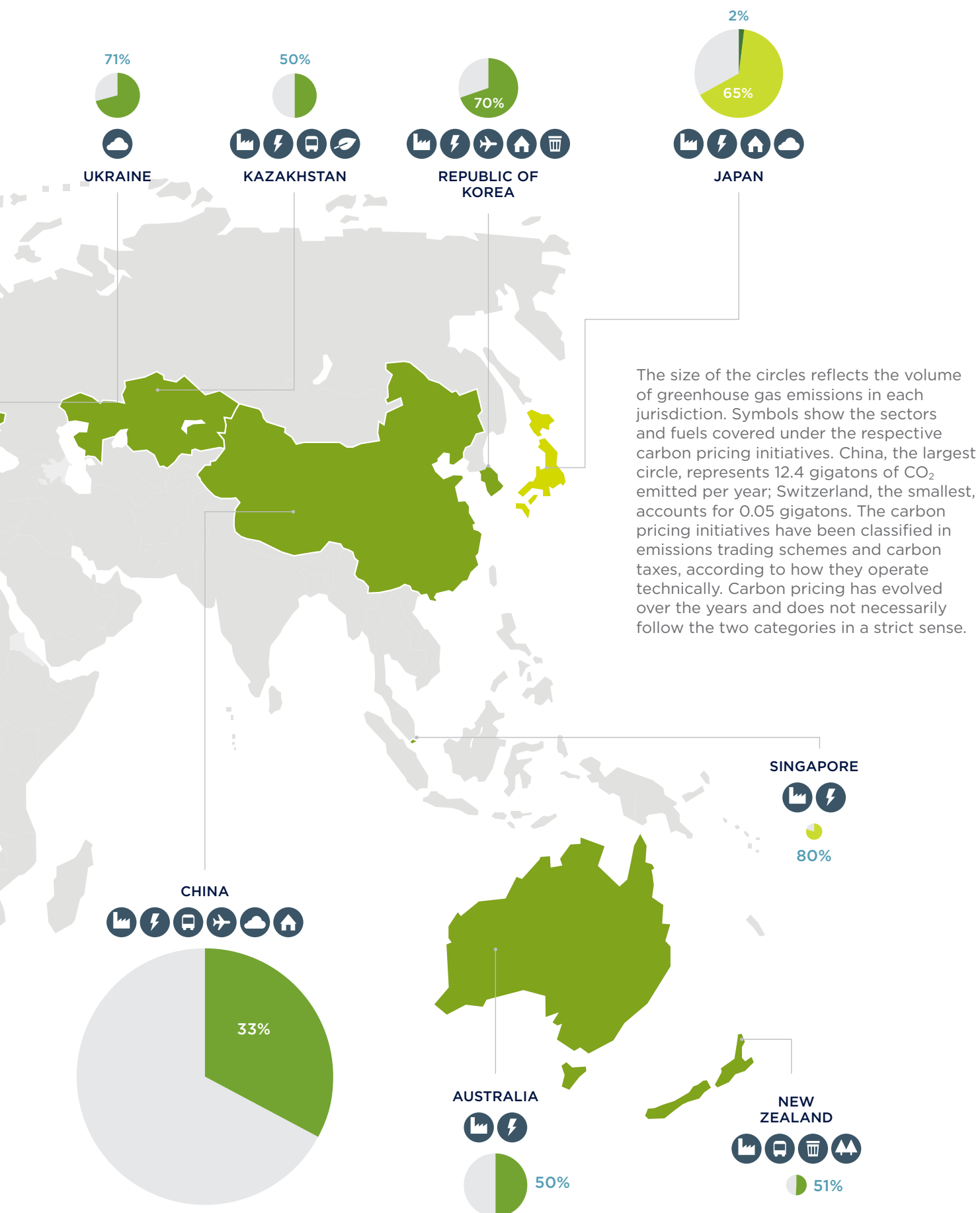
SELECTIVE WASTE-GAS RECIRCULATION ...

... is capable of cutting a sinter plant's waste-gas emissions in half by selectively sending the gas back to the sinter bed—and through the sinter. This makes use of the CO and the heat found in the off-gas. As a result, the recirculation can lower a sinter plant's carbon footprint by 10 percent.

ADDRESSING CARBON EMISSIONS

Many countries have already taken measures to tackle carbon emissions. This illustration (source: World Bank) shows where emissions-trading schemes and carbon taxes are already implemented or scheduled.





with MERIM for emissions from the blast furnace, and MERCON for off-gas from the basic oxygen furnace. MERCON is currently in the final stages of development. In addition to these three solutions, Primetals Technologies offers steel producers further options for addressing gas cleaning in accordance with the environmental regulations applicable in their respective countries.

TOWARD A GREENER FUTURE

Thanks to Primetals Technologies' extensive R&D efforts, the future of steel production will be significantly greener. The company's own innovators are partnering with universities, research centers, and other enterprises to safeguard the sustainability of steel pro-

duction. Equally important are Primetals Technologies' many customer collaborations. With the world's governments expected to impose even more stringent controls on carbon emissions, it is vital for steel-plant builders like Primetals Technologies to have an extensive pipeline of solutions that will facilitate the transition to a low-carbon economy.

The decarbonization of metals production will be a gradual process and will involve intermediate measures to capture and store carbon, as well as for carbon utilization. Gas fermentation is one of these intermediate technologies. It is offered in cooperation with Lanza-Tech and represents an already available solution that

SELECT GREEN-PRODUCTION TECHNOLOGIES



DRY SLAG GRANULATION ...

... is designed to recover heat energy from blast-furnace slag in a new and innovative manner. Each ton of slag can yield around 1.7 gigajoules of energy, which is currently lost at most steel-production sites. After heat extraction and granulation, the slag can be sold on to the cement industry.

WASTE-HEAT RECOVERY SYSTEMS ...

... make a massive contribution to greening today's steel plants. Waste-heat recovery is possible—and recommended—in most areas of steel production that generate substantial heat. Two examples are sinter plants, which achieve a reduction in coke consumption and CO₂ emissions, and electric arc furnaces.

turns carbon emissions from steel plants into biofuel. Gas fermentation uses microbial fermentation of carbon- and hydrogen-rich off-gases—such as coke-oven gas, blast-furnace top gas, and off-gas stemming from ferro-alloy production and converter steelmaking—to produce ethanol and other basic chemicals.

HYDROGEN-BASED PRODUCTION

HYFOR is a truly groundbreaking technology for lowering the carbon footprint of steel production. It stands for "Hydrogen-based Fine Ore Reduction" and is a carbon-free direct-reduction solution that Primetals Technologies is currently pioneering in close collaboration with an Austrian steel producer. This technology

relies exclusively on hydrogen as a reduction agent and works directly with iron ore concentrate fines after ore beneficiation. Since the announcement of HYFOR, Primetals Technologies has received an overwhelming number of inquiries—a clear indication of hydrogen's immense potential to revolutionize ironmaking and other energy-intensive aspects of steel production.

Primetals Technologies is committed to pioneering the green future of steel production—and to meeting the needs of its global customer base. We believe that, together with our customers, we can be catalysts for change; together, we will protect the environment for generations to come. ●



GAS FERMENTATION ...

... uses microbial fermentation of carbon- and hydrogen-rich off-gases and converts them into biofuel and other basic chemicals. It works with blast-furnace top gas, off-gases from converter steelmaking and direct reduction, and coke-oven gas. It is offered in partnership with LanzaTech.

HYFOR ...

... is a new breakthrough development pioneered by Primetals Technologies. This carbon-free, hydrogen-based direct-reduction solution works with iron ore concentrate fines after ore beneficiation, and has the potential to revolutionize ironmaking by making it a green process.

RECENT GREEN REFERENCES



3 MEROS PLANTS FOR BETTER AIR

Primetals Technologies supplied three full-fledged MEROS plants to Turkish steel producer Karabük Demir Çelik Sanayi ve Ticaret A.Ş. (Kardemir), each of which is capable of filtering 400,000 normal cubic meters of off-gas per hour. The first MEROS plant at Kardemir's sinter plant No. 3 was started up in December 2018, followed by those for sinter plants No. 1 (February 2019) and No. 2 (March 2019). All three projects were realized within a remarkably short time frame. The first of the three MEROS plants, for example, only took 10.5 months from technical specification to startup. Thanks to the new MEROS plants, air quality in the valley of Karabük is now considerably better.

PROJECT & TECHNOLOGY SUMMARY

Location:	Karabük, Turkey
Type:	Off-gas cleaning plant
Demand:	To date, 12 MEROS plants have been ordered, with four currently in the planning or construction stage.



THE POWER OF 5 ARVEDI ESP LINES

No fewer than five Arvedi Endless Strip Production lines were ordered by Chinese steel producer Rizhao—a true sign of trust in both Primetals Technologies and Arvedi ESP, the only genuine endless thin-slab casting and rolling technology available today. Rizhao wanted to manufacture strip of a quality comparable to cold-rolled products, which Arvedi ESP made possible. Two further arguments for Arvedi ESP were its high energy efficiency and comparably low carbon emissions. Thanks to its pioneering qualities and green characteristics, Arvedi ESP is currently in high demand. Additional production lines have recently been purchased by steel producers in the U.S.A. and China.

PROJECT & TECHNOLOGY SUMMARY

Location:	Rizhao, China
Type:	Arvedi Endless Strip Production
Demand:	With 10 Arvedi ESP lines ordered to date, the technology has raised significant interest among steel producers.

Primetals Technologies provides precisely the green-production solutions that steel producers require in their region. These technologies ensure that all environmental targets are fully met.



INCREASING PLANT EFFICIENCY

When Italian steel producer Acciaieria Arvedi S.p.A. (Arvedi) contracted Primetals Technologies to install a new electric arc furnace, the producer simultaneously ordered a waste-heat recovery system to optimize the energy balance of the plant, as well as a primary and secondary dedusting system. The waste-heat recovery system uses the heat it captures to generate steam, and lots of it: every hour, some 17 tons of steam are generated. This steam then helps to power the three pickling lines in the plant. Arvedi's plant had previously relied on a gas boiler for this purpose. The introduction of the waste-heat recovery system has led to a significant reduction in gas consumption and energy costs.

PROJECT & TECHNOLOGY SUMMARY

Location:	Cremona, Italy
Type:	Waste-heat recovery system
Demand:	Producers in many countries around the world are incentivized to increase their plants' energy efficiency.



MORE COMPREHENSIVE DEDUSTING

"We treat issues aimed at reducing our ecological footprint with the highest priority," said Geert Verbeeck, ArcelorMittal Poland's CEO, at a celebratory event marking the start of the construction of a new dedusting system at the company's steel plant in Dąbrowa Górnicza. Primetals Technologies was responsible for upgrading the primary dedusting system and the cooling stack for all three of the plant's LD (BOF) converters. For the dedusting, Primetals Technologies used a redesign of the well-known venturi-scrubber-based wet-dedusting principle for highest efficiency and minimal water consumption. The modernization was swiftly executed and took only 62 days per steelmaking line.

PROJECT & TECHNOLOGY SUMMARY

Location:	Dąbrowa Górnicza, Poland
Type:	Primary dedusting
Demand:	Environmental regulations in the E.U. and other regions will continue to require highly effective dedusting.

PIONEERS AT HEART

As pioneers, we go where no one else has gone before. Discovering better and cleaner ways to produce steel. Creating new technologies that will make a difference. In the steel plants of our customers, for nature, and for our planet.







THE WINDING ROAD TOWARD **ZERO-CARBON IRON**

IRON AND STEEL PRODUCTION IS RESPONSIBLE FOR 7 TO 10 PERCENT OF GLOBAL CO₂ EMISSIONS. A DECISIVE SHIFT AWAY FROM CARBON-BASED REDUCTANTS TO ALTERNATIVES LIKE HYDROGEN IS ALL BUT INEVITABLE—BUT IT WILL HAVE TO COME IN STAGES.

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Hydrogen
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Using hydrogen to decarbonize ironmaking and other industrial processes is a powerful idea—but not actually a new one. Leaders in the industry who are now nearing retirement may remember it vividly from their student days. There were peaks of interest in the '70s during the oil price shocks, the '90s with incipient concerns about climate change, and in the early 2000s on the same note. None of these developments resulted in a breakthrough moment for hydrogen. However, this time around may well be different: As the International Energy Agency (IEA) notes in a recent report, last year marked a period of unprecedented momentum for hydrogen, combining a new depth of political enthusiasm with a breadth of new possibilities around the world.

The steel industry's biggest product today isn't steel—it's carbon.

Roughly 1.8 tons of CO₂ are released into the atmosphere for every ton of liquid steel produced on the still predominant, integrated route. And this number is based on calculations that assume an average, modern blast furnace operated in OECD Europe—many plants around the world emit three or more tons of CO₂ per ton of steel. These facts are hardly news to decision makers inside the industry. But they are only beginning to dawn on governments around the world who are now weighing their options for bringing about the

massive reductions in greenhouse-gas emissions mandated by the Paris Climate Agreement. As some of these governments strive toward the even more ambitious goal of net-zero carbon emissions by 2050, scrutiny is inevitably going to increase and pressure is going to build on steel producers to bring down emissions in drastic ways. Emissions-trading schemes are going to be implemented and widened in scope, carbon taxes are looming, and consumers will ultimately show concern for the carbon footprint of steel products.

Producers in some parts of the world are already feeling the painful pinch of carbon pricing. The devel- »

PRICE-TAG INCREASES FOR CARBON

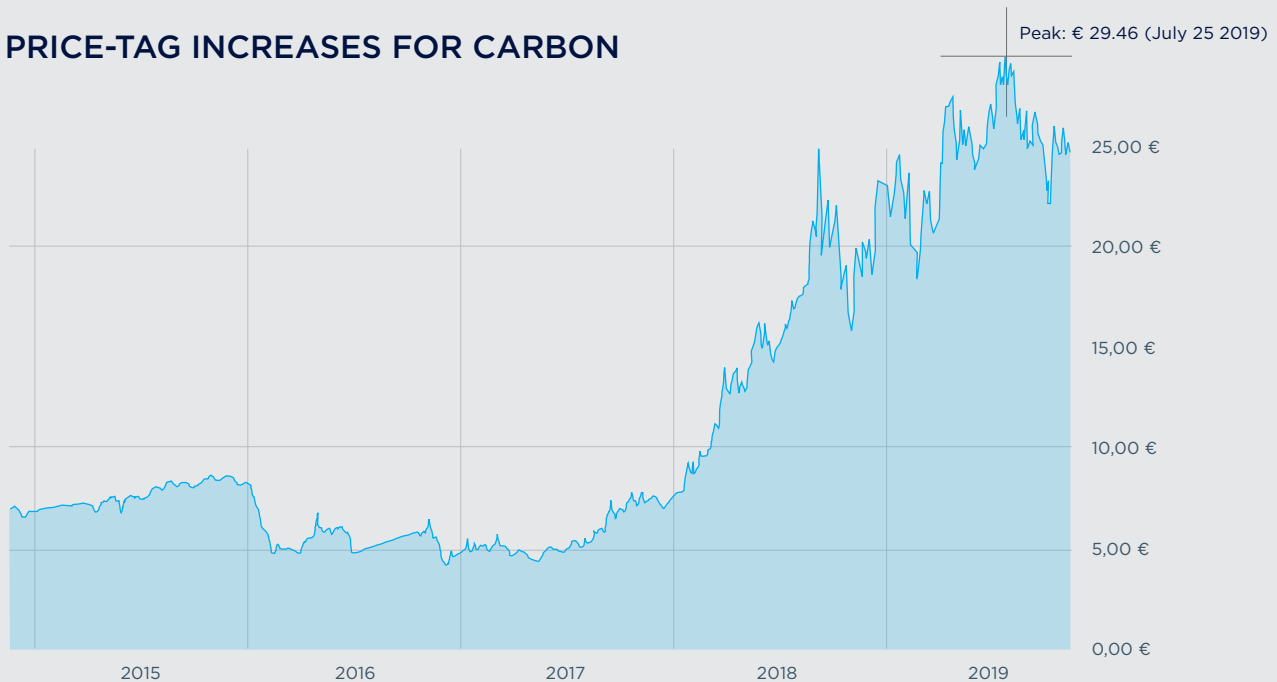


FIG. 1: After hovering at low levels for years, the price of European CO₂ Emissions Allowances has recently skyrocketed. As emissions-trading schemes are set to spread, allowances will inevitably become a significant driver of cost.

opment of prices for European CO₂ Emissions Allowances, as illustrated in Fig. 1, is a prime example. At their peak in mid-2019, prices had seen a sixfold increase over a two-year period. And they remain near record highs as the EU emissions trading scheme is poised to enter its next phase in 2021—when several measures kick in that will progressively tighten the supply of allowances.

In anticipation of such regulatory measures and market pressures, steel producers around the world are racing to deploy new technologies aimed at reducing carbon intensity in iron and steelmaking. Merely shifting production from coal and coke-based blast furnaces to direct reduction based on natural gas will not be sufficient. The industry will need to develop other energy sources without a direct carbon footprint, such as hydrogen, to commercial scale and in a manner that is economically feasible.

COMPARING THE PRODUCTION ROUTES

As Fig. 2 shows, the DR-EAF route, applying natural gas in the process, cuts carbon intensity for liquid steel by almost 50 percent in comparison with the conventional blast furnace to basic oxygen furnace route. By using green hydrogen instead, emissions can be

reduced by 75 percent. Most emissions at this point are actually attributable to electricity production for the EAF process. The calculations are based on a grid emissions factor of 0.452 kg of CO₂ per kWh—the average value for OECD Europe. Applying the emissions factor of Sweden (currently at 0.023 kg of CO₂ per kWh) would bring emissions down to only 181 kg CO₂ per ton—a whopping 90 percent reduction compared to the BF-BOF route. From there, all that stands in the way of true zero-carbon iron would be the provision of fossil-free energy for electricity, heat, and transport.

PRODUCING HYDROGEN AT SCALE

Needless to say, establishing a ready supply of hydrogen that can make iron and steelmaking truly carbon-free will be a major challenge. One of the key barriers is the sheer volume needed to support a massive upscaling in use by the industry. The amount that will be consumed is tremendous. Converting a typical integrated plant with a production of 5 million tons per year from coal and coke to hydrogen will require a supply of at least 480,000 Nm³ (equaling 44 tons) of hydrogen per hour. To put this into perspective, the largest proton exchange membrane (PEM) electrolyzer currently in operation generates only about 1,200 Nm³ (i.e. 0.1 ton) of hydrogen per hour. The largest one

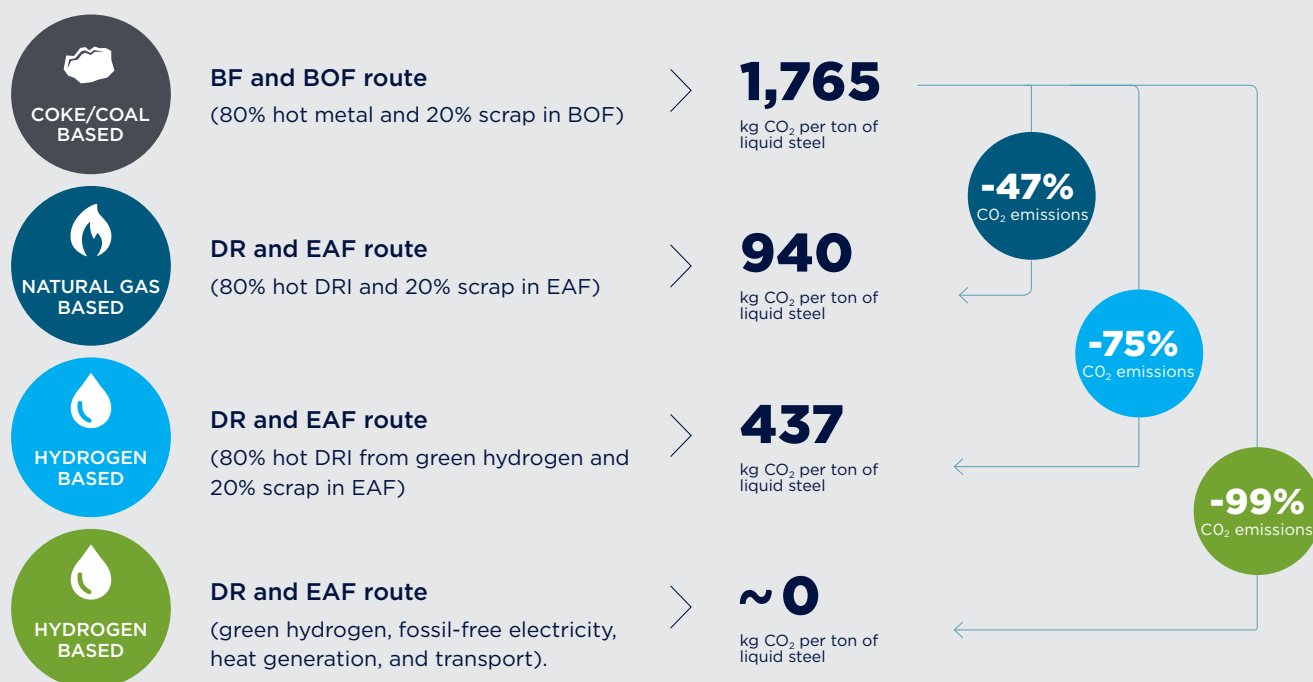


FIG. 2: Comparing CO₂ emissions of different process routes for liquid steel. Unless otherwise noted, calculations are based on emissions from electricity production on European OECD level.

currently in construction is a plant in Canada that is to produce 3,000 Nm³ (0.25 tons) per hour, starting in late 2020. Not only will vast quantities of additional hydrogen be needed to support the steel industry, but it will also have to be produced using alternative processes. Currently, around 95 percent of hydrogen is “gray”—meaning it is produced by extracting gas from fossil fuels. It is possible to use carbon capture, utilization, and storage (CCUS) technology to prevent emissions from being released into the atmosphere, resulting in “blue” hydrogen. But this only makes economic sense where a high volume of CO₂ can be captured at a single site. And it is only feasible in areas where there are geologically safe places to store captured carbon, such as beneath the sea or deep underground.

A GREEN-HYDROGEN REVOLUTION

To be a true game changer, the hydrogen used in the ironmaking process must be “green” hydrogen, generated by electrolysis from water, using fossil-free power only. To date, producing hydrogen in this way has proven too costly to be competitive. But this is changing, as the boom in renewable energy sources, like wind and solar power, brings down global electricity prices and the generation of hydrogen provides a way to store energy in times of excess electricity produc-

tion—when the wind is blowing or the sun is shining during times of low demand. Establishing a policy and financial-incentive framework for adopting hydrogen is an essential part of this shift toward a more sustainable future, which gives industry leaders the confidence to invest in long-term hydrogen projects.

For example, a project called the Asian Renewable Energy Hub plans to generate green hydrogen with up to 15 gigawatts of renewable power from thousands of large wind turbines and photovoltaic solar panels in Western Australia. Local government is providing crucial support and MHI Group company Vestas, a leader in wind-turbine technology, is a part of the consortium. The first hydrogen could be tapped in 2026 and production capacity could reach 1.5 million tons per year. This would be enough to produce 25 million tons of DRI per year, which equals 25 percent of today’s global production capacity. ●

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(All with Primetals Technologies Austria)

HYFOR

HYDROGEN-BASED FINE-ORE REDUCTION

- H₂ AS A REDUCING AGENT
- DIRECT USE OF IRON-ORE CONCENTRATE FINES
- NO AGGLOMERATION
- MODULAR PLANT DESIGN



FIG. 3: Drawings of the first HYFOR plant at a voestalpine site in Donawitz, Austria—currently in the engineering phase.

Hydrogen-based Fine-Ore Reduction (or HYFOR for short) is the world's first direct-reduction process for iron-ore concentrates from ore beneficiation that does not require any preprocessing of the material like sintering or pelletizing. Building on comprehensive experience from Primetals Technologies' Finmet and Finex processes, the new technology can be applied to all types of beneficiated ore. It works with particle sizes of less than 0.15 mm for 100 percent of the feedstock, while allowing a maximum grain size of 0.5 mm. Thanks to the large particle surface, the process achieves high reduction rates at low temperatures and pressures.

HYDROGEN OR HYDROGEN-RICH GASES

As a primary reduction agent, the new process uses H₂ from renewable energy or alternatively H₂-rich gases from conventional steam reformers. As yet another alternative, HYFOR can run on H₂-rich waste gases. Depending on the source of the hydrogen, this leads to a low or even zero CO₂ footprint for the resulting direct-reduced iron. The plant features a modular design with a rated capacity of 250,000 tons per module and year, making it suitable for all sizes of steel plants. A pilot plant for testing purposes is being constructed at voestalpine Stahl Donawitz, Austria and is due to be commissioned by the end of 2020.

WORKS WITH LOW-QUALITY ORES

HYFOR both drastically reduces CO₂ emissions and helps producers to effectively deal with the challenge

of reduced iron-ore quality, which has become more acute as of late—resulting in an increased need to beneficiate the ores. Rising demand for iron-ore pellets for blast furnaces and direct-reduction plants has led to higher prices for iron ore, especially pellet premium. With HYFOR, producers will be able to use pellet-feed fine ore directly and benefit from the rising global supply of ultrafines.

THE PILOT PLANT

The HYFOR pilot plant at voestalpine Donawitz will consist of three parts: A preheating-oxidation unit, a gas-treatment plant, and the core—the novel and unique reduction unit. In the preheating-oxidation unit, fine-ore concentrate is heated to approximately 900°C and fed to the reduction unit. The reduction gas H₂ is supplied over the fence from a gas supplier. A waste-heat recovery system that harnesses heat from the off-gas ensures optimal energy use and a dry-dedusting system takes care of dust emissions from the processes. The resulting hot direct-reduced iron (HDRI) leaves the reduction unit at a temperature of approximately 600°C and can subsequently be fed into an electric arc furnace (EAF) or used to produce hot-briquetted iron.

The purpose of the pilot plant is to provide practical evidence for this breakthrough process and to serve as a testing facility, collecting enough data to set up an industrial-scale plant at a later stage.



FIG. 4: With a capacity of 6 megawatts, the H2Future pilot plant on the premises of Austrian steel producer voestalpine in Linz is the largest hydrogen-electrolysis plant worldwide that runs entirely on renewables.

HYDROGEN ELECTROLYSIS WITH GREEN ENERGY

As of today, most of the hydrogen for industrial use is produced by steam methane reformers (SMRs). Since the natural gas that feeds these reformers (methane— CH_4) contains carbon, the resulting "gray" hydrogen causes a sizable amount of CO_2 emissions. To fully decarbonize the process, hydrogen for ironmaking will have to be produced by electrolysis from water, using fossil-free energy.

Since the year 2000, more than 230 hydrogen-electrolysis projects (counting both those based on renewable as well as conventional sources of energy) have entered into operation around the world. Most of them, like the H2Future project in Fig. 4, are based in Europe. But several have been started or announced in Australia, China, and the Americas. Almost all have been at a scale of less than 10 MW, but a 20 MW plant is being constructed in Canada and lately there have been several proposals for plants exceeding 100 MW—chief among them is the Asian Renewable Energy Hub project in Western Australia (see page 41).

There are three main electrolysis processes that make all of this possible: alkaline, proton-exchange membrane (PEM), and high-temperature steam electrolysis. The most advanced technology at this point—and the one that most recent hydrogen-generation projects have favored, is

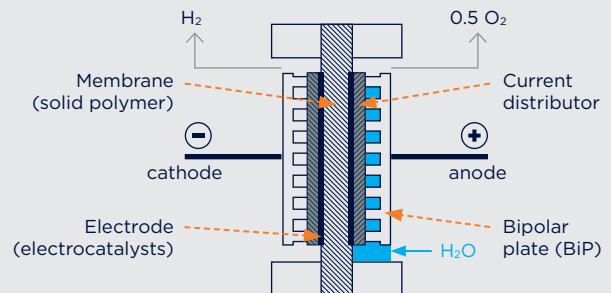


FIG. 5: Working principle of a proton-exchange membrane (PEM) electrolysis cell

PEM. It attaches electrodes on two sides of a solid polymer membrane, which acts as the electrolyte and as a separator to prevent the produced gases from mixing. Hydrogen ions form at the anode, pass through the membrane and combine with electrons from the cathode to form hydrogen gas.

The PEM-type electrolyzer has several advantages: It is highly efficient, features high power density, and has an extended dynamic operating range, allowing it to be directly coupled to renewable sources—because it can quickly react to changes in the electricity supply. Modules are available in the range of 3 to 100 MW, producing up to 20,000 Nm^3 (or roughly 2 tons) of hydrogen per hour.

APPLYING HYDROGEN

IN COMMERCIALLY PROVEN SOLUTIONS

Hydrogen is already part of the reduction-gas mix in mainstream direct-reduction processes—alongside carbon monoxide, of course. Most notably, perhaps, the Finmet (Finored) process, introduced by Primetals Technologies (VAI) in the 1990s, uses more than six parts of hydrogen for every part of carbon monoxide.

This flexibility of direct-reduction processes provides an enticing way for plant owners to switch to hydrogen in a gradual fashion, increasing the addition of hydrogen over time as prices come down. It also underlines the value of new investment into direct-reduction plants: Whatever the future might hold in terms of emissions regulations or prices for raw materials, direct-reduction technology allows for maximum adaptability.

ADDING HYDROGEN TO THE MIDREX PROCESS

Midrex direct-reduction plants produce roughly 60 percent of the world's DRI and have been available from Primetals Technologies for more than 30 years. The reducing gas—mainly a mixture of H_2 and CO —is produced from natural gas in a special CO_2 reformer supplied by Midrex Technologies. Without any modifications to the equipment, the process allows up to

30 percent of the natural gas to be replaced by hydrogen. To take an example, 60,000 Nm^3/h of hydrogen could be brought in to substitute 20,000 Nm^3/h of natural gas in the process. With minor additions to the equipment (to protect the reformer), the rate can reach as high as 100 percent—the limit may be determined by the required carbon content in the final product. The process can easily accommodate fluctuations in the hydrogen-addition rate, allowing the plant to react to changing hydrogen supplies (which are to be expected when sourcing the gas from water electrolysis with renewables like wind or solar).

MIDREX ON 100% HYDROGEN

If hydrogen is to be used as the sole reductant permanently (Fig. 7), the natural-gas reformer can be replaced by a reduction-gas heater. H_2 will be converted to H_2O during reduction and condensed in the top-gas scrubber. Since there is no source of carbon monoxide in the process loop, there is no need for a CO_2 removal system. The process uses approximately 550 Nm^3 of hydrogen per ton of DRI for reduction. Additionally, it requires about 250 Nm^3 of H_2 per ton of DRI for heat—which can be accommodated by other energy sources.



FIG. 6: Whatever the feedstock and reducing gas: direct-reduction solutions from Primetals Technologies are a sustainable and future-oriented investment.

MIDREX: ADDITION OF HYDROGEN

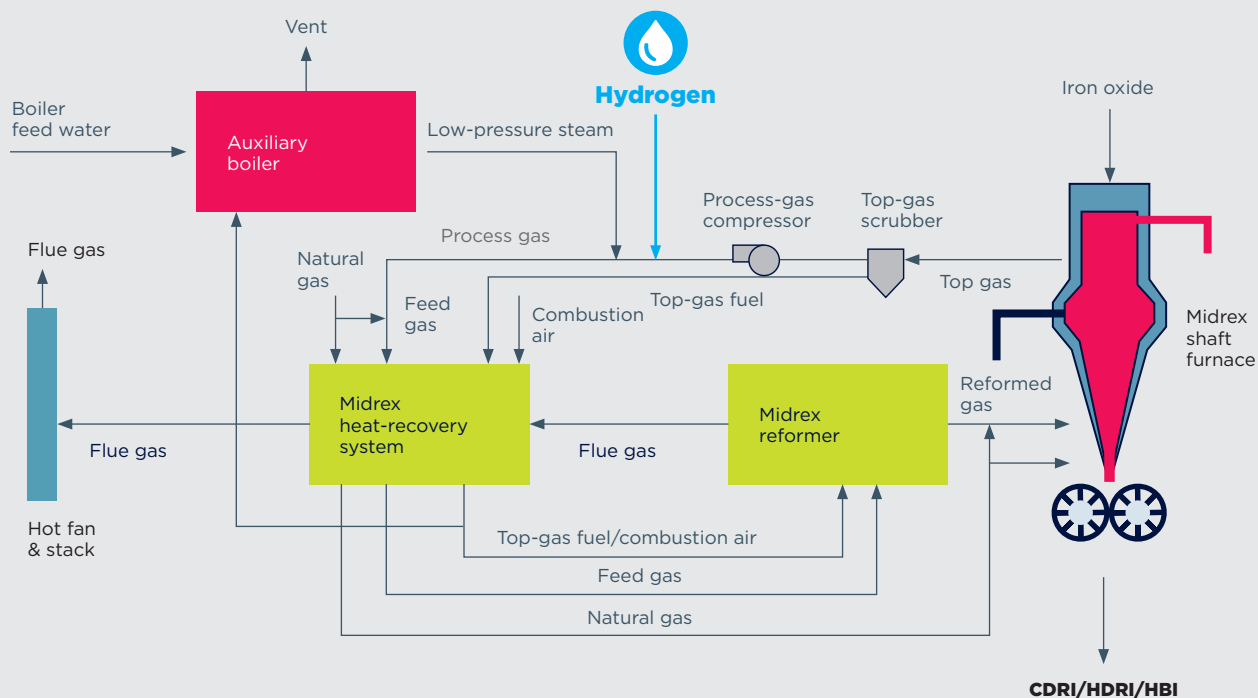


FIG. 6: A flow sheet for a Midrex plant that allows the addition of hydrogen to replace natural gas to various extents.

MIDREX: 100% HYDROGEN

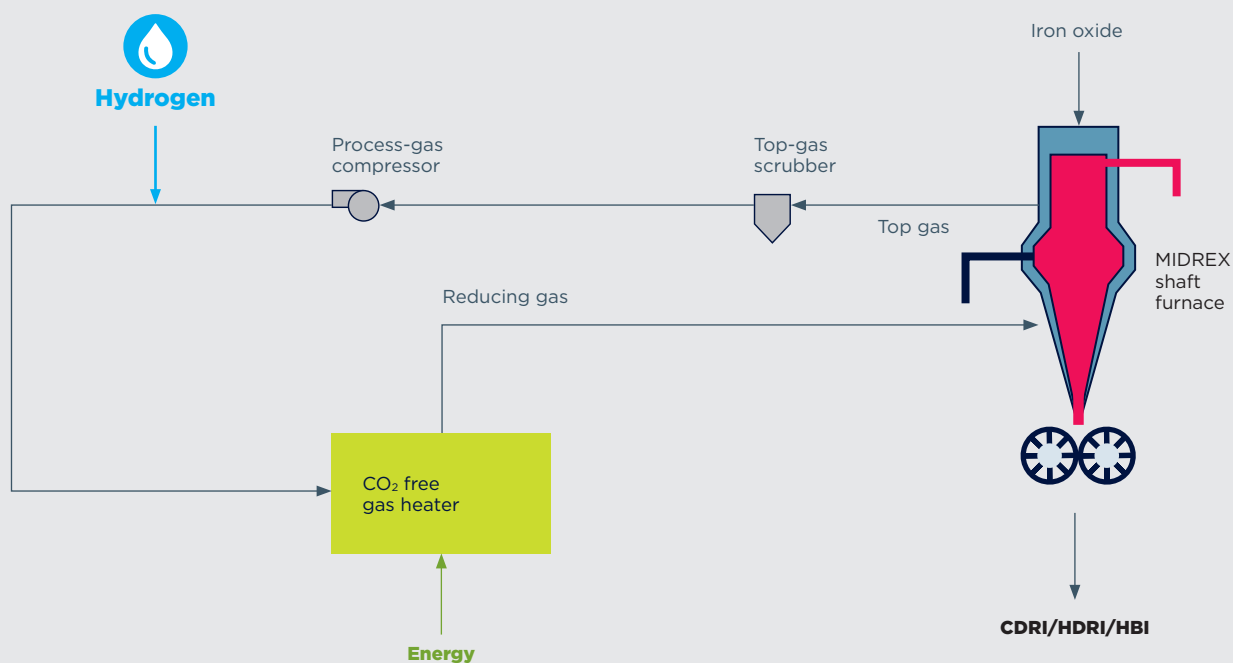


FIG. 7: When hydrogen is used as the sole reducing gas, the reformer can be replaced with a gas heater (which, ideally, is powered by carbon-free energy.)


TURNING OFF-GAS STREAMS **INTO REVENUE STREAMS**

AN ARCELORMITTAL PLANT IN POLAND HARNESSES HEAT AND PRESSURE FROM BLAST-FURNACE OFF-GAS TO GENERATE ELECTRICITY. THIS HELPS TO SAVE 115,000 TONS OF CARBON EMISSIONS PER YEAR—AND TURNS A HANDSOME PROFIT.

POWER FROM OFF-GAS

The two top-gas pressure recovery turbines generate a nominal 24.3 MW.



An aerial photograph of a large industrial facility, likely a steel mill. The scene is dominated by a complex network of large, bright yellow pipes that curve and run across the site. These pipes are supported by a dense structure of steel beams and scaffolding. In the foreground and middle ground, there are several large, horizontal, cylindrical industrial vessels or tanks, some of which are connected to the piping system. The ground is a mix of concrete and dirt. In the background, more industrial structures and a hazy sky are visible. The overall impression is one of a large-scale, complex industrial operation.

**Top-gas pressure
recovery turbines
turn blast-furnace
off-gas into a
revenue stream.**

MAXIMUM ELECTRICITY YIELD—STABLE PROCESS CONDITIONS

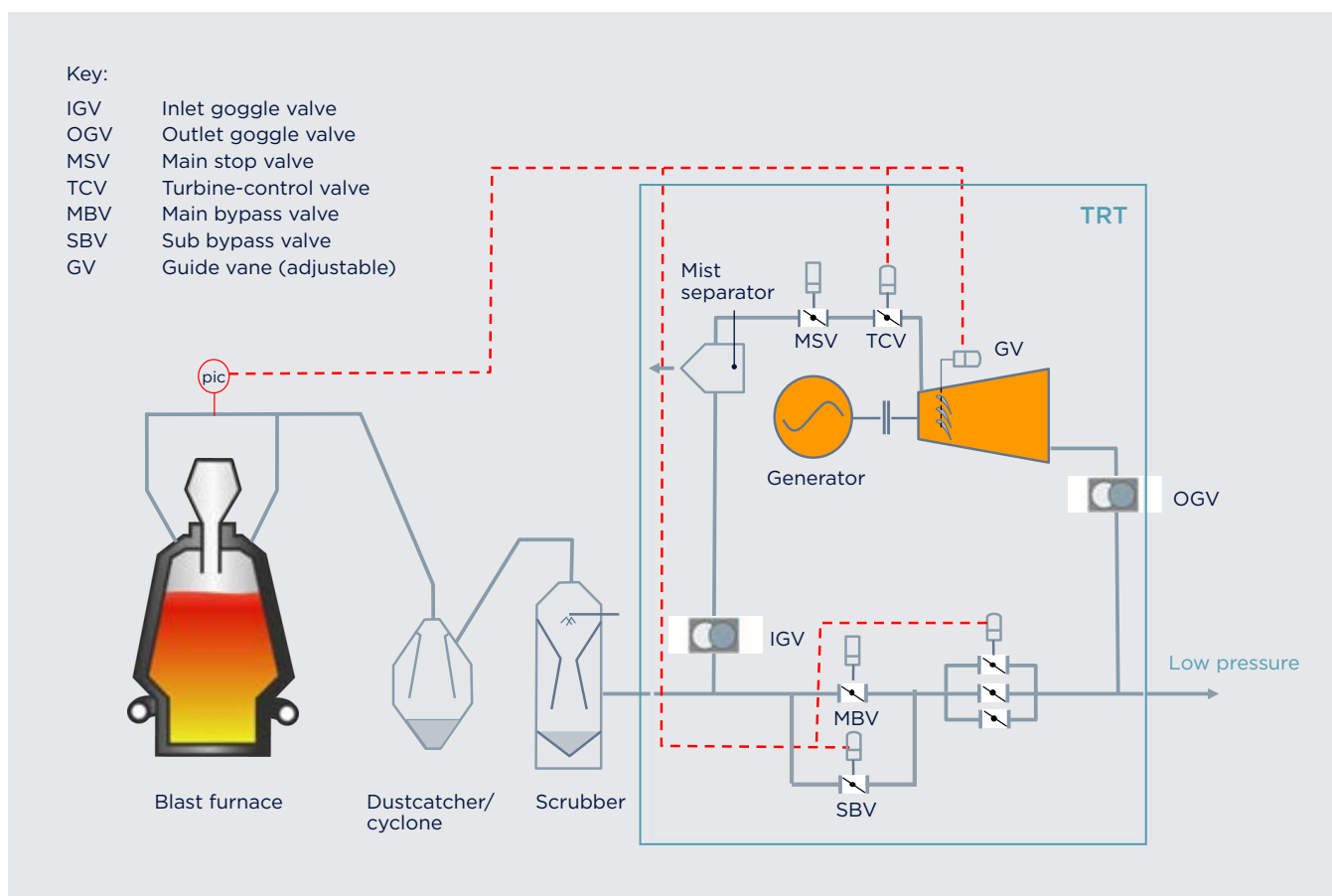


FIG. 1: A typical setup for a top-gas pressure recovery turbine running on blast-furnace off-gas. Quick-acting valves and a quick-bypass system ensure that the blast-furnace process remains undisturbed at all times.

The integrated plant of ArcelorMittal Poland in Dąbrowa Górnicza is the country's largest producer of steel. Situated in the southern voivodeship (province) of Silesia, the plant is only a few miles from the city of Katowice—famously the site of the 2018 United Nations Climate Change Conference (COP24), in which the parties to the historic 2016 Paris Agreement first formed a consensus on its implementation.

ArcelorMittal Poland's recent efforts in increasing sustainability at its plant are of course quite independent from the Katowice conference. In 2017, the company invested in new dedusting systems for the steel shop and sinter plant, as well as new denitrification and desulfurization installations to reduce emissions of dust, nitrogen oxides, and sulfur dioxides. In the area of energy efficiency, the efforts go back further: In 2014, ArcelorMittal Poland set up a joint venture with energy producer TAURON to form

TAMEH Holding, which, among other operations, runs the Nova Generation power plant on the premises of the Dąbrowa Górnicza steelworks. This facility encompasses boiler units fed by blast-furnace and coke-oven off-gas, and generates heat and electricity for the plant itself and other consumers in the surrounding area.

BOOSTING ENERGY EFFICIENCY

About 75 percent of the energy consumption in a typical integrated steel plant can be attributed to the blast furnaces. In a traditional setup, a significant portion of the energy contained in the blast-furnace gas goes unused: tremendous amounts of pressure and heat are wasted when the stream of gas hits a simple throttling group that reduces pressure to values suitable for the low-pressure gas network. Almost 80 percent of blast furnaces installed worldwide still operate this way—and so did the blast furnaces at Dąbrowa Górnicza. To take resource efficiency one step further and to reduce the environmental impact of electricity

“In terms of resource efficiency and ROI, installing a top-gas pressure recovery turbine really is a no-brainer.”

production on site, TAMEH decided to task Primetals Technologies with the installation of two top-gas pressure recovery turbines (TRT) and auxiliary systems on blast furnaces No. 2 and 3. The contract was signed in December of 2016. Only 24 months later, in December of 2018, the turbines first generated power at full capacity—it is the first such installation in Poland.

THE OPERATING PRINCIPLE

As Fig. 1 illustrates, the inherent energy in cleaned blast-furnace top gas (which, following wet dedusting, has a pressure of approximately 2.0 bar(g) and a temperature of 50°C) is first converted to mechanical energy in a turbine. This is achieved by means of a rotating shaft equipped with running blades made of erosion- and corrosion-resistant stainless steel. The shaft movement is used to produce electricity in a synchronous generator. A cleaning system using pressurized water prevents the build-up of dust on the blades. As a safety measure, nitrogen is injected into the shaft gland-seal system—this prevents top gas from leaking into the environment. To ensure excellent pressure control and safe operation of the blast furnace, the setup includes all-stage adjustable guide vanes and quick-acting valves. And as an additional layer of security, there is a quick-bypass function so the off-gas can be rerouted in case of unexpected events. In combination, these mechanisms ensure to a high degree of certainty that the pressure recovery never impinges on the blast-furnace process.

COMPACT, MODULAR DESIGN

Most of the mechanical equipment sits in a container construction—a rather unique, exceptionally compact design. The enclosure is about four meters wide, five tall, and 14 meters long. It includes the turbine, gearbox, lubrication, and hydraulic units. The containers were transported from Japan by ship and road. The generator unit was sourced from a supplier in the Czech Republic and was installed in the containers during erection. The design has several advantages: The plant layout is uniquely compact, yielding a smaller overall footprint, a shorter erection period, »



MAXIMIZING RESOURCE EFFICIENCY

Andras Varga is a process technologist at Primetals Technologies who specializes in upstream energy efficiency.

What were the most interesting challenges in this project?

Andras Varga: The installation included very long off-gas ducts, which was a challenge during operational mode transitions in commissioning—the top priority is of course always to keep the pressure stable so that the blast-furnace process can continue smoothly.

The benefits of the TRT seem straightforward—why are there still so many blast furnaces without top-gas energy recovery?

Varga: In terms of resource efficiency, a top-gas pressure recovery turbine makes sense for pretty much every mid to large size blast furnace. My guess is that many plant operators just haven't done the math—with energy prices broadly on the rise and regulatory pressure increasing across the board, we expect ROI calculations to shift even further in favor of the TRT. And the spread of dry-dedusting systems for blast furnaces means additional momentum, because they make for increases in energy output of 20–30 percent.

Which global regions do you have in mind specifically?

Varga: Plants in Europe and the Americas are the obvious candidates—there's a strong trajectory toward higher energy prices, and tighter regulatory regimes are looming. But there's also strong potential in India and Russia.

THE TOP-GAS PRESSURE RECOVERY TURBINES AT DĄBROWA GÓRNICZA



FIG. 2: Most of the mechanical equipment sits in a container construction. The enclosure measures about 4x5x14 meters and contains the turbine, gear-box, lubrication, and hydraulic units.

FIG. 3: A T-branch reroutes the blast-furnace off-gas toward the TRT container unit. A quick-bypass function makes sure the stream can be redirected in case of unexpected events.



FIG. 4: The turbine encompasses a rotating shaft equipped with running blades made of erosion- and corrosion-resistant stainless steel. Adjustable guide vanes at the inlet ensure high efficiency.

The turbines help conserve the staggering equivalent of 54,000 tons (or 900 wagons) of coal per year. This keeps 115,000 tons of carbon from being released into the atmosphere.

and considerable cost savings in the construction works—to take one example, there is no need to construct a turbine building. In the case of the Dąbrowa Górnicza plant, the setup includes two identical TRT container units with a nominal output of about 12 MW each, situated side by side.

A significant challenge in the project was the installation of a T-branch (Fig. 3) in the original blast-furnace layout between the gas cleaning and septum valve construction—and the fact that the remote site designated for the TRT necessitated unusually long off-gas ducts. The T-branch was needed to re-route the top gas toward the TRT in standard operating conditions, or to the septum valve when there is a need for a bypass. This branch also includes the bypass armatures. Everything had to be installed during a pre-scheduled 48-hour maintenance period for the blast furnaces.

GREAT ENVIRONMENTAL BENEFITS

TAMEH expects the two turbine units to produce 140 GWh of zero-emission electric energy every year—roughly the production equivalent of 25 on-shore windmills. Since in coal-rich Silesia the electricity would otherwise be produced by coal-fired power plants, the turbines will save a staggering 54,000 tons (or 900 wagons) of coal per year, keeping 115,000 tons of carbon out of the atmosphere. And the environmental benefits do not end there: reducing the use of coal by this amount will help to avoid 180 tons of sulfur dioxide and nitrogen oxide emissions, as well as about ten tons of dust per year. In terms of particulate matter emissions, this is equivalent to taking almost 170,000 diesel-fueled passenger cars off the road (assuming compliance with Euro 5 standards and an annual mileage of 12,000 kilometers).

A PROFITABLE INVESTMENT

With carbon pricing, stricter energy-efficiency regulations, and more comprehensive emissions-trading schemes looming in many parts of the world, it goes

without saying that technologies harnessing energy from the most carbon-intensive processes in an integrated steel plant have a bright future.

Something else to consider is the effect of global climate action and increasing energy demand on industrial electricity prices. Recent data from the International Energy Agency clearly shows that even at this point in time, a single top-gas pressure recovery turbine can yield millions in annual revenue in practically every market. If ever there was a time for steel-plant owners to get into the clean-energy business, it is now. ●

Andras Varga, Process Technologist

Harald Sprenger, Senior Project Manager

(Both with Primetals Technologies Austria)



WATCH THE TRT IN ACTION

Scan the QR code or type in the link below to watch our new video about the top-gas recovery turbine.

meta.is/trtvid

A large industrial converter in a steel mill. The converter is a large, cylindrical vessel with a metallic, slightly weathered surface. It is surrounded by a complex network of steel structural beams and supports. A yellow ladder is visible on the left side of the frame. The background shows the interior of a large industrial facility with high ceilings and various structural elements.

GREENING CONVERTER STEELMAKING

INCREASING THE SCRAP RATE IN CONVERTER STEELMAKING GREATLY IMPROVES A PLANT'S CARBON FOOT-PRINT. THERE ARE FOUR MEASURES TO "GREEN" THE CONVERTER.



With the steel industry under increasing pressure to make production more environmentally friendly, many steel producers are looking for short-term and cost-effective solutions for making their existing plants greener. Primetals Technologies believes that, in many cases, an evolutionary approach is appropriate: an incremental increase of the scrap and hot-briquetted iron (HBI) rate in converter-based steelmaking can lead to greener and more sustainable steel production.

Steel is actually a very sustainable material, because it is easy to recycle with minimal or no loss in quality, provided proper collection sorting systems are in place. The CO₂ emissions from the production of steel through the recycling of scrap or the use of hot-briquetted iron (HBI) are much lower compared to steel production from iron ore via the blast furnace or the direct-reduction route, primarily because all the reduction work is required for iron making only, while scrap only needs to be heated and melted.

Global steel production is still dominated by the integrated route, where hot metal is produced in the blast furnace and then refined in an LD (BOF) converter. While in some countries scrap-based steel production via the electric arc furnace (EAF) is prevalent, on a global scale it accounts for less than 20 percent of total steel production. Another way to produce steel is direct reduction, which is currently experiencing high growth rates, but globally its share is still comparatively low.

The number of LD (BOF) converters installed worldwide remains relatively stable, but the steel plants using them are coming under increasing pressure to raise the scrap rate in order to reduce CO₂ emissions. Technologies for increasing the scrap rate already exist and can be implemented as a short-term solution for reducing CO₂ emissions in steel making, thereby avoiding any major investment in building completely new facilities.

INCREASING THE SCRAP RATE

There are four main ways to incrementally increase the scrap (or HBI) rate and contribute toward greener steel production, ranging from simple solutions that can be implemented for existing BOF converters—like process models, scrap-preheating lances, and post combustion

lances—to dedicated processes for the highest scrap rates like the Jet Process.

1. CONVERTER PROCESS MODEL

In typical LD (BOF) converter operations, cooling agents such as pig iron or iron ore are added toward the end of the process—if measurements indicate this measure is necessary—in order to achieve the target tapping temperature. With a modern process model from Primetals Technologies, it is possible to accurately predict and control the final chemical composition and temperatures of the heat, and no such cooling agents are required. As a result, all of the energy generated during the process can be used to melt scrap, which is charged right at the beginning of the process.

Furthermore, applying this kind of process model results in a reduction of the number of reblows and corrections, ultimately helping to stabilize production and reduce waiting times and, consequently, energy losses. In typical cases, the implementation of Primetals Technologies' process model on the converter in conjunction with process optimization can increase the scrap rate by as much as four percent.

2. SCRAP-PREHEATING LANCE

Scrap is typically charged to the converter in cold condition. Preheating the scrap adds more energy to the steelmaking process and allows for a higher scrap rate. In order to avoid dust formation and emissions in the plant, preheating is best done inside the converter before the hot metal is charged. This allows the refractory-lined converter vessel to be used as a combustion chamber and the primary dedusting equipment for heat recovery and off-gas cleaning. Scrap preheating itself is done with a burner lance using natural gas, and the same lance can also be used for converter preheating after relining or during standby times. »

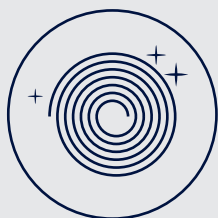
THREE KEY CHALLENGES

In order to increase the scrap rate in existing converter plants, steel producers will have to overcome three main challenges.



Scrap logistics

The first challenge involves putting in place an adequate transport infrastructure, so that the scrap can be transported to the plant for storage prior to its final use in the converter. The storage area has to be able to cope with the clear separation of different scrap qualities, which ensures the cost-effective use of the scrap. The scrap then has to be transported and loaded into the converter using scrap chutes. Depending on the scrap rate and space restrictions, two chutes per heat are required to achieve higher scrap rates, which can result in longer charging times and reduced plant productivity unless appropriate countermeasures are implemented.



Steel quality

The converter is the perfect aggregate to refine the steel and to remove elements such as silicon, carbon, phosphorus, or sulfur from the hot metal charged to the converter. However, there are trace elements like copper, chromium, and nickel that negatively impact steel quality but cannot be removed from the melt in the converter or through secondary metallurgy. This is why a scrap-sorting system and careful scrap quality control are required: they ensure that not too many undesirable trace elements are added to the heat in the first place. Additional process models are employed to calculate the degree to which trace elements will end up in the final product, as well as the amount and quality of the scrap required.



Energy balance and scrap melting

The processing of scrap requires energy for heating and melting. In the converter process, this energy is provided by the combustion of carbon and silicon in the hot metal or by adding heating agents to the process. Since the amount of these combustibles is limited, the share of scrap that can be processed in a converter is limited to some 15 to 20 percent, unless the steps described in this article are taken.



A converter, being charged with scrap. Higher scrap and HBI rates can lead to more environmentally friendly steelmaking.

In order to avoid extensive scrap oxidation, the preheating temperature needs to be limited to an average of 800 degrees Celsius; about ten minutes of preheating time is required to achieve this temperature. The additional energy input from preheating will allow the scrap rate to be increased by about five percent. This process is similar to the de-icing and drying process necessary in many northern countries when handling scrap in winter.

3. DUAL-FLOW POST-COMBUSTION LANCE

The combustion of silicon and carbon is what generates most of the energy in the converter. While silicon is fully combusted to SiO_2 , the carbon in the hot metal is only combusted in the reaction zone to CO. Additional oxygen needs to be supplied in a second step for post combustion in order to finally combust the CO to CO_2 and utilize the full energy potential of the carbon contained in the hot metal. This is best done using a dual-flow post-combustion lance, a lance equipped with an additional port where oxygen for post combustion is injected. Furthermore, a second control line is required to regulate the flow at the post-combustion port. This second line allows the post combustion to be controlled independently of the decarburization process.

The installation of a dual-flow post-combustion lance allows the rate of CO combusted to CO_2 inside the converter to be increased from 12 to 20 percent. The additional energy generated this way makes a scrap-rate increase of as much as four percent possible.

4. JET PROCESS

The Jet Process combines a bottom-blowing converter equipped with lime and coal injection and a hot-blast lance for the highest-possible post combustion. This design results in an almost complete combustion of the coal—which is found in the hot metal and additionally injected—to CO_2 inside the converter. This way, the chemical energy of the coal is used to the maximum extent possible; the resulting efficiency is higher than that of an electric arc furnace using electricity from a coal-based power plant.

For the LD (BOF) converter, it is possible to incrementally increase the scrap rate by implementation of the process model, scrap-preheating lance, and dual-flow post-combustion lance. But the maximum scrap rate is restricted to approximately 30 percent due to limited bath mixing in the converter, as all oxygen is blown from the top. To overcome this limit, the Jet Process uses bottom-blowing converter technology that allows for the melting of large scrap pieces, can use greater amounts of scrap in a reasonable timespan, and ensures that all scrap is molten before blowing ends.

The design of the Jet Process enables the highest possible post combustion as well as an excellent transfer of the generated heat to the steel bath. With the Jet Process, scrap rates of up to 50 percent are realistic, and thanks to its efficient use of coal, CO_2 emissions are almost 40 percent lower compared to traditional converter-based steelmaking. A first industrial reference for the Jet Process was installed at POSCO,

Increasing the scrap rate in converter steelmaking is an essential step toward more sustainable steel production.

Korea, and the principles and advantages of the process have been proven.

TOWARD A GREENER FUTURE

Global steel production is still dominated by the integrated route, which uses LD (BOF) converters to refine the steel. The typical charge mix for this type of converter consists of 20 percent scrap and 80 percent hot metal from the blast furnace; the latter is responsible for the majority of the total CO₂ emissions per ton of steel produced via the converter. The scrap rate—as well as the HBI rate—processed in the converter can be increased by more than 10 percent through the combined implementation of a process model, scrap-preheating lance, and dual-flow post-combustion lance—an easy upgrade for existing plants. For even higher scrap rates, the Jet Process is an excellent choice.

These improvement measures lead to a significant reduction in CO₂ emissions per ton of steel produced, and can be implemented in existing plants in a short timeframe by re-using the available infrastructure. As a consequence, increasing the scrap or HBI rate in converter steelmaking is an essential short-term step toward more sustainable steel production, and is available for implementation today. It will allow the gap to be bridged until more advanced solutions—for instance, hydrogen-based technologies—are ready from a technical and commercial perspective for full industrial application. ●

Dr. Gerald Wimmer, Vice President, Converter Steelmaking, Primetals Technologies Austria.



THE RIGHT SOLUTION AT THE RIGHT TIME

Dr. Gerald Wimmer is VP of Converter Steelmaking at Primetals Technologies. He believes that the converter still has great potential.

What in your view is the best upgrade for converter-based steelmaking facilities?

Dr. Gerald Wimmer: It's impossible to choose only one—I think that the process model and dual-flow post combustion lance are versatile tools that can be easily implemented in all plants, with benefits in several dimensions. Producers all around the world are currently evaluating such implementations.

What is the outlook for converter steelmaking in your personal opinion?

Wimmer: In the long run, I hope we will manage to replace the existing blast-furnace-to-converter route with more sustainable processes that require fewer resources and less energy while generating less CO₂ emissions. For the time being, converter steelmaking will remain the dominant process with lots of potential for improvement. Most potential steps for improving the process, such as increasing the scrap rate, are typical short-term measures: readily available and easy to implement.

Is there a new technology in steelmaking that you're particularly excited about?

Wimmer: 90 years ago, the invention of the Linde-Fränkler process for low-cost oxygen generation paved the way for converter steelmaking as we know it. I expect a similar development to happen with what I consider the likely next step: hydrogen-based steelmaking.



The LiquiRob robot system helps eliminate manual labor close to the liquid steel.

INCHING TOWARD **MANLESS CASTING**

A photograph showing a robotic arm (LiquiRob) in a steel mill environment. The arm is white and orange, with a large hydraulic cylinder at its end. It is positioned near a ladle, performing a connection task. The background is dark, and there are yellow safety railings in the foreground.

FULLY AUTOMATIC LADLE CONNECTION

In addition to a range of other tasks in continuous casting, the LiquiRob robot system can now connect ladles on the charging side of the turret fully automatically: it inserts the hydraulic cylinder to the slide gate and connects couplings for gases and electrical signals. This is a major step forward for workplace safety in continuous casting.

The continuous-casting process involves discontinuous operations that are critical for the quality of the cast product and that have to be performed dangerously close to the liquid steel. Luckily, recent advances in robot technology and machine vision have made it possible to fully automate many of these tasks—replacing semi-automatic manipulators operated by human personnel. The LiquiRob system from Primetals Technologies has been able to perform tasks such as shroud manipulation, probe handling, and feeding tundish powder for quite some time. Now we have added fully automated ladle connection to its list of capabilities.



FIG. 1: On the charging side of the ladle turret, LiquiRob can now fully automatically insert the slide gate cylinder on a ladle and connect couplings for gases and signals.

For years, steel producers have been increasing their efforts to improve working conditions and workplace safety for human operators. In the area of continuous casting, automated functions and manipulators have therefore become the norm. They are necessary to perform a range of discontinuous tasks that are integral to the process and critical for product quality:

- Connecting or disconnecting equipment to and from the ladle: the slide-gate cylinder, couplings for gases and electrical signals, and the ladle shroud
- Oxygen lancing of the ladle when the slide gate is stuck
- Covering the steel bath in the tundish with powder
- Measuring temperature and contents of accompanying elements (O_2 , H_2)
- Steel sampling in the tundish

Unfortunately, the devices currently being used to accomplish these tasks have serious shortcomings: They operate only semi-automatically, requiring the presence of human operators in hazardous areas at least some of the time; and the equipment is mostly designed for a single, highly specific task—making it hard to extend or modify its functionality.

Combining the latest in robot technology with state-of-the-art machine vision, our LiquiRob system has made it possible to fully replace human-operated semi-autonomous manipulators for every one of the aforementioned tasks in continuous casting—bringing the industry closer than ever to the ultimate goal of full automation and zero workplace injuries.

FULLY AUTOMATED LADLE CONNECTION

The area surrounding the charging side of the ladle turret has recently been the focus of activity for Primetals Technologies: This is an especially critical spot,



FIG. 2: A single robot can perform both shroud manipulation and probe handling—by using a pneumatically actuated tool changer.

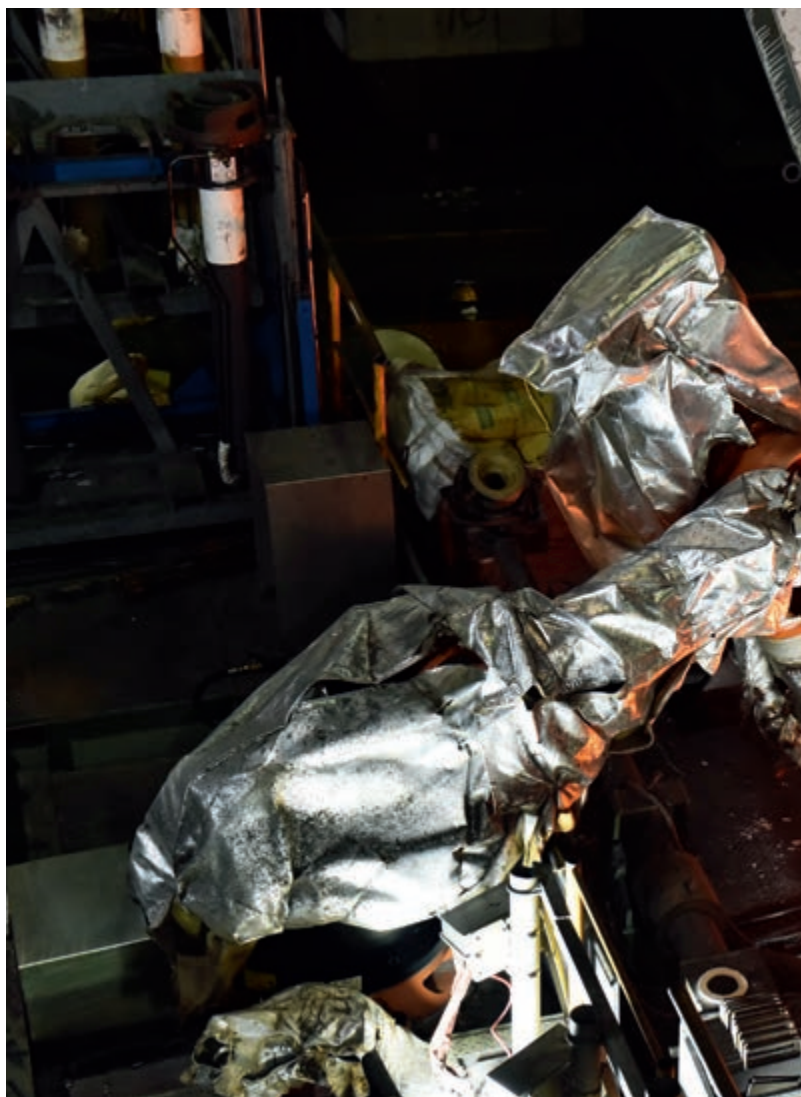
LiquiRob performs tasks directly at or under ladles full of liquid steel—substantially improving workplace safety in continuous casting.

where a whole number of tasks have to be performed directly at—and in some cases under—a ladle full of liquid steel. In the overwhelming majority of continuous casting plants, it is human operators who insert the hydraulic cylinder into the slide gate when a full ladle arrives at the turret. Another set of manual tasks involves connecting couplings for various media, such as argon for sealing, air for slide-gate cooling, and electrical signals for slag detection.

To fully automate these tasks, the LiquiRob system employs a standard 6-axis industrial robot that can withstand the harsh environment of the plant and that performs both cylinder manipulation and media connection. As the robot has to actively pick and position different parts, we have developed a pneumatically actuated tool changer that sits between the robot and the standardized counterparts. Sequences for connecting or removing media or a slide-gate cylinder to or from ladles are started remotely via a human-ma- »

Shroud manipulation, probe handling, tundish-powder feeding: leave it to the robot.

FIG. 3: Fully automatic ladle-shroud manipulation with the LiquiRob robot system.



chine interface. And a communication interface to the plant's programmable logic controller ensures that all necessary preconditions (like turret position and height) are met prior to starting any sequence. Another important aspect of the robot system is the safety concept—to avoid harming personnel that might be present in the vicinity of the robot. A fence around the robot area with safety locks ensures that the robot will only move when the doors are confirmed closed and locked from the outside. Besides the new functions surrounding the ladle turret, LiquiRob can help automate a range of other tasks, greatly benefiting workplace safety by reducing human presence close to the liquid steel.

AUTOMATIC SHROUD MANIPULATION

To control the flow from the ladle into the tundish and to prevent the liquid steel from picking up oxygen, the ladle shroud has to be attached to the ladle before opening the slide gate. This is typically done manually with a simple mechanical arm or by means of a hydraulically

assisted manipulator—which, again, requires human presence close to liquid steel. In order to improve safety, this task can be fully automated with LiquiRob. Using machine vision for accurate positioning, the robot connects the shroud to the nozzle. This is facilitated by a novel bayonet coupling on the shroud that guarantees the tightest-possible connection between the two parts: It allows the clamping force between the shroud and the short nozzle to be adjusted and can follow the movements of the slide gate during opening and closing without any relative movement—eliminating abrasion at the refractory nozzle tip that occurs when shrouds are handled by manipulators.

PROBE HANDLING

As opposed to shroud or slide-gate manipulation, the robot movements for performing tundish measurements or taking samples are not dependent on the exact position of any piece of movable equipment on the caster. Thus the tasks can be performed without camera input and adaptive robot paths. By using the



automated tool changer, the same robot that handles shroud manipulation can be used for measuring things like temperature, O₂, or H₂.

FEEDING TUNDISH POWDER

The liquid steel in the tundish needs to be kept from picking up ambient oxygen, which is normally achieved by applying tundish powder. The process usually involves operators in the tundish area, who throw bags of tundish powder into the trough. The LiquiRob that performs shroud manipulation is capable of handling high loads, so it can easily use a shovel filled with powder and empty it across several positions in the tundish. Numerous tests with samples of various powders have been executed to achieve high feeding rates—at the current stage, it takes less than ten seconds to feed 90 kilograms of powder. At this rate, the required cycle time for powder feeding can be easily achieved. ●

Mario Hirth, Mechatronics Expert, Continuous Casting, Primetals Technologies Austria.



THE POWER OF MACHINE VISION

Industrial robots are designed for repeating the very same movements with the highest precision and at great speeds. Needless to say, the conditions we encounter in steel plants are rarely that straightforward. To take an example, the typical position accuracy of a ladle on the ladle turret is in the range of $\pm 250\text{mm}$ in each horizontal direction. Moreover, turrets lift and lower the ladles without precise positioning, meaning that the position of a ladle can vary widely from one ladle to the next. So in order to allow a robot to interact with the equipment in any way, it first has to identify its exact position.

LiquiRob solves this problem with the aid of a stereoscopic camera system that is able to exactly identify the position of special targets in all three dimensions. These targets are mounted in predefined positions on the ladle and on the ladle turret. The resulting high reliability of the position measurement is one of the key elements in the successful deployment of LiquiRob in the dusty environment of a casting machine.

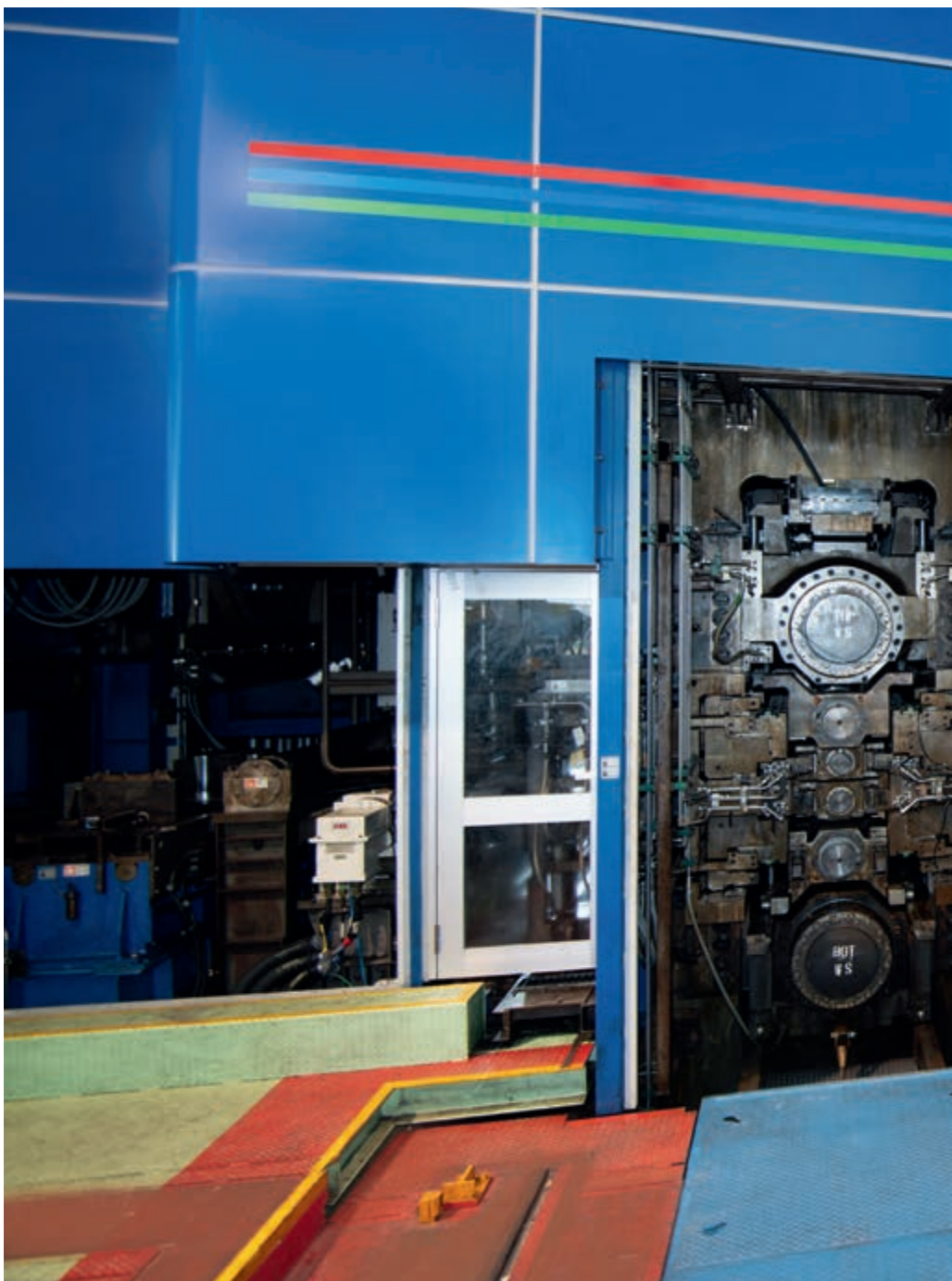


FIG. 1: Hyper UCM engineers Masahiko Natsume, Ryota Kono, Shinichi Yasunari, Fumihisa Shimaya, and Dr. Takehiko Saito in front of their testing mill.

THE RICH REWARD OF INNOVATION

A CLOSER LOOK AT THE PAST, PRESENT, AND FUTURE OF THE HYPER UNIVERSAL CROWN CONTROL MILL (HYPER UCM), THE PIONEERING COLD-ROLLING SOLUTION FROM PRIMETALS TECHNOLOGIES



The Hyper UCM is the result of pioneering innovation combined with decades of refinement. It represents the technology of choice for new cold rolling mills but can also be implemented in the context of reversing cold mill and tandem cold mill upgrades. This article examines the development and refinement of the Hyper UCM, and showcases a recent reference installation at Chinese steel producer Maanshan Iron & Steel Co. (Masteel).

Given its significance in the industry, it is no exaggeration to say that the 6-Hi mill design marked a major milestone in the history of rolling technologies. This invention changed the course and shape of rolling mills as we know them today, and renowned Japanese technologist Dr. Toshiyuki Kajiwara [see interview] was instrumental in its development. Inspired by his passion to create the most user-friendly, high-performance rolling mill possible, Primetals Technologies later evolved his design to create a highly sophisticated cold-rolling solution.

The Hyper UCM is the most advanced iteration of the Universal Crown Control Mill (UCM) and takes after Dr. Kajiwara's 6-Hi mill innovation. While retaining all the incredible advantages of the standard 6-Hi UCM, the Hyper UCM features work rolls that are 20 to 30 percent smaller than those used in the standard UCM. It can roll materials of much higher strength into thinner strip, achieving uncompromising levels of quality and productivity.

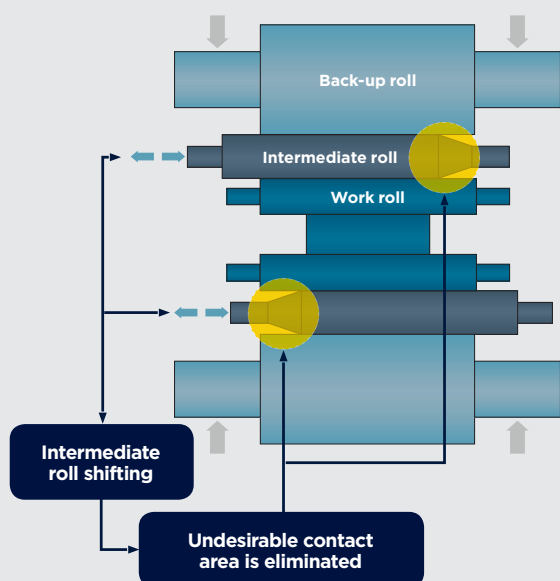
The installation of a Hyper UCM enables steel producers to expand their product portfolio and gain a competitive edge in the metals industry. For producers to stay relevant in a low-carbon world, the manufacture of extremely strong yet thinner and lighter strip is no longer merely an option, but a must. The implementation of production methods that consistently deliver sophisticated steels has become a key strategic goal, because the demand for electric and lightweight vehicles is continually rising. The Hyper UCM is ready to meet this challenge.

GENESIS OF THE 6-HI MILL

Before Dr. Kajiwara's innovation, which represents a quantum leap in terms of rolling methods, the 4-Hi mill consisted of a set of backup rolls and a set of work rolls were available as standard. In the 4-Hi mill, work rolls and backup rolls would come into contact with each other at their outer sections, at the areas that extend outside the strip width. These sections are known as the "undesirable contact area", since they cause work rolls to deflect and make it difficult to roll strip to the required flatness levels. To eliminate these areas and roll quality strip on the 4-Hi mill, profound knowledge and considerable experience in mill handling was necessary, owing to the large and complex selection of work rolls that needed to be exchanged according to pass schedule and materials.

Dr. Kajiwara's solution was to create a 6-Hi structure, a new mill design that employs shiftable intermediate rolls in between work rolls and backup rolls in order to eliminate the undesirable contact area. This groundbreaking method could then be used on a day-to-day basis to produce high-quality strip in a simple and straightforward process, much to the benefit of mill operators.

Arguably the greatest technological advancement of Dr. Kajiwara's 6-Hi mill was its use of work rolls that are smaller than those of the 4-Hi mill: the 6-Hi mill's smaller work rolls decreased rolling loads and led to a higher reduction ratio. Another key feature of his 6-Hi mill was its high degree of versatility—something that became particularly evident in day-to-day operation. »

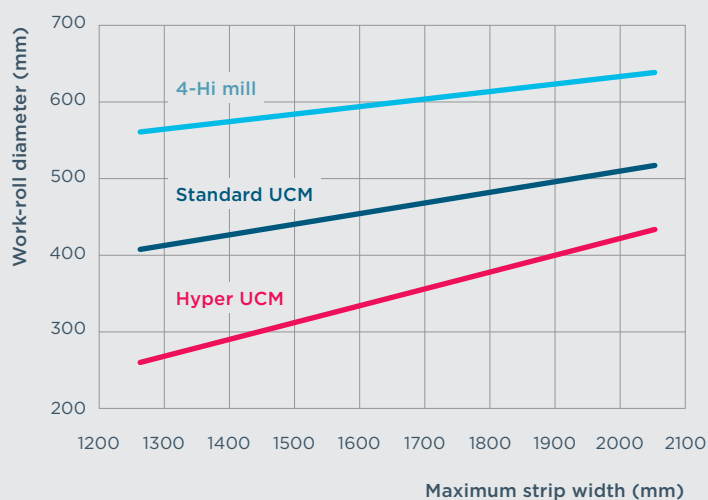


CORE DESIGN OF THE 6-HI MILLS OF PRIMETALS TECHNOLOGIES

In the 6-Hi mill—and therefore in the standard UCM and Hyper UCM of Primetals Technologies—the undesirable contact area between the work roll and the backup roll is eliminated by the introduction of an intermediate roll, which is designed to shift across its axis according to strip width. This design suppresses work-roll deflection and maximizes the effect of the roll benders, which help to control the finer strip shape. Thanks to this innovative mill design, a straight work roll can accommodate any pass-schedule change, and much easier mill operation becomes possible.

REFERENCE INSTALLATIONS OF THE HYPER UCM

CUSTOMER	PROJECT TYPE	SUMMARY	STATUS
Masteel, China	Reversing cold mill (No. 3)	Startup: 2013 Grades: Silicon steels Thickness: 0.35–0.65 mm	Running
Customer from East Asia	Tandem cold mill; 1 of the 5 stands was revamped to a Hyper UCM	Startup: 2017 Grades: AHSS	Running
Masteel, China	Revamp of reversing cold mill (No. 1)	Startup: 2018 Grades: Silicon steels Thickness: 0.35–0.65 mm	Running
Customer from China	Tandem cold mill; 1 of the 4 stands will be revamped to a Hyper UCM	Startup: 2020 Grades: HSS, silicon steels	In progress
Customer from China	Tandem cold mill; 1 Hyper UCM stand will be added to 5 existing stands	Startup: 2021 Grades: AHSS	In progress
Customer from Vietnam	Reversing cold mill	Startup: 2021 Grades: Low-carbon steels Thickness: 0.10–1.6 mm	In progress



COMPARISON OF 4-HI MILL, UCM, AND HYPER UCM

The discovery of the undesirable contact area in the 4-Hi mill and the respective solution—intermediate-roll shifting—enabled a reduction of work-roll diameter. The schematic to the left indicates the average work-roll diameter derived from plant-specific data of rolling mills worldwide, according to type of mill and strip width. In overall comparison, the work-roll diameter of the standard UCM is approximately 25 percent smaller than that of the 4-Hi mill. The Hyper UCM's work-roll diameter is further reduced by 20 to 30 percent from that of the standard UCM.

REFERENCE INSTALLATION:

UPGRADE TO HYPER UCM AT MASTEEL, CHINA



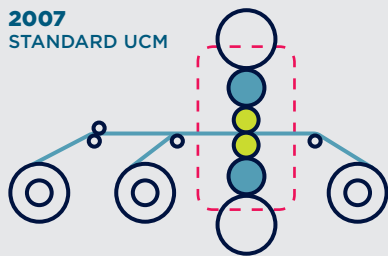
Primetals Technologies recently completed an upgrade of the Universal Crown Control Mill (UCM) for Maanshan Iron & Steel Co. (Masteel), a leading supplier of high-quality electrical steel. Masteel had been producing mid-grade non grain oriented (NGO) sheet since 2007, on their two standard UCMs in a single-stand reversing cold mill (RCM). Their third RCM was commissioned in 2010, using Primetals Technologies' more advanced Hyper UCM solution, which allows for the production of higher-grade electrical steels. In 2017, Masteel placed an order with Primetals Technologies, this time to upgrade one of their standard UCMs to the Hyper UCM. The project

resulted in a substantial boost of the plant's output and performance. In order to minimize the shutdown period, Primetals Technologies decided to re-use the original housing of the standard UCM, which was possible because its roll-stack dimensions were almost identical to those of the Hyper UCM. The only required modification on the housing was the application of new screw holes for new bending blocks.

The Hyper UCM introduced different work rolls with a diameter of only 260 mm, compared to 370 mm previously. Despite this reduction in the roll diameter, the Hyper UCM was to be work-roll driven just like the standard UCM. The smaller work rolls made it possible to decrease the rolling force and reduce the number of passes. To accommodate the smaller work-roll diameter and the change in rotating speed, a new pinion stand, a new mill drive motor, and a new type of spindle were also installed. Furthermore, Primetals Technologies renewed the bending block, roll-changing car, as well as the entry and exit cobble guards, which helped to realize the implementation of work rolls with smaller diameters. Thanks to the Hyper UCM technology, the revamped RCM is now able to produce higher grades of electrical steel such as 35W270, while the standard UCM only produces up to around 35W440.

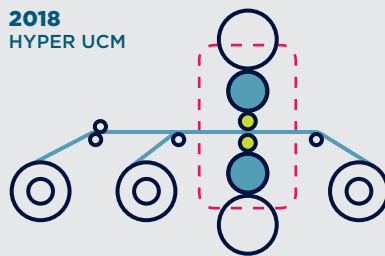
BEFORE REVAMP

2007
STANDARD UCM



AFTER REVAMP

2018
HYPER UCM



Products

Mid-grade non grain oriented (NGO) steels (35W440, 50W470)

High grade non grain oriented (NGO) steels (35W270, 50W290)

Mill type

Standard UCM

Hyper UCM

Work-roll diameter

370 mm max.

260 mm max.

Drive method

Work-roll driven

Work-roll driven

The UCM has made a massive contribution to a steel industry that was hungry for better and more effective steel production.

A single set of straight work rolls could be used for any pass schedule, and there was no need for the operator to change rolls when switching from one product to the next. Consequently, a much smaller roll-inventory size became possible.

THE UCM IS BORN

After the inception of the 6-Hi mill, market expectations kept changing and demand for thinner and harder strip with improved flatness characteristics increased. Consequently, R&D efforts to further develop the innovation continued and the Universal Crown Control Mill (UCM) was created. The UCM featured excellent strip-shape control capability, and a stable strip shape could be maintained under varying rolling loads with much less effort. Product yield was also improved as a result of the reduction in edge drop with the UCM. In the 1980s, it was recognized as a next-generation 6-Hi mill that, thanks to its performance, enabled steel producers to expand their portfolio to encompass sought-after high-quality materials.

The UCM has made a massive contribution to a steel industry that was hungry for better and more effective steel production, and has established itself as a reliable solution for rolling high-quality materials. Meanwhile, the growing demand for even harder and thinner materials in recent years has spurred further technological advancement. This is why Primetals Technologies has chosen to create a new mill design that can take the unique advantages of the UCM to the next level.

INTRODUCING THE HYPER UCM

The Hyper UCM represents this next step in cold-rolling technology. It uses even smaller work rolls, which are driven by a small work-roll drive system. During the Hyper UCM's development phase, the best combi- »



A NEW SPINDLE DESIGN FOR HIGHER TORQUE

Over the course of the development of the Hyper UCM, Primetals Technologies discovered the ideal combination of roll diameters. This brought the researchers one step closer to a new, advanced mill. The next step was the application of these findings. In order to implement the desired work-roll size, the technologists had to craft a downsized work-roll drive system with smaller spindles. Although the work roll diameter became smaller, a higher-strength spindle was needed to transmit the required high torque. Nothing short of a technological breakthrough was necessary: a new type of spindle that would be capable of transmitting higher torque to smaller work rolls had to be designed.

Primetals Technologies successfully pioneered this innovation. The new spindle design laid the foundations for the shift to the Hyper UCM. The spindle's material and structure were improved, significantly increasing its strength compared to conventional models. This new spindle is called Mitsubishi-Hitachi (MH) Spindle, and has the ability to transmit torque approximately 2.7 times higher than that of the conventional Universal Joint (UJ) type spindle. Since its development, the MH Spindle has already proven its merits in the cold mills of several Primetals Technologies customers.

TAKING NEW INSPIRATION FROM MILL OPERATORS

Dr. Toshiyuki Kajiwara (1928–2012) is known as the father of the pioneering 6-Hi mill with shiftable intermediate rolls. The Hyper UCM of Primetals Technologies is based on his mill design. In this interview, originally featured in Japan Metal Daily in 1990, we examine what inspired Dr. Kajiwara to create new solutions—and we hear about the steps he took that eventually led him to his 6-Hi innovation.



What got you interested in rolling mill development?

Dr. Toshiyuki Kajiwara: During college, I mainly studied thermal-engine technologies such as the gas turbine. But when I started my professional career, I was assigned to the rolling-mill division. Over time, I became deeply fascinated with the world of rolling mills, and it remained the area I worked in.

Where do you find inspiration for new inventions?

Kajiwara: I always find my inspiration on the work site. When I visit a steel plant, rather than meeting with executives, I go directly to the operators who actually handle the mills. I ask them how they run the mills, and see if they have any complaints about them.

What are the thoughts behind your inventions?

Kajiwara: Rolling mills belong to a group of machines that is somewhat closer to human beings compared to other types of machines such as engines. This is because their performance depends heavily on the expertise of the workers who operate them. It takes a skillful operator to unleash a mill's full potential. This is the nature of rolling mills, and it is what inspired me to design a new mill, which would be easier to handle than any other mill in the world—a machine that operators would love. The mill I was going to create had to be the best mill in the world, not the second best.

How did you arrive at the creation of the 6-Hi mill?

Kajiwara: The story of the 6-Hi mill began when I visited a Japanese steel producer in the early 60s. Their site with a 4-Hi mill had a large inventory of rolls with a great number of different crown shapes, and the operators would have to select different rolls depending on the specification of each customer order. Changing rolls really was a lot of hard work. For the sake of the

mill operators, I wanted to find a way to flexibly roll any pass schedule without having to exchange rolls.

And then you went on to invent the method of shifting the rolls to control the crown of the strip?

Kajiwara: Yes. You see, back in the day, it was thought that a larger backup-roll diameter was going to lead to less roll deflection. A method called work-roll bending was available to decrease deflection, but was not very effective. Deflection of backup rolls simply wasn't the root cause of work roll deflection. Rather, the "undesirable contact area"—the area between the back-up roll and the work roll in the 4-Hi mill that extends beyond the width of the strip—was to blame. I found that the back-up rolls and the work rolls, even though they were made of hard steel, would deform by elastic force as if they were made out of rubber, as long as the undesirable contact area existed.

How then was your 6-Hi mill design different?

Kajiwara: My 6-Hi mill with no undesirable contact area made rolling more simple. It can roll strip of any width using straight work rolls, by flexibly shifting the intermediate rolls across their axes according to strip width. Not only that, the mill is capable of consistently delivering stable strip shape—even if the rolling force changes.

Has the 6-Hi mill evolved since its inception?

Kajiwara: New methods often face resistance, and so did the 6-Hi mill. We were asked many questions: Does it work in a large mill just as well as it does in a small mill? It's fine for reversing mills, but how about for tandem mills? It works for cold rolling, does it for hot rolling? It can roll steel, what about aluminum? But every time we encountered a challenge, we overcame it—thanks to the passion of everyone involved.

nation of roll diameters for achieving the maximum reduction ratio was studied. Primetals Technologies used a simulation technique to calculate the maximum limit for rolling load required to maintain good strip shape, and maximum allowable loads based on roll strength. The simulation showed us what the suitable work-roll diameter would be in order to achieve the highest possible reduction ratio, according to maximum width of the mill. This research laid the groundwork for what would lead to a 20 to 30 percent reduction in work-roll diameter from the UCM to the Hyper UCM.

The technological superiority of the Hyper UCM results in major benefits to steel producers. The Hyper UCM reduces rolling force and the number of passes, and inherits the standard UCM's excellent strip shape controllability. It also boosts rolling efficiency and effectiveness, and enables the production of high quality materials with cutting-edge characteristics.

CUTTING-EDGE STEEL GRADES

Recently, production of the latest type of non grain oriented (NGO) steels—called “new NGO”—and advanced high-strength steels (AHSS), which are harder and thinner than ever, has been growing at a rapid pace. These steels are used in electrical and light automobiles, which support a low-carbon footprint. It is expected that these materials will become increasingly relevant, pushing steel producers to continually adapt and evolve their production lines. The Hyper UCM enables the production of space-age materials and contributes to the sustainable future of the industry, and to the environment.

READY FOR THE FUTURE OF ROLLING

The advanced features of the Hyper UCM are applicable to reversing cold mill (RCM) and tandem cold mill (TCM). In the case of TCM modifications, the Hyper UCM can be incorporated into the existing TCM to partially replace the stands, so as to facilitate a large-scale and effective production of the latest and highest-quality steel grades. As illustrated by this article's Masteel reference story [see page 68], RCM upgrades are also highly desirable.

The Hyper UCM is a mill design that has been proven to be remarkably reliable in providing a steady supply of materials that we need for modern living, both now and in the future. As our societies develop and technological progress is made, mill technology is also being continually refined and new, groundbreaking innovations are emerging. The cold-rolling experts of Primetals Technologies will continue to move the world of metals production forward and provide steel producers with the best-possible solutions to meet their strategic needs, wherever they may be located. ●

Shinichi Yasunari, Head of Cold-Rolling Mill Project Management
Chihiro Watanabe, Marketing and Communications Coordinator
 (Both with Primetals Technologies Japan)



HUNDREDS OF EXPERIMENTS ONE GREAT BREAKTHROUGH

Shinichi Yasunari is one of Primetals Technologies' most seasoned rolling experts. He was instrumental in developing the Hyper UCM.

What was your biggest challenge in the development of the Hyper UCM?

Shinichi Yasunari: We conducted hundreds of simulations to find the ideal combination of work-roll and intermediate-roll diameters. Our goal was to realize the highest-possible reduction ratio without compromising strip shape or exceeding contact-stress limits between rolls. In the end, we successfully applied work rolls that are 20 to 30 percent smaller than those of the standard UCM.

Is there any one aspect to the Hyper UCM that steel producers particularly value?

Yasunari: That would be the Hyper UCM's excellent performance in effectively producing extremely hard and light materials, which are vital for decreasing the carbon emissions of cars. For example, a recent TCM upgrade project that involved the replacement of one of the mill's five 4-Hi stands with a Hyper UCM enabled AHSS production.

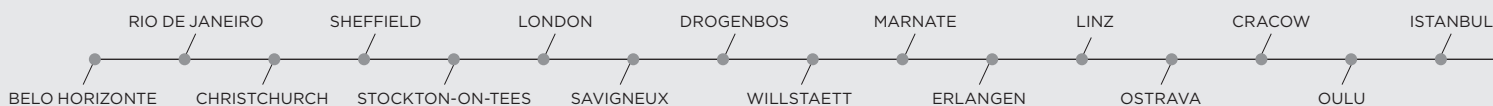
Can you share with us what you are currently working on? Any top-secret projects?

Yasunari: The Hyper UCM is operational at three locations, and three more projects are at the design and manufacturing stage. Also, we are working on several pre-projects for a new TCM application that will be used to produce electrical steel sheet, an essential material for hybrid and electric vehicles.

A SKY THE COLOR OF **LIQUID STEEL**



APODACA IS THE FEATURED COMPANY LOCATION IN THIS ISSUE OF METALS MAGAZINE



Primetals Technologies Mexico is located in Apodaca, which belongs to the metropolitan area of Monterrey, the country's third-largest city. The company location specializes in the manufacture of core components for electric arc and ladle furnaces, and performs a variety of maintenance operations for steel producers via its growing services business. Metals Magazine's Dr. Tom Widter visits the location and discovers what makes the place, the people, the culture, and the Mexican morning sky so unique.

I step outside Monterrey airport and am immediately greeted by the hot Mexican air. It's 8:30 pm on what must have been a testing, sun-scorched August day. Even after dusk, the temperature stays well within the "excessive" range. The 39 degrees Celsius of a few hours earlier has dropped only slightly to 34 degrees, and it takes just minutes for my clothes to feel as if they are glued to my skin. I have flown into Monterrey via Atlanta airport, which was an experience in itself, with stores selling Donald Trump-branded chocolate and sleeping pills that you'd never be able to buy without prescription in Europe. Contrary to Atlanta, there is no chocolate at Monterrey airport adorned with the face of López Obrador, the Mexican president—yet.

Upon arrival, my first impression is that Monterrey has the aura of a U.S. province with a Mexican twist; about half of the voices I hear are American. There's of course a reason for the American influence. The city has grown considerably over the last few decades, both in terms of population and productivity, thanks to an influx of international enterprises wanting to both be close to the U.S. market and profit from Mexico's lower labor costs. Many of the companies that define Monterrey today belong to the cement, glass, and automotive sectors—and of course to the steel industry. Steel producer Ternium alone has four production sites in various parts of the city and intends to keep growing. In Monterrey, you can feel the economy humming.

WELCOME TO APODACA

The Mexican company location of Primetals Technologies is based in Apodaca, which belongs to the greater Monterrey area. My taxi ride to the location is rather interesting weather-wise: it is close to sunrise, and the sky is filled with something gray that is neither fog nor clouds. While I can make out brighter and darker parts—an indicator of the time of day—all of the sky's blue is still in hiding. I check the weather app on my smartphone; evidently, the condition is called "smoke" and something characteristic of the region. Then, just as I arrive at the company location, the color on the horizon changes to that of liquid steel. So where there's smoke, there is fire, after all.

I am immediately welcomed by Rocio Pelayo, the CEO's personal assistant. Like many of her compatriots, Pelayo effortlessly embodies many of the wonderful, typically Mexican qualities: great warmth, openness, hospitality, joyfulness, and—as I will discover—enormous depth and complexity. Pelayo shows me around the site. It comprises two workshops and an office building, which itself consists of two sections and was custom-designed to reflect the Primetals Technologies brand. The section housing the main entrance is round, almost circular, and painted orange; viewed from above, it looks like the Primetals Technologies company logo, which consists of two half circles. And since the airport is relatively close, air travelers with a win- »

APODACA

Primetals Technologies Mexico is located in Apodaca, which is part of the Monterrey metropolitan area.



dow seat can catch a glimpse of the company logo on their approach.

I then meet Guillermo Gonzalez, CEO of Primetals Technologies Mexico [see interview on pg. 81], and Karsten Kliewe, the head of finance. Prior to his assignment to the Monterrey location, Kliewe worked in Germany, Brazil, the U.S.A, and China. I ask him what in his opinion stands out about the Apodaca workforce. “We have a great team spirit here,” he says. “Everyone is totally dedicated to implementing the long-term strategy we’ve developed. Sometimes, we’ll find the need to recalibrate certain aspects of this strategy, and it’s immensely gratifying to see just how open and ready the staff is to making the required adjustments. They always work in unison.”

TOURING THE WORKSHOPS

Integral to achieving the location’s goals are the two on-site workshops. They are 3,000 and 2,500 square meters in size, and there are plans for two more workshops, as the location keeps growing. Blas Zapata [see illustration pg. 72, with plant manager Santiago Duarte], the head of operations, takes me on a tour. “Our two current workshops are independent of one another but

essentially capable of manufacturing the same products,” he says. This setup enables Zapata to dynamically allocate resources, depending on what orders and maintenance contracts the location is fulfilling at the time.

One of the location’s specialties is the production of core components for electric arc and ladle furnaces. At the time of my visit, both workshops are very busy manufacturing electrode arms and fingers for the EAF Quantum, the electric steelmaking solution from Primetals Technologies capable of preheating the input material, scrap, before loading. This feature enables the furnace to achieve significant energy savings compared to more traditional models. Zapata shows me electric arc furnace components at various stages of assembly in Workshop One.

The electrode arms are welded from thick, dual-layer plates, which are cut on a special machine that resembles a large barbecue grill—but with a water tank underneath where you’d expect the coal fire. The plates are then welded together so that the steel layer ends up on the inside and the copper layer on the outside of the electrode arms. Since the arms have to withstand great heat, they employ a complex

TOURING THE APODACA WORKSHOPS



The Apodaca workshops manufacture various core components for electric arc and ladle furnaces. The picture shows the electrode arms used in the EAF Quantum.



This is one part of a cooling solution that will be mounted on the roof of an electric arc furnace. It will be combined with more components to cover all 360 degrees.



The company location invested in three new machines to be able to manufacture what is called “elbows.” These are welded to the ends of two adjacent pipes.

water-cooling architecture. “We rigorously test all water-cooling equipment we make,” Zapata says, “which is why we have testing stations in both of our workshops. We send pressurized water into the arms for an hour to make sure there is no leakage.”

THE FINGERS OF GIANTS

So what are the fingers for, I ask Zapata. “These are essential to the EAF Quantum’s functionality—in that they hold and release the scrap in the preheating shaft,” he says. Depending on the respective furnace configuration, the workshop staff will produce either 14 or 16 fingers per set. Each finger is massive, but just like the electrode arms, they remarkably begin their life at the plate cutter. Zapata tells me that the cutter could handle plates of even greater thicknesses. “Up to eight inches,” he says. “Plasma cutters can do that.” I find it quite impressive, and almost a little scary to think that this machine can go through steel plates as if they were slices of toast.

Zapata and I continue to make our way through Workshop One. We walk by several other products made at the workshop: a modular panel for installation inside the electric arc furnace, as well as side panels and vari-

ous other kinds of cooling equipment—from small to large to enormous. “This one goes on top of the furnace,” Zapata says, pointing to a particularly large device that has the shape of a large slice of pie. I wonder how the cooling would work with this part, given its strange shape. “Of course, you’d have to combine several of these elements to cover the entire furnace top, in 360 degrees,” Zapata explains. Now that he says it, it seems obvious.

One thing Zapata is particularly proud of is the location’s ability to manufacture elbows for its cooling equipment in-house. So what are elbows, and what do they do? A lot of the cooling solutions made at the workshop consist of copper or carbon-steel pipes, through which water will be pumped after installation. But while these pipes can be bent—in fact, the workshop has several different machines that do this—, they couldn’t be bent into a 180-degree angle. This is where the elbows come in. They connect one pipe to the adjacent one and ensure effective water flow through the complete cooling device. “We previously had to source elbows from third-party manufacturers. Now that we make them ourselves, we’ve been able to offer our customers even better prices.” »



Each of the two workshops has a plate cutter like this. It uses powerful plasma-based technology and can cut steel plates with thicknesses of up to 20 centimeters.



From these parts, the workshop staff will be creating the “fingers” for the Quantum electric arc furnace. The fingers hold and release the scrap during preheating.



One of the maintenance tasks carried out by the company location is the reconditioning of rolls used in continuous casting. Roll thickness is increased by 9 millimeters.

SERVICING CASTER ROLLS

Workshop Two focuses not only on the production of electric arc and ladle furnace components but also on the servicing of operational parts. Primetals Technologies Mexico has recently received a contract from steel producer Ternium for the offline maintenance of its continuous thin-slab caster, and Zapata guides me through the entire process of roll cleaning and reconditioning. This procedure is only one of the maintenance tasks Ternium has decided to outsource to Primetals Technologies, and involves complex welding, because a 9-millimeter thick metal layer has to be added onto the rolls.

First, every roll is warmed up using a gas burner to avoid the build-up of pores during the welding process, which could lead to cracks. Even at this stage, the roll is continually rotated for homogenous heat distribution. Then, while the roll keeps rotating, the welder makes two passes, each of which takes two hours and incrementally thickens the roll. The welder adds the

additional layer in a fine line, so that after welding the roll surface resembles the growth rings of a tree. Clearly, no roll could be used this way for production, which is why it is finally taken to the machining section of the workshop, where it loses the “tree rings” and receives a polished, professional, “good as new” look.

Metallurgical services like this one will become more and more central to the location's activities. Zapata and CEO Gonzalez both expect substantial growth in the services area, as they are targeting not only the Mexican market but also Canada, the U.S.A., and Central and Southern America. They strive to be the partner of choice to steel producers wanting to outsource maintenance work in order to further improve productivity and keep unscheduled plant downtime to a minimum. In terms of metallurgical services, Gonzalez believes that his team is only at the beginning—and having witnessed the incredible craftsmanship in the Apodaca workshops, I'm convinced he will be proven right.



WHAT MAKES ME PROUD TO BE MEXICAN ...

Employees of Primetals Technologies share many passions, such as pioneering new solutions for their customers. But every location also has unique qualities. In this section, we catch a glimpse of what makes Mexico so special.



“We have great cultural diversity in our country, which is reflected in our food, music, and dialects. This is a result of our rich history with different cultures coming together.”

Luis Gamboa
Sales Director



“The kindness of our people. Mexicans are kind and helpful. I also like our ‘warm love’—our temperament, which is evident in our music and wider culture. Plus, I really like our food.”

Rocio Pelayo
Personal Assistant to the CEO

MAKING A DIFFERENCE

After the workshop tour, I sit down with various members of the company location's team to learn more about their passions, their ambitions, and their culture. During our discussions, I find myself quite taken by the way they express themselves: Everyone uses well-chosen phrases to describe their thoughts and feelings, on top of which there is a beautiful shift in melody that the Spanish accent imparts on the English language. You can sense the large country; its rich history; the relative poverty of certain regions; the love of life; the strong commitment to family and friends; the determination to make a difference in this world.

One of the topics I bring up in my conversations is that of common misconceptions about Mexico. What surprises foreigners most when they first visit the country and meet its people? "I sometimes feel there is a widespread belief that Mexicans will not make an effort—the assumption that they'll do a sloppy job compared

to Americans," says Mayra Gonzalez, a logistics manager, knowing the opposite to be true. "Also, we don't always wear Sombreros, or ride donkeys to work," she adds. Which is also true—as I'd be happy to testify.

Luis, the location's sales director, points out that "so many parts of Mexico are actually much safer than people think," addressing foreigners' concerns about a lack of security in the country. "Our tap water is also much more drinkable than people assume," he adds. I ask Luis what role he'd like Mexico to play in ten years' time—on the world stage and in the hearts of its people. "I would want Mexico to make even greater advancements in terms of manufacturing," he says, "for instance, in the car, aerospace, and chemical industries, as well as in other areas with high value added products." He believes that the services sector has equally great potential and concludes by telling me that he wants the people of Mexico to be known "for their entrepreneurial spirit and engineering competence." »



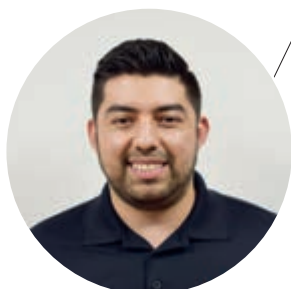
“The idea of family and home is paramount in how we interact with one another: with great warmth. We are hard-working people, it is part of our culture. And our food is always flavorful and offers so much variety.”

Marco Rito
Sales Manager



“It is part of our culture to be very hard-working people. We know that if we put our minds and hearts together, we'll achieve great results. We are also very creative and committed.”

Mayra Gonzalez
Logistics Manager



“We have a lot of diversity—in terms of weather and climate, the food, and local traditions. As far as landscapes go, we have mountains, deserts, beaches, and so much more, all within reach.”

Jesus Ayala
Project Manager



PERSISTENCE IS HOW YOU REAP THE REWARDS

Enrique Veazey is one of Primetals Technologies Mexico's most innovative engineers. He looks for creative solutions in furnace design.

Do you work systematically toward new ideas, or do they come to you “out of the blue?”

Enrique Veazey: I am constantly analyzing our own products for areas of improvement. Engineers typically have this quality, they are always looking for ways to refine things. I work very systematically to arrive at new ideas. My colleagues and I get additional input from other departments, such as R&D. And sometimes, I will also find inspiration in areas outside of work—in everyday life.

Are there any “tricks” you use to promote creativity and inventiveness?

Veazey: I make sure that we start our meetings in a relaxed mood. It can be informal. People will then think much more freely and consider possibilities they would not have considered under more stressful circumstances. I try to let them be who they are.

Is there any new technological area you are particularly fascinated by?

Veazey: The application of computer analysis to the equipment I use. Computers have become a lot more powerful, and in computer-aided design, you can really feel it. The improvements are extremely evident, for instance, in the 3D graphics we generate today. These graphics can be used as a basis for further and very sophisticated analysis. To me, 3D is like a springboard for new methods of optimizing technological solutions.

A FIERY SPECTACLE

Accompanied by Rocio, I conclude my stay in Monterrey with a visit to the city's “Museo del Acero,” its steel museum, which goes by the name of “Horno³.” It's a recommendation of Guillermo Gonzalez', who rightfully considers it a “must see” for anyone setting foot in the Monterrey metropolitan area. “The museum is effectively a converted steel plant, the oldest in all of Mexico, and has an 1880 Bessemer furnace and a 1970 blast furnace,” he tells me, as if I needed further persuasion.

Driving to the museum, Rocio tells me a bit more about the place. The original steel works, “la fundidora,” was built in 1890 to 1900—a time of political and social stability, general industrialization, and the construction of the country's railway network. Steel products such as beams, rods, and structural parts for bridges were in high demand, but had to be imported. The fundidora was going to change this—and it did, until May of 1986, when it closed its doors. On August 16, 2007, these doors were reopened, and the plant rose from the ashes as arguably the world's most innovative steel museum.

Horno³ [see pgs. 82–85] is full of interactive devices that make it easy to learn more about minerals, mining, ironmaking, steelmaking, alloying, rolling, and strip processing. I get to play musical notes on a xylophone made of drill cores, try my hand at being a furnace operator (I do surprisingly well), and watch a wrestling match where every wrestler represents an element in the steelmaking process—such as oxygen, sulfur, and “winners” iron and carbon. Rocio and I then take the rail trackway to the top of the furnace and watch the “furnace spectacle” that entails an LED-lit furnace replica, flashing to the rhythm of traditional Mexican music. Again, magnificent poetry meets masterful execution. The animated spectacle includes drill noise, smoke, and the molten pig iron's fiery glow. What better way to end my trip than with Horno³.

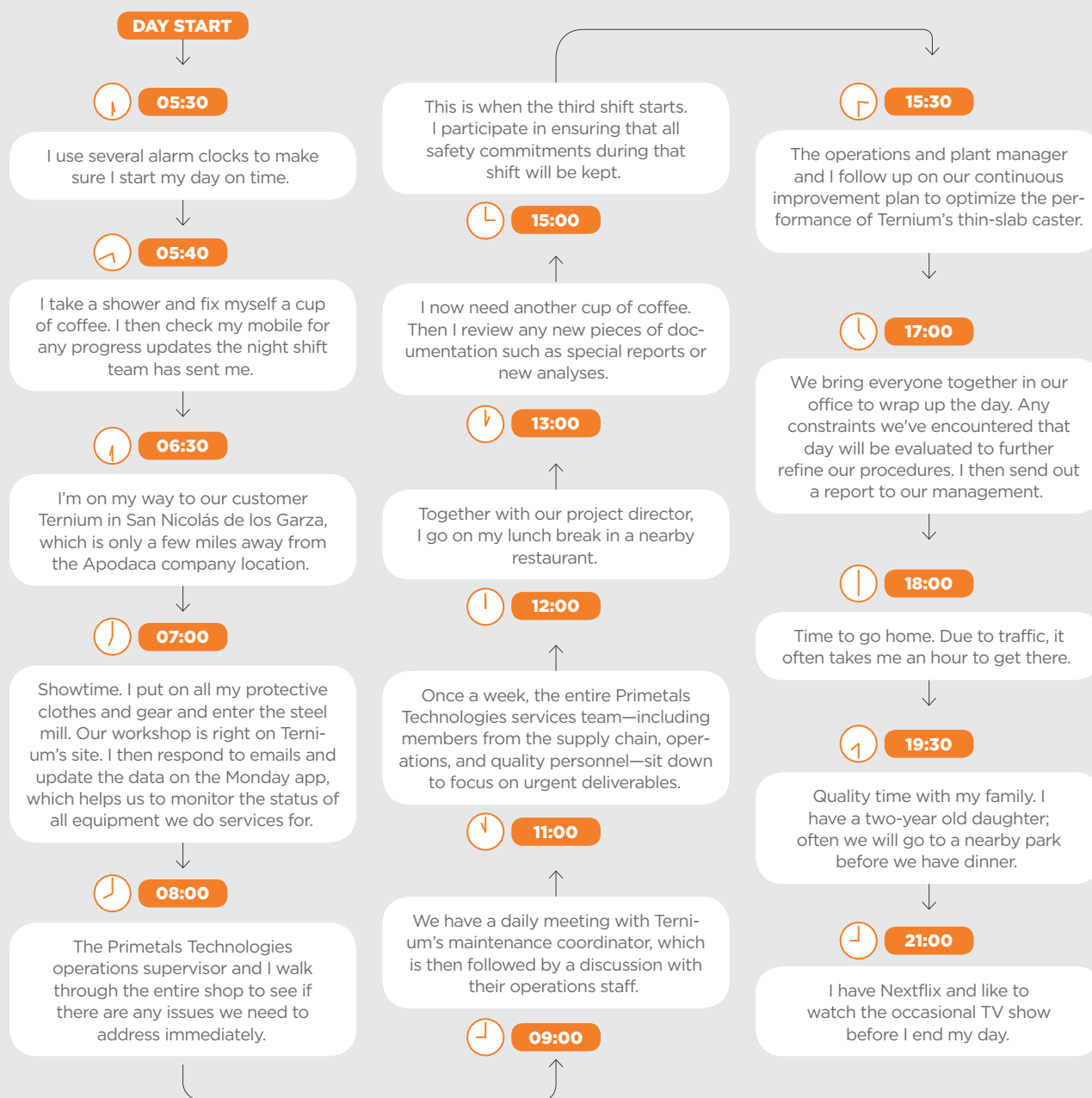
The plane takes off, and as I look outside the window I see the company location come into view, with its characteristically round, orange-colored building. In my thoughts, I wave goodbye—to the people, the warmth, the deep solidarity, the strong work ethic, and the poetic depth with which I've found my Mexican colleagues to express themselves. “Comparado con el alma mexicano, el cielo es limitado,” I think as the aircraft disappears into the sky. There is something so profound and special about the Mexican spirit, and yet it is so elusive when you try to capture or define it. Maybe it just can't be tamed—like you can't tame fire. Or liquid steel. I eventually stop trying—and wonder what my friends would say if I bought a bar of Trump chocolate in Atlanta as a souvenir. A bottle of Tequila or a sombrero might be the safer choice.

A DAY IN THE LIFE OF JOSE LUIS ROSALES

As part of the series “Visiting the Company Locations of Primetals Technologies,” the editorial team of Metals Magazine sits down with one employee of the respective location—with the aim of illustrating what a regular work day is like for them.



JOSE LUIS ROSALES
Operations and Quality Manager, Metallurgical Services



EXPERIENCING THE COMPANY LOCATION AND THE CITY OF MONTERREY



ONE FOR THE BIRDS

The first section of the location's office building is circular—and it is also painted orange. Viewed from above, its form resembles the shape of the company logo of Primetals Technologies, which consists of two orange-colored semicircles.

ONE FOR THE SHADOW SEEKERS

It can get quite hot in Apodaca, much more so than in southern regions of the country. As can be seen in this photo, the staff of Primetals Technologies Mexico are always on the lookout for places that will provide shelter from the hot summer sun.

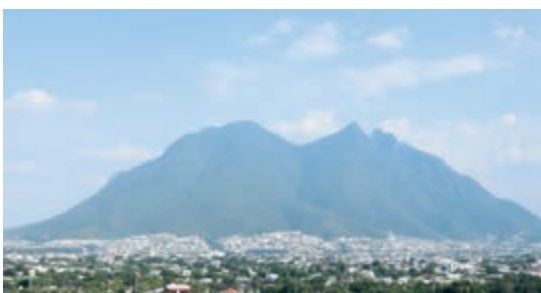
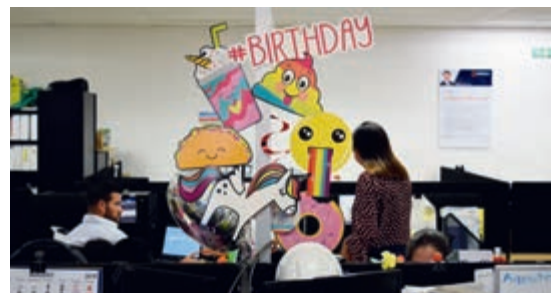


ONE FOR THE DAREDEVILS

Driving is pretty safe in Monterrey, even during rush hour. Most cars are well-maintained, and you can use Google Maps to get realtime traffic data updates and pick the best route. The motorbike to the left, however, might not be the city's safest vehicle ...

ONE FOR THE CAKE LOVERS

Working out whose birthday it was proved to be an exercise in futility. According to those familiar with the matter (i.e., the employees photographed), the decoration was put up many months ago. No one wanted to take it down, so it remained there.



ONE FOR THE MOUNTAINEERS

The Cerro de la Silla is a mountain with no less than four peaks, Pico Norte (North Peak) being the highest at 1820 meters above sea level. The mountain is popular with hikers, who take the 3-hour long trail to the top to catch the panoramic view of the city.

THE FASCINATION OF HEAT AND FIRE

Guillermo Gonzalez, CEO of Primetals Technologies Mexico, is a true veteran of the steel industry. Gonzalez has a degree in mechanical and electrical engineering, as well as an MBA—but these achievements pale in comparison to the decades he has spent covering practically all areas of steel production: from ironmaking and electric steel-making to continuous casting and rolling. Gonzalez is also a pioneer of enterprise resource planning software and shop-floor automation.



What are the core competences of the Apodaca, Monterrey, location?

Guillermo Gonzalez: We engineer and manufacture water-cooling parts for electric arc and ladle furnaces, EAF core components such as electrode arms, and copper-based spare parts. We also provide a growing number of metallurgical services and have recently received a contract from a Monterrey-based steel producer for the offline maintenance of a continuous thin-slab caster. In the future, we will be extending our services portfolio to the downstream area.

I understand that the location is currently about 100 employees strong. How is the workforce distributed over your different business areas?

Gonzalez: We are currently growing. Before too long, we will have 140 people working at Primetals Technologies Mexico. The split between blue and white collar workers is 55 to 45 percent. It's important to keep in mind that this group of white collars will sometimes handle up to 300 blue collars, for example, when a greater number of subcontractors is involved or during capex projects initiated by other company locations.

Is the steel industry currently in a relatively healthy state? What's the outlook, especially for Mexico?

Gonzalez: The U.S. steel industry is very active and we are participating in that trend. In Mexico, things are more steady now compared to the last two years. The political turmoil caused by U.S. foreign policy has inflated prices to some extent, but so far, we're doing okay. China's development should be positive for us, as the country moves from BOF- to EAF-based steelmaking and we're supplying several essential parts for our company's energy-saving Quantum EAFs.

How can Mexican steel producers best prepare for what's ahead?

Gonzalez: Our domestic market still consumes most steel products made for construction, for instance, rebars and high-quality flats. The real opportunity for producers, however, lies within automotive flats, specialty steels, and special bar qualities, because the country has relied on importing them. Two steel producers have now started projects that will enable them to substitute these imports with Mexican-made steels.

What do you love most about the steel industry?

Gonzalez: In steel production, everything is just so massive and powerful. I love the way EAFs work—the fact that they can withstand such heat. Humans have tried to tame fire forever; there is something profoundly symbolic about it. I am fascinated by the liquid steel, by its changes in color, particularly the orange when the steel starts to solidify in the caster. Steel production has been my life, and I deeply identify with it.

How will the world be different in 20 years' time?

Gonzalez: In terms of speed. Technologies such as email have enabled instant global communication. We can travel almost anywhere in just days. This affects the way we live and perceive the world.

Is there any kind of technology beyond steel production that intrigues you?

Gonzalez: There are several: Formula 1 racing cars, airplanes, and submarines.

What invention do you feel should be realized but probably never will?

Gonzalez: The time tunnel. ●



EFFORTLESSLY **WORLD CLASS**

1



2



3



4



5

1 Built on the site of a last-century steel plant, Horno³ combines the old and new. It includes a history section, a shop, as well as a host of other attractions (pictured).

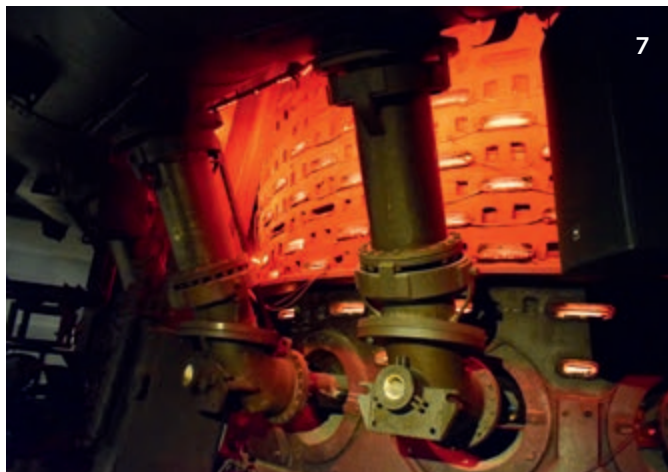
2 The museum features numerous interactive learning stations. While some of them use multimedia content, this one is old school: It's a xylophone made out of drill cores.

3 Ever wanted to compare minerals under a microscope to discern their differences in surface texture? There is no steel production without minerals and mining.

4 You have to pedal hard for all the lights of this treadmill to turn on. You'd need to continue for 5,257 hours to generate the energy a blast furnace uses for one ton of pig iron.

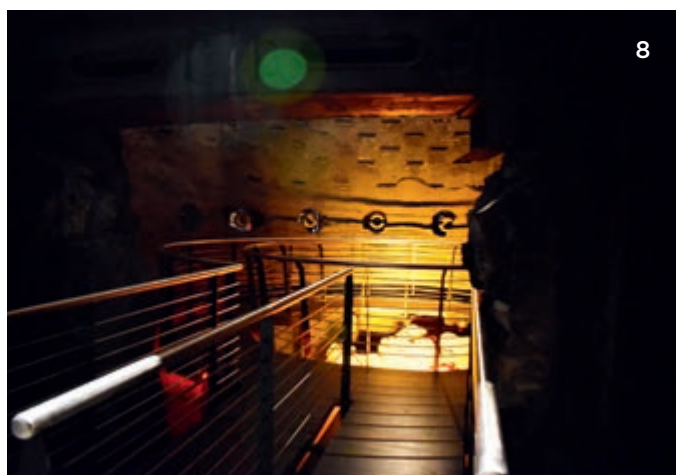
5 Here, you can touch both a used and a brand-new electrode—and familiarize yourself with this integral part of electric steelmaking. The surface feels porous.

The “Horno³” is a must-see steel museum for everyone visiting Monterrey, Mexico. It was built on the site of a former steel plant and houses a large number of innovative interactive stations that will teach you everything you need to know about the production of the world’s greatest metal. In this portrait, we showcase some of the museum’s attractions. Aspects such as the “furnace spectacle” or the rail trackway that takes you to the top of the site’s retired blast furnace make for an unforgettable experience.



6 The "furnace spectacle" is one of the museum's highlights. It features a full-size model of a blast furnace that is lit in changing colors while music plays.

7 Studying the furnace model more closely, you'll be impressed by the level of detail applied in its making. You'll also discover where the LED lights were placed.



8

8 If you've always wanted to step inside a blast furnace, you'll get your chance in Monterrey—and completely risk-free. The furnace looks fabulous on the inside, too.



9

9 This photo doesn't quite do the impressive nature of the furnace model's interior justice. You actually feel very small as you look up to the top of the furnace.

10 The team who created the "furnace spectacle" went as far as to simulate the complete tapping process. You'll even hear drill noises and see real smoke rise up.

11 Weather permitting, you can go up the furnace's exterior via a rail trackway—as if you were feed material. Don't worry, you'll arrive at the top in one piece.

12 The view from the top is impressive. All platforms are secured by railing, but you should still have a good head for heights if you intend to spend more time up there.

13 Standing on top of the furnace, you'll get a better idea of the size of the Monterrey metropolitan area. In this photo, you can see one of Ternium's sites on the horizon.



10



11



12



13

**DR. ALEXANDER FLEISCHANDERL ...**

... has pioneered many of Primetals Technologies' unique solutions. He has a passion for anticipating trends and designing cutting-edge innovations.

IN THIS SPECIAL INTERVIEW FORMAT, WE ASK AN EXPERT FROM PRIMETALS TECHNOLOGIES TO USE THEIR IMAGINATION.

Dr. Alexander Fleischanderl joined Primetals Technologies in 1997 and led the development of the MEROS sinter off-gas cleaning system and many other technologies. He currently holds the position of Technology Officer Upstream and is Vice President of Iron- and Steelmaking. A keen innovator, Dr. Fleischanderl has registered some 100 patents to date and is always driven to explore what's next. We asked him for his personal view on what if ...

“ I am sure that the hydrogen revolution will happen. Hydrogen is no longer confined to the lab, with governments and the private sector making huge investments.”



... YOU HAD TO PICK YOUR FAVORITE GREEN-PRODUCTION TECHNOLOGY? WHAT'S THE MOST PROMISING ONE?

Dr. Alexander Fleischanderl: Let me answer this question by focusing on a future technology rather than one that we have already brought to market. For one and a half years now, I have been closely following developments in the area of direct electrolysis of steel. There is a U.S.-based start-up that has developed and operated a pilot plant for a couple of years and is currently taking the next step toward industrial production. Electrolysis replaces the traditional steel-production route with one simple process. It uses iron ore as input material, and the reducing agent is electricity. What's more, electrolysis does not generate any carbon emissions; only oxygen is released into the atmosphere. It is simple and green—but it is still in the early stages. One challenge is the availability of cheap renewable energy: electrolysis can only be as environmentally friendly as its source of electrical energy. The second hurdle is the material the anode is made of—it has to be inert, chemically non-reactive. The third challenge is to get the metallurgy right and to achieve a proper distribution of trace elements between metal and slag. I am confident that these hurdles will be overcome within the next 5 years.



... HYDROGEN PRODUCTION SUDDENLY BECAME MUCH CHEAPER? HOW WOULD THIS IMPACT STEEL PRODUCTION?

Fleischanderl: I am sure that the "hydrogen revolution" will happen. Governments and the private sector are making enormous investments. There are extensive plans for future infrastructure projects—hydrogen pipelines, for example. Most of the problems related to the production and transport of hydrogen have already been solved. Even today, large amounts of hydrogen are already consumed by the oil and gas and chemical industries. But 95 percent of this hydrogen is "gray"—meaning that it was produced using hydrocarbon based energy sources. The future of hydrogen production has to be green. Wind and solar still have great potential, especially in certain parts of the world. Actually, I am in contact with an Australian initiative that intends to build large wind and solar farms in a desert close to them. They plan to use the resulting energy for the production of green hydrogen. Now, if you know that the same region is also home to iron ore mines ... it's very promising. At Primetals Technologies, we have initiated a lighthouse R&D project called HYFOR, a hydrogen-based fine-ore direct-reduction solution, which could be the perfect fit for the Australians. We'll be commissioning the first pilot plant next year.

Primetals Technologies is continually pioneering future-oriented green-production solutions.



... YOU IMAGINED THE WORLD IN 30 YEARS' TIME? HOW WOULD IT COMPARE TO THE WORLD OF TODAY?

Fleischanderl: If you compare the world of today to that of the 1980s, that gives you an idea of just how much can change over 30 years. I expect this progress to continue or even accelerate. In 2050, world steel production will be 40 to 50 percent higher, and new steel grades with incredible material properties will be available. Steel will also be produced with new methods, which will be significantly greener than those we are currently using. Many governments and leaders within the steel industry have set out goals that, by 2050, suggest an 80 to 95 percent reduction in carbon emissions. A reduction of this size has huge implications and will change the face of steel production forever. Aside from steel, 2050 will be different in many other ways, for instance, in terms of the energy sources we'll be using. There are many questions that will have to be answered before then. New and improved ways to generate, store, transfer, and distribute renewable energy will have to be established. As hydrogen becomes cheaper and more available, car makers will start selling fuel-cell vehicles, which are far more appropriate for long-distance driving and heavy traffic than today's electric cars and trucks.



... STEEL PRODUCERS WERE TO CERTIFY THEIR END PRODUCTS FOR "GREENNESS"—THEIR CO₂ AND ENERGY FOOTPRINT?

Fleischanderl: Digitalization is still—and will continue to be—a key topic for steel producers. Thanks to cheap smart sensors and tools like Primetals Technologies' Through-Process Optimization, the steel plants of today can generate and record vast amounts of data for every single coil they produce. This information does not have to be limited to process-relevant aspects but can extend to energy use and emission data. It is already common practice for plant operators to monitor and track emissions when and where they occur—with comprehensive online control systems. The same is true for energy use. Based on all of this information, it is actually quite easy to establish exactly how much energy was required to produce a given coil, and what the coil's carbon footprint looks like. It is only a small additional step to introduce "green labeling" for each coil. I think that it is important—not only for Primetals Technologies but also for leading steel producers—to get this global trend started and embrace green labeling for all steel products as an industry standard. End customers will take such green labeling into consideration in their purchasing policy, and governments will be able to better institute appropriate carbon taxes.



... YOU COULD, BY SNAPPING YOUR FINGERS, OVERCOME ONE OF THE STEEL INDUSTRY'S MAJOR CHALLENGES?

Fleischanderl: I think I would snap my fingers for more equality in the global steel industry. Steel producers in different countries are facing very different conditions—for instance, in terms of environmental regulations and energy prices. As a result, not every producer has the same opportunities. Energy costs are the crucial factor in this equation rather than labor, which only accounts for a few percent of overall production expenditures, and raw materials, which are traded on the global market. It would be of great benefit to the steel industry as a whole and the environment if everyone had the same chances.

“It would be of great benefit to the steel industry as a whole if everyone had the same chances.”



... YOU WERE ASKED TO CHOOSE ONLY THREE MEASURES TO PROTECT THE ENVIRONMENT ON A GLOBAL LEVEL?

Fleischanderl: The first measure I'd take is to accelerate the global efforts to achieve an order-of-magnitude increase in renewable energy production. This needs to happen over the next two decades. In 2018, wind and solar generated 65 times the power they did in 2000. Prices for renewable energy have fallen accordingly and are projected to reach the 30-dollars-per-MWh mark soon. As green energy becomes cheaper, hydrogen production will take off and lead to the decarbonization of the steel industry and other areas such as mobility and the chemical industry.

My second measure would be the mandatory implementation of meaningful energy-efficiency and recycling projects for heavy industry. Governmental institutions might have to support this initiative financially to make it economically viable. In the context of the steel industry, I'm talking about waste-heat recovery from the sinter cooler, electric arc furnace, and basic oxygen furnace, as well as from the liquid slag. Another technological area I see great potential in is that of bio-technologies. To give you an example: Primetals Technologies is a shareholder in the U.S.-based company LanzaTech, which ferments the carbon-rich waste gases into ethanol using microorganisms. The process is similar to brewing beer, but under the harshest conditions. The resulting alcohol can be easily converted into gasoline, kerosene, or plastic. We are a proud partner in Arcelor-Mittal's "Steelanol" project in Gent, Belgium, which will producing some 80 million liters of bio-ethanol per year from 2021 onward.

Third, I would want to ensure globally valid environmental standards and economic conditions. Moving steel-production sites from one country to the next to escape "expensive" environmental regulations does not help anyone in fighting climate change. All steel products should be labeled according to their carbon footprint, and carbon-intensive products should be taxed higher than low-carbon ones, worldwide. Unfortunately, you asked me to chose only three measures—there are so many more I can think of. ●

CONNECT



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METEC 2019

ANYONE WHO'S ANYONE IN THE METALS BUSINESS
ATTENDED THE INDUSTRY'S PREMIER TRADE SHOW
IN DÜSSELDORF, GERMANY. HERE'S A LOOK BACK.

TO NEXT

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ДОБРО ПОЖАЛОВАТЬ



With the steel industry bracing itself for a bumpy ride in an uncertain economic and regulatory environment, the METEC 2019 metallurgical trade fair provided a forum to reflect and learn, and to seek analysis, support, and guidance.

At Primetals Technologies, we took the opportunity of METEC to start a conversation, listen, exchange ideas, and find a common path forward to the benefit of our partners. The crisp, open, and bright design of our booth reflected that attitude and encapsulated it in a trade show motto: "Connect to Next." Four focus areas

in the booth served to steer the conversation toward trends that we think will shape the metals industry of tomorrow: digital plants ("Connect to Smart"), sustainable steel ("Connect to Green"), productive assets ("Connect to Efficient"), and new business ("Connect to Strategic"). And at a press event during the show, we took the opportunity to reveal a groundbreaking innovation that allows for hydrogen-based, carbon-free reduction of iron ore (read more on pgs. 38–45).

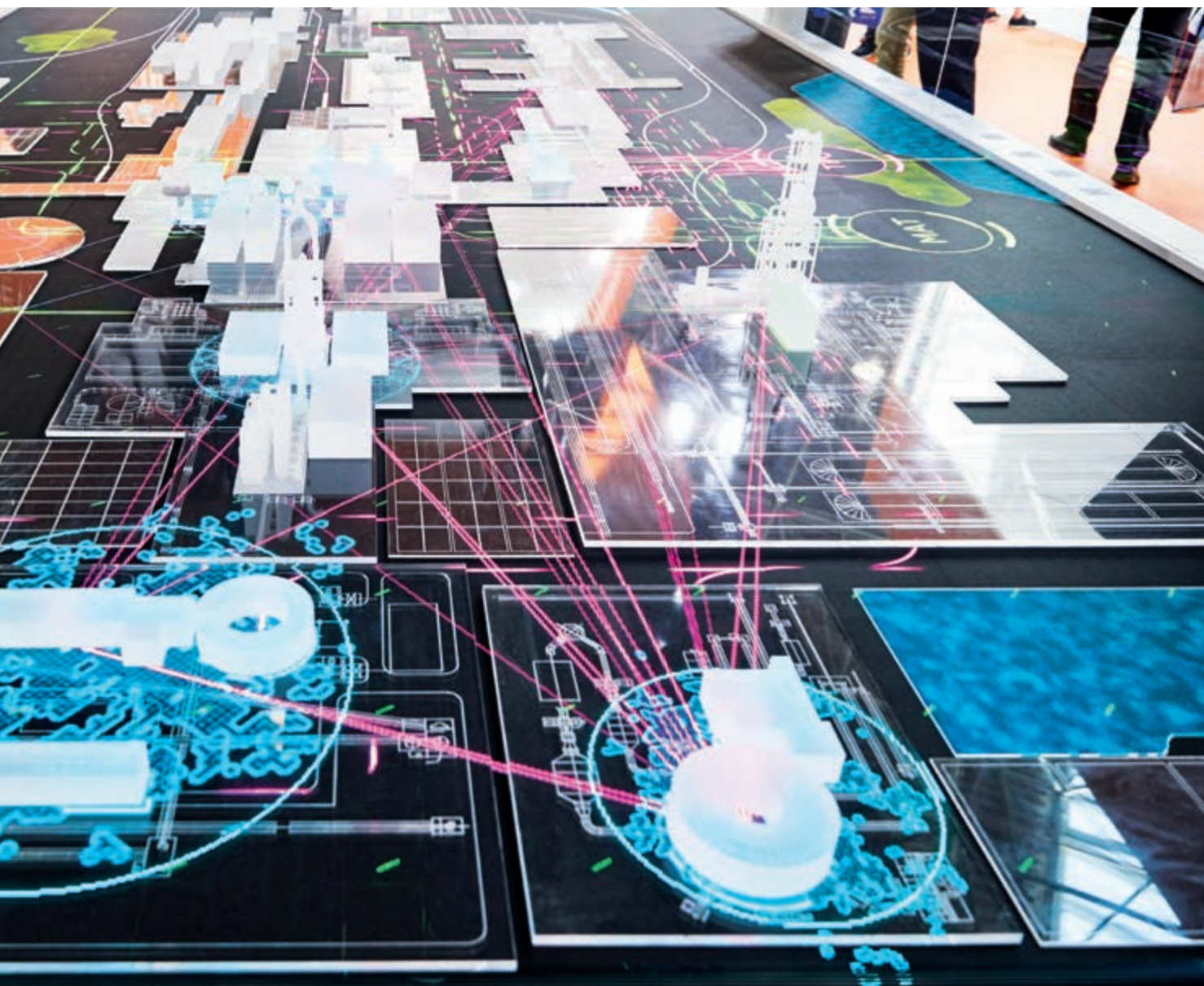
Please enjoy the following few pages with impressions from the show—we hope to see you next time!



STEEL CITY

—THE STEEL PLANT OF THE FUTURE

While the industry has been talking about the fully interconnected, digital steel plant for years, it is still a distant vision in the eyes of many. "Steel City," the dominant exhibit at the Primetals Technologies booth, was our way of making this vision a palpable reality—albeit in the form of acrylic models and LED screens. It allowed our experts to tell their stories from a bird's-eye view of a virtual steel plant—and demonstrate how the smart, digital orchestration of various process units, the optimization of quality and accumulation of know-how along the entire steel-production chain will benefit plant operators in countless ways.



FUTURE LAB

—HANDS-ON EXPERIENCE OF DIGITAL SOLUTIONS

A conversation over coffee in a meeting room only goes so far—there's a point where you want to get into the nitty-gritty. The "Future Lab" at the Primetals Technologies booth was set up to do just that. An area with several workstations, manned by experts in the respective fields, provided visitors with a hands-on experience of digital solutions—ranging from upstream and downstream process optimization, digital twins, condition monitoring and predictive maintenance, right the way through to the new array of online services under the umbrella of our new e-services platform m.space. The Future Lab proved to be exceptionally popular.





PIONEERS LOUNGE

—TALKS AND PANEL DISCUSSIONS

The exciting event program of the "Pioneers Lounge" at the booth attracted diverse audiences from all across the industry. The aim was to connect thought leaders from various fields with their peers and create a space for presentations, moderated panel discussions, Q&A sessions—and also to allow for some off-the-cuff conversation and networking between time slots. Highlights included a session on sustainability in steel production with guests from ArcelorMittal and voestalpine, a panel discussion on the minimill project of Bangladeshi steelmaker GPH Ispat, and a celebration of 10 years of Arvedi ESP with special guests from the Arvedi Group and U.S. Steel.



EAF QUANTUM

—LEGO EDITION

"Increasing efficiency piece by piece" was the inscription on this artifact, painstakingly assembled during the fair by German Lego artist Pascal Lenhard: A detailed model of Primetals Technologies' Quantum electric arc furnace with moving parts, including a fully functional scrap-charging elevator. The furnace was started up to much fanfare on day three of METEC 2019 by the managing director of Primetals Technologies Germany, Dr. Martin Fleischer, and has since been proven to use even less electricity than the original. The model now adorns the lobby of the Willstätt-Legelshurst location of Primetals Technologies.



GREAT PIONEERS

THAT INSPIRE US



At Primetals Technologies, we constantly strive to pioneer new and groundbreaking solutions for the steel industry. We work with passion, inspired by our close partnerships with steel producers from all around the world. Another source of inspiration are the great pioneers that have come before us—innovators who have made a profound impact on the way we live and changed the course of history. In this series, we look at the life, the challenges, and the achievements of some of the most outstanding pioneers of all time.

TIMELINE

1452

Leonardo di ser Piero da Vinci is born on April 15, 1452, in Vinci, to notary Piero da Vinci and a peasant woman named Caterina.

1467

Starts to learn technical skills such as drafting, chemistry, and metallurgy, as well as the artistic skills of sculpting and modeling.

1472

Qualifies as a Master in the Guild of Saint Luke, the guild of artists and doctors of medicine.

1481

Accepts his first commissioned work, "The Adoration of the Magi," for a Scopeto monastery, but the work is never finished.

1482

Leonardo moves to Milan and enters the patronage of Ludovico Sforza, Duke of Milan.

LEONARDO DA VINCI

RENAISSANCE PAINTER, SCULPTOR, SCIENTIST, INVENTOR, AND PIONEER OF BIOMIMICRY

Confucius said that everything has beauty, but not everyone sees it. Leonardo di ser Piero da Vinci not only saw it, he embraced it, took inspiration from it, and went on to establish himself as one of the greatest painters ever to have lived and one of the most talented and ingenious thinkers the world has ever known. The ultimate “Renaissance Man,” Leonardo da Vinci maintained that nothing mankind could ever create would compete with the elegance, beauty, economy, or functionality of any of Mother Nature’s inventions, and as such he was also one of the great innovators in biomimicry. He had the deepest respect for nature and for life, and it was his bio-inspired approach to innovation that sowed the seeds for the first ideas of flying machines, artificial wings, submarines, and a raft of other inventions.

The term “biomimicry” was popularized by scientist, author, and co-founder of the Biomimicry Institute Janine Benyus in her 1997 book “Biomimicry: Innovation Inspired by Nature.” The Biomimicry Institute defines the discipline as “an approach to innovation that seeks sustainable solutions to human challenges by emulating nature’s time-tested patterns and strategies.” Biomimicry (also biomimetics) is both a science and an art, and indeed da Vinci was a visionary who saw the two as indivisible. It aims to take nature’s best ideas and use them to solve the many sustainability problems caused by humans. The thinking is that nature—animals, plants, and microbes—has already spent billions of years working out solutions to many of the problems we are facing today, so why not tap into nature’s “engineering” expertise?

A CHAMPION OF BIOMIMICRY

Though there was no term for it in the 15th Century, Leonardo da Vinci was most definitely a champion of biomimicry and found inspiration in nature from an early age. Born out of wedlock in the Tuscan hill »



DID YOU KNOW ...?

- ... that da Vinci designed the first humanoid robot. His “Robotic Knight” was effectively a suit operated through an elaborate system of gears, wheels, pulleys, and cables.
- ... that da Vinci sketched out the first ideas for contact lenses. He believed that a person’s vision could be improved by wearing water-filled lenses over the eye.
- ... that da Vinci was the first to describe coronary artery disease and the first to describe the heart as a muscle.
- ... that the first recorded use of sonar was by Leonardo da Vinci in 1490. He inserted a tube into water to detect vessels by ear.
- ... that although da Vinci hated war, he came up with inventions for a great many machines of war, including the armored tank, a water-powered machine for manufacturing cannon barrels, a giant crossbow, a triple barrel canon, and a series of revolving and mobile bridges to allow armies to advance over bodies of water.
- ... that da Vinci’s well documented fascination with water also led him to design scuba gear. While working in Venice, da Vinci designed his scuba gear for surprise attacks on enemy ships from underwater. A bag-like mask covered the diver’s head, with air supplied from a diving bell on the surface via two cane tubes.

1487

Leonardo draws the anatomical drawing “Vitruvian Man.”

1490

Commences his work on the Bronze Horse for his patron Ludovico Sforza.

1495

Begins work on “The Last Supper” for the monastery of Santa Maria delle Grazie. It takes two years to complete.

1503

Begins work on a portrait of Lisa del Giocondo, the model of the “Mona Lisa.”

1519

Leonardo dies in Amboise aged 67, possibly of a stroke.

town of Vinci, Leonardo received no formal education whatsoever, and aged 15 he was apprenticed to Florentine artist Andrea del Verrocchio, which turned out to be an inspired move. It was his mentor who encouraged him to take cues from nature. The artist taught the young Leonardo to build images from the inside out when painting or sculpting the human form, and during his lifetime da Vinci would dissect about 30 corpses in the pursuit of perfecting his art.

Da Vinci's passion for perfect form can be seen in his many anatomical drawings, including the renowned "Vitruvian Man," which not only demonstrates Leonardo's absolute understanding of proportion, it also blends mathematics with art, and this is precisely what Leonardo was all about. Physicist, teacher, and writer Bulent Atalay said in a talk at NASA's Langley Research Center: "No self-respecting artist goes around counting tree branches, but Leonardo did. He was a scientist doing art. It was always the patterns he was after. Proportions, patterns, the mathematics behind it."

NATURE'S SECRET CODE

Many of Leonardo's works are said to illustrate the "golden ratio"—a mathematical principle repeated in natural models, from flower petals, seed heads, and tree branches to shells, spiral galaxies, and DNA molecules. The golden ratio was used by many Renaissance artists to achieve balance and beauty, and da Vinci applied it to the proportions in his "Last Supper" and used it in perhaps his best-known work of art, the "Mona Lisa." The golden ratio ties in closely with mathematician Leonardo Fibonacci's "Fibonacci sequence," which dates back to around 1200—and which has become one of the most famous mathematical formulas, where each number in the sequence is the sum of the two numbers that precede it. The sequence has been called "nature's secret code" and also governs

“Human subtlety will never devise an invention more beautiful, more simple, or more direct than does nature because in her inventions nothing is lacking, and nothing is superfluous.”

Leonardo da Vinci

THE FIBONACCI SEQUENCE IN NATURE

The Fibonacci sequence, credited to Italian mathematician Leonardo Fibonacci, is a formula where each number in the sequence is the sum of the two numbers that precede it: **0, 1, 1, 2, 3, 5, 8, 13, 21, 34**, etc. The mathematical equation is

$$F_n = F_{n-1} + F_{n-2}$$

The sequence reflects various patterns found in nature, and as such is also known as "nature's universal rule." These are a few of the most remarkable examples:



Shells:

Many shells, including snail shells and nautilus shells, follow the progressive proportional increase of the Fibonacci sequence.



Trees:

The way tree branches grow out of the tree and each other is an example of the Fibonacci sequence.



Seed heads:

The seeds of a flower—sunflowers are a good example—are often produced at the center and migrate outward.



Pinecones:

The seed pods spiral upward in opposite directions. The number of steps the spirals take tend to match Fibonacci numbers.



Flower petals and leaves:

Petals unfold more and more as the Fibonacci sequence increases, and the leaves of a plant are arranged so that the maximum number can spiral around the stem before a new leaf grows directly above it, ensuring that each leaf receives the optimum amount of sunlight and catches as much rain as possible.



DNA molecules:

A DNA molecule measures 34 angstroms by 21 angstroms at each full cycle of the double helix spiral, and in the Fibonacci series 34 follows 21.

the dimensions of many icons of architecture such as the Great Pyramid at Giza and the Parthenon in Athens.

Atalay also suggested that NASA scientists and engineers would benefit from taking a leaf out of Leonardo's book. "I think to optimize creativity, you have to bring together expertise in different fields," he said. "Obviously, Leonardo is the ultimate scientist-artist-inventor-mathematician ... following Leonardo's lead will not make any of us other Leonardos. But there are things to learn from his example. You should always take notes. You should sketch. Even if you renounce your artistic ability, try to sketch, and you will develop it. You will remember things much better."

IS IT A BIRD? IS IT A PLANE?

In the hope of enabling human flight, Leonardo da Vinci closely observed the anatomy and flight of birds and applied biophilic design principles to come up with various sketches of flying machines—in da Vinci's case a flapping ornithopter, where the pilot would spin cranks with his hands and feet so that the wings of the machine would flap. Da Vinci was such a visionary that his research into flight would never produce any working flying machines during his own lifetime, but his ideas would later inspire the Wright Brothers, who, incidentally, also closely observed the flight of pigeons. The Wright Brothers designed, built, and flew their first aircraft in 1903.

Da Vinci based his designs for the aerial screw, which was considered the first model of a helicopter, and a parachute—a necessity if humans were to fly—on observations of seed pods and flowers falling from trees. His theory for the aerial screw was based on the use of manpower to rotate the screw fast enough to create a spiral of air beneath the blades, lifting the structure off the ground, while the canopy in his design for the parachute was triangular rather than rounded. The first person to actually test da Vinci's parachute was Adrian Nichols in 2000, and his prototype proved a success and testimony to da Vinci's genius.

THE POWER OF WATER

The records of the Florentine government name Leonardo da Vinci a "Master of Water." He was fascinated by water, which he famously described as "vetturale di natura"—the vehicle of nature. He believed that water was to the world what blood is to the human body, and indeed his descriptions of cities were anatomical, with water flowing through arteries. While obsessed with water, he also lived in fear of its destructive power, having witnessed disasters such as the Arno river breaking its banks on two occasions. To the end of his days he was haunted by visions of great deluges destroying the earth.

Da Vinci observed the motion of water, the ebb and flow of tides, and was the first to advance the theory of erosion. He said: "Water gnaws at mountains and

“The question is, how do we make the act of asking nature's advice a normal part of everyday inventing?”

Janine Benyus
Co-founder Biomimicry Institute

fills valleys. If it could, it would reduce the earth to a perfect sphere." Perhaps as a consequence, da Vinci worked on the development of devices that could be used to control and divert water, also designing locks and canal systems. The relationship between water and energy also inspired Leonardo to develop ideas on the use of water to drive sawmills, forges, flour mills, factories, and silk-spinning works.

MASTER OF EVERY DISCIPLINE

Clearly Leonardo da Vinci was a jack of all trades, yet one who mastered every discipline to which he turned his hand. It's an impressive list: artist, anatomist, architect, paleontologist, botanist, scientist, writer, sculptor, philosopher, engineer, inventor, musician, poet, and more. He understood the power of nature to inspire, and was attuned to issues of sustainability. Indeed da Vinci was so far ahead of his time that he feared for the earth's forests as humanity continued to search for fuel, devising a system that would harness the solar power of the sun using concave mirrors to heat water for Renaissance Florence. Da Vinci also accurately described the hydrological cycle of evaporation, condensation, and precipitation, and even today we can use this cycle to help us understand the science behind climate change.

According to Vienna-born physicist and systems theorist Fritjof Capra, although Leonardo da Vinci's scientific discoveries have all been "re-discovered," we cannot fail to marvel at his genius and how he made all of these discoveries so early. We can take inspiration from da Vinci in many ways, says Capra: "His systemic way of thinking, of interconnecting problems, and seeing how things are connected. His profound respect of nature and his desire to imitate nature and learn from Her, in biomimicry, in eco-design. His science always went together with ethics. Animals to him were, ontologically, completely equivalent to humans, at the same level. He was a vegetarian and had a very deep respect of life." A thinker with boundless imagination and creativity, Leonardo da Vinci's ideas continue to influence art and science to this day; so inventive was he that a great many of his groundbreaking inventions were not—and, technologically, could not have been—realized until hundreds of years after the death of one of history's greatest pioneers. ●

STRAIGHT FROM THE LABS OF **PRIMETALS TECHNOLOGIES**

MANAGING DATA SETS

Steel plants use a large number of spare parts. Michaela Jaksch unites them in one online catalog.



MICHAELA JAKSCH ...

... makes it easier than ever before for steel producers to order spare parts—with her contribution to m.buy.



FIG. 1: After implementation of m.buy, codes will be attached to the equipment in a plant, to access the right spare parts.

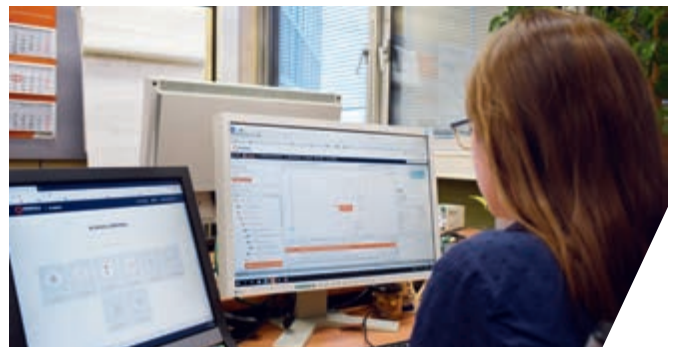


FIG. 2: Developing m.buy and its spare-parts catalogs involves constant testing to ensure that all functions are easy to use.

The extensive R&D efforts of Primetals Technologies are an integral part of the company's larger strategy to continually promote innovation for the metals industry. In this series, we present new, remarkable solutions pioneered by Primetals Technologies' engineers—solutions that may still be in their infancy today but have the potential to change the way steel and other metals will be produced in the decades ahead.

AT THE CUTTING EDGE OF SPARE-PARTS MANAGEMENT

"Working with m.buy, I have learned to love data," says Michaela Jaksch. m.buy is the new web-based spare-parts catalog from Primetals Technologies. Launched by the company's Services organization under the umbrella of m.space, it contains vast amounts of data about every possible spare that a steel producer could need. "With m.buy, we want to make it easier than ever before for our customers to order the spare parts they need," says Jaksch. "This is why we are adapting the m.buy catalog for each of our customers, so that they are presented exclusively with those spare parts that match the equipment they currently have installed."

A SYSTEMATIC APPROACH

Jaksch uses a systematic approach when creating new spare-parts catalogs. Depending on a steel producer's plant configuration, she first collects data on all potentially relevant spare parts. The accumulated data is then structured based on the layout of the plant. Here, one of m.buy's nicer features comes into play: the entire plant is represented by schematics based on assembly drawings—not only of the overall plant but also of individual sections and smaller components. Every drawing contains references to the spare parts

used by the equipment shown, and each part is labeled. For maintenance personnel who use m.buy, this means that they are given exactly the information they need, when they need it. No more time wasted on searching for the right spare part, hastily trying to ensure uninterrupted plant operation.

ENGINEERING OF THE FUTURE

Many of m.buy's technological underpinnings are very much at the cutting edge. Jaksch is a regular contributor to the "Engineering of the Future" initiative at Primetals Technologies, which aims to incorporate innovative concepts into existing and upcoming solutions. She interfaces with colleagues working on augmented reality applications, information management, and artificial intelligence. This exchange helps to ensure that everyone is using the latest and most advanced techniques in the development of their solutions. m.buy is constantly being optimized in collaboration with steel producers: "We try different approaches to make finding the right information as easy as possible," says Jaksch. So what does the future hold for Jaksch and her work on m.buy? More data, more customers, and even more functionality for m.buy? Certainly. And, for the time being, further optimization. ●



FIG. 3: "Emergency food" is what Michaela Jaksch calls these tiny containers of dried fruit and nuts. Blood sugar levels.



FIG. 4: Jaksch, letting her colleagues know of the latest developments around an m.buy spare-parts catalog.



THE PIONEER'S GUIDE TO **BOOSTING CREATIVITY**

In this series, we look at different ways of getting the creative juices flowing. This time, we focus on connecting with nature—how spending time in the great outdoors can improve your health, lift your spirits, boost your creativity, and increase your productivity as a result.



“ Life moves pretty fast. If you don’t stop and look around once in a while, you could miss it.”

Ferris Bueller

The concept of Mother Nature is rooted in Greek mythology. The primordial Earth goddess Gaia—whose name is derived from the ancient Greek word for “land”—was known as the “Mother of All,” and it is no coincidence that this personification of nature takes on the form of the life-giving and nurturing mother figure, continually striving for harmony and balance in the universe. Throughout history, many cultures and civilizations have worshiped the concept of a mother goddess embodying nature, motherhood, and creation. The word “nature” itself comes from the Latin “natura,” literally “birth.” And if we just stop to appreciate Her once in a while, we will find Mother Nature to be the most generous and inspirational of hosts.

An inevitable consequence of our increasingly tech-filled lifestyles has been a shift toward spending a disproportionate amount of time indoors. We have

become disconnected from a natural and plentiful source of energy and inspiration. And it doesn’t take that much effort on our part to reconnect with nature; research suggests that a couple of hours a week is enough to reap the benefits—feeling revitalized, grounded, at peace, and inspired. Is there anything better than breathing in the air after a summer downpour, feeling the wind in your face after scaling a mountain, or listening to the magnificent crash of ocean waves?

Simply put, spending time outdoors is good for you. According to a recent study carried out by the University of Exeter Medical School in the U.K., a stroll in the park, or even just sitting still in nature and drinking in the views, can reduce stress and lower blood pressure, while also boosting mental health. It’s so effective that doctors all over the world have begun prescribing »

time in nature as an antidote to a raft of conditions such as anxiety, depression, attention-deficit disorder, and child obesity. Hospital patients with views of natural landscapes have also been shown to get better faster. And the recommended dose? Just 120 minutes a week, dedicated to short runs, walks with the dog, or simply the mere enjoyment of green views.

NOURISHING THE CREATIVE MUSCLE

Someone who would likely have agreed with the Exeter study was the philosopher Friedrich Nietzsche. He said: "Sit as little as possible. Do not believe any idea that was not born in the open air and of free movement—in which the muscles do not also revel." And a large body of research backs up the idea of embracing movement. A study by Stanford University showed that exercise can have a major positive impact on certain types of cognitive efforts involved in creativity. Both convergent thinking—the capacity for problem-solving—and divergent thinking—which involves coming up with original ideas—showed a marked improvement through physical activity.

The Journal of Environmental Psychology recently published research linking creativeness and innovative thinking to the feeling of being connected to nature. According to Carmen Lai Yin Leong of Victoria University of Wellington, connecting with nature requires a willingness to embrace new experiences as well as a spirit of adventure. She says, "Venturing into the natural world often involves physical demands (such as hiking), risks (such as getting lost), and opportunities for uplifting experiences (such as viewing a sunrise

“Look deep into nature, and then you will understand everything better.”

Albert Einstein

from a mountain summit).” Opening up to new experiences forces us to be open-minded, and innovative thinkers must be open-minded in order to break with convention and embrace fresh and creative ideas.

DISCONNECT TO RECONNECT

New research also suggests that disconnecting from technology and multimedia and connecting with nature for four days can boost creativity by as much as 50 percent. Ruth Ann Atchley, associate professor of psychology at the University of Kansas, says: "There's a growing advantage over time to being in nature. We think that it peaks after about three days of really getting away, turning off the cellphone, not hauling the »



DID YOU KNOW ...?

... that the view from your window can affect your food cravings? According to a recent study in the journal *Health & Place*, you are less likely to crave unhealthy food if your view is of a natural green space.

... that even indoor plants can do a lot to lift your mood? Plants contribute to improved air quality by cleaning the air of toxins, and spread an uplifting energy within the indoor space.

... that "petrichor" is the name given to the earthy scent produced when rain falls on dry soil? The scent, which comes from a combination

of plant oils and soil-dwelling bacteria, aerates when raindrops fall on porous earth, burst, and release chemical compounds from the ground into the air.

... that the early bird catches the worm? Of course you did. But seriously, getting up early in the morning is a technique used by artists to soak up nature's creative energy.

... that Tai Chi, Quigong, and yoga are excellent ways of re-energizing your body and mind, and if practiced outdoors will do wonders for your creative energy.

FIRE

The sun is the source of life and energy and fuels the determination and passion to persevere through life's obstacles. Fire both gives life and takes it away. An imbalance of the Fire element might lead to impatience, greed, and anger, but could also manifest itself as fever, skin diseases like inflammation, or excessive sweating.

EARTH

The earth element, the solid state of matter, is a source of structure and stability and represents balance. Yoga and the martial arts, as well as simply walking, standing, or sitting on the ground, are great ways of keeping us grounded, which makes it easier to remain focused on our goals. An imbalance of the Earth element could be manifested by a general weakness in the body.

WATER

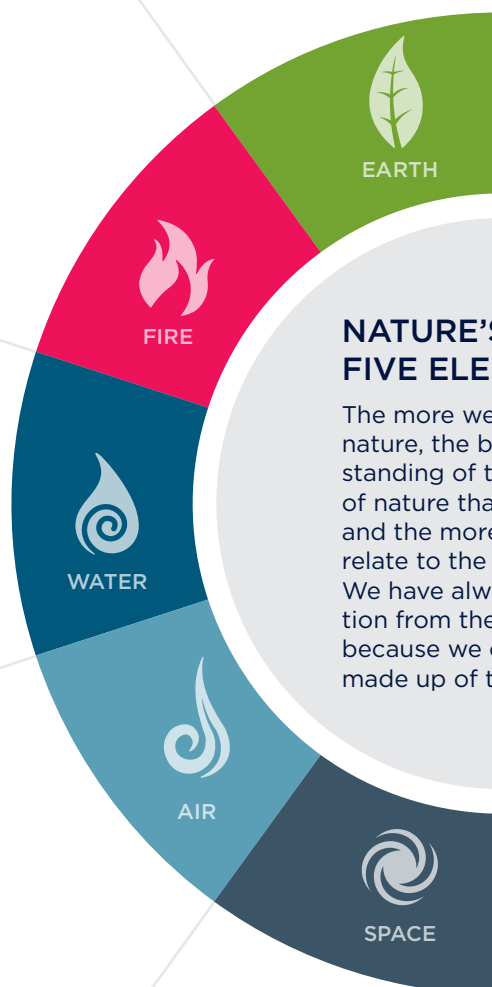
Our body—as well as the planet—comprises roughly 70 percent water, making this a vital element. It keeps us hydrated and regulates body temperature, while contact with water washes away toxins and swimming helps soothe the mind and heal the body, freeing us up to be more creative. Water is perpetually flowing, so it is important to allow our feelings and ideas to flow freely, too. An imbalance of the Water element might be manifested by excess mucus, a cold, or sinusitis.

AIR

This element is dynamic and represents a capacity for motion. Deep breathing and filling your lungs with fresh air is important for relaxing your mind, bringing peace, and improving concentration. An imbalance of the Air element might lead to anxiety and fear, as well as to physical conditions such as skin dryness, blood pressure issues, lethargy, or insomnia.

SPACE

Often referred to as the mother of all the other elements, space has no physical existence, and yet exists everywhere. It is the source of all matter, and allows for growth and change to take place. Hence an awareness of space can help us to see the bigger picture. An imbalance of the Space element could be visible as a Thyroid disorder, throat problem, or speech disorder.



**“In all things of nature
there is something
of the marvelous.”**

Aristotle



iPad, and not looking for Internet coverage. It's when you have an extended period of time surrounded by that softly fascinating environment that you start seeing all kinds of positive effects in how your mind works.”

The evidence that creativity can be inspired simply by switching off electronic devices and getting back to nature is overwhelming. Atchley goes on: “These distractions sap our resources to do the fun thinking and cognition humans are capable of—things like creativity, or being kind and generous, along with our ability to feel good and be in a positive mood. Nature is a place where our mind can rest, relax, and let down those threat responses. Therefore, we have resources left over—to be creative, to be imaginative, to problem solve—that allow us to be better, happier people who engage in a more productive way with others.”

AN ANTIDOTE TO MODERN LIFE

Author Richard Louv even goes so far as to claim the connection to nature as a human right, having coined the term “nature-deficit disorder” originally to describe the loss of connection with nature felt by children, and later extending the idea to adults as well. Louv says that nature-deficit disorder affects “health, spiritual wellbeing, and many other areas, including people’s ability to feel ultimately alive.” He also embraces the idea that spending a few days in the woods not only

improves our health, it improves our cognitive abilities and boosts creativity.

Louv cites how reconnecting with nature inspired Juan Martinez to completely turn his life around. On the fast track toward gang life in South Central Los Angeles, his school principal gave him the choice between detention or joining the eco club. He reluctantly chose the club and was handed an assignment to grow something. He successfully nurtured a jalapeno chili plant, and that simple achievement, combined with a trip to the Grand Tetons, inspired him to become an environmentalist and National Geographic explorer.

We live in a fast-moving world. Which means every now and again we must take steps to redress the delicate balance between mind, body and spirit. The answer lies in nature and its simplicity. The natural world is a rich source of inspiration and our creativity becomes more instinctive the more connected we are with nature. So whenever you’re feeling uninspired, step outside, disengage with the daily grind, take a walk in the park, a dip in the ocean, and before you know it everything will feel all right with the world once again. As Californian fiction writer M.P. Zarrella famously said, “Nature is cheaper than therapy.” And who could argue with that? ●

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