The steel industry might not be the bastion it was half a century ago, but it’s still a pillar of the world economy. Its product is used in virtually every sector, from transportation and construction to power and electronics. It employs over eight million people worldwide. More than 1.5 billion tons of steel were made in 2012, up from 0.85 billion tons in 2001.

For being such a behemoth, the industry is pretty lean and efficient. Steel, an alloy of iron and carbon, is the most recycled industrial material in the world. About 97% of steel products can be reused. And making a ton of the metal uses 30% less energy today than it did two decades ago.

But steel production is still energy-intensive. The industry consumes 5–6% of all globally generated power and accounts for 6.7% of all CO₂ emissions: Making a ton of steel emits about 1.8 tons of CO₂.

Steelmakers have thus far increased energy efficiency mainly by tweaking existing plants and processes. Rising raw material and energy costs as well as stricter environmental regulations are driving some to make steel production yet more streamlined and efficient. A handful of companies are testing breakthrough technologies that could change the way steel is made in 2020 and beyond.

“We know that consuming energy has environmental implications, and that we need to find ways to reduce energy consumption or reuse excess waste energy,” said Debashish Bhattacharjee, director of research, development, and technology at Tata Steel. “This is an active area of concern and action in the steel industry.”

Making steel typically involves first reducing iron ore to iron and then converting the iron to steel. In the first step, iron oxide ore, coke, and limestone are injected into the top of a blast furnace while pre-heated air is blown into the bottom. The preheated air reacts with the coke (carbon) to give carbon monoxide. This CO then reacts with the iron oxide to produce molten iron and carbon dioxide.

The process carries enormous energy baggage. Pre-heating air uses energy. So does making coke, which requires cooking crushed coal at temperatures of 1100°C in the absence of oxygen. What’s more, low-iron-content ore has to be fired in a furnace to produce larger sized pieces called pellets and sinter. All told, blast furnace iron reduction accounts for 80% of CO₂ created during steel manufacture.

In the second step, iron is converted to steel in a basic oxygen furnace by blowing pure oxygen at supersonic speed into the molten iron. This burns the excess carbon present in iron, resulting in CO and CO₂ emissions.

Some manufacturers are already making a dent in energy use by employing simple steps: capturing and reusing byproduct gases for heat and to generate electricity; using pulverized coal instead of coke; and using better thermal insulation. These measures are easy and inexpensive to install at existing plants.

However, the ideal sustainable steelmaking process is one that not only cuts energy use, but is also flexible in terms of raw materials and energy source, Bhattacharjee said. It would use low-quality, low-cost coal and iron. And it would allow a switch from coking coal to natural gas, biomass, or even clean electricity sources. But any such disruptive technology would require enormous capital expenses and support from governments or large industrial consortia.

Europe has been a leader in this regard. Driven by the European Union’s (EU’s) climate policy framework, the European Commission has made innovation in the steel industry a priority. In 2004, the European Commission and European steel industry launched the ULCOS (Ultra-Low Carbon Dioxide Steelmaking) program, a consortium of 48 companies and organizations with the goal of reducing the carbon emissions from steel production by 50%. ULCOS has invested USD$725 million in breakthrough steelmaking technologies, all at various developmental stages.

One, developed at the Tata Steel plant in IJmuiden, The Netherlands, and dubbed HIsarna, has captured the interest of steel- and policymakers. The process takes place in a special reactor that has a narrow cyclone furnace on top of a wider convertor. Pulverized iron ore, coal dust, and oxygen are injected into the cyclone furnace, where the ore partially reduces and melts, falling down to the convertor. Oxygen and coal introduced in the convertor form CO that finishes reduc-
ing the melted iron, creating hot gases that rise and provide heat for the reaction occurring in the cyclone furnace.

The technology does not need coke, sinter, or pellets, making it 30% more energy efficient and 25% less CO₂-intensive than a conventional blast furnace. Plus, it can work with cheaper non-coking coal (e.g., Pittsburgh Seam Coal), which contains volatile matter and low-quality iron ore, enabling flexibility on raw materials.

Pilot tests at a plant producing 8 tons of iron an hour have confirmed the researchers’ predictions on HIsarna’s reduced energy use and CO₂ emissions. A commercial-scale plant would have to be 30–40 times bigger, Bhattacharjee said, which would take more time and investment. For now, companies in the ULCOS consortium as well as the government-owned Steel Authority of India Limited are interested in moving the technology forward.

In the United States, 60% of steel comes from scrap steel recycled in an electric arc furnace (EAF), where an electric arc melts the scrap. A commercial-scale plant would have to be 30–40 times bigger, Bhattacharjee said, which would take more time and investment. For now, companies in the ULCOS consortium as well as the government-owned Steel Authority of India Limited are interested in moving the technology forward.

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