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American Iron and Steel Institute

U.S. Steel Industry Progress in Reducing Greenhouse Gas Emissions

Energy and Steelmaking

Due mainly to the inherent requirement for carbon in iron and steel making, as described below, the steel industry is highly dependent on carbon-based energy sources. Approximately 60% of the energy consumed by the steel industry is derived directly from coal and much of the electricity the industry uses is generated at coal-fired power plants. Natural gas accounts for nearly 30% of the industry's energy consumption. For electric arc furnace (EAF) steelmakers, the main energy source is electricity. For all steel producers, energy purchases represent about 15-20% of the total manufacturing cost, a fact that has provided a strong incentive for the industry to develop energy-saving opportunities. All major steel companies have ongoing conservation programs, and the industry has engaged in conservation, recycling, and economic use of energy for over 80 years. As a result of these measures and technological advancements in iron and steelmaking, the industry's energy requirement per ton of steel shipped has declined steadily. Since 1975 energy usage per ton of steel shipped has been reduced by about 45%. As a consequence, carbon dioxide (CO_2) emissions have declined correspondingly. From 1990 to 2000, U.S. steel industry CO_2 emissions per ton of shipped steel declined about 15%

The Role of Carbon in Iron and Steelmaking

Carbon is an essential raw material that serves as a chemical reactant to convert iron ore and other iron-bearing materials to iron and steel, and CO_2 is an unavoidable byproduct of this reaction. While some progress has been made over the years to improve the utilization rate of carbon, as discussed below, the amount required is dictated by laws of chemistry, physics, and thermodynamics, and current usage is very close to theoretical minimum levels. Consequently, any policies or initiatives designed to decrease steel industry carbon emissions need to reflect the fundamental principle that carbon used as a reductant cannot be reduced in the same manner as other carbon-based fuels.

Steel is produced by two methods in the U.S. The majority (about 53% in 2001) is made by integrated steelmakers in basic oxygen furnaces (BOFs), which typically use about 70 to 80% molten iron and 20 to 30% scrap. Molten iron used in BOFs is principally produced in blast furnaces from iron ore or ore concentrates, which consist of oxide minerals containing less than 65% iron. The remainder of the ore consists of oxygen and impurities contained in the rock formations from which the ore is extracted. In the blast furnace, coke, produced from coal having certain chemical and physical properties, is typically used as the source of carbon. Other carbon-bearing materials such as coal, coal derivatives, natural gas, or petroleum products can also be used as a source of carbon to supplement a portion of the coke. Iron produced in a blast furnace usually contains 3 to 4% carbon, which subsequently must be reduced to less than 1%

carbon in a steelmaking furnace to produce commercial grade steels. This is accomplished in a BOF where the molten iron is combined with scrap and refined and alloyed to produce the desired grade of steel.

The main function of coke and other carbon-bearing materials used in the blast furnace is to provide the source of carbon that serves as the chemical reactant to convert ("reduce") the iron ore to iron and to sustain the chemical reactions required for the process. Coke also has the physical characteristics to provide the necessary structural support for the blast furnace burden and to serve as a porous material so that the reducing gases can pass through the burden materials. Alternatives to the blast furnace process, such as direct-reduction and direct-smelting processes, have been developed in recent years and are still evolving. These processes allow for iron to be produced without the need for coke, but they still require sources of carbon, typically coal or natural gas, to reduce the iron oxides to iron.

EAFs account for the remainder of raw steel production in the U.S. (about 47% in 2001). EAFs use electricity as the primary source of energy to melt the charged materials, which typically consists of nearly 100% recycled steel, or scrap. Because the EAF process is mainly one of melting scrap as opposed to reducing oxides, carbon's role is not as dominant as in the blast furnace/BOF process. However, depending on the characteristics of the charged materials, some carbon may be added to serve as a chemical reductant or may be contained in the charged materials themselves. Also, carbon is often associated with the generation of electricity used in the process. Although EAF production has increased incrementally in recent years, the demand for steel in a growing economy cannot be met solely from recycled steel. In fact, some EAF producers have begun to use iron substitutes to displace some of the scrap.

Progress Toward Greenhouse Gas Emission Reductions

Following are a number of examples as to how energy and corresponding CO_2 emission reductions have been accomplished in the U.S. steel industry.

The recovery of byproduct gases is common practice in integrated steel plants. The blast furnace process generates large amounts of byproduct blast furnace gas. Some of this gas is used directly to support the blast furnace process by preheating blast air in regenerative "stoves." The remainder is typically utilized in boilers to produce steam used to drive the blowers that sustain the process and for other uses throughout the plant for other process and heating purposes. Some plants also generate electricity from this byproduct fuel, and the steel industry was a pioneer in cogeneration using blast furnace gas. In coke ovens, byproduct coke oven gas is also recovered for a variety of uses. About 40% is typically used to underfire the ovens themselves and the remainder is used for various process and heating purposes throughout the plant. Some companies also utilize waste heat from other processes (e.g., slab heating furnaces) to produce steam. These uses of byproduct fuels have a significant effect in reducing overall iron and steelmaking energy requirements that would otherwise have to be provided by purchased energy sources, and in recent years companies have strived to maximize use and minimize flaring of these gases.

Advancements in blast furnace technology beginning in the 1950s have resulted in significant reductions in the amount of coke required for iron production. These included beneficiation of iron ore and other raw materials and the use of sinter and pellets that improved blast furnace operation and allowed for the reduction of blast furnace coke rates, which in turn reduced the demand for production of coke in coke ovens. Use of pulverized coal injection and natural gas injection has also reduced coke rates. A number of technology alternatives to blast furnace ironmaking are in various stages of development but all are dependent on fossil fuel as a source of carbon and many are still coal-based.

Steelmaking trends have also had significant impact on energy consumption. In the 1960s, basic oxygen steelmaking began to displace the more energy-intensive open-hearth furnaces, and open hearths were completely phased out by 1991. In addition, the use of EAFs increased dramatically from less than 10% of overall production in 1960 to nearly 50% today. The greater use of EAFs also stimulated numerous technological advances in furnace design and operation intended to improve EAF productivity.

The trend toward more continuous processing of iron and steel and corresponding increases in yield has also given rise to significant improvements in energy efficiency. The prime example of this is the increase in continuous casting, which rose from nearly 0% in 1960 to about 95% today. Continuous casting has eliminated several energy-intensive steps previously associated with production of intermediate steel shapes. That trend continues with the adoption of thin slab, strip, and other near-net-shape casting processes. Continuous casting and other improvements in manufacturing efficiency have closed the gap between raw steel production and shipments, which means that less energy is required to produce a ton of steel product. Yields are now near 95% as compared to about 70% in the 1960s and 1970s.

Numerous other advancements also contribute to overall improvements in energy efficiency. They include: computerized process controls, more flexible and effective instrumentation, on-line sensors, hot charging, improved furnace insulation, scrap preheating, more efficient motors, improved reheat furnace burner technology, improved refractories, reduced processing delays due to improved maintenance and scheduling practices, and better energy management generally. The industry has a major collaborative R&D program in partnership with the U.S. Department of Energy entitled the Technology Roadmap Research Program (TRP). An investment of $26 million is earmarked for TRP projects with the goals of improved productivity, energy utilization, and emissions reduction.

Overarching all of these improvements is the dominant role of recycling in minimizing energy consumption associated with steel production. The infrastructure for recycling of iron and steel scrap has been in place for the past century and utilization of iron and steel scrap in all types of steelmaking furnaces has been a common practice for decades. Recycling of automotive steel, for example, is typically on the order of 98%. As a result, steel is the most recycled material in commerce. This is important because the energy required to produce steel from 100% scrap is about one-third of that required to produce steel from virgin iron ore. Although there are inherent differences in the amount of scrap that can be processed in BOFs and EAFs, other factors - such as scrap availability and quality and overall economic growth that dictates placement of steel into long-term applications - limit the ability to increase the use of scrap-based steel production. Over the past 20 years, for example, despite dramatic increases in EAF production, the overall percentage of new steel produced from recycled iron and steel sources has ranged from 65-70%. Nevertheless, steel companies continue to seek ways to recycle iron-bearing dusts, sludges, and other materials. Moreover, through the work of the Steel Recycling Institute, the industry has undertaken significant efforts to promote greater public awareness of steel recycling and expand recycling infrastructure through such initiatives as curbside recycling, municipal programs, and appliance take-back programs.

Finally, steel products play a significant role in conserving energy and reducing related greenhouse gases, particularly when evaluated on a life-cycle basis. For example:

- Advancements in so-called "electrical steels" have allowed for production of more energy-efficient electrical equipment such as motors, capacitors, and transformers.

- Advanced and Ultra High Strength Steels are stronger and lighter than conventional high strength steels. These new steels are now being used in cars and trucks and allow automotive designers to maximize structural efficiency and thus design high-mileage steel vehicles, which are not only affordable and recyclable but continue to retain their recyclability. This is all accomplished while retaining the driver and family safety demanded by consumers. The Ultra Light Steel Auto Body - Advanced Vehicle Concepts (ULSAB-AVC) program, a consortium of domestic and international steelmakers, worked with Porsche Engineering to develop a vehicle that was safe, affordable, fuel-efficient, and environmentally responsible. The results of this program provided auto manufacturers around the world with a design utilizing these new Advanced High Strength Steels for a five-passenger sedan with 52 mpg (gas) and 68 mpg (diesel) performance, while meeting projected 2004 safety requirements and costing no more to manufacture than present-day vehicles. U.S. and international automakers are beginning to incorporate ULSAB-AVC designs into their current production vehicles, which will accelerate improved fuel economy and emissions reductions. The DOE TRP program noted above contributes significantly to the manufacture of Advanced High Strength Steels.

- The use of steel framing for residential construction allows for more energy-efficient homes and preserves carbon-absorbing forests that would otherwise be harvested for construction of wood-framed houses.