American Security Project

Innovating Out of The Climate Crisis: Hard to Abate Sectors

Briefing Note

Quick Facts

- Hard to abate sectors are often grouped together because their production requires carbon and fossil fuels. Some produce carbon dioxide (CO2) as a result of industrial processes, while others have high heat or energy requirements that cannot yet be affordably substituted with electricity.

- In other industries, a net-zero transition requires a combination of energy efficiency and carbon-free energy sources. For these sectors, carbon emissions abatement is much more complex.

- Although there are technological innovations underway, there are currently no scalable commercial alternatives to using fossil fuels in these sectors.

- Heavy industry and transportation are ubiquitous. Steel is the world's second most-traded commodity after oil. Cement is the most common man-made material on the planet, while international shipping enables up to 90 percent of global trade.

Hard to abate sectors include:

Steel
Cement
Concrete
Petrochemicals
Trucking
Shipping
Aviation

- The economics of heavy industry are punishing. Iron, steel, and chemical manufacturers have high up-front capital costs, low profit margins, and intense international trade exposure. Higher costs for energy, process changes, or unequal trading practices could pose significant challenges for these industries without support from policymakers.

- Steel, cement, and chemical manufacturing—core heavy industries—together account for about 30 percent of global emissions. Global shipping on its own adds 1 billion tons of CO2 to the atmosphere, or 3 percent of the world's total emissions. Road freight accounts for about 7 percent of global emissions, while aviation comes to about half that.

- Demand for these industries is projected to grow in the coming decades as countries in Africa, Latin America, and Southeast Asia build new infrastructure. The world will need about 30 percent more steel by mid-century and demand for cement could rise by nearly a quarter, while shipping needs could grow by nearly half.

- Meeting Paris climate targets will require heavy industry to reach net zero emissions by 2050 or buy expensive, good-quality carbon offsets. Given the 15- to 25-year lifespan of critical equipment, all new heavy industrial investments will need to be near-zero emissions by 2030.

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Federal Policy and Regulatory Frameworks

- The Buy Clean Task Force is a federal interdepartmental initiative designed to encourage the use of lower-carbon construction materials in federally funded projects, including those funded by the Infrastructure, Investment, and Jobs Act (IIJA).
- Through the First Mover's Coalition, the State Department is catalyzing private sector demand for lower-carbon technologies in hard-to-abate industries. Companies in the group commit to purchasing low-carbon solutions even when they are more expensive, to stimulate the development of the market.
- In September 2022, to coincide with the launch of its Industrial Decarbonization Roadmap, the Department of Energy announced $104 million in funding for projects addressing related priorities, including energy efficiency, industrial electrification, low-carbon fuels and feedstocks, and carbon capture and storage.
- The 2022 Inflation Reduction Act (IRA) dramatically expanded the tax credit available for carbon capture, storage, and utilization—a change that will benefit industrial facilities that install carbon capture systems, and companies (like those using CO_2 to cure concrete) that are utilizing it.
- The IRA also expanded tax credits for sustainable aviation fuels and increased the value of the credits for fuels that achieved deeper emissions cuts.
- The IIJA committed $8 billion to establishing hydrogen hubs across the country, which are intended to stimulate new ecosystems of hydrogen producers and industrial consumers like steel and chemical plants.
- The IIJA also provided nearly $1 billion in funding for carbon capture pilot and demonstration projects at fossil fuel-powered industrial facilities, as well as $2.5 billion to scope, site, permit, and build new or expanded carbon capture systems.

Trucking, Shipping, and Aviation

- The IEA estimates that hydrogen and ammonia will play increasingly central roles in fueling trucking and international shipping in the coming decades. This will depend on large-scale research, development, and deployment of fuel cells, refueling stations, and other basic infrastructure.
- Researchers are working to improve the speed, efficiency, and affordability of manufacturing ammonia using renewable energy and water. If they succeed, ammonia—which is twice as energy dense as liquid hydrogen—could fuel long-distance shipping and trucking, or serve as a clean-burning electricity or heat source.
- The scale of the need is almost comically outpacing the scale of supply. Researchers estimate that renewable ammonia could provide 43 percent of the international shipping fuel mix by 2050. Achieving that penetration rate would require 183 megatons of renewable ammonia per year, or about as much as today's *total* global ammonia supply.
- In aviation, 96 percent of the technologies needed to decarbonize the sector are still in the prototype or demonstration phase.

Cement & Concrete

Challenges & Opportunities

Though the terms are often used interchangeably, cement and concrete are different products. ***Cement*** serves as the glue that holds together sand, gravel, and other aggregates, which harden as they dry into ***concrete***.

- Concrete is the most consumed human-made material in the world, with growth projected to grow from 14 billion cubic meters produced annually to 20 billion cubic meters by 2050.
- The key ingredient in cement is clinker, which is limestone that has been burned to 1450°C to produce calcium oxide (lime), a process which emits CO_2. Some two-thirds of cement emissions come from the process of making clinker.
- To hold global warming to 2°C, the IEA estimates that CO_2 emissions from the cement industry will need to fall by nearly a quarter by 2050.
- Because such a high proportion of emissions from cement are intrinsic to the chemical process of making it, nearly half of the industry's emissions reductions to 2050 will need to come from carbon capture and storage (CCS).
- Cement and concrete manufacturing are very local processes because they are heavy and expensive to move. Increasing collaboration across the value chain is key to any mitigation measures. Similarly, regulatory changes, such as altering building designs and codes could reduce global cement use by more than a quarter.

Technology and Innovation

- The composition of concrete can be altered to replace as much as half of the clinker with supplementary cementitious materials (SCMs) like limestone or industrial wastes. This has been done for decades to cut costs, but further research is needed to understand the specific tradeoffs between the clinker use and potential costs to the strength and durability of the resulting concrete.
- Captured CO_2, when exposed to an alkaline feedstock like mining waste or fly ash, forms a solid carbonate that can permanently store CO_2. These carbonates can be used to replace the sand and gravel in concrete, or to replace the cement. Further research and development is needed to refine these products and make them economically competitive, but they may offer improvements in strength, durability, and weight over current mixes.
- CO_2 can also be used instead of water to cure or treat concrete to ensure that it achieves a desired physical standard. Using CO_2 to cure concrete can increase its strength and durability while also permanently storing CO_2. Companies in the United States, Canada, Saudi Arabia, and elsewhere are in the process of commercializing this technology today.
- The largest cement carbon capture project today is on a single plant in China. It captures 50,000 of the plant's 1.5 million tons of annual CO_2 emissions, and loses money doing it. But, if all U.S. cement plants used it, 72 million tons of annual CO_2 emissions could be avoided, equivalent to 15 million cars.

Steel

Challenges & Opportunities

- To make steel, iron ore and coke (a form of coal) are heated to more than 1000°C in a blast furnace. The need for such extraordinary heat, combined with the built-in CO2 emissions from the chemical process of reducing iron, mean that steel accounts for some 8 percent of total global emissions.

- Three-quarters of the growth in steel production over the last two decades occurred in China and today some 85 percent of all steel is produced in emerging economies. Maximizing emissions reductions from the sector will require international cooperation on regulations or border adjustment taxes to place a premium on more carbon-intensive steel. The United States and Europe have taken some initial steps in this direction.

- Decarbonizing iron and steel will require a suite of approaches, ranging from the simple (using materials more efficiently) to the challenging (wide-scale deployment of carbon capture, adoption of hydrogen fuels). Less than half—just 38 percent—of the technologies that will be needed to decarbonize iron and steel manufacturing are mature today.

- Using resources more efficiently can make a huge difference. Altering building designs and codes, for instance, could reduce steel use by 40 percent.

Technology & Innovation

- Recycling steel requires just one-eighth compared to the energy of manufacturing it from raw materials. Scrap steel can be melted and purified in an electric arc furnace, which uses electricity rather than coal to generate heat, and which produces no process emissions. Despite recycling rates approaching 90 percent, however, there is simply not enough steel in the world to meet global demand through recycling.

- Researchers are exploring ways to replace coke as a carbon source in the process of reducing iron ore to iron in the steelmaking process. Using biomass, for example, could reduce emissions in steelmaking by approximately 20 percent with little technical change required to mills.

- Green hydrogen (produced with renewable energy) may be able to serve as a reducing agent in steel production and an alternative fuel for blast furnaces. Melting iron ore in the presence of hydrogen rather than coke would generate water, rather than CO2, and the resulting iron could be processed in an electric arc furnace, which itself could be decarbonized.

- Replacing coal with green hydrogen as a reducer and fuel source could raise the cost of a ton of steel by about a third, however, and would require total electricity production to rise by 20 percent in order to produce enough hydrogen.

This briefing note is part of ASP's *Innovating out of the Climate Crisis* programming, which seeks to explore innovations in technology and policies in key clean energy areas. These innovations will help facilitate our collective ability to adapt to climate change, ultimately leading to a more resilient nation.

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