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Building Back Cleaner With Industrial Decarbonization Demonstration Projects

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The Biden administration's infrastructure package should include $5 billion over five years in cost-shared demonstration projects that seek to drastically reduce greenhouse gas emissions from heavy industries such as steel, cement, and chemicals.

KEY TAKEAWAYS

- Industrial sources directly account for about one-fifth of U.S. and global greenhouse gas emissions, and their share is continuing to grow.
- Many promising solutions for industrial emissions are being developed, but only a few are being demonstrated on a large scale, due to the risks and costs. Nearly all of these demonstration projects are sited outside the United States.
- After years of neglect, federal policies, including new programs authorized by Congress and grants awarded by the Energy Department, have laid the groundwork for a substantial federal investment in industrial decarbonization demonstration projects.
- Complemented by other policies, this investment would put America's unmatched innovation resources to work in a globally vital cause, thrust U.S. vendors and producers to the forefront of global competition, and create jobs and economic activity.

OVERVIEW

The Biden administration plans to put forward a major infrastructure package to fulfill the president's pledge to "build back better." This package should include an investment of $5 billion over five years in cost-shared demonstration projects that seek to drastically reduce greenhouse gas (GHG) emissions from heavy industries such as steel, cement, and chemicals. These industries account for a large and growing proportion of U.S. and global GHG emissions. Many promising solutions for industrial emissions are being developed, but only a few are being demonstrated on a large scale, due to the risk and cost. Nearly all of these demonstration projects are sited outside the United States.

A substantial investment in industrial decarbonization demonstration projects in the United States, complemented by other policies—such as a substantial increase in research and development (R&D) spending, "Buy Clean" federal procurement standards, and other "demand-pull" policies—would put the United States' unmatched innovation resources to work in a globally vital cause. It would also thrust U.S. vendors and producers to the forefront of an emerging global competition to implement the most-effective climate solutions in emission-intensive industries in the coming decades. Success in this competition would bring jobs and economic activity to the United States.

A major infrastructure package should include $5 billion over five years in cost-shared demonstration projects that seek to drastically reduce greenhouse gas (GHG) emissions from heavy industries such as steel, cement, and chemicals.

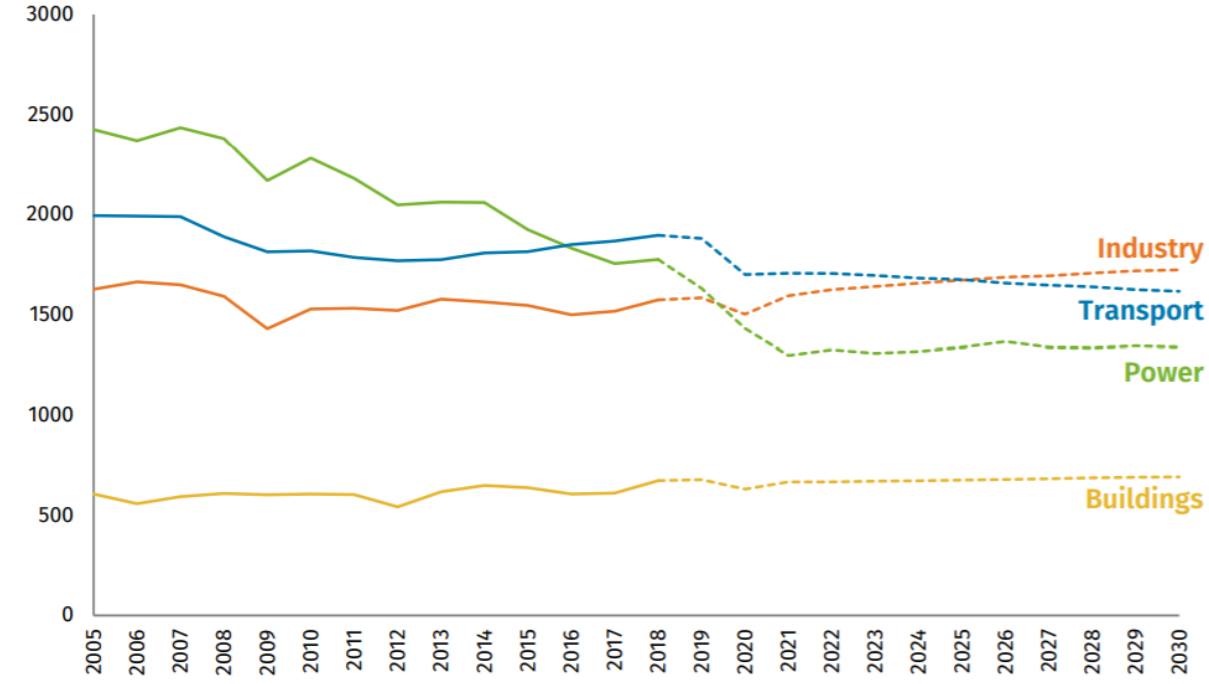
INDUSTRY: A LARGE AND GROWING SOURCE OF EMISSIONS

GHG emissions arise from a wide variety of human activities. Public attention has been dominated for decades by emissions caused by electricity generation, and rightly so, since that sector accounts for the largest portion of the global total. Pushed by public policies worldwide, cost-effective solutions to abate most electricity-sector emissions have been developed and are now being adopted globally. Light-duty transportation, which is responsible for another large portion of global emissions, has risen to the forefront of the climate change mitigation discussion more recently. This sector, too, seems to be on the cusp of a low-carbon transition as electric vehicles gain momentum.

The advances in power and transportation are momentous and will take decades to play out fully—yet they will leave a large part of global emissions untouched. These emissions arise from buildings, agriculture, land use change, waste, and, above all, industry. Iron and steel production alone produces an estimated 7 percent of global emissions; cement, 5 percent; and chemicals, another 6 percent. In all, the industrial sector accounts for about 19 percent of the total, even after the electricity it currently uses is taken out of the equation. In the United States, this figure is slightly higher—about 22 percent—according to the U.S. Environmental Protection Agency.[1]

As progress is made in other sectors, industry's share of total emissions will continue to grow, both globally and in the United States. The Rhodium Group projected (figure 1) that under current policies, "industry will surpass transportation and the power sector and become the largest source of US GHG emissions within the next ten years."[2]

Figure 1: Rhodium Group projection of U.S. greenhouse gas emissions (MMT CO_2e) in key sectors, 2005–2030[3]



Source: Rhodium Climate Service

INDUSTRIAL DECARBONIZATION: DAUNTING BARRIERS

Radically reducing industrial emissions is intrinsically more difficult than doing so for power or transportation. One reason is industry uses an enormous diversity of boilers, furnaces, and other fossil fuel combustion technologies. These technologies are typically integrated into complex production systems in factories and refineries. Changing the combustion components of these systems may have disruptive consequences for other components. Each GHG-abating innovation in industry therefore has fewer potential adopters than those in power or transportation—and typically must be customized to a greater degree.

A second aspect of this challenge is electricity is unsuited to replace combustion directly in some industrial applications. While batteries and electric motors can provide sufficient torque to turn the wheels of an automobile at a cost competitive with internal combustion engines, industry often needs heat, rather than torque—and at a level and scale electric technologies cannot easily provide. Cement manufacturing, for instance, typically requires temperatures of nearly 1,500 degrees Celsius.[4] "Electrify everything," an often-repeated rule of thumb for the energy transition, simply breaks down for industry.

The electrification strategy is further limited by the fact that a significant portion of industrial emissions is caused by chemical processes, rather than fossil fuel combustion. Calcination, a chemical transformation of limestone, for instance, emits carbon dioxide during cement production. Process emissions account for more than 50 percent of the cement industry's emissions, and about 18 percent of all industrial emissions.[5] These emissions must be captured, or else the industry must adopt fundamentally different production processes.

Industrial materials can be used more efficiently and recycled more frequently. Both strategies are vital to shave the peak off the industrial decarbonization challenge. But even if they were to be implemented to their maximum extent, the challenge will remain very steep and very large.[6]

THE FEDERAL RESPONSE: ANEMIC

The effort put forward by U.S. policymakers to tackle the daunting challenge of industrial decarbonization has been anemic. Federal regulators have not used the Clean Air Act to try to cut industrial GHG emissions. In fact, in one of its last actions, the Trump administration sought to "exclude every stationary greenhouse gas polluter in the U.S. aside from power plants" from regulators' jurisdiction.[7] While this position will undoubtedly be reversed by the Biden administration, a robust assertion of regulatory authority is unlikely in practice.

Nor is a carbon price on industrial emissions probable. While some states have adopted carbon prices for the power sector, the administration and Congress appear to have little appetite to adopt such a scheme at the federal level. A federal carbon pricing system that would extend to the industrial sector is even less likely. The failure of the Waxman-Markey carbon pricing bill in 2009–2010 weighs heavily on policymakers.[8]

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In lieu of direct regulation or a carbon price, the Biden administration has endorsed the use of government procurement to drive down industrial emissions. The State of California's Buy Clean strategy may provide the template for programs to decarbonize production of building materials, for which the public sector comprises a large portion of the market. Rebecca Dell of ClimateWorks, however, noted that the California approach is "a deployment policy, not an innovation policy." Buy Clean programs will have limited leverage if low-carbon options are much more expensive than products made with conventional processes, unless these programs are extremely generous.[9]

Unfortunately, this "green premium," to use Bill Gates's phrase, remains very large for many products. Low-carbon cement is between 75 and 140 percent more expensive than regular cement, according to Breakthrough Energy, Gates's organization. For steel, the premium is between 16 and 29 percent. An overwhelming majority of industrial energy experts and practitioners surveyed recently by Ali Hasanbeigi and his colleagues listed upfront, process modification, and relative fuel costs, as well as return on investment, as barriers to adoption of cleaner processes.[10]

THE PROMISE OF SUPPLY-PUSH POLICIES

Federal investment in research, development, and demonstration (RD&D) has the potential to provide a "supply-push" to reduce the green premium, enabling demand-pull policies such as regulation and procurement to have a much greater impact. Here, too, though, policymakers have fallen short. The U.S. Department of Energy (DOE), for instance, spends only 6 percent of its RD&D budget on industrial projects, far smaller than industry's share of emissions. Many of these projects focus on incremental improvements in energy efficiency, rather than the radical reductions needed to reach net zero across the economy by 2050.[11]

A boost in federal investment aimed at industrial decarbonization solutions is needed across the entire innovation process, from basic research to early adoption. The demonstration phase, which sits squarely in the middle of this process, is particularly important for a "supply-push" initiative. Many important climate solutions for industry will be capital intensive. Potential adopters are likely to see them as risky investments, especially in commodity sectors such as steel and bulk chemicals that run on narrow profit margins. By providing cost and performance data under real-world conditions, demonstrations provide vital validation to potential adopters that new investments will pay off.[12]

Congress acknowledged the industrial decarbonization demonstration gap in the 2009 American Recovery and Reinvestment Act (ARRA). ARRA committed about $1.5 billion to demonstrate one important set of potential solutions: carbon capture, utilization, and storage (CCUS). About half of this sum supported three large-scale demonstration projects, while the remainder went toward a variety of smaller ones. Two of the three large projects, one at an ethanol plant in Illinois and the other at a hydrogen plant in Texas, are still in operation, providing real-world proof points that could be replicated. The third, a methanol plant in Louisiana, was not built. Only 5 percent of the funds allocated to that project were actually spent, although it remains on the drawing board thanks to a conditional loan guarantee issued by DOE in 2016.[13]

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DOE was unable to expand its industrial decarbonization project portfolio in the years after ARRA. However, in the past year, it began laying the foundation to revitalize it. In July 2020, DOE's "H2@Scale" program, housed in the Office of Energy Efficiency and Renewable Energy (EERE), funded two projects at about $4 million each to investigate the substitution of zero-carbon hydrogen for natural gas in steel making. Two months later, DOE's Office of Fossil Energy (FE) awarded about five $1.5 million grants for initial engineering design for CCUS projects at steel, cement, hydrogen, and ethanol plants. In December 2020, FE issued a broad request for information about industrial CCUS.

Early in 2021, DOE's Advanced Manufacturing Office (AMO), also in EERE, issued grants worth between $1 million and $7 million (generally with an additional 20 percent non-federal cost share) for applied research aimed at improving energy efficiency in iron and steel (seven awards), drying (three), and chemicals (seven) as well as for industrial CCS (nine). Finally, at the behest of Congress, the National Renewable Energy Laboratory (NREL) has begun carrying out a road-mapping exercise that will lay out potential pathways to decarbonization across most major industrial sectors.[14]

These steps are encouraging but do not yet come near meeting the scope and urgency of the industrial emissions challenge. ClimateWorks' Dell has called for an annual RD&D investment of $5 billion. In last year's *Energizing America*, my co-authors and I recommended tripling federal clean energy RD&D investment over five years, with even faster growth for industrial decarbonization RD&D, including CCUS. The power sector still dominates DOE's RD&D budget, while work on industry is scattered across several of its units, as the funding for recent work shows. Meanwhile, the rest of the world is beginning to race ahead.[15]

DEMONSTRATION PROJECTS ABROAD

The growth in large-scale industrial decarbonization projects outside the United States reflects the ambitious emissions-reduction targets adopted by many governments and their willingness to back them with significant resources. Forward-leading industrial firms have taken these accumulating policies to be a signal that their markets may soon be disrupted by the drive to decarbonize and have sought to get a jump on the transition by demonstrating low-carbon production technologies in collaboration with public agencies.

For instance, the European Union identified decarbonization as a "top priority" in its "new industrial strategy" and will be adding energy-intensive sectors into its Emissions Trading System (ETS). China's target of achieving carbon neutrality by 2060 implies a wholesale transformation of its massive industrial complex. Australia has tabbed clean hydrogen, low-carbon steel and aluminum, and CCUS for support in its Technology Investment Roadmap.[16]

Steel

Perhaps the best-known demonstration projects seek to make cost-competitive "green steel." In Sweden, the HYBRIT (Hydrogen Breakthrough Ironmaking Technology) plant will use an all-electric process fueled by zero-carbon resources. Hydrogen produced through electrolysis (splitting water into hydrogen and oxygen) is used to turn iron ore into direct-reduced iron, avoiding process emissions as well as combustion emissions. The iron is then fed into an electric furnace to make steel. The International Energy Agency reported that "the project aims to deliver a demonstration plant by 2025, progressively scaling up successive trials until the mid-2030s." The Swedish Energy Agency has invested more than $50 million in this venture.[17]

In projects in the United Arab Emirates, the Netherlands, South Korea, and Japan, steelmakers are capturing and storing carbon rather than seeking to eliminate emissions. An Emirates Steel Industries plant retrofitted with the capacity to capture 800,000 tons of CO_2 per year became operational in 2016. Tata Steel Europe is demonstrating a new type of integrated steel plant that combines multiple processes in a single oven, concentrating carbon emissions so that they are easier to capture. Japanese and South Korean plants are applying CCUS to the ironmaking phase of conventional steel production.[18]

Cement

Like steel, cement creates process as well as combustion emissions. Commercial-scale projects demonstrating carbon capture technologies in this hard-to-abate sector are being developed in several countries, with operations expected to begin in the mid-2020s. For instance, the Norwegian government decided in December 2020 to invest in a Heidelberg Cement project in Brevik that would demonstrate CCUS in a full-scale cement plant for the first time. The plant is expected to capture 400,000 tons of CO_2 per year when it is completed in 2024.[19]

Other low-carbon cement projects are underway at pilot scale in Belgium, Canada, China, Germany, India, and Italy. Large-scale demonstrations have been announced for at least two of these technologies. One is an EU-funded project at a Heidelberg Cement facility in Lixhe, Belgium, in which process emissions are separated from combustion emissions, yielding a nearly pure stream of CO_2. The developers claim it will enable "both Europe's cement and lime industries to reduce their carbon dioxide (CO_2) emissions dramatically without significant energy or capital penalty."[20]

Petrochemicals

The chemical industry produces a wide variety of end products, but the bulk of its emissions derive from a relatively small group of intermediate products that are used as inputs downstream. Concern about plastic waste has helped drive greater attention to recycling, which is an important pathway to reduce emissions. But innovation to eliminate emissions from primary chemicals production has moved slowly. One bright spot is a demonstration that will get underway this year in Australia. The plant will make ammonia, a major chemical-industry source of CO_2, by using hydrogen produced by electrolysis.[21]

Ultimately, breakthroughs in biotechnology may be required to transform the chemical industry. U.S. start-ups have generated numerous promising biotechnologies, but when these firms seek to scale up toward commercial production, they must go abroad to find suitable facilities. Public-private partnerships in Belgium and Mexico, for instance, have established contract facilities that allow developers to prove fermentation processes on an intermediate scale. The United States has not yet built anything comparable.[22]

Other Industries

Promising industrial decarbonization solutions are being tested outside the United States in other industries as well. The EU-funded HYFLEXPOWER project in France, for instance, will substitute hydrogen made with electrolysis for natural gas at a paper and pulp factory. The hydrogen-combusting turbines developed for this project may be useful in other industries or in the power sector. The project plan envisions full hydrogen combustion beginning in 2023.[23]

Demonstration projects to cut emissions in the aluminum industry are underway in Canada and Russia. While much less aluminum is used globally than steel, its use is likely to grow rapidly as vehicle light-weighting (an important step to cut transportation emissions) expands. Conventional aluminum smelters rely on carbon anodes that are converted into CO_2 during production. Inert anodes—which the developers of these demonstration projects seek to bring to market within five years—would eliminate this source. (Apple is an investor in the Canadian project, which is a joint venture between Alcoa and Rio Tinto, along with the Quebec provincial and Canadian federal governments.)[24]

OPPORTUNITIES AT HOME

The rest of the world has moved ahead of the United States in demonstrating technologies with the potential to cut industrial emissions radically. But even taken together, current global efforts will not ensure success in the quest to reach net-zero emissions by 2050. Indeed, in the wake of the economic slowdown caused by the pandemic, the International Energy Agency reported "serious disquiet among [industrial sector] experts about keeping their innovation pipelines flowing."[25] Comprehensive reports on pathways to 2050 goals published recently by the Brookings Institution, Princeton University, and the University of Cambridge, among others, call for an exponential expansion of industrial sector technology-push policies.[26]

Congress provided the legal foundation for the United States to play its part in this push with the passage of the Energy Act of 2020 in omnibus legislation in late December. Sponsored by Sheldon Whitehouse (D-RI) and Shelley Moore Capito (R-WV) in the Senate and Sean Casten (D-IL) and David McKinley (R-WV in the House of Representatives, and cosponsored by House Science chair Eddie Bernice Johnson (D-TX) and current Senate Energy and Natural Resources

chair Joe Manchin (D-WV) among others, the act incorporates bipartisan legislation that authorizes DOE to establish an industrial emissions-reduction technology development program that extends to demonstration and commercial applications. The act separately authorizes funding for first- through third-of-a-kind industrial CCUS projects, along with programs for carbon sequestration and utilization. Elsewhere in the omnibus, appropriators called out industrial decarbonization as an area worthy of greater attention from DOE in the current fiscal year.[27]

U.S. industry is getting behind the cause as well. The American Iron & Steel Institute has called for adopting "policy measures that acknowledge that … new processes for steelmaking must be developed."[28] The Portland Cement Association is developing a roadmap "to facilitate its member companies achieving carbon neutrality across the concrete value chain by 2050."[29] The American Chemistry Council takes the position that "U.S. climate policy must support capital investment in state-of-the-art manufacturing capacity to achieve emission reductions..."[30]

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DOE's emerging portfolio of industrial decarbonization R&D projects adds to the momentum. Such work should provide operational insights that could be utilized by commercial-scale demonstrations. Initial engineering designs funded by FE, for instance, might be drawn upon in the more-detailed studies that must be completed before construction of demonstration projects can commence. The steelmaker Arcelor Mittal, for example, won an award in 2020 for an initial engineering design for a project at its Burns Harbor, Indiana, steel plant. Arcelor Mittal is also a partner in three AMO-funded applied research projects.[31]

BUILDING BACK CLEANER

The pump is primed for a major federal investment in industrial decarbonization demonstration projects to pay dividends. The need for solutions for industrial emissions is urgent. Numerous technologies that would contribute to these solutions are approaching commercial readiness, with more in the pipeline. Other governments around the world and their industrial partners have initiated projects through public-private partnerships. Congress and DOE have created the conditions for doing so in the United States, and U.S. industry has indicated its willingness to participate as well.

The pump is primed for a major federal investment in industrial decarbonization demonstration projects to pay dividends.

Such an investment would fit neatly into President Biden's Build Back Better program. Biden's campaign called for revitalizing U.S. manufacturing through innovation in the context of a drive to net-zero emissions by 2050. Because industrial investment cycles are very long, many plants built during this decade will still be capable of operating in 2050. If these new builds are not much cleaner, they may have to be shut down to avoid emissions before they are worn out. But industry will only invest in clean manufacturing technologies that are well proven through RD&D, including demonstration projects.[32]

The administration is preparing an infrastructure package to begin implementing the Build Back Better program in 2021. This package should include $5 billion over five years for industrial decarbonization demonstration projects. The federal share of these projects will vary in scale from 10s to 100s of millions of dollars each, so this amount should support about 50 projects and trigger a comparable investment from industrial partners. The portfolio should encompass numerous industries, pursue multiple technological pathways within each industry, and include the first- through third-of-a-kind projects, as authorized by Congress. This approach would accommodate the inevitable failures that will occur when unproven technologies are scaled up and allow the most promising ones to be de-risked to the point private investors have sufficient confidence to carry them forward with their own money. The administration's Made-in-America initiative should help ensure follow-on work occurs domestically. The five-year window would serve as a forcing function for aggressive action to get the projects built.[33]

These projects will eventually bring a significant number of construction jobs to the regions in which they are built, although most will need a year or more of planning before construction can commence. The permanent jobs they will create, by allowing U.S. producers to secure an advantage by reducing the green premium before international competitors do, will ultimately their most important contribution to the health of the nation's industrial areas.

CONCLUSION

The race to decarbonize industry is one that humanity must win. Industrial emissions are too big to ignore, and the products they make possible—steel, cement, chemicals, and more—are fundamental to human society. We cannot live without the infrastructure services these products provide.

The races within the global decarbonization race—among countries, regions, and companies for jobs and profits in many industries—could be decided in the coming decade. The coming transition to a low-carbon economy portends major shifts in industrial production paradigms. Such shifts are rare. First movers are sometimes able to establish durable advantages, as the United States' 20th-century experience in industries such as semiconductors and long-range passenger jets shows.

A substantial federal supply-push investment in industrial decarbonization demonstration projects would show that the United States is ready to join the global race in earnest. Combined with Buy Clean and other demand-pull policies, it would strengthen the chances for U.S. plants to win their fair share of future production. The Build Back Better infrastructure package would be an ideal vehicle to make it so.

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